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DEPARTMENT OF DEFENSE HANDBOOK

AIRWORTHINESS CERTIFICATION CRITERIA

THIS HANDBOOK IS FOR GUIDANCE ONLY.

DO NOT CITE THIS DOCUMENT AS A REQUIREMENT.

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FOREWORD

1. This handbook is approved for use by all Departments and Agencies of the Department of Defense.

2. The criteria contained herein are qualitative in nature. References are provided as background for understanding the criteria, and as a basis for tailoring standards and/or methods of compliance. Also, note that each section contains a list of typical certification source data that may be referenced for evaluating system compliance with that section's criteria. Terms such as "acceptable" used in the criteria are parameters whose specific definition must be determined and documented by the implementing office in the context of each unique air system.

3. Comments, suggestions, or questions on this document should be addressed to AFLCMC/ENRS, Bldg 28, 2145 Monahan Way, Wright-Patterson AFB OH 45433-7017 or emailed to Engineering.Standards@us.af.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

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1. SCOPE

1.1 Scope.

This document establishes the airworthiness certification criteria, standards and methods of compliance to be used in the determination of airworthiness of all manned and unmanned, fixed and rotary wing air systems. It is a foundational document to be used by the service airworthiness authority to define an air system's airworthiness certification basis. This handbook is for guidance only and cannot be cited as a requirement.

1.2 Applicability.

This handbook should be applied at any point throughout the life-cycle of an air system when an airworthiness determination is necessary, especially whenever there is a change to the functional or product baseline.

Each air system configuration, including but not limited to manned, unmanned, fixed or rotary-wing demands unique safety-of-flight (SOF) airworthiness certification requirements. Therefore, unique criteria are included for these types of systems to ensure that minimum levels of design for safe operation and maintenance are established. For unmanned air vehicles (UAVs), SOF risks associated with loss of aircrew may not apply. However, as with manned air vehicles, SOF risk associated with personnel, damage to equipment, property, and/or environment must be considered. UAVs which carry aircrew or passengers are subject to the same airworthiness certification requirements as manned aircraft. Any aircraft which may carry personnel (for example, passengers, patients, special mission personnel) are subject to certification requirements for passenger aircraft.

An Unmanned Aircraft System (UAS) is comprised of individual elements consisting of the UAV, the control station, and any other support elements necessary to enable operation including, but not limited to data links, communications systems/links, and UAS-unique launch and recovery equipment. UAV types vary greatly in size, weight, and complexity. Consideration should be given to the environment in which the UAS will be operated (controlled test range, national airspace, fleet usage, including ship based applications), to the life expectancy of the system for which it is designed, and to the "expendability" of the UAV.

Similarly, air vehicles intended for use aboard ships have unique requirements in areas such as structural integrity, propulsion system dynamic response and tolerance to steam ingestion, control systems response to approach and landings in high turbulence conditions, electromagnetic environmental effects, deck handling, support and servicing, and pilot field of view.

Commercial derivative aircraft (CDA) are initially approved for safety of flight by the Federal Aviation Administration (FAA) and may have an FAA approved Certificate of Airworthiness (that is, Type Certificate). Any non-FAA approved alteration to a CDA may render all FAA certifications invalid. While alterations to CDA are covered by rules unique to each branch of service, the operating service always has the responsibility for the airworthiness certification approval under public aircraft rules. Therefore, when planning any alterations to an FAA certified CDA, the modifier should, at the earliest opportunity, contact the FAA Military Certification Office (MCO) in Wichita, KS.

In all instances, complete and accurate documentation of both applicability and system specific measurable criteria values is critical to ensuring consistent, timely, and accurate airworthiness assessments.

1.2.1 Tailoring to create the certification basis.

Not all of the airworthiness criteria apply to every type of air system; also, platform-unique, previously undefined criteria may need to be added to fully address safety aspects of unique configurations. Therefore, tailor the total set of criteria to identify a complete (necessary and sufficient) subset of applicable airworthiness criteria, creating the system's certification basis. This certification basis should be fully documented and maintained under strict configuration control.

Tailoring rules are as follows:

a. Identify each criterion as applicable, partially applicable or non-applicable, considering system or product complexity, type, data, and intended use. Document the rationale for identifying any criterion as non-applicable.

b. Fully applicable criteria may not be deleted or modified in any manner.

c. If a portion of a criterion partially applies, identify the applicable or non-applicable portion. Document the rationale for identifying any criterion as partially applicable.

d. Supplement applicable or partially applicable criteria where appropriate for any capabilities or systems not fully addressed by the criteria contained in this handbook.

e. Develop additional criteria, as appropriate. Document the rationale for any capabilities or systems not fully addressed by the criteria contained in this handbook. Consider whether such criteria should be submitted for future inclusion in this handbook.

f. Standards and methods of compliance may be tailored, considering system type, capabilities and intended use.

1.3 Cross references and technical points of contact.

The criteria included in this document are written with the intent that an experienced engineer, trained in the specific technical area under consideration, should be able to interpret, tailor, apply, and evaluate a particular system's compliance with the criteria. To assist in this effort, military and civil references are included with the specific criteria.

For additional information or clarification call the appropriate service point of contact provided in Appendix A.2.

For Commercial Derivative Aircraft (CDA), contact the FAA Military Certification Office (MCO) point of contact, provided in Appendix A.2.

1.4 Information sources.

Where applicable, reference documents are identified for each Airworthiness Certification Criterion. Source reference documents may include, but are not limited to the following:

International Standardization Agreements
Federal Specifications
Federal Standards

Commercial Item Descriptions

Department of Defense (DoD) Specifications

Department of Defense Standards

Department of Defense Handbooks

Other Government documents, drawings and publications.

Non-Government standards and other publications.

The FAA Title 14, Code of Federal Regulations (CFR) Part (for example, 23, 25, 27, 29) referenced is dependent on aircraft type and must be consistent with aircraft size and usage. The list shown is not all inclusive and the user is cautioned to look at the reference material only as a guide and not for purposes of citing requirements. The user is also advised to use additional FAA Advisory Circulars or other FAA Policy documents, such as Orders and Notices that may be found on the FAA website, to assist in understanding the FAA's implementation of the regulatory requirements.

2. APPLICABLE DOCUMENTS

2.1 General.

The documents listed below are not necessarily all of the documents referenced herein, but are those needed to understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks.

The following specifications, standards, and handbooks form a part of this document to the extent specified herein.

INTERNATIONAL STANDARDIZATION AGREEMENTS

ALLIED ORDNANCE PUBLICATION

AOP-52	Guidance on Software Safety Design and Assessment of Munition-Related Computing Systems

(Copies of these documents are available online at https://assist.dla.mil or http//www.nato.int.)

ALLIED TACTICAL PUBLICATION (ATP)

ATP-3.3.4.2	Air-to-Air Refuelling ATP-56 (STANAG 3971 implements this standard.)
ATP-3.3.4.5	Air-to-Air (Aerial) Refuelling Equipment: Boom-Receptacle System and Interface Requirements (STANAG 7191 implements this standard.)

(Copies of these documents are available online at https://assist.dla.mil or http://nso.nato.int.)

THE INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)/
THE INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

ISO/IEC 12207:2008(E)	Systems and software engineering – Software life cycle processes
IEEE Std 12207	
ISO/IEC/IEEE 24765	Systems and software engineering - Vocabulary

(Copies of these documents are available online at http://webstore.iec.ch/.)

NATO STANDARDIZATON OFFICE (NSO)

STANAG 3098	Aircraft Jacking
STANAG 3230	Emergency Markings on Aircraft
STANAG 3278	Aircraft Towing Attachments and Devices
STANAG 3447	Air-to-Air Refuelling Equipment: Probe-Drogue Interface Characteristics

STANAG 3899	Ground Fit and Compatibility Criteria for Aircraft Stores
STANAG 3971	Air-to-Air Refuelling ATP-56
STANAG 4101	Towing Attachments
STANAG 4591	The 600 BIT/S, 1200 BIT/S and 2400 BIT/S NATO Interoperable Narrow Band Voice Coder
STANAG 4671	Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR)
STANAG 7191	Air-to-Air (Aerial) Refuelling Equipment: Boom-Receptacle System and Interface Requirements

(Copies of these documents are available online at https://assist.dla.mil or http//www.nato.int.)

FEDERAL STANDARDS

FED-STD-595	Colors Used in Government Procurement
FED-STD-595/13538	Yellow, Gloss
FED-STD-595/37038	Miscellaneous, Flat Lusterless

(Copies of these documents are no longer available from GSA. For further information go to www.gsa.gov/portal/content/142623.)

DEPARTMENT OF DEFENSE SPECIFICATIONS

JSSG-2000	Air System
JSSG-2001	Air Vehicle
JSSG-2005	Avionic Subsystem Main Body
JSSG-2006	Aircraft Structures
JSSG-2007	Engines, Aircraft, Turbine
JSSG-2008	Vehicle Control and Management System (VCMS)
JSSG-2009	Air Vehicle Subsystems
JSSG-2010	Crew Systems
JSSG-2010-1	Crew Systems Engineering Handbook
JSSG-2010-2	Crew Systems Crew Station Automation, Information and Control/Display Management Handbook
JSSG-2010-3	Crew Systems Cockpit/Crew Station/Cabin Handbook
JSSG-2010-4	Crew Systems Aircrew Alerting Handbook
JSSG-2010-5	Crew Systems Aircraft Lighting Handbook
JSSG-2010-6	Crew Systems Sustenance and Waste Management Handbook
JSSG-2010-7	Crew Systems Crash Protection Handbook

JSSG-2010-8	Crew Systems Energetics Handbook
JSSG-2010-9	Crew Systems Personal Protective Equipment Handbook
JSSG-2010-10	Crew Systems Handbook
JSSG-2010-11	Crew Systems Emergency Egress Handbook
JSSG-2010-12	Crew Systems Deployable Aerodynamic Decelerator (DAD) Systems Handbook
JSSG-2010-13	Crew Systems Survival, Search, and Rescue (SSAR) Handbook
JSSG-2010-14	Crew Systems Aircraft Windshield/Canopy Systems and Transparent Enclosures Handbook
MIL-W-5013	Wheel and Brake Assemblies, Aircraft General Specification for (Inactive for New Design)
MIL-PRF-5041	Tires, Ribbed Tread, Pneumatic, Aircraft
MIL-W-5088	Wiring, Aerospace Vehicle (Inactive for New Design) (Future designs should refer to SAE AS50881)
MIL-PRF-5096	Manuals, Technical - Inspection and Maintenance Requirements; Acceptance and Functional Check Flight Procedures and Checklists; Inspection Work Cards; and Checklists; Preparation of
MIL-PRF-5920	Manuals, Technical: Sample Basic Weight Checklists and Loading Data
MIL-T-6053	Tests, Impact, Shock Absorber Landing Gear, Aircraft (Inactive for New Design)
MIL-E-7016	Electric Load and Power Source Capacity, Aircraft, Analysis of
MIL-PRF-7032	Inverters, Aircraft, General Specification for
MIL-PRF-7115/4	Converter, Aircraft, 300 Ampere, Type II, Class A, Fan Cooled
MIL-DTL-7700	Flight Manual, Performance Data Appendix, Mission Crew Manual, Supplemental Manual, and Abbreviated Flight Crew Checklist
MIL-L-8552	Landing Gear, Aircraft Shock Absorber (Air-Oil Type)
MIL-PRF-8565	Battery Storage, Aircraft, General Specification for
MIL-B-8584	Brake Systems, Wheel, Aircraft, Design of
MIL-S-8812	Steering System: Aircraft, General Requirements for
MIL-A-8863	Airplane Strength and Rigidity Ground Loads for Navy Acquired Airplanes
MIL-A-8865	Airplane Strength and Rigidity Miscellaneous Loads
MIL-A-8870	Airplane Strength and Rigidity Vibration, Flutter, and Divergence
MIL-F-17874	Fuel Systems: Aircraft, Installation and Test of
MIL-A-18717	Arresting Hook Installation, Aircraft
MIL-A-19736	Air Refueling Systems, General Specification for

MIL-PRF-21480	Generator System, Electric Power, 400 Hertz, Alternating Current, Aircraft; General Specification for
MIL-E-22285	Extinguishing System, Fire, Aircraft, High-Rate-Discharge Type, Installation and Test of (Inactive for New Design)
MIL-D-23222	Demonstration Requirements for Helicopters
MIL-DTL-25959	Tie Down, Tensioners, Cargo, Aircraft
MIL-PRF-27260	Tie Down, Cargo, Aircraft, CGU-1/B
MIL-PRF-29595	Batteries and Cells, Lithium, Rechargeable, Aircraft, General Specification for
MIL-PRF-63029	Manuals, Technical: Requirements for Operator's Manuals and Checklists for Manned Aircraft Systems
MIL-T-81259	Tie-Downs, Airframe Design, Requirements for
MIL-PRF-81757	Batteries and Cells, Storage, Nickel-Cadmium, Aircraft General Specification for
MIL-C-83124	Cartridge Actuated Devices/Propellant Actuated Devices General Design Specification for
MIL-C-83125	Cartridge for Cartridge Actuated/Propellant Actuated Devices, General Design Specification for
MIL-C-83126	Propulsion Systems, Aircrew Escape, Design Specification for
MIL-DTL-85025	NATOPS Program Technical Publications and Products; Style, Format and Common Technical Content
MIL-DTL-85110	Bar, Repeatable Release Holdback (RRHB), Aircraft Launching. General Requirement for
MIL-L-85314	Light Systems, Aircraft, Anti-Collision, Strobe, General Specification for
MIL-E-85583	Electric Power Generating Channel, Variable Input Speed, Alternating Current, 400 Hz, Aircraft; General Specification for
MIL-PRF-85676	Lighting, Emergency Egress, Subassembly
MIL-L-85762	Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible
AFGS-87139	Landing Gear Systems
AFGS-87219	Electrical Power Systems, Aircraft
AFGS-87256	Integrated Diagnostics (Inactive for New Design)
MIL-L-85762	Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-188-141	Interoperability and Performance Standards for Medium and High Frequency Radio Systems

MIL-STD-188-181	Interoperability Standard for Access to 5-kHz and 25-kHz UHF Satellite Communications Channels
MIL-STD-188-182	Interoperability Standard for UHF SATCOM DAMA Orderwire Messages and Protocols
MIL-STD-188-242	Interoperability and Performance Standards for Tactical Single Channel Very High Frequency (VHS) Radio Equipment
MIL-STD-188-243	Tactical Single Channel Ultra High Frequency (UHF) Radio Communications
MIL-STD-331	Fuze and Fuze Components, Environmental and Performance Tests for
MIL-STD-411	Aircrew Station Alerting Systems
MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-464	Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-805	Towing Fittings and Provisions for Military Aircraft, Design Requirements for
MIL-STD-810	Environmental Engineering Considerations and Laboratory Tests
MIL-STD-882	System Safety
MIL-STD-889	Dissimilar Metals
MIL-STD-961	Defense and Program-Unique Specifications Format and Content
MIL-STD-1289	Airborne Stores, Ground Fit and Compatibility Requirements
MIL-STD-1290	Light Fixed and Rotary-Wing Aircraft Crash Resistance
MIL-STD-1310	Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility, Electromagnetic Pulse (EMP) Mitigation and Safety
MIL-STD-1399-300	Section 300 Electric Power, Alternating Current
MIL-STD-1399-390	Section 390 Electric Power, Direct Current (other than Ship's Battery) for Submarines (Metric),
MIL-STD-1425	Safety Design Requirements for Military Lasers and Associated Support Equipment
MIL-STD-1472	Human Engineering
MIL-STD-1474	Noise Limits
MIL-STD-1530	Aircraft Structural Integrity Program (ASIP)
MIL-STD-1568	Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems

MIL-STD-1683	Connectors and Jacketed Cable, Electric, Selection Standard for Shipboard Use
MIL-STD-1760	Aircraft/Store Electrical Interconnection System
MIL-STD-1787	Aircraft Display Symbology
MIL-STD-1791	Designing for Internal Aerial Delivery in Fixed Wing Aircraft
MIL-STD-1796	Avionics Integrity Program (AVIP)
MIL-STD-1797	Flying Qualities of Piloted Aircraft
MIL-STD-1798	Mechanical Equipment and Subsystems Integrity Program
MIL-STD-2161	Paint Schemes and Exterior Markings for U.S. Navy and Marine Corps Aircraft
MIL-STD-2169	High-Altitude Electromagnetic Pulse (HEMP) Environment (U)
MIL-STD-3009	Lighting, Aircraft, Night Vision Imaging System (NVIS) Compatible
MIL-STD-3013	Glossary of Definitions, Ground Rules, and Mission Profiles to Define Air Vehicle Performance Capability
MIL-STD-3022	Documentation of Verification, Validation, and Accreditation (VV&A) for Models and Simulations
MIL-STD-3024	Propulsion System Integrity Program (PSIP)
MIL-STD-5522	Test Requirements and Methods for Aircraft Hydraulic and Emergency Pneumatic Systems
MIL-STD-7080	Selection and Installation of Aircraft Electric Equipment
MIL-STD-7179	Finishes, Coatings, and Sealants, for the Protection of Aerospace Weapons Systems
MIL-STD-8591	Airborne Stores, Suspension Equipment and Aircraft-Store Interface (Carriage Phase)
MIL-STD-27733	Modification and Marking Requirements for Test Equipment in Aerospace Vehicles and Related Support Equipment
MIL-STD-38784	Standard Practice for Manuals, Technical: General Style and Format Requirements
MIL-STD-46855	Human Engineering Requirements for Military Systems, Equipment, and Facilities

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-61	Configuration Management Guidance
MIL-HDBK-217	Reliability Prediction of Electronic Equipment
MIL-HDBK-221	Fire Protection Design Handbook for U.S. Navy Aircraft Powered by Turbine Engines
MIL-HDBK-244	Guide to Aircraft/Stores Compatibility
MIL-HDBK-299	Cable Comparison Handbook Data Pertaining to Electrical Shipboard Cable

MIL-HDBK-310	Global Climatic Data for Developing Military Products
MIL-HDBK-419	Grounding, Bonding and Shielding for Electronic Equipments and Facilities, (Handbook contains both Volume 1 Basic Theory, and Volume II Applications)
MIL-HDBK-470	Designing and Developing Maintainable Products and Systems, Volume I
MIL-HDBK-454	General Guidelines for Electronic Equipment
MIL-HDBK-515	Weapon System Integrity Guide (WSIG)
MIL-HDBK-704-1	Guidance for Test Procedures for Demonstration of Utilization Equipment Compliance to Aircraft Electrical Power Characteristics (Part 1 of 8 Parts)
MIL-HDBK-704-2	Guidance for Test Procedures for Demonstration of Utilization Equipment Compliance to Aircraft Electrical Power Characteristics Single Phase, 400 HZ, 115 Volt (Part 2 of 8 Parts)
MIL-HDBK-704-3	Guidance for Test Procedures for Demonstration of Utilization Equipment Compliance to Aircraft Electrical Power Characteristics Three Phase, 400 HZ, 115 Volt (Part 3 of 8 Parts)
MIL-HDBK-704-4	Guidance for Test Procedures for Demonstration of Utilization Equipment Compliance to Aircraft Electrical Power Characteristics Single Phase, Variable Frequency, 115 Volt (Part 4 of 8 Parts)
MIL-HDBK-704-5	Guidance for Test Procedures for Demonstration of Utilization Equipment Compliance to Aircraft Electrical Power Characteristics Three Phase, Variable Frequency, 115 Volt (Part 5 of 8 Parts)
MIL-HDBK-704-6	Guidance for Test Procedures for Demonstration of Utilization Equipment Compliance to Aircraft Electrical Power Characteristics Single Phase, 60 HZ, 115 Volt (Part 6 of 8 Parts)
MIL-HDBK-704-7	Guidance for Test Procedures for Demonstration of Utilization Equipment Compliance to Aircraft Electrical Power Characteristics 270 VDC (Part 7 of 8 Parts)
MIL-HDBK-704-8	Guidance for Test Procedures for Demonstration of Utilization Equipment Compliance to Aircraft Electrical Power Characteristics 28 VDC (Part 8 of 8 Parts)
MIL-HDBK-828	Range Laser Safety
MIL-HDBK-1587	Materials and Process Requirements for Air Force Weapon Systems
MIL-HDBK-1599	Bearings, Control System Components, and Associated Hardware Used in the Design and Construction of Aerospace Mechanical Systems and Subsystems
MIL-HDBK-1760	Aircraft/Store Electrical Interconnection System
MIL-HDBK-1763	Aircraft/Stores Compatibility: Systems Engineering Data Requirements and Test Procedures
MIL-HDBK-1783	Engine Structural Integrity Program (ENSIP)

MIL-HDBK-2066	Catapulting and Aresting Gear Forcing Functions for Aircraft Structural Design
MIL-HDBK-2084	General Requirements for Maintainability of Avionic and Electronic Systems and Equipment
MIL-HDBK-2165	Testability Program for Systems and Equipments
MIL-HDBK-5400	Electronic Equipment, Airborne General Guidelines for
MIL-HDBK-6870	Nondestructive Inspection Program Requirements for Aircraft and Missile Materials and Parts
MIL-HDBK-87213	Electronically/Optically Generated Airborne Displays

(Copies of these documents are available online at http://quicksearch.dla.mil. Copies of MIL-STD-2169 are available from the Defense Threat Reduction Agency, 8725 John J. Kingman Road, Stop 6201, Ft. Belvoir, VA 22060 or email michael.rooney@dtra.mil.)

2.2.2 Other Government documents, drawings, and publications.

The following other Government documents, drawings, and publications form a part of this document to the extent specified herein

CODE OF FEDERAL REGULATIONS (CFR)

Title 14	Aeronautics and Space
Part 23	Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes
Part 25	Airworthiness Standards: Transport Category Airplanes
Part 27	Airworthiness Standards: Normal Category Rotocraft
Part 29	Airworthiness Standards: Transport Category Rotocraft
Part 33	Airworthiness Standards: Aircraft Engines
Part 35	Airworthiness Standards: Propellers
Part 60	Flight Simulation Training Device Initial and Continuing Qualification and Use
Part 121	Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons on Board Such Aircraft
Part 133	Rotocraft External-Load Operations
Title 21	Food and Drugs
Part 1040	Performance Standards for Lighting-Emitting Products

(Copies of these documents can be viewed on line at www.ecfr.gov or purchased from the U.S. Government Online Bookstore at http://bookstore.gpo.gov.)

DEPARTMENT OF DEFENSE

DoDM 4140.01, Volume 11	DoD Supply Chain Materiel Management Procedures: Management of Critical Safety Items, Controlled Inventory Items Including Nuclear Weapons-Related Materiel
DoDI 4650.1	Policy and Procedures for Management and Use of the Electromagnetic Spectrum
DoDI 5000.02 Interim	Operation of the Defense Acquisition System
DoDI 5000.36	System Safety Engineering and Management
DoDI 6055.11	Protecting Personnel from Electromagnetic Fields
DoDD 3150.02	DoD Nuclear Weapon Surety Program
DoD 6055.9-M	DoD Ammunition and Explosives Safety Standards, Vols 1 thru 8
DoDM 4140.01	DoD Supply Chain Materiel Management Procedures, Vols 1 thru 11

(Copies of the DoD documents are available online at www.dtic.mil/whs/directives.)

DoD AIMS 03-1000	Technical Standard For The ATCRBS/IFF/Mark XIIA Electronic Identification and Military Implementation of Mode S and Classified Addenda 1-4
DoD AIMS 97-1000	Technical Standard for the ATCRBS/IFF/MarkXII Electronic Identification and Military Mode S

(Copies of the DoD AIMS documents are available online at www.dod-aims.com.)

DD Form 250	Material Inspection and Receiving Report
DD Form 365-1	Weight Checklist Record, Chart A - Basic
DD Form 1494	Application for Equipment Frequency Allocation

(Copies of the DD Forms are available online at www.e-publishing.af.mil.)

JOINT/INTERSERVICE DOCUMENTS

TB 700-2/ NAVSEAINST 8020.8/ TO 11A-1-47	Department of Defense Ammunition and Explosives Hazard Classification Procedures

(Copies of the Joint Technical Bulletin are available online at https://www.ddesb.pentagon.mil/docs/TB200-2.)

SECNAVINST 4140.2/ AFI 20-106/ DA Pam 95-9/ DLAI 3200.4/ DCMA INST CSI (AV)	Management of Aviation Critical Safety Items

AFMAN 24-204 (Interservice)/ TM 38-250/ NAVSUP PUB 505/ MCO P4030.19J/ DLAI 4145.3	Preparing Hazardous Materials for Military Air Shipments
AR 702-7/ AFR 74-6/ SECNAVINST 4855.5/ DLAR 4155.24	Product Quality Deficiency Report Program
NAVAIR 01-1B-50 TO 1-1B-50 TM 55-1500-342-23	Army Aviation Maintenance Engineering Manual for Weight and Balance
NAVAIR 01-1A-505-1 TO 1-1A-14 TM 1-1500-323-24-1	Installation and Repair Practices, Volume 1 – Aircraft Electric and Electronic Wiring

(Copies of this document are available online at http://armypubs.army.mil/epubs or http://doni.daps.dla.mil.)

JOINT AERONAUTICAL COMMANDERS' GROUP (JACG)

JACG Aviation Critical Safety Item Management Handbook

(Copies of this document are available online at https://acc.dau.mil/CommunityBrowser.aspx?id=444472.)

JACG Aviation Source Approval and Management Handbook

(Copies of this document are available online at https://acc.dau.mil/CommunityBrowser.aspx?id=394562&lang=en-US.)

JOINT SOFTWARE SYSTEM SAFETY ENGINERING WORKGROUP

DoD Joint Software Systems Safety Engineering Handbook (JSSSEH)

(Copies of the JSSSEH are available online at http://www.acq.osd.mil/se/pg/guidance.html.)

RANGE COMMANDERS COUNCIL

RCC 319	Flight Termination Systems Commonality Standard
RCC 323	Range Safety Criteria for Unmanned Air Vehicles

(Copies of RCC documents are available online at www.wsmr.army.mil/RCCSITE.)

CHAIRMAN OF THE JOINT CHIEFS OF STAFF INSTRUCTION

CJCSI 6212.01	Net Ready Key Performance Parameter (NR KPP)

(Copies of this document are available online at http://www.dtic.mil/cjcs_directives/.)

ARMY PUBLICATIONS

ARMY REGULATIONS

AR 11-9	The Army Radiation Safety Program
AR 40-10	Health Hazard Assessment Program in Support of the Army Acquisition Process
AR 70-62	Airworthiness Qualification of Aircraft Systems
AR 385-10	The Army Safety Program

ARMY PAMPHLETS

DA PAM 5-11	Verification, Validation and Accreditation of Army Models and Simulations
DA PAM 385-16	System Safety Management Guide
DA PAM 385-24	The Army Radiation Safety Program

(Copies of Army Regulations and Pamphlets are available online at http://armypubs.army.mil/epubs.)

ARMY MATERIEL COMMAND PHAMPLET

AMCP 706-201	Helicopter Engineering, Part One - Preliminary Design (AD A002007)
AMCP 706-203	Engineering Design Handbook, Helicopter Engineering, Part Three, Qualification Assurance

(Copies of these documents are available online at www.dtic.mil.)

ARMY AVIATION AND MISSILE COMMAND (AMCOM)

AMCOMR 385-17	AMCOM Software System Safety Policy
AMCOMR 702-7	Flight Safety Parts/New Source Testing Program Management

(Copies of these documents are available online at https://amcom.aep.army.mil/PandP/Regulations.)

ARMY AVIATION SYSTEMS COMMAND (USAAVSCOM)

USAAVSCOM TR-89-D-22B	Aircraft Crash Survival Design Guide, Volume II – Aircraft Design Crash Impact Cnoditions and Human Tolerance (AD-A218 435)
USAAVSCOM TR 89-D-22E	Aircraft Crash Survival Design Guide, Volume V – Aircraft Postcrash Survival (AD-A218 438)

(Copies of these documents are available online at www.dtic.mil.)

ARMY AERONAUTICAL DESIGN STANDARDS

ADS-1-PRF	Rotorcraft Propulsion System Airworthiness Qualification Requirements Ground and Flight Test Surveys and Demonstrations

ADS-10-SP	Air Vehicle Technical Description
ADS-13-HDBK	Air Vehicle Materials and Processes
ADS-24	Structural Demonstration (Cancelled)
ADS-27-SP	Requirements for Rotorcraft Vibration Specifications, Modeling and Testing
ADS-29	Structural Design Criteria for Rotary Wing Aircraft (Cancelled)
ADS-33-PRF	Handling Qualities Requirements for Military Rotorcraft
ADS-36	Rotary Wing Aircraft Crash Resistance (Inactive)
ADS-37-PRF	Electromagnetic Environmental Effects (E^3) Performance and Verification Requirements
ADS-40-SP	Air Vehicle Flight Performance Description
ADS-43-HDBK	Qualification Requirements and Identification of Critical Characteristics for Aircraft Engine Components
ADS-44-HDBK	Armament Airworthiness Qualification for U.S. Army Aircraft
ADS-45-HDBK	Data and Test Procedures for Airworthiness Release for U.S. Army Helicopter Armament Testing (Guns, Rockets, Missiles)
ADS-50-PRF	Rotorcraft Propulsion Performance and Qualification Requirements and Guidelines
ADS-51-HDBK	Rotorcraft and Aircraft Qualification (RAQ) Handbook
ADS-62-SP	Data and Test Requirements for Airworthiness Release for Helicopter Sensor Data and Testing Requirements in Development Stage
ADS-63-SP	Radar System Airworthiness Qualification and Verification Requirements
ADS-64-SP	Airworthiness Reqirements for Military Rotorcraft (Inactive)
ADS-65-HDBK	Data and Test Guidance for Qualification of Sensor Systems on Aircraft
ADS-66-HDBK	Guidance for Data for Safety of Flight Airworthiness Release for Helicopter Aircraft Survivability Equipment (ASE)
ADS-79-HDBK	Condition Based Maintenance System for US Army AircraftVibration, Specifications, Modeling and Testing

(Copies of these documents are available online at http://www.amrdec.army.mil/amrdec/rdmr-se/tdmd/StandardAero.htm.)

ARMY MEDICAL PUBLICATIONS

TB MED 523	Control of Hazards to Health from Microwave and Radio Frequency Radiation and Ultrasound

(Copies of this document are vailable online at http://armypubs.army.mil/med/index.html or http://phc.amedd.army.mil.)

ARMY TEST AND EVALUATION CENTER

Personnel Airdrop Optimizatiopn (PAO) Models for New Personnel Airdrop Platforms; (C-141 Cumulative Distribution Function (CDF) Curve)

(Copies of this document are available from the US Army Test and Evaluation Command, Aberdeen Proving Ground Maryland by emailing usarmy.APG.atec.mbx.atec-hq-pao@mail.mil.)

NAVY PUBLICATIONS

NAVY INSTRUCTIONS

NAVAIRINST 4200.56	Critical Item Management
COMNAVAIRFORINST 4790.2	The Naval Aviation Maintenance Program (NAMP)
OPNAVINST 4790.2	The Naval Aviation Maintenance Program (NAMP)
NAVAIRINST 5000.21	NAVAL SYSCOM Risk Management Policy
NAVAIRINST 5100.3	Naval Aviation System Safety Program
NAVAIRINST 13034.1	Flight Clearance Policy for Air Vehicles and Aircraft Systems

(Copies of these documents are available online at http://www.navair.navy.mil/lakehurst/hro-lakehurst/inst.html. Copies of the NAMP are available online at www.navair.navy.mil/logistics/4790/.)

NAVY AERONAUTICAL REQUIREMENTS

AR-56	Structural Design Requirements (Helicopters)
AR-89	Structural Ground Test Requirements (Helicopters)

(Copies of Navy Aeronautical Requirements documents may be obtained via U. S. Mail from the following address: Structures Division, ATTN: Bldg. 2187, Suite 2340A, NAVAIRSYSCOM, 48110 Shaw Road, Unit 5, Patuxent River, MD 20670-1906. For inquiries, phone (301) 342-9381.)

NAVAL AIR SYSTEMS COMMAND

SD-24L, Vol II	General Specification for Design and Construction of Aircraft Weapon Systems – Rotary Wing Aircraft
NAVAIR 01-1B-50	Technical Manual, USN/USMC Aircraft Weight and Balance Control

(Copies of these documents are available from Naval Air Systems Command, Standardization Section (AIR-4.1C), 1421 Jefferson Davis Highway, Arlington VA 22243.)

NAVAL AIR ENGINEERING CENTER

NAEC-MISC-06900	Aircraft Carrier Reference Manual

(Copies of Naval Air System Command documents may be obtained via Commander, Naval Air System Command, 47123 Buse Rd, B2272 Unit IPT, Patuxent River MD 20670-1547. Copies of NAVAIR Flight Clearance instructions may be obtained online at https://mynavair.navair.navy.mil.)

NAVAL SEA SYSTEMS COMMAND INSTRUCTIONS

NAV SEA OP 3565	Electromagnetic Radiation Hazard

NAVAL SEA SYSTEMS COMMAND TECHNICAL MANUALS

NAVSEA TM-S9310-AQ-SAF-010	Technical Manual for Navy Lithium Battery Safety Program Responsibilities and Procedures

(Copies of Naval Sea System Command documents may be obtained via Naval Air System Command, 1333 Isaac Hull Ave S. E., Washington Navy Yard, D. C. 20376, phone (202) 781-0000. Copies of NAVSEA technical manuals can be ordered from the NAVSUP Weapon Systems Support (NAVSUP WSS), Mechanicsburg, PA or from the Naval Logistic Library (NLL) at http://www.nll.navsup.navy.mil. Tech Manuals can also be acquired at Defense Automatic Addressing System Center Automatic Message Exchange System (DAMES), Standard Automated Logistic Tool Set (SALTS) or Naval Message.)

AIR FORCE PUBLICATIONS

AF POLICY DIRECTIVES

AFPD 62-6	USAF Airworthiness
AFPD 63-1; AFPD 20-1	Integrated Life Cycle Management

AF INSTRUCTIONS

AFI 11-202V3	General Flight Rules
AFI 11-2C-130V3	C-130 Operations Procedures
AFI 21-101	Aircraft and Equipment Maintenance Management
AFI 48-139	Laser and Optical Radiation Protection Program
AFI 63-133	Aircraft Information Programs
AFI 63-137	Assurance of Communications, Navigation, Surveillance/Air Traffic Management (CNS/ATM), Navigation Safety, and Next Generation Air Transportation System (NEXTGEN) Performance
AFI 63-501	Air Force Acquisition Quality Program

AFI 63-101/20-101	Integrated Life Cycle Management

AF PAMPHLET

AFPAM 63-113	Program Protection Planning for Life Cycle Management

AF OCCUPATIONAL SAFETY AND HEALTH (AFOSH)

AFOSH

AFOSHSTD48-20	Occupational Noise and Hearing Conservation Program

(Copies of these documents are available online at http://www.e-publishing.af.mil/.)

AIR FORCE TECHNICAL ORDER (AFTO)

TO 00-5-1	AF Technical Order System (ATOS)
TO 00-5-3	AF Technical Order Life Cycle Management
TO 1-1B-50	Basic Technical Order for USAF Aircraft – Weight and Balance
TO 31Z-10-0	Electromagnetic Radiation Hazard
TO 31Z-10-4	Joint Services Command, Control, Communication, and Computer Systems Electromagnetic Radiation Hazards

(Copies of these documents are available online at www.tinker.af.mil/technicalorders/.)

AIR FORCE TECHNICAL REPORTS

AFFTC-TR-95-39	Evaluation of the C-17A Aircraft Personnel and Equipment Bundles Airdrop Capabilities; (C-17 High Altitude Entanglement Test Procedures)
AFRL-HE-WP-TR-2002-0118 (ADA405598)	Body Size Accommodation in USAF Aircraft

(Copies of these documents are available online at www.dtic.mil.)

OTHER AIR FORCE DOCUMENTS

ASC-TM-ENE-77-1	Criteria for Nonstandard Airdrop Loads
BP-99-06D	AFLCMC/LP USAF Propulsion Center of Excellence Best Practice, Risk Management Process
AWB-013	USAF Airworthiness Bulletin, Risk Identification and Acceptance for Airworthiness Determinations
ENFS-SB-05-002	Joint USAF/USN Aircraft Loads Flight Release Methodology to Establish Aircraft Operating Limits Utilizing Demonstrated Strength Capability

EN-SB-08-001	Revised Damage Tolerance Requirements and Determination of Fail-Safety Life Limits for Fail-Safe Metallic Structures
EN-SB-12-002	USAF Structures Bulletin: Methodology to Establish Bird Strike Design Criteria
ENFC-CSB-08-01	USAF Crew Systems Bulletin Aircrew Accommodation Requirements/Verification

(Copies of these documents are available by contacting Engineering.Standards@us.af.mil; copies of SBs are available online at https://cs4.eis.afmc.af.mil/sites/1636/ASIP/ASIPDistroA/Forms/AllItems.aspx.)

PROPULSION CENTER OF EXCELLENCE

PCoE BP 99-06	Aircraft Gas Turbine Engine Flight Safety Risk Management Process

(Copies of this document are available online at https://cs.eis.afmc.af.mil/sites/Propulsion/PCOE/default.aspx.)

AFLCMC/ENSM Manufacturing Development Guide

(Copies of the Manufacturing Guide may be obtained by mail ASC/ENSM, 2145 Monahan Way, Bldg 28, Wright-Patterson AFB, OH 45433-7017, Commercial (937) 656-5973, DSN 986-5973; or may be viewed online at the EN website: http://www.wpafb.af.mil/shared/media/document/AFD-100630-068.pdf.)

ASC/EN Systems Engineering Guide

(Copies of this document are available by contacting Engineering.Standards@us.af.mil.)

Flying Qualities Development Process (FQDP)

(Copies of this document are available from AFLCMC/EZFT, Mr. William Thomas, Wright-Patterson AFB OH 45433-7101; DSN 785-8579 or at 937-255-8579.)

USAF Weapon Systems Software Management Guidebook

(Copies of the WSSM are available online at https://acc.dau.mil/CommunityBrowser.aspx?id=280695&lang=en-US.)

Unmanned Systems Safety Guide for DOD Acquisition

(Copies of this document are available online at https://acc.dau.mil.)

DEPARTMENT OF TRANSPORTATION – FEDERAL AVIATION ADMINISTRATION (FAA)

FEDERAL AVIATION REGULATIONS (FAR)

Title 14	Aeronautics and Space
Part 23	Airworthiness Standards: Normal, Unility, Acrobatic, and Commuter Category Airplanes

Part 25	Airworthiness Standards: Transport Category Airplanes
Part 27	Airworthiness Standares: Normal Category Rotocraft
Part 29	Airworthiness Standards: Transport Category Rotocraft
Part 33	Airworthiness Standards: Aircraft Engines
Part 35	Airworthiness Standards: Propellers
Part 60	Flight Simulation Training Device Initial and Continuing Qualification and Use
Part 121	Operating Requirements: Domestic, Flag, and Supplemental Operations
Part 133	Rotorcraft External-Load Operations
Title 21	Food and Drugs
Part 1040	Performance Standards for Light-Emitting Products

(Copies of the FARs can be viewed on line at www.ecfr.gov or purchased from the U.S. Government Online Bookstore at http://bookstore.gpo.gov.)

ADVISORY CIRCULARS (AC)

AC 20-29	Use of Aircraft Fuel Anti-Icing Additives
AC 20-30	Aircraft Position Light and Anticollision Light Installations
AC 20-41	Substitute Technical Standard Order (TSO) Aircraft Equipment
AC 20-42	Hand Fire Extinguishers for Use in Aircraft
AC 20-53	Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Caused by Lightning
AC 20-60	Accessibility to Excess Emergency Exits
AC 20-115	Airborne Software Assurance
AC 20-119	Fuel Drain Valves
AC 20-128	Design Considerations for Minimizing Hazards Caused By Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure
AC 20-131	Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Associated Mode S Transponders
AC 20-136	Aircraft Electrical and Electronic System Lightning Protection
AC 20-138	Airworthiness Approval of Positioning and Navigation Systems
AC 20-140	Guidelines for Design Approval of Aircraft Data Link Communication Systems Supporting Air Traffic Services (ATS)
AC 20-145	Guidance for Integrated Modular Avionics (IMA) that Implement TSO-C153 Authorized Hardware Elements
AC 20-148	Reusable Software Components

AC 20-152	RTCA, Inc., Document RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware
AC 20-156	Aviation Databus Assurance
AC 20-170	Integrated Modular Avionics Development, Verification, Integration and Approval using RTCA/DO-297 and Technical Standard Order-C153
AC 23-1309-1	System Safety Analysis and Assessment for Part 23 Airplanes
AC 23-1311-1	Installation of Electronic Display in Part 23 Airplanes
AC 25-9	Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Emergency Procedures
AC 25-16	Electrical Fault and Fire Prevention and Protection
AC 25-17	Transport Airplane Cabin Interiors Crashworthiness Handbook
AC 25.853-1	Flammability Requirements for Aircraft Seat Cushions
AC 25.869-1	Fire Protection: Systems
AC 25.963-1	Fuel Tank Access Covers
AC 25.981-1	Fuel Tank Ignition Source Prevention Guidelines
AC 25.981-2	Fuel Tank Flammability Reduction Means
AC 25.994-1	Design Considerations to Protect Fuel Systems During a Wheels-Up Landing
AC 25-1309-1	System Design and Analysis
AC 27-1	Certification of Normal Category Rotorcraft
AC 29-2	Certification of Transport Category Rotorcraft
AC 33-1	Turbine Engine Foreign Object Ingestion and Rotor Blade Containment Type Certification Procedures
AC 33-2	General Type Certification Guidelines for Turbine Engines
AC 33-3	Turbine and Compressor Rotors Type Certification Substantiation Procedures
AC 33-4	Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines
AC 33.4-2	Instructions for Continued Airworthiness: In-Service Inspection of Safety Critical Turbine Engine Parts at Piece-Part Opportunity
AC 33-5	Turbine Engine Rotor Blade Containment/Durability
AC 33.28-1	Compliance Criteria for 14 CFR §33.28, Aircraft Engines, Electrical and Electronic Engine Control Systems
AC 33-76-1	Bird Ingestion Certification Standards
AC 43.13-1	Acceptable Methods, Techniques, and Practices - Aircraft Inspection and Repair

AC 90-96	Approval of U.S. Operators and Aircraft To Operate Under Instrument Flight Rules (IFR) in European Airspace Designated For Basic Area Navigation (B-RNAV)/RNAV 5 and Precision Area Navigation (P-RNAV)
AC 91-85	Authorization of Aircraft and Operators for Flight in Reduced Vertical Separation Minimum Airspace
AC 120-40	Airplane Simulator Qualification
AC 120-42	Extended Operations (ETOPS and Polar Operations)
AC 120-63	Helicopter Simulator Qualification

FAA TECHNICAL STANDARD ORDERS (TSO)

TSO-C70	Liferafts (Reversible and Nonreversible)
TSO-C77	Gas Turbine Auxiliary Power Units
TSO-C112	Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/MODE S) Airborne Equipment
TSO-C151	Terrain Awareness and Warning System (TAWS)
TSO-C153	Integrated Modular Avionics Hardware Elements

FAA TECHNICAL REPORTS

DOT/FAA/AR-07/48	Handbook for Real-Time Operating Systems Integration and Component Integration Considerations in Integrated Modular Avionics Systems
DOT/FAA/AR-99/58	Partitioning in Avionics Architecture: Requirements, Mechanisms, and Assurance

FAA GUIDES

Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety

(Copies of these documents are available online at https://www.faa.gov/about/office_org/headquarters_offices/ast/regulations/.

FAA CERTIFICATION AUTHORITIES SOFTWARE TEAM (CAST) POSITION PAPERS

CAST-24	Reliance on Development Assurance Alone When Performing a Complex and Full-Time Critical Function

SPECIAL FEDERAL AVIATION REGULATION (SFAR)

SFAR 88	Fuel Tank System Fault Tolerance Evaluation Requirements

(Copies of these documents are available online at www.faa.gov.)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NASA-STD-7009	Standard for Models and Simulations

NASA-STD-8719.13	Software Safety Standard
NASA-STD-8739.8	Software Assurance Standard
NASA-GB-8719.13	NASA Software Safety Guidebook

NASA PROCEDURAL REQUIREMENTS

NASA-NPR 7150.2	NASA Software Engineering Requirements

(Copies of these document are available online at https://standards.nasa.gov..)

2.3 Non-Government publications.

The following documents form a part of this document to the extent specified herein.

AERIAL REFELING SYSTEMS ADVISORY GROUP (ARSAG) INTERNATIONAL

ARSAG 03-00-03R	Aerial Refueling Pressures: Definitions and Terms, Design and Verification Guidance

(Copies of this document are available online at http://arsaginc.com or from ARSAG International, P.O. Box 340638, Beavercreek OH 45434 or by emailing arsaginc@earthlink.net.

AERONAUTICAL RADIO, INC. (ARINC)

ARINC Report 609	Design Guidance for Aircraft Electrical Power Systems
ARINC Specification 653	Avionics Application Software Standard Interface, Parts 1 thru 5
ARINC Report 667-1	Guidance for the Management of Field Loadable Software

(Copies of these documents are available online at http://store.aviation-ia.com or from ARINC Incorporated, 2551 Riva Road, Annapolis, MD 21401-7435.)

ACOUSTICAL SOCIETY OF AMERICA (ASA)

ANSI/ASA S3.2	Method for Measuring the Intelligibility of Speech over Communication Systems (DoDAdopted)
ANSI/ASA S3.5	Methods for Calculation of the Speech Intelligibility Index (DoD Adopted)

(Copies of these documents are available online at http://acousticalsociety.ord.)

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME Y14.5	Dimensioning and Tolerancing (DoD Adopted)

(Copies of this document are available online at www.asme.org.)

ASTM INTERNATIONAL

ASTM G85	Standard Practice for Modified Salt Spray (Fog) Testing (DoD Adopted)
ASTM B117	Standard Practice for Operating Salt Spray (Fog) Apparatus (DoD Adopted)
ASTM F330	Standard Test Method for Bird Impact Testing of Aerospace Transparent Enclosures (DoD Adopted)
ASTM F733	Standard Practice for Optical Distortion and Deviation of Transparent Parts Using the Double-Exposure Method
ASTM F735	Standard Test Method for Abrasion Resistance of Transparent Plastics and Coatings Using the Oscillating Sand Method
ASTM D1044	Standard Test Method for Resistance of Transparent Plastics to Surface Abrasion (DoD Adopted)
ASTM F2156	Standard Test Method for Measuring Optical Distortion in Transparent Parts Using Grid Line Slope
ASTM D2247	Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity (DoD Adopted)
ASTM F2316	Standard Specification for Airframe Emergency Parachutes
ASTM D2803	Standard Guide for Testing Filiform Corrosion Resistance of Organic Coatings On Metal (DoD Adopted)

(Copies of these documents are available online at www.astm.org.)

BATTELLE MEMORIAL INSTITUTE (BMI)

MMPDS-08	Metallic Materials Properties Development and Standardization (MMPDS) (DoD Adopted)

(Copies of the MMPDS are available at www.mmpds.org or by email at bcommmpds@battelle.org.)

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC. (IEEE)

IEEE Std C95.1	IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, Amendment 1: Specifies Ceiling Limits for Induced and Contact Current, Clarifies Distinctions between Localized Exposure and Spatial Peak Power Density (DoD Adopted)
IEEE Std 828	IEEE Standard for Configuration Management in Systems and Software Engineering
IEEE Std 1012	IEEE Standard for System and Software Verification and Validation
IEEE Std 1074	IEEE Standard for Developing a Software Project Life Cycle Process
IEEE Std 1220	IEEE Standard for Application and Management of the Systems Engineering Process (DoD Adopted)

IEEE Std 1228	IEEE Standard for Software Safety Plans

(Copies of these documents are available from the IEEE Standards Store online at www.techstreet.com/ieee.)

LASER INSTITUTE OF AMERICA (LIA)

ANSI Z136.1	American National Standard for Safe Use of Lasers (DoD Adopted)

(Copies of this document are available online at http://www.lia.org.)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 1	Fire Code
NFPA 70	National Electrical Code (DoD Adopted)

(Copies of these documents are available online at www.nfpa.org.)

RADIO TECHNICAL COMMISSION FOR AERONAUTICS (RTCA) Inc.

DO-160	Environmental Conditions and Test Procedures for Airborne Equipment
DO-178	Software Considerations in Airborne Systems and Equipment Certification
DO-181	Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRB/Mode S) Airborne Equipment
DO-185	Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II (TCAS II)
DO-186	Minimum Operational Performance Standards for Airborne Radio Communications Equipment Operating Within the Radio Frequency Range 117.975 – 137.000 MHz
DO-189	Minimum Operational Performance Standards for Airborne Distance Measuring Equipment (DME) Operating within the Radio Frequency Range of 960-1215 MHz
DO-200	Standards for Processing Aeronautical Data
DO-212	Minimum Operational Performance Standards for Airborne Automatic Dependent Surveillance (ADS) Equipment
DO-219	Minimum Operational Performance Standards (MOPS) for ATC Two-Way Data Link Communications
DO-236	Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation
DO-254	Design Assurance Guidance for Airborne Electronic Hardware
DO-255	Requirements Specification for Avionics Computer Resource (ACR)

DO-278	Guidelines for Communication, Navigation, Surveillance, and Air Traffic Management (CNS/ATM) Systems Software Integrity Assurance
DO-297	Integrated Modular Avionics (IMA) Development Guidance and Certification Considerations
DO-330	Software Tool Qualification Considerations
DO-331	Model-Based Development and Verification Supplement to DO-178C and DO-278A
DO-332	Object-Oriented Technology and Related Techniques Supplement to DO-178C and DO-278A
DO-333	Formal Methods Supplement to DO-178C and DO-278A

(Copies of these documents are available online at www.rtca.org.)

SOCIETY OF ALLIED WEIGHT ENGINEERS, INC. (SAWE)

RECOMMENDED PRACTICES

SAWE RP7	Mass Properties Management and Control for Military Aircraft (DoD Adopted)
SAWE RP8	Weight and Balance Data Reporting Forms for Aircraft (including Rotorcraft) (DoD Adopted)

(Copies of these documents are available online at www.sawe.org.)

SAE INTERNATIONAL

AIR1419	(R) Inlet Total-Pressure-Distortion Considerations for Gas-Turbine Engines (DoD Adopted)
AIR4845	The FMECA Process in the Concurrent Engineering (CE) Environment
AIR5826	Distortion Synthesis/Estimation Techniques

AEROSPACE MATERIAL SPECIFICATION

AMS3694	Aerodynamic Smoothing Compound, Flexible, -55 to +130 °C (-65 to +270 °F)

AEROSPACE RECOMMENDED PRACTICE

ARP994	(R) Recommended Practice for the Design of Tubing Installations for Aerospace Fluid Power Systems (DoD Adopted)
ARP1070	(R) Design and Testing of Antiskid Brake Control Systems for Total Aircraft Compatibility
ARP1420	Gas Turbine Engine Inlet Flow Distortion Guidelines (DoD Adopted)
ARP1493	Wheel and Hydraulically Actuated Brake Design and Test Requirements for Military Aircraft

ARP1538	(R) Arresting Hook Installation, Land-Based Aircraft
ARP1834	Fault/Failure Analysis for Digital Systems and Equipment
ARP1870	Aerospace Systems Electrical Bonding and Grounding for Electromagnetic Compatibility and Safety
ARP4754	(R) Guidelines for Development of Civil Aircraft and Systems
ARP4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
ARP5089	Composite Repair NDT/NDI Handbook
ARP5412	(R) Aircraft Lightning Environment and Related Test Waveforms
ARP5580	Recommended Failure Modes and Effects Analysis (FMEA) Practices for Non-Automobile Applications
ARP5583	(R) Guide to Certification of Aircraft in a High-Intensity Radiated Field (HIRF) Environment
ARP5794	Centrifugal Aircraft Fuel Pump Requirements, Design and Testing
ARP8615	Fuel System Components: General Specification For (DoD Adopted)

AEROSPACE STANDARD

AS1055	Fire Testing of Flexible Hose, Tube Assemblies, Coils, Fittings, and Similar System Components (DoD Adopted)
AS1426	Standard Galley System Specification Appendix II, 20.0 Data Requirements and Procedures
AS1831	Electrical Power, 270 V DC, Aircraft, Characteristics and Utilization of
AS4273	(R) Fire Testing of Fluid Handling Components for Aircraft Engines and Aircraft Engine Installations (DoD Adopted)
AS5440	(R) Hydraulic Systems, Military Aircraft, Design and Installation Requirements For (DoD Adopted)
AS5726	Interface Standard, Interface for Micro Munitions
AS6081	Fraudulent/Counterfeit Electronic Parts: Avoidance, Detection, Mitigation, and Disposition – Distributors (DoD Adopted)
AS6174	Counterfeit Materiel; Assuring Acquisition of Authentic and Conforming Materiel (DoD Adopted)
AS8049	Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft, and General Aviation Aircraft
AS8049/1	Performance Standards for Single-Occupant, Side-facing Seats in Civil Rotorcraft, Transport Aircraft, and General Aviation Aircraft
AS8091	(R) Aircraft Jacking PadsAdapters and Sockets Design and Installation Of (DoD Adopted)
AS8584	Brake Systems, Wheel, Military Aircraft
AS8775	Hydraulic System Components, Aircraft and Missiles, General Specification For (DoD Adopted)

AS9100	Quality Management Systems – Requirements for Aviation, Space and Defense Organizations(DoD Adopted)
AS9102	(R) Aerospace First Article Inspection Requirement
AS9103	(R) Aerospace Series – Quality Management Systems - Variation Management of Key Characteristics
AS18012	Markings for Aircrew Station Displays Design and Configuration of (DoD Adopted)
AS50881	Wiring Aerospace Vehicle (DoD Adopted)
AS94900	Aerospace - Flight Control Systems – Design, Installation and Test of Piloted Military Aircraft, General Specification For (DoD Adopted)
CMH-17-1	Composite Materials Handbook Volume 1 – Polymer Matrix Composites Guidelines for Characterization of Structural Materials
CMH-17-2	Composite Materials Handbook Volume 2 – Polymer Matrix Composites Materials Properties
CMH-17-3	Composite Materials Handbook Volume 3 – Polymer Matrix Composites Materials Usage, Design, and Analysis
CMH-17-4	Composite Materials Handbook Volume 4 – Metal Matrix Composites
CMH-17-6	Composite Materials Handbook Volume 6 – Structural Sandwich Composites

TECHNICAL REPORTS

SAE EIA-632	Processes for Engineering a System
SAE EIA-649	Configuration Management Standard

SAFETY ENGINEERING BULLETIN

EIA SEB6	System Safety Engineering in Software Development

(Copies of these documents are available online at www.sae.org.)

SOFTWARE ENGINEERING INSTITUTE – CARNEGIE MELLON UNIVERSITY

CMU/SEI-2010-TR-033	CMMI® (Capability Maturity Model Integration) for Development, Improving processes for developing better products and services

(Copies of this document are available at www.sei.cmu.edu.)

3. DEFINITIONS AND ACRONYMS

3.1 Definitions.

All definitions, unless otherwise referenced, are to be considered within the context of this document.

3.1.1 Advisory circular (AC).

The Federal Aviation Administration (FAA) issues advisory circulars (AC) to inform the aviation public, in a systematic way, of nonregulatory material. Unless incorporated into a regulation by reference, the contents of an advisory circular are not binding on the public. Advisory circulars are issued in a numbered-subject system corresponding to the subject areas of the Title 14, Code of Federal Regulations (14 CFR reference), Chapter I, Federal Aviation Administration. An AC is issued to provide guidance and information in a designated subject area or to show a method acceptable to the Administrator for complying with a related FAR. When using 14 CFR references for compliance with airworthiness certification criteria, consult applicable ACs for guidance.

3.1.2 Air system.

An air vehicle plus the training and support systems for the air vehicle (e.g., communications, control, ground/surface/control station, launch and recovery, and support elements), and any weapons to be employed on the air vehicle. (Reference: JSSG-2000). For example, an Unmanned Aircraft System (UAS) is an air system. An air vehicle, manned or unmanned, is a subset of its associated air system.

3.1.3 Air vehicle.

An air vehicle includes the installed equipment (hardware and software) for airframe, propulsion, on-board vehicle and applications software, communications/identification, navigation/guidance, central computer, fire control, data display and controls, survivability, reconnaissance, automatic flight control, central integrated checkout, antisubmarine warfare, armament, weapons delivery, auxiliary equipment, and all other installed equipment. (JSSG-2001)

3.1.4 Air vehicle system.

See air vehicle.

3.1.5 Airframe.

The structure of an aircraft, guided missile or the like, apart from accessories and power plant. The principal parts of the airframe include the fuselage, wings, empennage, landing gear, and nacelles or pods.

3.1.6 Airworthiness.

The property of a particular air system configuration to safely attain, sustain, and terminate flight in accordance with the approved usage and limits.

3.1.7 Airworthiness certification.

A repeatable process implemented to verify that a specific air system can be, or has been, safely maintained and operated within its described flight envelope. The two necessary conditions for issuance and maintenance of an airworthiness certification are: (1) the air system must conform to its type design; and (2) the air system must be in a condition for safe operation.

3.1.8 Allocated baseline.

The approved, performance-oriented documentation for a configuration item (CI) to be developed, which describes the functional and interface characteristics that are allocated from those of the higher level CI and the verification required to demonstrate achievement of those specified characteristics.

3.1.9 Baseline.

As applied to Computer Systems and Software: The approved and recorded configuration of one or more configuration items that serves as the basis for subsequent changes to those configuration items, and that is changed only through change control procedures (see also Configuration baseline).

3.1.10 Breakaway.

The command used by tanker or receiver crewmembers/operators indicating a need for emergency vertical and horizontal separation of their aircraft.

3.1.11 Cargo aircraft.

An aircraft (e.g., C-17, C-130, KC-135) that is designed or converted for the carriage of cargo (e.g., goods, freight).

3.1.12 Certification basis.

The complete (necessary and sufficient), documented set of airworthiness criteria, standards and methods of compliance utilized to assess the airworthiness and safety of flight of a specific system design.

3.1.13 Code.

As applied to Computer Systems and Software: The implementation of particular data and/or computer instructions in the form of source code, object code, or machine code.

3.1.14 Component.

As applied to Computer Systems and Software: Any item that is used to construct an element.

3.1.15 Computer software configuration item (CSCI).

An aggregation of software that satisfies an end use function and is designated for separate configuration management by the acquirer.

3.1.16 Computer system integrity level (CSIL).

A designation applied to an element/component which determines the set of development and verification processes that will be applied to the element/component in order to achieve a defined level of integrity in the design.

3.1.17 Configuration baseline.

(1) An agreed-to description of the attributes of a product at a specified point in time, which serves as a basis for defining change. (2) An approved and released document or set of documents, each of a specific revision, the purpose of which is to provide a defined basis for managing change. (3) The currently approved and released configuration documentation. (4) A released set of files consisting of a software version and associated configuration documentation. (SAE EIA-649)

3.1.18 Configuration control.

(1) A systematic process that ensures that changes to a baseline are properly identified, documented, etc. (2) The configuration management activity concerning: the systematic proposal, justification, evaluation, coordination, and disposition of proposed changes; and the implementation of all approved and released changes into (a) the applicable configurations of a product; (b) associated product information; and (c) supporting and interfacing products and their associated product information. (SAE EIA-649)

3.1.19 Configuration item (CI).

A configuration item is any hardware, software, or combination of both that satisfies an end use function and is designated for separate configuration management. Configuration items are typically referred to by an alphanumeric identifier which also serves as the unchanging base for the assignment of serial numbers to uniquely identify individual units of the CI. (MIL-HDBK-61)

3.1.20 Configuration management.

A management process for establishing and maintaining consistency of a product's performance, functional, and physical attributes with its requirements, design, and operational information throughout its life. (SAE EIA-649)

3.1.21 Configuration status accounting.

The configuration management activity concerning capture and storage of, and access to, configuration information needed to manage products and product information effectively. (SAE EIA-649)

3.1.22 Continuity of Service.

Uninterrupted service. Continuity of service is the property that a system will maintain its safety of flight performance level for the duration of an operation within the system's intended use, and presuming system availability at the beginning of that period. System hardware, software, and firmware may include redundant systems and processes to accommodate potential loss of service.

3.1.23 Control station.

A facility or device, consisting of hardware and software, from which one or more unmanned aircraft are controlled and/or monitored for any phase of flight operations. The control station may be stationary, mobile as carried by another ground vehicle, aircraft, or naval vessel, or carried by ground personnel.

3.1.24 Core tests.

As applied to Computer Systems and Software: A subset of test cases of the entire test suite that is required to verify the safety critical functions of a system for every flight release.

3.1.25 Coupling.

As applied to Computer Systems and Software: The degree of interdependency between components/elements.

3.1.26 Crew station.

The physical environment in which a pilot, crew member, or operator performs mission duties.

3.1.27 Crewmember.

As applied to Crew Systems, Section 9: Any person on the air vehicle who performs mission duties.

3.1.28 Criteria.

Principles for evaluating the airworthiness of an air system.

3.1.29 Criterion.

A principle for evaluating the airworthiness of an air system.

3.1.30 Critical safety item (CSI).

A part, an assembly, installation equipment, launch equipment, recovery equipment, or support equipment for an aircraft or aviation weapon system if the part, assembly, or equipment contains a characteristic any failure, malfunction, or absence of which could cause 1) a catastrophic or critical failure resulting in the loss of or serious damage to the aircraft or weapon system; 2) an unacceptable risk of personal injury or loss of life; or 3) an uncommanded engine shutdown that jeopardizes safety. (JACG Critical Safety Item Management Handbook, 16 March 2011)

3.1.31 Data channel.

As applied to Computer Systems and Software: The combination of transition medium(ia), protocols, and logical connections that is required to transfer data from a source to a destination.

3.1.32 Deactivated code.

As applied to Computer Systems and Software: Any code that exists in an application that is designed to not be executed during intended operational conditions.

3.1.33 Dead code.

As applied to Computer Systems and Software: Any code that exists in an application that is inaccessible during operation or whose outputs when executed are not utilized.

3.1.34 Element.

As applied to Computer Systems and Software: A logically grouped collection of items having a definitive interface and functional purpose.

3.1.35 End-item.

Equipment that can be used by itself to perform a military function or provides an enhanced military capability to a system and has a distinct management activity to control its technical and performance baseline.

3.1.36 Failure.

The inability of a system or system component to perform a required function within specified limits.

3.1.37 Failure modes, effects, and criticality analysis (FMECA).

A procedure for identifying potential failure modes in a system and classifying them according to their severity. A FMECA is usually carried out progressively in two parts. The first part identifies failure modes and their effects (also known as failure modes and effects analysis). The second part ranks the failure modes according to the combination of their severity and the probability of occurrence (criticality analysis).

3.1.38 Fault.

As applied to Computer Systems and Software: A manifestation of an error in software.

3.1.39 Fault tolerance.

The ability of a system to provide an acceptable level of operational performance and safety in the event of one or more failures.

3.1.40 Firmware.

The combination of a hardware device and one or more of the following: computer instructions, computer data, and programmable hardware logic. The programming/data is not readily capable of being changed. NOTE: For the purposes of this document, the functionality of firmware defined by the programmable hardware logic is considered to be hardware; and functionality of firmware with computer instructions/data is treated as software.

3.1.41 Flight clearance (Navy and Marine Corps use).

A formal document that provides assurance of airworthiness and safety of flight and ensures risk has been identified and accepted at the appropriate level, within acceptable bounds for the intended mission.

3.1.42 Flight critical.

A term applied to any condition, event, operation, process, or item whose proper recognition, control, performance, or tolerance is essential to achieving or maintaining controlled flight of an aircraft.

3.1.43 Flight termination system (FTS).

A system which provides the ability to end flight in a controlled manner. The FTS includes all systems, subsystems and components that control and execute the termination procedure The function may be commanded from a control station or by the air vehicle itself.

3.1.44 Functional baseline.

The approved configuration documentation describing a system's or top-level configuration item's performance (functional, interoperability, and interface characteristics) and the verification required to demonstrate the achievement of those specified characteristics.

3.1.45 Functional separation.

An attribute of a component/element that is achieved when its functional performance has no dependency on the functional performance of another component/element.

3.1.46 Hazard.

A real or potential condition that could lead to an unplanned event or series of events (i.e. mishap(s)) resulting in death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment. (MIL-STD-882)

3.1.47 Integrity.

The essential characteristics of a system, subsystem, or equipment that allow specific performance, reliability, safety, and supportability to be achieved under specified operational and environmental conditions, and over a specific service life.

3.1.48 Interface.

The performance, functional, and physical attributes required to exist at a common boundary. (SAE EIA-649)

As applied to Crew Systems, Section 9: A physical, graphical, and/or perceptual interaction between the pilot, operator or crewmember and the system.

3.1.49 Interlock.

System design mechanization to enable or disable systems, functions, subsystems, or modes at given times and conditions.

3.1.50 Method of compliance (MoC).

A logical or systematic means to demonstrate or verify compliance with airworthiness criteria and standards. Method(s) of compliance will generate artifacts and objective evidence used in an airworthiness authority's determination of airworthiness.

3.1.51 Mishap.

An event or series of events resulting in unintentional death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment. For the purposes of this document, the term “mishap” includes negative environmental impacts from planned events. (MIL-STD-882)

3.1.52 Mission critical.

A term applied to any condition, event, operation, process or item, the failure of which may result in the inability to achieve successful mission completion or to maintain combat capability.

3.1.53 Mission equipped.

Pilot, operator or crewmember fully outfitted with appropriate clothing and equipment to perform the mission and/or provide personal protection.

3.1.54 Multi place aircraft.

Aircraft that have multiple crewmembers (e.g., USAF E-3 Sentry, AC-130, B-52).

3.1.55 Operational state I (normal operation).

Operational State I is the normal state of Vehicle Control Function (VCF) operation providing sufficient performance, safety and reliability to accomplish the mission tasks and system requirements of the air vehicle within the required flight envelope and airspace. This state satisfies Level 1 flying qualities within the Region of Satisfactory Handling (ROSH).

3.1.56 Operational state II (restricted operation).

Operational State II is the state of less than normal VCF operational performance, safety or reliability with no loss of flight critical functions. Any degradation in mission effectiveness and restrictions of flight envelope will not prevent the vehicle from completing a modified mission or from making a degraded landing at the destination of original intent. This state results in minimal increase in crew workload and may result in a limited selection of VCF modes. This state satisfies Level I flying qualities within the Region of Satisfactory Handling (ROSH).

3.1.57 Operational state III (minimum safe operation).

Operational State III is the state of degraded VCF performance, safety or reliability which permits the vehicle to safely abort the current mission task; maneuver capability is limited to cruise, navigation, transition to appropriate operating areas and an emergency landing. This state results in objectionable pilot workload and tracking or maneuvering completion which is satisfactory. This state satisfies Level II flying qualities within the Region of Satisfactory Handling (ROSH).

3.1.58 Operational state IV (controllable to safe landing (manned) or safe termination/ predetermined heading (unmanned)).

Operational State IV is the state of degraded VCF operation at which continued safe flight is not possible; however, sufficient control remains to allow engine restart attempt(s), controlled descent and immediate emergency landing (or safe termination for UAS).

3.1.59 Operational state V (loss of control).

Operational State V is the immediate loss of VCF state which allows no control of the vehicle impact site or of heading prior to impact. The VCF capability is limited to maneuvers required to reach a flight condition at which crew evacuation may be safely accomplished.

3.1.60 Operator.

Person who performs critical air vehicle tasks such as controlling manned or unmanned aircraft, payload(s), radar, communication, navigation and/or weapon system deployment.

3.1.61 Partitioning.

As applied to Computer Systems and Software: A technique for providing system resource (e.g., memory throughput) isolation to a given piece of software.

3.1.62 Passenger.

Any person on board an air vehicle who is not mission trained regarding the passenger safety/emergency capabilities of that particular air vehicle and mission. For a specific flight, this includes any person who does not have active crewmember duties and is not essential for accomplishing mission tasks. Mission training constitutes specialized air vehicle training beyond preflight safety briefings.

3.1.63 Performance.

A quantitative or qualitative measure characterizing a physical or functional attribute relating to the execution of an operation or function. Performance attributes include quantity (how many or how much), quality (how well), coverage (how much area, how far), timeliness (how responsive, how frequent), and readiness (availability, mission/operational readiness). Performance is an attribute for all systems, people, products, and processes including those for development, production, verification, deployment, operations, support, training, and disposal. Supportability parameters, manufacturing process variability, reliability, and so forth are all performance measures.

3.1.64 Photometric.

Relating to the measurement of visible light in units that are weighted according to the sensitivity of the human eye or test instrumentation.

3.1.65 Physical separation.

As applied to Computer Systems and Software: A hardware item is considered to be physically separated from another hardware item when the two items are electrically isolated from each other. A software application (e.g., CSCI, load image) is considered to be physically separated from another software application when the two applications do not share throughput or memory resources (resource isolation can be achieved through a partitioning mechanism).

3.1.66 Probability of loss of control (PLOC).

An expression of the likelihood of the loss of control, based upon the failure probabilities of those elements contributing to control of the air vehicle system.

3.1.67 Product baseline.

The approved technical documentation which describes the configuration of a CI during the production, fielding/deployment and operational support phases of its life cycle. The product baseline prescribes all necessary physical or form, fit, and function characteristics of a CI, the selected functional characteristics designated for production acceptance testing, and the production acceptance test requirements (MIL-HDBK-61). When used for re-procurement of a CI, the product baseline documentation also includes the allocated configuration documentation to ensure that performance requirements are not compromised.

3.1.68 Qualified.

The resulting state or condition from a formal verification process being applied to hardware and/or software systems to verify that requirements have successfully been met.

3.1.69 Radiometric.

Relating to the measurement of energy in any portion of the electromagnetic spectrum.

3.1.70 Redundancy.

Utilization of two or more components, subsystems, or channels so that the functions that they support are capable of being sustained in the event of a failure.

3.1.71 Redundancy management.

The process of managing redundant elements in order to identify a failure, and then reconfiguring the system to remove or mitigate the effects of the failed element and continue operation with operating elements.

3.1.72 Remotely operated aircraft (ROA).

See Unmanned air vehicle

3.1.73 Robustness testing.

Testing that stresses software by running it under conditions (e.g., input values, timing) which are very near the performance limits of the software.

3.1.74 Safety critical.

A safety classification given to any condition, event, operation, process, or item whose proper recognition, control, performance, or tolerance is essential to safe system operation and support (e.g., safety critical function, safety critical path, safety critical software, or safety critical component). Safety critical is a broader definition of the categorizations of safety and includes flight critical, but may not be limited to controlling flight. The term safety critical, as defined in MIL-STD-882, is "a condition, event, operation, process, or item whose mishap severity consequence is either Catastrophic or Critical".

3.1.75 Safety critical function (SCF).

A function whose failure to operate or incorrect operation will directly result in a mishap of either Catastrophic or Critical severity. (MIL-STD-882).

3.1.76 Safety critical function (SCF) thread.

The combination of elements/components within a system and the required interfacing and interaction of those elements/components whose overall contribution is necessary for the operation of a given safety critical function.

3.1.77 Safety interlocks.

An interlock that is necessary for the operation of one or more safety critical functions.

3.1.78 Safety-of-flight (SOF).

The property of a particular air system configuration to safely attain, sustain, and terminate flight within prescribed and accepted limits for injury/death to personnel and damage to equipment, property, and/or environment. The intent of safety-of-flight clearance is to show that appropriate risk management has been completed and the level of risk (hazards to system, personnel, property, equipment, and environment) has been appropriately identified and accepted by the managing activity prior to flight of the air system.

3.1.79 Safety-of-flight (SOF) items or equipment.

Items or equipment which, if they failed, would have the potential for precluding the continued safe flight of the air vehicle within prescribed and accepted limits for injury/death to personnel and damage to equipment, property, and/or environment.

3.1.80 Safety supporting element (SSE).

A single instance, logical grouping, or combination of SSSEs and SSHEs that is necessary for the operation of an SCF. An SSE can be a combination of SSEs.

3.1.81 Safety supporting hardware element (SSHE).

An element, comprised only of computer hardware, that is necessary for the operation of an SCF.

3.1.82 Safety supporting software element (SSSE).

An element, comprised only of software, that is necessary for the operation of an SCF.

3.1.83 Second like safety critical failure.

A second failure in a system supporting an SCF which is of the same type as that which has already occurred.

3.1.84 Single event upset (SEU).

The resulting unintentional change in the state of a binary logic storage cell (i.e., changing from 0 to 1 or vice versa) that occurs when an ionizing particle or electro-magnetic radiation strikes the storage circuitry. The erroneous state change is not permanent and is considered a soft failure because resetting or rewriting to memory will clear the condition.

3.1.85 Situational awareness.

The ability to identify, process, and comprehend critical, perceived elements of information in one's environment in order to make decisions about a future state and/or needed actions. Any information that is presented to the pilot, operator, and crewmember can, or will, affect situational awareness. If a system or information is presented 'for situational awareness', then performance must be demonstrated to prove that the information or system contributes (increases situational awareness), does not increase workload, or present potentially hazardous and misleading information.

3.1.86 Software architecture.

The organizational structure and interrelationship of software that identifies its components, interfaces, and the control/flow of execution.

3.1.87 Standard.

Specific requirement(s) which must be met to establish that a criterion has been satisfied.

3.1.88 System.

A specific grouping of end-items, subsystems, components, or elements designed and integrated to perform a function.

3.1.89 System processing architecture (SPA).

A collection of processing elements, and the structure and interconnections of those elements, that form systems or subsystems to meet processing requirements.

3.1.90 System safety.

The application of engineering and management principles, criteria, and techniques to achieve acceptable risk within the constraints of operational effectiveness and suitability, time, and cost throughout all phases of the system life cycle. (MIL-STD-882)

3.1.91 Traceability.

The ability to take a particular piece of development or design information and trace it to related information (examples: System level requirements to subsystem level requirements, software requirements to software design components, hardware component requirements to hardware test cases, function to sub-function, sub-function to hardware and software components that support the sub-function). Bi-directional traceability is the ability to make the trace in both directions.

3.1.92 Transport aircraft.

Aircraft that are configured to carry passengers (e.g., C-21, C-40, VC-25, C-17 with passengers, C-130 with passengers).

3.1.93 Type certification.

A repeatable process implemented to verify that an air system design conforms to its type design. Type certification does not verify that the system has been properly maintained or operated in accordance with its technical data. (See airworthiness certification.)

3.1.94 Type design.

The type design consists of

a. The drawings and specifications, and a listing of those drawings and specifications, necessary to define the configuration and the design features of the air system shown to comply with the airworthiness criteria applicable to the air system;
b. Information on dimensions, materials, materiel properties, and processes necessary to define the structural strength of the product;
c. Any airworthiness limitations required for safe operation and maintenance; and
d. Any other data necessary to allow, by comparison, the determination of the airworthiness, noise characteristics, fuel venting, and exhaust emissions (where applicable) of later products of the same type.

3.1.95 Unmanned air vehicle (UAV)

A remotely piloted/operated, semi-autonomous, or autonomous air vehicle and its on-board operating system. This does not include air vehicles designed for one-time use as weapons (e.g., cruise missile).

3.1.96 Unmanned aircraft (UA).

See Unmanned air vehicle

3.1.97 Unmanned aircraft system (UAS).

A UAS is comprised of individual elements consisting of the unmanned air vehicle (UAV), the control station, and any other support elements necessary to enable operation including, but not limited to data links, communications systems/links, and UAV-unique launch and recovery equipment. There may be multiple unmanned aircraft, control stations, and support elements within a UAS. The control station may be located on the ground (stationary or mobile), on a ship, submarine, aircraft, etc.

3.1.98 Vehicle control functions (VCFs).

VCFs include an integrated combination of functions which are critical to safety of flight and which permit an air vehicle/aircraft to be controlled in a manner that allows its specified missions to be accomplished satisfactorily. VCFs include all components and functions used to sense vehicle position, velocity, speed, inertial attitudes, rates and accelerations, heading and altitude, and to generate and transmit appropriate commands to force and moment producers in response to flight path commands, whether internally generated or received from an on- or off-board pilot. These commands, often generated by Guidance and Navigation elements of the VCFs, normally result in control of aircraft altitude, airspeed, heading, attitude, aerodynamic or geometric configuration, ride quality, and structural modes.

3.2 Abbreviations and acronyms.

A	Attack Aircraft
AACAS	Automatic Air Collision Avoidance System
AC	Advisory Circular
ACGIH	American Conference of Governmental Industrial Hygienists
ADS	Aeronautical Design Standard
ADS-B	Automatic Dependent Surveillance-Broadcast
AED	Aviation Engineering Directorate
AFGS	Air Force Guide Specification
AFLCMC	Air Force Life Cycle Management Center
AFOSH	Air Force Occupational Safety and Health
AFPAM	Air Force Pamphlet
AFPD	Air Force Policy Directive
AGCAS	Automatic Ground Collision Avoidance System
AI	Articulation Index
AIMS	**A**ir Traffic Control Radar Beacon System, **I**dentification Friend or Foe, **M**ark XII/Mark XIIA, **S**ystems
ANSI	American National Standards Institute
AMAC	Aircraft Monitor and Control
AMAD	Airframe Mounted Accessory Drive
AMCOM	Aviation and Missile Command
AME	Alternate Mission Equipment
AMT	Accelerated Mission Test
AOA	Angle of Attack
AOP	Allied Ordnance Publication
AOS	Angle of Sideslip
APS	Auxiliary Power System
APU	Auxiliary Power Unit
AQP	Airworthiness Qualification Plan
AQS	Airworthiness Qualification Specification
AR	Army Regulation/Aerial Refueling
ARINC	Aeronautical Radio, Incorporated
AS	Aeronautical Standard

ASE	Aircraft Survivability Equipment
ASC	Aeronautical Systems Center
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
ATL	Acquisition, Technology and Logistics
ATS	Air Traffic Service
AV	Air Vehicle
AVPS	Air Vehicle Performance Specification
BER	Bit Error Rate
BIT	Built-In-Test
BLOS	Beyond Line of Sight
BP	Best Practices
BRNAV	Basic Area Navigation
BTPS	Body Temperature, Pressure, Saturated
CAD/PAD	Cartridge Actuated Devices and Pyrotechnic Actuated Devices
CB	Chemical/Biological
CBIT	Continuous Built-In-Test
CCDL	Cross Channel Data Link
CCT	Contractor Corrosion Team
CDA	Commercial Derivative Aircraft
CDF	Cumulative Distribution Function
CDR	Critical Design Review
CF	Centrifugal
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
CG or COG	Center of Gravity
CI	Configuration Item
CM	Configuration Management
CMP	Configuration Management Plan
CMRS	Calibration Measurement Requirements Summary
COTS	Commercial Off-the-Shelf
CNS/ATM	Communications, Navigation and Surveillance/Air Traffic Management
CPAT	Corrosion Prevention Advisory Team
CPCP	Corrosion Prevention and Control Plan
CRP	Certification Requirements Plan
CSA	Configuration Status Accounting
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
CSI	Critical Safety Item
CSIL	Computer System Integrity Level
CSU	Computer Software Unit

CTS	Critical to Safety
CW	Continuous Wave
da/dn	Crack Growth Rate
DAD	Deployable Aerodynamic Decelerator
DCMA	Defense Contract Management Agency
DD	Department of Defense Form
DLL	Design Limit Load
DME	Distance Measuring Equipment
DMWR	Depot Maintenance Work Requirement
DoD	Department of Defense
DoDD	Department of Defense Document
DoDI	Department of Defense Instruction
DOD	Domestic Object Damage
DOF	Degrees Of Freedom
DoT	Department of Transportation
DRI	Dynamic Response Index
DRR	Dynamic Response Radical
DUL	Design Ultimate Load
DT&E	Development Test and Evaluation
E^3	Electromagnetic Environmental Effects
E^3IA	Electromagnetic Environmental Effects Integration Analysis
EAS	Estimated Air Speed
ECP	Engineering Change Proposal
ECS	Environmental Control System
EFH	Engine Flight Hours
EHM	Engine Health Monitoring
EID	Electrically Initiated Devices
EL-CID	Equipment Location-Certification Information Database
EMAD	Engine Mounted Accessory Drive
EMC	Electromagnetic Compatibility
EME	External Electromagnetic Environment
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse
EMS	Engine Monitoring System/Environmental Management System
EPS	Electrical Power System/Emergency Power System
EPU	Emergency Power Unit
ESC	Electronic Systems Center
F	Fighter Aircraft
FAA	Federal Aviation Administration
ESOH	Environmental Safety and Occupational Health
FADEC	Full Authority Digital Engine Control

FAR	Federal Aviation Regulations
FCA	Functional Configuration Audit
FCS	Flight Control System
FD	Fault Detection
FEM	Finite Element Models
EFH	Engine Flight Hours
FFRR	First-Flight Readiness Review
FI	Fault Isolation
FHA	Functional Hazard Analysis or Assessment
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
FMET	Failure Modes and Effects Testing
FMS	Fuel Management System
FOD	Foreign Object Damage
FOV	Field of View
fps	Feet Per Second
FQDP	Flying Qualities Development Process
FSLL	Fail-Safe Life Limit
FSP	Flight Safety Part
FRACAS	Failure Report and Corrective Action System
FRIES	Fast Rope Insertion/Extraction System
FTA	Fault Tree Analysis
FTS	Flight Termination System
FW	Fixed Wing
GOTS	Government Off-the-Shelf
GVT	Ground Vibration Test
HCF	High Cycle Fatigue
HDBK	Handbook
HDD	Head-Down Display
HEDAD-O	Human Engineering Design Approach-Operator
HERF	Hazards of Electromagnetic Radiation to Fuel
HERO	Hazards of Electromagnetic Radiation to Ordinance
HERP	Hazards of Electromagnetic Radiation to Personnel
HF	High Frequency
HHA	Health Hazard Assessment
HITL	Hardware-in-the-Loop
HIRF	High-Intensity Radiated Field
HMD	Helmet Mounted Display
HMI	Hazardously Misleading Information
HQSim	Handling Qualities Simulation/Simulator
HUD	Head-Up Display

HWCI	Hardware Configuration Item
Hz	Hertz
I/O	Input/Output
IB	Iron Bird
IBIT	Initiated Built-In-Test
ICAO	International Civil Aviation Authority
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronics Engineers
IER	Information Exchange Requirements
IETM	Interactive Electronic Technical Manual
IMA	Integrated Modular Avionics
IMC	Instrument Meteorological Conditions
IOC	Initial Operation Capability
IR	Infrared
JACG	Joint Aeronautical Commanders' Group
JITC	Joint Interoperability Test Command
JOAP	Joint Oil Analysis Program
JSSG	Joint Service Specification Guide
JSSSEH	Joint Software Systems Safety Engineering Handbook
JSSSEW	Joint Software Systems Safety Engineering Workgroup
KC	Plane Stress Fracture Toughness
KEAS	Knots Equivalent Airspeed
KIAS	Knots Indicated Airspeed
KIC	Plane Strength Fracture Toughness
KISCC	Stress Corrosion Cracking
KTAS	Knots True Airspeed
L	Luminance
LASER	Light Amplification by Stimulated Emission of Radiation (commonly used, uncapitalized, as a word)
LCF	Low Cycle Fatigue
LCID	Location-Certification Information Database
LEP	Laser Eye Protection
LOA	Loss of Aircraft
LOS	Line of Sight
LRM	Line Replaceable Module
LRU	Line Replaceable Unit
M&O	Maintenance and Overhaul
MDR	Material Deficiency Report
MDRC	Multi-Axis Dynamic Response Criteria
MoC	Method of Compliance
MCO	Military Certification Office

MMPDS	Metallic Materials Properties Development and Standardization
MPCMP	Mass Properties Control and Management Process
MQT	Military Qualification Test
MRT	Modified Rhyme Test
MSL	Mean Sea Level
MTE	Mission-Task-Elements
MWL	Maximum Wear Limit
NAS	National Airspace System
NASA	National Aeronautics Space Administration
NATIPS	Naval Aviation Technical Information Products
NATOPS	Naval Aviation Training and Operating Procedures Standardization
NAVAIR	Naval Air Systems Command
NBC	Nuclear, Biological, and Chemical
NCIS	Nuclear Certification Impact Statement
NDI	Non-Destructive Inspection
NDI	Non-Developmental Items
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Test
NNMSB	Non-Nuclear Munitions Safety Board
NOSSA	Naval Ordnance Safety Security Activity
NSAR	Nuclear Safety Analysis Report
NVD	Night Vision Device or Non-Visual Device (see 6.1.10.10)
NVG	Night Vision Goggle(s)
NVIS	Night Vision Imaging System
O	Observer
O&SHA	Operating and Support Hazard Analysis
OEI	One-Engine-Interoperative
OFP	Operational Flight Program
OSD	Office of Secretary of Defense
OSHA	Occupational Safety and Health Agency
OSS&E	Opperational Safety, Suitability and Effectiveness
OT&E	Operational Test and Evaluation
OUSD	Office of Under Secretary of Defense
PA	Public Address
PBIT	Periodic Built-In-Test
PCA	Physical Configuration Audit
PCoE	Propulsion Center of Excellence
PDR	Preliminary Design Review
PESHE	Programmatic Environmental Safety and Health Evaluation
PFD	Primary Flight Display
PFR	Primary Flight Release

PHA	Preliminary Hazard Analysis
PIO	Pilot-in-the-loop-oscillations
PITL	Pilot-In-The-Loop
PLOA	Probability of Loss of Aircraft
PLOC	Probability of Loss of Control
PoCR	Proof of Concurrence Report
PPM	Physical Parameter Measurement
PRF	Performance
PRNAV	Precision Area Navigation
PSIP	Propulsion System Integrity Program
PTO	PowerTake-Off
PV	Pressure Velocity
PVI	Pilot Vehicle Interface
QDR	Quality Deficiency Report
RAT	Ram Air Turbine
RAQ	Rotorcraft and Aircraft Qualification
RBD	Reliability Block Diagram
REG	Regulation
RF	Radio Frequency
RNP	Required Navigation Performance
RMS	Rate Monotonic Scheduling
RMS	Root Mean Square
ROA	Remotely Operated Aircraft
RORH	Regions of Recoverable Handling (RORH)
ROSH	Regions of Satisfactory Handling
ROTH	Regions of Tolerable Handling
RPM	Revolutions per minute
RPV	Remotely Piloted Vehicle
RTCA	Radio Technical Committee for Aeronautics
RTO	Refused Takeoff
RVSM	Reversed Vertical Separation Minimums
RW	Rotary Wing
SAA	Sense and Avoid
SAE	Society of Automotive Engineers International
SAR	Safety Assessment Report
SAS	Stability Augmentation System
SAWE	Society of Allied Weight Engineers
SCF	Safety Critical Functions
SDIMP	Software Development Integrity Master Plan
SDP	Software Development Plan
SEP	Systems Engineering Plan

SEU	Single Event Upset
SF	Factors of Safety
SFAR	Special Federal Aviation Regulation
SHA	System Hazard Analysis
SII	Speech Intelligibility Index
SIL	System Integration Laboratory
SL	Sea Level
SME	Subject Matter Expert
SMI	Structural Mode Interaction
SMS	Stores Management System
SOF	Safety of Flight
SOFT	Safety of Flight Testing
SPA	System Processing Architecture
SRS	Software Requirements Specifications
SSE	Software Supporting Element
SSHA	System Safety Hazard Analysis
SSHE	Safety Supporting Hardware Element
SSP	Software Safety Plan
SSPP	System Safety Program Plan
SSOR	Strength Summary and Operating Restrictions
SSSE	Safety Supporting Software Element
STD	Standard
STI	Speech Transmission Index
STO	Short Takeoff
SwSSPP	Software System Safety Program Plan
T	Trainer
TAR	Test Accuracy Ratio
TB	Technical Bulletin
TCAS	Traffic Avoidance and Alert System
TEMP	Test and Evaluation Master Plan
TF	Trainer/Fighter Aircraft
TF/TA	Terrain Following/Terrain Avoidance
TLV	Threshold Limit Values
TO	Technical Order
TRR	Test Readiness Review
TSO	Technical Standard Order
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Air Vehicle
UAV/ROA	Unmanned Air Vehicle/Remotely Operated Aircraft
UHF	Ultra High Frequency

USAF	United States Air Force
USAR	Unmanned Aerial Vehicles Systems Airworthiness Reqirements
USN	United States Navy
Val/Ver	Validation/Verification
VCF	Vehicle Control Function
VCMS	Vehicle Control and Management System (VCMS)
VHF	Very High Frequency
VI	Visual Inspection
VIF	Vehicle Integration Facility
VL	Vertical Landing
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VSM	Vertical Separation Minimums
V/STOL	Vertical/Short Takeoff and Landing
VTO	Vertical Takeoff
VTOL	Vertical Takeoff and Landing
VV&A	Verification, Validation, and Accreditation
WCA	Warning, Caution, Advisory
WSESRB	Weapon System Explosive Safety Review Board

4. SYSTEMS ENGINEERING

EXAMPLES OF TYPICAL CERTIFICATION SOURCE DATA

1. Reliability, quality, and manufacturing program plans.
2. Contractor policies and procedures.
3. Durability and damage tolerance control plans.
4. Work instructions.
5. Process specifications.
6. Production/assembly progress reports.
7. Quality records.
8. Defect/failure data.
9. Failure modes, effects, and criticality analysis (FMECA) documentation.
10. Tech data package.
11. As-built list to include part numbers/serial numbers for all critical safety items/components.
12. List of deviations/waivers and unincorporated design changes.
13. List of approved class I engineering change proposals (ECPs).
14. DD Form 250, Material Inspection and Receiving Report.
15. Configuration management plans/process description documents.
16. Diminishing Manufacturing Sources Plan.
17. Obsolete Parts Plan.
18. Test reports.
19. Test plans.
20. FAA Airworthiness Directives and Advisory Circulars.
21. Manufacturer-issued service bulletins.
22. Civil aviation authority certification plan.
23. Civil aviation authority certification basis.
24. Civil aviation authority certification report.
25. System Safety Analysis Report.
26. Counterfeit Prevention Plan.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

4.1 Design criteria.

4.1.1 Requirements allocation.

Criterion: Verify that the design criteria, including requirements and ground rules, adequately address airworthiness and safety for mission usage, full permissible flight envelope, duty cycle, interfaces, induced and natural environment, inspection capability, and maintenance philosophy.

Standard: Allocated high level airworthiness and safety requirements down through the design hierarchy are defined. Allocated design criteria for all system elements and components result in required levels of airworthiness and safety throughout the defined operational flight envelope, environment, usage and life.

Method of Compliance: Inspection of process documentation verifies allocation of airworthiness and safety requirements and design criteria. Traceability is documented among requirements, design criteria, design and verification. Consistency between design criteria and airworthiness and safety requirements is confirmed by inspection of documentation.

References: Appropriate design criteria paragraphs of JSSG-2000, JSSG-2001, JSSG-2005, JSSG-2006, JSSG-2007, JSSG-2008, JSSG-2009, JSSG-2010, and others

MIL-STD-882

SAE ARP4761

4.1.2 Safety critical hardware and software.

Criterion: Verify that airworthiness and safety design criteria are adequately addressed at component, subsystem and system levels, including interfaces, latencies, software and information assurance.

Standard: Safety critical software and hardware (including Critical Safety Items (CSIs)) are identified. Design criteria and critical characteristics of safety critical software and hardware are defined, substantiated and documented in sufficient detail to provide for “form, fit, function and interface” replacement without degrading system airworthiness. Design criteria and critical characteristics of safety critical software and hardware incorporate relevant security requirements and mitigation techniques needed to ensure safety of flight.

Method of Compliance: Inspection of documentation verifies that a process is in place to adequately identify safety critical software and hardware, CSIs, and associated design criteria and critical characteristics at the component, subsystem and system levels. Inspection of documentation verifies that safety critical software and hardware, CSIs, and associated design criteria and critical characteristics resulting from this process are documented. Inspection of documentation verifies that security requirements and mitigation techniques that affect flight safety are incorporated into safety critical software and hardware and CSIs.

References: Appropriate design criteria paragraphs of JSSG-2000, JSSG-2001, JSSG-2005, JSSG-2006, JSSG-2007, JSSG-2008, JSSG-2009, JSSG-2010, and others

MIL-STD-882

SECNAVINST 4140.2

Joint Aeronautical Commanders Group (JACG) Aviation Critical Safety Item Management Handbook

Joint Aeronautical Commanders Group (JACG) Aviation Source Approval and Management Handbook

AMCOM REG 702-7

DoDM 4140.01

SAE AS6081

SAE AS6174

4.1.3 Commercial derivative aircraft.

Criterion: Verify that, for commercial derivative air vehicles, the air vehicle's certification basis addresses all design criteria appropriate for the planned military usage.

Standard: Commercial derivative aircraft has been assessed for its suitability for the intended military application and determined to be airworthy and safe. Limitations appropriate to the intended military usage and environment are identified.

Method of Compliance: Inspection of certification data and analyses substantiates that the military air vehicle is airworthy and safe for its intended military usage and environments. Military air vehicle airworthiness certification data addresses all equipment, usage, and environments not covered by the commercial certification.

References: Appropriate design criteria paragraphs of JSSG-2000, JSSG-2001, JSSG-2005, JSSG-2006, JSSG-2007, JSSG-2008, JSSG-2009, JSSG-2010, and others.

4.1.4 Failure conditions.

Criterion: Verify that safety of flight related failure conditions have been adequately addressed in the design criteria.

Standard: Safety of flight failure conditions (including applicable single point failures) have been identified. No single safety of flight failure condition results in a "Catastrophic" severity (i.e., death, permanent total disability, monetary loss equal to or exceeding $10 million or loss of air vehicle) with a frequency greater than "improbable" (i.e., a rate of less than one event per one million flight hours).

Method of Compliance: Inspection of the hazard analysis verifies that safety critical hazards have been identified and that catastrophic failures are no more frequent than improbable. Analysis of the design verifies that the required level of safety is achieved. Operating limitations are defined. The analysis includes ground rules and assumptions.

References: MIL-STD-882
NAVAIRINST 5000.21
NAVAIRINST 5100.3
AR 385-10
AR 385-16
DoDI 5000.36
SAE ARP4754
SAE ARP4761

4.1.5 Operating environment.

Criterion: Verify that the air system is designed to operate in the natural and induced environments for which it is intended.

Standard: The air system design criteria includes the intended natural and induced environments. The air system, including the air vehicle and control station equipment, is qualified to operate in the intended natural and induced environments (e.g., temperature, humidity, precipitation, icing, fungus, salt fog, particulate and liquid contamination, shock and vibration, and explosive atmosphere).

Method of Compliance: Inspection of documentation verifies that the air system intended natural and induced environments are documented. Analysis, demonstration and test verify that equipment provides required function and performance within the envelope of intended natural and induced environments without imposing a safety of flight risk. Inspection of qualification test results verifies that equipment is qualified for its intended environments.

References: JSSG-2005: 3.2.3, 4.2.3

MIL-HDBK-310

MIL-STD-810 provides guidance on environmental qualification

MIL-HDBK-87213: 3.2.3 provides guidance on environmental requirements for cockpit display equipment.

14 CFR 23.1309, 25.1309, 27.1309, 29.1309

4.1.6 Flight and safety critical functions.

Criterion: Verify that the air systems design criteria identify flight and safety critical functions, and their degraded and failed modes and states. Verify that the air system and air vehicle detect and respond appropriately, predictably, safely and in a timely manner to flight and safety critical function degraded states or failures.

Standard: The design criteria identify flight and safety critical functions, modes and states for the air system, including the air vehicle. The air system design criteria identify flight and safety critical function degraded states and failures.

The air system detects and responds appropriately, predictably, safely and in a timely manner to flight or safety critical function degraded states or failures.

The air vehicle detects and responds appropriately, predictably, safely and in a timely manner to air vehicle flight or safety critical function degraded states or failures, with or without operator intervention.

The air vehicle detects and responds appropriately, predictably, safely and in a timely manner to loss of flight and safety critical command and control data link(s) between the operator and air vehicle.

The air vehicle response to loss of command and control data link is appropriate and safe for the airspace in which the air system will be operated.

The air system detects and responds appropriately, predictably, safely and in a timely manner to the sense and avoid function for the airspace in which the air system will be operated, with or without operator intervention.

The air system (including air vehicle) responses to flight and safety critical function normal and degraded states or failures, and loss of flight and safety critical command and control data link(s):

a. Activate appropriately and in a timely manner,
b. Activate only when needed,
c. Safely transition to pre-determined modes and states (see also 6.2.2.4 of this document),
d. Activate pre-determined procedure(s) for restoring functionality,
e. Alert airspace control or air traffic control, as necessary, and
f. Prevent entry into pre-defined keep-out airspace or over-flight of pre-defined surface regions (see also 11.1.1.5 of this document).

(For information, see also 6.2; 8.3.10; 11.1.1 and 11.2.3; Section 15; and 17.2.9 of this document.)

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, and inspection of documentation.

Inspection of documentation verifies that design criteria and processes identify flight and safety critical functions, modes and states; flight and safety critical functions degraded states and failures; and loss of flight and safety critical command and control data link(s). Inspection of documentation verifies that design criteria and processes ensure air system responses are appropriate for the intended airspace.

Analysis verifies that flight and safety critical functions, modes and states for the air system, including the air vehicle, are identified.

Analysis verifies that flight and safety critical function degraded states and failures are identified.

A combination of ground testing and simulation verifies that the air system (including air vehicle) detects and responds appropriately, predictably, safely and in a timely manner to: (1) flight or safety critical function normal and degraded states or failures, with or without operator intervention, (2) loss of flight and safety critical command and control data link(s), and (3) sense and avoid function, with or without operator intervention. This testing and simulation verifies that the air system (including air vehicle) responses:

a. Activate appropriately and in a timely manner,
b. Activate only when needed,
c. Safely transition to pre-determined modes and states,
d. Activate pre-determined procedure(s) for restoring functionality,
e. Alert airspace control or air traffic control, as necessary, and
f. Prevent entry into pre-defined keep-out airspace or over-flight of pre-defined surface regions.

(For information, see also 6.2.2.4, 6.2.2.8, and 6.2.2.9 of this document.)

4.1.7 Flight termination system.

Criterion: Verify that the flight termination function, if incorporated into the design, is safe, secure and reliable.

Standard: Design criteria ensure that the flight termination function operates reliably and in a timely manner when commanded. The flight termination function results in a defined air vehicle flight state (e.g., zero lift, zero thrust). The likelihood of uncommanded flight termination is remote. A minimum of two operator actions is required to execute the flight termination function.

Method of Compliance: Inspection of documentation verifies that design criteria are in place to ensure that the flight termination function operates reliably and appropriately, and only when required. Inspection of test and simulation data verifies that the flight termination function operates appropriately, only when required, and results in the expected defined flight state(s). Inspection of analysis documentation indicates that the flight termination function operates reliably.

Reference: RCC 319-14

4.2 Tools and databases.

4.2.1 Tool and database processes.

Criterion: Verify that all tools, methods, and databases used in the requirements management, design, risk control and assessments of safety are applied appropriately and exhibit accuracy commensurate with their application.

Standard: Processes are in place to ensure that all analysis, modeling and simulation tools and databases are of appropriate accuracy and fidelity, are validated for the intended applications, and are configuration controlled. Requirements definition/traceability, design and performance analysis tools, prediction methods, models and simulations are applied appropriately, and exhibit accuracy commensurate with their applications.

Method of Compliance: Inspection of documentation verifies that processes are in place to ensure that tools and databases are validated and under configuration control. Inspection of documentation verifies that analysis tools, models, simulations and databases are applied appropriately. Inspection of documentation verifies that analysis, modeling and simulation tools and databases are of appropriate accuracy and fidelity for the intended applications. Inspection of documentation verifies the validation basis of design analysis, models and simulations is substantiated and based on actual hardware/software test data.

Inspection of documentation verifies that the design analysis, modeling and simulation tools are substantiated by and based on actual test data (when available). Actual system verification results are compared with design analysis, modeling and simulation tool results and databases for validation purposes.

References: Appropriate design criteria paragraphs of JSSG-2000, JSSG-2001, JSSG-2005, JSSG-2006, JSSG-2007, JSSG-2008, JSSG-2009, JSSG-2010, and others.

MIL-HDBK-470

MIL-STD-3022

ADS-51-HDBK

4.3 Materials selection.

4.3.1 Selection of materials.

Criterion: For Army and Navy air systems, verify that the material selection process uses validated and consistent material properties data, including design mechanical and physical properties such as material defects, and corrosion and environmental protection requirements (see also Section 19, Materials; Section 5, Structures; and Section 7, Propulsion; Section 8, Air Vehicle Subsystems of this document).

Standard: Material selection process uses materials covered by an industry specification, government specification (Military or Federal) or other specifications as approved by the procuring agency.

Method of Compliance: Inspection of documentation confirms that materials are adequately covered by either:

a. An Aerospace Materials Specification (AMS) issued by the SAE Aerospace Materials Division,
b. An ASTM standard published by ASTM International (formerly the American Society for Testing and Materials),
c. A government (Military or Federal) specification, or
d. Other specifications as approved by the procuring agency.

If an approved specification for the product is not available, an acceptable draft specification has been prepared.

References: JSSG-2001

JSSG-2006

MIL-HDBK-516: Sections 19, 5, 7 and 8

MMPDS-08

CMH-17

ADS-13-HDBK

4.4 Manufacturing and quality.

4.4.1 Key characteristics.

Criterion: Verify that key product characteristics (including critical characteristics) have been identified.

Standard: Physical characteristics which are key to the successful function of critical safety items (CSIs) and flight critical components are defined and documented. Tolerance allowances for each characteristic and traceability through the design hierarchy are defined, and the effects of adverse tolerance accumulation at higher (e.g., above the CSI) levels of product assembly are analyzed and reflected in the design documentation.

Method of Compliance: Key product characteristic (including critical characteristics) and tolerance definitions are verified by inspection and analysis of program design documentation at the applicable levels of the product hierarchy. Manufacturing process controls for specific key product characteristics identified as Critical to Safety (CTS) and manufacturing process parameters necessary to achieve and maintain acceptable process indices are verified by inspection and analysis of manufacturing process control documentation for the applicable stages of manufacture and assembly.

References: AFLCMC/EZSM Manufacturing Development Guide, Section 6.5, "Key Characteristics and Processes"

AFI 63-501

AMCOM REG 702-7 Management

Aviation Critical Safety Item Management Handbook, Joint Aeronautical Commanders Group

Aviation Source Approval and Management Handbook, Joint Aeronautical Commanders Group

SECNAVINST 4140.2

ASME Y14.5

SAE AS9100

SAE AS9103

14 CFR 23.601-23.605, 25.601-25.603, 27.601-605, 29.601-29.605

4.4.2 Critical processes.

Criterion: Verify that all critical process capabilities exist to meet key product characteristic requirements (including critical characteristics).

Standard: All key characteristics (including critical characteristics) are mapped to corresponding critical processes. Critical process capabilities are characterized, process capability indices (Cpk) are calculated and acceptable limits established. Process control plans for critical processes are defined and implemented throughout the supply chain. For Army and Navy only, quality control procedures for critical processes are defined and implemented throughout the supply chain.

Method of Compliance: Critical process capabilities and control plans are verified by inspection of design documentation and process control documentation and if applicable, on-site audit documentation, throughout the supply chain.

References: AFLCMC/EZSM Manufacturing Development Guide, Section 6.6, "Variability Reduction", for additional information on Cpk, Critical Processes, and Process Control Plans

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Aviation Critical Safety Item Management Handbook, Joint Aeronautical Commanders Group

Aviation Source Approval and Management Handbook, Joint Aeronautical Commanders Group

SECNAVINST 4140.2

SAE AS9100

SAE AS9103

14 CFR 23.601-23.605, 25.601-25.603, 27.601-605, 29.601-29.605

4.4.3 Critical process controls.

Criterion: Verify that all critical process controls exist to assure key product characteristic requirements (including critical characteristics) are met.

Standard: Work and inspection instructions are defined, documented and implemented for all critical manufacturing processes. A process capability index (Cpk) of at least 1.67 is maintained for processes Critical to Safety (CTS) or processes that produce Critical Safety Items (CSI). Quantitative product quality criteria (i.e., product acceptance criteria) are defined and used for product acceptance at all levels of the product hierarchy up to and including the air system level.

Method of Compliance: Work and product inspection instructions, product acceptance criteria are verified by inspection. Cpk is verified by analysis and inspection of design documentation and manufacturing process capability data. Design conformance (i.e., "as built" configuration is in accordance with design requirements) is verified by first article inspections or first article tests, review of manufacturing process control data, and/or periodic hardware quality audits.

References: AFLCMC/EZIM Manufacturing Development Guide, Section 5.6, "Variability Reduction", for additional information on Product Acceptance Criteria

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Aviation Critical Safety Item Management Handbook, Joint Aeronautical Commanders Group

Aviation Source Approval and Management Handbook, Joint Aeronautical Commanders Group

SECNAVINST 4140.2

SAE AS6081

SAE AS6174

SAE AS9100

SAE AS9102

SAE AS9103

FAR Part 9.3, First Article Testing and Approval

14 CFR 23.601-23.605, 25.601-25.603, 27.601-605, 29.601-29.605

4.4.4 Quality system.

Criterion: Verify that the as-built configuration matches the as-designed configuration.

Standard: The quality system is effective in assuring conformance to product design and realization, including production allowances and tolerances. The quality system addresses defect prevention and achieving stable, capable processes. The quality system employs methods sufficient for conducting root cause analyses and implementing effective corrective actions.

Method of Compliance: Compliance is determined by inspection of the Quality System's policies, processes and procedures and examples of Material Review Board records.

References: AFLCMC/EZSM Manufacturing Development Guide, Section 4, "Quality Systems", and Section 5.6 "Variability Reduction"

AFI 63-501

Aviation Critical Safety Item Management Handbook, Joint Aeronautical Commanders Group

Aviation Source Approval and Management Handbook, Joint Aeronautical Commanders Group

SAE AS6081

SAE AS6174

SAE AS9100

FAR Part 46, "Quality Assurance"

14 CFR 23.601-23.605, 25.601-25.603, 27.601-605, 29.601-29.605

4.4.5 Nondestructive inspections.

Criterion: Verify that nondestructive inspection (NDI) processes have been validated to assure conforming parts.

Standard: Nondestructive inspection (NDI) methods and equipment have been qualified to suitable standards and meet the requirements of the applicable specification and application. The specification being used ensures any non-conformance adversely affecting the part will be detected. Accept and reject criteria for safety and flight critical hardware are based on validated models and data.

Method of Compliance: Compliance is determined by inspection of NDI process, selection criteria, operator certification and method validation documentation. For new applications of specifications, test and inspection data confirms the inspection method is valid for the application.

References: JSSG-2006: A.3.11.6, A.4.11.6

MIL-HDBK-1783

SAE ARP5089

SAE AS6081

SAE AS6174

4.5 Operator's and maintenance manual/technical orders.

4.5.1 Procedures and limitations.

Criterion: Verify that processes are in place to identify and document normal and emergency procedures, limitations, restrictions, warnings, cautions and notes.

Standard: Operator handbooks or manuals identify all normal and emergency procedures, limitations, restrictions, warnings, cautions and notes. Warnings, cautions and notes are identified in such a manner as to attract attention and set them apart from normal text. When an unsafe condition is detected and annunciated, the operator's manual has clear and precise corrective procedures for handling the condition.

Method of Compliance: Inspection of operator handbooks or manuals process documentation describes procedures for developing normal and emergency procedures, limitations, restrictions, warnings, cautions and notes from system technical data. Process descriptions include methods for updating this information as needed. For Army and Navy, inspection of operating handbooks and manuals verifies that they include all normal and emergency procedures, limitations, restrictions, warnings, cautions and notes. The USAF confirms operator manual accuracy and completeness through other sections contained within this document.

References: MIL-HDBK-516: 9.4, Human performance
MIL-STD-38784
MIL-DTL-85025
NAVAIRINST 13034.1
14 CFR 23.1541, 23.1581, 25.1541, 25.1581, 27.1541, 27.1581, 29.1541, 29.1581

4.5.2 Technical data.

Criterion: Verify that processes are in place to identify and document the technical data, and that the technical data are consistent with the defined functional and product baseline.

Standard: Process is defined, documented and implemented to establish and update product requirement, design, manufacturing, and maintenance data, which are used to generate technical manuals (e.g., flight manuals, operator's handbooks, maintenance manuals). Maximum timelines to accomplish updates are consistent with the criticality of the change activity (e.g., an identified safety hazard, or a "performance based" change having a safety effect).

Method of Compliance: The adequacy of establishment and change processes for technical data is verified by inspection of process documentation. Inspection of examples of revised design or maintenance data verifies traceability to change events.

References: MIL-STD-38784
14 CFR 23.21, 23.601, 23.1301, 25.21, 25.601, 25.1301

4.5.3 Maintenance of safety.

Criterion: Verify that procedures are in place for establishing and maintaining air system flight safety, as affected by product design changes, safety issues, changes in operations, maintenance, transportation or storage.

Standard: Processes are defined, documented, and implemented to establish and accomplish timely updates to operator and maintenance manuals as made necessary by product design changes, identified safety issues (e.g., Category I Deficiency Reports), changes in operational concepts, usage, maintenance concepts, transportation, or storage. Current updated technical data are used to effect technical manual revisions. Maximum timelines to incorporate changes in manuals are based on the effect of the change and the severity of the identified hazard.

Method of Compliance: The adequacy of establishment and change processes for operator and maintenance manuals is verified by inspection of process documentation. Inspection of examples of revised operator and maintenance manuals (i.e., change pages) verifies traceability to change events.

References: JSSG-2001: 3.3.5.1, 3.3.7.1
JSSG-2009: Appendix I

MIL-HDBK-515
MIL-STD-1530
MIL-STD-1796
MIL-STD-1798
MIL-STD-3024
NAVAIRINST 13034.1

4.6 Configuration management (CM).

4.6.1 Functional baseline.

Criterion: Verify that the functional baseline is established and under configuration control to preclude unauthorized changes.

Standard: The functional baseline is properly documented, approved and brought under control by a Configuration Management Process.

Method of Compliance: The Configuration Management Plan (CMP) is defined and implemented in accordance with the contract. Inspection of documentation verifies that the functional baseline has been documented and approved.

References: MIL-HDBK-61: 5.5 Configuration Baselines; 6 Configuration Control
MIL-STD-961: Appendix A
NAVAIRINST 4130.1
14 CFR: 23.21, 23.601, 23.1301, 25.21, 25.601, 25.1301

4.6.2 Allocated baseline.

Criterion: Verify that the allocated baseline is established and under configuration control to preclude unauthorized changes.

Standard: The allocated baseline is properly documented, approved and brought under control by a Configuration Management Process.

Method of Compliance: The Configuration Management Plan is defined and implemented in accordance with the contract. Inspection of documentation verifies that the allocated baseline has been documented and approved. Inspection of the engineering release documentation verifies adequate capture of the allocated baseline.

References: MIL-HDBK-61 5.5 Configuration Baselines; 6 Configuration Control
MIL-STD-961, Appendix A
NAVAIRINST 4130.1

4.6.3 Product baseline.

Criterion: Verify that the product baseline is established and under configuration control to preclude unauthorized changes.

Standard: The product baseline is properly documented, approved and brought under control by a Configuration Management Process.

Method of Compliance: The Configuration Management Plan is defined and implemented in accordance with the contract. Inspection of documentation verifies that the product baseline has been documented and approved. Inspection of the approved engineering documentation and engineering release system verifies adequate capture of the product baseline.

References: MIL-HDBK-61: 5.5 Configuration Baselines; 6 Configuration Control

MIL-STD-961: Appendix A
NAVAIRINST 4130.1
14 CFR 23.21, 23.601, 23.1301, 25.21, 25.601, 25.1301

4.6.4 Safety critical item configuration management.

Criterion: Verify that all safety-critical items are tracked and under configuration control.

Standard: A configuration status accounting (CSA) system is adequately documented and maintained and tracks the configuration of safety-critical items.

Method of Compliance: CSA process documentation is verified by inspection. Inspection of CSA records and reports for CI/CSCIs verifies accuracy of the configuration status accounting system and that the system is able to track and record changes to the configuration.

References: MIL-HDBK-61: 7, Configuration Status Accounting
14 CFR 23.21, 23.601, 23.1301, 25.21, 25.601, 25.1301

5. STRUCTURES

The air vehicle structure, herein referred to as the aircraft, includes the fuselage, cockpit, wing, main and tail rotor, proprotor, empennage, tail pylon, structural elements of landing gear, the control system, control surfaces, drive system, rotor control systems, radomes, antennas, engine mounts, nacelles, pylons, thrust reversers (if not part of the engine), inlets, aerial refueling mechanisms, shipboard related airborne apparatus/devices (fixed wing catapult and arresting components; rotary wing/tiltrotor recovery assist, securing probe/harpoon system components and backup structure), structural operating mechanisms, structural provisions for seats, equipment, medical evacuation equipment, storage and on-board facilities payload, cargo, personnel accommodations, etc.

EXAMPLES OF TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria.
2. Loads analyses.
3. Internal load and stress analyses.
4. Materials, processes, corrosion prevention, nondestructive evaluation and repair data.
5. Results from any design development tests conducted.
6. Proof test results.
7. Flutter, mechanical stability and aeroservoelastic analyses.
8. Loads wind tunnel test data.
9. Flutter wind tunnel test data.
10. Ground vibration test results.
11. Damage tolerance and durability analyses .
12. Component/full-scale static and fatigue test results.
13. Live fire test results and ballistic analysis.
14. Bird strike test and analysis results.
15. Arresting wire strike test and analysis results.
16. User and maintainer manuals or equivalent.
17. Flight operating limits.
18. Strength summary and operating restrictions.
19. Damage tolerance and durability test results.
20. Full-scale durability test results.
21. Functional test results.
22. Flight loads test results.
23. Instrumentation and calibration test results.
24. Control surface, tabs and damper test results.
25. Thermoelastic test results.
26. Limit-load rigidity test results.
27. Flight flutter test results.
28. Mass properties control and management plan (interface).
29. Weight and balance reports (interface).
30. Inertia report.

31. Design trade studies and analyses.
32. Fuel system test results.
33. Results of actual weighing
34. Weight and balance handbook, or equivalent.
35. Hazard analysis.
36. Environmental criteria and test results.
37. Vibration and acoustic test results.
38. Aircraft tracking program.
39. Landing gear and airframe drop test plans and results.
40. Mechanical stability test plans and results.
41. Whirl test plans and results.
42. Tie-down test plans and results.
43. Structural description report.
44. Tipover and rollover stability analyses.
45. External store interface and release data.
46. Ground and/or air transport rigging procedures, interface loads, and associated inspections.
47. Failure modes, effects, and criticality analysis (FMECA) documentation.
48. Ground and rotor blade clearance dimensional data.
49. Loss of lubrication testing.
50. Heat generation/rejection analysis.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

The documents referenced under any criterion, standard and/or method of compliance may provide other standards which are applicable. In addition to the specifically enumerated criteria, standards and methods of compliance, structures are checked for a variety of 14 CFR references and Airworthiness Circulars. Due to the complexity of different design configurations, each section in 14 CFR 23 and 25 should be consulted for applicability.

5.1 Loads.

5.1.1 Design flight and ground loads.

Criterion **(Army, Navy and Air Force)**: Verify that the loads used in the design of the aircraft include the maximum, minimum and most critical combination of loads that can result from authorized ground and flight loading conditions for the air vehicle. These include loads during piloted or autonomous maneuvers, loss of control maneuvers, gusts, pressurization, turbulence, take-off, landing, catapult (if applicable), shipboard and land based arrestments (if applicable), ground operations, maintenance activity, systems failures from which recovery is expected (to include rapid depressurization) and loads expected to be seen throughout the specific lifetime of usage.

***Standard* (Army, Navy and Air Force)**: Flight loading conditions are based on aircraft response to pilot induced or autonomous maneuvers, loss of control maneuvers, pressurization and turbulence. These conditions consider both required, and expected to be encountered, critical combinations of configurations, gross weights, centers of gravity, thrust, power, altitudes, speeds, critical combinations of control system (surfaces and rotor system) deflections, control input variation and environmental factors and are used in the design of the aircraft. Flight loading conditions reflect symmetric and asymmetric flight operations and are established for both primary and secondary structural components by selection of flight parameters likely to produce critical applied loads. Symmetric and asymmetric flight operations include symmetric and unsymmetrical fuel and payload loadings and adverse trim conditions. Such loads also address normal and failure modes of operation, including rapid pressurization (Navy only) and depressurization, and loads expected to be seen throughout the specific lifetime of usage.

***Method of Compliance* (Air Force)**: Verification methods include analysis and inspection of documentation. Multiple variables and factors account for development of maximum and minimum load factors. The following compliance paragraphs are applicable to all standards.

a. Load factor selection considers the following items:
   (1) Mission and flying techniques employed to execute the required mission.
   (2) Weapon types and possible delivery methods.
   (3) Anticipated weight and power plant growth.
   (4) Maximum speed and time spent at maximum speed.
   (5) Utilization of external stores and external fuel tanks.
   (6) Training.
   (7) Past experience with similar types of aircraft, mission, etc..

b. Load factors are defined which include appropriate ranges for symmetrical, asymmetrical, directional maneuvers, and atmospheric turbulence for each configuration. Analysis verifies that the load factors are attainable by the air vehicle.

***Method of Compliance* (Army and Navy)**: Verification methods include analyses and inspection of documentation, wind tunnel tests, simulation, and flight testing. Compliance is shown for each combination of configurations at all critical altitudes, gross weights, centers-of-gravity, thrust, power, control input variation, and payload conditions.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.1.1, A.4.1.1; A.3.1.2, A.4.1.2; A.3.2.9, A.4.2.9; A.3.2.11, A.4.2.11; A.3.2.12; A.3.2.17, A.4.2.17; A.3.4.1, A.4.4.1; A.3.4.1.1–15; A.4.3.12

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51-HDBK, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the Air Vehicle Performance Specification (AVPS) Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.1.2 Use of probabilistic vs deterministic loads.

***Criterion**:* Verify that the limit loads used in the design of dynamic components and elements of the airframe subject to deterministic design criteria are the maximum and most critical combination of loads that can result from authorized ground and flight use of the air vehicle. These include loads during maintenance activity, system failures from which recovery is expected, and loads experienced throughout the specific lifetime usage.

***Standard* (Navy and Air Force)**: Only where deterministic values have no precedence or basis, is a combined load-strength probability analysis to predict the risk of detrimental structural deformation and structural failure used. In those cases, the airframe may not experience detrimental structural deformations with a probability of occurrence equal to or greater than that specified in the AVPS Addendum for the respective air vehicle. The resulting limit design loads are the maximum loads anticipated on the aircraft during its lifetime of service (see 5.1.1 of this document).

***Standard* (Army)**: Limit design loads are the maximum loads anticipated on the aircraft during its lifetime of service. For rotorcraft, the air vehicle structure is designed for load factors and airspeeds such that the structural design envelope exceeds the aircraft aerodynamic capability or operational limits. Limit loads for certain dynamic components may also require consideration of altitudes between sea level and service ceiling.

***Method of Compliance**:* Verification methods include analysis, test, demonstration and inspection of documentation.

a. Correlated ground and flight loads analyses are provided in which details of magnitudes and distribution of all applied external loads are identified for multiple air vehicle configurations, weights, center of gravity, and maneuvers covering all attainable altitudes, speeds and load factors. Service and maximum loads expected to be encountered are established for operation under all flight conditions. Wind tunnel tests are utilized for development of aerodynamic loads. Stiffness and ground vibration tests are utilized to update flexibility vs. rigid characteristics of loads analytical model. Flight controls and aerodynamic flight tests are utilized to update aircraft simulation models. Loads calibration tests are utilized to develop ground/flight load equations. 80% and 100% flight loads surveys/demonstrations are utilized to correlate analytical model and to substantiate the design loads.

b. For rotorcraft, loads analysis is performed for design load conditions specified in ADS-29 (cancelled). Structural demonstration flight testing is performed in accordance with ADS-24 (cancelled)) to demonstrate the safe operation of the aircraft to the maximum attainable operating limits consistent with the structural design and to verify that loads used in the structural analysis and static tests are not exceeded at the structural design limits of the airspeed and load factor envelope, or if analytical loads are exceeded during structural demonstration testing to establish the allowable flight envelope and the critical conditions for strength, rigidity, and operation.

c. For Navy rotorcraft, loads analyses are performed for conditions specified in sections 3 and 4 of the AVPS Addendum and/or AR-56. Ground and flight testing is performed in accordance with section 4 of the AVPS, AR-89 and MIL-D-23222 to demonstrate compliance with design requirements and to demonstrate safe operating limits.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.1.1, A.3.1.2, A.3.2.14.3, A.4.1.1, A.4.1.2, A.4.2.14

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.1.3 Foreign object damage (FOD).

***Criterion**:* Verify that loads used in the design of the airframe include loads due to FOD from birds, hail, runway, taxiway, and ramp debris.

***Standard**:* The aircraft is designed to withstand the impact of FOD during any phase of taxi, takeoff, flight and landing without loss of the air vehicle, incapacitation of the pilot or crew and without detectable or undetectable damage to structural elements that result in reductions in structural strength below ultimate load carrying capability throughout the flight envelope (including maneuvers). The aircraft, including main and tail rotor systems, is designed to ensure the capability of continued safe flight and landing following impact; windshields are designed to withstand impact, without penetration; and fairings that may be used to shield or enclose flight critical components (e.g., flight control computers) are designed with sufficient strength to ensure capability of continued safe flight and landing.

***Method of Compliance**:* Verification methods include analysis, test, and inspection of documentation. Probabilistic analyses are performed to address FOD occurrences. Lab tests such as bird strike tests are performed to validate analytical model(s) and/or structural capabilities.

References: (Air Force fixed wing) JSSG-2006: A.3.2.1; A.3.2.18, A.4.2.18; A.3.2.22, A.4.2.22; A.3.2.24, A.4.2.24

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or JSSG-2006: A.3.2.24, A.4.2.24; AR-56, AR-89, MIL-D-23222

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5.1.4 Repeated loads.

***Criterion**:* Verify that the air vehicle structure is designed such that all sources of repeated loads are considered and included in the development of the service loads spectra and do not detract from the airframe service life or dynamic component retirement intervals.

***Standard* (Army and Air Force)**:

a. Maneuvers - Designed such that final spectra accounts for variables such as maneuver capability, tactics, and flight control laws reflecting projected average usage with the design utilization distribution and also usage such that 90% of the fleet (95% for all fatigue damaging conditions for rotorcraft) is expected to meet the service life.
b. Gusts - Designed such that gust load spectra developed by continuous turbulence analysis methods.
c. Suppression system which enhances ride qualities such as active oscillation control, gust alleviation, flutter suppression and terrain following.
d. Vibration and aeroacoustics.
e. Landings - Designed with cumulative occurrences of sink speed per 1000 landings, by

type of landing, typical of projected service usage.

f. For rotorcraft - Designed with consideration of CF loads due to rotor start and stop cycle and torsional loads due to rotor braking cycles.

g. Buffet due to non-linear flow caused by vortex shedding during high angle of attack maneuvers, rotary-wing blade stall and transonic shock instabilities - Designed such that analytical predictions of the structural response are generated during flight operations in the buffet regime and adjusted as needed by test data.

h. Ground operation loads - Designed with: (1) the number of hard and medium braking occurrences per full stop landing along with associated braking effects; (2) number of pivoting occurrences; and (3) definition of roughness characteristics of the airfield(s) to be utilized and the number of taxi operations on each airfield.

i. Pressurization - Designed with the total number of cycles projected for one service life.

j. Impact, operational, and residual loads occurring from the normal operation of movable structures such as control surfaces.

k. Store carriage and employment loads.

l. Heat flux.

***Standard* (Navy)**: All sources of repeated loads affecting the fatigue life, durability and damage tolerance of the air vehicle structure are considered to ensure that the required service life of the system is not degraded. The durability capability of the airframe is adequate to resist fatigue cracking, corrosion, thermal degradation, delamination, and wear during operation and maintenance such that the operational and maintenance capability of the airframe is not degraded and the service life, usage are not adversely affected. These requirements apply to metallic and nonmetallic structures, including composites, with appropriate distinctions and variations as indicated in applicable specifications, Airworthiness and Design Standards and Regulations, 3.2.14.3 of JSSG-2006 and the Addendum to the AVPS. Durability material properties are consistent with those properties of the same material, in the same component, used for loads, structural dynamics, strength, damage tolerance and durability. Typical repeated loads sources include: maneuvers, gusts, operation of suppression systems, vibration, take-off and landings, buffet, ground and shipboard operations, pressurization, weapons carriage and employment, environmental factors, impact conditions etc. A comprehensive database of load sources, exceedances and other parameters, based on data recorded from actual usage experience, ensures the greatest possible accuracy in the representation of the design usage and function of the aircraft.

***Method of Compliance* (Army and Air Force)**: Verification methods include analysis, test, and inspection of documentation.

a. The following methods of compliance are applicable to all of the conditions of the standard:

    (1) Ground and flight loads analyses are correlated with test data.

    (2) For rotorcraft, flight load survey testing is performed to gather loads for each regime in the usage spectrum.

b. The following two compliances are applicable to item g of the standard:

    (1). Wind tunnel tests are utilized for development of buffet loads.

    (2). Buffet flight tests are utilized to verify analytical buffet predictions.

c. The following compliance is applicable to item d of the standard:

    (1) Updated predictions of the vibration and aeroacoustic environments are accomplished.

Method of Compliance **(Navy)**: Verification methods include ground and flight loads analyses, inspection of documentation, simulation, wind tunnel testing, static testing and flight test.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.2.14.3, A.4.2.14.3; A.3.2.24, A.4.2.24

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

Navy rotary wing) As identified in the Addendum to the AVPS for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.1.5 Propulsion loads.

Criterion*:* Verify that the air vehicle structure is designed such that the power or thrust of the installed propulsion system is commensurate with the ground and flight conditions of intended use, including system failures, and the capabilities of the propulsion system and crew.

Standard*:* See 5.1.1.

Method of Compliance*:* See 5.1.1.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.2.17, A.4.2.17

(Army rotary wing) ADS-29 (cancelled)

(Navy rotary wing) As identified in JSSG-2006: A.3.2.17, A.4.2.17; and as identified in the Addendum to the AVPS for the respective air vehicle and/or AR-56, AR-89, and MIL-D-23222

5.1.6 Flight control and automatic control device loads**.**

Criterion*:* Verify, in the generation of loads, that flight control and automatic control devices, including load alleviation and ride control devices, are to be in all modes (operative, inoperative, and transient) for which use is required. This includes use due to or likely due to single or multiple system failure conditions.

Standard*:* Stability augmentation; load and flutter alleviation; pilot cueing software and vibration control devices do not affect the short or long term strength and durability of the aircraft. Loads generated by these devices in all modes of operation are considered in the design, (on, off, system failure and/or overridden condition, if available) to ensure adequate structural integrity exists.

Method of Compliance **(Air Force)**: Verification methods include analyses, tests, and inspection of documentation.

Method of Compliance **(Army and Navy)**: Verification methods include analyses, inspection of documentation, simulations, wind tunnel, ground and flight test.

Method of Compliance **(All)**: Analyses and tests verify the normal operation as well as some potential modes of operation. Analyses and ground tests verify the emergency associated modes of operation. Correlated ground and flight loads analyses are accomplished. Wind tunnel tests are utilized for development of aerodynamic loads. Flight controls and aerodynamic flight tests are utilized to update aircraft simulation models. Per JSSG-2006, 80% and 100% flight loads surveys/demonstrations are utilized to correlate analytical model.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.2.18, A.4.2.18

(Army rotary wing) ADS-29 (cancelled)

(Navy rotary wing) As identified in the JSSG-2006: A.3.2.18 and A.4.2.18 and as identified in the Addendum to the AVPS for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

5.1.7 Analysis and testing of realistic flight loading conditions.

***Criterion**:* Verify that flight loading conditions are based upon realistic conditions of air vehicle structural response to pilot induced or autonomous maneuvers, loss of control maneuvers, gusts, and turbulence. Also verify that the realistic conditions considered are both required and expected to be encountered critical combinations of configurations, gross weights, centers of gravity, thrust or power, altitudes, speeds, and type of atmosphere and are used in the design of the air vehicle structure.

***Standard* (Army and Air Force)**:

a. Air vehicle structure is designed such that flight loading conditions reflect symmetric and asymmetric flight operations. Flight loading conditions are also established for both primary and secondary structural components by careful selection of flight parameters likely to produce critical applied loads. Symmetric and asymmetric flight operations include symmetric and unsymmetric fuel and payload loadings (including external stores) and adverse trim conditions.

b. Fixed wing air vehicle structure is designed such that symmetric maneuver conditions accomplished with and without a specified roll rate command above 80 percent maximum symmetric Nz providing acceptable roll capability throughout the specified flight envelope.

c. Air vehicle structure is designed such that symmetric maneuvers are performed with and without a 50 degrees per second roll rate command for A (attack aircraft), F (fighter aircraft), TF (trainer/fighter aircraft), O (observer aircraft) and T (trainer aircraft) fixed-wing aircraft and 30 degrees per second for all other fixed-wing aircraft. Symmetric maneuvers include steady pitching, abrupt pitching, flaps down pullouts, aerial delivery pullouts, and emergency stores release. For rotorcraft see ADS-29 (cancelled).

d. Air vehicle structure is designed such that asymmetric maneuvers restricted to 80 percent (100 percent for rotorcraft) of maximum design symmetric load factor (Nz). Asymmetric maneuvers are fully coordinated and, alternately, uncoordinated maneuvers. Asymmetric maneuvers include level fight rolls, elevated-g rolls, rolling pull-outs, aerial delivery rolls and takeoff/landing approach roll. For rotorcraft see ADS-29 (cancelled).

e. Air vehicle structure is designed for directional maneuvers which include sideslips, rudder kicks, rudder reversals, unsymmetrical thrust with zero sideslip, engine failure, and engine out operation. For rotorcraft see ADS-29 (cancelled).

f. Air vehicle structure is designed for evasive maneuvers which include jinking and missile break maneuvers as well as for stalls, departures, spins and tail slides. For rotorcraft see ADS-29 (cancelled).

g. Air vehicle structure is designed for operating in the atmosphere with vertical and lateral gusts representative of those expected to be encountered in which:

(1) Required missions and a gust exceedance rate of the lower of 1 x 10-5 cycles per hour or once in ten lifetimes.

(2) The power spectrum of the expected turbulence is defined by the equation located in JSSG-2006, A.4.3.1.6 and the turbulence field parameters in table XI of JSSG-2006.

(3) The air vehicle structure does not have strength less than a level established with limit gust velocity values Yd/Ā of:

(a) Forty feet per second, estimated air speed (EAS) from 0 to 1000 feet, then

(b) Varying linearly to 58 feet per second, EAS at 2500 feet, then
(c) Varying linearly to 62 feet per second, EAS at 7000 feet, then
(d) Varying linearly to 55 feet per second, EAS at 27,000 feet, then
(e) Varying linearly to 14 feet per second, EAS at 80,000 feet.

h. The air vehicle structure is designed for operating in the atmosphere with vertical and lateral gusts representative of those expected to be encountered in wake turbulence and gust plus maneuver.

i. The air vehicle structure is designed for operating under aerial refueling and aerial delivery conditions.

j. The air vehicle structure is designed for operating while using speed and lift controls as well as use of braking wheels in air.

k. The air vehicle structure is designed for extension and retraction of landing gear.

l. The air vehicle structure is designed for pressurization in which the pressure differentials used in the design of pressurized portions of the airframe, including fuel tanks, are the maximum pressure differentials attainable during flight within the design flight envelope, during ground maintenance, and during ground storage or transportation of the air vehicle. For normal flight operations, the maximum pressure differentials attainable are increased by a factor not less than 1.33 when acting separately or in combination with 1g level flight loads. For emergency flight operations or when combined with maximum maneuver flight loads, the maximum pressure differentials attainable are increased by a factor not less than 1.0. For ground operations including maintenance, the maximum pressure differentials attainable are increased by a factor not less than 1.33.

m. The air vehicle structure is designed to account for aeroelastic deformations when determining the final airload distributions.

n. The air vehicle structure is designed with the inclusion of dynamic response of the air vehicle resulting from the transient or sudden application of loads such as store ejection in the determination of design loads.

o. The air vehicle structure is designed such that when asymmetric or dissimilar stores are on opposing store stations the required lateral center of gravity position is based on 120% of the maximum loading of any single store station or the maximum attainable by loading one side of the aircraft, plus the maximum wing asymmetric fuel allowed operationally without limitations.

p. For rotorcraft, the air vehicle structure, including the airframe, rotors and controls is designed for the flight, ground and control system load conditions defined in 4.1, 4.2, 4.4 and 4.5 of ADS-29 (cancelled). These conditions encompass symmetric and unsymmetrical, powered and unpowered flight, nap of the earth and air combat maneuvers, landing, ground maneuvering and handling, tie-down and mooring, and control system loads. For rotorcraft, design load factors are identical for symmetrical and unsymmetrical flight maneuvers.

Standard (**Navy)**: Fixed Wing and Rotary Wing: The structural flight loading conditions for air vehicle structure, including the airframe, rotor and control systems is designed in such a way that the flight loading conditions of JSSG-2006: A.3.4.1 and subsequent subparagraphs, and A.4.3.1 and subsequent subparagraphs, in conjunction with the design conditions specified in JSSG-2006: A.3.1, A.4.1; A.3.2, A.4.2 are addressed (see also 5.1.1 of this document).

Method of Compliance (**Army and Air Force)**: Verification methods include analyses, tests, and inspection of documentation. The flight loading conditions used in the design of the airframe as defined in the standards are verified by a series of analyses and tests.

a. Correlated flight loads analyses are provided in which details of magnitudes and distribution of all applied external loads are identified for multiple air vehicle configurations, weights, center of gravity, and maneuvers covering all attainable altitudes, speeds and load factors. Service and maximum loads expected to be encountered are established for operation under all flight conditions. Wind tunnel tests are utilized for development of aerodynamic loads. Stiffness and ground vibration tests are utilized to update flexibility vs. rigid characteristics of loads analytical model. Flight controls and aerodynamic flight tests are utilized to update aircraft simulation models. Loads calibration tests are utilized to develop flight load equations. 80% and 100% flight loads surveys/demonstrations are utilized to correlate analytical model and substantiate the design loads.
b. For rotorcraft, loads analysis is performed for design load conditions specified in ADS-29 (cancelled). Structural demonstration flight testing is performed in accordance with ADS-24 (cancelled) to demonstrate the safe operation of the aircraft to the maximum attainable operating limits consistent with the structural design and to verify that loads used in the structural analysis and static tests are not exceeded at the structural design limits of the airspeed and load factor envelope, or if analytical loads are exceeded during structural demonstration testing to establish the allowable flight envelope and the critical conditions for strength, rigidity, and operation.

Method of Compliance (**Navy)**: Rotorcraft loads analyses are performed for conditions specified in sections 3 and 4 of the AVPS Addendum and/or AR-56. Ground and flight testing is performed in accordance with section 4 of the AVPS, AR-89 and MIL-D-23222 to demonstrate compliance with design requirements and to demonstrate safe operating limits.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.4.1 and A.3.4.1.1-15; JSSG-2006: Power Spectrum Equation in A.3.4.1.6 (for standard development); JSSG-2006: Table XI "Turbulence Field Parameters", (for standard development)

(Army) ADS-24 (cancelled), ADS-29 (cancelled)

(Navy rotary wing) Similar to JSSG-2006: A.3.4.1 and subsequent subparagraphs, and A.4.4.1; as applicable to rotary wing aircraft; the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

5.1.8 Analysis and testing of realistic ground loading conditions.

Criterion **(Army, Navy and Air Force)**: Verify that the aircraft is designed for ground loading conditions that reflect fleet operations. Verify that the airframe has sufficient structural integrity to take-off, catapult, land, arrest, and operate on the ground, ship, or other remote operating facilities.

Standard **(Army and Air Force)**:

a. For Fixed-Wing Aircraft:
    (1) The airframe is designed such that the maximum landing touchdown vertical sink speeds of the air vehicle center of mass used in the design of the airframe and landing gear are:
        (a) 13 feet per second (fps) for landing design gross weights of primary and basic trainers; 10 fps for all other classes.
        (b) 10 fps for maximum landing design weights of primary and basic trainers; 6 fps for all other classes
    (2) The airframe is designed such that crosswinds at take-off and landing are those components of surface winds perpendicular to the runway centerline with the

landing gear loads being 80% of the vertical reaction for the inboard acting load and 60% of the vertical reaction of the outboard acting load. This is based on the vertical reaction being 50% of the maximum vertical reaction from two point and level symmetrical landings.

(3) The airframe is designed such that the landing touchdown roll, yaw, pitch attitude, and sink speed combinations are based on a joint probability within an ellipsoid with axes of roll, yaw, and pitch.

(4) The airframe is designed such that taxi discrete bumps and dips are as defined in JSSG-2006 for wave length, amplitude and shape for the maximum ground weight. It is also designed such that the angle between the path of the aircraft and the lateral axis of the contour are at angles up to 45 degrees.

(5) The airframe is designed such that the maximum combination of wind loading and air vehicle load factor conditions that are utilized when assessing jacking of the air vehicle.

(6) The airframe is designed such that the ground loading conditions considered are those required and expected to be encountered in critical combinations of configurations, gross weights, centers of gravity, landing gear/tire servicing, external environments, thrust or power, and speeds and are used in the design of the airframe.

(7) The airframe is designed such that ground operations include symmetric and unsymmetric fuel and payload loadings and adverse trim conditions.

(8) The airframe is designed for ground operations consisting of taxing, turning, pivoting, braking, landing (including arrestment) and takeoff.

(9) The airframe is designed for ground handling conditions consisting of towing, jacking, and hoisting.

(10) The airframe is designed for dynamic response and shimmy during ground operations as well as for rough runway conditions.

(11) The airframe is designed for ground winds as a result of weather and jet blast.

b. For Rotary-wing Aircraft:

(1) The normal landing capability is defined for the structural design gross weight and associated center of gravity envelope. The aircraft is in the pitch and roll attitude for trimmed descent for landing. The rotor lift is equal to 2/3 the weight of the aircraft, and tail rotor forces and moments are as required for trimmed flight. The wind speed is 45 knots from any azimuth. The landing conditions are as follows:

(a) A level landing on a level surface at 12 fps sink speed with a forward velocity of 0-60 knots.

(b) A landing of 8 fps sink speed with a zero forward velocity on a 12 degree slope in any azimuth relative to the aircraft.

(c) For the maximum alternate gross weight, the landing capability in terms of sink speed, forward velocity and slope angle is defined based on the demonstrated capability. The rotor lift equals the weight of the aircraft.

(2) The air vehicle structure is designed such that crosswinds at take-off and landing are those components of surface winds perpendicular to the runway centerline with the landing gear loads being 80% of the vertical reaction for the inboard acting load and 60% of the vertical reaction of the outboard acting load. This is based on the vertical reaction being 50% of the maximum vertical reaction from two point and level symmetrical landings.

(3) The air vehicle structure is designed such that the landing touchdown roll, yaw, pitch attitude, and sink speed combinations are based on a joint probability within an ellipsoid with axes of roll, yaw, and pitch.

(4) The air vehicle structure is designed such that taxi discrete bumps and dips are as defined in JSSG-2006 for wave length, amplitude and shape for the maximum ground weight. It is also designed such that the angle between the path of the aircraft and the lateral axis of the contour are at angles up to 45 degrees.

(5) The air vehicle structure is designed such that the maximum combination of wind loading and air vehicle load factor conditions that are utilized when assessing jacking of the air vehicle.

(6) The air vehicle structure is designed such that the ground loading conditions considered are those required and expected to be encountered in critical combinations of configurations, gross weights, centers of gravity, landing gear/tire servicing, external environments, thrust or power, and speeds and are used in the design of the airframe.

(7) The air vehicle structure is designed such that ground operations include symmetric and unsymmetric fuel and payload loadings and adverse trim conditions.

(8) The air vehicle structure is designed for ground operations consisting of taxing, turning, pivoting, braking, ski loads, landing (including arrestment) and takeoff.

(9) The air vehicle structure is designed for ground handling conditions consisting of towing, jacking, and hoisting.

(10) The air vehicle structure is designed for dynamic response and shimmy during ground operations as well as for rough runway conditions.

(11) The air vehicle structure is designed for ground winds as a result of weather and jet blast.

(12) The air vehicle structure is designed for main gear obstruction loads. The main landing gear contacts the ground simultaneously, with the auxiliary landing gear just clear of the ground. The forward velocity is zero, rotor lift equals the aircraft weight, the sink speed is 12 fps, and the landing surface slope is zero. A load equal to one-half of the maximum vertical reaction at each point of contact, but not greater than the weight of the aircraft, is applied in a foreword, aft, inboard, and outboard direction, each in combination with a vertical load, considering each point of contact independently. The transverse loads on the other gear are zero.

(13) The air vehicle structure is designed for auxiliary gear obstruction loads. The auxiliary landing gear contacts the ground simultaneously, with the main gear just clear of the ground. The forward velocity is from zero to 5 mph, rotor lift equals the aircraft weight, the sink speed is 12 fps and the landing slope is zero. A load equal to one half of the maximum vertical reaction at the auxiliary gear points of contact, but not greater than the weight of the aircraft, is applied in a forward, aft, inboard, and outboard direction, each in combination with the vertical load. The transverse loads on the other gear are zero. Swiveled wheels are centered and locked. If positive locking provisions are not provided, it is assumed that the wheels remain centered and that the loads are reacted by the centering mechanism.

***Standard* (Navy)**: Ground loading conditions of MIL-A-8863; JSSG-2006: A.3.4.2; and AR-56 identify required and expected to be encountered critical combinations of configurations, gross weights, centers of gravity, landing gear/tire servicing, external environments, thrust and power, and vertical, lateral/drift and longitudinal landing and taxi speeds, as appropriate to the air vehicle type. Loads development considers landing gear arrangement; type; special equipment to support operations in snow or unprepared surfaces or add-on wheels to support movement of aircraft with nontraditional landing gear systems (e.g., skids, “feet”, air cushion) and how the air vehicle will be maneuvered and/or secured on the ground/ship (e.g., braking, towing, jacking). Ground operations include symmetric and unsymmetrical fuel and payload loadings and adverse trim conditions. Forcing functions and time histories for shipboard carrier catapult and arresting gear are provided in MIL-HDBK-2066. Barricade deceleration is provided in NAEC-MISC-06900. Rotary wing and UA platforms may require development of loads associated with recovery haul down, securing, or traversing and are defined in AVPS. In all cases, the structural integrity of the aircraft is expected to be adequate for the air vehicle to perform its intended mission. For Navy fixed wing and rotary wing aircraft, landing conditions define the “design load”.

***Method of Compliance* (Army and Air Force)**: Verification methods include analyses, tests, and inspection of documentation. The ground loading conditions used in the design of the airframe as defined in the standards are verified by a series of analyses and tests.

a. Correlated ground loads analyses including dynamic response analyses are provided in which details of magnitudes and distribution of all critical design loads are established. Dynamic stability/taxi analyses are provided to assess shimmy and development of design loads. Ground vibration tests and landing gear shimmy lab tests are utilized to define the dynamic characteristics of the gear. Loads calibration tests are utilized to develop ground load equations. Ground loads test demonstrations, shimmy ground tests, and rough runway tests are utilized to correlate analytical model and substantiate the design loads.

a. For rotorcraft, loads analysis is performed for design load conditions specified in ADS-29 (cancelled). Structural demonstration flight testing (which includes hard landings) is performed in accordance with ADS-24 (cancelled) to demonstrate the safe operation of the aircraft to the maximum attainable operating limits consistent with the structural design and to verify that loads used in the structural analysis and static tests are not exceeded at the structural design limits of the airspeed and load factor envelope, or if analytical loads are exceeded during structural demonstration testing to establish the allowable flight envelope and the critical conditions for strength, rigidity, and operation.

Method of Compliance (**Navy)**: Verification methods include analyses, tests, and inspection of documentation, simulation, component and/or full scale drop and static tests, and flight test. Compliance is shown for each combination of configurations at all critical gross weight, center of gravity, sink speed, longitudinal and lateral speed, lift, and payload condition and environmental condition specified in sections 3 and 4 of the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

References: (Navy/Air Force fixed wing) MIL-A-8863, JSSG-2006: A.3.4.2, 4.4.2; 3.4.2.1-11; 3.4.2.12; 3.4.2.15

ADS-29 (cancelled): 4.4

MIL-HDBK-2066

NAEC-MISC-06900

(Navy rotary wing) As identified in MIL-A-8863 and the AVPS Addendum for the respective air vehicle and AR-56, AR-89, MIL-D-23222

5.1.9 Crash loads.

***Criterion* (Army)**: Verify that in the generation of loads the air vehicle structure is able to withstand crashes and to protect personnel to the extent reflected by the ultimate loading conditions and parameters sufficient to prevent injury to occupants and to maintain the integrity of egress paths.

C*riterion* (Navy and Air Force): Verify that in the generation of loads the air vehicle structure, (including large mass items and their attachments (gearboxes, engines, APU etc.) is able to withstand crash and emergency water landings and to protect personnel sufficient to prevent injury to occupants and to maintain the integrity of egress paths.

***Standard* (Army and Air Force)**:

a. For Fixed Wing Aircraft:
   (1) The air vehicle structure is designed such that crash requirements are defined in terms of longitudinal, vertical and lateral crash load factors.
   (2) The air vehicle structure is designed such that the minimum longitudinal, vertical and lateral crash load factors are equal to the ultimate load factors required for strength of crew and passenger seats. This is as specified in the applicable specifications for seats or is in accordance with Table XIV of JSSG-2006. Ultimate loads are based on load factor times the combination of an appropriate amount of mass, the man plus personal equipment and the weight of any seat armor.
   (3) The air vehicle structure is designed such that all internal fuel tanks, including all critical amounts of fuel up to two-thirds of the individual tank capacities, are able to withstand the ultimate load factor requirements.
   (4) The air vehicle structure is designed such that all fixed and removable miscellaneous and auxiliary equipment and their subcomponent installations are able to withstand the following air vehicle load factors: Longitudinal 9.0 fwd, 1.5 aft; Lateral 1.5 right and left; Vertical 4.5 down and 2.0 up.
   (5) The air vehicle structure is designed such that the airframe attachments and carry through structure are able to withstand the following ultimate load factors: Longitudinal 3.0 fwd, 1.5 aft; Lateral 1.5 right and left; Vertical 4.5 down and 2.0 up. This is when cargo or fixed and removable equipment is located in a manner wherein failure could not result in injury to personnel or prevent egress.

b. For rotorcraft, the air vehicle structure is designed in accordance with 4, 5.1, 5.2, 5.3 and 5.4 of MIL-STD-1290. The aircraft acts as an energy absorbing system using design features such as stroking landing gear, crushable structure and stroking crew member seats to mitigate crash deceleration. The airframe maintains the integrity of the occupied space and the means for post-crash egress. High mass items that pose a hazard to the crew are retained during the crash event. Unmanned aircraft have no inherent crashworthiness requirements unless potentially operated with occupants.

***Standard* (Navy)**: The aircraft structure, including landing gear, seats and their interface structure, are designed as an energy absorbing system capable of reacting loads resulting from the specified crash criteria. During the specified crash environments, crash forces experienced by the occupants of aircraft equipped with crashworthy seats remain within human tolerance levels and occupiable space is retained in order to provide restraint and rapid egress from the aircraft under any conceivable post-crash attitude. For emergency water landings the design for egress considers all possible aircraft positions (e.g. afloat or submerged, and upright, rolled or inverted). The loads and loading conditions specified are applicable to the design of the airframe, crew seats, passenger seats, baggage areas, overhead storage compartments, cabin area bulkhead walls/dividers, lavatory and galley equipment, litters and medical equipment, attachments of mission equipment items, airframe attachments for internally carried air or ground based vehicles used to perform in-flight mission support, engines (including input modules), transmission components (main rotor, proprotor, tail rotor and intermediate gearboxes, as applicable), APUs, fuel tanks (with specified fuel quantities), ramp mounted and crew served weapons, external weapons pylons adjacent to egress areas, and their carry through structures, and any other items that pose a hazard to personnel resulting in injury or blockage of egress paths. For shipboard UAs crashworthiness may be required to ensure safety of the ship and ship's personnel.

***Method of Compliance* (Army and Air Force)**: Verification methods include analyses, tests, and inspection of documentation. The ground loading conditions and subsequent analyses and tests used in the design of the airframe are utilized to develop the crash loads.

a. Correlated ground loads analyses are provided in which details of magnitudes and distribution of all critical design loads are established. Ground loads test demonstrations are utilized to correlate analytical model and substantiate the design loads.
b. For rotorcraft, aircraft crash loads analysis is performed for various crash impact design conditions in accordance with applicable platform specifications typically based on MIL-STD-1290. Crash load factors applicable to retention of high mass items, occupants, cargo, and ancillary equipment are used in structural analysis in accordance with applicable platform specifications, typically based on MIL-STD-1290.

Method of Compliance (**Navy)**: Verification methods include analyses, inspection of documentation, simulation, component and/or static testing. Dynamic ground testing including full scale airframe drop tests, and airframe or component level dynamic impact and sled testing may be required. For rotorcraft, aircraft crash loads analysis is performed for various crash impact design conditions in accordance with the AVPS Addendum for the respective air vehicle and AR-56. Crash load factors applicable to retention of high mass items, occupants, cargo, and ancillary equipment are used in structural analysis in accordance with Air Vehicle Performance Specification (AVPS) Addendum for the respective air vehicle and AR-56.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.4.2.11, Table XIV, "Seat Crash Load Factors", (for standard development)

(Army) ADS-36

MIL-STD-1290

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and AR-56, AR-89

5.2 Structural dynamics.

5.2.1 Aeroelastic design - general.

***Criterion* (Army and Air Force)**: Verify that the air vehicle, in all configurations including store carriage and system failures, is free from flutter, whirl flutter, divergence, and other related aeroelastic or aeroservoelastic instabilities, including transonic aeroelastic instabilities, for all combinations of altitude and speed encompassed by the limit speed (V_L/M_L) versus altitude envelope enlarged at all points by the airspeed margin of safety. Also, verify that all aerodynamic surfaces and components of the air vehicle are free from aeroelastic divergence and that the inlet, transparency, and other aerodynamically loaded panels are designed to prevent flutter and limited amplitude oscillations when exposed to high transonic or supersonic flow.

***Criterion* (Navy)**: Verify that the air vehicle in all configurations including store carriage and system failures, and its components such as wings, main and tail rotors, vertical and horizontal tails, pylons, external stores, externally slung loads, control surfaces, drive systems, drive shafts, are free from flutter, stall flutter, whirl flutter, divergence, buzz, coupled rotor/pylon instabilities, air and/or ground resonances, landing gear shimmy and other aeroelastic, aeroservoelastic, aerothermoelastic instabilities, including limit cycle oscillations and transonic aeroelastic instabilities, for all combinations of altitude and speed encompassed by the limit speed (V_L/M_L) versus altitude envelope enlarged at all points by the airspeed margin of safety. Verify that all inlets, transparency, and other aerodynamically loaded panels are designed to prevent flutter and limit cycle oscillations.

***Standard* (Army and Air Force)**:

a. The airframe is designed such that a margin of safety of 15% or greater is maintained in equivalent airspeed (Ve) at all points on the V_L/M_L envelope of the air vehicle, both at constant Mach number and separately, at constant altitude.

b. The airframe is designed such that the total (aerodynamic plus structural) damping coefficient, g, is not less than 0.03 for any critical flutter mode or for any significant dynamic response mode for all altitudes and flight speeds from minimum cruising speeds up to V_L/M_L.

***Standard* (Navy)**: The air vehicle and its components demonstrate the required airspeed margin, damping, gain and phase margins to prevent dynamic aeroelastic, aerothermoelastic, engine/drive/shafting system, rotor and ground instabilities within the air vehicle's flight and ground operational envelopes. This standard applies throughout the design range of altitudes, speeds, maneuvers, weights, fuel loadings, thermal conditions, external store, external sling load, landing and power conditions.

***Method of Compliance* (Army and Air Force)**: Verification methods include analyses, tests, inspection and review of documentation. Validity of the flutter requirements as identified in the standards is verified by a series of analyses and tests. The following compliance instruments are applicable in addressing both standards:

a. Updated flutter analyses of the complete air vehicle including external stores if carried, as well as flutter analyses of the air vehicles control surfaces, tabs, and other components.

b. Parametric flutter analyses involving variations of the mass, positions of center of gravity and mass moment of inertia.

c. Analyses involving variable fuel conditions for external tanks.

d. Full-span flutter analyses which identify flutter characteristics of various asymmetric store loadings.

e. Updated whirl flutter analyses in which the blade aerodynamics, flexibility and power plant flexibilities, mounting characteristics and gyroscopic effects are included especially for propeller or large turbofan driven air vehicles.

f. Updated divergence and buzz analyses as well as panel flutter analyses. Where applicable updated whirl flutter analyses and aeroservoelastic stability analyses.

g. Panel flutter analyses in which the aerodynamic conditions used are the local conditions existing at the panel surface including those altered from the free stream by airplane altitude or surface shape.

h. Panel flutter analyses in which a buckled or near buckled condition is assumed for panels subjected to in-plane compressive stresses and where an accurate prediction of the compressive stresses and their effects was not possible.

i. Wind tunnel and unsteady pressure model tests along with model tests which investigate lifting surface shock induced separation oscillations and other related transonic aeroelastic instability phenomena.

j. Laboratory tests such as component ground vibration and stiffness tests such as that involving the engine with propeller for turbo-prop aircraft as well as pylons with and without stores/tanks, as well as launchers and racks with stores.

k. Mass measurements of control surfaces/tabs, balance weight attachment verification tests, damper qualification tests, thermoelastic tests as well as control surface, tab, and actuator rigidity, free play, and wear tests.

l. Complete air vehicle ground vibration modal tests which include modal tests on components attached to the air vehicle such as turboprop propeller plane as well as tests in which the modes and frequencies of flutter critical skin panels are obtained.

m. Aeroservoelastic ground tests.

n. Flight flutter tests and flight aeroservoelastic stability tests of the air vehicle which substantiate the air vehicle is free from aeroelastic instabilities. Incorporation of sway brace preloads into the appropriate user manual.

***Method of Compliance* (Navy)**: Verification methods of the JSSG and MIL-A-8870 include analyses (e.g., flutter, mechanical and torsional stability), component level test (e.g., mass property verification, stiffness, force-velocity, free-play and rigidity of flight control system and surfaces), wind tunnel tests, ground test (e.g., ground vibration tests, whirl tests, torsional stability, mechanical stability), pre-flight correlations to ground test results, flight test, inspection and review of documentation. Compliance is shown for each combination of configurations at all critical gross weight, center of gravity, lift, payload and environmental condition specified.

References: Navy/Air Force FW: JSSG-2006: A.3.7 and subparagraphs; A.4.7; MIL-A-8870

US Army rotary wing: ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

US Navy rotary wing: As identified in the Air Vehicle Performance Specification (AVPS) Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.2.2 Aeroelastic design - aeroservoelasticity.

***Criterion* (Navy and Air Force)**: Verify that the air vehicle is free from the occurrence of any aeroservoelastic instability resulting from the interactions of air vehicle systems, such as aerodynamics, commanded or uncommanded control systems coupling with the airframe, rotor systems and/or external slung loads, as appropriate.

***Criterion* (Army)**: Verify that the air vehicle is free from the occurrence of any aeroservoelastic instability resulting from the interactions of air vehicle systems, such as the control systems coupling with the airframe.

***Standard* (Army and Air Force)**: The air vehicle is designed such that the structural modes have stability margins involving a gain margin of at least 6dB and separately, a phase margin of at least 60 degrees for any single flight control system feedback loop at speeds up to V_L/M_L. The operative states (on and off) of the systems are commensurate with the uses authorized in the flight manual as applicable throughout the full flight envelope.

***Standard* (Navy)**: The air vehicle is designed such that the airframe, and rotor system(s) if applicable, structural modes do not couple with the pilot or flight control system feedback loops at any time, including during ground operations and speeds up to V_L/M_L, for all aircraft configurations (e.g., external stores, externally slung loads, internal load distributions). The operative states (on and off) of the systems are commensurate with the uses authorized in the flight manual as applicable throughout the operating envelope. Flight control sensor location and system transfer function, as well as unsteady aerodynamic characteristics, are considered during control system and airframe design.

***Method of Compliance* (Army and Air Force)**: Verification methods include analysis, tests, and review of documentation. The following compliance instruments are applicable in addressing the standards:

a. Updated aeroservoelastic stability analyses correlated with aeroservoelastic ground tests that are conducted for the critical flight conditions, taking into account the flight control systems gain scheduling and control surface effectiveness.

b. Flight aeroservoelastic stability tests of the air vehicle and its flight augmentation system.

***Method of Compliance* (Navy)**: Verification methods include analysis, pilot-in-the-loop simulations, component level testing, full scale air vehicle ground tests and flight tests, and review of documentation. The following compliance instruments are applicable in addressing the standards: Updated aeroservoelastic stability analyses correlated with aeroservoelastic ground tests conducted for the critical ground and flight conditions, taking into account the flight control systems gain scheduling, control surface effectiveness, rotor system operating conditions, and airframe modal characteristics. Flight aeroservoelastic stability tests of the air vehicle and its flight augmentation system are performed with and without external stores/sling loads.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.7, A.4.7; MIL-A-8870

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the Air Vehicle Performance Specification (AVPS) Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.2.3 Aeroelastic design - control surfaces and other components.

***Criterion* (Army and Air Force)**: Verify that the control surfaces and tabs contain sufficient static and dynamic mass balance, or sufficient bending, torsional, and rotational rigidity; or a combination of these means to prevent flutter; or limited-amplitude instabilities of all critical modes under all flight conditions for normal and failure operating conditions of the actuating systems. Verify that all control surfaces and parts thereof are free from single-degree-of-freedom flutter, such as buzz. Also verify that all other air vehicle components exposed to the airstream, such as spoilers, dive brakes, scoops, landing gear doors, weapon bay doors, ventral fins, movable inlet ramps, movable fairings, and blade antennae are free from aeroelastic instability.

***Criterion* (Navy)**: Verify that the control surfaces and tabs contain sufficient static and dynamic mass balance, or sufficient bending, torsional, and rotational rigidity; or a combination of these means to prevent flutter; and limit cycle instabilities of all critical modes under all ground and flight conditions for normal and failure operating conditions. Normal wear of control system components and actuating systems does not result in adverse free-play or hysteresis that would degrade control or alter stability characteristics. All fixed or movable control surfaces and parts thereof, and tail rotor systems are free from single-degree-of-freedom flutter, such as buzz. All other aircraft components exposed to the airstream, such as spoilers, dive brakes, scoops, landing gear doors, weapon bay doors, ventral fins, movable inlet ramps, movable fairings, and blade antennae are free from aeroelastic instability.

***Standard* (Army and Air Force)**:

a. The air vehicle is designed such that the physical characteristics of the control surfaces, tabs, and other components are not changed by exposure to any natural or manmade environment. This is throughout the service life of the airframe.

b. The air vehicle is designed such that the following control surface free play limits are not exceeded during the service life of the airframe. This is when circuit stiffness of control surfaces or tabs is utilized to prevent any aeroelastic instability.

   (1) Total free play not greater than 0.13 degrees when a trailing-edge control surface extends outboard of the 75-percent-span station of the main surface.

   (2) Total free play not greater than 0.57 degrees when a trailing-edge control surface extends outboard of the 50-percent-span station but inboard of the 75-percent-span station of the main surface.

   (3) Total free play not greater than 1.15 degrees when a trailing-edge control surface is inboard of the 50-percent-span station of the main surface.

   (4) Total free play of all-movable control surfaces not greater than 0.034 degrees.

   (5) Total free play not greater than 1.15 degrees when a tab span does not exceed 35 percent of the span of the supporting control surface.

   (6) Total free play not greater than 0.57 degrees when a tab span equals or exceeds 35 percent of the span of the supporting control surface.

   (7) Total free play not greater than 0.25 degrees for leading edge flaps.

   (8) Total free play not greater than 0.25 degrees for a wing fold.

   (9) Total free play not greater than the applicable value specified in (1) through (6) for other movable components which are exposed to the airstream such as trailing edge flaps, spoilers, dive brakes, scoops, etc.

c. Flaps extending outboard of the 50 percent-span station of the main surface, rigidly locked in the retracted position when not displaced from the retracted position in flight and when practicable.

d. Establishment of maximum allowable inertia properties which are not exceeded during the service life of the airframe when circuit stiffness of control surfaces or tabs is utilized to prevent any aeroelastic instability.

e. Establishment of mass balance design requirements when mass balancing of control surfaces or tabs is utilized to prevent any aeroelastic instability.

f. Use of two parallel hydraulic dampers to prevent any aeroelastic instability of a control surface, tab, and any other movable component which is exposed to the airstream when mass balance or rigidity criteria are impracticable.

***Standard* (Navy)**: Control surfaces, tabs, rotor blades and other aircraft components exposed to the airstream are designed to prevent flutter and limit cycle oscillations. Rigidity of all actuating elements and supporting structure and the rigidity of the aerodynamic surface are defined and free-play limits of JSSG-2006, 3.7, 4.7 and MIL-A-8870 are maintained and are not exceeded over the service life of the air vehicle

***Method of Compliance* (Army and Air Force)**: Verification methods include analyses, tests, and review of documentation. Validity of the control surface flutter requirements as identified in the standards is verified by a series of analyses and tests. The following compliance instruments are applicable in addressing all standards:

a. Updated flutter analyses including non-linear analyses of the air vehicles control surfaces and tabs.
b. Parametric variation flutter analyses which provides the sensitivity of the airspeed and damping margins of the airplane due to the variation of mass properties of all control surfaces, tabs, flaps and components which are exposed to the airstream.
c. Mass measurements of all control surfaces and tabs.
d. Control surface, tab, actuator rigidity, component rigidity, free play, stiffness and wear tests which are conducted for both normal and design failure conditions.
e. If utilized, balance weight attachment verification tests and damper qualification tests which demonstrate the integrity of the balance weight or damper installation.
f. Flight flutter tests which also include tests that substantiate the maximum allowable freeplay.

***Method of Compliance* (Navy)**: Verification methods include analyses, component level testing, wind tunnel tests, air vehicle ground tests, flight tests, and review of documentation. Component level testing includes mass property, rigidity, free-play, stiffness and wear testing of aerodynamic surfaces. If utilized, balance weight attachment wear and endurance verification tests and /or damper qualification tests are performed.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.7, A.3.7.1.1, A.3.7.1.3, A.3.7.1.8, A.3.7.2, A.3.7.3, A.3.7.4, A.3.7.5, A.4.7 and MIL-A-8870

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.2.4 Aeroelastic design - fail safe.

***Criterion* (Navy and Air Force)**: Verify that, after each of the failures listed below as well as for air vehicle augmentation system failures, the air vehicle is free from flutter, limited amplitude oscillations, divergence, and other related aeroelastic or aeroservoelastic instabilities, including limit cycle oscillations.

a. Failure, malfunction, or disconnection of any single element or component of the main flight control system, augmentation systems, automatic flight control systems, tab control system, or hydraulic system affecting individual flight control system components.
b. Failure, malfunction, or disconnection of any single element of any flutter damper connected to a control surface or tab, single failure of any individual main rotor or tail rotor damper, as applicable.
c. Failure of any single element in any hinge mechanism and its supporting structure of any control surface, tab or tail plane.
d. Failure of any single element in any actuator's mechanical attachment to the structure of any control surface, tab or tail plane.

e. Failure of any single element in the supporting structure of any pylon, rack, external store or externally slung load, as applicable.
f. Failure of any single element in the supporting structure of any large auxiliary power unit.
g. Failure of any single element in the airframe and supporting structure of any engine, engine pod, main rotor gearbox, tail rotor gearbox, or intermediate gearbox.
h. For air vehicles with turbopropeller or prop-rotor engines:
   (1) Failure of any single element of the structure supporting any engine or independently mounted propeller shaft.
   (2) Any single failure of the engine structure that would reduce the yaw or pitch rigidity of the propeller rotational axis.
   (3) Absence of propeller aerodynamic forces resulting from the feathering of any single propeller, and for air vehicles with four or more engines, the feathering of the critical combination of two propellers.
   (4) Absence of propeller aerodynamic forces resulting from the feathering of any single propeller in combination with the failures specified above in a and b.

***Criterion* (Army)**: Verify that, after each of the failures listed below as well as for air vehicle augmentation system failures the air vehicle is free from flutter, divergence, and other related aeroelastic or aeroservoelastic instabilities.

a. Failure, malfunction, or disconnection of any single element or component of the main flight control system, augmentation systems, automatic flight control systems, or tab control system.
b. Failure, malfunction, or disconnection of any single element of any flutter damper connected to a control surface or tab.
c. Failure of any single element in any hinge mechanism and its supporting structure of any control surface or tab.
d. Failure of any single element in any actuator's mechanical attachment to the structure of any control surface or tab.
e. Failure of any single element in the supporting structure of any pylon, rack, or external store.
f. Failure of any single element in the supporting structure of any large auxiliary power unit.
g. Failure of any single element in the supporting structure of any engine pod.
h. For air vehicles with turbopropeller or prop-rotor engines:
   (1) Failure of any single element of the structure supporting any engine or independently mounted propeller shaft.
   (2) Any single failure of the engine structure that would reduce the yaw or pitch rigidity of the propeller rotational axis.
   (3) Absence of propeller aerodynamic forces resulting from the feathering of any single propeller, and for air vehicles with four or more engines, the feathering of the critical combination of two propellers.
   (4) Absence of propeller aerodynamic forces resulting from the feathering of any single propeller in combination with the failures specified above in a and b.

***Standard* (Army and Air Force)**:

a. The airframe is designed such that after a failure, a margin of safety of 15% or greater is maintained in equivalent airspeed (Ve) at all points on the V_L/M_L envelope of the air vehicle, both at constant Mach number and separately, at constant altitude.

b. The airframe is designed such that after a failure, the total (aerodynamic plus structural) damping coefficient, g, is not less than 0.03 for any critical flutter mode or for any significant dynamic response mode for all altitudes and flight speeds from minimum cruising speeds up to V_L/M_L.

c. The air vehicle is designed such that after a failure, the structural modes have stability margins involving a gain margin of least 6dB and separately, a phase margin of at least 60 degrees for any single flight control system feedback loop at speeds up to V_L/M_L. The operative states (on and off) of the systems are commensurate with the uses authorized in the flight manual as applicable throughout the full flight envelope.

d. The airframe is designed such that it will not experience failures that lead to loss of adequate structural rigidity or proper structural functioning, or structural failure resulting in the loss of the air vehicle at a rate equal to or more frequent than 1x10-7 occurrences per flight.

Standard **(Navy)**: The airframe is designed such that in the event of the loss of function or a malfunction of a system due to failure or malfunction of a single element of the system the pilot/operator can return the air vehicle to a safe flight/ground condition, and continued safe flight or ground operation of the air vehicle is possible.

Method of Compliance*:* Verification methods include analyses, tests, and review of documentation. The following compliance instruments are applicable in addressing the standards:

a. Updated flutter analyses of the complete air vehicle including external stores if carried, as well as flutter analyses of the air vehicles control surfaces, tabs, and other components.

b. Updated divergence and buzz analyses as well as panel flutter analyses. Where applicable updated whirl flutter analyses and aeroservoelastic stability analyses.

c. Wind tunnel and unsteady pressure model tests along with model tests which investigate lifting surface shock induced separation oscillations and other related transonic aeroelastic instability phenomena.

d. Laboratory tests such as component ground vibration and stiffness tests, mass measurements of control surfaces/tabs, balance weight attachment verification tests, damper qualification tests, thermoelastic tests as well as control surface, tab, and actuator rigidity, free play, and wear tests.

e. Complete air vehicle ground vibration modal tests as well as aeroservoelastic ground tests.

f. Flight flutter tests and flight aeroservoelastic stability tests of the air vehicle which substantiate the air vehicle is free from aeroelastic instabilities.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.7.3, A.3.1.2, A.3.7.1, A.3.7.2, 4.7, MIL-A-8870

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.2.5 Environment design - sonic fatigue.

Criterion: Verify that the airframe structure (including cavities), equipment, and equipment provisions withstand the aeroacoustic loads and vibrations induced by the aeroacoustic environment for the air vehicle specified service life and usage without cracking or functional impairment.

***Standard* (Army and Air Force)**:

a. All aeroacoustic loads sources associated with the air vehicle and its usage are identified.
b. The airframe is designed such that an uncertainty factor of +3.5 dB is applied on the predicted aeroacoustic sound pressure levels.
c. The airframe is designed for fatigue life such that a factor of 2.0 is applied on the exposure time derived from the air vehicle specified service life and usage.

***Standard* (Navy)**: The aircraft and its components are designed to withstand, without cracking or functional impairment, loads resulting from vibratory sources and hot surface flow; engine, propeller, prop-rotor, and main or tail rotor passage frequency and pressure loads; power lift systems; cavity noise, blast pressures and recoil forces due to gun and rocket firing; buffeting forces; unbalances of rotating components; structural response to gusts and airfield and ship landing surfaces; exhaust turbulence noise and temperatures during operations in close proximity to shipboard catapult systems, jet blast deflectors and other air vehicles operating in close proximity; and acoustic/sonic loadings due to auxiliary power units, motors and pumps. Natural frequencies are separated from predominate main and tail rotor frequencies, and other driving sources such as gearboxes, shafting, engines, auxiliary power units.

***Method of Compliance* (Army and Air Force)**: Verification methods include analyses and tests. The following compliance instruments are applicable in addressing the standards:

a. Predictions of the near field aeroacoustic loads and fatigue life encompassing the air vehicles service life and usage and the identified aeroacoustic load sources.
b. Wind tunnel, jet models which define acoustic levels.
c. Component acoustic fatigue tests based on fatigue life predictions.
d. Ground and flight aeroacoustic measurements from full scale test aircraft including internal noise measurements.

***Method of Compliance* (Navy)**: Verification methods include analyses, wind tunnel testing, review of documentation component fatigue testing, airframe and component ground vibration testing, and powered ground testing including operations of engines, while opening and closing doors and compartments and when in close proximity to other parked and/or operating air vehicles; and flight testing throughout the full range of flight and ground operations, including gunfire and stores or cargo release. Transducers are utilized to record the operational acoustic and vibration environments.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.5, A.3.5.1, A.3.6, A.3.3.8, A.3.3.9, A.4.5, A.4.6, A.4.8 and A.4.9

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.2.6 Environment design - cavity flows.

***Criterion*:** Verify that the structures, equipment, and equipment provisions in, adjacent to, or immediately downstream of cavities open to the airstream during flight are designed for the effects of oscillatory air forces.

***Standard* (Army and Air Force)**:

a. All aeroacoustic loads sources associated with the air vehicle and its usage are identified.

b. The airframe is designed such that an uncertainty factor of +3.5dB is applied on the predicted aeroacoustic sound pressure levels.

c. The airframe is designed for fatigue life such that a factor of 2.0 is applied on the exposure time derived from the air vehicle specified service life and usage.

***Standard* (Navy)**: Airframe is designed such that pressure oscillations within and downstream of cavities are minimized by the addition of air flow devices, where practicable.

Method of Compliance*:* Verification methods include analyses and tests. The following compliance instruments are applicable in addressing the standards:

a. Predictions of the cavity aeroacoustic loads and fatigue life encompassing the air vehicles service life and usage.

b. Wind tunnel models that define acoustic levels.

c. Component acoustic fatigue tests based on fatigue life predictions.

d. Ground and flight aeroacoustic measurements from full scale test aircraft.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.3.9, A.4.3.9

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.2.7 Environment design - personnel exposure to aircraft noise.

Criterion*:* Verify that sound pressure levels in areas of the air vehicle occupied by personnel during flight are controlled as required by human factors requirements.

Standard*:* Sound treatments are designed and developed in conjunction with the airframe. Human factor requirements are defined in accordance with AFOSH 48-19 and multicommand ORD CAF-MAF-AETC 319-93-I-A.

Method of Compliance*:* The following compliances are applicable in addressing the standards:

a. Predictions of internal acoustic levels based on internal noise sources and the near field aeroacoustic predictions for pertinent operational flight and ground usage.

b. Measurements at personnel stations of internal acoustic levels for pertinent flight conditions.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.6.2, A.4.6.2

MIL-STD-1474

AFOSH 48-19

ORD CAF-MAF-AETC 319-93-I-A

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

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5.2.8 Environment design - vibration.

***Criterion* (Army and Air Force)**: Verify that the airframe is designed such that it can operate in the vibration environments induced by the operational use for the specified service life. Also verify that the airframe is designed such that no fatigue cracking or excessive vibration of the airframe structure or components occurs that would result in the air vehicle or the components of the air vehicle systems not being fully functional.

***Criterion* (Navy)**: Verify that the aircraft is designed such that it can operate in the vibration environments induced by the operational usage environment for the specified service life. The aircraft, for all flight conditions, specified gross weight, centers of gravity, airspeeds, and when for rotorcraft operating at the specified rotor speed(s), is designed such that no fatigue cracking or excessive vibration of the airframe structure or components occurs that would result in the air vehicle or the components of the air vehicle systems not being fully functional. The vibration spectrum provided for design and qualification of equipment to be installed on the aircraft is acceptable. A separate set of spectra, addressing each portion of the flight envelope including maneuvers, is defined. (Aircraft are typically divided into selected zones based upon regions of influence of the source of (vibration).)

***Standard* (Navy and Air Force)**:

a. Identification of vibratory sources associated with the air vehicle and its usage.
b. Estimates of vibration levels that are the basis for structural development testing as well as establishment of equipment qualification test criteria. These vibration levels are used to develop designs to control the environment in areas occupied/equipment.
c. Utilization of MIL-STD-810 during air vehicle design and equipment development when reasonable measurements of equipment vibration are unavailable.

***Standard* (Army)**:

a. All vibratory sources associated with the air vehicle and its usage are identified.
b. Estimates of vibration levels are the basis for preliminary structural development testing as well as establishment of equipment qualification test criteria. The levels are utilized for developing designs to control the environment in areas occupied by personnel and equipment.
c. MIL-STD-810 is utilized during air vehicle equipment development when reasonable estimates of equipment vibration are unavailable.

***Method of Compliance* (Army and Air Force)**: Verification methods include analyses and tests. The following compliance instruments are applicable in addressing the standards:

a. Updated predictions of the vibration environment.
b. Component tests verifying analytical fatigue life predictions and which demonstrate that components meet service usage requirements in the vibration environment.
c. Ground and flight vibration tests which identify the response characteristics of the aircraft to forced vibrations and impulses.

Method of Compliance (**Navy)**: Verification methods include analyses, tests, and review of documentation. The following compliance instruments are applicable in addressing the standards: Analytical predictions of the vibration environment impact on service life updated by component tests, as well as ground and flight vibration tests which identify the vibratory response characteristics of the aircraft.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.6, A.4.6

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

MIL-STD-810

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5.2.9 Environment design - vents and louvers.

Criterion*:* Verify that equipment and structure behind and near vents and louvers are designed for the effects of flow through the vents and louvers during conditions of normal and reverse flows.

Standard*:* Airframe designed such that effects of FOD, thermal, sand abrasion, rain, ice, etc., are covered for one lifetime of the specified usage.

***Method of Compliance* (Army and Air Force)**: Verification methods include analyses, tests and review of documentation. The following compliance instruments are applicable in addressing the standards: Analytical predictions of the effects of gas temperatures and airflow environment through vents and louvers, updated by component tests.

***Method of Compliance* (Navy)**: Verification methods include analyses and ground tests.

Reference: JSSG-2006: A.3.3.8, A.4.3.8

5.3 Strength.

5.3.1 Static strength verification.

***Criterion* (Army and Air Force)**: Verify that sufficient static strength is provided to react to all design loading conditions without yielding and detrimental deformations (including delamination) at limit load, unless higher loads are specified, and without structural failure at ultimate loads. Verify that sufficient strength exists for operations, maintenance functions, occurrences of system failures, and any tests that simulate load conditions. This includes modifications, new or revised equipment installations, major repairs, extensive reworks, extensive refurbishment, or remanufacture.

***Criterion* (Navy)**: Verify that sufficient static strength is provided in the airframe, landing gear, rotor and control system structure to react all loading conditions without yielding, detrimental deformations (including delamination) or failures degrading the structural performance capability of the airframe. The air vehicle has sufficient strength for operations, maintenance functions (to include modifications, new or revised equipment installations, major repairs, extensive reworks, extensive refurbishment, or remanufacture), occurrences of systems failures, and any tests that simulate load conditions.

***Standard* (Army and Air Force)**:

a. Limit loads are obtained by multiplying Design Limit Load (DLL) by a factor of safety of 1.0.

b. Detrimental deformations, including delaminations, do not occur at or below 115 percent of limit loads and during the functional, strength and pressurization tests necessary for flight clearances. Temperature, load and other induced structural deformations/deflections resulting from any authorized use and maintenance of the air vehicle does not:

   (1) Inhibit or degrade the mechanical operation of the air vehicle or cause bindings or interferences in the control system or between the control surfaces and adjacent structures.

   (2) Affect the aerodynamic characteristics of the air vehicle to the extent that performance guarantees or flying qualities requirements cannot be met.

   (3) Result in detrimental deformation, delamination, detrimental buckling, or exceedance of the yield point of any part, component, or assembly which would result in subsequent maintenance actions.

   (4) Require repair or replacement of any part, component, or assembly.

   (5) Reduce the clearances between movable parts of the control system or rotor system and adjacent structures or equipment to values less than the minimum permitted for safe flight.

   (6) Result in significant changes to the distribution of external or internal loads without due consideration thereof.

c. Rupture or collapsing failures do not occur at or below Design Ultimate Loads (DUL).

   (1) Air vehicle is designed such that ultimate loads are obtained by multiplying the limit loads by a 1.5 DUL factor of safety.

   (2) In the case of crash conditions, the ultimate loads are obtained by applying the appropriate crash load factors sufficient to prevent injury to occupants and to maintain the integrity of egress paths.

d. Air vehicle is designed with a thermal load factor when thermal loads are significant.

***Standard* (Navy)**: The aircraft and all structural components are designed such that detrimental deformations, including delamination, in composite structure, do not occur at or below design limit load multiplied by the appropriate factors of safety for yield and ultimate strength. Air vehicles are designed to the defined load factor and have no limitations to preclude operation to the velocity-load factor and landing conditions specified. Yield and/or permanent deformation of metallic structure does not occur at or below 115 percent of design limit load; composite structure does not yield at or below 150 percent design limit load and failures do not occur at or below 150 percent of design limit load.

***Method of Compliance* (Army and Air Force)**: Validity of static strength is verified by analyses, tests and inspections. The following compliance paragraphs are applicable to all standards:

a. Validation information includes formal checked and approved internal loads and strength analysis reports. Analytical distributions on major components are correlated with test instrumentation measurements of stress and strain from static test and the structural strength analysis is updated.

b. Development and full scale laboratory load tests of instrumented elemental, component and full scale air vehicle verify the air vehicle structure static strength requirements. The applied test loads, including ultimate loads, simulate the loads resulting from critical operational and maintenance loading conditions. Environmental effects (such as temperatures, moisture, fuel immersion, chemicals, etc.) are simulated along with the load applications on air vehicle structure where operational environments impose significant effects.

(1) Element tests conducted with sufficient sample size to determine statistical compensated allowables.

(2) Component tests conducted with a smaller sample size to validate the analytical procedures and establish design allowables.

(3) Large component development tests of large assemblies conducted to verify the static strength capability of final or near final structural designs of critical areas.

(4) Static tests, including tests to design limit load yield and to design ultimate load, performed on the complete, full scale instrumented air vehicle to verify its limit and ultimate strength capability. Structural modifications have been incorporated into the test article. Ultimate load test conditions selected for substantiating the strength envelope for each component of the air vehicle. The testing to ultimate performed without environmental conditioning only if the design development test demonstrated that a critical failure mode is not introduced by the environmental conditioning.

***Method of Compliance* (Navy)**: Static strength is verified by analyses, tests and inspections. Verification methods include:

a. Review of internal loads and strength analyses.
b. Development and full scale laboratory tests of instrumented elemental, component and full scale test articles where the applied test loads, including ultimate loads, simulate the loads resulting from critical operational and maintenance loading conditions. Environmental effects (such as temperatures, moisture, fuel immersion, chemicals, etc.) are simulated along with the load applications on air vehicle structure where operational environments impose significant effects.
c. Element tests conducted with sufficient sample size to determine statistical compensated allowables.
d. Component tests conducted with a smaller sample size to validate the analytical procedures and establish design allowables.
e. Component development tests of large assemblies to verify the static strength capability of final or near-final structural designs of critical areas.
f. Static tests, including tests to design limit, yield and ultimate load, performed on the complete, full scale, instrumented air vehicle to verify its limit and ultimate strength capability. Structural modifications have been incorporated into the test article. Ultimate load test conditions selected for substantiating the strength envelope for each component of the air vehicle. The testing to ultimate load is performed without environmental conditioning only if the design development test demonstrated that a critical failure mode is not introduced by the environmental conditioning. Analytical strength models are correlated using load, stress and strains measurements from the instrumented static test and structural flight test aircraft.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.2.13; A.3.10.5, A.4.10.5; A.4.10.5.1; A.3.10.9, A.4.10.9; 3.10.10, A.4.10.10

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.3.2 Materials and processes.

***Criterion**:* Verify that the allowables for materials are estimated minima derived using statistical compensations appropriate to part criticality and the nature of the material; are established considering component and assembly variability, the expected environmental extremes, fabrication processes, repair techniques, and quality assurance procedures; and are validated. Verify that conditions and properties associated with material repairs satisfy design requirements.

***Standard**:* Materials and processes are selected in accordance with the following requirements so that the air vehicle structure meets the operational and support requirements.

a. Relevant producibility, maintainability, supportability, repairability, and availability experience with the same, or similar, materials processes are a governing factor for suitability of the air vehicle structure design. Material systems and materials processes selected for design are stable, remain fixed, and minimize unique maintenance and repair practices in accordance with the specified operational and support concepts.

b. Material systems and materials processes (including radioactive materials and processes) are environmentally compliant, compliant with best occupational safety and health practices, and minimize hazardous waste generation.

c. The processes and joining methods do not contribute to unacceptable degradation of the properties of the materials when the air vehicle structure is exposed to operational usage and support environments. Whenever materials are proposed for which only a limited amount of data is available, the acquisition activity is provided with sufficient background data so that a determination of the suitability of the material can be made. The allowable structural properties include all applicable statistical variability and environmental effects, such as exposure to climatic conditions of moisture and temperature; exposure to corrosive and corrosion causing environments; airborne or spilled chemical warfare agents; and maintenance induced environments commensurate with the usage of the air vehicle. Specific material requirements are:

    (1) "A" basis design allowables are used in the design of all critical parts. "A" basis design allowables are also used in the design of structure not tested to ultimate load in dynamic component or full scale air vehicle static testing. "B" basis design allowables can be used for all other structure.

    (2) "S" basis design allowables are acceptable for design when "A" or "B" basis allowables are not available, provided they are specified in a governing industry/government document that contains quality assurance provisions at the heat, lot, and batch level in the as-received material condition. Appropriate test coupons accompany the material in the as received condition and the material is subject to testing for verification of minimum design properties after final processing.

The guidance contained in MIL-STD-1568, MIL-HDBK-1587, as well as CMH-17, ADS-13 and MMPDS-08 serves as the baseline approach for addressing materials/processes and corrosion requirements and is deviated from only with appropriate supporting engineering justification. The aforementioned documents provide extensive guidance/lessons learned for materials processes selection and application.

***Method of Compliance**:* Inspections, analyses, and tests verify that the materials and processes selected are in compliance with requirements. The following compliance section is applicable to all standards.

Standardized test methods used to establish metallic and composite material systems properties are used. When such standardized methods (e.g., MIL-STD-1568, MIL-HDBK-1587, as well as CMH-17, ADS-13 and MMPDS-08) are not available, a program was undertaken to explore and develop standardized test methods. All test methods used in establishing material system performance is documented. The following requirements also apply:

a. Materials and processes development and characterization and the selection process are documented. Second source materials (when established as a program requirement) are qualified and demonstrated through testing to have equivalent performance and fabrication characteristics as the selected baseline material.
b. Environmentally conditioned tests are performed at the appropriate development test level to meet relevant design conditions.
c. Materials and processes characteristics for critical parts comply with the requirements of parts control processes.
d. Environmental compliance with all applicable environmental statutes and laws for all materials systems and processes selected is verified. This includes life cycle management of hazardous materials.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.2.19, A.4.2.19; A.3.2.19.1; A.3.2.19.2, A.4.2.19.2

(Army rotary wing) ADS-13, ADS-29 (cancelled)

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

MIL-STD-1568

MIL-HDBK-1587

CMH-17

MMPDS-08

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5.3.3 Stress and strain design controls.

Criterion: Verify that stresses and strains in structural members are controlled through proper sizing, detail design, and materials selection. Verify that for all limit, design (including the Navy design landing condition, where applicable), and ultimate loads are reacted resulting in zero or positive margins of safety for all configurations within allowable operating conditions (including probable failure and defined emergency conditions).

***Standard* (Army and Air Force)**:

a. All structure is designed to nominal dimensional values or 110 percent of minimum values, whichever is less (for Navy, see JSSG-2006 and specific rotary wing AVPS addenda).
b. The determination of margins of safety is based on the smaller of the design or procurement specification allowable.
c. Thermal stresses and strains are determined for structures that experience significant heating or cooling whenever expansion or contraction limited by external or internal constraints. Thermal stresses and strains are combined with concurrent stresses produced by other load sources in a conservative manner.
d. In laminated composites, the stresses and ply orientation are compatible and residual

stresses of manufacturing are accounted for, particularly if the stacking sequence is not symmetrical.

e. For each fitting and attachment whose strengths are not proven by limit and ultimate load tests in which actual stress conditions are simulated in the fitting and surrounding structure, the design stress values are increased in magnitude by multiplying these loads or stress values by a fitting factor. The fitting factor is 1.15 (for Navy, see JSSG-2006 and specific rotary wing AVPS addenda) for all bolted and welded joints and for structure immediately adjacent to the joints. A fitting factor does not have to be used for continuous lines of rivets installed in sheet-metal joints.

f. The design stress values for bolted joints with clearance (free fit) that are subjected to relative rotation under limit load or shock and vibration loads, are increased in magnitude by multiplying by a 2.0 bearing factor times the stress values (for Navy, see JSSG-2006 and specific rotary wing AVPS addenda). This bearing factor does not have to be multiplied by the fitting factor.

g. Structural doors and panels as well as access doors and components with one or more quick-opening latches or fasteners do not fail, open, vibrate, flap or flutter in flight. The most critical combinations of latches or fasteners are designed for left unsecure.

h. Castings are classified and inspected, and all castings conform to applicable process requirements. A casting factor of 1.33 is used (for Army, see ADS-13 and ADS-29 (cancelled); for Navy, see JSSG-2006 and specific rotary wing AVPS addenda). The factors, tests and inspections of this section are applied in addition to those necessary to establish foundry quality control. The use of castings or C/Hipped parts for primary or critical applications and/or castings with a casting factor less than 1.33 (for Army, see ADS-13 and ADS-29 (cancelled); for Navy, see JSSG-2006 and specific rotary wing AVPS addenda), have successfully completed a developmental and qualification program. These castings meet the analytical requirements without a casting factor and meet the service life requirements for both crack initiation and crack growth for flaws representative of the casting and manufacturing process.

i. Due to the nature of some structural designs or materials, high variability may be encountered around the nominal design. Such design features have a minimum level of structural integrity at the acceptable extremes of dimensions, tolerances, material properties, processing windows, processing controls, end or edge fixities, eccentricities, fastener flexibility, fit up stresses, environments, manufacturing processes, etc. In addition to meeting the standard strength requirements, the structure has no detrimental deformation of the maximum once per lifetime load and no structural failure at 125 percent of design limit load (for Navy, see JSSG-2006 and specific rotary wing AVPS addenda) for the critical combinations of the acceptable extremes.

j. (Army) The allowable stresses used in the design do not exceed those applicable to the grain directions resulting from fabrication. So far as practical, structural members are designed such that the directions of the critical stresses are favorably related to the directions of the grain resulting from forging, rolling, extruding, and other fabrication processes. Minimization or elimination of residual stress effects are a primary design concern.

Standard **(Navy)**: Stresses and strains in the aircraft and its components resulting from the application of design, limit and ultimate loads are defined and static margins of safety support the intended use of the air vehicle. Environmental factors are considered. Appropriate factors (e.g., fitting, bearing, and casting factors) are applied to address uncertainties that exist in regard to stress distributions within components. The designs of attachments for components, doors, panels, ramp are fail-safe and do not fail, open, vibrate, flap or flutter in flight in normal operation or with critical combinations of latches or fasteners unsecured. The allowable stresses used in the design do not exceed those applicable to the grain directions resulting from fabrication. Structural members are designed such that the directions of the critical stresses are favorably related to the directions of the grain resulting from forging, rolling, extruding, and other fabrication processes. NOTE: Minimization or elimination of residual stress effects are a primary design concern.

***Method of Compliance* (Army and Air Force)**:

a. Validity of internal loads, stresses and strains are verified by inspections, analyses, and tests. This compliance paragraph is applicable to all standards. Validation information includes formal checked and approved internal loads and strength analysis reports. Analytical distributions on major components are correlated with measurements of stress and strain obtained from development and static tests and the analysis is updated.

   Additional compliance requirements apply for castings (see 5.3.3.8) and high variability structure (see 5.3.3.9).

b. All castings are shown to satisfy the casting factor requirements by analysis. Critical castings, castings used in primary structure, or castings with a casting factor less than 1.33 meet the following (for Army, see ADS-13 and ADS-29 (cancelled)):

   (1) Receive 100 percent inspection by visual and magnetic particle or penetrant or approved equivalent non-destructive inspection methods.

   (2) Three sample castings from different lots are static tested and shown to not have experienced detrimental deformation at or below 115 percent of design limit load and no rupture or collapse failures at or below a load of the casting factor times the ultimate load. After successful completion of these tests, a casting factor of greater than 1.00 does not have to be demonstrated during the full scale static test.

   (3) The castings are procured to a specification that guarantees the mechanical properties of the material in the casting and provides for demonstration of these properties by test coupons cut from cut-up castings on a sampling basis and from test tabs on each casting.

c. High variability structure is shown to satisfy the requirements by analyses. These analyses are conducted considering critical combinations of the acceptable extremes including critical ranges of dimensions, thicknesses, fastener flexibilities, tolerance buildups, eccentricities, end fixities and minimum material allowables.

d. (Army applicable) to demonstrate compliance with item j of the standard, component/element stress analysis is performed and compared to directional material allowables in compliance with the criterion in 5.3.2. Destructive tests and inspections are performed as necessary to verify grain direction and residual stresses resulting from fabrication.

***Method of Compliance* (Navy)**: Validity of internal loads, stresses and strain is verified by analyses, component and full scale ground tests of NDI, and measured data from ground and flight test air vehicles. Component/element stress analyses are correlated to directional material allowables. Destructive tests and inspections are performed as necessary to verify grain directions and residual stresses from fabrication (see JSSG-2006: 3.10, 4.10; A.3.10, A.4.10).

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.7, A.3.1.1, A.3.10.4, A.3.10.4.1 though A.3.10.4.4, A.3.10.5, A.3.10.6 and A.4.3.1.1, A.4.10.4, A.4.10.4.1, through A.4.10.4.4, A.4.10.5, A.4.10.6, A.4.7

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.4 Damage tolerance and durability (fatigue).

Damage tolerance is a means for preventing catastrophic structural failure or loss of control of the aircraft after a predefined limit of structural damage has occurred as a result of, but not limited to, low energy impact, in-service damage, loads environment, inherent materials defects, sub-critical cracks, manufacturing defects, repeated loads application, and ballistic damage.

5.4.1 Damage tolerance.

***Criterion* (Army and Air Force)**: Verify that all safety-of-flight (SOF) structure, including dynamic components, have adequate safe life or damage tolerance capability (depending on certification authority) for the required service life.

***Criterion* (Navy)**: Verify that all SOF aircraft structure(s), including dynamic components, have sufficient damage tolerance and/or safe life capability for the required service life. Damage tolerance is in addition to, rather than in lieu of, provisions for adequate structural fatigue life, flaw tolerance and fail safe characteristics. NOTE: Methodologies and criteria may differ between the services, and agencies and reference to the appropriate Services/Agency reference documents is required.

***Standard* (Army and Air Force)**: Slow damage growth or fail-safe design concepts are allowed. For special applications, a safe-life design methodology may be utilized.

a. Slow damage growth design concepts: The initial flaws presumed to exist in the structure (defined below) do not grow to a critical size and cause failure of the structure due to the application of the maximum internal member load in two lifetimes of the service life and usage. Average crack growth data (da/dN) are used if the variation of crack growth data is a typical distribution. Minimum values of fracture toughness are used in the damage tolerance analysis.

   (1) At holes and cutouts, the assumed initial flaw is a 0.05 inch through the thickness flaw at one side of the hole when the material thickness is equal to or less than 0.05 inch. For material thicknesses greater than 0.05 inch, the assumed initial flaw is a 0.05 inch radius corner flaw at one side of the hole.

   (2) At locations other than holes, the assumed initial flaw is through the thickness flaw of 0.25 inch length when the material thickness is equal to or less than 0.125 inch. For material thicknesses greater than 0.125 inch, the assumed initial flaw is a semicircular surface flaw with a length equal to 0.25 inch and a depth equal to 0.125 inch. Other possible surface flaw shapes with the same initial stress intensity factor can be considered as appropriate; e.g., corner flaws at edges of structural elements and longer and shallower surface flaws in plates which are subjected to high bending stresses.

   (3) For welded structure, flaws are assumed in both the weld and the heat affected zone in the parent material.

   (4) For embedded defects, the initial flaw size assumption is based on an assessment of the capability of the non-destructive inspections procedure.

   (5) The use of castings in SOF applications is discouraged. The assumed initial flaw sizes for proposed applications take into consideration the defect frequency and size distribution from all sources, to include shell inclusions and hard alpha

contaminations.

(6) For composite structures:

(a) Surface scratch 4.0 inches long and 0.02 inch deep.

(b) Interply delamination equivalent to a 2.0 inches diameter circle with dimensions most critical to its location.

(c) Damage from a 1.0 inch diameter hemispherical impactor with 100 ft-lbs of kinetic energy or with that kinetic energy required to cause a dent 0.10 inch deep, whichever is less.

(d) No significant growth resulting from manufacturing defects or high energy impact damages in two service lifetimes of usage.

(7) For special applications, the safe life design methodology may be used for approved structural components (e.g., landing gear components and rotorcraft dynamic components). Damage tolerance evaluations are conducted for all safe life designed components. These evaluations define critical areas, fracture characteristics, stress spectra, maximum probable initial material and/or manufacturing defect sizes, and options for either eliminating defective components or otherwise mitigating threats to structural safety. Such options may include design features, manufacturing processes, or inspections. Additionally, the damage tolerance evaluation establishes the individual aircraft tracking requirements so that the safe life component replacement times and any scheduled safety inspections can be adjusted based on actual usage. For individual tracking of Army rotorcraft see ADS 79-HDBK.

b. Fail-safe design concepts: Catastrophic failure or deformation which could adversely affect flight characteristics of the aircraft, will not occur after a load path failure (fail-safe multiple load path) or partial failure (fail-safe crack arrest) where rapid propagation is arrested due to damage containment features in the design, up to the fail-safe life limit (FSLL). The failure or partial failure is either readily detectable or malfunction evident. At the time of, and at any time subsequent to the failure or partial failure of the load path, the remaining structure is able to sustain limit loads without failure and be free of any effects (e.g., flutter) due to reduced stiffness until the structure is repaired, replaced or modified. For composites, bonded structure is capable of sustaining the residual strength loads without a safety of flight failure with a complete bond line failure or disbond.

c. The loads and environment spectra represent the service life and usage adjusted for historical data, potential weight growth, and future aircraft performance at least to initial operation capability (IOC). The spectra also reflect baseline utilization within the design utilization distribution and are such that the average aircraft usage of the fleet will be expected to meet the service life.

d. For rotorcraft, adequate safe life for dynamic components is accomplished by following the guidance of AMCP 706-201, Chapter 4 and 7-6 of ADS-51-HDBK. The goal of the design, qualification, and maintenance and operations phases is to produce and maintain a rotorcraft system level reliability that results in less than one (1) catastrophic failure due to component fatigue in the service life of the aircraft fleet. The safe life fatigue methodology shown below is used to establish the design life and maintenance procedures for Flight Safety Parts (FSPs) in a helicopter dynamic system.

(1) The design usage spectrum is based on worse case fleet usage to ensure that the aircraft with the worse usage will meet the established service life. The usage spectrum is updated as the mission of the aircraft changes.

(2) Flight loads are established by flight load surveys of an instrumented aircraft where

loads are generated for each regime of the usage spectrum. Replicate load conditions are performed for critical regimes or the loads generated are from rigorous flight such that they will be infrequently exceeded in service. Top of scatter loads (or highest loads in the regime) are used in damage fraction calculations.

(3) Component fatigue strength is established by laboratory testing of at least six (6) production specimens to failure. The fatigue design curve (working curve) and safe life are established using an approved fatigue methodology report (typically a mean minus three (3) sigma working curve).

(4) Fatigue retirement lives for dynamic components are established based on the design usage spectrum (or updated usage spectrum) and the loads and strength data obtained during flight and laboratory testing. Sufficient conservatisms, such as prohibiting dynamic component fatigue damage during a sustained condition (e.g., level flight), are incorporated into the calculations to achieve the desired system reliability.

(5) Maintenance and overhaul repair limits and processes are limited to minimizing the impact that repairable damage could have on the component fatigue strength and resulting safe life.

e. For rotorcraft, the primary structure incorporates materials, stress levels, and structural configurations that will minimize the probability of loss of the aircraft due to damage of a single structural element (including control system or dynamic components), or due to propagation of undetected flaws, cracks, or other damage. Slow damage growth, crack arrestment, alternate load paths and systems, and other available design principles are used to achieve this capability. Airframe structure is qualified by either safe life or damage tolerance methodologies which have been approved by the procuring activity. Redundant rotorcraft airframe safe lives are based on either analysis or test with a life scatter factor of four (4). Rotorcraft airframe fatigue damage during a sustained condition (e.g., level flight) is not allowed.

***Standard* (Navy)**: For Navy rotary wing aircraft, the guidance provided in d.(4) above applies. Standards applicable to individual rotary wing aircraft are defined in the specific AVPS structural addenda. Design for damage tolerance is applied to metallic and composite structure and addresses damage applicable to each type of material/component throughout their life cycle, with the exception of landing gear. In metallic structure, crack growth under sustained and repeated loads does not occur at a rate where cracks would reach critical size at the residual strength load within one lifetime. In composite structure, non-visible damage does not require inspections or repair. In fail-safe structure, damage tolerance is satisfied by the secondary member consistent with dynamic loading and fail-safe requirements. Composite rotor and control system, and drive system components have the capability to operate with a readily detectable crack, delamination, or flaw from the point of reliable crack, flaw detection to critical size, which is defined as limit load capability or loss of function/dynamic capability or unacceptable deformation for a minimum of three phase inspections. The minimum requirement is to provide this capability with the non-destructive inspection methods presently available within the maintenance plan for the aircraft. Limits for design and analysis purposes are established by each service and agency as applicable to its individual methodologies and standards. For Force Management and Individual aircraft and component tracking see 4.15 of JSSG-2006, and specific rotary wing AVPS Addendum.

***Method of Compliance* (Army and Air Force)**: Verification methods include analysis, test, and inspection of documentation.

a. Analyses and tests are performed to verify that the airframe structure meets the damage tolerance requirements. Damage tolerance and residual strength analyses are conducted for each critical location of every safety of flight component. The analysis assumes the presence of flaws in the most unfavorable location and orientation with respect to the applied stresses and material properties. The analysis demonstrates that cracks growing from the presumed flaw sizes do not result in sustained crack growth under the maximum flight and ground loads for a minimum of two service lifetimes. Compliance with damage tolerance requirements are obtained without considering the beneficial effects of specific joint design and manufacturing processes such as interference fit fasteners, cold-expanded holes and joint clamp-up.

Damage tolerance testing of a complete airframe is conducted to demonstrate compliance with requirements which satisfies the following:

(1) The test airframe or components are structurally identical to the operational airframe as production practicalities will permit. Any differences, including material or manufacturing process changes, are assessed for impact. The assessment includes additional component testing if the changes are significant. When changes are not significant and additional testing cannot be accomplished, the re-design, repair, or modification is designed to three (3) lifetimes of the service life and usage. The test article includes artificially induced damage by the techniques developed in development testing. The sharp fatigue cracks introduced are of the appropriate size and shape consistent with the initial flaw size assumptions for the component.

(2) The duration of the tests is sufficient to verify crack growth rate predictions. The test duration is a minimum of one lifetime unless sufficient information is derived in a shorter period.

(3) The test is subjected to the design flight-by-flight loads spectra. Truncation, elimination, or substitution of load cycles is allowed subject to approval by the acquisition activity.

(4) Major inspections are performed as an integral part of the damage tolerance testing. Proposed in-service inspection techniques will be evaluated during the tests. Surface crack length measurements are recorded during the tests. The end-of-test inspection includes a structural teardown, removal of cracked areas, and fractographic analysis of all significant fracture surfaces.

b. Flight-by-flight damage tolerance stress spectra and chemical and thermal environment spectra are developed and spectra interaction effects are accounted for.

c. For rotorcraft, fatigue and damage tolerance methodologies and a composite worst case usage spectrum are established and documented for the platform. Fatigue reliability is appropriately considered within the fatigue methodology to avoid airworthiness impacts (specifically, the methodology includes appropriate considerations of strength, loads, and usage variability). Flight load survey testing is performed for each regime in the usage spectrum.

(1) For safe-life components, fatigue strength curve shapes and coefficients of variation are established in the fatigue methodology based on historical testing of similar components or based on coupon testing with appropriate adjustments due to full-scale component size and fabrication/design details. Component fatigue laboratory testing is performed to establish endurance limits with appropriate confidence, typically using identical instrumentation as used in the flight load survey testing. Fatigue substantiation analysis is performed in accordance with the applicable platform fatigue methodology based on flight and laboratory test data.

(2) For all rotorcraft dynamic components and airframe elements, materials are selected

after considering damage tolerance properties. For components and airframe elements with structural integrity ensured by inspections based on damage tolerance methodologies, component/element spectrum testing is performed to establish damage growth rates. The approved damage tolerance methodology may also identify areas where the procuring activity has approved use of damage growth analysis in place of testing. Inspection intervals are based on damage growth and demonstrated (and representative) inspection probability of detection.

Method of Compliance **(Navy)**: For Navy rotary wing aircraft, the guidance provided in paragraph (3) applies. Standards applicable to individual rotary wing aircraft are defined in the specific AVPS structural addenda. Verification methods include analysis, component and full-scale ground test, and inspection; followed by structural teardown, removal of cracked areas and fractographic analysis where appropriate, and flight loads survey testing. Compliance assumes that the benefits of specific joint design and manufacturing processes (e.g., interference fit fasteners, cold-expanded holes and joint clamp-up) are not considered. Tests are performed on structure and components that are structurally identical to the operational air vehicle, limited only by production practicalities. Test requirements are established by each service and agency as applicable to its individual methodologies and standards.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.12, A.4.12; 4.15; A.4.15
EN-SB-08-001
(Army rotary wing) ADS-79-HDBK, AMCP 706-201, ADS-51-HDBK
(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222
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5.4.2 Durability.

Criterion **(Army and Air Force)**: Verify that the air vehicle structure has sufficient durability to preclude adverse effects on safety, economic, operational, maintenance, repair, and modification costs throughout its intended service life. Durability includes crack initiation, crack growth, fatigue and safe life.

Criterion (**Navy)**: Verify that the airframe structure has sufficient durability to resist cracking, corrosion, thermal and acoustic degradation, delamination and wear to preclude adverse effects on safety, economic, operational, maintenance, repair, or modification cost throughout its intended service life.

Standard **(Army and Air Force)**:

a. The air vehicle structure is free of cracking, delaminations, disbonds, deformations, or defects which require repair, replacement, inspection to maintain structural integrity, cause interference with the mechanical operation of the aircraft, affect the aircraft aerodynamic characteristics, cause functional impairment, result in sustained growth of cracks/delaminations resulting from steady-state level flight or ground handling conditions, result in water intrusion, or result in visible damage from a single 6 ft-lb impact for one lifetime of service usage.
   (1) Typical manufacturing initial quality flaws presumed to exist in the structure do not reach functional impairment in two lifetimes of the service life and usage.
   (2) The design of the airframe is such that there is sufficient aeroacoustic durability. An uncertainty factor of +3.5dB is applied on the predicted aeroacoustic sound pressure levels and a factor of 2.0 is applied on the exposure time derived from the service usage.

(3) Structural components which are subjected to wear under normal operating conditions are designed to withstand the environment and minimize the number of scheduled inspections throughout the service life.

(4) Corrosion prevention systems are effective for minimizing corrosion damage and repair, and do not degrade fatigue allowables, to include crack initiation, and are effective at maintaining the validity of the fatigue allowables throughout the service life.

(5) The thermal protection systems are designed to be effective for minimum periods of service usage.

(6) The design, manufacture, inspection, use, and maintenance (including repair) of coatings, films, and layers is a fully integrated effort and will not degrade the structural integrity of the airframe.

(7) Durability criteria are established to ensure that the onset of widespread fatigue damage will not occur during the design service life.

b. The loads and environment spectra represent the service life and usage defined for the aircraft adjusted for historical data, potential weight growth, and future aircraft performance at least to initial operation capability (IOC), to reflect severe utilization within the design utilization distribution such that 90 percent (95 percent for all fatigue damaging conditions for rotorcraft) of the fleet will be expected to meet the service life.

(1) Rotorcraft dynamic components are designed with consideration of maneuver to maneuver load cycles, centrifugal (CF) loads due to rotor start and stop cycles, and torsional loads due to rotor braking cycles.

(2) Rotorcraft dynamic components are designed to avoid level flight fatigue damage. Envelope air speed restrictions based on density altitude and gross weight may be required to avoid retreating blade stall or advancing blade compressibility effects in level flight or sustained low angle of bank steady state maneuver.

c. For rotorcraft, the objectives and requirements for design service life, cost, reparability, readiness and growth potential are identified in the performance specification for the rotorcraft system. Meeting these requirements has a direct impact on airframe durability as follows:

(1) The airworthiness qualification of the rotorcraft airframe includes both static strength and fatigue considerations to maintain structural capability during service, which directly impacts safety.

(2) Reliable and robust design minimizes down time due to unscheduled maintenance and enhances operational readiness. Repair and replacement parts are available when needed.

(3) Maintenance is minimized by robust design including an active corrosion prevention program to account for environmental conditions with few special inspections.

(4) Design and qualification of the airframe considers the structural impact of both depot level and field repairs.

(5) Rotorcraft airframes have repeatedly demonstrated the inherent capability for growth potential due to increased weight or airframe life extension with acceptable impact on modification cost.

(6) Durability capability of airframe has positive effect on life cycle cost of ownership.

***Standard* (Navy)**: Aircraft structure, including rotor, control and drive system components, is free of cracking; delaminations; disbonds; interferences; deformations or defects requiring repair; replacement; inspections; and functional impairments resulting from growth of cracks or delaminations during steady-state level flight, ground handling and dynamic loading conditions or from acoustic sources. Components subject to wear and corrosion under normal operating conditions withstand the environments, including foreign object impact, and minimize the number of scheduled inspections throughout their service life. NOTE**:** The objectives and requirements for design service life, cost, reparability, readiness and growth potential are identified in the performance specification for the respective air vehicle system.

Method of Compliance **(Army and Air Force)**: Verification methods include analysis, test, demonstration and inspection of documentation.

a. Durability analyses and tests are performed to verify that the airframe structure meets the durability requirements. A full scale airframe is durability tested to show that the structure meets the required service life which satisfies the following:

   (1) The airframe is as close to structurally identical to the operational airframe, as practices allow. Significant differences require additional tests. When changes are not significant and additional testing cannot be accomplished, the re-design, repair, or modification is designed to three (3) lifetimes of the service life and usage.

   (2) Two (2) lifetimes of testing plus the indicated inspections verify adequate durability.

   (3) Test anomalies which occur within the duration of the test are evaluated for production and retrofit modifications. Test anomaly analysis is correlated to test results and adjusted results are shown to meet the durability requirements. Modifications are also shown to satisfy durability and damage tolerance requirements by either test or analysis at the discretion of the acquisition activity.

   (4) The test is subjected to the design flight-by-flight loads spectra. Truncation, elimination, or substitution of load cycles is allowed subject to approval by the acquisition activity.

   (5) Inspections are performed as an integral part of the durability tests and at the completion of testing and include design inspections, special inspections, and post-test teardown inspections.

   (6) A minimum of two (2) lifetimes of durability testing is required to certify the airframe structure. A third lifetime testing is performed to support damage tolerance, repairs and modifications, usage changes, and life extension potential.

   (7) Durability testing demonstrates that the onset of widespread fatigue damage will not occur during the design service life.

b. A flight-by-flight durability stress spectra and chemical and thermal environment spectra is developed and spectra interaction effects are accounted for.

c. For rotorcraft, a fatigue methodology and composite worst case usage spectrum are established and documented for the platform, including consideration of maneuvering loads, maneuver to maneuver load cycles, centrifugal (CF) loads due to rotor start and stop cycles, and torsional loads due to rotor braking cycles. Fatigue reliability is appropriately considered within the fatigue methodology to avoid airworthiness impacts (specifically, the methodology includes appropriate considerations of strength, loads, and usage variability). In addition to expanding the load factor, aeromechanical, or aero-elastic stability limitations, envelope expansion flight testing establishes airspeed, gross weight, center of gravity, and density altitude restrictions for each configuration to avoid level flight fatigue damage. Flight load survey testing is performed for each regime in the usage spectrum. For safe-life components, fatigue strength curve shapes and coefficients of variation are established in the fatigue methodology based on historical testing of similar components or based on coupon testing with appropriate adjustments due to full-scale component size and fabrication/design details. Component fatigue laboratory testing is performed to establish endurance limits with appropriate confidence, typically using identical instrumentation as used in the flight load survey testing. Fatigue substantiation analysis is performed in accordance with the applicable platform fatigue methodology based on flight and laboratory test data.

***Method of Compliance* (Navy)**: Verification methods include analysis, test, demonstrations and inspections. Testing typically includes component and airframe fatigue testing. Inspections are performed as an integral part of the durability tests, and at the completion of testing these include design inspections, special inspections, and post-test teardown inspections. Testing addresses the flight-by-flight durability stress spectra, chemical and thermal environment spectra and spectra interaction effects. Flight testing is performed to characterize critical maneuver spectra and provide data, using flight test instrumentation that replicates or correlates with that used on the ground test articles.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.11, A.4.11

ADS-24 (cancelled)

ADS-51-HDBK

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.4.3 Durability and damage tolerance control processes.

***Criterion**:* Verify that a durability and damage tolerance control process is established and implemented in the engineering design and manufacturing process.

***Standard* (Army and Air Force)**:

a. The durability and damage tolerance control process is established to ensure that maintenance and fatigue/fracture critical parts meet the durability and damage tolerance requirements.
b. For Army rotorcraft life cycle control of Flight Safety Parts (FSPs) fatigue strength is accomplished by following the guidance of AMCOMR 702-7.

***Standard* (Navy)**: The durability and damage tolerance control process ensures that maintenance and fatigue/fracture critical parts meet durability and damage tolerance requirements. Navy Flight Safety Flight Parts control follows requirements defined in NAVAIRINST 4200.56.

***Method of Compliance* (Army and Air Force)**: Verification methods include analysis, test, demonstration and inspection of documentation.

a. The durability and damage tolerance control process is properly documented and implemented with the following tasks:
   (1) A disciplined procedure for durability design is implemented to minimize the possibility of incorporating adverse residual stresses, local design details, materials, processing, and fabrication practices.
   (2) Basic data (i.e., initial quality distribution, fatigue allowables, fracture toughness (KIC (plane strain fracture toughness), KC (plane stress fracture toughness), KISCC (stress corrosion cracking), da/dn (crack growth rate), etc.)) utilized in the initial trade studies and the final design and analyses are obtained from reliable sources or developed as parts of the program.
   (3) Criteria for identifying and tracing fatigue/fracture critical parts are established and

are approved by the procuring agency. A fatigue/fracture critical parts list is established by the contractor and is kept current as the design of the airframe progresses.

(4) Design drawings for the maintenance critical parts and fatigue/fracture critical parts identify critical locations, special processing (e.g., shot peening), and inspection requirements.

(5) Material procurement and manufacturing process specifications is developed and updated as necessary to ensure that initial quality and fracture toughness properties of the critical parts exceed the design value.

(6) Experimental determination sufficient to estimate initial quality by microscopic or fractographic examination is performed for those structural areas where cracks occur during full scale durability testing.

(7) Complete nondestructive inspection requirements, process control requirements, and quality control requirements for maintenance, fatigue/fracture critical parts is established and approved by the procuring agency. This task includes the plan for certifying and monitoring subcontractor, vendor, and supplier controls.

(8) The durability and damage tolerance control process includes any special nondestructive inspection demonstration programs conducted to satisfy the durability and/or damage tolerance requirements.

(9) Traceability requirements are defined and imposed on those fatigue and fracture critical parts that receive processing and fabrication operations which could degrade the design material properties.

(10) For all fracture critical parts that are designed for a degree of inspectability other than in-service non-inspectable, the necessary inspection procedures are defined for field use for each appropriate degree of inspectability.

b. For Army rotorcraft, life cycle control of FSPs fatigue strength is accomplished as follows:

(1) A disciplined procedure for fatigue design is implemented to minimize the possibility of incorporating adverse residual stresses, with specific attention to local design detail, materials, processing and fabrication practices. The design considers a potential reduction in beneficial residual stresses for metal components and creation of defects in composite components due to the application of limit load.

(2) While analytical predictions of component fatigue strength are utilized in the early design phase, fatigue testing of a minimum of two representative flight components is to be performed to establish fatigue strength prior to first test flight. For fielding, the fatigue strength curve is established by testing six (6) production components. The fatigue design curve (working curve) is established utilizing an approved fatigue methodology report.

(3) FSPs are identified and controlled for the life cycle of the component. The engineering drawing identifies the component as an FSP and clearly identifies critical characteristics. The drawing specifies the inspection requirements for FSPs. The criteria for identifying and tracking FSPs is established and an FSP part list is developed and kept current for the life cycle of the aircraft.

(4) Manufacturing planning is developed for all FSPs. Parts manufactured utilizing these plans meet all necessary requirements. The manufacturing plan is frozen once the design is qualified. All changes to the frozen manufacturing plan pertaining to critical characteristics require approval by the procuring agency.

(5) Experimental determination, sufficient to estimate initial component quality, by

microscopic or fractographic examination is performed for FSPs where cracks occur during fatigue testing.

(6) Maintenance and Overhaul (M&O) planning is developed for all FSPs. Each M&O process affecting an FSP critical characteristic as identified in the Depot Maintenance Work Requirement (DMWR) or other authorized M&O procedure is qualified to substantiate that there is no reduction in performance of the FSP. Changes to frozen M&O planning pertaining to critical characteristics require approval by the procuring agency.

(7) New component procurement and M&O procedures utilize manufacturing sources approved by the procuring agency.

***Method of Compliance* (Navy)**: Method of Compliance is in general agreement with that specified above. Specific compliance requirements are defined in JSSG-2006 and applicable rotary wing AVPS structures addenda. Verification methods include analysis, test, demonstration and inspection of documentation to verify that control process is established and implemented in accordance with the requirements of NAVAIRINST 4200.56.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.13, A.4.13

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62, AMCOMR 702-7

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

NAVAIRINST 4200.56

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5.4.4 Corrosion prevention and control.

Criterion*:* Verify that corrosion prevention systems remain effective during the service life. Specific corrosion prevention and control measures, procedures, and processes are identified and established commensurate with the operational and maintenance capability required of the air vehicle structure.

Standard*:* Corrosion prevention and control process is satisfactorily established to maintain structural integrity for the operational and maintenance capabilities throughout the service life of the air vehicle structure. A Corrosion Prevention and Control Plan (CPCP) is established. The CPCP charters a Corrosion Prevention Advisory Team (CPAT) and the Contractor Corrosion Team (CCT) to describe and establish the corrosion resistant design of the system.

Method of Compliance*:* Verification methods include analysis, test, demonstration and inspection of documentation. Corrosion prevention and control measures are established and implemented via implementation of the CPCP and CPAT.

a. The criteria for the selection of corrosion resistant materials and their subsequent treatments are defined. The specific corrosion control and prevention measures are defined and established as an integral part of airframe structures design, manufacturing, test, and usage and support activities.

b. Organic and inorganic coatings for all airframe structural components and parts, and their associated selection criteria are defined.

c. Procedures for requiring drawings to be reviewed by and signed off by materials and processes personnel are defined.

d. Finishes for the airframe are defined. General guidelines are included for selection of finishes in addition to identifying finishes for specific parts, such that the intended finish for any structural area is identified (see also MIL-STD-7179).

e. The organizational structure, personnel, and procedures for accomplishing these tasks are defined and established.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.11.2, A.4.11.2

(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

MIL-STD-1568

MIL-STD-7179

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

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5.5 Mass properties.

5.5.1 Evaluation of mass properties.

***Criterion**:* Verify that the mass properties fully support safe vehicle operations for all defined mission requirements, variation in useful load, basing/deployment concepts, interfaces, and necessary maintenance.

***Standard**:*

a. The mass properties used in verifying compliance with defined mission requirements and conducting the design, analysis, and test of the air vehicle are derived combinations of the operating weights, the defined payload, and the fuel configuration.
b. The mass properties reflect the current configuration of the air vehicle.

***Method of Compliance**:*

a. The mass properties (weights and center of gravities) are verified by inspections, analyses, and actual vehicle weighing. Pieces and parts are verified by calculation as drawings are released and actual weighing when parts are available. A detailed breakout list of components by function is maintained in accordance with Society of Allied Weight Engineers (SAWE) Recommended Practice (RP) 8. Each vehicle is weighed in a completely assembled and dry condition and the data assembled and reported as an Actual Weight Report in accordance with SAWE RP7 and delivered in accordance with DI-MGMT-81501, Weight and Balance Report for Aircraft. Estimates at program PDR and Calculations at program CDR of the Air Vehicle Mass Properties are verified and assembled into reports in accordance with SAWE RP7 and delivered in accordance with DI-MGMT-81501 (Estimated and Calculated Weight and Balance Report). Periodic Status changes are tracked, assembled, and reported in accordance with SAWE RP7 and delivered in accordance with DI-MGMT-81501 (Status Report).
b. The Mass Properties are verified to reflect the current configuration of the air vehicle and comply with defined mission requirements through the master plan for controlling and managing Mass Properties in accordance with SAWE RP7 and delivered in accordance with DI-MGMT-81452. The Mass Properties Control and Management Process (MPCMP) Report contains elements for meeting program mass properties objectives and contractual requirements. Both technical and organizational needs are considered and necessary supporting plans for sensing and correcting weight and balance trends are identified.

References: JSSG-2006: 3.2.5
SAWE RP7: 3.2.2., 3.2.6 and 3.3
DI-MGMT-81501
DI-MGMT-81504
DI-MGMT-81452

5.5.2 Weight and center of gravity.

***Criterion**:* Verify that center of gravity margins are properly defined to handle aerodynamic, center of gravity, and inertia changes resulting from fuel usage, store expenditure, asymmetric fuel and store loading, fuel migration at high angle of attack and roll rates, and aerial refueling, and release of external sling loads, and air drop of internal cargo.

***Standard**:*

a. The aircraft center of gravity remains within the approved flight envelope for all mission scenarios.
b. The provisions for determining the vehicle weight and longitudinal, lateral, and vertical center of gravity of the vehicle have been provided.
c. The center of gravity envelopes are commensurate with the requirements at all weights, and account for manufacturing variations, addition of planned equipment, variations in payload, flight attitudes, density of fuel and fuel system failures.
d. A fuel system calibration methodology to determine the weight and center of gravity of the fuel has been defined.

***Method of Compliance**:*

a. The center of gravity is verified to remain in the approved envelope for all mission scenarios as described in the master plan for controlling and managing Mass Properties in accordance with SAWE RP7 and delivered in accordance with DI-MGMT-81452. The Mass Properties Control and Management Process (MPCMP) Report contains elements for meeting program mass properties objectives and contractual requirements. Both technical and organizational needs are considered and necessary supporting plans for sensing and correcting weight and balance trends are identified.
b. The provisions for determining the weight, center of gravity, and inertias are verified to adhere to stated requirements through inspections, analysis, test in accordance with SAWE RP7 and 8. The inertias are verified and documented as an Inertia (Mass Properties) Report for Aircraft in accordance with RP7 and delivered in accordance with DI-MGMT-81504.
c. The center of gravity envelope is verified to encompass all possible mission and production variations to ensure safe flight in accordance with SAWE RP7 and 8. Mission calculations are verified and documented as part of Status, Estimated, Calculated, and Actual Weight Reports in accordance with SAWE RP7 and 8.
d. The fuel system calibration methodology is verified by determination of trapped fuel weight and center of gravity, determination of unusable fuel weight and center of gravity, determination of the usable fuel mass properties (weight and center of gravity), and comparison of onboard fuel indicating equipment to actual usable fuel mass properties. A fuel cell calibration test is used to verify actual fuel system mass properties and documented in accordance with SAWE RP7.

References: JSSG-2006: 3.2.6
SAWE RP7: 3.2.2, 3.2.7.3.1, 3.2.7.3.1.4, 3.4.9, 3.5

DI-MGMT-81501
DI-MGMT-81504
DI-MGMT-81452

5.5.3 Manuals.

***Criterion**:* Verify that flight and maintenance manuals are consistent and contain all required checklists and loading data necessary to conduct required weight and balance checks while complying with specific weight and balance requirements.

***Standard**:* Inventory checklist DD Form 365-1, Chart A and loading data contained in DD Form 365-4, Chart E (contained in TM 55-1500-342-23) is consistent as published in the operators and maintenance manuals and listed in the Weight and Balance handbook.

***Method of Compliance**:* The DD Form 365-1, Chart A and DD Form 365-4, Chart E are verified through analysis and test with actual part weighings of inventory items. The forms and manuals adhere to SAWE RP7 requirements and are delivered in accordance with DI-MGMT-81502 (see SAWE RP7, 3.4.9).

References: SAWE RP7: 3.4.9
TO 1-1B-50
NAVAIR 01-1B-50
DI-MGMT-81502
TM 55-1500-342-23

5.6 Flight release.

5.6.1 Substantiation of release.

***Criterion**:* Verify that the flight release is based on up-to-date design criteria and mass properties, and the completion of all required analyses; laboratory, ground, and flight tests relating to loads, strength, durability, damage tolerance, structural dynamics, and stiffness; and verify that the structural data generated by the required analysis and test substantiates the integrity and flight worthiness of the design.

***Standard* (Navy and Air Force)**: Initial strength flight release restricts the air vehicles from experiencing loads greater than those qualified by test or by analysis in accordance with procedures established by the procuring agency. The accuracy of the loads predictive methods is validated by using instrumented and calibrated flight test air vehicle(s) to measure actual loads and load distributions during flight. Appropriate monitoring values are defined with suitable warnings and limits for instrumented flight test aircraft. Un-instrumented aircraft operate within reduced limits demonstrated by the structural flight test aircraft. Navy fixed wing aircraft comply with requirements established in ENFS-SB-05-002R1. For final strength flight release for operation up to 100 percent of limit strength, for production air vehicles or flight test air vehicles, the airframe has exhibited ultimate load static test strength for ultimate loads, environmentally compensated where appropriate. Maximum speed is Vh/Mh such that the required margin of safety is maintained at all points on the V_L/M_L envelope of the air vehicle, both at constant Mach number and separately, at constant altitude.

***Standard* (Army)**:

a. The accuracy of the loads predictive methods is validated by using an instrumented and calibrated flight test air vehicle to measure actual loads and load distributions during flight within the 100% DLL flight release envelope.
b. Prior to strength flight release for operation up to 100% of DLL for either production air

vehicles or flight test air vehicles not strength proof tested to 100% of DLL, the airframe has exhibited ultimate load static test strength for ultimate loads, environmentally compensated as applicable, which reflect verified external limit loads and validated and updated structural analysis. Test conditions are selected for substantiating the strength envelope for each component of the airframe.

c. For the flight release, flight restrictions are defined as:

(1) Load factors and maneuvers are limited such that the air vehicle does not experience loads greater than 100% of DLL.

(2) For rotorcraft, see ADS-24 (cancelled) and ADS-29 (cancelled) for definitions of Vh and Vne. Rotorcraft airspeed limitations may be required to avoid level flight fatigue damage, retreating blade stall, or advancing blade compressibility effects.

(3) The loads resulting from overshoots, upsets, and the recovery from overshoots and upsets, and the loads during and following system failures are included in the establishment of the flight restrictions.

***Method of Compliance* (Army and Air Force)**: Validity of the requirements as identified in the standards is verified by a series of analyses and tests. The following compliances are applicable in addressing the standards:

a. Formal updated structural analysis (external loads, internal loads and strength, limited durability and damage tolerance, structural dynamics) is correlated to all available ground and flight testing. Strength, durability and damage tolerance analyses showing margins >0.0. Finalization of the service and maximum loads expected to be encountered during operation under all flight conditions. Issuance of Strength Summary and Operating Restrictions. Inspection and maintenance intervals are established to ensure continued safe operations

b. Wind tunnel tests. Component ground vibration, acoustic and stiffness tests. Mass measurements of control surfaces/tabs. Control surface, tab, and actuator rigidity, free play, and wear tests. Complete air vehicle ground vibration modal tests. Aeroservoelastic ground tests. Updated predictions of near field aeroacoustic, vibration and internal noise. Ground loads test demonstrations, shimmy ground tests, rough runway tests.

c. Successful completion of appropriate flight flutter, vibroacoustics, loads testing (100%) and ultimate loads static tests. The latter includes extensive examination of static test article instrumentation to ensure that test measured values are within, or well correlated to, predicted values as adjusted by verified external loads. Structural analyses are validated and updated for all testing such that the predictive methods ensure adequate strength levels and understanding of the structural behavior.

d. For rotorcraft, the flight release includes any restrictions and limitations identified by the Strength Summary and Operating Restrictions (SSOR) report, Structural Flight Test reports (including envelope expansion, flight load survey, and structural demonstration), or Fatigue Substantiation report. In addition, any structural inspections or retirement intervals necessary for maintaining continued airworthiness are incorporated into the flight release.

Method of Compliance (**Navy)**: Validity of the fixed and rotary wing aircraft requirements as identified in the referenced standards is verified by a series of analyses, wind tunnel tests, component level ground tests, dynamic compliance ground tests, stiffness tests, airframe/component and control surface rigidity, free play, and wear tests. Such tests include: Complete air vehicle ground vibration modal test, aeroservoelastic ground test, measurements of near field aeroacoustic/vibration/internal noise, ground loads test demonstrations, shimmy ground tests, and rough runway tests. Structural Flight Test (including envelope expansion, flight load survey, and structural demonstration and final submittal of a Fatigue Substantiation report. Aeroelastic, aeroservoelastic, flutter, aeroacoustic, and vibration survey flight testing. Additionally, rotary wing ground resonance and torsional stability testing. Minimum data requirements typically required to support the first flight release are listed in Table 1. Additional data requirements may be identified as the design matures. Final determination on applicability is determined by the procuring agency.

TABLE I. Navy first flight release minimum data requirements.

CONTRACTOR TYPICALLY HAS SUBMITTED AND PROCURING ENGINEERING HAS APPROVED THE ANALYSES	CONTRACTOR TYPICALLY HAS SUCCESSFULLY COMPLETED AND SUBMITTED RESULTS FROM THE FOLLOWING TESTS	CONTRACTOR SUBMITTED AND AGENCY ENGINEERING ACCEPTED THE FOLLOWING TEST PLANS
Design Criteria Report	Flight Test Instrumentation and Calibration Test Report	Flight and Ground Test Instrumentation and Calibration Test Plan
Structural Description Report	Aircraft Ground Vibration (Shake) Test Report	Mechanical Stability Test Plan
Structural Drawing Package (as required)	Control System Proof Test Report	Envelope Development Flight Test Plan
Flight Control System Block Diagram	Control System "RAP" Test Report	Flight Loads Survey Test Plan
Aircraft Modification Plan	Main and Tail Rotor Whirl Test Report	Flight Vibration Survey Test Plan
Flight Readiness Roadmap	Ground Tie Down Test Vehicle Test Report*	Aeroelastic Stability Flight Test Plan
Nondestructive Inspection Test Plan	Damper Force Velocity Test Report	Aeroservoelastic Stability Flight Test Plan
Flight Loads Report	Landing Gear Drop Test Report	Drive System Torsional Stability Test Plan
Ground Loads Report	Drive System Torsional Stability Ground Test	Flight Clearance Document
Inertial Loads Report	Hydraulic System Proof Test Report	Shakedown Flight Test Plan
Control System Loads Report	Hydraulic System "RAP" Test Plan	Elastomeric Bearing Qualification Reports
Rotor Systems Loads Report	Preliminary Fatigue Test Report	Structural Dynamics Compliance Test Report
Internal Loads Report	Safety Assessment Report	Drive System Torsional Stability Test Report
Airframe Structural Analysis Report	Windshield Bird Strike Test Report	Ground Test Plan
Control System Structural Analysis Report	Control System "RAP" Test Report	Ground Test Results
Rotor (main and Tail) Structural Analysis	Hydraulic System "RAP" Test Report	Structural Dynamics Compliance Test Plan
Drive System Structural Analysis Report	System Test Results	Functional Test Plan

TABLE I. Navy first flight release minimum data requirements - continued.

CONTRACTOR TYPICALLY HAS SUBMITTED AND PROCURING ENGINEERING HAS APPROVED THE ANALYSES	CONTRACTOR TYPICALLY HAS SUCCESSFULLY COMPLETED AND SUBMITTED RESULTS FROM THE FOLLOWING TESTS	CONTRACTOR SUBMITTED AND AGENCY ENGINEERING ACCEPTED THE FOLLOWING TEST PLANS
Landing Gear Structural Analysis Report	Engineering Simulation Math Model Data, Assumptions and Validation Report	Aircraft Ground Vibration (Shake) Test Plan
Mechanical Stability Analysis Report		Control System "RAP" Test Plan
Aeroelastic Stability Analysis Report		Hydraulic System "RAP" Test Plan
Drive System Torsional Stability Analysis		Control System Proof Test Plan
Preliminary Vibration Environment Analysis		Main and Tail Rotor Whirl Test Plans
Safety Assessment Report		Ground Tie Down Test Vehicle Test Plans
Flight Control System FMECA Report		Main Rotor Damper Force Velocity Test Plan
Strength Summary and Operating Restrictions		Drive System Torsional Stability Test Plan
Air Vehicle Technical Description Report		Landing Gear Drop Test Plan
		Hydraulic System Proof Test Plan
		Fuel System Proof Test Plan
		Shakedown Flight Test Plan
		Preliminary Fatigue Plan

a. The contractor typically has successfully competed:

(1) Fatigue Tests of at least two((2) specimens of dynamic components for twice the number of cycles expected in the flight program at load levels 1.5 times the maximum expected vibratory load.

(2) Test on the Structural Test Article for which an ultimate factor of safety of 1.5 has been demonstrated. In the event that such tests have not been performed, tests are not completed and/or results have not been submitted. The operating limits are those for which a factor of safety of 2.0 for metallic structure and 3.0 for composite material structure has been substantiated by analyses.

(3) Fifty hours of tie-down testing prior to first flight. A two to one relationship between ground time successfully accumulated and flight time is typically required.

(4) Pre-flight whirl test of main and tail rotor systems of at least 10 hours with aerodynamic performance and stress and motion survey of the main rotor system.

(5) 100 hours of endurance testing

(6) Endurance testing of main and tail rotor systems to demonstrate at least 250 hours of time between overhaul

b. Inspections.

(1) As required to support airworthiness activities (including substantiating data for probability of detection and inspection interval):

(a) Visual - photographic, human eye.

NDI - dye penetrant, radiographic, eddy current, ultrasonic, magnetic particle.

References: (Navy/Air Force fixed wing) JSSG-2006: A.3.5, A.3.6, A.3.7, A.3.17, A.4.7, A.4.10.5.3, A.4.10.5.4, A.4.10.5.5, A.4.17

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(Army rotary wing) ADS-10-SP, ADS-24 (cancelled), ADS-27-SP, ADS-29 (cancelled), ADS-51, ADS-64-SP (inactive), AR-70-62

(Navy rotary wing) As identified in the AVPS Addendum for the respective air vehicle and/or AR-56, AR-89, MIL-D-23222

14 CFR 23, 25, 27, 29

STANAG 4671: USAR 321

6. FLIGHT TECHNOLOGY

Flight technology comprises the flight mechanics functional areas consisting of stability and control, flying qualities, flight control functions, external aerodynamics, internal aerodynamics and performance. The air vehicle aerodynamic and stability configuration, engine/inlet/nozzle compatibility, performance and integrated control airworthiness of an air vehicle should be assessed using the criteria provided in the text below (not all items apply in each case; similarly, items may have to be added for vehicles employing new or innovative technology/techniques).

EXAMPLES OF TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria.
2. Design studies and analyses.
3. Design, installation, and operational characteristics.
4. Simulation tests, modeling, and results (including simulation verification, validation and accreditation data).
5. Design approval and function/system compatibility tests.
6. Component and functional level qualification and certification tests.
7. Electromagnetic environmental effects.
8. Installed propulsion compatibility tests.
9. Acceptance criteria for test results.
10. Failure modes, effects, and criticality analysis/failure modes and effects testing (FMECA/FMET).
11. Hazard analysis and classification.
12. Safety certification program.
13. Computational, theoretical, and/or semi-empirical prediction methods.
14. Configuration: aerodynamic design and component location.
15. Wind tunnel test results and correction methods.
16. Mathematical representation of system dynamics.
17. Ground resonance and loop stability tests.
18. Aeroservoelastic design criteria and analysis.
19. Performance analysis.
20. Flight manual.
21. Natural environmental sensitivities.
22. Flight path guidance analysis and simulation to include ship launch and recovery routines if applicable (including sensor or processor failure modes and effects on flight control).
23. Interface/integration control documents.
24. Function, subfunction, and component specifications.
25. Selection criteria and patterns selected for screens constructed to demonstrate inlet/engine compatibility.
26. Flight test plan.
27. Detailed flight profiles.
28. Aircraft/engine operating limitations.
29. Control laws.

30. Flight test reports.
31. Aerodynamic and air data uncertainty sensitivity studies.
32. Force and Moment Accounting system.
33. Mass properties: weights, centers of gravity, and inertias.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

The documents referenced under any criterion, standard and/or method of compliance may provide other standards. References provide supporting rationale, guidance, lessons learned and other important information useful in properly understanding, interpreting, and applying the relevant criterion, standard and/or method of compliance.

6.1 Flying qualities.

Flying qualities are those characteristics of the complete air vehicle/system which allow the pilot/operator to perform to his/her satisfaction the flying tasks required to safely accomplish the mission, with an acceptable workload, while operating in the real world environment for which it is intended to operate. These characteristics are applicable for assuring the flight safety of an Unmanned Aircraft System (UAS).

NOTE: (USAF only) The Flying Qualities Development Process (FQDP) provides a framework for defining and managing the process by which fixed-wing air vehicle stability and control and flying qualities are to be required, specified, designed, evaluated, analyzed, verified, validated, qualified and tested to assure the integrity of the system. This same process can be applied to Unmanned Aircraft Systems (UAS).]

References: JSSG-2001, including Appendix C (NOTE: JSSG-2001 relevant criteria can be found in every MIL-STD-1797 criterion cited within 6.1)

JSSG-2008

MIL-STD-1797 (references to MIL-STD-1797 paragraphs align with MIL-STD-1797B and its successors)

ADS-33-PRF

14 CFR 23, 25, 27, 29, 60

Flying Qualities Development Process (FQDP) (USAF only)

6.1.1 Preliminary steps in application of flying qualities.

6.1.1.1 Determining operational missions.

Criterion: Verify that the operational mission requirements of the air vehicle system have been determined and adequately defined for which safety of flight is to be assured.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.1 Determining operational missions (see table I and figure 1 for guidance).

For rotorcraft, the air vehicle meets the standards within ADS-33-PRF, 3.1.1 Operational missions and Mission-Task-Elements (MTEs) and 3.1.3 Operational environment.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

Additional Reference: 14 CFR 27.143 Controllability and maneuverability

6.1.1.2 Determining applicable flight phases.

Criterion: Verify that all applicable flight phases have been determined for which safety of flight is to be assessed for accomplishing the operational mission.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.2 Determining applicable flight phases (see table II for guidance).

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.1 Operational missions and Mission-Task-Elements (MTEs), 3.1.3 Operational environment, and 3.11 Mission-Task-Elements.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

Additional References: 14 CFR 23.143 General; 25.143 General

6.1.1.3 Defining air vehicle states.

Criterion: Verify that all Air Vehicle States have been defined for which safety of flight is to be assessed.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.3 Defining Air Vehicle States. For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.6 Flight envelopes.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

6.1.1.3.1 Determining internal and external stores.

Criterion: Verify that all internal and external stores combinations have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.3.1 Determining internal and external stores. For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.7 Configurations.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

6.1.1.3.2 Defining air vehicle loadings.

Criterion: Verify that all air vehicle loadings have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.3.2 Defining air vehicle loadings. For rotorcraft, the air vehicle meets standards within ADS-33-PRF , 3.1.8 Loadings.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

Additional References: 14 CFR 23.21 Proof of compliance, 23.23 Load distribution limits, 23.25 Weight limits

14 CFR 25.21 Proof of compliance, 25.23 Load distribution limits, 25.25 Weight limits, 25.27 Center of gravity limits

14 CFR 27.21 Proof of compliance, 27.25 Weight limits, 27.27 Center of gravity limits

6.1.1.3.3 Determining moments and products of inertia.

Criterion: Verify that all the moments and products of inertia have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.3.3 Determining moments and products of inertia.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

6.1.1.3.4 Determining air vehicle configurations.

Criterion: Verify that all air vehicle configurations have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.3.4 Determining air vehicle configurations. For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.7 Configurations.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

6.1.1.3.5 Identifying air vehicle normal states.

Criterion: Verify that all Air Vehicle Normal States have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.3.5 Identifying Air Vehicle Normal States. Table III from MIL-STD-1797 is completed. For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.6 Flight envelopes.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

6.1.1.3.6 Identifying air vehicle extreme states.

Criterion: Verify that all Air Vehicle Extreme States have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.3.6 Identifying air vehicle extreme states.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

6.1.1.3.7 Identifying air vehicle failure states.

Criterion: Verify that all Air Vehicle Failure States have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.3.7 Identifying Air Vehicle Failure States. For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.14 Rotorcraft failures.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

6.1.1.3.8 Identifying air vehicle special failure states.

Criterion: Verify that all Air Vehicle Special Failure States have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 4.1.3.8 Identifying Air Vehicle Special Failure States. For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.14.3 Rotorcraft Special Failure States.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

6.1.1.4 Defining the regions of handling.

Criterion: Verify that all Regions of Handling have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 4.1.4 Defining the Regions of Handling (see figure 4 for guidance)
b. 4.1.4.1 Defining the Regions of Satisfactory Handling (ROSH). Table IV is completed.
c. 4.1.4.2 Defining the Regions of Tolerable Handling (ROTH). Table V is completed.
d. 4.1.4.3 Defining the Regions of Recoverable Handling (RORH). Table VI is completed.

Method of Compliance: Verification methods include inspection of requirements, design, and configuration documentation.

6.1.1.5 Modeling, simulation, analysis tools and databases.

Criterion: Verify that all modeling, simulation, analysis tools and databases are of appropriate fidelity and accurately represent the air vehicle for evaluating airworthiness criteria and safety of flight.

Standard: Verify and validate that modeling, simulation, analysis tools and databases which are utilized for evaluating airworthiness criteria across the flight envelope, for all expected center-of-gravity ranges and mass properties, for all flight phases, tasks and flight control modes, for all configurations and store loadings as tailored from tables I, II and III of MIL-STD-1797, and in the expected atmospheric disturbances for which the air vehicle is to perform its mission(s) are of sufficient fidelity and accuracy. A suitable verification, validation and accreditation (VV&A) process, as outlined in MIL-STD-3022, is demonstrated. Configuration control across all such tools is demonstrated to assure currency and traceability.

Review of modeling, simulation, analysis tools and database documentation verifies and validates that predicted data, as well as offline and piloted simulation results, are generated by the most appropriate and accurate tools and processes. Review of the documentation verifies and validates that the frequency and time domain based analysis tools, models, simulations and all the databases/components thereof (e.g., aerodynamics, ground and ground effects, flight control system and flight control laws, sensors, actuators) are of sufficient fidelity and pedigree for each phase of a development program (e.g., Preliminary Design Review (PDR), Critical Design Review (CDR), Test Readiness Review (TRR), First-Flight Readiness Review (FFRR), Functional Configuration Audit/Physical Configuration Audit (FCA/PCA), Production), having incorporated updates as a result of component testing, ground testing and flight testing, as appropriate, to assure that the results are complete and suitable for airworthiness and safety of flight analyses.

Method of Compliance: Verification methods include inspection of maturity, fidelity and accuracy of analysis, modeling and simulation tools and databases, as well as the processes in place to assure their currency, traceability and configuration control. Analysis, modeling and simulation tools and databases, including the verification and validation of their results, reflect industry best practices for the purpose of their intended use.

Additional Reference: 14 CFR 60 (including appendices), for airplane flight simulation devices only

6.1.2 Primary flying qualities.

Criterion: Verify that flying qualities have been defined and assessed for safety of flight for all Air Vehicle States (6.1.1.3 and subparagraphs) encountered in the Flight Phases and tasks (6.1.1.2) of the operational missions (6.1.1.1).

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.1 Primary requirements. For rotorcraft, the air vehicle meets the standards within ADS-33-PRF, 3.1 General.

Method of Compliance: Verification methods include analysis, simulation, and inspection of requirements, design, and configuration documentation.

6.1.2.1 Primary flying qualities for air vehicle states in common environmental conditions.

Criterion: Verify that the air vehicle states in common environmental conditions have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.1.1 Primary requirements for air vehicle states in common environmental conditions.

Method of Compliance: Verification methods include analysis, simulation and inspection of requirements, design, and configuration documentation.

6.1.2.2 Allowable levels for air vehicle normal states.

Criterion: Verify that allowable Levels for Air Vehicle Normal States have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.1.1.1 Allowable levels for air vehicle normal states (see table VII for guidance).

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.13 Levels for Normal States.

Method of Compliance: Verification methods include analysis, simulation, and inspection of requirements, design, and configuration documentation.

6.1.2.3 Allowable levels for air vehicle extreme states.

Criterion: Verify that allowable Levels for Air Vehicle Extreme States have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.1.1.2 Allowable Levels for Air Vehicle Extreme States. Table VIII is completed.

Method of Compliance: Verification methods include analysis, simulation, and inspection of requirements, design, and configuration documentation.

6.1.2.4 Primary flying qualities for failure states.

Criterion: Verify that the primary requirements for Failure States have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.1.1.3 Primary requirements for failure states.
b. 5.1.1.3.1 Probability of encountering degraded levels of flying qualities due to failures.
c. 5.1.1.3.2 Allowable Levels for specific air vehicle failure states. Table IX is completed.
d. 5.1.1.3.3 Failures outside the ROTH.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.14 Rotorcraft failures.

Method of Compliance: Verification methods include analysis, simulation, and inspection of requirements, design, and configuration documentation.

6.1.3 Flying qualities in degraded environmental conditions.

Criterion: Verify that flying qualities in degraded environmental conditions have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.1.2 Flying Qualities in degraded environmental conditions. Table X is completed. See tables XI through XVII and figures 10 through 16 for guidance.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.3 Operational environment and 3.2.2 Required Response-Types.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.3.1 Flying qualities in icing conditions.

Criterion: Verify that flying qualities in icing conditions have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within 14 CFR 25.21(g), or 14 CFR 23.1419(a).

For rotorcraft, the air vehicle meets the standards pertaining to handling qualities within 14 CFR 29.1419, or 14 CFR 27.1419.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: MIL-STD-1797: 5.1.2 Flying Qualities in Degraded Environmental Conditions

ADS-33-PRF: 3.1.3 Operational environment and 3.2.2 Required Response-Types

6.1.4 Control margin.

Criterion: Verify that control margins have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.1.3 Control margin (see table XVIII and figures 17 and 18 for guidance).

Method of Compliance: Verification methods include analysis, simulation, and inspection of requirements, design, and configuration documentation.

6.1.5 General flying qualities.

6.1.5.1 Approach to dangerous flight conditions.

Criterion: Verify that approaches to dangerous flight conditions have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.1.1 Approach to dangerous flight conditions.
b. 5.2.1.1.1 Warning and indication.
c. 5.2.1.1.2 Operation of devices for indication, warning, prevention, and recovery.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.15 Rotorcraft limits.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.207 Stall warning, 23.703 Takeoff warning system, 23.729 Landing gear extension and retraction system;
14 CFR 25.207 Stall warning, 25.703 Takeoff warning system, 25.729 Retracting mechanism

6.1.5.2 Buffet.

Criterion: Verify that buffet characteristics have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.1.2 Buffet.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.5.3 Release of stores.

Criterion: Verify that release of stores has been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.1.3 Release of stores.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.5.4 Effects of armament delivery and special equipment.

Criterion: Verify that effects of armament delivery and special equipment have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.1.4 Effects of armament delivery and special equipment.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.5.5 Failures.

Criterion: Verify safety of flight following failures.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.1.5 Failures (see table XIX for guidance).

b. 5.2.1.5.1 Transients following failures (see table XX for guidance).

c. 5.2.1.5.2 Trim changes due to failures (see table XXI for guidance).

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.14 Rotorcraft failures, 3.7 Specific failures and 3.10.2 Failure of external load system.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.145 Longitudinal control, 23.147 Directional and lateral control, 23.149 Minimum control speed, 23.672 Stability augmentation and automatic and power-operated systems, 23.691 Artificial stall barrier system, 23.701 Flap interconnection

14 CFR 25.147 Directional and lateral control, 25.149 Minimum control speed, 25.671 General, 25.672 Stability augmentation and automatic and power-operated systems, 25.701 Flap and slat interconnection, 27.141 General, 27.143 Controllability and maneuverability

14 CFR 27; 27 Appendix B VII Stability Augmentation System (SAS)

6.1.5.6 Pilot-in-the-loop oscillations.

Criterion: Verify that there are no pilot-in-the-loop-oscillations (PIO) tendencies.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.1.6 Pilot-in-the-loop oscillations.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.16 Pilot-induced oscillations.

For unmanned air vehicles, pilot/system-induced oscillations do not interfere with the operation of the aircraft or accomplishment of mission tasks.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.5.7 Residual oscillations.

Criterion: Verify that residual oscillations characteristics are safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.1.7 Residual oscillations.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.17 Residual oscillations.

For unmanned air vehicles residual oscillations do not interfere with operation of the aircraft or accomplishment of mission tasks.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.5.8 Ride qualities.

Criterion: Verify safe, acceptable ride qualities.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.1.8 Ride qualities (see tables XXIII and XXIV and figure 21 for guidance).

For unmanned air vehicles ride qualities do not interfere with operation of the aircraft or accomplishment of mission tasks.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.6 Longitudinal flying qualities.

6.1.6.1 Longitudinal response to the pitch controller.

Criterion: Verify that the longitudinal response to the pitch controller is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.2.1 Longitudinal response to the pitch controller.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.143 General, 23.145 Longitudinal control, 23.153 Control during landings, 23.155 Elevator control force in maneuvers, 23.173 Static longitudinal stability, 23.175 Demonstration of static longitudinal stability, 23.181 Dynamic stability;

14 CFR 25.143 General, 25.145 Longitudinal control, 25.173 Static longitudinal stability, 25.175 Demonstration of static longitudinal stability, 25.181 Dynamic stability, 27.173 Static longitudinal stability, 27.175 Demonstration of static longitudinal stability;

14 CFR 27; 27 Appendix B IV Static longitudinal stability

6.1.6.1.1 Longitudinal lower-order equivalent system dynamics.

Criterion: Verify that longitudinal lower-order equivalent system dynamics are safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.2.1.1 Longitudinal lower-order equivalent system dynamics (see figure 22 for guidance).
b. 5.2.2.1.1.1 Phugoid dynamics (see table XXVI for guidance).
c. 5.2.2.1.1.2 Short-period dynamics (see table XXVII and figures 28 through 31 for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.6.1.2 Longitudinal time responses to the pitch controller.

Criterion: Verify that longitudinal time responses to the pitch controller are safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.2.1.2 Longitudinal time responses to the pitch controller.
b. 5.2.2.1.2.1 Long-term longitudinal response (see table XXVIII for guidance).
c. 5.2.2.1.2.2 Short-term pitch response to pitch controller (see tables XXIX and XXX and figures 32 through 39 for guidance).
d. 5.2.2.1.2.3 Steady-state flight-path response to pitch controller (see table XXXI and figure 40 for guidance).
e. 5.2.2.1.2.4 Speed response to attitude change.
    (1) 5.2.2.1.2.4.1 Direction of speed change.
    (2) 5.2.2.1.2.4.2 Relaxation in transonic flight.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.3.2.3 Mid-term response to control inputs, 3.3.3 Moderate-amplitude pitch (roll) attitude changes (attitude quickness), 3.3.4 Large-amplitude pitch (roll) attitude changes, 3.4.1.2 Mid-term response to control inputs and 3.4.4 Longitudinal static stability.

For UAS, the delay is evaluated in the context of the full control system design. Delay is considered from the command to the AV response.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.6.1.3 Longitudinal frequency response to the pitch controller.

Criterion: Verify that longitudinal frequency response to the pitch controller is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.2.1.3 Longitudinal frequency response to the pitch controller.
b. 5.2.2.1.3.1 Pitch attitude bandwidth (see figures 41 and 48 for guidance).
c. 5.2.2.1.3.2 Pitch attitude frequency response envelopes (see figure 49 for guidance).
d. 5.2.2.1.3.3 Transient flight-path response to pitch attitude change (see figure 51 and table XXXII for guidance).

For rotorcraft, the air vehicle meets the standards within ADS-33-PRF, 3.3.2.1 Short-term response to control inputs (bandwidth), 3.4.1.1 Short-term response (bandwidth), and 3.4.3.1 Flight path response to pitch attitude (frontside).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.6.1.4 Closed-loop analysis with a pilot model.

Criterion: Verify that closed-loop analysis with a pilot model is safe.

Standard: The air vehicle meets the standard within MIL-STD-1797, 5.2.2.1.4 Closed-Loop Analysis with a Pilot Model (see figure 57 and table XXXIII for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional Reference: 14 CFR 23.145 Longitudinal control

6.1.6.1.5 Pitch PIOs.

Criterion: Verify that there are no-pitch PIOs.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.2.1.5 Pitch PIOs (see figures 58 through 62 for guidance).

For rotorcraft, the air vehicle meets the standards within ADS-33-PRF, 3.1.16 Pilot-induced oscillations.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.6.1.6 Normal acceleration at the pilot station.

Criterion: Verify that normal acceleration at the pilot station is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.2.1.6 Normal acceleration at the pilot station.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.6.1.7 Longitudinal control power.

Criterion: Verify that longitudinal control power is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.2.1.7 Longitudinal control power.
b. 5.2.2.1.7.1 Longitudinal control margin (see nose-down control margin table for guidance).
c. 5.2.2.1.7.2 Longitudinal control power in unaccelerated flight.
d. 5.2.2.1.7.3 Longitudinal control power in maneuvering flight (see table XXXIV for guidance).
e. 5.2.2.1.7.4 Load factor onset and peak pitch rate (see tables XXXV and XXXVI for guidance).
f. 5.2.2.1.7.5 Longitudinal control power for takeoff (see table for guidance on blanks (1) and (2)).
   (1) 5.2.2.1.7.5.1 Longitudinal control power in catapult takeoff.
   (2) For launch assisted take-off the air vehicle system can safely transition to normal flight for all conditions in the launch envelope.
g. 5.2.2.1.7.6 Longitudinal control power in landing (see tables for guidance on blanks (1) through (3)).
   (1) For alternate or unique recovery methods the air vehicle system can safely land for all conditions in the recovery envelope.

For rotorcraft, the air vehicle meets the standards within ADS-33-PRF, 3.4.2 Pitch control power.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: JSSG-2001

14 CFR 23.143 General; 23.145 Longitudinal control, 23.153 Control during landings

14 CFR 25.143 General, 25.145 Longitudinal control

14 CFR 27.143 Controllability and maneuverability

6.1.6.1.8 Longitudinal control forces and displacements.

Criterion: Verify that longitudinal control forces and displacements are safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.2.1.8 Longitudinal control forces and displacements (see table XXXVII and figures 64 through 66 for guidance).
b. 5.2.2.1.8.1 Steady-state control force and deflection per G (see table XXXVIII for guidance).
c. 5.2.2.1.8.2 Transient control force per g (see table XXXIX for guidance).
d. 5.2.2.1.8.3 Control force variations during rapid speed changes.

e. 5.2.2.1.8.4 Control force versus control deflection.
f. 5.2.2.1.8.5 Pitch controller breakout forces (see table XLII for guidance).
g. 5.2.2.1.8.6 Longitudinal control force and travel in takeoff (see table for guidance on blanks (1) through (3)).
h. 5.2.2.1.8.7 Longitudinal control force limits in dives within the ROTH (see tables for guidance on blanks (1) through (4)).
i. 5.2.2.1.8.8 Longitudinal control force limits in dives within the RORH (see tables for guidance on blanks (1) through (4)).

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.4.1.3 Mid-term response - maneuvering stability and 3.6 Controller characteristics.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.153 Control during landings, 23.173 Static longitudinal stability, 23.175 Demonstration of static longitudinal stability, 23.155 Elevator control force in maneuvers;

14 CFR 25.143 General, 25.145 Longitudinal control, 25.173 Static longitudinal stability, 25.175 Demonstration of static longitudinal stability;

14 CFR 27.151 Flight controls;

14 CFR 27; 27 Appendix B IV Static longitudinal stability

6.1.6.2 Longitudinal response to the designated flight path controller.

Criterion: Verify that longitudinal response to the designated flight path controller is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.2.2 Longitudinal response to the designated flight path controller.
b. 5.2.2.2.1 Flight path response to designated flight path controller (see figures 80 through 83 for guidance).
c. 5.2.2.2.2 Flight path control power (see table XLIII for guidance).
d. 5.2.2.2.3 Flight path controller characteristics.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.7 Lateral-directional flying qualities.

Criterion: Verify that lateral-directional flying qualities have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.3 Lateral-directional flying qualities. For rotorcraft, the air vehicle meets the standards for lateral-directional flying qualities within ADS-33-PRF.

Method of Compliance: Verification methods include analysis, simulation, and inspection of requirements, design, and configuration documentation.

6.1.7.1 Lateral-directional modal characteristics.

Criterion: Verify that lateral-directional modal characteristics are safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.3.1 Lateral-directional modal characteristics.

b. 5.2.3.1.1 Roll mode (see table XLIV for guidance).

c. 5.2.3.1.2 Dutch roll frequency and damping (see table XLV for guidance).

d. 5.2.3.1.3 Spiral stability (see table XLVI for guidance).

e. 5.2.3.1.4 Coupled roll-spiral oscillation (see table XLVII for guidance).

f. 5.2.3.1.5 Roll time delay (see table XLVIII for guidance).

(1) For UAS, the delay is evaluated in the context of the full control system design. Delay is considered from the command to the air vehicle (AV) response.

g. 5.2.3.1.6 Yaw time delay (see table XLIX for guidance).

(1) For UAS, the delay is evaluated in the context of the full control system design. Delay is considered from the command to the AV response.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.4.9 Lateral-directional stability.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.181 Dynamic stability

14 CFR 25.181 Dynamic stability

14 CFR 27; 27 Appendix B VI Dynamic stability

6.1.7.2 Lateral-directional dynamic response characteristics.

Criterion: Verify that lateral-directional dynamic response characteristics are safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.3.2 Lateral-directional dynamic response characteristics (see figures 119 through 122 for guidance).

b. 5.2.3.2.1 Roll rate response to small roll commands (see figure 123 for guidance).

c. 5.2.3.2.2 Bank angle response to roll commands (see figure 135 for guidance).

d. 5.2.3.2.3 Roll rate response to large roll commands (see table L for guidance).

e. 5.2.3.2.4 Lateral acceleration at the pilot station (see table LI for guidance).

f. 5.2.3.2.5 Yaw response to small roll control commands (see figure 138 for guidance).

g. 5.2.3.2.6 Yaw response to large roll control commands (see table LII for guidance).

h. 5.2.3.2.7 Coordination in turn entry and exit (see figures 142 through 149 and tables LIII through LVI for guidance).

i. 5.2.3.2.8 Linearity of roll response to roll controller (see figure 173 for guidance).

For rotorcraft, the air vehicle meets standards within the following ADS-33-PRF paragraphs:

a. 3.3.2 Small-amplitude pitch (roll) attitude changes.

b. 3.3.3 Moderate-amplitude pitch (roll) attitude changes (attitude quickness).

c. 3.3.4 Large-amplitude pitch (roll) attitude changes.
d. 3.3.5 Small-amplitude yaw attitude changes.
e. 3.3.6 Moderate-amplitude heading changes (attitude quickness).
f. 3.3.8 Large-amplitude heading changes.
g. 3.4.6 Roll attitude response to lateral controller.
h. 3.4.7 Roll-sideslip coupling.
i. 3.4.8 Yaw response to yaw controller.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.7.3 Roll PIO.

Criterion: Verify that there are no roll PIOs.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.3.3 Roll PIO.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.16 Pilot-induced oscillations.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.7.4 Yaw PIO.

Criterion: Verify that there are no yaw PIOs.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.3.4 Yaw PIO.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.1.16 Pilot-induced oscillations.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.7.5 Roll control effectiveness.

Criterion: Verify that roll control effectiveness is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.3.5 Roll control effectiveness (see table LVIII for guidance).
b. 5.2.3.5.1 Additional roll requirements for Class IV air vehicles (see tables LX, LXI and LXII for guidance).
c. 5.2.3.5.2 Roll termination.
d. 5.2.3.5.3 Roll control power with asymmetric loads.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.7.6 Lateral-directional control with speed changes.

Criterion: Verify that lateral-directional control with speed changes is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.3.6 Lateral-directional control with speed changes (see table LXIII for guidance).
b. 5.2.3.6.1 Lateral-directional control with speed changes - asymmetric loads (see table

LXIV for guidance).

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.4.8.4 Yaw control with speed change.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.7.7 Yaw control forces in waveoff (go-around).

Criterion: Verify that yaw control forces in waveoff (go-around) are safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.3.7 Yaw control forces in waveoff (go-around) (see table LXV for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.143 General
14 CFR 25.143 General

6.1.7.8 Lateral-directional control forces and displacements.

Criterion: Verify that lateral-directional control forces and displacements are safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.3.8 Lateral-directional control forces and displacements (see figures 169 through 171 and table LXVI for guidance).
b. 5.2.3.8.1 Lateral-directional breakout forces (see table LXVII for guidance).
c. 5.2.3.8.2 Roll control sensitivity (see table LXVIII and figure 173 for guidance).
d. 5.2.3.8.3 Roll control force limits in rolls (see tables LXX and LXXI for guidance).
e. 5.2.3.8.4 Yaw control forces in rolls (see table LXXII for guidance).
f. 5.2.3.8.5 Control forces in steady turns.
g. 5.2.3.8.6 Roll control displacement limits.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.6 Controller characteristics.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.143 General; 23.177 Static directional and lateral stability
14 CFR 25.143 General; 25.177 Static lateral-directional stability
14 CFR 27.151 Flight controls

6.1.7.9 Steady sideslips.

Criterion: Verify that steady sideslips are safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.3.9 Steady sideslips.
b. 5.2.3.9.1 Yaw control force and deflection in steady sideslips.
c. 5.2.3.9.2 Bank angle in steady sideslips.
d. 5.2.3.9.3 Roll control force and deflection in steady sideslips.
e. 5.2.3.9.4 Roll control power in steady sideslips.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.4.10 Lateral-directional characteristics in steady sideslips.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.177 Static directional and lateral stability.
14 CFR 25.177 Static lateral-directional stability.
14 CFR 27; 27 Appendix B V Static Lateral Directional stability.

6.1.7.10 Lateral-directional control in crosswinds.

Criterion: Verify that lateral-directional control in crosswinds is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.3.10 Lateral-directional control in crosswinds (see tables LXXIII and LXXIV for guidance)
b. 5.2.3.10.1 Final approach in crosswinds
c. 5.2.3.10.2 Take-off run and landing rollout in crosswinds
    (1) 5.2.3.10.2.1 Additional requirements for carrier-based air vehicles
    (2) For alternate and unique launch and recovery methods the air vehicle system exhibits safe flight characteristics for all flight conditions in the launch and recovery envelopes.
d. 5.2.3.10.3 Taxiing wind speed limits.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.9.3 Wheeled rotorcraft ground requirements.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.233 Directional stability and control.
14 CFR 25.233 Directional stability and control; 25.237 Wind velocities.
14 CFR 27.143 Controllability and maneuverability.

6.1.7.11 Lateral-directional control with asymmetric thrust.

Criterion: Verify that lateral-directional control with asymmetric thrust is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.3.11 Lateral-directional control with asymmetric thrust.
b. 5.2.3.11.1 Thrust loss during takeoff run.
c. 5.2.3.11.2 Thrust loss after takeoff (see table LXXV for guidance).
d. 5.2.3.11.3 Thrust loss during waveoff/go-around.
e. 5.2.3.11.4 Yaw controls free (see table LXXVI for guidance).
f. 5.2.3.11.5 Two-engine failures in multi-engine air vehicles (more than two engines).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.51 Takeoff speeds; 23.73 Reference landing approach speed; 23.147 Directional and lateral control; 23.149 Minimum control speed

6.1.7.12 Wings-level turn.

Criterion: Verify that wings-level turn with the designated side force controller is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.3.12 Wings-level turn.
b. 5.2.3.12.1 Dynamic response to direct side force controller (see table LXXVII for guidance).
c. 5.2.3.12.2 Steady-state response to direct side force controller.
d. 5.2.3.12.3 Direct side force controller forces and displacements.
e. 5.2.3.12.4 Crew restraints.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.7.13 Lateral translation.

Criterion: Verify that lateral translation is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.3.13 Lateral translation.
b. 5.2.3.13.1 Dynamic response to lateral translation controller input.
c. 5.2.3.13.2 Steady-state response to lateral translation controller input.
d. 5.2.3.13.3 Lateral translation controller forces and displacements.
e. 5.2.3.13.4 Crew restraints.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.8 Cross-axis responses.

Criterion: Verify that cross-axis responses have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.4 Cross-axis responses. For rotorcraft, the air vehicle meets the standards for cross-axis responses within ADS-33-PRF.

Method of Compliance: Verification methods include analysis, simulation, and inspection of requirements, design, and configuration documentation.

6.1.8.1 Longitudinal control forces in sideslips.

Criterion: Verify that longitudinal control forces in sideslips are safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.4.1 Longitudinal control forces in sideslips.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.8.2 Lateral-directional control in dives and pullouts.

Criterion: Verify that lateral-directional control in dives and pullouts is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.4.2 Lateral-directional control in dives and pullouts.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.253 High speed characteristics
14 CFR 25.253 High-speed characteristics

6.1.8.3 Cross-axis coupling in roll maneuvers.

Criterion: Verify that cross-axis coupling in roll maneuvers is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.4.3 Cross-axis coupling in roll maneuvers.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.3.9 Interaxis coupling and 3.4.5 Interaxis coupling.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.8.4 Crosstalk between pitch and roll controllers.

Criterion: Verify that crosstalk between pitch and roll controllers is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.4.4 Crosstalk between pitch and roll controllers.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.8.5 Control harmony.

Criterion: Verify that control harmony is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.4.5 Control harmony (see table LXXIX for guidance).

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.6.5 Control harmony.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.8.6 Control cross-coupling.

Criterion: Verify that control cross-coupling is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.4.6 Control cross-coupling.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.3.9 Interaxis coupling and 3.4.5 Interaxis coupling.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.9 High angle-of-attack.

Criterion*:* Verify that high angle-of-attack characteristics have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.5 High angle of attack requirements (see table LXXX for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.9.1 Warning cues.

Criterion: Verify that warning cues are safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.5.1 Warning cues.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.207 Stall warning
14 CFR 25.207 Stall warning

6.1.9.2 Stall approach.

Criterion: Verify that stall approach is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.5.2 Stall approach (see tables LXXXI, LXXXII and LXXXIII for guidance).
b. 5.2.5.2.1 Stall warning.
c. 5.2.5.2.2 Uncommanded oscillations prior to stall.
d. 5.2.5.2.3 Cockpit controls prior to stall.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.201 Wings level stall
14 CFR 25.203 Stall characteristics

6.1.9.3 Stall characteristics.

Criterion: Verify that stall characteristics are safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.5.3 Stall characteristics.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 23.201 Wings level stall; 23.203 Turning flight and accelerated turning stalls
14 CFR 25.201 Stall demonstrations; 25.203 Stall characteristics

6.1.9.4 Stall prevention and recovery.

Criterion: Verify that stall prevention and recovery is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.5.4 Stall prevention and recovery .
b. 5.2.5.4.1 Stall recovery (see table LXXXIV for guidance).
c. 5.2.5.4.2 Control power for stall recovery.
d. 5.2.5.4.3 One-engine-out stalls for multi-engine air vehicles (more than one engine) (see table LXXXV for guidance).

For air vehicles with stall or loss of control prevention functions, prevention functions are effective and safe.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation. Also evaluate stall or loss of control prevention functions in all expected levels of atmospheric disturbances.

Additional References: 14 CFR 23.201 Wings level stall; 23.203 Turning flight and accelerated turning stalls; 23.691 Artificial stall barrier system

14 CFR 25.201 Stall demonstration; 25.203 Stall characteristics

6.1.9.5 Departure from controlled flight.

Criterion: Verify that departure from controlled flight characteristics is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.5.5 Departure from controlled flight.
b. 5.2.5.5.1 Departure warning.
c. 5.2.5.5.2 Uncommanded motions.
d. 5.2.5.5.3 Departure avoidance following sudden asymmetric loss of thrust.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.9.6 Recovery from post-stall gyrations and spins.

Criterion: Verify that recovery from post-stall gyrations and spins is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.5.6 Recovery from post-stall gyrations and spins.
b. 5.2.5.6.1 Turns and altitude loss for recovery (see table LXXXVI for guidance).
c. 5.2.5.6.2 Avoidance of spin reversal.
d. 5.2.5.6.3 Control forces for recovery (see table LXXXVII for guidance).
e. 5.2.5.6.4 Operation of automatic stall, departure, spin prevention or recovery devices.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional Reference: 14 CFR 23.203 Turning flight and accelerated turning stalls; 23.221 Spinning

6.1.10 Shipboard operations.

Criterion*:* Verify that shipboard operations have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.6 (see tables LXXXVIII and LXXXIX for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.10.1 Deck handling.

Criterion: Verify that deck handling is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.6.1 Deck handling.

Standards for UAS shipboard operations are provided by the airworthiness authority.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.2 Catapult launch.

Criterion: Verify that catapult launch is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.6.2 Catapult launch.
Standards for UAS shipboard operations are provided by the airworthiness authority.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.3 Carrier approach and landing.

Criterion: Verify that carrier approach and landing are safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.6.3 Carrier approach and landing.
Standards for UAS shipboard operations are provided by the airworthiness authority.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.4 Bolter.

Criterion: Verify that bolter is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.6.4 Bolter.
Standards for UAS shipboard operations are provided by the airworthiness authority.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.5 Waveoff.

Criterion: Verify that carrier waveoff is safe**.**

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.6.5 Waveoff.
Standards for UAS shipboard operations are provided by the airworthiness authority.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.6 Single engine failure (multi-engine air vehicles).

Criterion: Verify that carrier single engine failure (for multi-engine air vehicles) is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.6.6 Single engine failure (multi-engine air vehicles).

Standards for UAS shipboard operations are provided by the airworthiness authority.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.7 Launches and recoveries.

Criterion: Verify that launches and recoveries from any approved spot are safe.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.8 Wind envelopes.

Criterion: Verify that wind envelopes for all approved landing spots aboard ship are safe.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.9 Multi-aircraft vertical launch and recovery.

Criterion: Verify that multi-aircraft vertical launch and recovery operations at adjacent spots are safe.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.10 Visual cues.

Criterion: Verify that visual cues for both unassisted and night vision devices (NVD) are adequate for safe operations on all planned spots day and night.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.11 Airwake effects.

Criterion: Verify that airwake effects are safe for the planned operations aboard ship.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.12 Control law modes.

Criterion: Verify that all allowable control law modes are safe for the planned operations aboard ship.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.13 Run-on landings.

Criterion: Verify that run-on landings are safe.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.14 Pilot workload.

Criterion: Verify that pilot workload is not excessive for the planned operations and environments aboard ship.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.15 Ship motion limits for required operational sea states.

Criterion: Verify that ship motion limits for required operational sea states are safe for launch and recovery.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.16 Ship assisted recovery devices.

Criterion: Verify that ship assisted recovery devices are safe for ship recovery and traverse.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.17 Vertical replenishment/external slung loads.

Criterion: Verify that vertical replenishment/external slung load operations are safe to designated spots.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.10.18 Rotorcraft performance in ship motion/ship airwake conditions.

Criterion: Verify that rotorcraft performance is adequate for worst case combination ship motion/ship airwake conditions.

Standard: Provide piloted simulation, land-based flight test data, or analysis against historical standards to show this is safe. A logical and measured flight test build-up from benign to more stressing conditions may be allowable in lieu of this data.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11 Vertical/Short Takeoff and Landing (V/STOL) air vehicles.

***Criterion**:* Verify that V/STOL characteristics have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7 V/STOL specific requirements (see table XC for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.11.1 V/STOL operations.

Criterion: Verify that V/STOL operations are safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.1 V/STOL operations.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.1.1 Short takeoff (STO).

Criterion: Verify that short takeoff (STO) is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.1.1 Short takeoff (STO).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.1.2 Vertical takeoff (VTO).

Criterion: Verify that vertical takeoff (VTO) is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.1.2 Vertical takeoff

(VTO).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.1.3: Shipboard recovery pattern.

Criterion: Verify that V/STOL shipboard recovery pattern is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.1.3 Shipboard recovery pattern.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.1.4 Powered-lift landing.

Criterion: Verify that V/STOL powered-lift landing is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.1.4 Powered-lift landing.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.1.5 Hover.

Criterion: Verify that V/STOL hover is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.1.5 Hover.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.1.6 Vertical landing (VL).

Criterion: Verify that V/STOL vertical landing is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.1.6 Vertical landing (VL).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.1.7 Ground handling.

Criterion: Verify that V/STOL ground handling is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.1.7 Ground handling.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.1.8 Transition/conversion.

Criterion: Verify that V/STOL transition/conversion is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.1.8 Transition/Conversion.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.1.9 Hovering translation.

Criterion: Verify that V/STOL hovering translation is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.1.9 Hovering translation.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.2 V/STOL dynamic response.

Criterion*:* Verify that V/STOL dynamic response characteristics have been defined and assessed for safety of flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2 V/STOL dynamic response requirements.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.11.2.1 Flying qualities in hovering flight.

Criterion: Verify that V/STOL flying qualities in hover are safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2.1 Flying qualities in hovering flight.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.2.1.1 Pitch axis response in hovering flight.

Criterion: Verify that pitch axis response in hovering flight is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2.1.1 Pitch axis response in hovering flight (see table XCI for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.2.1.2 Roll axis response in hovering flight.

Criterion: Verify that roll axis response in hovering flight is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2.1.2 Roll axis response in hovering flight (see table XCII for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.2.1.3 Yaw axis response in hovering flight.

Criterion: Verify that yaw axis response in hovering flight is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2.1.3 Yaw axis response in hovering flight (see table XCIII for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.2.1.4 Vertical axis response in hovering flight.

Criterion: Verify safe vertical axis response in hovering flight.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2.1.4 Vertical axis response in hovering flight (see table XCIV for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.2.1.5 Longitudinal translation response in hovering flight.

Criterion: Verify that longitudinal translation response in hovering flight is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2.1.5 Longitudinal translation response in hovering flight (see table XCV for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.2.1.6 Lateral translation response in hovering flight.

Criterion: Verify that lateral translation response in hovering flight is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2.1.6 Lateral translation response in hovering flight (see table XCVI for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.2.1.7 Cross-axis coupling in hovering flight.

Criterion: Verify that cross-axis coupling in hovering flight is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2.1.7 Cross-axis coupling in hovering flight.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.2.1.8 Angular (moment-generating) control power in hovering flight.

Criterion: Verify that angular (moment-generating) control power in hovering flight is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2.1.8 Angular (moment-generating) control power in hovering flight (see table XCVII for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

6.1.11.2.2 Flying qualities in the transition region.

Criterion: Verify that V/STOL flying qualities in the transition region are safe

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.7.2.2 Flying qualities in the transition region.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, design, test, or configuration documentation.

Reference: MIL-STD-1797: 5.2.7.2.2 Flying qualities in the transition region

6.1.12 Characteristics of the primary flight control system.

6.1.12.1 Transfer to alternate control modes.

Criterion: Verify that transfer to and from alternate control modes is safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.8.1 Transfer to alternate control modes (see tables XCVIII and XCIX for guidance).

a. Automatic functions such as automatic ground collision avoidance systems (AGCAS), automatic air collision avoidance systems (AACAS), terrain following/terrain avoidance (TF/TA), automatic takeoff/landing, etc. are safe.
b. Pilot/operator over-ride transitions and commands, and autonomously directed maneuvers (e.g., collision avoidance, sense and avoid (SAA), air traffic control instruction) are safe.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.8 Transfer between Response-Types.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.12.2 Augmentation systems.

Criterion: Verify that the augmentation system is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.8.2 Augmentation systems.
b. 5.2.8.2.1 Rate of control surface displacement.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional Reference: 14 CFR 27; 27 Appendix B VII Stability Augmentation System (SAS)

6.1.12.3 Cockpit controller characteristics.

Criterion: Verify that the cockpit/control station controller characteristics are safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.8.3 Cockpit controller characteristics.
b. 5.2.8.3.1 Control force versus control deflection.
c. 5.2.8.3.2 Control centering.
d. 5.2.8.3.3 Control free play.
f. 5.2.8.3.4 Control displacement limits.
g. 5.2.8.3.5 Dynamic characteristics (see table C and CI for guidance).
h. 5.2.8.3.6 Control system damping.
i. 5.2.8.3.7 Direct force controllers.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.6 Controller characteristics.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.12.4 Displays and instruments.

Criterion: Verify that displays and instruments are safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.8.4 Displays and instruments.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Reference: MIL-STD-1797: 5.2.8.4 Displays and instruments.

6.1.13 Characteristics of secondary flight control systems.

6.1.13.1 Trim system.

Criterion: Verify that the trim system is safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.9.1 Trim system (see table CII for guidance).
b. 5.2.9.1.1 Trim system irreversibility.
c. 5.2.9.1.2 Rate of trim operation.
d. 5.2.9.1.3 Stalling of trim systems.
e. 5.2.9.1.4 Trim for asymmetric thrust (for multi-engine air vehicles).
f. 5.2.9.1.5 Automatic trim system.

For rotorcraft, the air vehicle meets standards within ADS-33-PRF, 3.6.6 Trimming characteristics.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.13.2 Operation of secondary control devices and in-flight configuration changes.

Criterion: Verify that operation of secondary control devices and in-flight configuration changes are safe.

Standard: The air vehicle meets the standards within the following MIL-STD-1797 paragraphs:

a. 5.2.9.2 Operation of secondary control devices and in-flight configuration changes.
b. 5.2.9.2.1 Pitch trim changes (see table CIII and CIV for guidance).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.13.3 Auxiliary dive recovery devices.

Criterion: Verify that auxiliary dive recovery devices are safe.

Standard: The air vehicle meets the standards within MIL-STD-1797, 5.2.9.3 Auxiliary dive recovery devices.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Reference: MIL-STD-1797: 5.2.9.3 Auxiliary dive recovery devices

6.1.14 Rotorcraft unique criteria.

6.1.14.1 Translational rate response-type.

Criterion: Verify that translational rate response in hover is safe.

Standard: The air vehicle meets the standards within ADS-33-PRF, 3.3.12 Translational Rate Response-Type.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.14.2 Response to collective controller.

Criterion: Verify that vertical axis response in hover is safe.

Standard: The air vehicle meets the standards within ADS-33-PRF, 3.3.10.1 Height Response Characteristics and 3.3.10.3 Vertical Axis Control Power.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.14.3 Equilibrium characteristics.

Criterion: Verify that hover in winds is safe.

Standard: The air vehicle meets the standards within ADS-33-PRF, 3.3.1 Equilibrium characteristics. The aircraft is safely controllable and maneuverable, with control margins not less than 10 percent, while hovering in winds from any azimuth up to the wind speed defined by the procuring activity.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 27.143 Controllability and maneuverability
14 CFR 29.143 Controllability and maneuverability

6.1.14.4 Position hold.

Criterion: Verify that position hold is safe.

Standard: The air vehicle meets the standards within ADS-33-PRF, 3.3.11 Position Hold.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.14.5 Rotor revolutions per minute (RPM) governing.

Criterion: Verify that rotor speed response is safe.

Standard: The air vehicle meets the standards within ADS-33-PRF, 3.3.10.4 Rotor RPM governing and 3.4.3.3 Rotor RPM governing.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.14.6 Torque response.

Criterion: Verify that engine torque response is safe.

Standard: The air vehicle meets the standards within ADS-33-PRF, 3.3.10.2 Torque response.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.14.7 Slope landing and takeoff characteristics.

Criterion: Verify that slope landing and takeoff characteristics are safe.

Standard: The air vehicle can safely perform vertical landings and takeoffs from surfaces with slope as specified by the procuring activity. Safe landings and takeoffs can be accomplished in all required orientations.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.14.8 Ground operation.

Criterion: Verify that ground operation characteristics are safe.

Standard: The air vehicle meets the standards within the following ADS-33-PRF paragraphs:

a. 3.9.1 Rotor start/stop.
b. 3.9.2 Parked position requirement.
c. 3.9.3 Wheeled rotorcraft ground requirements.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.14.9 External slung loads.

Criterion: Verify that carriage, release, and jettison of external loads are safe.

Standard: The air vehicle can safely perform external load operations and emergency jettisons throughout the defined external load envelope at the required operational conditions.

For jettison and failures, the air vehicle meets the standards within ADS-33-PRF, 3.10 Requirements for externally slung loads.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.14.10 Water landing.

Criterion: Verify that water landing characteristics are safe.

Standard: The air vehicle meets the standards within ADS-33-PRF, 3.9.4.1 Water landing requirement.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

6.1.14.11 Autorotation.

Criterion: Verify that autorotation characteristics are safe.

Standard: The air vehicle meets the standards within the following ADS-33-PRF paragraphs:

a. 3.4.5.1.3 Pitch control in autorotation.
b. 3.7.2 Engine failures.
c. 3.7.3 Loss of engine and/or electrical power.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and inspection of process, requirements, design, test, and configuration documentation.

Additional References: 14 CFR 27.143 Controllability and maneuverability
14 CFR 29.143 Controllability and maneuverability

6.1.15 Manuals.

Criterion: Verify that the Flight, Performance, and Operations Manuals, and any supplements, contain the air vehicle's operating limits and instructions (e.g., Cautions, Warnings, Advisories, Notes, Corrective Actions, etc.) to assure flight safety for all conditions, configurations, loadouts, etc.

Standard: The manuals accurately document/identify aircraft operating limits and emergency characteristics and procedures.

Method of Compliance: Review of the manuals verifies that the limits and emergency procedures documented are appropriate and adequate.

Reference: MIL-STD-1797 Guidance and Lessons Learned

6.2 Vehicle control functions (VCF).

References: JSSG-2008
MIL-STD-1797
ADS-33-PRF
ADS-51-HDBK
14 CFR 23: Aeronautics and Space, Part 23 – Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes
14 CFR 25: Aeronautics and Space, Part 25- Airworthiness Standards: Transport Category Airplanes
14 CFR 27: Aeronautics and Space, Part 25- Airworthiness Standards: Normal Category Rotorcraft
14 CFR 29: Aeronautics and Space, Part 25- Airworthiness Standards: Transport Category Rotorcraft

6.2.1 VCF architecture design.

6.2.1.1 Functional criteria.

Criterion: Verify the functional criteria to be safe.

Standard: The functional criteria are the requirements or other bases for establishing the parameters of the system. The VCF is a safety critical function that includes, but is not limited to control laws, auto control modes, aerodynamic control margins, computer resources including software, actuation, air data, inertia sensing feedback, Pilot Vehicle Interface (PVI), diagnostics, pre-flight, in-flight, and post-flight Built-In-Test (BIT). For Unmanned Aircraft Systems (UAS), VCF also includes control station interfaces required to safely control the vehicle. Any failure within the VCF and/or the integrated system is clearly identified and annunciated to the pilot/operator for corrective action to prevent loss of control or damage to the aircraft. The VCF also includes integration with all other subsystems required for safe operation of the aircraft. These subsystems include, but are not limited to hydraulics, Environmental Control System (ECS), Fuel Management System (FMS), Electrical Power System (EPS), avionics, propulsion, and Stores Management System (SMS). The safety criticality of VCF requires specific consideration for operational states, air vehicle performance, data latency, redundancy management, communications, displays, and Structural Mode Interaction (SMI).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Modeling and simulation is used to analyze and evaluate the VCF architecture. Testing of the VCF includes, but is not limited to component development, qualification, and Failure Modes and Effects Tests (FMET) or failure modes testing. System Integration Laboratory (SIL), Vehicle Integration Facility (VIF), and hardware in the loop (also known as Iron Bird (IB)) are used to verify and validate integration of VCF with all other subsystems. The primary focus of SIL, VIF and hardware in the loop testing is to evaluate the operation of VCF under normal and failed states. FMET, or failure modes testing, is a particularly critical part of system level testing. Prior to first flight, Ground Vibration Testing (GVT), Structural Mode Interaction (SMI), Electromagnetic interference (EMI), and on aircraft ground testing are completed to demonstrate safe operation of the VCF under all natural and induced environments.

References: JSSG-2008: 3.0 through 3.8; associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.1.2 High-level architecture function.

Criterion: Verify the VCF high-level architecture function to be safe.

Standard: Requirements are defined for architecture of vehicle control with other functions such as, but may not be limited to electrical power, hydraulics, avionics, inertial platforms, engines, and unique functions.

Safety critical functions are properly managed for redundancy and integration. Non-safety critical functions are identified and properly accounted. Functional separation exists for all components and functions that affect air vehicle control. Separation and isolation exist between critical and non-critical systems.

For normal operating conditions, the VCF control system has sufficient control power to maintain Level I flying qualities.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Testing of the VCF includes, but is not limited to component development, qualification, and FMET (failure modes testing). System Integration Laboratory (SIL), Vehicle Integration Facility (VIF), and hardware in the loop (also known as Iron Bird (IB)) are used to verify and validate integration of VCF with all other subsystems. The primary focus of SIL, VIF and hardware in the loop testing is to evaluate the operation of VCF under normal and failed states. FMET, or failure modes testing, is a particularly critical part of system level testing. Flying qualities analysis provides an assessment on the failure modes. Prior to first flight, Electromagnetic interference (EMI) and on aircraft ground testing are completed to demonstrate safe operation of the VCF and the integrated architecture under all natural and induced environments.

References: JSSG-2008: 3.1.7 through 3.1.7.3, and associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.1.3 Safety critical functions and components.

Criterion: Verify that the integrated VCF architecture safely implements the proper levels of redundancy, fault tolerance, and physical/functional separation of safety critical functions and components.

Standard: Safety critical functions are properly managed for redundancy and integration. Non-safety critical functions are identified and properly accounted. Functional separation exists for all components and functions that affect air vehicle control. Separation and isolation exist between critical and non-critical systems.

Each function is properly tested and examined (e.g., walk around, preflight, Built-In-Test (BIT), Periodic Built-In-Test (PBIT), Continuous Built-In-Test (CBIT), crew monitoring, flight test monitoring).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Analysis, SIL, VIF, hardware in the loop and flight tests validate redundancy management, fault detection and fault isolation. FMET, failure modes testing, is a particularly critical part of the tests. For flight safety testing, such as FMET, all various failure modes of hardware (including data buses) are tested for flight/safety critical or mission critical functions. Analysis and inspection of interface control and installation drawings show physical separation. Analysis and inspection of block diagrams show functional separation.

References: JSSG-2008: 3.0, 3.1, 3.1.11 through 3.1.12.1; associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.1.4 Integration of functions.

Criterion: Verify each function integrated in or by the VCF design is safe.

Standard: VCF functions are designed such that no failure external to VCF can propagate in and cause loss of control. Requirements are defined for redundancy and integration management for all vehicle control aspects. No single failure or dissimilar failure in the VCF results in any failure effect which may create significant in-flight hazards before a pilot/operator or safety device can take effective corrective action.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Verify that the following are provided as a minimum:

a. FMET (failure modes test) reports and analyses from SIL, VIF and hardware in the loop.
b. Hazard analysis for the air vehicle.
c. Fault Tree Analysis (FTA).

References: JSSG-2008: 3.1.1 through 3.1.4; associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.1.5 Failures.

Criterion: Verify that no single fail, dual fail, and special single fail/combination failure(s) in any VCF result in an unacceptable Probability of Loss of Control (PLOC).

Standard: Failure combinations and special failure states for the integrated architecture are defined by government-contractor agreement. No single failure, combination of single independent failures and failures of unique functions (e.g., flaps, speed brakes including single hard-over) may result in a departure or loss of control.

The probability of a common mode failure is extremely remote (1x10^-9 or as specified by the procuring activity) and is verified by fault tree and hazard analysis.

As a minimum, no single failure degrades VCF below Operational State I. No combination of dual failures degrades VCF below Operational State III. No combination of single or dual failures across multiple VCF subsystems degrades VCF below Operational State IV. Any likely dual failure or combination of single failures does not cause loss of control or any of the following:

a. Flutter, divergence, or other aero-elastic instabilities within the permissible flight envelope of the aircraft, or a structural damping coefficient for any critical flutter mode below the fail-safe stability limit of MIL-A-8870C.
b. Uncontrollable motions of the aircraft or maneuvers which exceed limit airframe loads.
c. Inability to land the aircraft safely.
d. Any asymmetric, unsynchronized, unusual operation or lack of operation of flight controls that results in worse than VCF Operational State IV.
e. Exceedance of the permissible flight envelope or inability to return to the service flight envelope.
f. VCF failures that could cause loss of total thrust.
g. Erroneous and misleading aircraft airspeed, altitude, attitude, Angle of Attack (AOA), or Angle of Sideslip (AOS) information displayed to the aircrew that could result in incorrect pilot/operator inputs to the VCF.

Method of Compliance: Verification methods for flight worthiness certification requirements include analysis, test, demonstration, simulation, inspection and review of documentation. SIL, VIF, FMET (failure mode tests) and hardware in the loop testing are also performed as a part of flight worthiness certification requirements.

References: JSSG-2008: 3.0, 4.0, 3.1, 4.1, 3.1.9, 4.1.9, 3.1.11 through 3.1.11.2, 4.1.11 through 4.1.11.2.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.1.6 Reliability and redundancy.

Criterion: Verify that the level of VCF redundancy and reliability are appropriate for the vehicle's size category and planned operational area/airspace.

Standard: If UAS are required to operate within the National Airspace System (NAS), the redundancy and reliability requirements are equal to or better than those of piloted air vehicles. For smaller UAS restricted to limited operating area, lower redundancy and reliability levels are assessed for acceptance or rejection by the procuring agency. To determine the acceptable levels of VCF redundancy and reliability, the cost of both UAS and collateral damage on the ground is considered.

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. VCF robustness including redundancy management and reliability is verified by analysis, component testing, and system level testing.

Reference: JSSG-2008

6.2.1.7 Probability of loss of aircraft (PLOA).

Criterion: Verify that PLOA requirements have been correctly allocated down to a design-controllable Probability of Loss of Control (PLOC) for the Vehicle Control Function (VCF) and that estimates and associated assumptions are adequately substantiated.

Standard: The procuring agency determines an acceptable PLOA. It is recommended to specify this requirement in the air vehicle/weapon system specification. Based on PLOA, the procuring agency determines the PLOC requirement is within the VCF specification.

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. The VCF robustness including redundancy management and reliability is verified by analysis, component testing, and system level testing. The PLOC and PLOA requirements are verified by analysis, such as a Fault Tree Analysis (FTA) or Reliability Block Diagram (RBD) representations. The contractor provides a complete system level analysis including verifiable reliability and failure rates. The contractor provides justifiable rationale for all assumptions included in the analysis. If historical reliability data is used, all pertinent information regarding the legacy system is provided to support applicability to the system under review.

Reference: JSSG-2008

6.2.1.8 In-line fault coverage.

Criterion: For systems providing only dual redundancy, verify that in-line fault coverage has been correctly assessed for PLOC calculations.

Standard: Dual redundant systems rely heavily on in-line fault monitoring where each channel monitors its own health and integrity and detects, isolates, and annunciates failures. The monitoring scheme is evaluated to assure 100% coverage for all critical failures resulting in loss of control. The in-line monitoring is robust enough to identify all actual safety critical failures and prevent false annunciations.

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. The dual redundant system is analyzed and tested in a SIL to validate that all safety critical failures are monitored, detected, isolated, mitigated, and annunciated to crew/ground controller. The results of the Built-In-Test (BIT) testing in the SIL are used to verify the coverage factor in the PLOC calculation due to in-line monitoring.

Dual redundant elements are considered to have a net reliability equal to p^2 + 2p(1-p)c where p is the reliability of a single element (typically e^(-lambda*t)) and c is the coverage factor ranging from zero to one.

Reference: JSSG-2008

6.2.1.9 UAS unrestricted operation

Criterion: For UAS operations in the National Airspace System (NAS), verify that the VCF will not degrade below Operational State I after any single failure.

Standard: For UAS operations within the NAS, the redundancy and reliability requirements are equal to or greater than piloted air vehicles. No single point failures within the integrated VCF cause degradation below Operational State I. The degraded VCF does not cause any instability or limit cycle oscillations preventing safe control and landing.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. The VCF after single failure is verified through simulation, software analysis, SIL, FMET (failure modes tests), and ground test, for both air vehicle and control station.

Reference: JSSG-2008

6.2.1.10 UAS degraded operation.

Criterion: For UAS operations in restricted airspace, warning areas, maritime environments, and combat zones, verify that the VCF will not degrade below Operational State III for single failures.

Standard: For UAS operations in restricted airspace, warning areas, maritime environments, and combat zones, the VCF is robust and provides a minimum Operational State III for any single failure. There are no instabilities or limit cycle oscillations after any single failure. No single failure within the integrated VCF causes degradation of the air vehicle system stability preventing safe control and landing.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. The VCF after single failure is verified through simulation, software analysis, SIL, FMET (failure modes tests), and ground test, for both air vehicle and control station.

Reference: JSSG-2008

6.2.2 VCF safety of design.

6.2.2.1 Safety protection functions and devices.

Criterion: Verify that safety protection functions/devices are safely implemented.

Standard: The VCF has a safety program compatible with the air vehicle system for the VCF development, integration, manufacturing, and maintenance.

The safety program defines that devices, procedures, or limitations implemented to accommodate failures do not cause loss of control/vehicle or pilot coupling. A single component failure is extremely remote (1x10^-9 or as specified by the procuring activity).

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation.

The VCF safety program is verified by ensuring the use of MIL-STD-882, applicable DoD, Air Force Occupational Safety and Health (AFOSH) and Occupational Safety and Health Agency (OSHA) standards/guidelines, checklists, and evaluation matrix criteria.

References: JSSG-2008: 3.1.5.3, 3.1.5.2, 3.1.5.4, 3.1.9, 3.1.11.1, 3.1.10, 3.1.11.1.1, 3.1.13 to 3.1.13.2, 3.1.16, 3.2.2.5.4.1, 3.2.4 through 3.2.4.6, associated section 4 paragraphs.

MIL-STD-882

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.2.2 Flight critical components.

Criterion: Verify that the VCF flight-critical components meet safety requirements.

Standard: The VCF flight-critical components meet requirements in MIL-STD-810 for all environmental conditions.

The VCF flight-critical components are designed without a single point failure. For applications where single point failures cannot be avoided analysis will be done to demonstrate that these single point failures are extremely remote ($1x10^{-9}$ or as specified by the procuring activity).

The assemblies, subassemblies, and item parts used within the VCF are capable of withstanding physical, induced, chemical, biological, and nuclear stresses.

As a minimum, sufficient testing (10% or 25% of cycles required for full qualification testing) is accomplished to demonstrate the aircraft is safe for flight.

Safety of Flight testing is accomplished for, but is not limited to, temperature, altitude, operating vibration, operating shock, EMI and requirements for electrical power quality and quantity.

Mechanical transmission devices (e.g., actuators) meet the design limit load conditions and provide a 50 percent structural margin

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. Safety requirements are verified through tests such as, but are not limited to, component level, system level, environmental, FMET (failure modes tests), on-aircraft and ground.

Physical characteristics are verified by inspection, analysis, tests of components, and drawings.

VCF design operational usage is verified by evaluation and correlation of flight test measured data to analytical simulations.

References: JSSG-2008: 3.1.11.1, 3.1.11.1.1, 3.1, 3.1.2, 3.1.5.5, 3.1.5.6, 3.1.7.3, 3.1.9, 3.1.11.4, 3.1.11.7, 3.1.12, 3.1.13.2, 3.1.14.4, 3.1.17, 3.2.2.2 through 3.2.2.2.13, 3.3.3, 3.4.2, 3.5.7, associated section 4 paragraphs.

MIL-STD-704

MIL-HDBK-704 (all sections, as applicable)

MIL-STD-810

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.2.3 Preflight checklists.

Criterion: Verify that preflight checklists of VCF are all-inclusive and safe.

Standard: Pre-flight test/diagnostics/redundancy/monitoring includes all test sequences required to determine the status of the VCF and integrated systems prior to take-off. The tests and checklists are safe for crew and the vehicle.

Initiated pre-flight and post-flight Built-In-Test (BIT) detects 100% of safety critical faults and at least 98% of all subsystem faults, with less than 1% false indications.

BIT does not rely on ground test equipment for successful completion. Interlocks are provided to prevent in-flight engagement and to terminate pre-flight BIT when the conditions for engagement no longer exist.

Test provisions include the capability for determining the integrity of sensors, electronics, and servo-systems through fault monitoring and fault isolation.

The overall tests performed (BIT, Visual Inspection (VI), Physical Parameter Measurement

(PPM)) contain the necessary specific tests to establish full VCF integrity.

Method of Compliance: Verification methods include analysis, ground test, flight test, integration tests (FMET, failure modes tests, and SIL), demonstration, inspection and review of documentation. These methods verify that the pre-flight checklist(s) provide proper functionality, are all-inclusive and safe.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.5, 3.1.13, 3.1.14 through 3.1.14.9, 3.1.15 through 3.1.18, 3.2.3 through 3.2.3.3, 3.4 through 3.5.2, 3.5.3, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.2.4 Loss of function.

Criterion: Verify the effects of loss of function(s) on safety.

Standard: Complete hazard analysis, Failure Modes, Effects and Criticality Analysis (FMECA) combined with Failure Modes and Effects Testing (FMET) establishes the effects of loss of function(s). Piloted evaluations demonstrate flying qualities of Level II or better for failures more likely than Probability of Loss of Control (PLOC) of 1x10^-7 or as specified by the procuring activity.

Separation/isolation/accommodation between internal and external VCF interfaces prevents propagated or common mode failures that are less than extremely remote (1x10^-9) or as specified by the procuring activity.

The VCF does not have any single failure, combination of functionally independent single failures, or multiple failures greater than Probability of Loss of Control (PLOC).

For UAS, in the event of unexpected loss or corruption of command link, the system will transition to a pre-determined and expected state and mode.

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. Quantitative flight safety requirements are verified by analysis considering all failure modes that threaten flight safety, whether single or combination of failures, and whether extremely remote or not.

Hazard analysis supported by Failure Modes, Effects and Criticality Analysis (FMECA) verifies that single point failures are less likely than 1x10^-9 per flight hour or as specified by the procuring activity.

Effects of loss of function(s) are verified through testing, such as FMET (failure modes tests), performed on an Iron Bird (IB) or high fidelity integration lab with all hardware and software in the loop.

Analyses of reliability, design integrity, and redundancy alone are not acceptable as the sole mitigation justification of these types of failure modes without understanding the complete system interaction.

Command and control communications are integrated safely with other linked vehicles and ground control, are secure against unwanted intrusions, safely implement security techniques, and that the data link is sufficient to support command and control and any additional bandwidth for payload data.

References: JSSG-2008: 3.0 through 3.3.8, 3.5.3, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.2.5 Functional modes and limiters.

Criterion: Verify that any functional modes do not defeat any limiters designed for vehicle safety.

Standard: The control law limiters protect the aircrew and air vehicle from unsafe flight regimes. The VCF incorporates structural, angle of attack, sideslip, data input rate, command, data input max and min, time, persistence, stale data, and other limiters/filters defined by the application at hand.

Each limiter used accomplishes the intended limiting without ever causing loss of the control function, a departure from controlled flight, loss of vehicle and/or aircrew for any condition throughout the entire flight and ground envelopes.

No VCF or integrating control function induces conditions that defeat control law limiters.

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. Analysis determines the limiters required, where in the control scheme they are used, and the conditions that need to be limited.

Hardware-In-The Loop (HITL) testing of each function or probable combinations of functions conducted at worst case limiting conditions verifies the adequacy of the limiter.

References: JSSG-2008: 3.0, 3.1, 3.1.5.2, 3.1.5.8, 3.1.5.9, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.11.2, 3.1.13.1, 3.1.13.3, 3.1.14, 3.1.14.7, 3.2.2.2.4, 3.2.2.2.5, 3.2.2.2.9, 3.2.2.2.11, 3.2.2.4, 3.2.2.5.1, 3.2.2.5.1.1 through 3.2.2.5.1.4, 3.2.2.5.4.1, 3.2.2.6, 3.3.2.1, 3.3.6.2, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.2.6 Failure mode and effects.

Criterion: Verify that failure mode effects for critical maneuvers and critical flight regions are safe.

Standard: The maximum acceptable loss of VCF is not greater than 1x10^-7, or as specified by the procuring activity.

Critical failure modes do not degrade performance below Operational State III resulting in aircraft loss.

Failure mode effects are considered in 1g trimmed flight and for critical maneuvers in all flight regions. The effects at these critical flight regimes do not cause loss of the air vehicle or aircrew.

Method of Compliance: Verification methods include analysis, test, simulation, and review of documentation. Fault Tree Analysis (FTA) is used to identify possible combinations of failure modes for critical maneuvers.

Failure mode effects are verified by Hardware-In-The Loop (HITL) testing of each function or probable combinations of functions conducted at critical flight regimes.

Reference: JSSG-2008: 3.0, 3.1, 3.1.5, 3.1.5.7, 3.1.5.8, 3.1.5.9, 3.1.9, 3.1.14, 3.2.1.3, 3.2.1.2, 3.2.2.2, 3.2.2.5, 3.2.2.5.4, 3.2.2.6, 3.3, associated section 4 paragraphs.

6.2.2.7 Environmental requirements.

Criterion: Verify that VCF equipment meets all environmental requirements as installed on the aircraft.

Standard: The VCF is designed to withstand the full range of natural and induced environment requirements established for the air vehicle without permanent degradation of performance below VCF Operational State I.

Natural environments include, but are not limited to, lightning, dielectric strength, sand and dust, fungus, extreme temperatures, humidity, corrosion, and icing.

Induced environments include, but are not limited to, Electromagnetic interference (EMI)/Electromagnetic Compatibility (EMC), fluctuating pressure, turbulent aerodynamic flow, acceleration, acoustic noise, vibration, shock, nuclear environment, and explosive atmosphere.

Method of Compliance: Verification methods for all natural and induced environmental requirements include analysis, test and review of documentation. Natural and induced environmental requirements are assessed by component hardware qualification testing and analysis using military and industry standards as defined by the procuring activity.

References: JSSG-2008: 3.1.14, 3.4, 3.5, associated section 4 paragraphs.

MIL-STD-810

MIL-STD-461

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.2.8 Emergency procedures.

Criterion: Verify that emergency procedures are safe and appropriate.

Standard: Development of VCF emergency procedures covers in-flight and ground failures. Emergency procedures are reviewed and coordinated with aircrew, maintainers, functional engineers and contractors.

The emergency procedures in the flight manuals (e.g., operator manuals) and ground operation manuals are clear and unambiguous concerning problems and associated corrective actions. Procedures are configuration controlled and no procedure is released without meeting the above requirements and verification.

Method of Compliance: Verification methods include analysis, test, demonstration, and review of documentation. Emergency procedures are verified by engineers, aircrew, maintainers and contractors for completeness and accuracy. Verification is accomplished through FMET (failure mode tests), SIL, and testing in a functional mockup or ground testing on the actual aircraft with the aircrew and ground personnel.

6.2.2.9 Flight termination system.

Criterion: If the Flight Termination System (FTS) utilizes the flight control system, verify that the probability of an erroneous termination command is at least one hundred times less likely than PLOC and is included in the PLOC calculations.

Standard: The procuring agency determines an acceptable Probability of Loss of Control (PLOC) for the flight control system and states this in the flight control system specification. All factors contributing to PLOC are design controllable and verifiable through analysis.

If the FTS utilizes the flight control system, safety provisions and interlocks are included to prevent an erroneous command from the FTS to the flight control system. These safety provisions and interlocks are redundant and robust to assure that the probability of erroneous FTS command to the flight control system is at least one hundred times less likely than PLOC. No single point failure in the FTS/flight control system causes unintentional activation of flight termination.

Method of Compliance: Verification methods include analysis, test, demonstration, and review of documentation. The FTS/flight control system is analyzed and tested in a SIL for normal and failed conditions. The FTS is ground tested to demonstrate that the system can safely execute the intended termination function. The probability of receiving an erroneous termination command is verified by Failure Modes and Effects Criticality Analysis (FMECA).

References: JSSG-2008

6.2.3 VCF actuator safety.

6.2.3.1 Redundancy management.

Criterion: Verify that the actuator redundancy management meets the necessary requirements and is safe for operation during flight.

Standard: Actuator redundancy requirements meet the handling qualities and flight safety probability requirements for the appropriate operational states.

Switching between redundant functions based on failure detection and isolation does not cause a disruption which could jeopardize the air vehicle or aircrew.

For cases where there are two or more actuators per control element, there is no force fight between actuators that would degrade air vehicle performance or damage/deform structure.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Actuator redundancy is verified by failure analyses, and actual hardware/software in-the-loop FMET (failure modes test). Redundancy includes detection, isolation and corrective action, as well as preventing propagation of failures.

References: JSSG-2008

6.2.3.2 Failure detection and isolation.

Criterion: Verify that the VCF actuation failure detection and isolation design is safe.

Standard: Separation and isolation are provided for the VCF actuation to ensure that the probability of propagated or common mode failure is extremely remote (1x10^-9) or as specified by the procuring activity.

Actuator combinations of redundancy and integration management are monitored, conditioned, and transmitted at a sufficient rate for Pilot Vehicle Interface (PVI) display requirements.

A combination of a single hydraulic and single actuator failure does not reduce VCF performance below Operational State III.

Actuator failure detection and isolation design addresses redundant servos and techniques for all single point failures. Actuator design accounts for hydraulic contamination effects, valve shearing force, or any other contaminations.

Switching between redundant functions based on failure detection and isolation does not cause a disruption which would jeopardize the air vehicle or aircrew.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. Actuator failure testing is done to the lowest Line Replaceable Unit (LRU)/Line Replaceable Module (LRM). Hardware-In-The-Loop (HITL) FMET (failure modes tests) verifies failure detection, isolation and accommodation. A HITL and/or Iron Bird (IB) facility that integrates VCF control hardware with air vehicle subsystems (e.g., hydraulics and electrical power) provides a high fidelity facility to develop, integrate, and test the aircraft as a total system.

Stability of the actuation system is verified by a combination of simulation and laboratory testing of individual components. Failure Modes and Effect Analysis (FMEA) is used to verify and assess failure scenarios and probabilities.

References: JSSG-2008

6.2.3.3 Hydraulic contamination.

Criterion: Verify that VCF actuation design is not susceptible to hydraulic contamination effects and does not cause loss of actuation with subsequent loss of control.

Standard: Actuation provides protection from hydraulic contamination due to the largest particle able to block or wedge an actuation spool in the smallest passage. Hydraulic contamination does not contribute to cavitation.

Actuation continues to operate with hydraulic contamination and is able to chip shear the largest particle that could pass through the hydraulic system filtration (see also 8.1).

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation (see also 8.1).

References: JSSG-2008
MIL-HDBK-516: 8.1

6.2.3.4 Bottoming and snubbing.

Criterion: Verify that actuator bottoming is prevented and actuator snubbing is designed within tolerable limits.

Standard: Bottoming of any valve or ram is designed out.

The actuator is capable of withstanding bottoming loads in the event of misrigging.

Actuation system operates at controllable speeds with sufficient control in the actuator to prevent structural damage. Snubbers are useful in high load and fast velocity actuators to prevent damage to the housing of the actuator. Snubbing can also be accomplished by reducing the outlet flow area, which dampens the actuator from the end of travel.

The VCF provides electronic or mechanical snubbing at 5% of overall travel of the actuator.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Bottoming loads and load limitations are verified by analysis and inspection.

Snubbing is verified by Hardware-In-The-Loop (HITL), Iron Bird (IB) and aircraft analysis and test.

References: JSSG-2008

6.2.3.5 Environmental requirements.

Criterion: Verify that the VCF actuation system is safe for normal performance, pressure impulses, and burst pressure for both high and low temperatures (see also 8.1).

Standard: The VCF actuation is designed to withstand the full range of natural environment extremes established for the vehicle without permanent degradation of performance below VCF Operational State I.

The probability of any single point failure within the actuation system that can result in catastrophic failure is extremely remote, 1x10^-9 or as specified by the procuring activity.

Both linear and rotary actuators meet the following:

a. Materials used in friction, bearing, or wear out components, withstand the operating and environmental temperature range.
b. In the event of a catastrophic failure, Operational State III is maintained at a minimum. This is achieved by detection and isolation of the failure, prevention of runaways, and reversion to a fail-safe mode such as damped bypass, powered to a neutral position or locked in the failed position. The control laws are reconfigured to use aerodynamic control power from the remaining operative surfaces to override control moments generated by the failed actuator.
c. Limit load is 1.5 times the normal load and ultimate load is at least 2 times the normal load.
d. Backlash accumulation and hysteresis do not exceed a total of 1 degree when measured at the surface.
e. Steady state and variable loads do not produce buffeting.
f. Pre-flight, post-flight, and in-flight built-in-test and monitoring are provided for integrity.
g. Failure detection and reconfiguration time is less than or equal to 100 milliseconds.
h. Full operation after two (2) electronic failures and one (1) hydraulic/pneumatic failure.
i. Minimum stability margins for any actuator loop closure, at the worst-case tolerance and operating conditions, meets gain margin of 6 dB and phase margin of 45 degrees.
j. Bandwidth with no buzz or coupling to the first or second fuselage bending modes and the first wing bending mode.
k. Actuator hysteresis, feedback tracking, and linearity meet VCF performance requirements.
l. Anti-cavitation protection (for hydraulic actuators).
m. Excitation of flutter modes prevention.
n. Internal or external leakage meets the allocation as specified by hydraulic Interface Control Document (ICD) (for hydraulic actuators).
o. Self-cleaning of rods to prevent seal contamination (for hydraulic actuators).

Electrically powered actuators, including electro-hydrostatic actuators and electro-mechanical actuation used to actuate relatively low-duty cycle (e.g., trim, spoiler) require specific approval from the procuring activity before use in flight/safety critical applications.

Actuators may have special feedback features in the design such as delta pressure or velocity sensors to enable the VCF to maintain stability. The interface between actuation system, support structure, control, control surface stops, control surface gust protection, control surface locks, and control surface flutter are accounted for in VCF stability margins.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Supplier Safety of Flight (SOF) test reports verify that the VCF actuation system meets all environmental requirements including but not limited to low pressure, low/high temperature, temperature-altitude, temperature shock, and vibration test. Hardware-In-The-Loop (HITL), Vehicle Integration Facility (VIF), and Iron Bird (IB) testing including FMET (failure modes and effects testing) verify that the VCF actuation system is safe (see also 8.1).

References: JSSG-2008: 3.0, 3.1, 3.1.5.6, 3.1.14.1, 3.1.14.3, 3.2.2.1, associated section 4 paragraphs.

MIL-HDBK-516: 8.1

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.3.6 Motor/torque tube driven and rotary actuators.

Criterion: Verify that motor/torque tube driven and rotary actuators are safe (e.g., performance, implementation, and redundancy management) (see also 8.1).

Standard: The probability of loss of the motor/torque tube driven control actuation mechanisms is extremely remote 1x10^-9 or as specified by the procuring activity.

The VCF control actuators are designed in accordance with the required static and dynamic stiffness to prevent flutter. After loss of hydraulic or electrical power, the actuator and feedback components do not experience flutter or any other instability anywhere in the flight envelope.

The motor/torque actuation mechanisms redundancy requirements meet all the handling qualities and Safety of Flight (SOF) requirements.

Actuators are susceptible to numerous and various types of failures induced by environmental contamination. Examples include, but are not limited to: sand and dust that grind screw actuators, and icing which prevents screw jacks from working.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Supplier Safety of Flight (SOF) test reports verify that the motor/torque tube driven and rotary actuators meet all environmental requirements including but not limited to low pressure, low/high temperature, temperature-altitude, temperature shock, and vibration test . Hardware-In-The-Loop (HITL), Vehicle Integration Facility (VIF), and Iron Bird (IB) testing including FMET (failure modes and effects testing) verify that the motor/torque tube driven and rotary actuators are safe (see also 8.1).

References: JSSG-2008: 3.0, 3.1, 3.1.5.6, 3.1.5.7, 3.1.9, 3.1.11, 3.1.11.1, 3.1.11.1.1, 3.1.12, 3.1.14.1, 3.1.14.3, 3.2.2.1, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.3.7 Surface rate, hinge moment and stiffness.

Criterion: Verify that the VCF actuation system meets surface rate, hinge moment and stiffness requirements under normal and failed conditions.

Standard: Under the most adverse flight, environmental, and load conditions, no actuator hinge moment degradation or blow back causes departure from controlled flight, loss of control, or pilot coupling.

Control surface rates are adequate to meet VCF gain and phase margin; prevent pilot-in-the-loop oscillations (PIOs); support dynamic control surface stiffness; and preclude structural coupling, aero-elastic coupling, and flutter.

The characteristics of the backup hydraulic power system define the flight limitations, the adequacy of "switch-over" time constants, and the static and dynamic hinge moment stiffness.

Method of Compliance: Verification methods include analysis, simulation, test, and review of documentation. The VCF surface rate and hinge moment are verified by analysis, simulation, pilot-in-the-loop (PITL), HITL, SIL, Iron Bird (IB), and ground testing.

Pilot-in-the-loop (PITL) simulations, HITL, SIL, and Iron Bird (IB) testing verify that the hydraulic and actuator sizing is adequate for all probable combinations of operational states and hydraulic failure modes. With the primary hydraulic system, flying qualities are Level I with no hydraulic system or actuator saturation. With the backup hydraulic system, Operational State III or better is maintained.

VCF actuation system stiffness requirements are validated by test.

References: JSSG-2008: 3.1.5.6 through 3.1.5.7, 3.2.2.1, 3.2.1, 3.2.1.1, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.3.8 Physical constraints.

Criterion: Verify that each flight control actuator is adequately constrained to limit the range of motion.

Standard: The flight control actuator mechanical stop is designed for (as applicable) a maximum angular travel, a maximum linear travel, a maximum unloaded rate, maximum loaded rate and a nominal unloaded speed, a maximum output force when stalled, and a maximum hinge moment when surface has stalled.

The actuator mechanical stop is capable of withstanding maximum loads in the event of miss-rigging.

The VCF provides electronic or mechanical snubbing at 5% of stop-to-stop travel.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Bottoming, load limitations and snubbing are verified by analysis and test.

References: JSSG-2008

6.2.4 VCF air data safety.

6.2.4.1 Accuracy and tolerances.

Criterion: Verify that the accuracy and tolerances of the air data system are safe especially for sensitivities with variations in slope and bias conditions.

Standard: Air data accuracy and tolerances are evaluated for: dynamic pressure, static pressure, altitude, angle of attack, angle of side slip, and Mach number. These air data systems establish an anticipated range of gain and phase errors which exist between predictions and flight test. The air data system parameters are repeatable within acceptable tolerances.

The required accuracy is appropriate for safe operation of the VCF and has 10% margin for adverse effects.

Accuracy analysis considers scaling, nonlinearity, higher order dynamics, resolution, lag, latency, manufacturing tolerances, aging, wear, maintenance, and any other parameters such as voting thresholds that affect overall accuracy.

Areas to consider for air data system errors and failures may include, but are not limited to:

a. Noise on air data signals.
b. Calibration table errors in slope and bias.
c. Blockages in pneumatic lines or total and static pressure ports.
d. Total system performance tolerance.
e. Intermittent signal failures (especially failures of duration shorter than the persistence counter).
f. Lags - pneumatic, sensor, computational, electrical.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. Air data sensitivities, accuracy, and performance are verified by modeling, analysis, simulation, wind tunnels, ground, and flight test. Flight test includes comparison of flight test boom data with the aircraft air data system to validate accuracy and performance.

References: JSSG-2008: 3.0, 3.1, 3.1.2.1, 3.1.5, 3.1.5.7, 3.1.7, 3.1.7.2, 3.1.7.3, 3.1.11.4, 3.1.11.6, 3.1.17, 3.2.1.1, 3.2.1.2, 3.2.2.4, 3.2.2.5, 3.2.2.5.4.4, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.4.2 Integration.

Criterion: Verify safe integration of air data sensors with VCF.

Standard: The VCF air data architecture provides control scheduling/inputs for all tasks throughout the flight envelope and provides sufficient processing, memory, and data communications capability to meet the requirements for the VCF integrated functions (e.g., navigation, engines, displays, and Stores Management System (SMS)), both internal and external to the VCF.

Air data parameters from any single source or combination of sources are transmitted only after verification of accuracy.

The air data function supports:

a. Pre-flight, in-flight and post-flight built-in-test (BIT).
b. Redundancy and fault tolerance – Fail-operational/fail-operational/fail-safe capability.

Method of Compliance: Verification methods for control functionality and performance of the integration of the air data with the VCF include analysis, test (FMET (failure modes and effects testing), ground and flight), simulation, demonstration and review of documentation.

Verification methods for air data communication include Hardware-In-The Loop (HITL) tests such as FMET.

References: JSSG-2008: 3.0, 3.1, 3.1.2.1, 3.1.7, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.13.4, 3.1.17, 3.2.2.2.12, 3.2.2.4, 3.2.2.5.2, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.4.3 Ground provisions.

Criterion: Verify that ground provisions are safe.

Standard: The air data ground safety provisions are the following:

a. Allow ground checkout prior to flight for functionality.
b. Have protection from the elements.
c. Have protection for the crew when the heaters are on such as display notification, ground panel display notification, and circuit breaker protection.
d. Allow for maintenance fault isolation to the individual probe level.
e. Specific ground handling procedures to prevent any damage to the probes.

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, inspection and review of documentation. VCF air data fault isolation is verified by analysis, inspection, Hardware-In-The Loop (HITL) test to include FMET and ground test.

Reference: JSSG-2008: 3.1.14, 3.1.14.1, 3.1.14.2, 3.1.14.2.4, 3.1.14.3, 3.1.14.5, 3.1.14.7, 3.2.2.4, 3.2.6.7, associated section 4 paragraphs.

6.2.4.4 Ice prevention.

Criterion: Verify that ice prevention measures are safe.

Standard: Air data ice prevention is provided by heaters. This protection is provided wherever the probes/sensors are located. Design does not allow the entrapment of moisture that can result in the formation of ice. Built-In-Test (BIT) determines the health of the air data ice prevention components. Redundancy in ice prevention, including power sources, is provided to meet air data system requirements on safe integration with VCF (see 6.2.4.2, this document).

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. The VCF air data ice prevention functions are verified through test including FMET, ground, and flight tests for the anticipated environments.

References: JSSG-2008: 3.1, 3.1.11.6, 3.1.11.11.2, 3.1.14.1, 3.1.14.2.5, 3.1.14.7, 3.2.2.4, associated section 4 paragraphs.

14 CFR 23.775, 23.1189, 23.1323, 23.1325, 23.1416, 23.1419, 25.21, 25.207, 25.1323, 25.1325, 25.1419, 27.1323, 27.1325, 27.1419, 29.773, 29.1189, 29.1323, 29.1325, 29.1419.

6.2.4.5 Safety provisions.

Criterion: Verify that there are adequate provisions for in-flight safety of the air data system.

Standard: The air data system provides the following in-flight safety provisions:

a. In-flight monitoring of the air data health and integrity is annunciated to the operator/crew.
b. Mitigation or accommodation for shorting or opening of power wires that removes electrical power.
c. Mitigation or accommodation for loss of the mounting structure such as a radome that takes out more than one (1) probe at a time.
d. Alternate methods for air data to compensate for loss of air data.
e. Provisions to handle possible bird strikes.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. The VCF in-flight safety provisions are verified through simulation, systems analysis, HITL, FMET, ground, and flight tests.

References: JSSG-2008: 3.1.14.9, 3.2.2.4, associated section 4 paragraphs.

14 CFR 23.775, 23.901, 23.1323, 25.571, 25.631, 25.773, 25.775, 25.1323, 29.631.

6.2.5 VCF control law safety.

6.2.5.1 Flight envelope.

Criterion: Verify that the VCF control laws are safe throughout the entire flight envelope.

Standard: The VCF control laws provide longitudinal, lateral-directional, lift, drag, performance limiting, and variable geometry control (if applicable) that meet flying qualities Level I throughout the entire envelope. The VCF control laws provide a phase and gain margin of at least 45 degrees and 6 dB for the entire flight envelope.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. The VCF control laws are analyzed and evaluated through an off-line quantitative analysis and a 6 degrees of freedom (DOF) simulation. The safety and adequacy of the VCF control laws are verified in a Handling Qualities Simulator (HQSim) or a SIL.

Analysis, simulation, and integrated testing verify that the VCF provides adequate and redundant control power to provide safe stability and control. This verification demonstrates the adequacy of the cockpit controls and control surface responses, overshoot, and surface saturation throughout the flight envelope.

References: JSSG-2008: 3.1, 3.1.5.2, 3.1.5.3, 3.1.5.5, 3.1.5.7, 3.1.8, 3.1.11.6, 3.1.11.8, 3.1.13, 3.1.14.8, 3.1.16, 3.1.17, 3.1.18, 3.2.1 through 3.2.1.4, 3.2.2.1, 3.2.2.4, 3.2.2.5.2, 3.2.2.5.4 through 3.2.2.5.4.5, 3.2.2.6, 3.3.1, 3.3.4, 3.3.5, 3.3.7 , associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.5.2 Nonlinearities.

Criterion: Verify that VCF control law nonlinearities are safe.

Standard: Nonlinearities within the integrated system (e.g., mechanical, electrical, hydraulic, digital, and analog interfaces) as well as computational paths nonlinearities as an aggregate cannot induce a departure from controlled flight, loss of control, or Pilot-in-the-loop oscillation (PIO).

The VCF should have gain margins no worse than 6 dB and the phase margin no worse than 45 degrees throughout the entire flight envelope.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. Analysis and simulation verify the stability gain and phase margins to ensure safe system operation, both in the linear and nonlinear ranges. Hardware-in-the-Loop (HITL) testing identifies system nonlinearities and verifies safe operation. Ground and flight tests results verify safe VCF operation throughout the flight envelope.

References: JSSG-2008: 3.2.2.5.4 through 3.2.2.5.4.5, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.5.3 Transients.

Criterion: For both normal and failed conditions, verify that control law transients for normal gain and mode changes are safe.

Standard: In general for manned aircrafts, transients limits for mode transitions is 0.05 g normal or lateral acceleration and between 1 to 5 degrees per second roll rate (with a recommendation of 3 degrees per second) at the pilot station and 5 degrees of sideslip for a period of 2 seconds. The cockpit control for pitch, roll, and yaw should not exceed 20, 10, and 10 lbs respectively.

For unmanned aircrafts, transients are contained to preclude loss of control, damage to equipment, excitement of structural modes, or interruption of mission task.

Separation, isolation, and redundancy of the control laws is provided between VCF and integrated systems to make the probability of propagation of common mode failure extremely remote (1x10^-9) or as specified by the procuring activity.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. For nominal and worst case flight conditions, analyses and tests for control law transient margins are verified by offline simulation, Handling Qualities Simulator (HQSim), SIL, FMET, hardware/software in the loop, ground, and flight tests.

References: JSSG-2008: 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.5, 3.1.5.1, 3.1.5.2, 3.1.5.4, 3.1.5.5, 3.1.5.7, 3.1.5.8, 3.1.7, 3.1.7.2, 3.1.7.3, 3.1.9, 3.1.10, 3.1.11, 3.1.11.2, 3.1.11.4, 3.1.11.5, 3.1.11.6, 3.1.11.9, 3.1.11.10, 3.1.11.11.2, 3.1.11.11.3, 3.1.12, 3.1.12.1, 3.1.13.1, 3.1.13.2, 3.1.14.2.2, 3.1.14.2.4, 3.2.2.1, 3.2.2.2, 3.2.2.5, 3.3 through 3.3.4, 3.3.6, 3.3.6.2, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

6.2.5.4 Redundancy and failure management.

Criterion: Verify that control law redundancy and failure management are safe for detected, undetected, latent, or unannounced failures.

Standard: Within the flight envelope, no single failure or single failure combination in the VCF, which is not extremely remote, produces any uncontrollable condition.

For Operational State I or II (after failure): For manned aircraft, there is no more than ±0.5g incremental normal or lateral acceleration at the pilot’s station and ±10 degrees per second roll rate. For all aircraft, stall Angle of Attack (AOA) or structural limits are not exceeded under any conditions. For tasks requiring tight control of spatial position, vertical or lateral excursions limits are less than or equal to 5 ft and ±2 degrees bank angle or as specified by the procuring activity.

For Operational State III (after failure): No dangerous attitude or structural limits are reached, and no dangerous alteration of the flight path results from which recovery is impossible.

No instability, limit cycle oscillations or worse than Level II flying qualities are allowed for undetected, latent or unannounced failures. No undetected, latent or unannounced failures are allowed in critical control modes.

Undetected, latent, or unannounced failures are those failures which cannot be identified by Initiated Built-In-Test (IBIT) or Periodic Built-In-Test (PBIT) and are not easily inspected prior to flight.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. Redundancy and failure management are verified by off-line and pilot-in-the loop (PITL) simulation, SIL, FMET, HITL and ground tests.

References: JSSG-2008: 3.0, 3.1, 3.1.1, 3.1.2, 3.1.2.1, 3.1.4, 3.1.5.5, 3.1.5.7, 3.1.7, 3.1.7.2, 3.1.8, 3.1.9, 3.1.10, 3.1.11, 3.1.11.2, 3.11.5, 3.1.11.6, 3.1.11.7, 3.1.12, 3.1.12.1, 3.1.13.1, 3.1.17, 3.2.2.4, 3.2.2.5, 3.2.2.5.1.4, 3.2.2.5.4, 3.2.5.2, 3.3.1, 3.3.2, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.5.5 Aerodynamic and air data uncertainty.

Criterion: Verify that the control law sensitivity to aerodynamic and air data uncertainty is safe for all flight phases.

Standard: Sensitivity analysis varies key system parameters affecting aircraft stability and control to demonstrate design robustness. At all conditions analyzed, vehicle stability will be shown to be positive with at least Level III flying qualities. Key stability derivatives are varied by 25 percent in the most adverse direction. Sensitivity analyses include representations of errors which exist due to nonlinear and higher order dynamics.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. Stability margins are verified by analysis, modeling, simulation and test.

References: JSSG-2008: 3.0, 3.1, 3.1.5, 3.1.5.7, 3.1.5.8, 3.1.5.9, 3.1.7.2, 3.1.7.3, 3.1.11.2, 3.1.11.10, 3.1.11.11.1, 3.1.17, 3.2.2.1, 3.2.2.2.9, 3.2.2.5.4, 3.2.2.5.4.2, 3.2.2.5.4.3, 3.2.2.5.4.4, 3.2.2.6, 3.3.2.1, 3.3.4, 3.5, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.5.6 Time delays.

Criterion: Verify that the VCF time delays are safe.

Standard: Time delays are measured from the instant a controller input is provided to the time the desired response is attained. This sum total delay allowed (to include, but not limited to, data transfer and update rates) is 100 milliseconds for Level I flying qualities in the applicable axis of control. Limits on effective time delay apply to the open loop airplane response which includes aerodynamic and aero-elastic influences. Iteration and sampling rates for the VCF functions are compatible with the control law iteration rates and provide sufficient sampling ability.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. Verification by analysis, modeling, simulation, and flight test verifies the allocated time delay limits.

References: JSSG-2008: 3.0, 3.1, 3.1.5.1, 3.1.5.5, 3.1.5.6, 3.1.7.3, 3.1.17, 3.3.2.1, 3.3.4, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.5.7 Autonomous modes.

Criterion: Verify that the autonomous modes within the VCF are safe.

Standard: Every function within the autonomous mode is analyzed and tested for both normal and failed conditions. PLOC includes loss of control failures in autonomous modes. No single point failure within the integrated system of the autonomous mode causes loss of control. If ground-controlled mode exists as a backup, no dual failure of any combination prevents the air vehicle from switching from autonomous to ground-controlled mode.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. The VCF autonomous modes are verified by analysis, simulations, SIL and flight tests. This includes FMET for full functionality, and flight testing to identify operational capabilities and limitations.

Reference: JSSG-2008

6.2.6 VCF pilot vehicle interface (PVI) safety.

6.2.6.1 Crew commands.

Criterion: Verify that the VCF transmits, generates and/or conveys crew control commands safely for the entire range of vehicle and crew responses.

Standard: Operator commands, including manual overrides and engineering test commands, are implemented such that the air vehicle response is predictable and controllable under normal conditions and failure conditions that are not extremely remote. Effects of lost or corrupt messages do not affect safety of flight. Mechanical/analog/electrical component functional characteristics are defined and do not induce a departure or loss of control.

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, inspection and review of documentation. VCF command control elements are verified by inspection, test, integration testing, simulation and demonstration.

References: JSSG-2008: 3.1.1, 3.1.11.10, 3.1.11.11 through 3.1.11.11.4, 3.2.2 through 3.2.2.5.4, associated section 4 paragraphs.
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.6.2 Functional characteristics.

Criterion: Verify that functional characteristics of friction levels, breakout forces, dead zones, hysteresis, and backlash are safe.

Standard: Functional characteristics of friction levels, breakout forces, dead zones, hysteresis, and backlash do not induce a failure or loss of control or a departure and that the combined probability of these items producing a failure is extremely remote (1x10^-9 or as specified by the procuring activity).

Non-linear characteristics are properly accounted for in the design, math models, simulations or emulations.

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, inspection and review of documentation. Characteristics are verified at a cockpit/operator evaluation facility, a handling qualities simulation facility or a SIL, and on-aircraft ground test.

References: JSSG-2008: 3.0, 3.2.2.5.1.1, associated section 4 paragraphs.
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.152.

6.2.6.3 Cockpit/operator control forces.

Criterion: Verify that the cockpit/operator control forces are safe for any control mechanization.

Standard: Cockpit/operator control forces including trim for all axes meet the anticipated mission and flight condition with no obstructed movement for the crew.

Probability of aircraft loss due to Pilot Vehicle Interface (PVI) failure is no greater than 1x10^-8 (one order of magnitude less than PLOC) or as specified by the procuring activity.

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, inspection and review of documentation. Characteristics are verified at a cockpit/operator evaluation facility, a handling qualities simulation facility or a SIL, on-aircraft ground test, and flight test.

References: JSSG-2008: 3.2.2.3, 3.2.2.5.1, 3.2.2.5.1.1, 3.2.2.5.1.3, associated section 4 paragraphs.
14 CFR 23.779, 25.779, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.6.4 Ratio changers and artificial feel devices.

Criterion: Verify that ratio changers and artificial feel devices are safely implemented.

Standard: The ratio changers are implemented in mechanical systems, provide feedback to the pilot and in case of failure, remain engaged in a safe position.

Any artificial feel device with adjustable features does not produce departure, loss of control or pilot coupling.

Any loss of artificial feel function is recoverable with Level II flying quality or better.

Units, components, and parts which transmit control commands mechanically meet design limit conditions and have 50% margin over the nominal design loads.

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, inspection and review of documentation. Characteristics are verified at a cockpit/operator evaluation facility, a handling qualities simulation facility or a SIL, on-aircraft ground test, and flight test. In addition, FMET verifies system robustness.

References: JSSG-2008: 3.0, 3.1.7.2, 3.1.11.11, 3.1.11.11.1, 3.1.12.1, 3.1.14.4, associated section 4 paragraphs.
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.6.5 Warning, caution, and advisory functions.

Criterion: Verify that warning, caution, and advisory functions safely operate and properly notify the crew.

Standard: The warning, caution and advisory system provides the crew with adequate information in a timely manner to minimize workload, take appropriate actions, maintain acceptable flying qualities, and retain situational awareness.

The VCF displays, panels, annunciators, switches and indicators provide positive unambiguous state/status information, problem recognition, and corrective action to the crew.

The warning, caution and advisory functions of the VCF are able to identify the most probable cause of multiple failures occurring simultaneously, and lead the crew to implement safe corrective action.

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. The warning, caution and advisory functions/devices are verified by inspection, simulation, and ground testing. Test cases include multiple failures occurring simultaneously. In addition, SIL testing, including FMET, verifies that the system has been properly implemented.

References: JSSG-2008: 3.0, 3.1, 3.1.11.10, 3.1.13.4, 3.1.17, 3.2.2.2.7, 3.2.2.5.1.2, 3.2.2.5.1.4, associated section 4 paragraphs.
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.7 VCF integrated systems safety.

6.2.7.1 Control surface positions.

Criterion: Verify that the vehicle control system is able to obtain the maximum required control surface positions without mechanical interference or jamming situations.

Standard: Under the most adverse flight, manufacturing, environmental, and load conditions control surface positions are attained without mechanical interference from the structure or surrounding devices.

Degradation in VCF operation due to anticipated and delineated environments are within specified limits. System design supports the ability to command the actuators to the full range of surface positions taking into account any possible rigging or installation bias.

Probability of aircraft loss due to unsafe mechanical interference or jamming is extremely remote (1x10^-9 or as specified by the procuring activity).

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Verification of free movement of the mechanical components is accomplished by analysis and inspection. Ground testing of the actual installation verifies nominal clearance while analysis accounts for manufacturing, environmental, and flight conditions.

References: JSSG-2008: 3.0, 3.1.11.11, 3.1.11.11.1, 3.1.14, 3.2.1 through 3.2.1.4, 3.2.2.1, 3.2.2.5 through 3.2.2.5.1.1, 3.2.3, 3.5.7, associated section 4 paragraphs.
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.7.2 Intermittent devices.

Criterion: Verify that control devices used intermittently are safe in both normal and failed conditions (e.g., trailing edge flaps, leading edge flaps, speed brakes, geometry mechanisms).

Standard: Failure of control devices that operate intermittently, including latent failures, do not cause loss of control or cause pilot-in-the loop oscillations (PIO), and meet requirements for failure immunity and fault tolerance.

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. Adequate control is verified by analysis and integrated test.

Failure mode effects are verified by using Iron Bird/SIL, simulation, and ground testing as a part of Development Test & Evaluation (DT&E).

Redundancy management and failure immunity requirements are verified by appropriate analysis, simulation, and FMET.

References: JSSG-2008: 3.1.8, 3.2.1.3, 3.2.1.4, 3.2.1, 3.2.2.5.4.5, 3.1.12 through 3.1.12.1, and associated section 4 paragraphs.
14 CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529 and 25.1501-25.1529.

6.2.7.3 Foreign object damage (FOD).

Criterion: Verify that the physical clearances available can safely tolerate FOD.

Standard: No probable combination of temperature effects, air loads, structural deflections, vibration, buildup of manufacturing tolerances, wear, sag, or installation results in insufficient clearance to tolerate FOD.

Deformation damage to surfaces or associated structure from foreign objects (e.g., objects from tires, birds) does not result in insufficient clearances over the range of the aircraft operating envelope.

Method of Compliance: Verification methods include analysis, inspection and review of documentation. Clearance criteria are verified by inspecting and measuring clearance area around wirings, cables, and plumbing systems and any other control mechanisms.

Clearance analysis verifies that temperature effects, air loads, structural deflections, vibration, buildup of manufacturing tolerances, wear, installation, and flight loads are accounted for in establishing the clearance requirements.

Installation drawings are verified for currency and accuracy.

References: JSSG-2008: 3.0, 3.1, 3.1.7.2, 3.1.7.3, 3.1.11.11, 3.1.13, 3.1.14, 3.1.14.5, 3.2.3, 3.2.3.3, 3.4.4, 3.5.7, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.7.4 Structural mode interaction (SMI).

Criterion: Verify that sensors are safely located to minimize/avoid SMI, including vibration from configuration loading and gun fire, and have safe margins.

Standard: Sensors locations do not cause erroneous feedback.

As integrated into the VCF, sensors do not aggravate SMI, including vibration from configuration loading and gun fire. As necessary, the VCF contains features (e.g., SMI filters) to minimize these interactions.

Sensors location analyses account for sensitivities to actual manufacturing, variations in key stability derivatives, and structural mode frequencies.

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. Verification of air vehicle structural interactions is verified by analysis, simulation, SMI, ground vibration test (GVT), and flight tests. Ground testing is conducted with the aircraft on a soft suspension system to eliminate any constraints imposed by the landing gears. Locations of sensors are verified by inspection.

References: JSSG-2008: 3.0, 3.1, 3.1.2.1, 3.1.5, 3.1.5.6, 3.1.7.2, 3.1.11, 3.1.13, 3.1.15, 3.1.17, 3.2.2.2, 3.2.2.5, 3.2.2.5.1.1, 3.2.2.5.2, 3.2.2.5.4.3, 3.2.2.5.4.4, 3.3.4, 3.3.6.2, 3.5.7, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

6.2.7.5 Integration with avionics systems.

Criterion: Verify that the VCF interfaces/integration with the avionics system are safe.

Standard: The requirements for the avionics system interfaces are treated to have the same criticality as the VCF function to which it is integrated.

The probability of air vehicle loss due to the VCF integration with avionics does not exceed PLOC. This probability takes into account the interdependence of all air vehicle functions within the integrated VCF.

Method of Compliance: Verification methods include analysis, test, simulation, and review of documentation. The quantitative flight safety requirement is verified by analysis consisting of all the safety critical failure modes. Special consideration is taken where integration has several fault layers, including single, dual or a combination of failures. The integration and fault accommodation may be order sensitive and is considered in the analysis.

Test cases are defined for the avionics system interfaces/integration.

Interfaces/integration with other functions and sub-functions are verified to be safe through FMET performed on an Iron Bird, SIL or high fidelity integration lab with all hardware and software in the loop.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.5, 3.1.7, 3.1.8, 3.1.11, 3.1.12, 3.1.13, 3.1.14.4, 3.2.2.2, 3.2.2.4, 3.2.2.5, 3.2.2.6, 3.3, 3.2.4, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.7.6 Integration with propulsion systems.

Criterion: Verify that the propulsion control integration, control mechanisms, feedback loops, automatic throttle control systems, symmetric and asymmetric thrust controlling conditions, special thrust control conditions, atmospherics, and hypersonic effects on thrust control are safe.

Standard: The probability of air vehicle loss due to VCF integration with propulsion does not exceed PLOC. This probability accounts for the interdependence of all air vehicle functions affecting the propulsion function.

The VCF compensates for any hazardous flight condition which results from asymmetric propulsion system.

The propulsion control functions integrated with the VCF provide:

a. Fault tolerance.
b. Redundancy management.
c. Integrated diagnostics and reporting/annunciation.
d. Data latency and equivalent time delay requirements.

Method of Compliance: Verification methods include analysis, test, simulation, and review of documentation. The quantitative flight safety requirements including asymmetric operation is verified by the FMECA.

Integrated propulsion control requirements are verified by analysis, simulation, SIL, FMETand ground tests.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.5.3, 3.1.5.5, 3.1.7.3, 3.1.11, 3.1.13, 3.1.13.3, 3.1.17, 3.2.2.2.9, 3.2.2.5.1.1, 3.2.2.5.4.5, 3.3.1, associated section 4 paragraphs.
14 CFR 25.901.

6.2.7.7 Vehicle recovery.

Criterion: Verify that the VCF can safely recover the air vehicle under a combination of worst-case flight envelope and engine failure conditions, and identify any flight limitations in the flight manual.

Standard: The limits of the VCF are defined for a combination of worst-case flight envelope and engine failure conditions where the VCF can no longer guarantee safe recovery of the air vehicle. These limits define the safe envelope for the air vehicle and are identified in the flight manual.

Method of Compliance: Verification methods include analysis, test, simulation, and review of documentation.

The combinations of worst-case flight envelope and engine failure conditions are verified by analysis, simulation, SIL and FMET.

Documentation review verifies that limitations are identified in the flight manual.

References: JSSG-2008: 3.0, 3.1, 3.1.5, 3.1.5.3, 3.1.5.7, 3.1.5.8, 3.1.5.9, 3.1.9, 3.1.14, 3.2.1.3, 3.2.1.2, 3.2.2.2, 3.2.2.5, 3.2.2.5.4, 3.2.2.6, 3.3, associated section 4 paragraphs.

14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.7.8 Latencies and synchronizations.

Criterion: Verify that vehicle control, payload, and ground system latencies and synchronizations are safe.

Standard: The vehicle control function integrated with any payload or ground functions does not induce latencies that result in flying qualities worse than Level I. Data latency time delays are measured from the instant of a control input to the time a recognizable response occurs. This is specified as 100 milliseconds for Level I flying qualities.

The VCF integration with the payload or the control station is evaluated for safe and adequate timing, synchronization rates, instruction set architecture, misinterpretation of instructions or data, degraded data link and inability to handle basic faults. Any synchronization done in any of or the integrated functions, including a single synchronization failure or multiple single independent synchronization failures, do not cause loss of the vehicle/crew and have flying quality levels no worse than Level I.

Vehicle control, payload, and ground redundancy of the integrated portions of these functions are able to operate autonomously without loss of the vehicle/crew, and have flying quality levels no worse than Level II.

The VCF integration with the ground or payload function is classified flight/safety critical.

The VCF integration with the ground or payload function has a stability margin of 6 dB and 45 degrees in phase and gain for each feedback loop and control loop for all flight conditions throughout the entire flight envelope.

Method of Compliance: Verification methods include analysis, test, simulation, and review of documentation. The VCF vehicle control, payload, and ground system latencies and synchronizations are verified through simulation, systems analysis, FMET, and ground tests.

For each control and feedback loop, analysis and simulation verifies the phase and gain margins. The analysis and simulation are validated by actual flight test data.

References: ADS-51-HDBK
ADS-33-PRF

6.2.7.9 Automatic take-off and landing.

Criterion: Verify that the automatic take-off and landing systems are safe.

Standard: Every function within the automatic take-off and landing systems is analyzed and tested for both normal and failed conditions.

The flight control system employs safety interlocks to prevent inadvertent automatic take-off and landing. In case of a failure within the automatic take-off and landing modes of the flight control system, the operator is notified and provides capability to take over control of the air vehicle.

No single point failure within the integrated system of the automatic take-off and landing system causes loss of control.

Method of Compliance: Verification methods include analysis, test, simulation, and review of documentation. The automatic take-off and landing systems are verified through simulation, software analysis, SIL, FMET, ground test, and flight test.

References: JSSG-2008

6.2.8 VCF engage, disengage, and interlocks safety.

6.2.8.1 Interlocks.

Criterion: Verify that non-operative devices/programs can be safely locked out.

Standard: Interlocks prevent hazardous operation or sequencing of non-operative devices/programs.

Appropriate methods of interlocks are provided to ensure that the non-operative devices/programs can never be turned on inadvertently. Some methods may be: removal of memory or processor chip, double access to partitioned memory, removal of power, cockpit switches.

Of particular concern are parts of Operational Flight Programs (OFPs) that deal with diagnostics. Built-In-Tests (BITs) that are not to be executed in-flight have interlocks that preclude them from ever starting. As a minimum, for the non-operative in-flight devices/programs, there are at least two (2) independent types of interlocks to prevent in-flight engagement. As a general rule, the redundancy of the interlocks matches the redundancy of the basic functions.

Method of Compliance: Verification methods include analysis, tests (SIL, ground and flight), simulation, demonstration, inspection and review of documentation. FMET cases introduce attempts to access non-operative devices/programs including rogue partition(s).

References: JSSG-2008: 3.0, 3.1, 3.1.13, 3.1.13.1, 3.1.13.3, 3.1.14.7, 3.2.2.2.2, 3.2.2.5.1.3, 3.2.2.6, associated section 4 paragraphs.
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.8.2 Incompatible modes.

Criterion: Verify that interlocks safely preclude incompatible modes, simultaneous engagement and engagement with incompatible flight conditions or air vehicle configurations.

Standard: The VCF safety interlocks as well as engage/disengage functions/devices prevent the engagement of incompatible modes that could create an immediate undesirable situation.

The VCF provides proper disengagement of any mode prior to engaging another mode.

Emergency disengagement of modes does not result in degradation of flying qualities.

The VCF provides proper notification to the operator/pilot for engagement or disengagement of any mode.

Method of Compliance: Verification methods include analysis, tests (SIL and ground), simulation, inspection and review of documentation. Simulation, FMECA, FMET, inspection, and ground testing verify proper mode engagement/disengagement and lockouts.

References: JSSG-2008: 3.0, 3.1, 3.1.5.2, 3.1.5.8, 3.1.5.9, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.11.2, 3.1.13.1, 3.1.13.3, 3.1.14, 3.1.14.7, 3.2.2.2.4, 3.2.2.2.5, 3.2.2.2.9, 3.2.2.2.11, 3.2.2.4, 3.2.2.5.1, 3.2.2.5.1.1-3.2.2.5.1.4, 3.2.2.5.4.1-3.2.2.5.4.4, 3.2.2.6, 3.3.2.1, associated section 4 paragraphs
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.8.3 Engage, disengage and mode transition transient times.

Criterion: Verify that engage, disengage and mode change transient times are safe.

Standard: The transient times associated with the engage, disengage and mode transitions are supported by the dynamics of the vehicle such that the vehicle stays well within flight and structural limits. The engage, disengage, and mode change transient times for the entire integrated VCF are on the order of 100 milliseconds or less. Larger transient times may be justified and acceptable depending on the application.

Although 100 milliseconds or less is the standard for transient time, programs may provide actual simulation and flight test data to show that transients greater than 100 milliseconds are safe.

Method of Compliance: Verification methods include analysis, tests (SIL and ground), simulation, inspection and review of documentation. Simulation, FMECA, FMET, inspection, and ground testing verify proper mode engagement/disengagement.

References: JSSG-2008: 3.0, 3.1, 3.1.5.2, 3.1.5.8, 3.1.5.9, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.11.2, 3.1.13.1, 3.1.13.3, 3.1.14, 3.1.14.7, 3.2.2.2.4, 3.2.2.2.5, 3.2.2.2.9, 3.2.2.2.11, 3.2.2.4, 3.2.2.5.1, 3.2.2.5.1.1-3.2.2.5.1.4, 3.2.2.5.4.1-3.2.2.5.4.4, 3.2.2.6, 3.3.2.1, and associated section 4 paragraphs.
14 CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529 and 25.1501-25.1529.

6.2.9 VCF command and control communications safety.

6.2.9.1 Integration.

Criterion: Verify that command and control communications within the air vehicle, other linked air vehicles, and control station are integrated safely.

Standard: Separation and isolation among internal and external VCF interfaces has a probability of propagation or common mode failures that is extremely remote (1x10^-9 or as specified by the procuring activity).

Command and control communication integration allows for the sharing of information among different systems and does not result in loss of aircraft.

Command and control processing resources support the functional requirements as allocated to computer hardware and software.

Information communication is capable of determining integrity of information received, processed and sent.

Command and control communication provides the following:

a. Fail operation/safe mechanization to keep Level I flying qualities.
b. Communication integrity check.
c. Reasonableness checks based on expected state information.
d. State change check.
e. Range verification checks.
f. Rate of expected change checks.
g. Source (heartbeat) checks.
h. Sample rate checks.
i. Information control limiting.
j. Anti-aliasing filters

k. De-bounce protection.

Command and control hardware have segregated channels and power supplies.

Command and control serial and parallel communications between internal, physically separated VCF components are compliant with established military or commercial standards.

Communication requirements consider flight critical data, classified data, distributed processing, centralized processing, diagnostics, and sensor support.

Degradation to command and control communication is handled by the VCF in a predictable and repeatable manner. Probability of aircraft loss due to degradations in command and control communication does not exceed PLOC.

Method of Compliance: Verification methods include analysis, tests, simulation and review of documentation. Ground testing verifies system operation, interface, warm-up time and engage/disengagement. Analysis and simulation verifies communication requirements. In-flight and ground testing includes the signal types and component interfaces. Component and SIL testing including FMET verify the communication and interface paths.

References: JSSG-2008: 3.1, 3.1.8, 3.1.7.3, 3.1.11, 3.1.11.7, 3.1.11.9, 3.1.13, 3.2.2.2, 3.2.2.5.1.2, 3.2.2.5.3, 3.3, 3.3.1, 3.3.2.3, 3.3.3, and associated section 4 paragraphs.
14 CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529 and 25.1501-25.1529.

6.2.9.2 Security.

Criterion: Verify that all command and control communications are secure against unwanted intrusions and security techniques used are implemented safely.

Standard: VCF command and control communications meet the system security requirements as specified in the air vehicle/weapon system specification.

Command and control communication security implementation does not degrade VCF performance.

Command and control system security levels are selected based upon the sensitivity of data. Integrity of information passed through security channels is guaranteed.

The VCF contains features to prevent unauthorized access or use of the system to change or add data, limits, or information that could result in loss of the aircraft.

Command and control communications security procedures apply to all field support as well as depot support.

Any wireless computing and networking capabilities (aircraft and support systems) are secure from external influences.

Method of Compliance: Verification methods include analysis, tests, simulation, demonstration, inspection, and review of documentation. The command and control communications security provisions are verified by inspection of requirements, analysis of the security provisions and their effectiveness, and demonstration of the security design methods and procedures. VCF performance with implemented security measures is verified through analysis, simulation and SIL test.

References: JSSG-2008: 3.1.8, 3.1.14.6, 3.1.16, 3.2, 3.3.1, and associated section 4 paragraphs.
14 CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529 and 25.1501-25.1529.

6.2.9.3 Lost communications and failures.

Criterion: Verify that the guidance, navigation and control functions implement robust and safe contingency logic for dealing with lost-communications and on-board failures.

Standard: Safe contingency logic is provided for lost-communications, on-board failures, and failures within guidance, navigation, and control functions. No single point failure within the communication, guidance, navigation, and control causes loss of control.

In case of total loss of communication with the control station, the air vehicle is capable of autonomous guidance, navigation and control for a safe landing.

Method of Compliance: Verification methods include analysis, tests, simulation, and review of documentation. The contingency logic within the guidance, navigation and control is verified through simulation, software analysis, SIL, FMET, ground test, and flight test, for both the air vehicle and the control station.

Reference: JSSG-2008

6.2.9.4 Loss of command.

Criterion: Verify that the VCF will not degrade below Operational State III in the event of loss of command from the control station.

Standard: The air vehicle VCF function provides an emergency autonomous mode which is activated once the communication link between the air vehicle and control station is lost or degraded. This emergency mode provides Operational State III, determines the current location, and identifies the nearest approved landing site. No instability, limit cycle oscillations are allowed for the loss of command from the control station.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. The emergency autonomous mode is verified through simulation, software analysis, SIL, FMET, and ground test, for both air vehicle and control station.

Reference: JSSG-2008

6.2.9.5 Sensor operability.

Criterion: For UAS equipped with remote control capability, verify that sensors used to provide feedback to a remote operator are fully operational under natural and induced environmental conditions.

Standard: Environmental effects do not degrade operator cognitive capabilities to recognize visually all flight safety and mission critical related problems. Provisions are incorporated to protect on-board devices (e.g., sensors, cameras) against FOD, obscuration of the sensor transparency, and laser threats.

No single point failure within the remote control function of the UAS causes loss of information that the operator needs for safe operation. In case of total loss of the remote control capability, the UAS has contingency to switch to autonomous mode for safe control and landing.

Method of Compliance: Verification methods include inspection, demonstration, SIL, FMET, and ground test.

6.2.10 VCF hydraulic power source safety.

6.2.10.1 Hydraulic distribution.

Criterion: Verify that hydraulic distribution has no single failure points resulting in loss of more than one hydraulic system.

Standard: No single failure within the hydraulic distribution system results in loss of the hydraulic function.

No single failure within the hydraulic distribution system results in control instabilities or loss of VCF.

No single failure within the hydraulic distribution system results in flying qualities worse than Level II.

Gain and phase margin reductions of 25% are allowed after a single failure.

Method of Compliance: Verification methods include analysis, tests, simulation, and review of documentation. Hazard and fault tree analyses for hardware and software verify no loss or instabilities of VCF.

SIL and Iron Bird testing including FMET verify that there is no loss of hydraulic function for any single hydraulic failure.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.11.11.3, 3.1.12, 3.1.12.1, 3.1.14.4, 3.1.14.9, 3.2.1.3, 3.2.2.2.1, 3.2.2.2.5, 3.2.3.1, and associated section 4 paragraphs.
14 CFR references: 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529 and 25.1501-25.1529.

6.2.10.2 Hydraulic system dynamics.

Criterion: Verify that hydraulic function dynamics do not have any unsafe pressure pulsating or resonant conditions.

Standard: The primary and secondary hydraulic functions do not have any dynamic pulsating and/or resonant conditions that cause any instability or loss of VCF.

If there are any pulsating or resonant conditions, phase and gain margin requirements for the VCF are 45 degrees and 6 dB.

Method of Compliance: Verification methods include analysis, tests, simulation, and review of documentation. Iron Bird testing including FMET and ground tests verify that there is no pulsating or resonant condition for the hydraulic function.

References: JSSG-2008: 3.0, 3.1, 3.1.5.6, 3.1.7.2, 3.1.11.11.3, 3.2.2.2.1, 3.3 through 3.3.4, 3.3.6, 3.3.6.2, associated section 4 paragraphs.
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.10.3 Flow/pressure irregularities.

Criterion: Verify that backup and emergency hydraulic power function(s) do not have any unsafe effects from reduced flow rates or pressure or flutter margin.

Standard: The emergency/secondary hydraulic power system does not cause loss of VCF or any instability due to flow rates, lower pressure or reduced flutter margin.

Method of Compliance: Verification methods include analysis, tests, simulation, and review of documentation. Hazard/fault tree analyses for actual hardware verify no loss of the VCF.

Iron Bird testing including FMET verify that there is no loss of VCF or instabilities due to lower rates, pressures and flutter margin.

References: JSSG-2008: 3.0, 3.1, 3.1.5.6, 3.1.7.2, 3.1.11.11.3, 3.2.2.2.1, 3.2.2.2.5, associated section 4 paragraphs.
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.10.4 Transients/fluctuations.

Criterion: Verify that VCF flight limitations for emergency/backup hydraulic power and switchover time constants are safe.

Standard: Hydraulic power transients due to switching sources (e.g., Auxiliary Power System (APS), Emergency Power System (EPS)), accumulators, valves, relays, controllers, and any other devices do not cause any power fluctuations that result in loss of VCF.

Hydraulic power transients do not cause loss of VCF.

Health monitoring is provided and meets other criteria in Section 10, Diagnostics Systems, with regards to diagnostics and Built-In-Test (BIT).

Method of Compliance: Verification methods include analysis, tests, simulation, and review of documentation. Hardware in the Loop (HITL) and on aircraft ground tests verify no loss of VCF for any power transients.

Hardware in the Loop (HITL) testing including FMET with induced transients verify no loss of VCF.

The diagnostic and health monitoring to support the hydraulic and VCF functions is verified through Hardware in the Loop (HITL) and ground testing.

References: JSSG-2008: 3.0, 3.1, 3.1.5.2, 3.1.5.6, 3.1.7.2, 3.1.10, 3.1.11.11.3, 3.1.13, 3.2.2.2.1, 3.2.2.2.5, associated section 4 paragraphs.
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.10.5 Failures.

Criterion: Verify that there is no loss of VCF due to failures within the hydraulic system.

Standard: No single hydraulic failure results in total loss of hydraulic power.

The VCF integration with the hydraulic system provides redundancy control and reconfiguration of the air vehicle to prevent loss of control.

The hydraulic system design includes redundancy and fault tolerance and accounts for internal and interface latency. The probability of loss of all hydraulic power is better than 1x10^-8 or as specified by the procuring activity.

Method of Compliance: Verification methods include analysis, tests, simulation, inspection and review of documentation.

Analysis and simulation verify hydraulic loading under various flight and ground conditions.

VCF effects due to loss of any hydraulic function are verified by Iron Bird testing including FMET.

Pilot/Operator in the Loop simulation verifies Level II flying qualities (Operational State III) or better for single or multiple failures in the hydraulic system.

On aircraft inspection verifies accurate installation of all components for the hydraulic system.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.7.3, 3.1.11.11.3, 3.1.12.1, 3.1.13, 3.1.14.4, 3.1.14.9, 3.2.1.3, 3.2.2.2, 3.2.2.2.1, 3.2.2.2.5, 3.3 through 3.3.4, 3.3.6, 3.3.6.2, associated section 4 paragraphs
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.11 VCF electrical power system safety.

6.2.11.1 Backup.

Criterion: Verify that electrical power normal/backup/emergency capability following loss of engine(s) and generator(s) for VCF is safe.

Standard: Electrical power is provided independently to each control channel long enough for an immediate descent and landing following total loss of the engines and generators. If safe landing is not possible, the emergency/backup power is sufficient to steer to an appropriate area for a controlled crash. The minimum safe time of this electrical power capability is 30 minutes if no other time is specified. The time may be longer depending on the application.

Method of Compliance: Verification methods include analysis, tests, simulation and review of documentation. Analysis verifies sufficient electrical power for normal and emergency capability.

Hardware in the Loop (HITL) testing including FMET verifies the presence of sufficient electrical power for normal/backup/emergency conditions.

Hardware in the Loop (HITL) testing including FMET and ground tests verifies normal VCF operation for 30 minutes after total loss of electrical generating capability.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.5.2, 3.1.5.4, 3.1.7.2, 3.1.10, 3.1.11, 3.1.11.11.2, 3.1.13, 3.2.2.2, 3.2.2.2.2, 3.2.2.2.5, 3.3 through 3.3.4, 3.3.6, 3.3.6.2, associated section 4 paragraphs.
14 CFR 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.11.2 Independent sources.

Criterion: Verify that independent sources provide safe and redundant electrical power for VCF.

Standard: Electrical power system is defined to include all components: i.e., sources, wiring, controls and associated grounding schemes. The electrical power sources used to power the VCF or backup the VCF do not induce any conditions that result in loss of the VCF.

No single failure in any source propagates to other sources with the consequent result of loss of power.

No wiring or grounding architecture propagates failures or causes loss of electrical power sources or the VCF.

No combination of independent single failures among sources causes loss of the VCF.

The probability of loss of all electrical power is less than 1x10^-8 or as specified by the procuring activity.

Method of Compliance: Verification methods include analysis, tests, simulation and review of documentation. Hardware in the Loop (HITL) including FMET and ground tests verify no loss of VCF for any power source condition.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.11, 3.1.11.11.2, 3.1.12,

3.1.12.1, 3.2.2.2.2, 3.2.2.2.5, 3.3 through 3.3.4, 3.3.6, 3.3.6.2, associated section 4 paragraphs
14 CFR 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.11.3 Transients.

Criterion: Verify that electrical power transients, both normal and switching, are safe.

Standard: Electrical power transients due to switching sources, shorts, opens, contactors, relays, fuses, diodes and any other devices that can cause power transients do not result in any power upset to, degradation of or loss of VCF.

Electrical power transient times do not upset or cause loss of the VCF.

Method of Compliance: Verification methods include analysis, tests, simulation and review of documentation. Hardware in the Loop (HITL) including FMET and ground tests verify no loss of VCF for any power transient and switching conditions.

References: JSSG-2008: 3.0, 3.1, 3.1.5.2, 3.1.7.2, 3.1.10, 3.1.11.11.2, 3.2.2.2.2, 3.2.2.2.5, associated section 4 paragraphs.
14 CFR 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.11.4 Battery.

Criterion: Verify that, if batteries are employed for backup power, adequate charging methods and monitoring are provided and installation provisions for all batteries are safe.

Standard: Minimum of 30 minutes capability is provided where backup batteries are used.

Nickel-Cadmium batteries are prohibited.

Location of lead acid batteries in the same bay as flight critical components is prohibited.

Adequate charging methods exist and monitoring is performed to assess battery health, and condition status is provided to the crew.

If dedicated batteries are used for the VCF, use of these batteries is exclusive to the VCF.

Method of Compliance: Verification methods include analysis, tests, simulation and review of documentation. Analyses confirm the battery architecture and loads.

Assumptions are validated via simulation and testing in representative environments.

Hardware in the Loop (HITL) and ground tests confirm battery life, loads and health. The most adverse electrical loading, environmental, fault, and endurance conditions required of the VCF are tested.

Battery integrity is verified by pre/post flight checklists, maintenance tech data, analyses and ground testing.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.5.2, 3.1.7.2, 3.1.11.11.2, 3.1.13, 3.2.2.2.2, 3.2.2.2.5, associated section 4 paragraphs.
14 CFR 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.11.5 Bus separation.

Criterion: Verify that independent electrical power bus separation for prevention of single failure points is safe, and that a failure on one bus does not cause loss of function for the VCF.

Standard: Loss of one electrical bus does not result in loss of VCF function.

Ensure physical separation meets the guidelines of 12.2.6 inclusive (electrical wiring system installation).

Method of Compliance: Verification methods include analysis, tests, simulation, inspection and review of documentation. Design documentation, installation drawings, and ground test verify separation/isolation of redundant buses. Tests performed on a subsystem mockup that accurately simulates the aircraft installation verifies safe operation.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.7.3, 3.1.10, 3.1.11.11.2, 3.1.12, 3.1.12.1, 3.1.14.4, 3.2.1.3, 3.2.2.2.2, 3.2.2.2.5, 3.2.3.1, associated section 4 paragraphs.
MIL-HDBK-516: 12
14 CFR 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.11.6 Effects of failure modes.

Criterion: Verify that effects of normal, abnormal, and failure modes of the electrical power function are safe for VCF.

Standard: An independent power generation source, not subject to corruption of power quality by adverse modes on the primary electrical power system, provides reliable electrical power at the lowest possible engine speeds.

The failure modes and transitions to and from the auxiliary power or emergency power sources provide the VCF with uninterruptible, quality power.

The electrical power sources for the VCF are dependable and redundant. Independent, direct sources of electrical power for each redundant channel of flight/safety critical or flight phase critical control function are provided. In this context, direct means that the power source only powers the VCF. No system or subsystem not related to the VCF or integrated with the VCF is allowed use of the direct source.

Control coordination is provided for the electrical power system and the VCF for engagement and propulsion auto start capability.

The design accommodates redundancy, fault tolerance, and high availability of electrical power sources for the common displays. Transients in the display of certain parameters such as pitch and roll attitude are eliminated.

Electrical power transients do not cause loss of program memory, memory scramble, erroneous commands, or loss of ability for continued operation and over/under-voltage/over-current shutdowns of the VCF or electrical power control.

Method of Compliance: Verification methods include analysis, tests, simulation, and review of documentation. Analyses, Hardware in the Loop (HITL) testing including FMET, and on-aircraft ground testing verify normal, abnormal, and failure modes of the electrical power function do not result in loss of VCF channel or function. Pilot/Operator in the loop evaluations demonstrate Level II flying qualities or better for single or dual failures.

Testing includes the most adverse electrical loading, environmental, fault, and endurance conditions required of the subsystem. Failure modes that could be hazardous to personnel or the aircraft are simulated.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.7.3, 3.1.11.11.2, 3.1.13, 3.1.14.4, 3.2.1.3, 3.2.2.2.2, 3.2.2.2.5, 3.3 through 3.3.4, 3.3.6, 3.3.6.2, associated section 4 paragraphs.
14 CFR 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529

6.2.11.7 Uninterruptible power.

Criterion: Verify that direct, uninterruptible, quality electrical power for the VCF is safe.

Standard: Independent, direct, uninterruptible power sources of adequate quality meet requirements of essential redundancy of VCF channels including after power system malfunction(s). The degree of isolation and number of isolated channels that may be required are dependent upon specific requirements of the vehicle.

If a dedicated VCF electrical bus is provided, devices which are not related to or integrated with the VCF are not permitted use of the VCF bus.

The electrical power to the VCF is designed for at least 30 minutes operation when VCF is totally dependent on battery for electrical power for 1g flight with minimum maneuvering.

Method of Compliance: Verification methods include analyses, tests, simulation, and review of documentation. Complete hazard analysis coupled with electrical loads analysis (see 12.1 inclusive) and Hardware in the Loop (HITL) testing including FMET verifies that no single failure results in loss of VCF function.

Pilot/Operator in the loop evaluations demonstrate Level II flying qualities or better for dual or multiple failures.

References: JSSG-2008: 3.0, 3.1, 3.1.2, 3.1.2.1, 3.1.3, 3.1.7.2, 3.1.7.3, 3.1.11, 3.1.11.11.2, 3.1.12, 3.1.12.1, 3.1.14.4, 3.2.1.3, 3.2.2.2.2, 3.2.2.2.5, 3.3 through 3.3.4, 3.3.6, 3.3.6.2, associated section 4 paragraphs.
14 CFR 23.1351-23.1367, 25.1351-25.1363, 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.12 VCF electronic systems safety.

6.2.12.1 Computer design.

Criterion: Verify that the VCF computer design is safe.

Standard: The VCF computer is safety critical.

The VCF computer design meets Electromagnetic interference (EMI) safety requirements (see 13.1, this document, inclusive).

The VCF computer processor throughput has a 50% margin under normal conditions and 25% margin under most demanding processing conditions.

The VCF computer continues to operate for 30 minutes with no cooling air and no fan.

The VCF allows for single point operational flight program (OFP) load.

The VCF computer meets the redundancy requirements of PLOC. The design meets Operational State I in the presence of any single failure or combination of single independent failures. No single point failure within the VCF computer causes loss of VCF function.

The VCF computer hardware and software meet the criteria in Section 15, Computer Systems and Software.

Method of Compliance: Verification methods include inspection, analysis, component tests, integration tests to include FMET, ground, and flight tests.

References: JSSG-2008: 3.0, 3.1, 3.1.14.6, 3.1.18, 3.2.2.2, 3.3, 3.3.1, 3.3.2, 3.3.2.1, 3.3.2.2, 3.3.2.3, 3.3.4, associated section 4 paragraphs.
MIL-HDBK-516: 13, 15
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.2.12.2 Electronic sensors.

Criterion: Verify that VCF electronic sensors are safe.

Standard: The VCF electronic sensors meet the redundancy requirements for PLOC. No single point failure within the electronic sensors causes loss of VCF function.

The VCF electronic sensors continue to operate for 30 minutes with no cooling air and no fan.

The VCF electronic sensors meet the Electromagnetic interference (EMI) safety requirements (see 13.1 inclusive).

Method of Compliance: Verification methods include inspection, analysis, component test, integration tests to include FMET, ground, and flight tests.

References: JSSG-2008: 3.0, 3.1, 3.1.14.6, 3.1.18, 3.2.2.2, 3.3, 3.3.1, 3.3.2, 3.3.2.1, 3.3.2.2, 3.3.2.3, 3.3.4, associated section 4 paragraphs.
MIL-HDBK-516: Section 13
14 CFR 23.141-23.253, 25.21-25.255, 23.321-23.459, 25.321-25.459, 23.1501-23.1529, 25.1501-25.1529.

6.3 Air vehicle aerodynamics and performance.

6.3.1 Engine-airframe compatibility.

Criterion: The installed propulsion system provides for engine and airframe compatibility to ensure safe operation of the air vehicle.

Standard: Verify that the propulsion system is free of instabilities resulting from:

a. Flow disturbances entering the engine from the inlet.
b. Flow disturbances entering the engine from the afterburner/nozzle.
c. Flow/mechanical/thermal interfaces with the airframe and subsystems.
d. Operation of flight, engine and subsystem controls.

Method of Compliance:

a. Propulsion system instabilities are identified during design and development through test, analysis, and demonstration. These instabilities are addressed in a joint stability assessment performed by the airframe and engine contractors. Verify through inspection of documentation that the effects of steady-state total-pressure inlet distortion, maximum instantaneous total-pressure inlet distortion, temperature distortion, swirl distortion, and in-phase pressure oscillations (planar waves) are included in the joint stability assessment. Verify through inspection of documentation that flow disturbances from secondary air systems located in the inlet, steam ingestion, hot anti-icing air discharged into the inlet, armament gas and debris ingestion, inlet sand and dust separator effects, and distortion resulting from ice formation on the inlet are included in the joint stability assessment.

   NOTE: The joint stability assessment provides quantitative estimates of the effect of inlet distortion and other destabilizing influences on compressor stability margins . Recommended assessment procedures are outlined in SAE ARP1420 and SAE

AIR1419.

b. Exhaust system back pressure and nozzle matching effects are verified by analysis, test, and demonstration.

c. Thermal boundary, fuel, air induction, exhaust and bleed air extraction system, ambient temperature, ambient pressure, vibratory environment, and altitude cold start and hot restart capability effects are verified by analysis, test, and demonstration.

d. Steady state and transient response characteristics of the engine and engine control system, engine response to input signals at different frequencies, fuel flow modulation, engine control and vehicle control system communication, and auxiliary engine control function effects to propulsion system instabilities are verified by analysis, test, and demonstration.

References: JSSG-2001, JSSG-2006, JSSG-2007, JSSG-2008
MIL-HDBK-516
MIL-STD-1797
SAE ARP1420
SAE AIR1419
14 CFR Parts 23, 25, 27, 29

6.3.2 Performance information.

Criterion: Verify that air vehicle performance information provided to the pilot/operator is accurate to ensure safe flight.

Standard:

a. Flight manual air vehicle performance for all flight phases including, but not limited to, launch, takeoff, climb, cruise, endurance, maneuver, hover, in-flight refueling, descent, approach, landing, and recovery is sufficiently accurate to allow safe operations.

b. Flight manual air vehicle performance includes the full range of mass properties and atmospheric conditions for all air vehicle variants, configurations, and loadings within the flight envelope.

c. Air vehicle performance information provided to the pilot/operator by other means (e.g., checklist, calculator, laptop, mission planning tool, onboard embedded system) is sufficiently accurate to allow for safe operation.

Method of Compliance:

a. An air vehicle force and moment accounting system is defined for all air vehicle variants, configurations, and flight conditions. All coordinate systems, sign conventions, control effectors, aerodynamic and propulsion forces and moments, and aerodynamic/propulsion reference conditions have been defined to support performance simulation.

b. Aerodynamic, installed propulsion, and mass properties databases are based on the latest information available, have been placed under configuration control, and are sufficient in scope for all air vehicle configurations, loadings, and flight conditions. All aerodynamic data corrections of the original source analysis/test data to the final, full-scale, flight representative configuration are defined. All propulsion data is corrected for losses and efficiency changes going from uninstalled to installed configurations. Mass properties are representative of all air vehicle configurations and loadings.

c. Predictions of trimmed lift and drag in and out of ground effect, installed thrust, power available, power required, fuel flow, fuel quantity, inertias, center of gravity, and weights allow for accurate simulation of air vehicle performance for all atmospheric conditions within the flight envelope.

d. Flight manual air vehicle performance is based on simulation models that have been verified against actual air vehicle flight performance and accounts for flight test data measurement uncertainty.

e. All flight manual air vehicle performance charts, procedures, and instructions are defined, clearly written, and traceable back to the supporting analysis and data basis.

f. Flight manual performance is verified by inspection of documentation. Performance information provided to the pilot/operator by other means is verified against the flight manual or simulation model by test and inspection of documentation.

References: JSSG-2001
JSSG-2006
JSSG-2007
MIL-STD-3013
MIL-DTL-7700
MIL-PRF-63029
MIL-DTL-85025
ADS-10-SP
ADS-40-SP
14 CFR 23 - Airworthiness Standards: Normal, Utility, Acrobat, and Commuter Category Airplanes
14 CFR 25 - Airworthiness Standards: Transport Category Airplanes
14 CFR 27 - Airworthiness Standards: Normal Category Rotorcraft
14 CFR 29 - Airworthiness Standards: Transport Category Rotorcraft

6.3.3 Performance limits.

Criterion: Verify that all air vehicle performance flight limits are provided to the pilot/operator to ensure safe operation.

Standard: Any flight performance limitation that affects safe operation of the air vehicle for both normal and degraded/emergency operating conditions is identified and documented including, but not limited to, weight, center of gravity, acceleration, speed, altitude, stall, buffet, engine operability, propulsion system limits, rate-of-climb, rate-of-descent, maneuverability, structural load limit, landing gear, brake energy, store carriage, temperature, wind, runway condition, and icing.

Method of Compliance:

a. An air vehicle force and moment accounting system is defined for all air vehicle variants, configurations, and flight conditions. All coordinate systems, sign conventions, control effectors, aerodynamic and propulsion forces and moments, and aerodynamic/propulsion reference conditions have been defined to support performance simulation.

b. Aerodynamic, installed propulsion, and mass properties databases are based on the latest information available, have been placed under configuration control, and are sufficient in scope for all air vehicle configurations, loadings, and flight conditions. All aerodynamic data corrections of the original source analysis/test data to the final, full-scale, flight representative configuration are defined. All propulsion data is corrected for losses and efficiency changes going from uninstalled to installed configurations. Mass properties are representative of all air vehicle configurations and loadings.

c. Predictions of trimmed lift and drag in and out of ground effect, installed thrust, power available, power required, fuel flow, fuel quantity, inertias, center of gravity, and weights allow for accurate simulation of air vehicle performance for all atmospheric conditions within the flight envelope.

d. Flight manual air vehicle performance is based on simulation models that have been verified against actual air vehicle flight performance and accounts for flight test data measurement uncertainty.

e. Air vehicle buffet and stall characteristics accounting for Mach number effects as well as deployed flaps, spoilers, landing gear, and store carriage are identified and assessed using wind tunnel and flight test data.

f. Stall angle-of-attack and/or stall speed account for air vehicle weight, center of gravity, configuration, and store loading.

g. Charts depicting bank angle versus minimum speed to maintain altitude account for air vehicle weight, configuration, and store loading.

h. For air vehicles without adequate anti-ice protection, the effect of icing on air vehicle aerodynamics and performance is characterized using analysis, wind tunnel, and/or flight test data to establish operational limits.

i. Rotorcraft performance limits account for vortex ring state, settling with power, retreating blade stall, and advancing blade compressibility effects.

j. All flight limit charts, procedures, and instructions are defined, clearly written, and traceable back to the supporting analysis and data basis.

k. Flight manual performance is verified by inspection of documentation. Performance information provided to the pilot/operator by other means (e.g., checklist, calculator, laptop, mission planning tool, onboard embedded system) is verified against the flight manual or simulation model by test and inspection of documentation.

References: JSSG-2001
JSSG-2006
JSSG-2007
JSSG-2008
MIL-STD-1797
MIL-STD-3013
MIL-DTL-7700
MIL-DTL-85025
MIL-PRF-63029
ADS-40-SP
ADS-10-SP
14 CFR 23 - Airworthiness Standards: Normal, Utility, Acrobat, and Commuter Category Airplanes
14 CFR 25 - Airworthiness Standards: Transport Category Airplanes
14 CFR 27 - Airworthiness Standards: Normal Category Rotorcraft
14 CFR 29 - Airworthiness Standards: Transport Category Rotorcraft

6.3.4 Failures affecting performance.

Criterion: Verify that air vehicle performance provided to the pilot/operator is characterized for propulsion system and other performance-relevant failures, providing for safe operation.

Standard:

a. The flight manual characterizes the effect of propulsion system failure(s) (e.g., engine, transmission, driveshaft, propeller, thrust reversers, rotor) on air vehicle performance, flight envelope, and flight limits. The flight manual provides all necessary information for safe operation.

b. The flight manual characterizes the effect of performance-relevant failures (e.g., loss of flaps, spoilers, speed brakes) on air vehicle performance, flight envelope, and flight limits. The flight manual provides all necessary information for safe operation.

c. Propulsion system and other performance-relevant failure effects on air vehicle performance, flight envelope, and flight limits provided to the pilot/operator by other means (e.g., checklist, calculator, laptop, mission planning tool, onboard embedded system) provide all necessary information for safe operation.

Method of Compliance:

a. An air vehicle force and moment accounting system is defined for all air vehicle variants, configurations, and flight conditions. All coordinate systems, sign conventions, control effectors, aerodynamic and propulsion forces and moments, and aerodynamic/propulsion reference conditions have been defined to support performance simulation.

b. Aerodynamic, installed propulsion, and mass properties databases are based on the latest information available, have been placed under configuration control, and are sufficient in scope for all air vehicle configurations, loadings, and flight conditions. All aerodynamic data corrections of the original source analysis/test data to the final, full-scale, flight representative configuration are defined. All propulsion data is corrected for losses and efficiency changes going from uninstalled to installed configurations. Mass properties are representative of all air vehicle configurations and loadings.

c. Predictions of trimmed lift and drag in and out of ground effect, installed thrust, power available, power required, fuel flow, fuel quantity, inertias, center of gravity, and weights allow for accurate simulation of air vehicle performance for all atmospheric conditions within the flight envelope.

d. Flight manual air vehicle performance is based on simulation models that have been verified against actual air vehicle flight performance and accounts for flight test data measurement uncertainty.

e. All performance charts, procedures, and instructions required for safe operation and/or recovery (e.g., autorotation) as a result of propulsion system and/or other performance-relevant failure(s) are defined, clearly written, and traceable back to the supporting analysis and data basis.

f. Flight manual performance is verified by inspection of documentation. Performance information provided to the pilot/operator by other means (e.g., checklist, calculator, laptop, mission planning tool, onboard embedded system) is verified against the flight manual or simulation model by test and inspection of documentation.

References: JSSG-2001
JSSG-2006
JSSG-2007
JSSG-2008
MIL-STD-1797
MIL-STD-3013
MIL-DTL-7700
MIL-PRF-63029
MIL-DTL-85025
ADS-10-SP
ADS-40-SP

14 CFR 23 - Airworthiness Standards: Normal, Utility, Acrobat, and Commuter Category Airplanes
14 CFR 25 - Airworthiness Standards: Transport Category Airplanes
14 CFR 27 - Airworthiness Standards: Normal Category Rotorcraft
14 CFR 29 - Airworthiness Standards: Transport Category Rotorcraft

7. PROPULSION AND PROPULSION INSTALLATIONS

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria.
2. Design studies and analyses.
3. Design, installation, and operational characteristics.
4. Engine ground and simulated altitude tests.
5. Engine design function/system compatibility tests.
6. Engine component and functional level qualification and certification tests.
7. Electromagnetic environmental effects.
8. Installed propulsion compatibility tests.
9. Acceptance test results.
10. Failure modes, effects, and criticality analysis/testing (FMECA/FMET).
11. Hazard analysis and classification.
12. Safety certification program.
13. Engine endurance and accelerated mission testing.
14. Engine and component structural and aeromechanical tests.
15. Flight test plans and results.
16. Propulsion system integrity program (PSIP) analyses and tests.
17. Engine life management plans.
18. Over-speed and over-temperature tests.
19. Overall engine and component performance analyses.
20. Flight manual.
21. Natural environmental sensitivities.
22. Inlet airflow distortion/engine stability assessments and audits.
23. Interface/integration control documents.
24. Function, subfunction, and component specifications.
25. Selection criteria and inlet distortion patterns selected to demonstrate inlet/engine compatibility.
26. Engine control system rig tests.
27. Engine health monitoring system design reports and tests.
28. Aircraft/engine operating limitations.
29. Engine software development plan and product specifications.
30. Engine software test plans, test procedures and test reports.
31. Engine software configuration control/management plan and procedure.
32. Propulsion and Power Flight Clearance Plan, JSSG-2007A, Table XLVIIIb.
33. Diminishing manufacturing sources plan.
34. Obsolete parts plan.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

7.1 Propulsion risk management.

7.1.1 Safety-critical propulsion system.

***Criterion**:* Verify that safety-critical propulsion system risks are identified, probabilities are validated, and risk controls are in place.

Standard: Failure of any propulsion system or component does not result in exceeding the Loss of Aircraft (LOA) rate for the system.

Propulsion risk management practices are in place to manage risk levels to meet established safety thresholds:

a. *Single engine/Dual engine:* Non-recoverable in-flight shutdown rates less than 0.5 per million Engine Flight Hours (EFH) and propulsion system related loss of aircraft less than 0.5 events for the life of the air vehicle.

b. *Multi engine:* Non-recoverable in-flight shutdown rates less than one per million EFH and propulsion system related loss of aircraft less than 0.5 events for the life of the air vehicle.

Hazard controls are reflected in technical data to include normal operating procedures, emergency procedures, restrictions, and limits for the air vehicle propulsion system. Maintenance and inspection requirements are documented in the technical data.

Method of Compliance: Verification methods include analysis, inspection and review of documentation. A Failure Modes Effects and Criticality Analysis (FMECA) and System Safety Hazard Analysis detail all known potential failure modes and their associated probabilities. Evaluation of these documents show that propulsion system allocated LOA rate has not been exceeded. The documented system safety approach describes the practices to manage propulsion risks to the required in-flight shutdown rates.

Inspection/review of technical data ensures maintenance and inspection requirements and special procedures have been documented.

References: JSSG-2007: A.3.1, A.4.1; A.3.2, A.4.2; A.3.2.1, A.4.2.1; A.3.3.1, A.4.3.1; A.3.3.2, A.4.3.2; A3.4, A.4.4; A.3.5.1, A.4.5.1; A.3.7, A.4.7; A.3.7.2.1, A.4.7.2.1; A.3.11, A.4.11; A.3.12, A.4.12; Table XLIXa
USAF PCoE BP 99-06D
14 CFR 33.5, 33.35, 33.7, 33.75, 33.8
FAA AC 33-2

7.1.2 Engine out.

Criterion: Verify that an engine out condition on multi-engine aircraft allows safe recovery of the aircraft.

Standard: Special control modes to address engine out conditions are characterized to allow safe recovery of the air vehicle (see also 6.3.4).

Method of Compliance: Verification methods include a combination of engine test, analysis and review of documentation. Testing is done at representative ground and altitude conditions to characterize and verify special control mode performance. Analysis is performed with a model based on measured test data for characterization of performance at conditions that have not been tested.

References: JSSG-2007: A.3.2, A.4.2; A.3.11, A.4.11; A.3.12, A.4.12.
14 CFR 33.35, 33.5, 33.7, 33.8
FAA AC 33-2

7.1.3 Technical data.

Criterion: Verify that technical data includes all operational and maintenance procedures and limitations necessary for safe operation of the air vehicle.

Standard: All propulsion systems maintenance and inspection procedures and limits are documented in the applicable technical orders and manuals. Critical engine performance and emergency procedures are documented in the flight manual. Mission performance data in flight manuals are generated with engine performance data that has been validated and under configuration control. A system is in place to properly maintain and update all maintenance and inspection technical orders and flight manuals for the engine and propeller or rotary wing drive systems.

Method of Compliance: Verification methods include inspection and review of documentation. Inspection of the maintenance and inspection of the technical orders and flight manuals provides assurance that all information is current and up to date.

Review of the system and process used to maintain the technical orders and flight manuals provides assurance that critical information will be correctly updated in a timely manner.

References: JSSG-2007: A.3.4.1.7, A.3.1.1.1, A.4.12
14 CFR 23.1585

7.1.4 Propulsion configuration management.

Criterion: Verify that the engine configuration is controlled.

Standard: The Configuration Management Plan (CMP) defines how configuration management will be implemented (including policies and procedures) for a particular acquisition or program. Configuration documentation identifies and defines the item's functional and physical characteristics. All engine hardware is documented in the engineering drawings and qualified parts lists. The CMP addresses procedures for qualification of modifications, instrumentation, test specific configurations, etc.

Method of Compliance: Inspection and review of the CMP ensure that a process and plan are in place to monitor and control the engine configuration.

Inspection and review of the engine drawings verify that all hardware components are documented.

References: JSSG-2007: A.3.1.9, A.4.1.9 (Design Control); A.3.12, A.4.12 (Engine Qualification)
MIL-HDBK-61

7.1.5 Critical safety items.

Criterion: Verify that critical safety items (CSI) and critical characteristics are identified.

Standard: Documentation identifies and categorizes all critical propulsion system parts, assemblies, or installations containing critical characteristics whose failure, malfunction, or absence may cause a catastrophic or critical failure resulting in the loss or serious damage to the air vehicle, an unacceptable risk of personal injury or loss of life, or an uncommanded engine shutdown that jeopardizes safety.

Method of Compliance: Verification methods include analysis, inspection and review of documentation. Inspection of the Critical Safety Item (CSI) list and FMECA ensures that all items have been accounted for.

References: DoDM 4140.01, Vol 11, Enc 3, Procedures 3, CSI-Specific Procedures
NAVAIRINST 4200.56
Critical Item Management Desktop Guide (to NAVAIR 4200.56)
JACG Aviation Critical Safety Item Management Handbook

7.1.6 Propulsion system operation.

Criterion: Verify that the engine and associated components will operate safely within the flight and maneuver envelope and operational environment.

Standard: Engine thrust or power, fuel consumption, endurance, and structural integrity are characterized with representative installation effects over the expected flight and maneuver envelope and are shown to support the safe operation of the air vehicle. Installation includes inlet effects due to external protuberances (sensors, probes), anti-ice devices, sand and dust separators, exhaust system effects due to infrared (IR) or noise suppressors, and customer extractions due to bleed air and mechanical power. Operational environments include cold and hot days, and weather such as rain, snow, or ice. Additionally, operational environments can include bird, ice, sand, volcanic ash ingestion, as well as hot gas ingestion from any source (including armament gases). Maneuver envelope includes rotational velocities, accelerations, and gyroscopic moment conditions.

Method of Compliance: Verification methods include a combination of engine test, analysis and review of documentation. Testing is done at representative ground and altitude conditions to characterize and verify baseline performance, installation effects and deteriation caused by the operational environment. Analysis is performed with a model based on measured test data for characterization of performance at conditions that have not been tested. Analysis verifies that component deflections under gyroscopic loading conditions do not impair operation of the engine under ultimate loading levels and meet life requirements under limit load conditions.

References: JSSG-2007: A.3.2, A.4.2 (Performance and Operability); A.3.3, A.4.3 (Environmental Conditions); A.3.4, A.4.4 (Integrity)
14 CFR 33.23, 33.5, 33.35, 33.7, 33.75, 33.8, 33.91

7.2 Gas turbine engine applications.

7.2.1 Performance.

7.2.1.1 Installed performance.

Criterion: Verify that the data for assessment of installed propulsion system performance meet the applicable specification requirements. This includes consideration of all installation effects imposed by the air vehicle, and all intended operational environments.

Standard: Engine thrust or power and fuel consumption are characterized with representative installation effects over the range of flight conditions expected and are shown to support the safe performance of the air vehicle. Installation effects include considerations of inlet and exhaust temperature, pressure and drag effects due to external protuberances such as sensors and probes; anti-ice devices; sand and dust separators; exhaust system effects due to IR and noise suppressors; customer extractions of air bleed and mechanical power; etc. Operational environments include cold and hot days, and weather such as rain, snow, or ice.

Method of Compliance: Verification methods include a combination of engine tests and analyses. Testing is done at representative ground and altitude conditions to characterize and verify baseline performance. Analyses are performed with a model based on measured test data for characterization of performance at conditions that have not been tested.

References: JSSG-2007: A.3.1, A.4.1; A.3.7, A.4.7; A.3.2, A.4.2; A.4.2.1, A.4.2.1.1; A.3.3.1, A.4.3.1; A.3.3.2, A.4.3.2; A.3.11, A.4.11; A.3.12, A.4.12; Table XLIXa
JSSG-2001: 3.3.1.1, 4.3.1.1
14 CFR 33.5, 33.35, 33.7, 33.8
FAA AC 33-2

7.2.1.2 Degraded performance.

Criterion: Verify that degraded installed propulsion system performance is assessed. Degraded engine performance includes performance in any backup control mode, as well as performance after bird, ice, water and sand ingestion.

Standard: Installed engine thrust or power is characterized in backup control mode, at field removal limits (if defined), and after bird, ice, water and sand ingestion and meets applicable specification requirements.

Method of Compliance: Verification is accomplished by engine testing and analyses.

References: JSSG-2007: A.3.7.2.1.1, A.4.7.2.1.1 Backup control; A.3.3.2.1, A.4.3.2.1 Bird ingestion; A.3.3.2.3, A.4.3.2.3 Ice ingestion; A.3.3.2.4, A.4.3.2.4 Sand ingestion; A.3.4.1.6, A.4.4.1.6 Icing Conditions; A.3.11/A.4.11 Engine system and controls and externals verification; and A.3.12/A.4.12 Engine qualification
14 CFR 33.68, 33.76, 33.77, 33.89
FAA AC 33-76-1

7.2.2 Operability.

References: JSSG-2007: A.3.2, A.4.2; A.3.11, A.4.11; A.3.12, A.4.12
14 CFR 33.5, 33.7

7.2.2.1 Stability margin.

Criterion: Verify that positive stability margin exists at all flight conditions or that placards are documented in the flight manual.

Standard: Stability audits show positive engine surge margin at conditions that are critical to the safety of the flight vehicle. Evaluation conditions include crosswind takeoff, take-offs on cold days following a rapid reaction start, and extreme maneuvers. Stability audits use the correct installation effects (bleed, horsepower extraction, nozzle suppression, and inlet recovery, distortion, and swirl), and consider all destabilizing effects, such as: engine deterioration, non-standard day effects, steam ingestion, armament gas ingestion, liquid water ingestion, and transient response. When operator actions are used to mitigate risk of engine stalls, the flight manual includes proper operator instructions, placards, warnings or cautions.

Method of Compliance: Verification methods include analysis, test and review of documentation. Verification of the stability audits follows guidelines outlined in SAE ARP1420 and SAE AIR1419. The audits are based on data from numerous rigs and engines throughout the development program. Rig and/or engine tests are conducted to measure fan and compressor stall lines. A stability methodology is developed by testing fan/compressor sensitivity to distortion and other destabilizing influences. Inlet model tests are conducted to quantify the levels of performance, distortion, and inlet stability. Analysis is conducted via a validated stability audit which combines the above factors.

References: JSSG-2007: A.3.2.2.6, A.4.2.2.6; A.3.2.2.11, A.4.2.2.11; A.3.3.2.5, A.4.3.2.5; A.3.3.2.6, A.4.3.2.6; A.3.3.2.7, A.4.3.2.7; A.4.11.1.2 (Altitude test); Table XLIXa.
SAE ARP1420
SAE AIR1419
14 CFR 33.65, 33.73 (stability); 33.78 and 33.5 (distortion)

7.2.2.2 Transient operation.

Criterion: Verify that the engine has adequate stability during throttle transients. The entire range of required transients should be considered, including those during land and ship approaches, aerial refueling, and quick stops; for rotorcraft, bob-up and remask, and nap of the earth ridgeline crossings.

Standard: Thrust or power response times meet air system mission performance requirements during all required maneuvers. Stability margin is evaluated per the criterion of 7.2.2.1. Control system phase and gain margin is as described in the criterion of 7.2.4.1.3.

Method of Compliance: Verification is accomplished by analysis, electronic and closed loop bench tests, engine tests, vehicle integration tests, flight tests and inspection of documentation.

References: JSSG-2007: A.3.2.2.6, A.4.2.2.6; A.3.2.2.7, A.4.2.2.7
MIL-HDBK-516: 7.2.4.1.3.
14 CFR 33.65 Surge and stall characteristics; 33.73 Power or thrust response; and 33.89 Operation test

7.2.2.3 Air start.

Criterion: Verify that air start requirements are met and documented in the flight manual. Air starts include spool-down, windmill, cross-bleed and starter-assisted as appropriate for the air vehicle system.

Standard: Airstart capability is documented in the flight manual.

Method of Compliance: Verification methods include test and review of documentation. The airstart envelope is initially verified from ground testing in altitude test cells and then verified by flight test.

References: JSSG-2007: A.3.2.2.3.2, A.4.2.2.3.2; A.4.11.1.2 (Altitude test)
14 CFR 33.69 (Ignitions system); 33.89 Operation test

7.2.2.4 Stall recoverability.

Criterion: Verify that the engine recovers from instability induced by external influences (such as inlet distortion and steam and armament gas ingestion) after the external influence is removed, without employing measures such as commanded idle or shutdown and without exceeding thermal or structural limits.

Standard: The engine or air vehicle control system can detect and recover from an engine stall without commanded idle or shutdown or the engine demonstrates the ability to self-recover.

Single engine applications possess an automatic relight system for recovery from combustor blowout, unless it has been demonstrated that automatic relight offers no improvement in engine recoverability.

Method of Compliance: Verification methods include test and review of documentation. Control system detection is verified by engine ground and bench testing; self-recovery is demonstrated from engine ground and altitude cell testing.

References: JSSG-2007: A.3.2.2.3.5, A.4.2.2.3.5; A.3.2.2.11.2, A.4.2.2.11.2; A.3.7.2.1, A.4.7.2.1
14 CFR 33.28 engine control systems; 33.65 Surge and stall characteristics

7.2.3 Structures.

7.2.3.1 Engine structure.

Criterion: Verify that the engine structure does not exhibit detrimental permanent set or deflect to the extent that operation or performance is impaired when operated to limit load conditions (singly or in combination) within the flight and ground envelope. Verify that the engine structure does not experience catastrophic failure under ultimate load conditions or combinations of ultimate loading.

Standard:

a. Factors of safety (SF) are applied to loads that occur within the flight and ground envelope to establish limit load and ultimate load conditions:

   Limit loads:

   1.0 SF for in-flight loads.

   1.5 SF for pressure vessels/cases.

   1.33 SF for cast structures (unless the material has been fully characterized).

   Ultimate loads:

   1.5 SF for in-flight loads.

   2.0 SF for pressure vessels/cases.

   2.0 SF for cast structures.

   Positive margins of safety exist for the range of manufacturing tolerances and operational conditions.

b. Rotor Integrity: The engine is capable of withstanding overspeeds of 115 percent maximum allowable steady state speed at maximum allowable measured gas temperature for five (5) minutes. The engine is capable of withstanding gas temperatures 75 °F in excess of the maximum allowable measured gas temperature and at maximum allowable steady state speed for five (5) minutes.

c. Gyroscopic moments: The engine can operate satisfactorily at maximum allowable steady state engine speed when subjected to rotational velocities and accelerations within the flight envelope and gyroscopic moment conditions. Two conditions are assessed: 3.5 radians per second for a period of 15 seconds with a 1g maneuver load, and 1.4 radians per second for 10E7 cycles at all load factor conditions within the flight envelope.

d. Disk burst speed: The minimum disk burst speed is at least 115 percent of the maximum steady state speed (with a target of 122 percent which represents a factor of safety of 1.5) or 5 percent above the worst transient speed, whichever is higher. Worst case thermal conditions should be applied.

e. Blade and disk deflection: Blades and disks do not contact any static parts of the engine other than seals and shrouds when operating at all points within the flight and ground envelope. Seals and clearances remain effective under all internal and external loads, manufacturing tolerances, cold and hot day operation including transient thermal conditions.

f. Blade out: Subsequent to blade failure at maximum allowable steady state speed, the engine does not experience uncontained fire, catastrophic rotor, bearing support or mount failures, overspeed conditions, leakage of flammable fluid, or loss of ability to shut down the engine. Blade loss loads for conventional blades are based on the imbalance equivalent to fracture in the blade attachment at the minimum neck section above the outermost retention feature. Blade loss loads for integrally bladed rotors are based on the imbalance equivalent to liberation of the airfoils including the fillet material down to the rotor rim diameter. Additional imbalance due to secondary damage is included.

g. Engine mounts can withstand limit load conditions without permanent deformation and ultimate loads (including crash loads) without fracture.

h. Ground handling mounts support the weight of the engine (including all engine mounted equipment and accessories, components and operating fluids) under a 4g axial, 2g lateral, and 3g vertical load acting in combination at the engine center of gravity.

i. Engine cases and each gas pressure loaded component of the engine are capable of withstanding maximum operational pressure loads that occur within the flight and ground envelope including safety factors.

j. Engine pressure balance provides thrust loading to assure bearing operation without skid damage at all power settings throughout the flight and ground envelope.

k. Containment: The engine can completely contain a fan, compressor or turbine blade failure. No fires result and the engine contains all parts damaged and released by the failure of a single blade.

l. Ingestion: The engine meets all requirements of the specification during and after the sand and dust ingestion test specified. The engine operates and performs during and after ingestion of hailstones and sheet ice at the take-off, cruise, and descent aircraft speeds. The engine cannot be damaged beyond field repair capability after ingesting the hailstones and ice. The engine continues to operate and perform during and after impact of birds as specified in JSSG-2007.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation.

a. Factor of safety (SF): The requirements are evaluated by analyses and tests. Strain gauges and other instrumentation are used during tests to validate analysis methods. Tests are conducted progressively to limit or ultimate load conditions.

b. Rotor integrity: Analysis confirms the overspeed and overtemperature capability of the engine. Engine testing validates analytical predictions.

c. Gyroscopic moments: Analysis verifies that component deflections under gyroscopic loading conditions do not impair operation of the engine under ultimate loading levels and meet life requirements under limit load conditions.

d. Disk burst speed: Disk burst testing is conducted on the most limiting rotor (disk with the minimum burst capability) of each module. Maximum test speed is sufficient to demonstrate that a minimum tensile strength component (-3 Sigma) can meet the burst margin requirement based on the specific ultimate strength capability of the test component. These conditions are maintained for a minimum of 30 to 60 seconds. The test is considered successfully completed if there is no evidence of imminent failure.

e. Blade and disk deflection: Analysis verifies that positive clearances, both axial and radial, exist under all operational and maneuver load conditions.
f. Blade out: Evaluation of blade out requirements includes analyses of the fan, compressor, and turbine sections of the engine. Evaluation of the most critical rotors is accomplished by an engine test. Failure is assumed to occur at the maximum transient rotor speed.
g. Engine mounts: Engine-mount requirements are evaluated by analysis of the worst-case engine-mount failures and their consequences. Testing of mount capability to limit and ultimate load conditions is accomplished for qualification. Testing is taken to mount failure to validate analytical models.
h. Ground handling mounts: Tests are conducted to load levels sufficient to evaluate limit load and ultimate load operational requirements and to evaluate that minimum strength components can meet the load requirements.
i. Pressure vessel/case design: The analyses show that all pressure-loaded parts and components can meet the limit and ultimate load conditions when constructed with minimum-strength materials. The analyses are substantiated/correlated with pressure vessel/case testing. All pressure-loaded parts and components are tested to at least two times (2X) the maximum operating pressure in combination with the external ultimate loads based on the external loads encountered during engine operation. These tests are conducted at the maximum allowable temperature or at a test pressure adjusted to account for the differences between operating and test temperatures.
j. Engine pressure balance: Analysis results indicate that loads imposed on the engine bearings are of sufficient magnitude to ensure adequate bearing operation without skid damage. The analysis is validated with suitably instrumented engine testing. This test is conducted in an altitude test cell to simulate altitude and ram conditions representative of operational use.
k. Containment: The engine contractor performs a blade containment analysis which relates the released blade kinetic energy to the energy required for containment. The analysis is substantiated/correlated with rig or engine containment tests.
l. Ingestion: Verification is accomplished via analyses, component, and full-up engine tests.

References: JSSG-2007: A.3.4.1.6, A.4.4.1.6 Strength; A.3.1.1.4.3, A.4.1.1.4.3 Engine Stiffness; A.3.4.1.2.1, A.4.4.1.2.1 Externally Applied Forces
14 CFR 33.23, 33.75, and 33.91

7.2.3.2 Durability.

Criterion: Verify that the engine has positive durability margins over the defined operational interval and duty cycle to preclude adverse safety, economic, or operational effects.

Standard:

a. Positive low cycle fatigue life margins have been used for component design.
b. Vibratory stresses are kept below 60 percent of the minimum Goodman allowable limit for one billion cycles.
c. Material corrosion does not degrade the engine function, integrity or maintenance for the design service life (see to 19.2.1 and 19.2.2).
d. Parts cannot creep to the extent that acceptable field engine operation is impaired for the operating conditions, operating interval and design usage.
e. Maximum engine mechanical vibration limits are established as a function of frequency,

engine order, and location and direction of measurement. Maximum engine mechanical vibration limits should be based on an acceptable margin of safety for structural capability. Damaging rotor critical speeds have probabilistic margin over the operating speed range to account for variation in influence parameters. When there is insufficient confidence in probabilistic solutions, a deterministic margin of at least 20 percent is specified for rotor critical speeds that exist above maximum operating speed or below idle speed.

f. The engine meets the design service life requirements in the presence of the acoustic environment produced during installed and uninstalled operation at flight and ground conditions consistent with the design usage.

g. Foreign object/domestic object damage (FOD/DOD): The engine is capable of operating for one inspection interval after ingestion of foreign or domestic objects which produce damage equivalent to a stress concentration factor (Kt) of three (3). If validated probabilistic methods are used, a failure threshold of one failure in 10 million engine flight hours is met.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation.

a. Low cycle fatigue (LCF) margin: Low cycle fatigue analyses and testing are accomplished. Testing consist of component and accelerated mission test (AMT) testing. Rotating components have cyclic life demonstrated by spin pit testing with thermal gradients applied, where appropriate. The spin pit testing is continued until crack initiation or five times (5X) the design service life.

b. High cycle fatigue (HCF): Aeromechanical stress surveys are conducted using final configuration hardware and control schedules. Testing is conducted over the range of operating pressures and temperatures to clear the design flight envelope. Sensitivity testing over the expected range of influence parameters is part of the test program to demonstrate robustness to expected variations. Analytical models are validated using the HCF Test Protocol defined in JSSG-2007.

c. Corrosion: A corrosion prevention and control plan is prepared. Corrosion resistance is verified through engine testing in a corrosive environment as defined in JSSG-2007.

d. Creep: Analytical prediction of creep and component growth and percent stress rupture life, as a function of design life, is accomplished on each creep-critical component. Design operating stresses are established based on past experience that indicates a high probability that satisfactory creep and stress rupture life can be achieved (e.g., 0.2 percent plastic creep life, 0.005-inch diametrical rim growth, 50 percent stress rupture life). Component and engine AMT testing validates analytical predictions.

e. Vibration: Engine AMT testing is accomplished at allowable field levels of vibration for the duration of the test to validate structural integrity of components and assemblies. Instrumented engine tests confirm rotor critical speed margins.

f. Acoustic environment: The capability of the engine to meet the strength and durability requirements in the presence of the acoustic environment generated during engine operation is verified by test. Acoustic measurements are made during operation in the test cell at various conditions. Analysis of the data is made to establish whether pressure levels are of sufficient magnitude to cause structural cracking. Inspection of AMT engines is used to verify resistance to component structural cracking.

g. FOD/DOD: Analysis of aeromechanical test results validates that airfoils stresses remain under the 100 percent Goodman allowable for a Kt=3 notch or probabilistic analysis verifies a failure rate of <1e-7. Goodman allowables are validated with fatigue tests of damaged airfoils. The applied damage produces a minimum stress concentration factor (Kt) of 3 at the critical location.

References: JSSG-2007: A.3.4.1.5, A.4.4.1.5, Durability; A.3.4.1.5.2, A.4.4.1.5.2, LCF; A.3.3.1.5,A.4.3.1.5, Corrosive atmosphere; A.3.4.1.8,A.4.4.1.8, Vibration and dynamic response; A.3.4.1.5.1, A.4.4.1.5.1, High cycle fatigue (HCF) life guidance; A.3.2.1.4, A.4.2.1.4, Performance retention guidance; A.3.4.1.10, A.4.4.1.10 Acoustic noise; A.3.3.2.2, A.4.3.2.2, Foreign object damage (FOD)
14 CFR 33.14, 33.19, 33.5, 33.63, and 33.83.

7.2.3.3 Damage tolerance.

Criterion: Verify that all safety- and mission-critical parts are designed to be damage tolerant over the defined operational interval and duty cycle.

Standard:

a. Safety- and mission-critical engine parts maintain damage tolerance for two times (2X) the inspection interval in the presence of material, manufacturing, processing, and handling defects.
b. Assumed initial surface flaw sizes are based on the non-destructive inspection (NDI) methods to be used during manufacture and depot maintenance. Assumed initial imbedded flaw sizes are based on the intrinsic material defect distribution or the NDI methods to be used during manufacture. Flaw size detection reliability is verified to have a probability of detection and confidence level of 90%/95% for manual inspections or 90%/50% for fully automated inspection methods.
c. The residual strength is equal to the maximum stress that occurs during the design service life to the required design usage conditions.
d. Safety and mission critical parts are serialized, properly marked and tracked, and subjected to the required process control and NDI procedures.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation.

a. Fracture critical component: Damage tolerance analysis is conducted on each component classified as safety or mission critical. Damage tolerance analysis that addresses imbedded defects can be based on probabilistic methods that account for the distribution of variables. Analyses demonstrate that the assumed initial flaws will not grow to critical size for the usage, environment, and required damage tolerance operational period. The analyses account for repeated and sustained stresses, environments, and temperatures, and include the effects of load interactions. Analysis methods are verified by test, utilizing engine or spin pit testing.
b. Initial flaw size: Controls and inspection methods are established through the damage tolerance control plan. Demonstration programs, in the absence of existing data, are performed to ensure that flaws greater than the assumed design flaws will not occur in finished components. Subsequent to successful completion of these demonstration programs, the selected inspection methods and processes become part of the production requirements and are not changed without approval of the Procuring Activity.
c. Residual strength: Analyses verify that at the end of the required damage tolerance operational period, the strength requirement can be met for the flaw configuration and the required load.
d. Damage tolerance controls: Inspection of drawings, specifications, and damage tolerance control plan verifies that parts are serialized, marked, tracked and comply with

process and NDI controls.

References: JSSG-2007: A.3.4.1.4, A.4.4.1.4 Parts classification; A.3.4.1.7, A.4.4.1.7 Damage tolerance; 3.4.1.7 through 3.4.1.7.4 and A.4.4.1.7 through A.4.4.1.7.4, Composites damage tolerance
14 CFR 33.75

7.2.3.4 Material characterization.

Criterion: Verify that the allowables for materials are minima and are established considering statistical variability, the expected environments, fabrication processes, repair techniques, and quality assurance procedures. Verify that conditions and properties for material repairs satisfy design requirements.

Standard: Structural properties used in design are based on minimum material capabilities. All material properties except fracture toughness and crack growth are based on minus three sigma values with a 50% confidence level or minus two Sigma values with a 95% confidence level. Another option is to state that material properties will be based on B0.1 probability values. The confidence level for B0.1 is 50%. B50 properties may be used to characterize fracture toughness and crack growth rate.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Test and modeling programs have been used to establish material structural properties. Anticipated properties under damage states (e.g., fretting) have been verified through combinations of laboratory specimens, sub-element and component testing, material damage models which have been validated against databases and supplemented with historical data which cover the range of potential damage states, or databases which cover the properties under damage states. Material properties established by test have been based on specimens fabricated from "as produced" parts, from parts produced by equivalent practices, or from parts sufficiently similar in processing and size, since critical structural properties are dependent upon the manufacturing processes. Damage states in the parts which may occur during field usage have been verified for their potential effect on high cycle fatigue life.

References: JSSG-2007: A.3.4.1.3, A.4.4.1.3 Material characterization
14 CFR 33.15

7.2.3.5 Design service life.

Criterion: Verify that the engine is designed such that pertinent environmental variables and all sources of repeated loads are considered and these considerations are included in the development of the design duty cycle.

Standard: The design usage includes missions and mission mix, usage parameters, externally applied forces, operating envelope, engine attitude limits, ambient temperature distribution, icing environment conditions, sand and dust ingestion, corrosive atmosphere conditions, acoustic environment, customer bleed air extraction, loaded accessory pads and power takeoff usage, and engine performance retention characteristics. Sensitivity analysis is conducted on critical components to identify the effects of probable ranges in usage variables on engine life limits. The results of the sensitivity analysis are used to condense the design service life and design usage into a minimum number of design duty cycles. The design duty cycle equivalent damage content is equal to or greater than the damage content of the full mission set.

Method of Compliance: Verification methods include analysis, inspection and review of documentation. The specification and/or the Structural Integrity Program (e.g., strength and life report), as appropriate, document the design duty cycle details and life analyses.

References: JSSG-2007: A.3.4.1.2, A.4.4.1.2 Design usage
14 CFR 33.4

7.2.3.6 Life management.

Criterion: Verify that all inspection intervals and life-limited components are identified in the technical manuals and a process to track life consumption is operational and current.

Standard: Required maintenance actions (component inspection, repair, or replacement requirements) have been defined to ensure adequate structural integrity and operational readiness for the design service life. Required maintenance actions are based on duty cycles defined by operational usage of the airframe/engine. Individual component maintenance times are based on applicable parameters that contribute to life degradation. The critical component tracking system has been established and defines the analysis procedures, serialization, data collection, and computer programs necessary to establish maintenance times of individual components based on accrual of parameter events.

Method of Compliance: Verification methods include inspection and review of documentation of the Engine Life Management Plan, applicable maintenance manuals (e.g., Technical Orders, Naval Aviation Technical Information Products (NATIPs) and the parts life tracking program.

References: JSSG-2007: A.3.4.1.1, A.4.4.1.1 Design service life.
14 CFR 33.4

7.2.4 Engine subsystems, components, computer resources and software.

7.2.4.1 Subsystems.

7.2.4.1.1 Engine control system.

Criterion: Verify that the engine control system maintains safe engine operation under all required conditions.

Standard: The control system provides required levels of engine performance and operability in accordance with 7.2.1 and 7.2.2 without exceeding engine design limits. The architecture accommodates all control mode operations, including failure conditions.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. A Failure Modes, Effects and Criticality Analysis (FMECA) and a System Safety Hazard Analysis (SSHA) of the control system establish a list of all known potential failure modes, their associated probabilities and an analysis of engine effects. Closed loop bench testing, using production qualified components, ensures that the system can properly interact with all other systems and components on the engine. Engine sea level and altitude testing demonstrate the control system's ability to maintain required levels of speed, temperature, pressure and fuel flow throughout the flight envelope. Closed loop fault injection bench testing ensures the control system can correctly identify and accommodate known critical failures. Engine sea level and altitude testing provide opportunities to inject faults into the control system and evaluate the engine's ability to respond within specification limits. Flight testing ensures the engine performs as required and that there are no unaccounted for installation effects. Alternative compliance approaches include similarity to other military systems or previous civil (e.g., FAA) airworthiness certification support documentation.

References: JSSG-2007: A.3.7.2, A.4.7.2 Control systems design and verification
14 CFR 33.27, 33.28, 33.91

7.2.4.1.2 Isolation of subsystems.

Criterion: Verify that an engine's subsystems are isolated from each other to prevent cascading failures.

Standard: Controls and subsystem components are physically isolated or protected to minimize collateral or secondary damage in the event of failure.

Controls and subsystems are systemically and operationally isolated to avoid possible cascading failures due to any single or common cause.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Inspection of design review and test data, drawings and installed hardware provide information to evaluate adequate physical isolation of engine subsystem components. Mock-ups can be used if they adequately represent fielded systems. For example, a common mode multiple signal failure test evaluates simultaneous signal failures due to a common cause.

A Failure Modes, Effects and Criticality Analysis (FMECA) details all known potential failure modes and their associated probabilities. The FMECA is used to conduct a system analysis of engine effects resulting from propulsion system failures.

References: JSSG-2007: A.3.7.2, A.4.7.2 Control systems guidance
14 CFR 33.27, 33.28, 33.91

7.2.4.1.3 Stability.

Criterion: Verify that the control system maintains both stable engine operation and response during all steady state and transient conditions.

Standard: All engine control loops demonstrate a minimum of 6 db gain margin and 45 degrees of phase margin. The engine provides safe and stable thrust/power levels in response to all operator commands.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Phase and gain stability margins are verified through analysis, open and closed loop modeling, bench testing (wet rig) and full-up engine testing. These verification methods are conducted using the entire range of expected power level angle inputs and transients. Closed loop models are validated using closed loop bench and full-up engine testing. Ground and flight testing demonstrate the engine's ability to respond to all pilot/operator commands.

References: JSSG-2007: A.3.7.2, A.4.7.2 Control systems guidance
MIL-HDBK-516: 7.2.2.2.
14 CFR 33.27, 33.28, 33.91

7.2.4.1.4 Failure modes.

Criterion: Verify that any failure of the engine controls and supporting subsystems results in a fail-operational or fail-safe condition.

Standard: Loss of redundancy does not affect control system capability. Failures may be accommodated by the following:

a. Fail-operational capability provides full-up engine performance.
b. Fail-safe capability allows continued engine operation at a degraded level of performance sufficient to sustain safe air vehicle operation.
c. Failure accommodation on multi-engine platforms may include engine shutdown if loss of aircraft does not result.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Failure Modes, Effects and Criticality Analysis (FMECA) establishes a list of all known potential failure modes and their associated probabilities. Closed loop and fault injection bench testing ensures the control system can correctly identify and accommodate all known failures that can affect safe operation of the air vehicle. During engine sea level and altitude testing, faults are injected into the control system and the engine responds within specification limits.

References: JSSG-2007: A.3.7.2, A.4.7.2 Control systems guidance
14 CFR 33.27, 33.28, 33.91

7.2.4.1.5 Failure criticality.

Criterion: Verify that engine control system failures and accommodations do not cause unacceptable controllability, stability, or handling quality effects; or require urgent or excessive pilot/operator action.

Standard: Engine responses to control system failures do not unacceptably distract or increase the workload of the pilot/operator or affect continued safe operation of the air vehicle.

Critical failures that could affect continued safe operation of the air vehicle are recorded (e.g., engine health monitoring (EHM), engine monitoring system (EMS)) and the pilot/operator is notified via alarms or warnings.

Non-critical failures are recorded and are available to the pilot/operator and maintenance personnel when the system is queried.

Method of Compliance: Verification methods include analysis, test, and review of documentation. A Failure Modes, Effects and Criticality Analysis (FMECA) of the control system details all known potential failure modes, their associated probabilities and an analysis of engine effects.

Closed loop bench and fault injection testing ensures that the control system correctly identifies and accommodates all known critical failures and that the appropriate level of information is provided to the pilot/operator and maintenance personnel.

During engine sea level and altitude testing, faults are injected into the control system and the engine responds within specification limits. Flight testing for degraded engine control modes (e.g., reversionary, backup) verifies acceptable handling qualities.

References: JSSG-2007: A.3.7.2, A.4.7.2; A.3.7.6, A.4.7.6.
14 CFR 33.27, 33.28, 33.91

7.2.4.1.6 Fuel system.

Criterion: Verify that the engine fuel system safely provides the required fuel supply to the combustor, augmentor, and fueldraulics subsystems under all required conditions.

Standard: Fuel system components such as pumps, regulators, carburetors, flow metering valves, check valves, nozzles, spray bars, and tubing are adequately sized to provide the necessary fuel flows, pressures and temperatures to simultaneously satisfy the requirements of the main combustor, augmenter, heat exchangers/cooling systems and all variable geometry fueldraulic subsystems. An in-line filtration system includes cleaning, replacement and a bypass indication (manual or electronic) provision(s).

The fuel system can safely perform under severe operating conditions such as high vapor/liquid ratios, temperature ranges, contamination, and suction lift for primary, alternate, and emergency fuels.

Fuel system pressure vessels and lines can withstand one and a half times (1.5X) (proof) normal operating pressures (without performance degradation or leakage) and two times (2X) (burst) maximum operating pressures (without permanent deformation or leakage).

All fuel carrying components and lines are fire resistant.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. A complete analysis of fuel system requirements versus capabilities, using worse case flight conditions, establishes the system design parameters.

Bench (wet rig) testing demonstrates the fuel systems ability to produce required flows, pressures and temperatures.

Ground engine testing demonstrates the fuel system's ability to provide properly conditioned fuel to the engine.

A fuel filter flow and contamination test ensures that the filter adequately cleans debris from the fuel, maintains acceptable flow and pressure and activates bypass when needed. Inspection of the fuel filter determines its capabilities for required maintenance.

Applicable fuel system performance testing (suction lift, cavitation, vapor to liquid ratio (V/L), lubricity, etc.) ensures that the engine can safely operate under anticipated worse case conditions.

Proof and burst pressure component testing ensures adequate safety margin across the entire flight envelope.

Testing verifies fire resistance where a 2000 °F flame is applied for five (5) minutes with no fire propagation.

References: JSSG-2007: A.3.7.3.2, A.4.7.3.2 Fuel Systems Performance, Engine fuel system design and verification testing; and A.3.1.8.1, A.4.1.8.1 Flammable Fluid Systems - fire resistance testing requirements and procedures.
SAE AS4273
SAE AS1055
14 CFR 33.17, 33.67, 33.87(a)(7), 33.89

7.2.4.1.7 Ignition system.

Criterion: Verify that the engine ignition system provides a safe and effective ignition source for the main combustor and augmentor.

Standard: Operation of the ignition exciters, igniters and cables ensures safe and reliable light-off of the main combustor and augmenter throughout the ground and air start envelopes.

The engine control system detects a flameout and activates the ignition system (auto-relight) without operator involvement or the operator can manually activate the main and augmenter ignition systems.

External cabling has been sufficiently insulated to prevent inadvertent conduction and shock hazard.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. The ignition system's ability to provide adequate spark energies to the main combustor and augmenter is verified by bench testing and full-up engine and flight testing.

The control system's ability to correctly identify an engine flameout and automatically activate the ignition system without pilot/operator action is verified by full-up engine and flight testing. All ignition system functions are fully exercised by pilot/operator command with the engine installed in the air vehicle.

References: JSSG-2007: A.3.2.2.3.5, A.4.2.2.3.5 Auto-Relight; and A.3.7.5, A.4.7.5 Ignition Systems
14 CFR 33.69, 33.89

7.2.4.1.8 Anti-ice/de-ice systems.

Criterion: Verify that the engine anti-ice/de-ice system prevents damaging ice buildup or provides safe and non-damaging ice removal at all engine speeds/power levels and will not result in heat-induced damage to the engine's front frame structure.

Standard: Anti-ice systems prevent ice from accumulating on the engine structure that could result in ingestion and subsequent mechanical damage to internal rotating components.

De-ice systems remove existing ice accumulations before they can be ingested and cause mechanical damage to internal rotating components.

If the engine control system is capable of automatically operating the anti-ice and de-ice systems without operator action, the operator can override the engine control system and operate the anti-ice or de-ice systems.

Anti-ice and de-ice system operational temperatures are monitored and, where applicable, the systems are automatically turned off in the event engine front frame damage is likely to occur. Moisture cannot accumulate and freeze in areas (sensors, lines, etc.) that could result in control system malfunctions.

Notification is provided to the operator in the event of anti-ice or de-ice system malfunction.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation.

Analysis of the air vehicle mission defines the engine's icing environment.

Bench and engine tests of the anti-ice or de-ice plumbing, valves and sensors demonstrate the system's ability to prevent or remove ice prior to it damaging the engine.

Bench testing of the control system demonstrates that it can identify the existence of icing conditions and turn on the anti-ice or de-ice system.

All anti-ice and de-ice system controls are tested to ensure that the pilot or operator can override the control system and manually operate the anti-ice or de-ice system.

Fault injection testing of the anti-ice and de-ice systems demonstrate the ability to properly recognize temperature exceedances and initiate system function shutdown.

Analysis and inspection of all critical control system components verifies resistance to moisture collection and freezing.

References: JSSG-2007: A.3.7.1, A.4.7.1 Anti-ice and De-ice Systems
14 CFR 25.1419

7.2.4.1.9 Cooling and thermal management.

Criterion: Verify that engine cooling and thermal management systems safely remove excess heat from the engine and its subsystems and integrate with the air vehicle thermal management system, if applicable (see 8.2.15, this document).

Standard: Cooling and thermal management systems function properly during ground and flight operation, under all atmospheric conditions and for all flight conditions/attitudes in the air vehicle operating envelope.

Cooling and thermal management systems are properly sized to remove heat from those components (e.g., electronic controls, sensors, lubrication system) which could become damaged or operate erratically when exposed to excessive thermal loads.

Engine and air vehicle cooling and thermal management systems function together, to ensure adequate thermal load dissipation for the entire air vehicle, including post-shutdown conditions such as engine soakback.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Analysis and modeling of engine components determine their thermal loading and heat rejection characteristics. Results from this analysis and modeling are used to verify the engine components' ability to continue operation when exposed to engine induced thermal loads. Analysis and modeling of the combined air vehicle and engine thermal management systems ensures there are no conditions that result in exceedance of established loss of aircraft (LOA) rates. Engine testing is used to validate the results of thermal modeling and analyses. Aircraft installation surveys are performed to verify that component maximum operating temperatures and maximum non-operating temperatures are not exceeded.

References: JSSG-2007: A.3.2.2.13, A.4.2.2.13; A.3.7.3.3, A.4.7.3.3
14 CFR 27.1121

7.2.4.1.10 Variable geometry systems.

Criterion: Verify that the engine variable geometry systems safely operate under all engine operating conditions.

Standard: Variable geometry system components such as pumps, actuators, bleed valves, plumbing and mechanical cables that are powered by electric, air, oil, fuel or mechanical means, operate with a full range of motion and adequate force margins to properly operate the engine variable geometry systems.

Variable geometry system components maintain full functional capability when exposed to the maximum static and dynamic loads, temperatures and flows throughout the operating envelope. All variable geometry components and lines that carry fuel are fire resistant and those that carry oil are fire proof.

For Full Authority Digital Engine Control (FADEC) systems, guide vane control is maintained under fixed fuel flow failure conditions.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Analysis and bench testing of each variable geometry system component demonstrate the system's ability to meet engine specification requirements.

Engine and flight testing of the variable geometry system demonstrate its ability to meet engine specification requirements.

Fire resistance is demonstrated by testing with a 2000 °F flame for five (5) minutes without flame propagation. Fire proof is demonstrated by testing with a 2000 °F flame for 15 minutes without flame propagation.

References: JSSG-2007: A.3.7, A.4.7 variable geometry system design and verification testing; and A.3.1.8.1, A.4.1.8.1 Flammable Fluid Systems - fire resistance and fire proof testing
SAE AS1055
SAE AS4273
14 CFR 25.671, 27.695, 29.695, 33.17, 33.72, 43.1

7.2.4.1.11 Lubrication system operation.

Criterion: Verify that the engine lubrication system safely operates under all engine operating conditions.

Standard: Engine lubrication systems provide safe and reliable oil supply, scavenge, cooling, filtration and de-aeration under all engine operating conditions.

The engine safely operates in a low or no lubrication condition for specified periods.

An in-line filtration system includes cleaning, replacement and a bypass indication (manual or electronic) provisions.

Lubrication system temperature, pressure and quantity information is monitored by an appropriate sensor, gage or manual means (dipstick) and has features for overfill protection.

Lubrication system debris is monitored (e.g., magnetic chip detectors, quantity debris monitors and the Joint Oil Analysis Program (JOAP)).

All oil carrying components, lines and manifolds are fire proof.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis of the lubrication supply and scavenge system requirements versus capabilities identifies conditions to be tested. Lubrication system bench, engine and flight testing demonstrate its ability to provide the operating pressures, temperatures and flows required in the engine specification.

Lubrication system simulator test verifies operational attitudes and ensures all components maintain proper lubrication and scavenging.

Engine testing verifies engine operation in low or no lubrication condition.

An oil deaeration test ensures the system deaerator removes entrained air from the oil. An oil filter flow and contamination test demonstrates its ability to clean debris, maintain acceptable flow and pressure and activate bypass. Inspection of the oil filter determines its capabilities for required maintenance.

Analysis, bench and engine testing of all monitored lubrication system information ensures the pilot, operators and maintainers are provided the information to determine the lubrication system is operating properly.

Fireproof is verified by testing with a 2000 °F flame applied to the component or line for 15 minutes with no flame propagation.

References: JSSG-2007: A.3.7.8, A.4.7.8 Lubrication System; A.3.1.8.1, A.4.1.8.1 Flammable Fluid Systems - fire resistance and fireproof testing
SAE AS1055
14 CFR 33.5, 33.71, 33.87, 33.89

7.2.4.1.12 Lubrication system discharge.

Criterion: Verify that the lubrication system is free from excessive discharge at the breather.

Standard: Lubrication system breather exhaust does not pose a health risk or inhibit ground maintenance personnel from performing tasks around and underneath the installed engine. The location and orientation of the breather exhaust port minimizes ground personnel's exposure.

Breather system exhaust particle limits do not exceed the Occupational Safety and Health Administration (OSHA) health and safety Threshold Limit Values (TLV) (5 mg/cubic meter per current American Conference of Governmental Industrial Hygienists (ACGIH) requirements.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis of breather emissions establishes test parameters.

Instrumented engine testing measures breather emissions and ensures they do not exceed OSHA requirements.

Reference: JSSG-2007: A.3.7.8.3, A.4.7.8.3 Breather Mist - engine breather exhaust emissions design and verification testing.

7.2.4.1.13 Lubrication system non-combustion.

Criterion: Verify that the lubrication system and bearing compartments do not support combustion.

Standard: Lubrication and bearing compartments such as tanks, lines, gearboxes and sumps do not allow the collection or buildup of materials that initiates or supports combustion.

Components that are exposed to both fuel and oil (e.g., heat exchangers, fuel lubricated oil pumps) do not allow engine fuel flow to enter the lubrication system, bearing compartments or gearboxes.

All oil carrying components, lines and manifolds are fire proof.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis of bearing compartments, tanks, lines, gearboxes and sumps establish the system design parameters.

Analysis and bench testing verifies fuel and oil carrying component failures do not allow mixing of the two systems.

Fireproof is verified by testing where a 2000 °F flame is applied to the component or line for 15 minutes with no flame propagation.

References: JSSG-2007: A.3.7.8, A.4.7.8 Lubrication System; and A.3.1.8.1, A.4.1.8.1 Flammable Fluid Systems - fire resistance and fireproof testing
SAE AS1055

7.2.4.1.14 Propulsion monitoring system.

Criterion: Verify that the propulsion monitoring system provides adequate warnings in a timely manner to reduce occurrences of in-flight shutdowns and power losses.

Standard: All safety/mission-critical faults and warnings are supplied to the operator/maintainer.

The propulsion monitoring system detects, isolates and records all engine faults that affect continued safe operation of the air vehicle or require maintenance before next flight.

Critical faults, affecting continued safe operation of the air vehicle, result in immediate notification to the operator.

All faults requiring maintenance action are recorded for post-flight download.

The propulsion monitoring and control systems provide accurate information and do not allow false positive faults to occur.

Method of Compliance: Verification methods include analysis and review of documentation . Analysis and fault injection bench testing verifies the capability of the monitoring system to detect and isolate all failures that affect safe operation of the air vehicle. Engine/air vehicle testing provides assurance that the pilot/operator is provided clear notification of any critical failure.

Engine fault download testing verifies the operators/maintainers have full access to failure data.

Analysis of all cockpit and/or control station engine data demonstrates the pilot/operator can receive and properly interpret the information necessary to safely operate the air system.

Inspection of the Interface Control Document (ICD) and pilot/operator manual covers the engine information being provided to the pilot/operator.

References: JSSG-2007: A.3.7.6, A.4.7.6 Engine Health Monitoring Systems (EHMS)
14 CFR reference 33.28

7.2.4.1.15 Engine bleed air system.

Criterion: Verify that engine bleed air system operation, including malfunctions, does not adversely affect safety of flight.

Standard: Engine bleed air systems provide the proper amount of bleed air at the required temperatures and airflow conditions during ground and flight operation, under all atmospheric conditions and for all flight conditions in the air vehicle operating envelope. Air vehicle bleed airflow requirements are met across the entire flight envelope. For multi-engine platforms, bleed air is balanced such that power/thrust available is not adversely affected. For high pressure bleed systems, failures (e.g., impingement of high pressure air) do not cause damage or adversely affect safety of flight.

Method of Compliance: Bleed air interface airflow and quality is verified by test and demonstration. Bleed air tests are usually conducted in conjunction with engine performance tests at sea level and altitude. The tests should include the air vehicle requirements and the maximum bleed flow specified by the engine contractor.

References: JSSG-2007: A.3.1.1.7, A.4.1.1.7

7.2.4.2 Components: mechanical and electrical.

7.2.4.2.1 Controls and subsystems rotating components.

Criterion: Verify that high-energy controls and subsystem rotating components are designed to be damage tolerant, or that there are provisions for containment of failed parts.

Standard: The design of controls and subsystem components with rotating parts applies damage tolerance methodologies.

Containment of failed components with rotating parts (e.g., pumps, turbochargers) provides protection against damage to neighboring critical systems or components.

Method of Compliance: Verification methods include analysis and review of documentation . Analysis of components' damage tolerance design characteristics, location and orientation demonstrates their ability to continue to meet specification requirements when exposed to an uncontained failure of a neighboring system or component. Analysis of components' protections (shields, locations, orientations, etc.) demonstrates that they are protected and can continue to meet specification requirements when exposed to an uncontained failure of neighboring components.

References: JSSG-2007: A.3.7, A.4.7 Subsystems, engine subsystem component design and verification; A.3.4.1.7, A.4.4.1.7 Damage Tolerance; and A.3.4.1.6.3, A.4.4.1.6.3 Containment, component containment design requirements.

7.2.4.2.2 Bearing thrust balance.

Criterion: Verify that changes in bearing thrust balance do not result in the bearing operating in failure prone regions of operation.

Standard: Engine bearings can withstand the maximum expected changes in load and load direction (crossover) across the entire operating envelope. Engine bearings can maintain minimum load conditions to prevent skidding and no/low load operation.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis followed by bearing rig and full-up instrumented engine testing ensures engine bearing radial and thrust loading is within design limitations and ensures satisfactory operation of the bearing and rotor support system.

References: JSSG-2007: A.3.4.1.5.4, A.4.4.1.5.4 Pressure Balance; A.3.4.1.8, A.4.4.1.8 Vibration and Dynamic Response
14 CFR 33.93

7.2.4.2.3 Tubing/plumbing routing.

Criterion: Verify that all engine mounted tubing, manifolds and clamps are safely affixed and routed on the engine.

Standard: External hardware is mounted/routed such that there is no interference or contact with neighboring components or the engine structure and that no wear or chafing conditions exist. Typical clearances are one (1) inch and are usually documented in the engine specification and Interface Control Document.

The orientation and routing of tubes/lines carrying combustible fluid meet engine specification requirements by providing separation from all potential sources of extreme temperatures or ignition such as electrical components, cables and hot air bleed lines.

Method of Compliance: Verification methods include analysis, demonstration, inspection and review of documentation. Inspection and analysis of engine externals drawings and hardware, mock-ups and an engine installation demonstration verify that there are no interferences, chafing conditions or ignition sources.

References: JSSG-2007: A.3.5.2.2, A.4.5.2.2 Maintainability qualitative requirements; and A.3.11, A.4.11 Engine system and controls and externals verification
SAE ARP994, Tubing/Plumbing Routing
14 CFR 33.5

7.2.4.2.4 Tubing/plumbing vibratory response.

Criterion: Verify that all engine mounted components do not contain natural frequencies within the engine and air vehicle operating ranges or that any such natural frequencies are sufficiently damped under maximum excitation levels in order that specified fatigue life is achieved.

Standard: Engine mounted components, tubing, manifolds and clamps do not contain natural (resonant) frequencies within the engine or air vehicle (e.g., gearboxes, driveshaft(s), transmissions) operating range or have adequate damping provisions to prevent resonances, damage or failure. Engine mounted components, tubing, manifolds and clamps withstand an engine full blade out vibration excitation without failure.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis and vibration surveys (ping testing) and vibration (shaker table) testing on external components, tubes/manifolds and lines ensures natural frequencies are outside the engine and air vehicle operating range or are sufficiently damped to prevent damage or failure.

Analysis and engine testing results confirms the externals capability to withstand excitations resulting from a blade out condition.

References: JSSG-2007: A.3.4.1.5.1.1, A.4.4.1.5.1.1: A.3.4.1.5.1.2, A.4.4.1.5.1.2; A.4.11.2.1.5.2
SAE ARP994

14 CFR 33.63, 33.83

7.2.4.2.5 Externals maximum operating conditions.

Criterion: Verify that all pressure vessels, tubes and manifolds have design margin for their maximum operating conditions.

Standard: Pressure vessels and lines withstand one and a half times (1.5X) (proof) normal operating pressures (without performance degradation or leakage) and two times (2X) (burst) maximum operating pressures (without permanent deformation or leakage).

All pressure vessels and fluid carrying tubes/manifolds withstand the maximum amount of pressure cycles encountered during normal engine operation.

All fuel components and lines are fire resistant and all oil carrying components and lines are fireproof.

Safety critical electrical connectors contain redundant, visually verifiable, locking features.

Tubing and lines meet damage tolerance (e.g., leak before burst) criteria.

Method of Compliance: Verification methods include analysis, test, inspection, demonstration and review of documentation. Analysis and bench top (1.5X) proof and (2X) burst pressure component testing ensures adequate safety margin across the entire flight envelope.

Analysis and bench top pressure cycle testing ensures the components and lines do not leak or rupture during operation.

Fire resistance is demonstrated by testing with a 2000 °F flame for five (5) minutes with no flame propagation.

Fireproof is demonstrated by testing with a 2000 °F flame for 15 minutes with no flame propagation.

Inspection and analysis of engine externals drawings and hardware, mock-ups and an engine installation demonstration verify the existence of redundant locking features for critical connections. Analysis of design review information ensures a damage tolerance capability (e.g., leak before burst).

References: JSSG-2007: A.3.1.4, A.4.1.4 Fasteners; A.3.1.8.1, A.4.1.8.1, Flammable fluid systems; A.3.4.1.6, A.4.4.1.6 Strength; A.3.7.3.2, A.4.7.3.2 Fuel system performance; A.3.7.8, A.4.7.8 Lubrication system
SAE AS1055

7.2.4.2.6 Gearboxes.

Criterion: Verify that propulsion gearboxes have design margin for their maximum operating conditions.

Standard: The gearboxes provide(s) sufficient mechanical speed, power and torque to all mounted components.

All internal gears are free from damaging resonance at all speeds up to the maximum overspeed condition.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Analysis, bench and engine testing verify the gearbox ability to support all mounted components.

Analysis and vibration testing identify and evaluate any internal gearing resonances.

Analysis and testing verifies the gearbox is capable of simultaneous operation of all the drives when each drive is subjected to 1.2 times the maximum permissible torque or power rating specified for the individual drive.

References: JSSG-2007: A.3.7.16, A.4.7.16 Gearbox

7.2.4.2.7 Gearbox mounted component failures.

Criterion: Verify that failure of any gearbox mounted component (e.g., oil pumps, fuel pumps, starters, generators) does not result in failure of the gearbox itself.

Standard: The gearbox and mounted components allow disengagement (e.g., shear sections) prior to causing secondary damage to the gearbox or other components.

Components, whose continued operation is required to maintain safe air vehicle operation, do not contain shear sections.

Method of Compliance: Verification methods include analysis, inspection and review of documentation. Analysis and inspection of the gearbox and mounted components ensures adequate disengagement provisions have been incorporated into the design.

References: JSSG-2007: A.3.7.16, A.4.7.16, Gearbox

7.2.4.2.8 PTO shaft.

Criterion: Verify that failure of the engine power take-off (PTO) coupling assembly or driveshaft does not adversely affect safe operation of the air vehicle.

Standard: The design of the PTO/driveshaft coupling assembly prevents that assembly from unacceptably damaging surrounding hardware (e.g., anti-flail design).

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis and inspection of the PTO drawings and hardware ensures a failed coupling cannot unacceptably damage surrounding hardware and air vehicle. Testing verifies driveshaft coupling assembly life and anti-flail capability.

References: JSSG-2007: A.3.1.1.10, A.4.1.1.10 Power Take-Off; and A.3.7.16, A.4.7.16 Gearbox

7.2.4.2.9 Electrical components and cable routing.

Criterion: Verify that all engine mounted electrical components and cabling are safely affixed and routed on the engine.

Standard: Minimum specified clearances (typically one (1) inch) are maintained with adjacent components and engine and air vehicle structure and that no wear or chafing conditions exist.

The separation between combustible fluids and potential ignition sources prevents wear and chafing and minimizes the possibility of fire/ignition.

Safety critical electrical connectors contain redundant, visually verifiable, locking features.

Dielectric strength and explosion proof capabilities exist.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Inspection and analysis verifies adequate clearances, no wear or chafing conditions exist, adequate separation between combustible fluids and ignition sources and safety critical connectors contain visually verifiable redundant locking features. Bench testing verifies dielectric and explosion proof capability.

References: JSSG-2007: A.3.7.4.3, A.4.7.4.3
MIL-STD-464 for requirements for proper bonding and grounding
14 CFR reference 33.5

7.2.4.2.10 Electromagnetic environment.

Criterion: Verify that all engine electrical components and cabling can safely operate in the lightning and electromagnetic effects environment of the air vehicle.

Standard: All engine electrical components (e.g., electronic controls, alternators/generators, cables, wires, sensors) can safely operate when exposed to the worst case expected electromagnetic (EMI), nuclear (EMP) or lightning induced energy environments required for the platform.

All engine electrical components do not generate or emit EMI that could affect the continued safe operation of any engine or aircraft electrical system or component.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis of the air vehicle EMI, EMP and lightning threat/exposure environment and the engine EMI generation characteristics determines the types and levels of verification testing to be accomplished. Control and electrical subsystem closed loop bench testing verifies the engine EMI, EMP and lightning operational capabilities meet engine specification requirements.

Safety of Flight Testing (SOFT) evaluates the engine's ability to meet specification requirements when installed inside the air vehicle.

References: JSSG-2007 for guidance on engine EMI, EMP, and Lightning design and verification testing: paragraphs A.3.3.3, A.4.3.3; A.3.3.3.1 - A.3.3.3.4, A.4.3.3.1 - A.4.3.3.4
MIL-STD-461
MIL-STD-464
14 CFR 33.28

7.2.4.2.11 Electrical components and cables vibratory response.

Criterion: Verify all engine electrical components and associated cabling do not react to engine or air vehicle induced vibratory and acoustic excitations.

Standard: All components and cabling are designed such that their natural frequencies are outside the engine and air vehicle operating range or have adequate damping provisions to prevent resonances, damage or failure.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis of vibration surveys and vibration (shaker table) testing on components and cabling verifies capability to operate in the expected vibratory environment and that natural frequencies are outside the engine operating range.

Full-up engine testing, with vibration measuring instrumentation, provides assurance that electrical components and cabling can safely operate within the engine operating envelope.

Inspection of all components and cabling after engine testing verifies no wear, chafing, stretching and/or damage exists.

References: JSSG-2007: A.3.4.1.5.1.1 - A.3.4.1.5.1.2, A.4.4.1.5.1.1 - A.4.4.1.5.1.2; A.4.11.2.1.5.2,
14 CFR 33.63, 33.83

7.2.4.2.12 Electrical power.

Criterion: Verify that electrical power is supplied to all safety critical engine systems under all flight conditions.

Standard: The engine driven alternator/generator is adequately sized to provide safe and reliable electrical power at all specified engine speeds.

Seamless transition to and from back-up power is supplied by the air vehicle for all engine safety critical systems and components.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis of the engine's total power consumption establishes the power required to be generated by the alternator, generator and air vehicle.

Analysis, bench and engine testing demonstrate the ability to meet the electrical power generation requirements of the engine specification, when not installed in the air vehicle.

Flight testing demonstrates the engine's ability to meet the electrical power generation requirements of the engine specification, when installed in the air vehicle.

Analysis and test of the air vehicle's power generation and battery systems demonstrate their ability to meet the back-up power requirements of the engine specification.

References: JSSG-2007: A.3.7.4.1 - A.3.7.4.2, A.4.7.4.1 - A.4.7.4.2
14 CFR 33.28

7.2.4.3 Computer resources and software.

For subsystems that use computer systems and software, see Section 15 for additional specific criteria, standards and methods of compliance.

7.2.5 Installations.

7.2.5.1 Physical installations.

7.2.5.1.1 Physical interfaces.

Criterion: Verify that all engine to air vehicle physical interfaces such as mechanical, fluid, and electrical connections are safe.

Standard: All engine to air vehicle interfaces meet all safety related requirements as defined in the Interface Control Document (ICD).

All engine to air vehicle interfaces remain securely connected and do not leak when subjected to the operating conditions (e.g., vibration, temperature) of the air vehicle.

All engine to air vehicle interfaces are free of any contact with neighboring components that result in a wear or chafing condition.

All engine to air vehicle interfaces can withstand the maximum combination of static and dynamic loading throughout the defined flight and ground envelopes and environments. All safety critical engine to air vehicle interfaces are fault tolerant or fail safe with no single failure or combination of failures having an unacceptable probability of loss of the air vehicle.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Inspection of the hardware and a demonstration of installing the engine ensures ICD requirements are met.

Analysis, full-up engine and flight tests ensure interface loads are within design limitations.

Analysis and inspection of the interfaces, with the engine installed in the air vehicle, verifies the absence of wear or chafing conditions.

Engine/Air Vehicle physical interface requirements are verified by inspection of program documentation such as interface control and design documents. System interfaces are analyzed to withstand maximum loading at worst case single failure operating and loading conditions (e.g., bending/torsional loads, pressures, temperatures, vibratory, misalignment).

System interface critical analysis assumptions are verified by stress, thermal, pressure or vibration surveys during ground and flight tests as appropriate.

References: JSSG-2007: A.3.1.1.3, A.4.1.1.3 Interface Loads.
14 CFR 33.5

7.2.5.1.2 Engine mounts.

Criterion: Verify that the aircraft/engine mounts contain adequate design margin to secure and protect the engine properly under all operating conditions and failure modes.

Standard: The engine is securely retained in the air vehicle at all flight, takeoff, landing, and ground operating conditions.

The engine mounts withstand all limit loads resulting from air vehicle maneuvers and engine failures without permanent deformation.

The engine mounts withstand all ultimate loads and crash loads without complete fracture.

The engine mounts keep the engine from entering the flight deck or passenger compartments in the event of a crash landing. The engine mounts meet established durability, strength and damage tolerance design requirements.

Engine mount damping systems provide adequate protection from airframe induced vibrations.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Analysis, full-up engine and flight testing ensure the mounts retain the engine under all operation and known failure conditions.

Engine mount testing ensures adequate design safety margins.

Analysis of the engine mount design review data and drawings ensures a damage tolerant design.

References: JSSG-2007: A.3.1.1.4, A.4.1.1.4, Mounts
14 CFR 33.5, 33.23

7.2.5.1.3 Power-take-off (PTO) shaft vibratory response.

Criterion: Verify that, when applicable, the installed PTO shaft system or driveshaft is free of any potentially damaging resonant conditions for all loads and modes of operation.

Standard: Installed PTO system or driveshaft withstands vibratory induced loads from startup to maximum operating speed under any combined expected torsional (power extraction) and air vehicle maneuver induced loading. The system contains no natural (resonant) frequencies within the normal operating range or has adequate damping provisions to prevent resonances, damage or failure.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Inspection of design criteria establishes suitable critical speed margins that accommodate manufacturing variation, wear and unknown system dynamics. Analysis (e.g., dynamic model) of end to end system predicts compliance with the speed margin goal. Analysis results evaluate the capability of the system components to withstand excitations. Component tests validate response, stiffness and other characteristics used in the analysis. Installed system vibratory response testing verifies critical speed margin and is consistent with the analysis. (A static type test typically shows lower margins due to lack of dynamic stiffening effects, whereas a dynamic test with a shaker is typically more definitive and desirable but not always possible due to installation constraints.) System run up tests reveal no actual or impending resonance conditions throughout the operating speed range.

7.2.5.1.4 Uncontained rotating parts.

Criterion: Verify that the probability of failure due to uncontained rotating parts damaging air vehicle safety of flight/critical safety items is acceptable.

Standard: The severity of all hazards associated with uncontained failures are reduced to an acceptable level or have residual risk accepted in accordance with MIL-STD-882.

Method of Compliance: Verification methods include analysis, inspection and review of documentation. Inspection of the safety analyses documentation verifies that hazards associated with uncontained failures are reduced to an acceptable level.

Reference: MIL-STD-882

7.2.5.1.5 Engine/air vehicle clearances.

Criterion: Verify that clearance between the air vehicle and engine (including associated components, plumbing, and harnesses) is maintained under all operating conditions within the ground and flight envelopes.

Standard: Except at controlled interfaces, Engine/Air Vehicle physical separation is maintained under all operating conditions within the ground and flight envelopes. Static clearances of no less that one (1) inch is provided unless positive clearance is validated under operational loading.

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. Engine/Air Vehicle clearance requirements are verified by inspection of design documentation. System clearances are validated by inspection of system design analysis and simulation which properly accounts for flight loads and thermal growth. S ystem design analysis and simulations are validated by first article inspections and flight tests.

7.2.5.1.6 Drains and ventilation systems.

Criterion: Verify that drain systems have sufficient capacity, operate throughout required ground and flight attitudes and regimes, and expel/store the fluids in a safe manner.

Standard: Propulsion system drain and vent system accommodates the combined maximum leakage and ventilation flow rates. No flight conditions inhibit the function to the extent that propulsion system operation is affected or a hazardous condition is created. Storage or expulsion of fluids and vapors do not create a hazardous condition to the air vehicle or personnel (refer to 8.4.4.1 for more drainage provisions).

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Propulsion drain and ventilation system sizing is validated by inspection of design documents and analysis identifying flow requirements and volume capacities for projected missions. System operation under ground attitudes and flight conditions is validated by analysis of in-flight pressure gradients and attitudes. Analysis assumptions (e.g., pressure gradients, attitudes) are validated by ground and flight test. Storage or expulsion hazards of fluids are validated by inspection of System Safety documentation.

Reference: JSSG-2007: A.3.1.1.8, A.4.1.1.8 for design and verification guidance for drains

7.2.5.1.7 Engine stall loads.

Criterion: Verify that the worst case engine stall loads are within Interface Control Document (ICD) limits.

Standard: To ensure structural integrity of the air inlet system, worst case engine stall loads (e.g., hammer shock) are within required limits.

Note: The inlet structure design is governed by section 5 requirements.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Engine air inlet components requirements are verified by inspection of design documents. Maximum induced inlet stall pressures generated by inlet/engine anomalies are validated by inspection of analyses and/or test. Capability of the components to withstand required inlet stall pressure is verified through component proof analysis and test.

7.2.5.1.8 Installed engine accessibility.

Criterion: Verify reasonable accessibility to propulsion-system-related equipment for the performance of flight critical servicing, inspections, and maintenance.

Standard: Flight critical installed propulsion system servicing, inspections, and maintenance activities can be accomplished by the multivariate maintainer population. Access accommodates the maintainer's anthropometric dimensions and strength limitations, taking into consideration all environmental conditions, and any required mission equipment (e.g., chemical protective gear, gloves).

Method of Compliance: Verification methods include analysis, demonstration, inspection and review of documentation. Inspection of design criteria (to include Interface Control Document data) establishes required servicing, inspections and maintenance requirements. Analysis of virtual models or physical mock-ups verifies accessibility to required servicing, inspection and maintenance areas. Maintenance demonstration verifies the ability to accomplish required tasks.

7.2.5.1.9 FOD/DOD.

Criterion: Verify that design practices and processes are in place to eliminate sources of self-induced foreign/domestic object damage (FOD/DOD) to the propulsion system.

Standard: Design practices and processes adequately ensure that airframe equipment, fasteners, etc., in the intake path of the installed propulsion system are properly secured to prevent damaging ingestion or functional loss of the propulsion system.

Method of Compliance: Verification methods include analysis, inspection and review of documentation. Inspection and analysis of documentation (e.g., FMEA, FMECA, SHA, SSHA) of systems within or upstream of the inlet verifies the absence of FOD/DOD generating failure modes. Inspection verifies that manufacturing and maintenance procedures contain FOD/DOD control practices.

7.2.5.2 Functional installations.

7.2.5.2.1 Functional compatibility.

Criterion: Verify that functional compatibility of the integrated system is safe.

Standard: Engine/Air Vehicle interfaces maintain functional compatibility throughout all normal operating and flight conditions. Hazardous conditions to interfacing subsystems do not result from normal or abnormal operation of the associated subsystem. Critical functional interfaces are fault tolerant or fail safe to the extent that no single failure or combination of failures results in an unacceptable risk in accordance with 7.1.1.

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, inspection and review of documentation. Engine/Air Vehicle functional interface requirements are verified by inspection of program documentation such as interface control and design documents. Integrated system functional compatibility is verified by simulation, test and demonstration of system functionality at integration test facilities and on the air vehicle during ground and flight test. Engine/Air Vehicle functional hazards and probability of air vehicle loss are verified by inspection of System Safety documentation.

7.2.5.2.2 Customer extractions.

Criterion: Verify that the engine can safely supply all flight critical customer extractions (e.g., bleed air, horsepower, electrical power) under all operating conditions.

Standard: Air vehicle bleed airflow requirements are met across the entire flight envelope.

The engine does not introduce foreign matter or contaminants into the air vehicle environmental control system that could damage its operation.

Air vehicle horsepower extraction requirements are met across the entire flight envelope.

The propulsion system has the capacity to provide necessary torque for air vehicle electrical power demands across the entire flight envelope.

Method of Compliance: Verification methods include analysis, test, demonstration, and review of documentation. Bleed air interface airflow and quality are verified by demonstration and test . Power takeoff horsepower extraction is verified by demonstration and test. Gearbox horsepower extraction is verified by analysis and test. Electrical power demands are verified by analysis, demonstration, and test.

References: JSSG-2007: A.3.1.1.7, A.4.1.1.7 bleed air interface design and verification; A.3.1.1.10, A.3.7.16, A.4.1.1.10 and A.4.7.16, PTO horsepower extraction; A.3.2, A.3.7, A.4.2 and A.4.7, engine performance and operability effects of customer extractions; and A.3.7.4.1, A.4.7.4.1 electrical power design and verification requirements.

7.2.5.2.3 Bleed air contamination.

Criterion: Verify that customer bleed air contamination does not exceed safe limits.

Standard: The engine(s) do(es) not introduce foreign matter or contaminants into the air vehicle environmental control system that could result in contaminating the pilot's breathable air supply.

Method of Compliance: Customer bleed air contamination is verified by analysis and tests.

Reference: JSSG-2007: A.3.1.1.7.1, A.4.1.1.7.1 customer bleed air contaminants guidance

7.2.5.2.4 Engine shutdown.

Criterion: Verify the engine's ability to safely and reliably shutdown in the event of a platform initiated fuel shutoff.

Standard: Engine shutdown does not affect platform controllability. The engine does not experience damage that jeopardizes the platform. The engine does not experience a post-shutdown fire.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Analysis, rig testing (dry bench) and engine testing are conducted to assure that the engine will shutdown safely in the event of a platform initiated fuel shutoff.

7.2.5.3 Inlet compatibility.

Criterion: Verify that the air induction system(s) functions under all expected ground, flight, and environmental (including ice, sand, and dust, as applicable) conditions without adversely affecting engine operation or resulting in engine damage.

Standard: All expected ground, flight, induced and natural environmental conditions (e.g., inlet ice accretion and separation, distortion, sand and dust ingestion, water ingestion, gas ingestion) do not adversely affect engine performance and operability.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Analysis and installed engine testing verify inlet performance for all expected environmental conditions. For icing environments, analysis, icing tunnel or ground icing tests and/or flight tests reveal acceptable icing build up and/or levels of shedding that are compatible with the engine(s).

References: JSSG-2007: A.3.3.2.4, A.4.3.2.4 for sand and dust design and verification; A.3.3.2.3, A.4.3.2.3 for ice ingestion guidance; A.3.2.2.11, A.4.2.2.11 distortion guidance; and A.3.3.2.5, A.4.3.2.5 for atmospheric liquid water ingestion guidance.

7.2.5.4 Exhaust system compatibility.

7.2.5.4.1 Exhaust gas impingement.

Criterion: Verify that exhaust systems direct exhaust gases to the atmosphere clear of all personnel, externally mounted equipment, fluid drains, air intakes, stores, rotor blades, and airframe structure.

Standard: Under all anticipated environmental and flight conditions (e.g., wind) exhaust plume(s) do(es) not: impinge on aircraft structure or equipment to the extent that their maximum temperatures are exceeded, impinge on or mix (except when designed) with any flammable fluid drainage or vapor discharge to the extent that the fluid/vapor auto ignition temperature is achieved or exceeded, impose an unavoidable hazard to flight/ground crew or impede a pre-flight/launch activity.

Method of Compliance: Verification methods include analysis, test and review of documentation. Exhaust plume interaction with structure, fluid/vapor discharge, and all personnel is validated by inspection of plume and thermal analysis and models and ground and flight testing. Acceptability of hazards is validated by inspection of system safety documentation.

Reference: JSSG-2007: A.3.7.10, A.4.7.10 engine exhaust nozzle system design and verification.

7.2.5.4.2 Thrust reverser/thrust vectoring.

Criterion: Verify that thrust reverser/thrust vectoring systems are fail-safe and compatible with engine and air vehicle (sub)systems.

Standard: Thrust reverser/thrust vectoring operation does not adversely affect engine performance, operability or aircraft structure. No single failure or combination of failures results in an unacceptable risk in accordance with 7.1.1.

Forces and moments and dynamic response from the thrust vector are quantified and compatible with aircraft flying qualities.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analyses (e.g., Failure Modes and Effects Criticality Analysis, System Safety Hazard Analysis) verify the design is free from single or combined failures modes that would create an unacceptable risk hazard. Analysis of reverser flow field patterns verifies acceptable conditions relative to impingement, inlet ingestion (e.g., propulsive, environmental control system, ventilation, auxiliary power system), and FOD/Sand and Dust generation. Ground tests demonstrate reverser safety features and compatibility with engines and airframe. Flight tests demonstrate safe reverser deployment and operation.

References: JSSG-2007: A.3.1.1.12, A.4.1.1.13 for exhaust system and thrust reverser interfaces design and verification guidance; A.3.7.10, A.4.7.10 Exhaust Nozzle System; and A.3.7.10.2, A.4.7.10.2 Vectored Nozzle

7.2.5.5 Environmental compatibility.

7.2.5.5.1 Engine bay/nacelle cooling and ventilation.

Criterion: Verify that adequate engine bay/nacelle cooling and ventilation provisions exist.

Standard: Engine bay/nacelle cooling and ventilation provisions are adequate to maintain the temperatures of power plant components, engine fluids, other bay/nacelle equipment and structure within the temperature limits established for these components and fluids, under ground and flight operating conditions, and after normal engine shutdown. Refer to 8.4 for further fire protection provisions.

Method of Compliance: Verification methods include analysis, test, simulation, inspection and review of documentation. Temperature limit requirements are verified by inspection of design documentation. System thermal performance is verified by inspection of design analysis, thermal models and simulations. Engine bay/nacelle environments are verified by thermal surveys during ground and flight tests.

References: JSSG-2007: A.3.7.10, A.4.7.10 engine exhaust nozzle system design and verification.

7.2.5.5.2 Vibratory compatibility.

Criterion: Verify the installed vibratory compatibility of the engine with airframe-induced vibrations.

Standard: Airframe-induced engine vibration does not exceed engine limits within the aircraft and engine operational envelope. If the system includes damping engine mounts, they adequately protect the engine against airframe induced vibrations.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Airframe induced engine vibration is established by analysis, and ground and flight vibration tests which identify the response characteristics of the aircraft/engine to forced vibrations and impulses. Analysis of vibration response data verifies that engine limits are not exceeded.

References: JSSG-2001: 3.3.1.1.2 and 4.3.1.1 exhaust integration design and verification requirements

7.2.5.5.3 Shipboard jet blast deflectors.

Criterion: Verify compatibility with shipboard jet blast deflectors.

Standard: Areas hazardous to personnel and equipment are appropriately defined and included in technical data. Any special restrictions on engine power setting or nozzle vector positions are defined and included in operator instructions. Appropriate modifications to jet blast deflectors have been incorporated consistent with propulsion system jet wake characteristics and operating limitations.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Propulsion system jet wake temperature and velocity characteristics for various power settings and nozzle vector angles are verified by analysis and test. Any modifications made to jet blast deflectors to ensure compatibility with the propulsion system are verified by analysis and test.

References: JSSG-2007: A.3.1.8.7, A.4.1.8.7

7.2.5.6 Installation other.

7.2.5.6.1 Crew/operator station compatibility.

Criterion: Verify that the air vehicle propulsion controls and information are adequate for proper operator control and operation of the propulsion system.

Standard: Crew/operator station provides capability to reliably do the following: start and stop each engine independently, independently control/set thrust for each engine, assess engine operating condition to the extent necessary for flight safety. The system provides warnings, cautions and advisories to operators and maintainers for hazardous failure conditions.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Crew/operator station propulsion control capabilities are validated by inspection of design documentation, analyses (e.g., FMEA, FMECA, Sneak circuit, common cause, software) and hardware and software tests in integration facilities and on the air vehicle. Warnings, cautions and advisories to operators and maintainers for hazardous failure conditions are validated by inspection of design and system safety documentation, tests (software and hardware) in integration facilities and demonstration at the air vehicle level.

References: JSSG-2001: 3.4.3.1.6 and 4.4.3.1.6
MIL-STD-411

7.3 Alternate propulsion systems.

7.3.1 Propeller driven systems.

7.3.1.1 Design margins.

Criterion: Verify that adequate margins exist for the performance, strength, and durability of the following: propeller and propeller system components, including the propeller drive shaft, reduction gearbox, torque measurement system, negative torque system, propeller brake, and mechanical over-speed governor.

Standard: Propellers provide sufficient performance to ensure the capability of the air vehicle to accomplish established missions.

The propeller steady state performance is represented by a steady-state performance computer program.

During all permissible power transients and times of accomplishment of such transients established for the engine, the propeller response is compatible with the transient engine performance requirements stated in the engine model specification. Transient response of the propeller system is represented by a transient performance computer program.

All propeller steady-state and transient operating limits (maximum, minimum) are specified for all modes of operation. The limits are predicated on the most critical tolerances of the propeller. The propeller system operates satisfactorily in all thrust modes up to these limits.

Engine negative torque signal input is provided.

Structural design considerations include the application of appropriate limit and ultimate load factors.

The propeller meets design service life requirements for the operating conditions, operating interval and design usage.

Method of Compliance: Verification methods include analysis, a combination of component, stand and systems tests, visual inspection of components and inspection of test documentation. Analysis verifies durability and positive margins of safety for all operating conditions. Durability exceeds requirements of the air vehicle specification. Tests are as follows:

a. Component Testing - propeller components including the blades and barrel, pitch changing mechanism, pitch lock, negative torque signal, control unit, and ice control system are durability tested to establish their capability to perform their function for the period established in the model specification or 1,500 hours between overhaul. A complete teardown inspection is conducted at the conclusion of the test. Records are made of failures, wear and other unusual conditions.

b. Whirl Stand Testing - stand testing is conducted to calibrate sea level performance characteristics, demonstrate durability, overspeed capability, vibratory stress and overspeed feathering. A complete teardown inspection is conducted at the conclusion of the test. Records are made of failures, wear and other unusual conditions.

c. System Tests as follows:

    (1) The preliminary air vehicle test of the propeller is conducted on the air vehicle test bed or a suitable air vehicle having a nacelle configuration similar to the application.

    (2) Installation static functional check

    (3) Steady State check at appropriate power settings as noted in the air vehicle specification

    (4) Transient check to determine the stability of the control system, rate of pitch change and the response of the propeller-engine pitch combination

    (5) Ground vibratory stress survey

    (6) Flight vibratory stress survey

    (7) Miscellaneous checks as applicable in the air vehicle specification

References: JSSG-2009: L.3.4.12, L.4.4.12; and L.3.4.12.4, L.4.4.12.4 performance and structural design and compliance methods

7.3.1.2 Critical speeds.

Criterion: Verify that any critical speeds of the propeller system (e.g., speeds that can excite resonant frequencies and can cause detrimental stresses to propeller components) are outside the engine operating range or identified limitations are placed in the appropriate operators and maintenance technical manuals.

Standard: The propeller system is free of destructive vibrations at all steady state and transient operating conditions and is capable of being balanced to remove vibration that could cause equipment to operate below specified requirements or cause excessive crew discomfort. The propeller is free from flutter in both forward and reverse thrust modes under conditions up to 120 percent of maximum rated engine speed and at power settings up to the standard day maximum take-off power rating of the engine. Propeller critical speeds existing below the operating range are at least 20 percent below the minimum steady state operating speed.

Method of Compliance: Verification methods include analysis, a combination of stand, system ground tests, flight testing, and inspection of documentation. Analysis verifies critical speeds of the propeller system. Tests are as follows:

a. Whirl Stand Tests: A vibration stress survey conducted on the whirl stand establishes the stress characteristics of the hub and blade and the flutter characteristics of the blade. The data obtained in this survey define the test operational limitations for subsequent testing of the propeller on the whirl rig. Blade angle settings for the test are selected so that, if flutter is present, a flutter boundary can be determined for the propeller.

b. Propeller and Engine Test Stand Tests: A vibration stress survey of the propeller covering all appropriate conditions of engine operation on the test stand defines the stress characteristics of the engine and propeller system. Measured stresses for any vibratory modes within the operating range are within the allowable material limits.

c. Flight Vibratory Stress Survey: A flight vibratory stress survey of the propeller on all nacelles of the air vehicle establishes the stress characteristics of the propeller when operated in the air vehicle environment. Measured stresses for any vibratory modes within the operating range are within the allowable material limits. Safe operation is demonstrated in all modes of use.

Inspection of operators and maintenance technical manuals verifies that any appropriate limitations are defined.

Reference: JSSG-2009: L.3.4.12, L.4.4.12; and L.3.4.12.6, L.4.4.12.6 propeller vibration and flutter criteria and compliance methods

7.3.1.3 Reversing and pitch controls.

Criterion: Verify the safety and functionality of the hardware and software components of propeller reversing systems and pitch controls for all steady state, transient, and emergency operating conditions.

Standard: Risk levels meet established safety thresholds for safe operation as stated in 7.1.1, this document. All identified single point failures have acceptable risk mitigation procedures in place.

Overspeed during propeller reversal is compatible with engine overspeed limits. The primary features of the self-contained type propeller control systems function independently of the engine oil system or the air vehicle electrical system insofar as flight safety features are concerned. T he propeller control system includes an adequate mechanical pitch lock that engages in the event of overspeeding or loss of hydraulic pressure or similar failure.

Manual and automatic feathering systems are operational for all steady state, transient, and emergency operating conditions.

Method of Compliance: Verification methods include analysis, test, and inspection of documentation. A Failure Modes, Effects and Criticality Analysis (FMECA) details all known potential failure modes and their associated probabilities. Risk levels meet the safety thresholds. Demonstration of satisfactory control of the propeller is accomplished through the control response test, the steady state check, the transient check and miscellaneous checks conducted as part of the engine and propeller test stand and air vehicle flight testing.

References: JSSG-2009: L.3.4.12, L.4.3.12
14 CFR 35.21

7.3.1.4 Propeller interfaces.

Criterion: Verify the safety of all physical and functional interfaces between the propeller and any system that drives the propeller.

Standard: The interfaces between the airframe and the propeller are established and controlled to ensure compatibility and proper operation.

The allowable range of characteristics of the propeller at the engine interface is specified. No resonant frequency is transmitted to or from the engine through the propeller.

Method of Compliance: Verification methods include analysis, test, and inspection of documentation. A Failure Modes Effects and Criticality Analysis (FMECA) details all known potential failure modes and their associated probabilities.

Testing: The propeller and engine system endures a 150 hr ground test (e.g. test stand, test cell). The system and hardware will be subjected to and meet the conditions and transients as specified in the engine and air vehicle specification. A complete teardown inspection is conducted at the conclusion of the test. Records are made of failures, wear and other unusual conditions. Air vehicle flight tests demonstrate no detrimental interactions between the engine, propeller and air vehicle.

References: JSSG-2009: L.3.4.12, L.4.4.12; and L.3.4.12.1.G, L.4.4.12.1.G
14 CFR 35.21, 35.39, 35.41

7.3.1.5 Feathering system.

Criterion: Verify that the manual and automatic feathering systems are operational for all steady state, transient, and emergency operating conditions and are achieved in the specified amount of time.

Standard: The propeller feathering system remains operable under all flight conditions, including windmilling dives. The command to feather results in an increase pitch action at the fastest rate available from the pitch actuating system. Pitch change traverses fully to the full feather position without further operator/pilot commands. An emergency means of initiating feathering is incorporated which is independent of the normal means for such operations. Upon receiving a signal from the airframe for feathering, the propeller pitch advances completely to the feather position within an appropriate period of time. The time required for the propeller to achieve full feather position is consistent with flight safety requirements as determined by asymmetric thrust on multi-engine air vehicles and loss of flight energy due to drag on single engine air vehicles. Rotation of the propeller is not required to complete the feathering cycle.

Method of Compliance: Verification methods include analysis, test, demonstration and inspection of documentation. A Failure Modes, Effects and Criticality Analysis (FMECA) details all known potential failure modes and their associated probabilities. Risk levels meet the safety thresholds. Demonstration of satisfactory control of the propeller is accomplished through the control response test, the steady state check, the transient check and miscellaneous checks conducted as part of the engine and propeller test stand and air vehicle flight testing.

References: JSSG-2009: L.3.4.12.1, L.4.4.12.1 feathering systems

7.3.1.6 Propeller control.

Criterion: Verify the compatibility of the propeller and engine control systems under all steady state, transient, and emergency operating conditions.

Standard: Control of the propeller is accomplished by means of a propeller control system which is required to assure compatibility with the engine and air vehicle requirements under steady state, transient and emergency conditions. The control system architecture and related functional propeller capability requires a description that shows compliance with operational, environmental, and mission requirements. The propeller control system should include all necessary provisions required for proper and complete automatic, manual, or emergency control of the propeller.

Method of Compliance: Verification methods include analysis, test, demonstration and inspection of documentation. Analysis includes detailed descriptions with associated schematics and drawings of the entire propeller control system and its component parts, their arrangement, functional relationships, and engine and engine control interfaces.

Demonstration of satisfactory control of the propeller is accomplished through the control response test, the steady state check, the transient check and miscellaneous checks conducted as part of the engine and propeller test stand and air vehicle tests specified.

References: JSSG-2009: L.3.4.12.5, L.4.4.12.5 control system compatibility

7.3.1.7 Vibration and balancing.

Criterion: Verify that the propeller system is free of destructive vibrations at all steady state and transient operating conditions.

Standard: The propeller system is free of destructive vibrations at all steady state and transient operating conditions and is capable of being balanced to remove vibration that could cause equipment to operate outside specified requirements, cause equipment damage or cause excessive crew discomfort.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis shows all critical vibratory modes, their frequencies and stresses as a function of blade angle and rpm. This vibration analysis forms the basis for instrumentation and data reduction during testing. The vibratory characteristics of the propeller are verified from the data obtained during the vibratory stress surveys conducted during the whirl stand tests, the engine and propeller test stand tests and the air vehicle tests. Data representing all bending and twisting modes as well as unbalance are identified and compared to design calculated values and to specified limits. Verification of balancing methods is based on analysis of vibration data obtained during propeller and engine stand tests and flight tests. Verification of balancing and re-balancing provisions is accomplished by inspection of assembly and maintenance procedures.

References: JSSG-2009: L.3.4.12.6, L.4.4.12.6 guidance on vibration and balance

7.3.1.8 Ice control system.

Criterion: Verify that the propeller ice control system prevents the dangerous accumulation of ice during all operating conditions.

Standard: When required by operational and environmental usage, the propeller incorporates an ice control system for the blades, cuffs, and spinner. Electrical, fluid, gas, compound, or mechanical ice control systems are used when approved by the procuring activity. The ice control system(s) are specified in the model specification. The type of ice control is continuous, cyclic, or a combination of both as specified in the model specification. Unless continuous ice control is provided, operation of the ice control system is accomplished either automatically or manually as specified in the model specification. Continuous operation of the ice control system in flight does not damage the propeller system or compromise any other flight critical air vehicle (sub)system/component.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Analysis, component and rig testing verify that the ice control system provides the necessary level of protection against ice formation throughout the required icing envelope and does not damage the propeller system or compromise any other flight critical air vehicle (sub)system/component.

References: JSSG-2009: L.6.3.1 for guidance on propeller anti-icing systems

7.3.1.9 Bird strike resistance.

Criterion: Verify that the propeller can tolerate bird strikes.

Standard: The propeller blades and spinner are capable of withstanding the impact of a four-pound bird at the critical location(s) and critical flight condition(s) of the air vehicle without causing a structural failure or inability to control the propeller.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Component/rig tests or analysis based on relevant acceptable birdstrike tests verify the structural integrity and controllability of the propeller and spinner under bird ingestion conditions.

Reference: 14 CFR 35.36

7.3.1.10 Environmental conditions.

Criterion: Verify that the propeller system can safely and reliably operate in world wide environments as required by the system specification.

Standard: All environmental conditions (e.g., ice accretion and separation, distortion, sand and dust ingestion, water ingestion) do not adversely affect propeller performance and operability beyond the air vehicle specification requirements. The design usage includes missions and mission mix, usage parameters, externally applied forces, operating envelope, engine attitude limits, ambient temperature distribution, icing environment conditions, corrosive atmosphere conditions, acoustic environment, and engine performance retention characteristics. The loads and environment spectra represent the service life within the design utilization distribution such that the average usage of the system will meet the service life.

Method of Compliance: Propeller system components are verified for expected usage and environmental conditions using analyses, component test, and ground/flight tests.

7.3.2 Rotary wing systems.

7.3.2.1 Design margins.

Criterion: Verify that the rotary wing and all associated components and systems (drive shaft, reduction gearbox, torque measurement system, negative torque system, brake system, and mechanical overspeed governor) provide sufficient power, torque, strength, and durability for safe operation at sea level hover, and margin for vertical climb and hover throughout the flight envelope.

Standard: The rotary wing and all associated components and systems provide sufficient power to ensure safe operation of the air vehicle throughout its envelope. The steady state performance (horsepower and torque) described in the flight manual is consistent with delivered production engine performance and all installation effects. The rotary wing and all its associated components and systems safely operate throughout the air vehicle and engine envelopes without any degradation in structural strength or durability. Strength and durability limitations include the application of appropriate limit and ultimate load factors. The power drive subsystem is of a robust design capable of operating beyond its maximum rated condition for those instances where excursions may occur such as autorotation, other emergency conditions and defined transients. Excursion capabilities are defined as:

a. An applied torque of at least 20 percent greater than the subsystem (e.g., gearbox, shafting) input maximum continuous rating.
b. An output shaft speed of at least 20 percent greater than the maximum operating speed of the power absorber. System load limits are established.

Each gearbox of the power drive subsystem and associated components is rated at the most severe input power condition (torque and speed) for all allowed operating modes exclusive of transient conditions. Transient capability of the power drive subsystem is defined by the contractor relative to the specific application. The rating is based on the durability, dynamic response and structural integrity requirements specified.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Analysis verifies the expected levels of power produced by the rotary wing and its associated components and systems. Rig testing verifies the rotary wing's ability to provide adequate power. Instrumented air vehicle/engine testing verifies that the rotary wing and all associated components and systems provide the levels of power required to safely operate the air vehicle throughout its envelope. Analysis verifies the expected strength and durability of the rotary wing and its associated components and systems for the expected life of the air vehicle. Rig testing verifies that the rotary wing, its components and systems meet strength and durability limitations. Instrumented air vehicle/engine testing verifies that the rotary wing and all associated components and systems operate safely as an integrated system. Verification is performed incrementally by analysis and a series of bench and system level tests, to ensure structural integrity, endurance, performance, and capability to withstand all specified transient excursions, operational and environmental conditions, including emergency conditions and autorotation.

Typical drive system tests include, but are not limited to:

a. Integrity/Overstress.
b. 200 hr Production Configuration.
c. System Level Pre-Flight Acceptance.
d. 200 hr Verification Military Qualification Test (MQT).

References: JSSG-2007: A.3.7.16, A.4.7.16

JSSG-2009: K.4.4.11 for drive system bench and system level testing
14 CFR 29.1309

7.3.2.2 Safe controllability.

Criterion: Verify that the rotor system provides safe controllability of the air vehicle under all expected operating conditions.

Standard: The rotor system provides the required response to maintain safe control of the air vehicle under all operating conditions, including loss of lubricant, One-Engine-Inoperative (OEI), and autorotations.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Analysis verifies the response levels required to maintain safe air vehicle operation. Rig testing verifies that the rotary wing provides the expected response. Instrumented air vehicle/engine testing verifies that the rotary wing properly responds to maintain safe control of the air vehicle. Typical rotor system tests include, but are not limited to, ground testing, flight testing, and component testing.

References: JSSG-2007: A.3.7.16, A.4.7.16
14 CFR 27.1143

7.3.2.3 Main rotor blade passage frequencies.

Criterion: Verify that, for rotary wing air vehicles, the effects of high-energy, low-frequency vibrations, generated by main rotor blade passage (fundamental and harmonic) frequencies at all engine and related component operating speeds and powers, do not adversely affect the operation of the engine and the drive system.

Standard: Vibrations induced by the airframe rotor combination (including the tail rotor) do not exceed engine limits within the aircraft and engine operational envelope or adversely affect the operation of the drive system.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Verification is by engine test and ground/flight test. During ground/flight test, vibration levels of engine and drive train components are monitored throughout the operating range of the air vehicle at all applicable rotor speeds, aircraft gross weights, and center of gravity limits.

References: JSSG-2007: A.3.4.1.8, A.4.4.1.8 for engine vibration and dynamic response
14 CFR 29.907

7.3.2.4 Engine/airframe vibratory response.

Criterion: Verify, for rotary wing air vehicles, that a satisfactory interface is achieved between the engine (including subsystems/accessories) and the airframe relative to both high-frequency engine-excited and low-frequency vibrations.

Standard: High frequency vibration modes generated by the propulsion system, including the drive system; and/or low frequency vibrations; do not cause potentially damaging vibration to the propulsion subsystems or other parts of the aircraft. T he propulsion system, including the drive system, is free from potentially damaging vibration levels.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Verification is by propulsion/drive system test and ground/flight test. During ground/flight test, vibration levels of the propulsion system, including the drive system and airframe components are monitored throughout the operating range of the air vehicle at all applicable rotor speeds, aircraft gross weights, and center of gravity limits.

References: JSSG-2007: A.3.4.1.8, A.4.4.1.8 for engine vibration and dynamic response
ADS-27-SP
ADS-50-PRF
14 CFR 29.907

7.3.2.5 Lubrication system.

Criterion: Verify that the transmission/gearbox lubrication system safely operates under all air vehicle operating conditions.

Standard: For pressurized lubrication systems, the lubricant is provided at the required pressure and flow rate to all required components and accessories at all allowed gearbox attitudes. Suitable means are provided for setting the gearbox internal pressure and flow to the required level during steady state ground operation, and for maintaining required gearbox internal pressures under all operating conditions and gearbox attitudes. For non-pressurized lubrication systems, the lubricant is provided to all required components and accessories at all allowed gearbox attitudes. Suitable means are provided for maintaining required gearbox internal pressures and flows under all operating conditions and gearbox attitudes.

For pressurized and non-pressurized lubrication systems, breathers are equipped with filtration devices which remove air-borne particles of 10-microns or larger and have provisions to dehydrate the air entering the gearbox. Breathers are arranged to prevent loss of oil from the gearbox under all operating conditions and gearbox attitudes.

For pressurized lubrication systems, the operating oil temperature and pressure are continuously monitored, and provisions should be made for display of the oil pressure and temperature, as well as the operating limits, on air system instrumentation.

For pressurized and non-pressurized lubrication systems, the gearbox design maintains the gearbox oil temperature below the maximum allowed under all possible combinations of gearbox power level, ambient conditions, gearbox attitudes, and lubricant levels.

Method of Compliance: Verification methods include analysis, test, and review of documentation. Verification is by analysis and testing at the element, component, and system levels. Analysis includes a functional description of the lubrication system indicating the limits of the lubrication system with respect to environments (high and low temperature) and air vehicle flight envelope limits (attitude and altitude) and associated schematics showing all components and indicating minimum flow rates to each oil jet. The design of the cooling system for all transmissions and gearboxes is substantiated by applicable schematics, analysis and pertinent testing. The cooling system or heat balance analysis includes consideration of the highest ambient air condition specified in the air vehicle specification, the minimum gearbox oil flow, the maximum allowable oil temperatures and the minimum cooling airflow as a basis for sizing the cooling system.

References: JSSG-2007: A.3.7.8, A.4.7.8 Lubrication System.
JSSG-2009: K.4.4.11.4 for lubrication element, component, and system level testing.
ADS-50-PRF

14 CFR 29.907

7.3.2.6 Dynamic coupling.

Criterion: Verify that unfavorable dynamic coupling modes do not occur when the engine, engine accessories, rotor system, and all dynamic transmission components are operated as a combined dynamic system.

Standard: For sub-critical shafting, the operating speed is in the range of 20 to 30% below critical speed. For super-critical shafting, a sufficient design margin (e.g., adequate separation of speed, adequate damping) exists above and below applicable critical speeds to ensure safe operation. f supercritical shafting is used, during transient operation, damping is provided to the extent necessary to prevent stress and deflection amplitudes from exceeding design allowables. Range of vibratory characteristics at the power drive system interfaces are defined. Vibration limits are defined. The engine control system ensures adequate gain and phase margins to avoid torsional instabilities.

Method of Compliance: Verification methods include analysis, test, demonstration and review of documentation. Verification is through similarity analysis or a combination of analyses, static (such as rap testing of components to confirm modal prediction) and dynamic testing. Analysis shows all critical speeds in relation to operational speeds throughout the range of possible shaft misalignments. The critical speeds of all shafting are determined by demonstration. Demonstration of critical speeds on supercritical shafts includes measurement of stresses at the critical speed to ensure they are within design limits. Substantiation data are provided to show the absence of dynamic coupling modes that are destructive or limit the use of the air vehicle for all permitted ground and flight modes. Analysis defines all power drive subsystem spring constants, inertia and damping coefficients for use in torsional stability assessments.

The power drive subsystem dynamic analysis considers engine control system interfaces to avoid torsional instabilities in the power drive subsystem.

Resonance frequencies and mode shapes are determined for each gear. For the gear resonance test, the dynamic stress levels in each gear are measured in locations sensitive to all significant vibratory modes. A speed scan from 0 to the speed of maximum overspeed is performed with:

a. Minimum load.
b. Approximately 50-percent load.
c. Maximum load.

Reference: JSSG-2009: K.4.4.11.1

7.3.2.7 Control system stability.

Criterion: Verify that the engine's control/rotor system torsional stability has required gain and phase margins and main rotor torque damping during steady-state and transient operation.

Standard: Engine control is stable throughout the operational envelope of the air vehicle and over the operating range of the engine.

Control system gain margin is a minimum of 6dB for both single engine and multi-engine operation.

Drive train resonant peaks are attenuated by at least 6dB below unity gain.

Control system phase margin is between 30 degrees and 60 degrees for both single engine and multi-engine operation.

Method of Compliance: Verification is by simulation, analysis, and test.

The analysis includes linearized models of the engine control loops and the rotor system. The control design is verified throughout the operational envelope of the helicopter, including ambient conditions, engine power level, airspeed, and degraded lag damper operation, etc. Open and closed loop bench testing of the control with a simulation of the engines and helicopter shows stable operation and compliance with the design goals of the engine control system.

Engine control system stability is evaluated by flight test. The pilot's and operator's controls (collective and/or cyclic) are cycled at the frequency of interest to demonstrate stable control response. Other methods that excite drive train torsional modes are also acceptable, such as fuel flow interrupts or pedal inputs. Testing is conducted at multiple power levels and rotor speeds as necessary to show stable response throughout the operational envelope of the helicopter.

References: ADS-1-PRF
ADS-50-PRF
14 CFR 29.939

7.3.2.8 Misalignment.

Criterion: Verify that the torque and misalignment capabilities of drive shaft couplings are suitable for all possible combinations of torque and speed when installed in the aircraft at the maximum permissible misalignment. Verify that coupling design minimizes maintenance effort.

Standard: Driveshaft coupling mechanisms demonstrate the endurance life specified in the air vehicle specification under conditions of maximum permissible misalignment and 110% of rated torque at any power level and duration allowed by the flight spectrum. Fatigue life calculations are based on minus 3-sigma working curves. Damage and fault tolerance testing on coupling components is conducted at test conditions based on worst case combinations of misalignment, torque and speed as dictated by expected air vehicle operating conditions. Fault tolerance testing demonstrates continued operation from initial failure indication to complete loss of function for a duration of at least three times the normal inspection interval. Testing includes anti-flail testing of coupling components where applicable.

Replacement of coupling mechanisms does not require realignment of the associated shafting. Couplings are the dry type to avoid the necessity of doing maintenance checks before every flight.

Method of Compliance: To substantiate compliance with the criterion, verification is by analysis and testing. Vibration and stress analyses of all components subjected to potential stress or vibration induced failure are conducted prior to component testing. The analysis includes prediction of the range of values for steady, cyclic and vibratory stresses, and the design point and life predictions relative to the analysis. Verification by analysis insures the loading reflects the influence of all environmental and operational factors on the life calculation methods of all fatigue sensitive coupling components.

The following tests, as a minimum, are completed on couplings that are representative of the production units.

a. Endurance Testing: Two couplings undergo an endurance fatigue test run at the maximum permissible misalignment and at 110% of the maximum torque seen by the coupling in service to validate required coupling fatigue life.
b. Fault Tolerance Demonstration: Using one of the two endurance test couplings, testing is performed to demonstrate the flexible coupling's ability to transmit torque after a

flexure failure. Prior to the test, the coupling is intentionally damaged by scratching and/or punching the flexure surface at a location approved by the Using Service. Testing demonstrates continued operation from initial failure indication to complete loss of function for a duration of at least three times (3X) the normal inspection interval. Visual and audible inspections of the specimens are performed during the test. The vibration characteristics of the coupling are monitored and recorded. If the coupling is so designed as to not become unserviceable within an acceptable period of testing, then a determination as to the safe inspection interval is made at that time.

References: JSSG-2009: K.3.4.11.2, K.4.4.11.2

7.3.2.9 Rotor securing.

Criterion: Verify that the rotors can be held from rotating in winds at specified velocities and directions, during engine nonoperation, power up, and ground idle conditions.

Standard: A means of preventing rotation of the rotor in winds up to 45 knots is provided. The system is capable of being operated from the cockpit, by the operator, or by the maintainer and capable of 1000 engagements without failure of any of the parts.

Method of Compliance: Verification methods include analysis, test, demonstration and review of documentation. Analyses include heat generation, provisions for isolation from flammable materials or fluids, energy absorption rate and effects on the dynamic response of the transmission. Component bench and system level testing demonstrate the capability to keep the rotors from rotating when exposed to the specified conditions. The brake's ability to perform the specified repeated single engine startup cycles at the specified power without failure or damage to other components is demonstrated by component endurance tests and a limited demonstration at the system level.

The system level test demonstrates the ability of the engine interlock safeguard system to prevent actuation during specified periods.

References: JSSG-2009: K.4.4.11.3
ADS-50-PRF

7.3.2.10 Braking.

Criterion: Verify that the normal and emergency braking systems (consisting of aerodynamic rotor drag and subsequent mechanical braking) are capable of stopping the rotor, from 100% speed, within specified times after engine shutdown, and provide gust-lock capability.

Standard: The rotor brake system is capable of stopping the rotor 400 times, without replacement of any part, from the required rotor speed as specified in the air vehicle specification, within the specified duration after engine shutdown. For emergency shutdown purposes, the braking system is capable of accomplishing two stops from 100 percent rotor speed within the shortest duration possible (the brake is permitted to be nonrepairable after the second emergency stop). The minimum stopping time is based on a structural analysis to protect power drive subsystem gears and components from overloads due to sudden stops.

The braking system is capable of holding the rotor(s) stopped against a 45-knot wind, from any direction, while the air vehicle is not in use; and holds the rotor(s) stopped while the engine(s) are at ground idle.

Engine control interlock safeguards are provided to prevent inadvertent actuation of the system. The brake cannot be applied if the commanded engine speed is above ground idle.

When the rotor brake is applied, slippage of air vehicle under various ground conditions is prevented. There are no critical vibratory modes for the braking system from 0 to 120 percent of maximum operating speed.

Method of Compliance: Verification methods include analysis, test, demonstration and review of documentation. Analyses verify margins against heat generation limits, provisions for isolation from flammable materials or fluids, and transmission energy absorption rate limit. Component bench and system level testing demonstrate the capability to keep the rotors from rotating when exposed to the specified conditions. Component bench and system level testing demonstrate the ability of the brake to stop the rotor within the specified stop time (at the specified engagement speed) and number of braking cycles from the specified speed for both normal and emergency operation.

The brake's ability to perform the specified repeated single engine startup cycles at the specified power without failure is demonstrated in component endurance tests and a limited demonstration at the system level.

The system level test demonstrates the ability of the engine interlock safeguard system to prevent actuation during specified periods.

References: JSSG-2009: K.4.4.11.3
ADS-50-PRF

7.3.2.11 Condition monitoring.

Criterion: Verify that drive system condition monitoring provides warning of impending failure that could result in loss of the air vehicle or prevent a safe landing.

Standard: Applicable elements of the drive system condition monitor, listed below, are configured for incorporation with other subsystems into any planned integrated diagnostic system.

a. Debris monitoring. Debris monitors capable of detecting oil borne particles for the purpose of identifying an impending failure are used on all gearboxes and transmissions. The monitors are capable of isolating faults to each gearbox or module. The monitors are insensitive to normal wear debris.
b. Lubrication system - Oil pressure and temperature. The oil operating temperature and pressure (for pressurized systems) provide continuous real time indications of out-of-control limits to operator/cockpit instrumentation.
c. Health monitoring. Sensor number and location are selected to isolate the condition of critical rotating components including drive shafts, heat exchanger blowers and internal gearbox components. Sensor mounting positions are provided as an integral part of the gearbox and drive shaft system design.
d. Usage monitoring. A system is provided for accurate in-flight monitoring of the power drive subsystem operational usage (power and time) for life management of specified components.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Inspection and analysis of designs, schematics and functional descriptions of the monitoring systems verifies compliance with the criterion.

The following tests apply to the elements of the drive system monitor functions:

a. Debris monitor. Debris monitor testing demonstrates the ability to detect debris of the size, shape and material specified, the characteristic of debris considered abnormal and its insensitivity to normal wear. Component level testing demonstrates capture efficiency.
b. Lubrication system - Oil pressure and temperature. Full up rig and flight testing

demonstrate the required monitoring capability of the lubrication system.

c. Health monitoring. Testing identifies a characteristic normal baseline for applying diagnostic indicators to isolate mechanical component faults. Data are recorded in a manner that can be used for incorporation into any planned integrated diagnostic system. The number of sensors, tachometer frequency, recorder specifications and record length are selected so as to adequately isolate the characteristics of the dynamic components in each gearbox.

d. Usage monitoring. Testing demonstrates acceptable and accurate in-flight monitoring of the power drive subsystem operational usage (power and time).

References: JSSG-2009: K.3.4.11.5

7.3.2.12 Load absorbers.

Criterion: Verify that the drive system permits engagement and disengagement of the engines to and from the load absorbers as required for all applicable modes of air vehicle operation.

Standard: For rotary-wing air vehicles in autorotation mode, the engine(s) not supplying torque is immediately and automatically disengaged from the power drive subsystem. For multi-engine air vehicles conducting single engine operations, the engines not supplying torque are similarly disengaged to permit continued operation of the rotor system and accessory drive for two (2) hours without damage to the overrunning mechanism.

The number of engagements without losing the ability to transmit the required power (torque and speed) should be consistent with all applicable reliability and operational requirements.

Method of Compliance: Verification methods include test and review of documentation. The following bench tests demonstrate compliance:

a. Static torque test. During the static torque check, the torsional spring rate (angular deflection of the outer race relative to the inner race) of the clutch is determined. Static torque is gradually increased until the occurrence of slip such that further torque increase is not possible. The torque transmitted is based on the limit of system dynamic loads as determined by test or equal to 200 percent maximum rated torque.

b. Cyclic fatigue (stroking) test. Stroking tests are performed to define the clutch's fatigue characteristics.

c. Overrunning test. The overrunning clutch test is conducted in two parts for two hours each. The first is a differential overrunning test at 100 percent differential speed (the clutch driving member stationary and the driven member at 100 percent speed). The second overrun test is to the worst case engagement element pressure velocity (PV).

d. Cold temperature engagement test. The clutch is subjected to cold temperature engagement tests, at temperatures as specified by the air vehicle specification, using specified lubricants.

e. Clutch durability test. A minimum number of clutch engagements, as specified by the air vehicle specification, is conducted on two of each clutch configurations of the power drive subsystem. In each engagement, the clutch is loaded to rated torque and speed after engagement. The clutch engagements include a minimum number of dynamic engagements, as specified by the air vehicle specification; e.g., second engine starts, practice autorotation (for engine clutches), in percentages that estimate usage. A dynamic engagement is defined as a condition where the clutch engages a rotating shaft in a manner that simulates how it will be used in service. The time between engagements represents the minimum time expected in usage. Af ter completion of the specified number of engagements, the static torque test is conducted to verify component condition.

References: JSSG-2009: K.4.4.11.7

7.3.2.13 Loss of lubrication.

Criterion: Verify that, during a loss of the primary lubrication system, the gearboxes continue to function and transmit required power until appropriate operator action can be accomplished as required in the aircraft specification.

Standard: Gearboxes function for at least 30 minutes after complete loss of the lubricant from the primary lubrication system and are in a condition such that the gearbox is still capable of transmitting the required power and that no components are in a state of imminent failure. The operational conditions are such that the loss of lubricant occurs at the most severe power condition and that the air vehicle can transition to cruise and land vertically at the end of the thirty minute period. The power drive subsystem is capable of safe operation in the overrunning mode for at least 30 minutes with complete loss of gearbox lubricant. If an emergency/auxiliary lubrication system is used, any resulting attitude limitations during loss of lubricant operation are defined.

Method of Compliance: Verification methods include test, demonstration and review of documentation. Two, thirty minute tests are conducted with teardown inspections. Testing is conducted after completion of the gearbox system level verification test (i.e., 200 hour verification MQT). Transmission and gearbox lubrication systems are starved at the system's supply side (downstream from the pump) and continue to scavenge. Operation is demonstrated for a thirty minute period, as follows:

a. Two minutes at rated power to simulate hover.

b. Twenty six minutes at a power condition to simulate cruise.

c. Two minutes at a power condition simulating vertical landing.

Creditable run time starts at the point at which the cockpit low oil pressure warning would be displayed. For non-pressurized gearboxes, creditable run time starts when the oil being drained from the gearboxes ceases to flow in a steady stream. The transmission is configured in an air vehicle attitude simulating the cruise power condition. For a VTOL air vehicle, the test spectrum and attitudes are commensurate with expected field use. A thirty minute loss-of-lubrication overrunning test consistent with the loss-of-lubricant test spectrum above demonstrates the ability of continued safe operation.

References: JSSG-2009: K.4.4.11.8

7.3.2.14 Rotor meshing.

Criterion: Verify that operation of externally phased intermeshing-rotor systems cannot occur if the rotors become dephased. Verify that indications are provided to the pilot/operator that the rotors are locked in phase.

Standard: For intermeshing-rotor systems, phased externally, means are provided in the power drive subsystem to prevent operation with dephased rotors. Dephasing devices are provided with positive mechanical interlocks to prevent operation of rotors unless they are locked in phase. Means are included for pilot/operator indication that the rotors are locked in phase.

Method of Compliance: Verification methods include analysis, demonstration, inspection and review of documentation. Analysis and demonstration are accomplished during system verification for the air vehicle. Pilot/operator indication is verified by inspection, analysis of drawings and by demonstration (see also 9.2).

References: JSSG-2009: K.3.4.11.9
MIL-HDBK-516: 9

7.3.2.15 Accessory drives.

Criterion: Verify that failure or seizure of any individual accessory does not cause damage to any power drive subsystem components during all phases of air vehicle operation and failure of flight-critical accessories is annunciated to the pilot/operator.

Standard: Accessories driven by the gearbox are driven during an auto-rotation or whenever the rotor system is rotating. Accessory drive splines are protected with spline inserts. Failure of the accessories does not cause failure of the gearbox(s). The accessories are designed so that there is no damage to the gearbox(s) if an accessory should seize. Accessory drive gears do not have any resonances which affect the strength of the gear at all possible operating conditions. Any failure of flight-critical accessories is annunciated to the pilot/operator.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Testing and inspection are accomplished during gearbox system level verification. Pilot/operator annunciation is verified by inspection, analysis of drawings and by demonstration (see also 9.2).

References: JSSG-2009: K.3.4.11.10
MIL-HDBK-516: 9

7.3.2.16 Environmental conditions.

Criterion: Verify that the rotor/drive system can safely and reliably operate in world-wide environments as required by the system specification.

Standard: All intended natural and induced environments, which may include; temperature, humidity, precipitation, icing, fungus, salt fog, particulate and liquid contamination, shock and vibration, and explosive atmosphere conditions do not adversely affect rotor/drive system performance and operability. The design usage includes missions and mission mix, usage parameters, externally applied forces, operating envelope, engine attitude limits, ambient temperature distribution, icing environment conditions, corrosive atmosphere conditions, noise environment, and engine performance retention characteristics. The loads and environment spectra should represent the service life within the design utilization distribution such that the average usage of the system will be expected to meet the service life.

Method of Compliance: Rotor/drive system components are verified for expected usage and all intended and induced environmental conditions using analyses, component test, and ground/flight tests.

References: MIL-STD-810
MIL-HDBK-310

7.3.2.17 Drive system design.

Criterion: Verify that the drive system design is capable of operating beyond its maximum rated torque and speed conditions for those instances where excursions may occur such as autorotation, defined transients and other emergency conditions as required in the air vehicle specification.

Standard: The power drive system is of a robust design capable of operating beyond its maximum rated condition for those instances where excursions may occur such as autorotation, other emergency conditions and defined transients. Excursion capabilities are defined as:

a. An applied torque of at least 20 percent greater than the system input maximum continuous rating without degradation of component performance or life.
b. An output shaft speed of at least 20 percent greater than the maximum operating speed of the power absorber without degradation of component performance or life.

Transient capability of the power drive system is defined by the system specification for the air vehicle. The rating is based on the durability, dynamic response and structural integrity requirements specified.

Method of Compliance: Verification methods include analysis, test and review of documentation. Verification is performed incrementally by analysis and a series of bench and system level tests, to ensure structural integrity, endurance, performance, and capability to withstand all specified transient excursions, operational and environmental conditions, including emergency conditions and autorotation.

References: JSSG-2009: K.3.4.11
ADS-50-PRF

7.3.2.18 Wear/chafing.

Criterion: Verify that closely located components are not allowed to develop wear/chafing during operation.

Standard: Ensure adequate clearance is accounted for between components to prevent wear/chafing while the drive system is operating. A minimum of ¼ inch is provided between rotating and static hardware.

Method of Compliance: Verification methods include test, inspection and review of documentation. Inspection after air vehicle drive/rotor system qualification testing is accomplished to assure minimum clearances are maintained and that components do not have wear/chafing due to contact with each other.

References: JSSG-2009: K.3.4.11
ADS-50-PRF

7.3.2.19 Protection from environmental elements.

Criterion: Verify that the transmission and associated drive system components are adequately protected/sealed from environmental elements (e.g., water, dust, and other contaminants), and that external cleaning procedures will not breach the sealing of those components.

Standard: Design of transmission and drive components ensures protection from contaminants that would result in potential failures. Transmission and drive components are designed such that approved external cleaning procedures and compounds do not result in the introduction of contaminants into these components.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis of the designs, along with component level tests, verify that protective provisions have been incorporated to prevent contaminants from penetrating critical areas.

References: JSSG-2009: Appendix K
ADS-50-PRF

7.3.2.20 Accessibility.

Criterion: Verify reasonable accessibility to rotor and drive system-related equipment for the performance of required servicing, inspections, and maintenance.

Standard: Required installed rotor and drive system servicing, inspections, and maintenance activities can be accomplished by the multivariate maintainer population. Access accommodates the maintainer's anthropometric dimensions and strength limitations, taking into consideration all environmental conditions, and any required mission equipment (e.g., chemical protective gear, gloves).

Method of Compliance: Verification methods include analysis, inspection and review of documentation. Inspection of design criteria (to include Interface Control Document data) verifies that required servicing, inspections and maintenance requirements have been established. Analysis of virtual models and/or physical mock-ups verifies accessibility to required servicing, inspection and maintenance areas. Verification of technical manuals (e.g., TOs) demonstrates ability to accomplish and verify required maintenance tasks.

Reference: JSSG-2009: Appendix K

7.3.2.21 Faults and warnings.

Criterion: Verify that the rotor and drive system health monitoring and prognostics systems provide adequate warnings in a timely manner to ensure safety of flight.

Standard: All safety/mission-critical faults and warnings are available to operators/maintainers. Critical faults, affecting continued safe operation of the air vehicle, result in immediate notification to the operator. All faults requiring maintenance action are recorded for post-flight download. Critical rotor and drive system information, such as speed, control operating mode and fluid quantities and pressures, are provided to the maintainer. The rotor and drive system health monitoring system provides accurate information and minimizes false positive faults.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis and fault injection bench testing verify the capability of the monitoring system to detect and isolate all failures that affect safe operation of the air vehicle. Air vehicle level testing provides assurance that the operator is provided clear notification of any critical failure. Fault download testing verifies that the maintainers have full access to failure data.

Analysis of all work station rotor and drive system data demonstrates that the maintainer can receive and properly interpret the information necessary to safely maintain the air vehicle. Inspection of the Interface Control Document (ICD) and operator's manual ensures that they match the rotor and drive system information being provided to the pilot/operator.

Reference: ADS-79-HDBK

7.3.2.22 Contamination.

Criterion: Verify that components do not allow contaminants to become trapped in rotating components, on external surfaces, or around seals without the ability to run off or be removed.

Standard: Components are designed to prevent contaminants/fluids from puddling or becoming trapped in rotating components or on external surfaces.

Method of Compliance: Verification methods include inspection and review of documentation. Inspection of the design of components and external surfaces should determine if any areas that could trap contaminants/fluids exist. If contaminants/fluids can be trapped, verify that procedures are adequate to remove those contaminants/fluids.

7.3.3 Reciprocating engines.

Criterion: Verify that reciprocating engines meet Title 14 CFR criteria as used for the military mission.

Standard: Comparison of the Title 14 CFR for reciprocating engines against the engine specification, mission requirements and verification results, provides assurance that the engine can maintain safe operation under all conditions.

Method of Compliance: Verification will be by inspection of the type certificate against engine specification, mission requirements, and verification results. If the type certificate does not meet military operational and environmental requirements, additional analysis, testing and data are required beyond the Title 14 CFR type certification to validate the military mission. Original Type Certificate data are required to verify the military operational and environmental requirements. Hazard risk identification and an airworthiness assessment are performed using all available certification data, technical data, safety analysis, system description, and other relevant information.

If no type certificate exists, analysis and testing in compliance with Title 14 CFR is performed and approved by the appropriate airworthiness authority. For USAF, if analysis and testing in compliance with Title 14 CFR is not performed, a risk based (non-design based) assessment of Airworthiness is provided.

References: 14 CFR 33 subpart C for design requirements for commercial applications
14 CFR 33 subpart D for verification requirements for commercial applications

7.3.4 Other propulsion systems.

Criterion: Verify the other propulsion systems (e.g., rotary, wankel, electric) are safe.

Standard: The propulsion system provides safe operation under all intended conditions.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation.

References: 14 CFR 33 subpart C for design requirements for commercial applications
14 CFR 33 subpart D for verification requirements for commercial applications

8. AIR VEHICLE SUBSYSTEMS.

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria.
2. Functional operations test results.
3. Performance test results.
4. Failure modes, effects, and criticality analyses (FMECA).
5. Hazard analysis.
6. Component and system SOF certifications/qualifications.
7. Design studies and analysis.
8. Installation and operational characteristics.
9. Flight manual and limitations.
10. Electromagnetic environmental effects analysis and test results.
11. Diminishing manufacturing sources plan.
12. Obsolete parts plan.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

(NOTE: For subsystems that use computer systems and software, see Section 15 for additional specific criteria, standards and methods of compliance.)

The contents of this section are applicable to relevant subsystems/components of both air vehicles and associated elements such as control stations.

8.1 Hydraulic and pneumatic systems.

References: JSSG-2009: Appendix B, Appendix M
MIL-STD-5522
ADS-50-PRF
SAE AS5440
14 CFR 23.1435, 23.1438, 25.1435, 25.1438, 27.1435, 29.1435

8.1.1 Redundant hydraulic system operation.

Criterion: If there is more than one hydraulic system or pneumatic system, verify that safe operation can be continued if any one hydraulic or pneumatic system fails.

Standard: A single failure in a hydraulic and pneumatic power system component or a total hydraulic and pneumatic system failure does not result in loss of aircraft or unacceptable flying qualities. The platform is capable of safe flight and safe landing after a single failure. The hydraulic and pneumatic systems are configured such that any one system failure due to combat or other damage, which causes loss of fluid or pressure, does not result in complete loss of flight control. Systems are separated as far as possible (i.e., on opposite sides of the fuselage or the wing spar) to obtain maximum advantage of the dual system.

When two or more using functions are pressurized by a common pressure source, the non-essential function is isolated from the essential function (e.g., landing gear is isolated in flight from flight controls to limit exposure of the hydraulic and pneumatic system to damage). If there are points on the platform where two or more hydraulic and pneumatic systems come together (e.g., valves, switching valves, actuators) and a single failure will result in the loss of two systems, safe operation of the air vehicle is maintained.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. System characteristics are verified by analysis (e.g., modeling and simulation) and testing (e.g., iron bird, ground and flight). Inspection of drawings, subsystem tests to include ground test and demonstration, hardware-in-the-loop testing, and flight tests verify safe operation in the event of failure.

References: JSSG-2009: B.3.4.2, B.4.4.2; B.3.4.2.1.10, B.4.4.2.1.10; B.3.4.2.1.16, B.4.4.2.1.16 Emergency Operation; and M.3.4.13, M.4.4.13, Pneumatic Subsystems

MIL-STD-5522

ADS-50-PRF

SAE AS5440

14 CFR 25.1435 b4

8.1.1.1 Single point failures.

Criterion: Verify that any single-point failure locations are identified and their consequences of failure are acceptable, eliminated, or mitigated.

Standard: All single point failures are identified, risks are eliminated or the risks are accepted by the appropriate decision maker per MIL-STD-882. If the hydraulic and pneumatic system is configured such that any one single-point failure causes failure (e.g., loss of pressure, binding) in multiple systems, those failures are identified and the consequences documented. If there are points on the platform where two or more hydraulic and pneumatic systems come together (e.g., valves, switching valves, actuators) and a single failure will result in the loss of two systems, failures are identified and consequences documented.

Method of Compliance: Verification methods include analysis and review of documentation. Failure Modes Effects and Criticality Analysis (FMECA) and hazard analyses identify single point hydraulic and pneumatic system failures and their consequences which affect safe operation of the air vehicle. All safety risks are eliminated or accepted by the appropriate decision maker per MIL-STD-882.

References: JSSG-2009: B.3.4.2, B.4.4.2 Hydraulic Power Subsystem; M.3.4.13, M.4.4.13 Pneumatic Subsystem

MIL-STD-5522

MIL-STD-882

ADS-50-PRF

SAE AS5440

8.1.2 Interfaces and redundancies.

Criterion: Verify that interfaces and redundancies with other systems (e.g., flight controls, electrical, propulsion and avionics) are evaluated and verified to be safe.

Standard: Interface and redundancy requirements with other systems (e.g., flight controls, electrical, propulsion and avionics) are defined in program documentation such as Interface Control Documents (ICDs) and specifications. Hydraulic and pneumatic systems function safely and are compatible with other systems, subsystems and components.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Inspection of ICDs and specifications verify that the interfaces are defined.

Analysis of steady state and dynamic performance, component qualification tests, full-scale functional hydraulic system mockup/simulator testing, ground and flight tests verify hydraulic and pneumatic system interfaces are safe. Failure mode testing in the simulator and aircraft verify adequacy of redundant systems.

References: JSSG-2009: B.3.4.2, B.4.4.2; B.3.4.2.1.10, B.4.4.2.1.10 Emergency Operation; B.3.4.2.1.9, B.4.4.2.1.9 Leakage Control; B.3.4.2.2, B.4.4.2.2 Interface requirements; B.3.4.2, B.4.4.2 Hydraulic power subsystem; and M.3.4.13, M.4.4.13 Pneumatic Subsystem

MIL-STD-5522

ADS-50-PRF

SAE AS5440

FAA AC 25.1309-1A

8.1.3 Transition to backup systems.

Criterion: Verify normal, back-up, and emergency hydraulic or pneumatic system operation.

Standard: The hydraulic and pneumatic systems have sufficient power to maintain safe operation during normal, back-up and emergency operation for all conditions. Transition of power from the primary to the backup and emergency system is predictable, manageable and safe (e.g., minimal sag in power, no detrimental pressure spikes).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, and review of documentation. Analysis and simulation coupled with demonstrations, iron bird testing, ground and flight tests, verify safe operation during normal, backup and emergency conditions. Actual operational conditions of the air vehicle are used for the test verifications. Start up, take off, flight, weapons delivery, return to base, and landing conditions are included.

References: JSSG-2009: B.3.4.2.1.2, B.4.4.2.1.2 System Fluid Capacity; B.3.4.2.1.10, B.4.4.2.1.10 Emergency Operation; M.3.4.13, M.4.4.13

MIL-STD-5522

ADS-50-PRF

SAE AS5440

14 CFR 25.1301, 25.1309

8.1.4 Fluid operating temperatures.

Criterion: Verify that hydraulic fluid operational temperatures remain between the minimum and maximum allowable limits.

Standard: High/low temperature operating conditions are assessed to ascertain fluid thermal conditioning needs. High temperature conditions are controlled to prevent degradation of pressure seals and to prevent overpressurization or leakage due to thermal expansion which creates a fire hazard condition. Low temperature operating conditions (e.g., during start-up, in-flight cold-soak) are controlled to ensure adequate flow capability, minimize system leakage, and prevent filter bypass.

Method of Compliance: Verification methods include analysis, test, simulation, inspection, and review of documentation. Analysis of steady state and dynamic performance, component tests and full-scale functional hydraulic power subsystem mockup/simulator testing, ground and flight tests verify hydraulic power subsystem temperatures remain between maximum and minimum allowable limits.

Analysis, inspection of drawings, and tests verify protection features are functioning properly.

References: JSSG-2009: B.3.4.2.1.14, B.4.4.2.1.14 High Temperature Operation; B.3.4.2.1.14.1, B.4.4.2.1.14.1 Thermal Relief; B.3.4.2.1.15, B.4.4.2.1.15 Fire and Explosion Proofing

MIL-STD-5522

ADS-50-PRF

SAE AS5440

14 CFR 25.1435

8.1.5 Operator interface.

Criterion: Verify that adequate information is available to notify the operator(s) of the hydraulic and pneumatic systems' operating conditions.

Standard: As necessary to safely operate the system:

a. Means are provided to monitor hydraulic and pneumatic system parameters (e.g., fluid quantity, pressure, temperature).

b. Warnings, cautions and advisories are provided.

c. Information is provided to the operator(s) when a hydraulic and pneumatic subsystem is degraded or fails.

Method of Compliance: Verification methods include test, simulation, inspection, and review of documentation. The hydraulic and pneumatic system parameters that are being monitored are verified by inspection, laboratory tests (e.g., failure modes and effects testing (FMET)) and air vehicle ground and flight tests, as are the warnings, cautions, advisories and information provisions.

References: JSSG-2009: B.3.4.2.1.3, B.4.4.2.1.3 System Fluid Monitoring; B.3.4.2.1.4.3, B.4.4.2.1.4.3 System Pressure Indication; B.3.4.2.1.4.4, B.4.4.2.1.4.4 System Low-Pressure Warning; B.3.4.2.2.3, B.4.4.2.2.3 Instrumentation interface(s); M.3.4.13.3, M.4.4.13.3 Status Indication

MIL-STD-5522

ADS-50-PRF

SAE AS5440

14 CFR 23.1435 a2, 25.1435 b1

8.1.6 Technical manuals.

Criterion: Verify that flight and maintenance manuals include normal, back-up and emergency operating procedures, limitations, restrictions, servicing, and maintenance information.

Standard: Engineering data (e.g., system parameters, normal and emergency operational limitations, and hydraulic and pneumatic system maintenance requirements) have been developed as input to flight and maintenance manuals. Flight manuals address hydraulic and pneumatic system normal and emergency procedures, warnings and cautions, and aircraft operating limitations. Maintenance manuals address hydraulic and pneumatic system servicing and maintenance procedures.

Method of Compliance: Verification methods include analyses, test, demonstration of operating procedures, and inspection of flight and maintenance manuals (e.g., Technical Orders (TOs), Naval Air Training and Operating Procedures Standardization (NATOPS), Interactive Electronic Technical Manuals (IETMs)). Engineering data are validated during ground and flight testing. Ground testing, flight testing, and validation and verification of flight and maintenance manuals verify compliance with criteria.

References: JSSG-2000: 3.6.2
MIL-STD-5522
ADS-50-PRF
SAE AS5440

8.1.7 Plumbing installations.

Criterion: Verify that the plumbing and component installations are safe for flight.

Standard: The installation of the system components, hoses, tubing, and component/tubing mounts accounts for operation under combined conditions and environments. Environments include natural, man-made, air vehicle induced and hydraulic system induced environments that the air vehicle may encounter within the performance envelope, structural limitations and design life of the air vehicle. The conditions include vibration, thermal expansion, platform bending, structural loading, acceleration, shock, etc. Sufficient clearances are maintained under these conditions and also account for tolerance stack-up and installation preloads to avoid problems such as binding, chafing or jamming. Hydraulic system tubing is not used to support other tubing, wiring or components. Multiple systems are physically separated as much as practical to increase survivability due to battle damage. Hydraulic drain and vent lines exhaust in areas where the fluid cannot be blown into the air vehicle, pool within the structure, or be blown onto or near exhaust stacks or other ignition sources. Hydraulic lines are separated and routed below exhaust stacks, electrical wiring, avionics, and insulating materials to the extent practical to prevent fire from line leakage. Hydraulic connections are designed such that they are unable to be installed in reverse or inadvertently cross-connected with different systems.

Method of Compliance: Verification methods include test, analysis, demonstration, and inspection. Analysis, component qualification tests, demonstrations, ground/flight tests and inspection of drawings and aircraft verify system performance and system separation for all combinations of internal and external environmental conditions within the performance envelope (e.g., start up, take off, flight, weapons delivery, return to base, landing).

References: JSSG-2009: B.3.4.2.1.1, B.4.4.2.1.1 Fluid Selection; B.3.4.2.1.2, B.4.4.2.1.2 System fluid capacity; B.3.4.2.1.4, B.4.4.2.1.4 System Pressure; B.3.4.2.1.5, B.4.4.2.1.5 Pressure Control; B.3.4.2.1.14.1, B.4.4.2.1.14.1 Thermal Relief; B.3.4.2.1.15, B.4.4.2.1.15 Fire and Explosion Proofing; B.3.4.2.1.17, B.4.4.2.1.17 Clearances, M.3.4.13.2, M.4.4.13.3 Pressure, M.3.4.13.4, M.4.4.13.4 Moisture Content, M6.4 Component Information
MIL-STD-5522
ADS-50-PRF
SAE AS5440
14 CFR 23.1435 a1, a3, c1, c2, 25.1435 a2, a4, a5

8.1.8 Power levels.

Criterion: Verify that the air vehicle hydraulic and pneumatic systems' size/power meets demand.

Standard: The hydraulic and pneumatic power subsystem(s) is sized and configured to supply hydraulic and pneumatic power, as required at sufficient flow rates and pressure to the using systems and utility functions in all modes of ground and flight operation (including backup and emergency). The total fluid volume, including reserves, is sized to provide for system fluid exchanges, compressibility, thermal effects and leakage.

Method of Compliance: Verification methods include test, analysis, demonstration, simulation, inspection and review of documentation. Analysis of steady state and dynamic performance, component qualification tests, full-scale mockup/simulator testing and ground/flight tests verify hydraulic and pneumatic systems power requirements. A hydraulic and pneumatic simulation (e.g., iron bird, computer model), capable of performing all normal, back-up and emergency functions, demonstrates adequate system fluid capacity. Acceptable fluid loss levels from the system overboard relief valves are verified by the simulator (i.e., iron bird). All combinations of internal and external environmental conditions within the performance envelope of the air vehicle (e.g., start up, take off, flight, weapons delivery, return to base, landing) are used for the test verifications.

References: JSSG-2009: B.3.4.2, B.4.4.2 Hydraulic Power Subsystem; B.3.4.2.1.2, B.4.4.2.1.2 System Fluid Capacity; M.3.4.13, M.4.4.13 Pneumatic Subsystems

MIL-STD-5522

ADS-50-PRF

SAE AS5440

8.1.9 Pressure variance.

Criterion: Verify that undesirable pressure fluctuations are precluded from the system.

Standard: The hydraulic systems have been designed to withstand pressure spikes of 135 percent of system pressure. Pressure spikes above 135 percent are precluded from the system. System pressure relief valves and thermal relief valves are provided to prevent sustained excessive pressures which may cause component structural failures. Pressure relief for hydraulic and pneumatic fluid thermal expansion is provided for all components in hot locations and closed plumbing segments. Pressure ripple generated by high-speed rotating fluid equipment does not result in subsystem instabilities. The hydraulic and pneumatic systems are designed such that proper functioning of components, such as internal actuator locks, brakes etc., is not affected by the maximum back-pressure in the system. The hydraulic and pneumatic systems are designed such that the minimum pressure required by the pump is maintained at all times.

Method of Compliance: The performance of the hydraulic and pneumatic power subsystem pressure control devices is verified by analyses, inspections, laboratory tests, and ground tests. Peak pressures are predicted by computer analysis. Component, iron bird, and air vehicle tests are used to verify the transient pressure characteristics. Pump ripple characteristics (e.g., amplitude, frequency) are verified by component level test, and the effects of pump ripple on the hydraulic system are evaluated by aircraft representative tests.

References: JSSG-2009: B.3.4.2.1.5, B.4.4.2.1.5 Pressure Control; B.3.4.2.1.5.1, B.4.4.2.1.5.1 Peak Pressure; B.3.4.2.1.5.2, B.4.4.2.1.5.2 Pressure Ripple; M.3.4.13.2, M.4.4.13.2 Pressure

MIL-STD-5522

ADS-50-PRF
SAE AS5440
14 CFR 23.1435 a3, 25.1435 b2

8.1.10 Impurities.

Criterion: Verify that methods, procedures and provisions exist for controlling and purging impurities from the hydraulic and pneumatic systems and that the systems' levels of contamination are acceptable.

Standard: Means are provided to remove contaminants (e.g., solid particulate) from hydraulic and pneumatic power subsystems fluid during flight, ground and filling operations in order to prevent component wear and contaminant-induced component malfunctions. Provisions are provided for bleeding air from the hydraulic fluid at critical points for maintenance purposes. System design restricts the ingestion and collection of moisture which causes malfunctions from corrosion, shorts in electrical devices and freezing. In order to assure minimum contamination, provisions exist for taking a representative fluid sample from the hydraulic system return line. Sampling locations are reasonably free from external contaminants and are accessible to the maintainer.

Method of Compliance: Verification methods include test, analysis, demonstration, inspection and review of documentation. Acceptable contamination (e.g., solid particulates, chlorine, water, barium) levels are defined, documented and verified by inspection. Methods of contaminant detection and removal are documented and verified by inspection of drawings and laboratory test data (e.g., patch, portable oil diagnostic system). Entrained air phenomena are evaluated and verified in functional test rigs (i.e., iron bird). The provisions for air removal are verified by inspection, demonstration, and tests.

References: JSSG-2009: B.3.4.2.1.6, B.4.4.2.1.6 System Level Contamination Prevention; B.3.4.2.1.7, B.4.4.2.1.7 System Air Removal; B.3.4.2.1.8, B.4.4.2.1.8 Moisture Removal; M.3.4.13, M.4.4.13 Pneumatic Subsystem.

MIL-STD-5522
ADS-50-PRF
SAE AS5440

8.1.11 Qualification testing.

Criterion: Verify that all components, either individually or as part of a subsystem, have passed all safety-related qualification tests (e.g., proof, burst, impulse, endurance, EMI, vibration, containment, over-speed, acceleration, explosive atmosphere, pressure cycling, temperature cycling and fluid compatibility) as required for airworthy performance.

Standard: Components require analysis, component level testing or ground based simulator testing to confirm safe performance. Safety of flight testing is considered if a limited amount of verification to permit initial flight test without fully qualified hardware is required. Life limits and restrictions are defined as required.

Method of Compliance: Verification methods include test, analysis, demonstration, simulation, inspection and review of documentation. Components performance is verified through qualification test, simulator/iron bird, and ground test. Limited component and subsystem testing can be used for initial safety of flight testing.

References: MIL-STD-810
MIL-STD-461

MIL-STD-464
MIL-STD-5522
ADS-50-PRF
ADS-51-HDBK
SAE AS5440
SAE AS8775

8.2 Environmental control system (ECS).

Reference: 14 CFR Reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.

8.2.1 Design for safety.

Criterion: Verify that the design incorporates system safety requirements of the air vehicle.

Standard: The design approach provides overall system level integrity for safety of flight. System safety program requirements are incorporated into the functional baseline and operating procedures of the environmental control system. Environmental control system design integrates into the overall air vehicle design approach philosophy. System safety requirements, analyses, time lines and other milestones are in synchronization with the rest of the program schedules.

Method of Compliance: Verification methods include test, analysis, demonstration, simulation, inspection and review of documentation. Installed air vehicle level testing validates and verifies performance for the environmental control system and other interlinked systems involving thermal stability for safety of flight. Review of operational procedures and appropriate documents validate the incorporation of the system safety program. NOTE: This compliance is integral to the air vehicle performance and functionality activities required for overall air vehicle safety of flight.

References: JSSG-2009: 3.3.3, 4.3.3
14 CFR 23, 25, 27 and 29 Miscellaneous and Thermal Conditioning paragraphs

8.2.2 Integration.

Criterion: Verify that the ECS meets safety requirements when operating under intended conditions over the design envelope and maintains integration integrity to ensure the weapon system's safety of flight.

Standard: The components and the ECS are designed to ensure an integrated/installed ECS in the air vehicle that meets safety requirements and weapons system environment profiles.

Method of Compliance: ECS safety of flight and safety requirements are verified by the following activities:

a. Component level safety of flight testing demonstrates safe operation under all intended conditions over the design envelope.
b. ECS level integrated testing verifies safe operation of the air vehicle (bleed subsystem, environmental protection subsystem, and thermal conditioning function for flight control system).
c. Simulator and/or air vehicle ground testing demonstrates safe operation under all intended conditions over the design envelope and including failure(s).
d. Flight test data from ECS flight test profile(s) validates analysis results and predictions of

critical design envelope points.

e. FMECA and hazard analysis of the ECS including the control station system verifies that the ECS does not affect safety of flight operations.

References: JSSG-2001: 3.3.10, 3.3.10.1

JSSG-2009: 3.3.6, 4.3.6

8.2.3 Alternate cooling.

Criterion: Verify the availability of alternate means of thermal conditioning of safety-critical avionics (including the control station) and sufficient cockpit ventilation when the primary ECS is nonoperational.

Standard: System design (including emergency equipment and/or auxiliary methods) provides an alternate means of thermal conditioning and ventilation to ensure system and personnel safety.

Method of Compliance: Acceptable performance of alternate cooling methods is verified by the following:

a. Thermal analysis predicts acceptable performance of alternate methodology and technology employed to provide thermal stability to air vehicle during primary ECS loss.

b. Test performed both inflight and ground level to verify flowpath and ensure thermal balance exists to sustain safe operation conditions for the air vehicle system and personnel.

References: JSSG-2009: D.3.4.4.5.2, D.4.4.4.5.2 Occupied compartment emergency ventilation and smoke removal; D.3.4.4.5.3, D.4.4.4.5.3 Avionic equipment and equipment compartment emergency cooling

14 CFR 23.831, 25.831, 27.831, 29.831

8.2.4 Pressurization.

Criterion: Verify that normal and emergency pressurization requirements are met in the air vehicle system and, as appropriate, are indicated or monitored at the control station to ensure safety of flight.

Standard: System design (including emergency equipment and/or auxiliary methods) provides an acceptable pressure environment for crew operation and equipment affecting safety of flight (see also 9.6.7 and 18.3.1, this document).

Method of Compliance: The standard is verified by the following activities:

a. Analyses and/or simulation determine the severity of the environment that drives pressurization needs for the air vehicle system.

b. Capability analysis and test verify the adequacy of pressurization subsystem mechanisms required for air vehicle system safety of flight profile.

c. Critical functional test verifies the adequacy of pressurization subsystem based on the formulated and projected threats for the air vehicle system.

d. Analyses and flight tests verify pressure schedule and tolerance requirements for occupied compartments.

References: JSSG-2009: D.3.4.4.1, D.4.4.4.1

MIL-HDBK-516: 9, 18

14 CFR 23.365, 25.841

8.2.5 Degraded system operation.

Criterion: Verify that the effects of loss of some or all ECS functions on air vehicle system safety and performance are understood and acceptable.

Standard: If ECS function is degraded and ram air or alternate methods cannot assure continuous airworthy operations, safety-critical items will function long enough to safely land the air vehicle.

Method of Compliance: The standard is verified by the following activities:

a. FMECA and System Hazard Analysis verify safe operation.
b. ECS system level analyses verifies safe operation and acceptable performance of the air vehicle system after loss of some or all ECS functions.
c. Simulator and/or air vehicle system flight and ground testing verifies safe operation and acceptable performance.
d. Flight test data from ECS flight test profile validates FMECA and system level analyses.

References: JSSG-2009: 3.2.4, 4.2.4; 3.2.5, 4.2.5; 3.2.7.4.4, 4.2.7.4.4; 3.2.7.6, 4.2.7.6; 3.3.3, 4.3.3; D.3.4.4.3, D.4.4.3.3; D.3.4.4.5, D.4.4.4.5; D.3.4.4.12, D.4.4.4.12; D.3.4.4.5.2, D.4.4.4.5.2 Occupied compartment emergency ventilation and smoke removal; D.3.4.4.5.3, D.4.4.4.5.3 Avionic equipment and equipment compartment emergency cooling; D.3.4.4.12.2, D.4.4.4.12.2 Bleed air source shut off; D.3.4.4.14.1, D.4.4.4.14.1 Proof pressure; D.3.4.4.14.2, D.4.4.4.14.2 Burst pressure; D.3.4.4.14.3, D.4.4.4.14.3 Rotating equipment structural integrity

8.2.6 Technical manuals.

Criterion: Verify that normal and emergency operating procedures, limitations, restrictions, servicing, and maintenance information are included in the flight and maintenance manuals and training curriculum.

Standard: Engineering data, e.g., system parameters, normal and emergency operational limitations, and environmental control system maintenance requirements, have been developed as input to flight and maintenance manuals and the training curriculum. Flight manual addresses environmental control system normal and emergency procedures, warnings and cautions, and aircraft operating limitations. Maintenance manuals address environmental control system servicing and maintenance procedures.

Method of Compliance: Review of flight and maintenance manuals and training curriculum verify that proper instructions are provided for procedures required to ensure safety of flight operations under both normal and emergency operation conditions.

References: MIL-STD-38784

14 CFR 23.1581, 25.1581, 27.1581, 29.1581

8.2.7 Operator interface.

Criterion: Verify that adequate controls and displays for the environmental control system are installed in the crew station/control station or other appropriate locations to allow the environmental control system to function as intended.

Standard: Adequate provisions exist from a controls and display perspective to ensure the functional integrity of the design for safety of flight operations. Sufficient cautions, warnings, and advisories are provided to alert the pilot, operator and/or crew to problems in time for corrective action to be taken from a safety of flight perspective.

Method of Compliance: Inspection of drawings and the air vehicle system verifies the incorporation of the required controls, warning, cautions, and advisories. Analysis and test demonstrate functionality of all controls, sensors, and warning devices.

References: JSSG-2009: D.3.4.4.3, D.4.4.4.3 ECS crew station interface

8.2.8 Personnel accommodation.

Criterion: Verify that the environmental control system meets the requirements for personnel atmosphere including adequate crew/occupant thermal conditioning, humidity control and ventilation; and protective flight garment supply systems (e.g., oxygen equipment, pressure suits, anti-g garments or ventilation garments).

Standard: The environmental control system supplies air at the pressure, flow, temperature, humidity, and contamination levels compatible with the respective equipment and protective flight garment supply systems.

Method of Compliance: Analysis and laboratory tests verify protective flight garment supply systems or other ventilation equipment requirements are met. Flight and ground testing verify complete installed function. FMECA and hazard analysis of the ECS including the control station verifies acceptability of personnel thermal conditioning effects on safety of flight activities for the air vehicle system.

References: JSSG-2009: D.3.4.4.3; D.4.4.3.3; D.3.4.4.5.4, D.4.4.4.5.4 ECS Suit ventilation and pressurization

8.2.9 Environmental protection.

Criterion: Verify that subsystems used for environmental protection (e.g., windshield rain/snow/ice removal, ice protection and defog) provide for safe operation of the air vehicle system throughout the specified design envelope.

Standard: No single environmental protection subsystem failure (including control station functions that are critical to air vehicle system flight safety) results in flying qualities less than level three or loss of aircraft.

Method of Compliance: The standard is verified by the following activities:

a. Analysis and/or simulation determine the severity of the environment that drives protection needs for the air vehicle system.
b. Capability analysis and test verify the adequacy of environmental protection system mechanisms required for air vehicle system safety of flight profile.
c. FMECA and hazard analysis including the control station verifies that any failure of the environmental protection subsystem does not affect safety of flight operations.

References: JSSG-2009 D.3.4.4.8, D.4.4.4.8 Transparent area fog and frost protection; D.3.4.4.9, D.4.4.4.9 Rain removal; D.3.4.4.10, D.4.4.4.10 Transparency cleaning; D.3.4.4.11, D.4.4.4.11 Ice protection

14 CFR References 23.1419, 25.1419 and 23 Miscellaneous (Safe Operations Certification)

8.2.9.1 Ice detection and protection.

Criterion: Verify (if required for proper operation of ice protection equipment) that monitoring of external surfaces can be accomplished by the crew throughout the design envelope.

Standard: No single environmental protection subsystem failure (including control station functions that are critical to air vehicle flight safety) results in flying qualities less than level three or loss of aircraft.

Method of Compliance: The standard is verified by the following activities:

a. Analysis and/or simulation determine the severity of the environment that drives protection needs for the air vehicle system.
b. Capability analysis and test verify the adequacy of environmental protection system mechanisms required for air vehicle system safety of flight profile.
c. FMECA and hazard analysis including the control station verifies that any failure of the environmental protection subsystem does not affect safety of flight operations.

References: JSSG-2009: D.3.4.4.11, D.4.4.4.11 Ice protection
14 CFR 23.1419, 25.1419, 27.1419, 29.1419

8.2.9.2 Icing environment.

Criterion: Verify (if required for proper operation of ice protection equipment) that monitoring of icing conditions or incipient icing can be accomplished by the crew throughout the design envelope.

Standard: No single environmental protection subsystem failure (including control station functions that are critical to air vehicle flight safety) results in flying qualities less than level three or loss of aircraft.

Method of Compliance: The standard is verified by the following activities:

a. Analysis and/or simulation determine the severity of the environment that drives protection needs for the air vehicle system.
b. Capability analysis and test verify the adequacy of environmental protection system mechanisms required for air vehicle system safety of flight profile.
c. FMECA and hazard analysis including the control station verifies that any failure of the environmental protection subsystem does not affect safety of flight operations.

References: JSSG-2009: D.3.4.4.11, D.4.4.4.11 Ice protection
14 CFR 23.1419, 25.1419, 27.1419, 29.1419

8.2.10 Personnel air quality.

Criterion: Verify that the operators'/crew members' breathing air is protected from contamination in all forms, including oil leakage in the engine and nuclear, biological, and chemical (NBC) warfare conditions.

Standard: A method to shut off all air flow to occupied compartments is incorporated to prevent introduction of smoke, fumes, toxic gases or other such contaminants, into the occupied compartments (when the source of the contaminant is the environmental control system). NBC protection provisions are provided to remove deadly or incapacitating agents from the environmental control systems air to provide for the safety of the operator/crew and to improve the survivability of the air vehicle system.

Method of Compliance: Inspection of drawings and air vehicle system tests and demonstrations verify the ability to shut off air flow. Laboratory testing with simulants and live agent testing verifies the NBC system performs as required.

References: JSSG-2009: D.3.4.4.2.8, D.4.4.4.2.8 Occupied compartment flow shutoff; D.3.4.4.5.1, D.4.4.4.5.1 Occupied compartment normal ventilation; D.3.4.4.5.2, D.4.4.4.5.2 Occupied compartment emergency ventilation and smoke removal; D.3.4.4.6.1, D.4.4.4.6.1 Occupied compartment; D.3.4.4.6.3, D.4.4.4.6.3 Nuclear, biological, and chemical contamination

14 CFR 23.1109, 23.1111, 25.832

8.2.11 Leak monitoring/detection.

Criterion: Verify that the bleed air or other compressed air duct system is monitored for leaks and structural integrity. Verify that hot air leaking from damaged ducting does not create an ignition source for any flammable fluids or other materials, or cause damage to safety of flight items/critical safety items.

Standard: Verify a leak monitoring/detection system or methodology/process is employed to ensure safety of flight when using bleed air or compressed air sources on an air vehicle. Shutdown capability, with a crew station advisory or a crew station warning, is provided when a potentially damaging or fire-producing leak occurs. The sensors for the leak monitoring/detection system recover functionality following exposure to a leak and the functionality is verified.

Method of Compliance: The standard is verified by the following activities:

a. Perform assessment study to establish the set point for leak monitoring/detection system based upon the effect of leakage on installed environment conditions. The study includes the assessment on the propulsion system.
b. Analysis determines the required performance parameters.
c. Component and system testing verifies safety of flight performance with special focus on ensuring auto-ignition temperature limits are established for the installation environment and the fluids in this area.
d. Fire hardening and fire protection criteria as defined in 8.4 (this document) are coordinated with the aforementioned compliance methods for this criterion.

References: JSSG-2009: D.3.4.4.12, D.4.4.4.12; D.3.4.4.12.8, D.4.4.4.12.8 Bleed air leak detection

MIL-HDBK-221: 2.8

MIL-HDBK-516: 8.4

14 CFR 23.1109, 23.1111

8.2.12 Bleed air shut-off.

Criterion: Verify that bleed air shut-off provisions are available at, or as close as possible to, the bleed source.

Standard: Provisions exist for bleed air shut off in order to provide the air vehicle with secure means for preventing bleed air from jeopardizing safety of flight. No single point bleed air system failure causes an uncontrollable flow of high temperature bleed air into the interior of the air vehicle.

Method of Compliance: Inspection of installation drawings, FMECA, hazard analyses, and air vehicle testing verifies redundant shut-off provisions. Simulation and testing demonstrates the timing and mechanisms used to ensure safety of flight operations in the event of bleed system failure.

References: JSSG-2009: D.3.4.4.12.2, D.4.4.4.12.2 Bleed source shut off; D.3.4.4.12.3, D.4.4.4.12.3 Bleed distribution control; D.3.4.4.12.4, D.4.4.4.12.4 Isolation and crossover control; D.3.4.4.12.10, D.4.4.4.12.10 Uncontrolled bleed air

14 CFR 23.1109, 23.1111

8.2.13 Pressurization stabilization control.

Criterion: Verify that pressurization rate control is available to preclude pressure surges in the cockpit, control station and avionics environment.

Standard: Pressure schedules are defined for the air vehicle system to minimize discomfort to any crew and passengers and prevent hypoxia. Pressurization system reacts quickly to changes in flight conditions, and air conditioning flow rates are maintained at the required pressure schedule to ensure safe operations. Protection from excessive pressure differentials and partial decompression is provided for crew safety and to prevent air vehicle system or equipment structural damage. If the air vehicle system is pressurized in flight, pressure is relieved prior to crew exit or equipment access to prevent personal injury or structural damage.

Method of Compliance:

a. Analysis and flight tests verify pressure schedule and tolerance requirements for occupied and avionics compartments.
b. Ground test is performed to show relief methods for adverse pressurization conditions.

References: JSSG-2009: D.3.4.4.1.1, D.4.4.4.1.1 Occupied compartment pressure schedule; D.3.4.4.1.4, D.4.4.4.1.4 Compartment positive and negative pressure relief; D.3.4.4.1.5, D.4.4.4.1.5 Occupied compartment pressure release; D.3.4.4.1.6, D.4.4.4.1.6 Occupied compartment leakage rate; D.3.4.4.1.7, D.4.4.4.1.7 Occupied compartment pressure source

14 CFR 23.841, 23.843, 25.841, 25.843

8.2.14 Nuclear, biological and chemical (NBC) protection provisions.

Criterion: Verify that NBC equipment and/or procedures are provided for protecting or maintaining environmental control system air free from contaminants.

Standard: NBC protection provisions are made to remove deadly or incapacitating agents from the environmental control system air to provide for the safety of the operator/crew and to improve the survivability of the air vehicle system.

Method of Compliance: Laboratory testing with simulants and live agent testing verifies the NBC system performs as required. Inspection of training curriculum, flight and maintenance manuals verifies proper instructions are provided for procedures required to ensure safety of flight operations under both normal and emergency operation conditions.

References: JSSG-2009: D.3.4.4.2.8, D.4.4.4.2.8 Occupied compartment flow shutoff; D.3.4.4.5.1, D.4.4.4.5.1 Occupied compartment normal ventilation; D.3.4.4.5.2, D.4.4.4.5.2 Occupied compartment emergency ventilation and smoke removal; D.3.4.4.6.1, D.4.4.4.6.1 Occupied compartment; D.3.4.4.6.3, D.4.4.4.6.3 Nuclear, biological, and chemical contamination

8.2.15 Thermal management.

Criterion: Verify that the air vehicle's thermal management system is stable and meets all safety of flight performance requirements throughout the design envelope.

Standard: Mass flow and delivery temperature of thermal management media are sufficient for the air vehicle system heat loads and provide the necessary thermal stability to ensure safety of flight conditions for the air vehicle system. Thermal conditioning ensures there is no loss of critical function.

Method of Compliance: The standard is verified by the following activities:

a. Analysis/simulation establishes the energy balance requirements for the air vehicle system.
b. Dynamic control system analysis verifies that system stability exists to ensure safety of flight.
c. Simulation profiles the system stability critical envelope points. This study is performed to bound the limitations of the ECS responsibility for thermal stability of the air vehicle system.
d. Ground-based thermal survey of the air vehicle system validates the thermal analyses and system stability projections.
e. Thermal survey conducted during air vehicle system flight testing validates the fidelity of model projections and viability of the design.

References: JSSG-2001: 3.3.10, 3.3.10.1

JSSG-2009: D.3.4.4.2, D.4.4.4.2; D.3.4.4.18, D.4.4.4.18

8.2.16 Smoke removal.

Criterion: Verify adequate smoke clearance is available to ensure safe operation with or without an operational ECS.

Standard: Rapid means for smoke removal from cockpit, control station, and passenger-occupied cargo compartments is provided to allow operator/crew visibility and prevent nausea or asphyxiation.

Method of Compliance: Analysis, inspection of drawings, ground test and demonstrations verify adequate emergency smoke removal for occupied compartments.

References: JSSG-2009: D.3.4.4.5, D.4.4.4.5; D.3.4.4.5.1, D.4.4.4.5.1 Occupied compartment normal ventilation; D.3.4.4.5.2, D.4.4.4.5.2 Occupied compartment emergency ventilation and smoke removal

14 CFR 23.831, 25.831, 27.831, 29.831

8.2.17 Surface touch temperatures.

Criterion: Verify that all surface touch temperatures remain within required limits to maintain safety of flight operations of the air vehicle.

Standard: The system design ensures that no surface touch temperatures present unacceptable hazards for safety of flight operations.

Method of Compliance: The standard is verified by the following activities:

a. Analysis, component testing, and ground/flight testing verify that surface temperatures are adequate for human tolerance and interaction and does not adversely affect safety of flight equipment.

b. Temperature measurement activities are performed during flight and ground testing to verify and validate the analyses used in assessing the ECS.

References: JSSG-2009: D.3.4.4.4, D.4.4.4.4
14 CFR 23.831, 25.831, 27.831, 29.831

8.3 Fuel system.

(Refuel, defuel, feed, transfer, pressurization, vent, quantity gauging, dump, and inerting, including external and auxiliary fuel systems (tanks, plumbing, and pumps))

References: JSSG-2009: Appendix E
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14 CFR 23.951-23.979, 23.991-23.1001, 25.951-25.981, 25.991-25.1001, 27.951-27.977, 27.991-27.999, 29.951-29.979, 29.992-29.1001

NOTE: 14 CFR Reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.

8.3.1 Integration.

Criterion: Verify that the fuel system is safely compatible with other system interfaces.

Standard: The fuel system design requirements, including interfaces, are functionally and physically compatible with other air vehicle systems (e.g., propulsion, hydraulic, electrical, pneumatic, inerting, display, aerial refueling and other unique interfaces) and other ground support equipment (e.g., fuel trucks, hydrant delivery systems, closed circuit refueling).

Method of Compliance: Interface requirements are documented and verified through design analysis and modeling, component qualification tests, system functional checkout tests, and ground/flight tests.

References: JSSG-2009: 3.4.4.1, 4.4.4.1; E.3.4.5.1.1, E.4.4.5.1.1; E.3.4.5.1.2, E.4.4.5.1.2; E.3.4.5.1.3, E.4.4.5.1.3; E.3.4.5.1.3.11, E.4.4.5.1.3.11; E.3.4.5.2.1, E.4.4.5.2.1; E.3.4.5.2.2, E.4.4.5.2.2; E.3.4.5.3, E.4.4.5.3
14 CFR 23.951-23.979, 23.991-23.1001, 25.951-25.981, 25.991-25.1001, 27.951-27.977, 27.991-27.999, 29.951-29.979, 29.992-29.1001

8.3.1.1 Operator interface.

Criterion: Verify that adequate information is available to notify operator(s) of the system operating conditions.

Standard: Fuel system information and status are monitored and reported to operators and maintenance personnel as appropriate.

Method of Compliance: Analysis, modeling, simulation, ground tests and flight tests verify that safety of flight information (e.g., fuel quantity, pump status, CG of fuel in tanks (if applicable), leak detection) is reported to the appropriate operators and maintenance personnel.

References: JSSG-2009: E.3.4.5.1.12, E.4.4.5.1.12; E.3.4.5.8.11, E.4.4.5.8.11; E.3.4.5.12, E.4.4.5.12; E.3.4.5.12.1, E.4.4.5.12.1; E.3.4.5.12.2, E.4.4.5.12.2; E.3.4.5.12.3, E.4.4.5.12.3; E.3.4.5.12.4, E.4.4.5.12.4; E.3.4.5.12.5, E.4.4.5.12.5

8.3.2 Qualification tests.

Criterion: Verify that all components, either individually or as part of a subsystem, have passed all safety-related qualification tests as required for airworthy performance.

Standard: All fuel system components have been subjected to qualification testing commensurate with their intended operational usage. The following represent typical airworthiness standards: performance for the specified operational envelope, proof, burst, vibration, containment, over-speed, acceleration, explosive atmosphere, pressure cycling, electromagnetic environmental effects, temperature cycling and fluid compatibility. This does not represent a comprehensive and complete list; additional qualification may be needed based upon the operational requirements of the air vehicle system.

Method of Compliance: Fuel system components are verified for all specified operating and environmental conditions using analyses, simulator tests, component tests, and ground/flight tests. Components require analysis, component level testing or ground based simulator testing to verify safety. Limited safety of flight testing can be considered to permit initial flight test without fully qualified hardware. Life limits and restrictions are defined as required.

Reference: SAE ARP8615

8.3.3 Compatibility with approved fuels.

Criterion: Verify that the fuel system functions safely under all specified conditions with the approved fuels and additives.

Standard: Primary fuels allow continuous aircraft operation without any restrictions to aircraft envelope performance. Alternate/restricted fuels impose operational restrictions on the aircraft and may be used only when primary fuels are not available. Emergency fuels are used on a limited basis when an urgent need exists; their use imposes operational restriction and possible system damage. Fuels include required and allowed additives. Aircraft operating restrictions and additional maintenance actions are defined for each alternate/restricted and emergency fuel.

Method of Compliance: Fuel system compatibility and performance with all specified air vehicle fuels, under all specified flight and environmental conditions, are verified using analyses, simulator tests, component tests, and ground/flight tests.

References: JSSG-2009: E.3.4.5.1.1, E.4.4.5.1.1; E.3.4.5.1.2, E.4.4.5.1.2; E.3.4.5.1.3, E.4.4.5.1.3; E.3.4.5.1.4, E.4.4.5.1.4; E.3.4.5.2.1, E.4.4.5.2.1; E.3.4.5.2.2, E.4.4.5.2.2

14 CFR 23.951-23.979, 23.991-23.1001, 25.951-25.981, 25.991-25.1001, 27.951-27.977, 27.991-27.999, 29.951-29.979, 29.992-29.1001

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8.3.4 Failure modes and effects.

Criterion: Verify that all fuel system critical failure modes and hazards have acceptable risk levels.

Standard: When using any approved fuel, no single failure within the fuel system results in loss of aircraft or fuel delivered to the engine outside prescribed pressure, flow rate and temperature.

Method of Compliance: The FMECA addresses safe operation of the air vehicle following fuel system failures. Safety Hazard Analyses address all fuel system related failures, including single point failure and realistic multiple failures, and have acceptable risk levels. Failure mode tests conducted during component tests verify performance necessary for single failure operation. Fuel system simulator and/or aircraft ground testing verify redundancy of the system critical functions.

References: JSSG-2009: E.3.4.5.1.12, E.4.4.5.1.12

14 CFR 23.951-23.979, 23.991-23.1001, 25.951-25.981, 25.991-25.1001, 27.951-27.977, 27.991-27.999, 29.951-29.979, 29.992-29.1001

8.3.5 Fuel system strength.

Criterion: Verify the safe installation of the fuel system and components.

Standard: Fuel components and plumbing withstand expected loading conditions for all phases of flight for static and durability related loads as well as internal pressure loads. Adequate brackets and clamps are provided for the expected conditions.

Method of Compliance: Component performance is validated through qualification testing. System performance is validated through simulator and air vehicle testing. Inspections of fuel system plumbing and component installations after air vehicle operation confirm appropriate clearance and support. Installation integrity is confirmed by on-aircraft system-level proof pressure test.

References: JSSG-2009: 3.3.3.1, 4.3.3.1, 3.3.8, 4.3.8

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14 CFR 23.963, 23.993, 23.994, 25.963, 25.993, 25.994, 27.963, 27.993, 29.963, 29.993

8.3.6 Pressure capability.

Criterion: Verify that the plumbing and components in the fuel system (as completely assembled and installed within the air vehicle) can withstand exposure to the specified proof pressure limit for the subsystem, including negative pressure, without resulting in fuel leakage, critical system performance degradation or critical life limited durability; and can withstand exposure to the specified burst pressure without external fuel leakage. Verify that surge pressure does not exceed the proof pressure limit.

Standard: All components, lines and connections are capable of withstanding a proof pressure (twice maximum operating pressure or the maximum observed pressure during qualification testing) without failure or distortion; a burst pressure of 1.5 times the proof pressure without rupture and a negative pressure of one atmosphere (14.7 psi) without air leakage and collapse or damage of the components. Surge pressure does not exceed the associated proof pressure of the fuel system.

Method of Compliance: Component-level proof and burst pressure testing verifies capability of components to withstand specified proof and burst pressures. Bench testing verifies the capability of the engine feed line to withstand required pressure. Proof and surge pressure testing of the installed system (on air vehicle or acceptable fuel system simulator) verifies the capability of plumbing to withstand specified proof and surge pressures.

References: JSSG-2009: E.3.4.5.1.5, E.4.4.5.1.5; E.3.4.5.1.6, E.4.4.5.1.6; E.3.4.5.1.7, E.4.4.5.1.7; E.3.4.5.1.8, E.4.4.5.1.8; E.3.4.5.6.1, E.4.4.5.6.1

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14 CFR 23.993, 25.993, 27.993, 29.993

8.3.7 Fuel flow.

Criterion: Verify that the fuel feed system provides a continuous supply of fuel to the engine at sufficient pressure throughout the flight and ground operation envelopes, including starting, fuel jettison and all flight maneuvers.

Standard: The fuel system supplies the required amount of fuel (in accordance with engine interface requirements) at the required pressure and flow rate to the engines within the temperature limits during all phases of the mission, to include afterburner and inverted flight, if applicable. Fuel jettison operations do not degrade engine feed performance.

Method of Compliance: Fuel feed system analysis and engineering modeling verify continuous fuel supply at the required pressure and flow rate under all specified conditions. Ground and flight tests verify the performance of the fuel feed system.

References: JSSG-2009: G.3.4.7.3, G.4.4.7.3, G.3.4.7.6, G.4.4.7.6

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14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.3.8 Fuel transfer rates.

Criterion: Verify that fuel transfer flow rates meet the operational ground and flight envelope requirements.

Standard: The fuel system meets transfer requirements for all functions including center of gravity management, thermal management, and engine feed. The rate of fuel transfer from any transfer tank to an engine feed tank is equal to or greater than the maximum rate of fuel consumption of the engine to the specified low level fuel quantity of the transfer tank; and provisions are provided to notify the operator of low fuel quantity in the feed tank, or a loss of fuel transfer.

Method of Compliance: Analyses, ground tests and flight demonstrations verify the fuel transfer rates under all operational conditions. Ground and flight tests verify the performance of the fuel transfer subsystem.

Analyses, fuel system simulator tests and flight tests verify that the fuel transfer subsystem is not affected by operation of the fuel jettison system.

References: JSSG-2009: E.3.4.5.2.3, E.4.4.5.2.3; E.3.4.5.4, E.4.4.5.4; E.3.4.5.4.1 ,E.4.4.5.4.1

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14 CFR 23.951, 23.952, 23.953, 23.955, 23.961, 25.951, 25.952, 25.953, 25.955, 25.961, 27.951, 27.953, 27.955, 27.961, 29.951, 29.953, 29.955, 29.961

8.3.9 Center of gravity.

Criterion: Verify that the air vehicle center of gravity limits are not exceeded during any fuel system and air vehicle functions, including release of stores, aerial refueling (if applicable), fuel transfer, fuel dumping operations, wing sweep operations, catapult launches, arrested landings, and engine feed.

Standard: The fuel system (and associated control software, if applicable) maintains the aircraft within the center of gravity limits throughout the entire operational envelope (for single operator aircraft, without action by the operator) for all mission phases.

Method of Compliance: Analysis indicates that center of gravity limits are not exceeded for any fuel loading under all specified flight conditions. Ground calibration tests verify fuel gauging system accuracy at those conditions critical to the air vehicle operation (e.g., stores release, fuel dump, aerial refueling). Ground and flight tests verify the performance of the air vehicle systems computer management system and cockpit or control station interfaces.

References: JSSG-2009: E.3.4.5.5, E.4.4.5.5
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14 CFR 23.1001, 25.1001, 27.1001, 29.1001

8.3.10 Pressure tolerance.

Criterion: Verify that the fuel system is designed to prevent pressures from exceeding the system's proof pressure limits (both minimum and maximum) during refueling (aerial and ground), defueling, transfer, fuel feed, fuel dump operations and engine feed.

Standard: The fuel system is designed such that positive and negative proof pressure limits are not exceeded during all phases of fuel system operations including refueling, defueling, fuel transfer, fuel feed, and fuel dump. Fuel valve closure rates, simultaneous valve closures, operation of fuel pumps or fuel manifold architecture do not result in steady-state and/or transient pressures exceeding the proof pressure limits.

Method of Compliance: System analysis verifies that proof pressure limits are not exceeded throughout air vehicle operation. Simulator and/or ground air vehicle testing verifies that proof pressure limits are not exceeded during normal and single failure conditions. Flight testing verifies analysis and previous testing. Fuel system simulator, ground and flight tests verify that negative pressure limits are never exceeded in the engine feed line.

References: JSSG-2009: E.3.4.5.1.7, E.4.4.5.1.7; E.3.4.5.1.8, E.4.4.5.1.8; E.3.4.5.8, E.4.4.5.8
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14 CFR 23.963, 23.979, 25.963, 25.979, 27.963, 27.979, 29.963, 29.979

8.3.11 Technical manuals.

Criterion: Verify that the flight and maintenance manuals include normal and emergency operating procedures, limitations, restrictions, servicing, and maintenance information.

Standard: Engineering data (e.g., system operation descriptions, system parameters, normal and emergency operational limitations, and fuel system maintenance requirements) have been developed as an input to flight and maintenance manuals. The flight manual addresses fuel system normal and emergency procedures, warnings, cautions and advisories, and aircraft operating limitations. Maintenance manuals address fuel system servicing and maintenance procedures.

Method of Compliance: Verification methods include analyses, test, demonstration of operating procedures, and inspection of flight, ground servicing and maintenance manuals (e.g., Technical Orders (TOs), Naval Air Training and Operating Procedures Standardization (NATOPS), Interactive Electronic Technical Manuals (IETMs)). Engineering data are validated during ground and flight testing. Ground testing, flight testing, and validation and verification of flight and maintenance manuals verify compliance with criteria.

References: JSSG-2009: 3.2.6, 4.2.6

8.3.12 Contamination.

Criterion: Verify that the design and procedures are adequate for controlling and purging impurities from the fuel system and that the fuel system's level of contamination is acceptable at all times.

Standard: The fuel system components are qualified to safely operate with specified contaminant size, distribution, and quantity, including water (free water content and icing). The fuel system has provisions to drain water and contaminants from sump areas in the tanks and/or provide in-flight scavenge capability. Procedures for controlling and purging impurities are included in the maintenance and servicing procedures.

Method of Compliance: Component qualification testing verifies the capability of components to operate at specified contamination levels. Ground tests verify compliance with fuel system purging requirements. Bench and ground testing verifies the performance of water scavenging system. Maintenance manuals are validated and verified.

References: JSSG-2009: E.3.4.5.6.2, E.4.4.5.6.2; E.3.4.5.6.3, E.4.4.5.6.3; E.3.4.5.1.3, E.4.4.5.1.3

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14 CFR 23.971, 23.973, 23.977, 23.997, 25.971, 25.973, 25.977, 25.997, 27.971, 27.973, 27.977, 27.997, 29.971, 29.973, 29.977, 29.997

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8.3.13 Electrical and electromagnetic effects.

Criterion: Verify that the system is designed to withstand the hazards associated with lightning, static electricity, fuel leaks, and the introduction of electrical power into fuel tanks.

Standard: The fuel system is designed to withstand any fire or explosion hazards caused by direct lightning strikes. The fuel system design prevents static electricity discharge to minimize sparks from occurring and creating ignition hazards. Electromagnetic environmental effects on the fuel system are compliant with MIL-STD-464. Hazards from external fuel leakage are mitigated during normal operating conditions, including ground and in-flight refueling. Fuel tank and component sealing design criteria are adequately defined.

Method of Compliance: Air vehicle inspection and measurements verify compliance with the air vehicle bonding and lightning protection requirements. Components qualification and drawing inspections verify compliance with the bonding and lightning protection requirements. Lightning ground tests verify adequacy of the protection designs. Fuel tank and component sealing are analyzed and tested at the component/simulator level to confirm sealant integrity. On aircraft leak checks are conducted to confirm final assembly. A FMECA verifies risk is mitigated to an acceptable level.

References: JSSG-2009: E.3.4.5.1.9, E.4.4.5.1.9; E.3.4.5.1.11, E.4.4.5.1.11; E.3.4.5.7, E.4.4.5.7; E.3.4.5.8.11, E.4.4.5.8.11

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14 CFR 23.863, 23.954, 23.971, 23.975, 25.863, 25.954, 25.971, 25.975, 25.981, 27.863, 27.954, 27.971, 27.975, 29.863, 29.954, 29.971, 29.975

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AC 25-16

AC 25.981-2

AC 25.981-1B

8.3.13.1 Explosive atmosphere.

Criterion: Verify that the fuel system is designed and arranged to prevent the ignition of fuel vapor within the system.

Standard: All fuel subsystem components located in an explosive atmosphere are capable of operating without initiating an explosion, including under electrical fault conditions. All components inside of a fuel tank have energy levels low enough to prevent an ignition source, prevent introduction of an ignition source through the wiring or components, or are qualified as explosion proof in accordance with MIL-STD-810.

Method of Compliance: A System Safety Hazard Analysis verifies the ability of the fuel systems components to operate, including single failure conditions, in flammable vapor-laden environments. Analyses and ground tests demonstrate that fuel tank surface temperatures do not exceed the auto-ignition temperature of the fuel. On-aircraft fuel system component bonding measurements demonstrate compliance with bonding requirements. Component explosive atmosphere tests verify the ability of the fuel system components to operate safely in a flammable vapor-laden environment.

References: JSSG-2009: E.3.4.5.1.9, E.4.4.5.1.9; E.3.4.5.1.11, E.4.4.5.1.11

JSSG-2009: G.3.4.7, G.4.4.7

MIL-STD-810

SAE ARP5794 (at the time of publication of this document, this was a work in progress)

SAE ARP8615

14CFR 23.954, 23.975, 25.954, 25.975, 25.981, 27.954, 27.975, 29.954, 29.975

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AC 25.981-1B

AC 25.981-2

8.3.13.2 Secondary barriers.

Criterion: Verify that secondary fuel and vapor tight barriers are provided between fuel tanks, fire hazard areas, and inhabited areas.

Standard: Dual vapor and liquid-proof barriers are installed between fuel tanks and other zones on the aircraft that contain ignition sources (e.g., avionics bays, sensor bays) and inhabited areas. Provisions are made to allow detection of fuel leakage across the primary barrier.

Method of Compliance: Analysis and component tests verify performance of the primary and secondary fuel and vapor tight barriers. Engineering test models verify performance of the fault isolation provisions to detect a failure of the primary fuel barrier. Ground demonstration verifies adequacy of the secondary barrier design to isolate and remove flammable vapors to a safe location.

References: JSSG-2009: E.3.4.5.6.11, E.4.4.5.6.11

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14 CFR 23.863, 23.967, 25.863, 25.967, 25.1185, 25.981, 27.863, 27.967, 27.1185, 29.863, 29.967, 29.1185

AC 25.81-1B

AC 25.981-2

8.3.13.3 Drainage.

Criterion: Verify that drainage provisions are provided to remove all normal and accidental fuel leakage and water to a safe location outside of the air vehicle.

Standard: Compartment and fuel tank drainage provisions are provided for the removal of fuel and water to a safe location outside of the air vehicle under ground and flight conditions.

Method of Compliance: Drawing inspections verify that all areas surrounding fuel tanks or containing fuel system components are properly drained to remove fuel leakage and water to a safe location. Analysis and on-aircraft tests verify that the drain rates are in compliance with the air vehicle design requirements.

References: JSSG-2009: E.3.4.5.6.2, E.4.4.5.6.2; E.3.4.5.1.10, E.4.4.5.1.10

MIL-F-17874

14 CFR 23.977, 23.997, 23.999, 25.977, 25.997, 25.999, 27.977, 27.997, 27.999, 29.977, 29.997, 29.999

8.3.13.4 Safe fuel release.

Criterion: Verify that fuel jettison, fuel venting, fuel leaks, and fuel spills cannot be ingested by the engine(s), flow into hazardous ignition areas, onto the environmental management system, or become reingested into the air vehicle.

Standard: Fuel dump, drainage, and vent outlets do not permit fuel impingement on the aircraft or come into contact with hazardous ignition areas (e.g., engine/auxiliary power unit intake and exhaust, environmental control systems).

Method of Compliance: Ground and flight tests verify performance of the fuel jettison subsystem. Design analysis and ground demonstration verifies the safe location of the fuel jettison in relation to potential ignition sources (e.g., hot brakes, bleed air ducts, engine, APU). Ground and flight demonstrations verify that fuel does not re-enter the air vehicle after fuel jettison. Ground and flight tests verify that no drained flammable fluid impinges on potential ignition sources.

References: JSSG-2009: E.3.4.5.2.6, E.4.4.5.2.6

MIL-F-17874

14 CFR 23.971, 23.999, 23.1001, 25.971, 25.999, 25.1001, 27.971, 27.999, 29.971, 29.999, 29.1001

8.3.14 Fuel tank strength.

Criterion: Verify that fuel tanks are capable of withstanding, without failure, the vibration, inertia, fluid, and structural loads that they may be subject to in operation.

Standard: Fuel tanks are designed to withstand stresses and loads expected during all phases of the operational envelope of the aircraft. This includes loads resulting from fuel slosh, vibration, relative movement from fuel lines and fittings, fuel system operation, expected pressure changes, and thermal stress.

Method of Compliance: Structural analyses and tests verify that the fuel tanks are capable of withstanding all ground and flight conditions and environments.

Fuel system functional checks verify that the fuel tanks are designed to withstand fluid and structural loads during transfer, refueling and defueling operations. Analysis and system ground and/or flight tests verify that adequate pressure and thermal relief have been provided.

References: JSSG-2009: E.3.4.5.6, E.4.4.5.6; E.3.4.5.6.13, E.4.4.5.6.13

MIL-F-17874

14 CFR 23.963, 23.965, 23.993, 25.963, 25.965, 25.993, 27.963, 27.965, 27.993, 29.963, 29.965, 29.993

AC 25.963-1

8.3.15 Tank pressure.

Criterion: Verify that tank pressure does not exceed tank structural limits due to a single failure under normal operation.

Standard: The fuel vent system maintains internal tank pressure within limits during normal fuel system operation, including during single failure conditions (e.g., failed open fuel control valve during refueling, failed climb/dive valve).

Method of Compliance: Analysis and tests verify that the fuel tanks withstand the maximum pressure expected on the ground or in flight due to a fuel system failure. Component tests, structural analysis, ground test and fuel system analysis verify that a fuel system failure during refueling operations does not result in fuel tank pressures exceeding limit loads of the fuel tanks.

References: JSSG-2009: 3.2.9.1, 4.2.9.1; E.3.4.5.1.7, E.4.4.5.1.7; E.3.4.5.1.8, E.4.4.5.1.8; E.3.4.5.1.12, E.4.4.5.1.12

MIL-F-17874

14 CFR 23.957, 23.963, 23.965, 25.957, 25.963, 25.965, 27.963, 27.965, 29.957, 29.963, 29.965.

AC 25.963-1

8.3.16 Refueling/defueling.

Criterion: Verify that the air vehicle can be safely refueled and defueled.

Standard: The refueling system, including the vents and fuel tanks, accommodates maximum refueling rates during normal and single failure conditions without causing hazardous conditions to the aircraft and personnel (e.g., tank overpressurization, fuel venting, static discharges).

Method of Compliance: Demonstration verifies the capability to safely refuel the internal tanks from 10% full to high level shut off at maximum refueling servicing pressure without venting fuel. Analysis and demonstration verify aircraft hot pit refueling requirements. Component demonstration and ground testing verifies static discharge does not occur inside the tanks during refueling operations. Inspections verify the absence of external leakage during ground refueling operations. Gravity refueling, if applicable, is demonstrated by analysis, full scale simulator and/or on aircraft tests.

References: JSSG-2009: E.3.4.5.1.12, E.4.4.5.1.12; E.3.4.5.8.1, E.4.4.5.8.1; E.3.4.5.8.4, E.4.4.5.8.4; E.3.4.5.8.5, E.4.4.5.8.5; E.3.4.5.8.6, E.4.4.5.8.6; E.3.4.5.8.7, E.4.4.5.8.7; E.3.4.5.8.8, E.4.4.5.8.8

MIL-F-17874

14 CFR 23.863, 23.973, 23.975, 23.979, 25.863, 25.973, 25.975, 25.979, 27.863, 27.973, 27.975, 29.863, 29.973, 29.975, 29.979

8.3.17 Spill prevention.

Criterion: Verify that the fuel system has been designed to prevent fuel spills during pressure refueling operations.

Standard: The pressure refueling system provides a means to terminate fuel flow when tanks reach full or a preset fuel level, including single failure conditions. Any failed conditions that would prevent safe, reliable fuel flow termination (e.g., failed level control valve) are detected (e.g., incorporation of a pre-check capability of the pressure refueling system, vent box monitoring).

Method of Compliance: Demonstration verifies the capability to safely refuel the internal tanks from 10% full to high level shut off at maximum refueling servicing pressure without venting fuel. Inspections verify the absence of external leakage during ground refueling operations. Fuel volume thermal expansion is demonstrated by analysis and simulated worst case hot day operations by overfilling fuel tanks.

References: JSSG-2009: E.3.4.5.1.12, E.4.4.5.1.12; E.3.4.5.6.1, E.4.4.5.6.1; E.3.4.5.8.1, E.4.4.5.8.1; E.3.4.5.8.11, E.4.4.5.8.11; E.3.4.5.8.14, E.4.4.5.8.14; E.3.4.5.9, E.4.4.5.9

MIL-F-17874

14 CFR 23.969, 23.975, 25.969, 25.979, 25.975, 27.969, 29.969, 29.979

8.3.18 Operator interface.

Criterion: Verify that adequate controls and displays for the fuel system functions are provided to the operator(s) to indicate the necessary fuel system functions and warn of hazardous conditions.

Standard: Fuel system critical information and status (e.g., Warnings, Cautions, and Advisories) are monitored and reported to the operator(s) and maintenance crew, including in a night vision imaging systems (NVIS) environment, if applicable.

Method of Compliance: Flight simulator, inspection and ground demonstration verify the adequacy of the refueling subsystem controls and displays. Flight simulator, ground tests and flight demonstration verify that the required fuel system monitored parameters (e.g., fuel pressure, fuel temperature, low level fuel, c.g. monitoring) are properly displayed and available to the operator(s).

References: JSSG-2009: E.3.4.5.1.12, E.4.4.5.1.12; E.3.4.5.8.11, E.4.4.5.8.11; E.3.4.5.12, E.4.4.5.12; E.3.4.5.12.1, E.4.4.5.12.1; E.3.4.5.12.2, E.4.4.5.12.2; E.3.4.5.12.3, E.4.4.5.12.3; E.3.4.5.12.4, E.4.4.5.12.4; E.3.4.5.12.5, E.4.4.5.12.5

8.3.19 Diagnostics.

Criterion: Verify that built-in-test (BIT) and fault isolation provisions are available to ensure safe fuel system operations.

Standard: The fuel system provides BIT capability and fault isolation to identify failure modes to the operator(s) and facilitate maintenance troubleshooting procedures.

Method of Compliance: Analysis of the design verifies that the necessary BIT and fault isolation provisions are provided. Fuel system simulator testing, ground demonstrations, and troubleshooting procedure reviews verify performance of the fault isolation provisions and BIT.

References: JSSG-2009: 3.2.9, 4.2.9; E.3.4.5.8.11, E.4.4.5.8.11; E.3.4.5.12.5, E.4.4.5.12.5
14 CFR 23.979, 25.979, 29.979

8.3.20 Crashworthiness.

Criterion: If applicable, verify that the fuel system design precludes fuel leakage following a survivable crash impact.

Standard: Air vehicle fuel systems are designed in accordance with MIL-STD-1290. Criterion is applicable for all military rotary wing air vehicle systems. Applicability for light fixed wing air vehicle systems is determined in cooperation with the program and system safety offices. Applicability for unmanned aircraft systems is determined in cooperation with the Program and systems safety offices, taking into consideration acceptable aircraft loss rates and whether or not shipboard operations will be required. Generally, shipboard operations will require some level of crashworthiness to ensure the safety of the ship and its crew.

Method of Compliance: Compliance with crashworthiness is verified through system level analysis and component/system level ground test (e.g., fuel cell, breakaway valve qualification).

References: JSSG-2009: E.3.4.5.6.13, G.3.4.7.7
MIL-STD-1290
USAAVSCOM TR 89-D-22B
14 CFR 25.561, 25.863, 25.994, 27.561, 29.561, 27.863, 29.863, 27.952, 29.952

8.4 Fire and hazard protection.

Includes prevention, detection, extinguishing and explosion suppression provisions.

References: 14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

NOTE: 14 CFR Reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.

8.4.1 Integration.

Criterion: Verify that the fire protection system safely integrates within the air vehicle system, both physically and functionally.

Standard: The design approach provides overall system level integrity for safety of flight. System safety program requirements are incorporated into the functional baseline and operating procedures of the fire protection system. Fire protection system design integrates into the overall air vehicle system design approach philosophy. Fire protection equipment is capable of withstanding the hazards they are designed to control. A means of controlling the fire protection system is provided. System safety requirements, analyses, time lines and other milestones are in synchronization with the rest of the program schedules.

Method of Compliance: Inspection of documentation verifies that appropriate requirements have been flowed down to the different systems/elements of the air vehicle system. Design analysis indicates air vehicle system compliance. Component acceptance tests and system functional checkout tests verify functional compatibility of all elements of the installed system. Ground/flight tests verify functional and physical compatibility with other air vehicle systems.

References: JSSG-2009: G.3.4.7, G.4.4.7; G.3.4.7.1, G.4.4.7.1; G.3.4.7.2, G.4.4.7.2; G.3.4.7.29, G.4.4.7.29
14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.1.1 Failure modes and effects.

Criterion: Verify that any single-point failure conditions are identified and their consequences of failure are acceptable, eliminated or mitigated.

Standard: Single-point failure conditions are identified and their consequences of failure are acceptable, eliminated or mitigated.

Method of Compliance: Review of Failure Modes, Effects and Criticality Analysis (FMECA), lab testing and integrated system ground/flight testing verifies that all single-point failure conditions of the fire protection system are identified, and these failures are mitigated, eliminated or occur at an acceptably low frequency.

References: MIL-STD-882
USAF AWB-013A

8.4.1.2 Qualification tests.

Criterion: Verify that all components, either individually or as part of a subsystem, have passed all safety-related qualification tests (e.g., proof, burst, vibration, containment, over-speed, acceleration, explosive atmosphere, pressure cycling, and temperature cycling) as required for airworthy performance.

Standard: Components require analysis, component level testing or ground based simulator testing to confirm sufficient safety verification. Safety of flight testing demonstrates minimum safety verification to permit initial flight test without fully qualified hardware. Life limits and restrictions are defined as required.

Method of Compliance: Fire protection components are verified for expected usage and environmental conditions using analyses, simulator tests, component tests, and ground/flight tests.

Reference: MIL-STD-810

8.4.1.3 Operator interface.

Criterion: Verify that adequate crew station information is available to notify the operator(s) and crew of the system operating conditions.

Standard: Warnings, cautions, advisories and other fire protection system information is defined and provided to appropriate operator, crew and maintenance personnel.

Method of Compliance: Analysis, demonstration, inspection, ground tests and flight tests data verify that information is defined and reported to the appropriate operator, crew and maintenance personnel.

References: MIL-HDBK-516: 9.2, 9.4

8.4.2 Hazard protection zones.

Criterion: Verify that each compartment of the air vehicle is properly zoned according to the fire and explosion hazards and that protection is provided to counter the hazards such that no fire or explosion hazards exist under normal operating conditions.

Standard: Each aircraft zone is identified as one of the following fire hazard zones: Fire Zone, Flammable Leakage Zone, Flammable Zone, Ignition Zone, or Support Equipment Zone. Fire protection criteria are defined for each zone.

Method of Compliance: Analyses identify which zones in the air vehicle contain flammable fluids or ignition sources, and documentation appropriately classifies those zones as a fire zone, flammable leakage zone, flammable zone, ignition zone or support equipment zone. Analysis of the air vehicle zones verifies separation of flammable leakage sources and ignition sources. Analysis indicates that flammable fluids and vapor systems are isolated from engines, engine compartments and other designated fire zones. Analysis identifies the potential leak sources and control measures for each zone of the air vehicle. Single point failures and dual failures are analyzed for risk and mitigation for each fire protection zone.

References: JSSG-2009: G.3.4.7, G.4.4.7

MIL-HDBK-221: 2.11

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.2.1 Control station protection.

Criterion: Verify the design of the control station incorporates fire detection and protection under normal and single failure conditions.

Standard: The control station is fire tolerant, provides protection to occupants and allows for continued safe operation of the air vehicle system in the event of a fire.

Method of Compliance: Control station fire safety is verified by analysis, inspection and ground test. Single point failures and dual failures are analyzed for risk and mitigation.

Reference: NFPA 1

8.4.3 Hazard consideration in designs.

Criterion: Verify that the designs of subsystems (other than fire protection) have taken into consideration any potential for fire hazards.

Standard: Fire protection criteria are applied to all systems on the air vehicle system: e.g., explosion-proof/explosive atmosphere qualified (see MIL-STD-810), leakage control, ventilation, drainage, low surface temperatures.

Method of Compliance: Fire and explosion hazard analysis determines the fire and explosion protection features for the air vehicle system. Component testing and inspections verify incorporation of the safety features for the fire protection zones and control station (if applicable).

References: JSSG-2009: G.3.4.7.1, G.4.4.7.1

MIL-HDBK-221: 2.1, 2.2.1.2, 2.2.1.4, 2.2.1.5, 2.2.1.6, 2.2.1.7, 2.2.1.8, 2.2.2 through 2.2.9, 2.5, 2.6, 2.7.3, 2.7.11, 2.7.13, 2.10.2 through 2.10.8.

MIL-STD-810

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207,

23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.3.1 Minimization of ignition potential.

Criterion: Verify that, in areas where a fluid system might leak flammable fluids or vapors, there is a means to minimize the probability of ignition of the fluids and vapors and to minimize the resultant hazards if ignition does occur.

Standard: Ignition sources are separated from flammable vapors to prevent fire/explosion. Ventilation, drainage, containment, detection and suppression are provided as required for each fire hazard zone.

Method of Compliance: Analyses verify that provisions are implemented to provide separation of combustible and ignition sources. Air vehicle system inspections verify that appropriate clearances are provided between the electrical wiring and flammable fluid carrying lines under all operational conditions. Review of component and air vehicle system design verifies that adequate drainage, ventilation and hardening control measures are implemented. Bench testing and ground testing of components verify that the subsystem designs are free of potential ignition arcing or friction ignition sources and have maximum surface temperature that does not cause auto ignition of flammable vapors within the zone and control station (if applicable).

References: JSSG-2009: G.3.4.7.3, G.4.4.7.3; G.3.4.7.6, G.4.4.7.6

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.3.2 Safety critical components.

Criterion: Verify that provisions exist for air vehicle system safety-critical components to withstand fire and heat to a predetermined safe level.

Standard: Safety critical components withstand worst case temperatures and heat flux for the expected flammable fluids and operating conditions (e.g., for JP-8, 2000°F fire with a heat flux of 10 Btu/sec/ft^2).

Method of Compliance: Analysis identifies the appropriate level of containment capability and the time duration that the air vehicle system components must meet to maintain the necessary level of performance under a fire condition. Analysis demonstrates material and component compliance with the established fireproof or fire-resistance air vehicle system requirements. Laboratory component tests demonstrate compliance to the fire protection requirements when exposed to the required flame temperature and heat flux density for the required time (15 minutes for fireproof and 5 minutes for fire resistance).

References: JSSG-2009: G.3.4.7.6, G.4.4.7.6; G.3.4.7.21, G.4.4.7.21

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.4 Drainage and ventilation.

Criterion: Verify that provisions for drainage and ventilation of combustible fluids and vapors are adequate to preclude the occurrence of fire or explosion hazards.

Standard: Drainage systems remove all hazardous quantities of flammable liquids. Ventilation systems that operate in flight provide adequate active ventilation for flammable fluid leakage zones (e.g., 1 volumetric air change per minute for flammable fluid leakage zones) and fire zones (e.g., 2-3 volumetric air changes per minute for fire zones). Drainage and ventilation collection systems are fire hardened. Drains and vent systems for flammable zones are separated from other systems. Drains and vent systems for ignition zones are separated from other systems.

Method of Compliance: Analysis for flight and ground conditions verifies that ventilation is provided to minimize flammability. Flight and maintenance manuals identify necessary procedures for ground operations (e.g., requirement for opening bay doors when ventilation to a bay is no longer available under ground operation).

References: JSSG-2009: G.3.4.7.3, G.4.4.7.3; G.3.4.7.4, G.4.4.7.4; G.3.4.7.5, G.4.4.7.5; G.3.4.7.18, G.4.4.7.18
MIL-HDBK-221: 2.4
14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411

8.4.4.1 Location of drainage and ventilation.

Criterion: Verify that drainage and ventilation provisions are located so that combustibles are removed from the air vehicle to a safe location on the ground and cannot reenter the air vehicle in flight or ground operations.

Standard: The location of the drained fluids and vapors is such that they do not reenter the air vehicle or impinge on potential ignition sources under all operational conditions. Adequate drainage paths exist and are not prone to blockage.

Method of Compliance: Analysis demonstrates that the location of the drained fluid does not reenter the air vehicle or impinge on potential ignition sources under all operational conditions. Manufacturing and inspection processes and procedures are in place to assure there are no blockages of drainage paths. Ground and flight tests demonstrate the removal of flammable fluids to a safe location.

References: JSSG-2009: G.3.4.7.3, G.4.4.7.3; G.3.4.7.4, G.4.4.7.4; G.3.4.7.17, G.4.4.7.17; G.3.4.7.18, G.4.4.7.18; G.3.4.7.22, G.4.4.7.22
14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.5 Dedicated drainage and ventilation design.

Criterion: Verify that drains and vents from areas that might carry flammable fluids (i.e., liquids and vapors) are not manifolded with drains and vents from areas that do not carry potentially flammable fluids.

Standard: Drains and vents from areas that might carry flammable fluids are not manifolded with drains and vents from areas that do not carry potentially flammable fluids.

Method of Compliance: Inspection of the air vehicle drain system drawings verifies that flammable fluid drains are independent from non-flammable fluid drains.

References: JSSG-2009: G.3.4.7.3, G.4.4.7.3; G.3.4.7.5, G.4.4.7.5
14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.6 Engine fire zone provisions.

Criterion: Verify that engine fire zone (nacelle/cowling) cooling and ventilation provisions are adequate to provide required heat rejection and maintain engine fire zone conditions necessary to avoid both hot surface ignition sources and collection of vapors.

Standard: Engine bays/nacelles are ventilated with the greater of:

a. Between 2-3 volumetric air changes per minute.
b. The minimum required flow to keep hot surfaces less than autoignition temperature of the fuel or other flammable fluid in or near the engine bay.

Method of Compliance: Design analysis and thermal models establish heat rejection and cooling requirements for components for normal and worst case operations and environments. Component tests verify heat rejection models. Ground and flight tests verify cooling capability to eliminate the presence of hot surface ignition during all expected flight and ground conditions. Installed ground and flight tests verify ventilation capability to remove hazardous fluids and vapors to a safe location during all expected flight and ground conditions.

References: JSSG-2009: G.3.4.7.4, G.4.4.7.4, G.3.4.7.18, G.4.4.7.18

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.7 Fire detection.

Criterion: Verify that all potential fire zones (e.g., engine, auxiliary power unit and other compartments, such as engine-driven airframe accessory area) are designated as such and that suitable fire warnings and protection are provided.

Standard: Appropriate warning and fire prevention methods such as shut-off of flammable fluids, elimination of ignition sources, ventilation, drainage, fire detection, fire hardening of components and fire containment have been used for fire zones.

Method of Compliance: Analysis identifies all potential fire zones. Thermal analysis establishes the performance requirements of the fire detection systems (e.g., activation temp, activation time, clearance signal time, repeatability). Component tests verify that the alarm activation time meets the air vehicle response time criteria. Laboratory testing supports analysis and verifies performance of the fire detection systems under vibration, inertia, and other loads to which it is subjected in operation. Aircraft ground test verifies the operation of the fire detection, suppression and containment systems and its warnings.

References: JSSG-2009: G.3.4.7.19, G.4.4.7.19; G.3.4.7.20, G.4.4.7.20; G.3.4.7.24, G.4.4.7.24; G.3.4.7.27, G.4.4.7.27

MIL-HDBK-221: 2.12, 2.13 (All except any reference to Halon) and 2.17

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.8 Essential equipment in fire zones.

Criterion: Verify that essential flight controls, engine mounts, flammable fluid lines and other flight structures located in designated fire zones or adjacent areas are qualified to withstand the effects of fire and heat to a predetermined safe level.

Standard: All flammable fluid lines and components as well as safety critical components located in the fire zone withstand worst case temperatures and heat flux for the expected flammable fluids and operating conditions (e.g., for JP8, 2000°F fire with a heat flux of 10 Btu/sec/ft^2).

Method of Compliance: Hazard analysis determines the level of protection required for the safety critical components. Analysis of potential fire scenarios establishes the appropriate fire test criteria (fire proof or fire resistance). Analysis and inspection indicates at least 1/2 inch of clear airspace between a fuel tank and a fire wall. Fire testing simulates the fire environment and proves that the materials and components provides the appropriate fire containment.

References: JSSG-2009: G.3.4.7.19, G.4.4.7.19; G.3.4.7.20, G.4.4.7.20; G.3.4.7.24, G.4.4.7.24; G.3.4.7.27, G.4.4.7.27

MIL-HDBK-221: 2.12, 2.13 (All except any reference to Halon) and 2.17

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.9 Electrically powered fire protection.

Criterion: Verify that each electrically powered fire protection subsystem (e.g., fire detection, extinguishing, and explosion suppression) is provided power at all times during air vehicle operations, including electrical power system failure conditions, engine start and battery operations.

Standard: Power is provided to all fire protection equipment during all phases of operation, including electrical power system failure conditions, engine start and battery operations.

Method of Compliance: Analysis demonstrates that electrical power is provided to the fire protection system under all phases of operation, including electrical power system failure conditions, engine start and battery operations. Component laboratory tests and simulation tests verify the ability of the fire protection system to operate at all times including electrical power failure conditions. Ground and flight tests verify the ability of the fire protection system to operate at all flight and ground conditions including electrical power system failure conditions.

References: JSSG-2009: G.3.4.7.20, G.4.4.7.20; G.3.4.7.21, G.4.4.7.21

MIL-HDBK-221: 2.7.4

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.10 Explosion suppression performance.

Criterion: Verify that the air vehicle explosion suppression system meets performance requirements for fire and hazard protection.

Standard: Passive explosion suppression is provided for all fire hazard zones; e.g., ventilation, drainage, containment, detection, suppression and shut-off of flammable fluids, as appropriate. Active fire suppression is provided for zones where passive protection is not adequate.

Method of Compliance: Hazard analysis identifies the level of protection required for the explosion suppression system. Component tests verify the safety provisions (e.g., oxygen dilution, flame quenching devices). Analysis and component tests verify that the explosion suppression system limits the overpressure to levels that do not result in loss of aircraft. Ground and flight tests verify the explosion suppression system performance under actual or simulated flight conditions.

References: JSSG-2009: G.3.4.7.10, G.4.4.7.10
14 CFR 3.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 25.981, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.11 False warnings.

Criterion: Verify that the fire detection system is designed to preclude false warnings.

Standard: Redundancy is provided in the fire detection system to avoid false warnings. All failures of the fire detection system are flagged and reported to maintenance.

Method of Compliance: Analysis demonstrates avoidance of false warnings. Component tests verify performance of the failure indication systems. Component tests verify the alarm set points to avoid false alarm. Ground and flight tests verify there are no false alarms at all ground and flight conditions.

References: JSSG-2009: G.3.4.7.8, G.4.4.7.8; G.3.4.7.9, G.4.4.7.9; G.3.4.7.26, G.4.4.7.26; G.3.4.7.27, G.4.4.7.27; G.3.4.7.28, G.4.4.7.28
14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.12 Performance of fire suppression.

Criterion: Verify the performance of the fire suppression system.

Standard: The fire suppression system provides agent concentrations and duration levels that extinguish a fire under all ground and flight conditions.

Method of Compliance: Hazard analysis determines the need for a fire extinguishing system for each designated fire zone. Analysis establishes agent concentrations and duration levels that extinguish a fire. Ground and flight testing verifies that the appropriate agent concentrations are present under all ground and flight conditions.

References: JSSG-2009: G.3.4.7.9, G.4.4.7.9; G.3.4.7.10, G.4.4.7.10; G.3.4.7.11, G.4.4.7.11; G.3.4.7.12, G.4.4.7.12; G.3.4.7.13, G.4.4.7.13; G.3.4.7.14, G.4.4.7.14; G.3.4.7.15, G.4.4.7.15
MIL-E-22285 (Inactive for New Design)
14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.13 Fire isolation.

Criterion: Verify that fireproof protective devices are provided to isolate a fire within a defined fire zone from any portion of the air vehicle where a fire could create a hazard.

Standard: Containment is provided for all fire zones to prevent the fire from spreading to other compartments. Barriers are provided to withstand worst case temperatures and heat flux for the expected flammable fluids and operating conditions (e.g., for JP-8, 2000°F fire with a heat flux of 10 Btu/sec/ft^2) for the time required to take appropriate emergency actions (typically 15 minutes). All other flammable fluid components in the fire zone withstand this fire condition.

Method of Compliance: Analysis of potential fire scenarios establishes the appropriate fire test criteria. Component level testing demonstrates firewall compliance with the fireproof requirements. Fire testing simulates a fire environment and proves that the firewall components provide the appropriate fire containment and isolation.

References: JSSG-2009: G.3.4.7.24, G.4.4.7.24; G.3.4.7.25, G.4.4.7.25; G.3.4.7.26, G.4.4.7.26
14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.14 Fire resistance.

Criterion: Verify that air vehicle system interior finishes and materials deter combustion and that any toxic by-products of combustion are at acceptable levels.

Standard: Use of combustible materials is avoided in any of the fire hazard zones. Combustible materials do not produce toxic smoke or bi-products.

Method of Compliance: Analysis establishes the design criteria for flammability properties and quantities of toxic by-products. Design analyses and thermal models adequately represent system's materials and predict suitable performance during a fire. Component analysis and/or tests validate flammability and toxicity requirements. Testing verifies the properties of uncharacterized materials.

References: JSSG-2009: G.3.4.7.20, G.4.4.7.20
MIL-HDBK-221: 2.7.8 and 2.11
14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.15 Protection of inhabited and critical areas.

Criterion: Verify hazardous quantities of smoke, flames, or extinguishing agents are prevented from entering inhabited areas, control stations, or flight-critical sensor bays (e.g., for unmanned aircraft systems, remotely operated aircraft).

Standard: Provisions exist to prevent smoke, vapors, extinguishing agents, flames or fumes from creating a safety of flight condition for the air vehicle, creating an unacceptable hazard to personnel or adversely affecting flight critical sensors. The unmanned aircraft system control station is protected to National Fire Protection Association standards.

Method of Compliance: Provisions exist to prevent smoke, vapors, extinguishing agents, flames or fumes from creating a safety of flight condition for the air vehicle, creating an unacceptable hazard to personnel or adversely affecting flight critical sensors. The unmanned aircraft system control station is protected to National Fire Protection Association standards.

References: JSSG-2009: G.3.4.7.7, G.4.4.7.7; G.3.4.7.22, G.4.4.7.22
MIL-HDBK-221: 2.7.9
14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411
FAA AC 25-9
FAA AC 25.853-1
FAA AC 25.869-1

8.4.16 Equipment separation.

Criterion: Verify that proper separation is provided between oxidizers, flammable fluid systems and electrical components.

Standard: Flammable fluids and oxidizers are separated from electrical wiring by at least ½ inch. Electrical wiring is routed above flammable fluid lines so that leakage does not impinge on the wiring.

Method of Compliance: Hazard analysis of the air vehicle verifies that provisions are implemented to provide for separation of combustible, oxidizers and ignition sources. Air vehicle inspections verify that appropriate clearances are provided between the electrical wiring and flammable fluid carrying lines under all operational conditions (minimum of ½ inch under worst case). Air vehicle inspections verify that oxygen equipment is not installed in a fire zone and that flammable fluid lines and oxygen lines are not routed together or in proximity to each other without proper isolation design. Ground and flight tests show that clearance requirements are met under all ground and flight conditions. Inspections indicate proper separation between a fuel tank and an ignition zone.

References: JSSG-2009: G.3.4.7.22, G.4.4.7.22

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.17 Fluid shut off.

Criterion: Verify that provisions are available to shut off flammable fluids and de-energize all electrical ignition sources in the identified fire zone(s) for all mission phases including ground operations.

Standard: Shutoff valves are provided that can close off all flammable fluids to fire zones during a fire. All electrical equipment in a fire zone can be de-energized to prevent further ignition of flammable fluids.

Method of Compliance: Ground tests verify that the closing of any of the fuel shutoff valves does not affect fuel availability to the remaining propulsion system, if applicable. Drawing inspections and component tests verify that each flammable fluid shut-off means and controls are fireproof or protected from a fire or fire zone. Ground test verify all electrical equipment in fire zones are able to be de-energized in case of a fire.

References: JSSG-2009: G.3.4.7.16, G.4.4.7.16; G.3.4.7.17, G.4.4.7.17

MIL-HDBK-221: 2.7.2, 2.7.10, 2.10.4.2, 2.10.2.1

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 29.851, 29.863, 27.1411, 29.1411

8.4.18 Ground access.

Criterion: Verify that ground firefighting access provisions are compatible with standard ground firefighting systems and that fire suppression can be accomplished through this access provision.

Standard: Access to fire zones is provided to permit ground firefighting crews to extinguish a fire on the ground.

Method of Compliance: Analysis verifies the location and interface requirements of ground firefighting provisions. Demonstration on the aircraft verifies that ground firefighting access provisions are compatible with standard ground firefighting systems.

References: JSSG-2009: G.3.4.7.17, G.4.4.7.17; G.3.4.7.19, G.4.4.7.19

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

FAA AC 20-42

8.4.19 Post-crash protection.

Criterion: Verify that the air vehicle provides safety features for post-crash fire and explosion hazards.

Standard: Flammable fluids are contained during a post-crash condition to avoid further explosions or feeding a ground fire. Hazards from post-crash related ignition sources are mitigated (e.g., hot surfaces during a wheels up landing in close proximity to a flammable fluid) (see also 8.3.21 Criterion).

Method of Compliance: Analysis verifies flammable fluids are contained and ignition sources are minimized in a post-crash landing scenario.

References: JSSG-2009: G.3.4.7.7, G.4.4.7.7; G.3.4.7.13, G.4.4.7.13; G.3.4.7.31, G.4.4.7.31

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 29.851, 29.863, 27.865, 29.865, 27.1411, 29.1411

FAA AC 25-17

FAA AC 25.994.1

8.4.20 Detection and control of overheating.

Criterion: Verify that the air vehicle has provisions to detect and control overheat conditions that are potential fire and explosion hazards.

Standard: Performance requirements of the overheat protection systems (e.g., set temperature, activation time, clearance signal time, repeatability) are defined. Overheat detection for the air vehicle subsystems (e.g., bleed air lines, electrical equipment) meets the expected usage and environments in the installed condition while providing adequate detection, activation and reset time as well as avoiding false alarms.

Method of Compliance: Thermal analysis verifies performance requirements of the overheat protection systems. Component tests verify that the alarm activation time meets the air vehicle response time criteria. Laboratory testing verifies the performance requirements of the overheat protection systems under vibration, inertia, and other loads to which it is subjected in operation . Aircraft functional checkouts demonstrate the operation of the overheat protection system and its warnings.

References: JSSG-2009: G.3.4.7.7, G.4.4.7.7

MIL-HDBK-221: 2.15

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.863, 27.865, 29.851, 29.863, 29.865, 27.1411, 29.1411

8.4.21 Protection of cargo holds.

Criterion: Verify, if unoccupied cargo holds are present, that fire protection, fire detection/suppression, and smoke detector requirements are met.

Standard: Unoccupied cargo holds meet fire protection zone definition and criteria. Hazard analysis determines the requirements for fire detection, suppression and smoke detection for unoccupied cargo holds.

Method of Compliance: Analysis, ground and flight test verify unoccupied cargo holds incorporate adequate fire protection, detection and suppression . Ground and flight test verify smoke detection performance.

References: JSSG-2009: G.3.4.7.23, G.4.4.7.23; G.3.4.7.28, G.4.4.7.28

14 CFR 23.851-23.865, 25.851-25.869, 23.1181-23.1203, 25.1181-25.1207, 23.1411, 25.1411, 27.855, 27.863, 29.851, 29.855, 29.863, 27.1411, 29.1411

8.5 Landing gear and deceleration systems.

The landing gear and deceleration systems provide the air vehicle with the safe capabilities of holding position, towing, taxi, takeoff, landing touchdown, balanced field, critical field length abort, directional control and arresting systems compatibility. The landing gear and deceleration systems include shock absorbers; landing gear and door actuation mechanisms; nose gear steering system; wheels; brakes; tires; drag chutes; arresting gear hooks; anti-skid control; brake control; brake actuation mechanisms; mooring rings; and tow fittings. In addition, specialized systems are included such as kneeling, crosswind positioning, skis, skids and in-flight tire pressure control e.g..

References: JSSG-2009: Appendix A

AFGS-87139

14 CFR 23.721-23.745, 25.721-25.737

NOTE: 14 CFR Reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.

8.5.1 Ground flotation.

Criterion: Verify safe ground flotation capability of the landing gear systems.

Standard: Landing gear systems apply loads to the airfield surface which do not exceed the bearing strength of the airfield surface for all types of airfields called out in the Operational Requirements.

Method of Compliance: Verification method includes analysis. Flotation analysis verifies compliance with the flotation requirements for the given tire sizes, tire pressures and specified mission weights.

References: JSSG-2009: A.3.4.1.2.1, A.4.4.1.2.1 Ground Flotation

AFGS-87139: 3.2.1.1.b Ground Flotation.

8.5.2 Arrangement, dynamics, and clearances.

References: AFGS-87139: 3.2.1.1, 3.2.1.2

14 CFR 23.721-23.745, 25.721-25.737 - Covers dynamics and some of arrangements, no clearances

8.5.2.1 Ground clearances.

Criterion: Verify that the landing gear arrangement and servicing criteria prevents ground contact (including servicing equipment, arresting cables, runway lights, etc.) at all weapons loading configurations, engine runs, and for flat gear or flat tire, or flat gear and flat tire situations.

Standard: The design provides sufficient clearance between landing gear parts, all of the air vehicle structure, other systems and the ground. Minimum clearances are maintained at all times and for all operational conditions.

Method of Compliance: Verification methods include analysis and demonstration. Clearance analysis verifies ground clearance for all possible operations. Taxi and turning demonstrations validate the clearance analysis.

References: JSSG-2009: A.3.4.1.1.1, A.4.4.1.1.1 Gear arrangement; A.3.4.1.1.3, A.4.4.1.1.3 Extended Clearances; A.3.4.1.1.6, A.4.4.1.1.6 Clearance with flat tire and flat strut.

AFGS-87139 3.2.1.2 Arrangement; 3.2.1.3.a Clearances.

14 CFR 13.1-13.2.4, 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

8.5.2.2 Aircraft stability and control on the ground.

Criterion: Verify that, for all ground operations, the air vehicle maintains operational control and stability such that no part of the air vehicle or its weapons contacts the ground or other permanent ground structures (servicing equipment, arresting cables, runway lights, etc.).

Standard: The air vehicle maintains an acceptable level of dynamic stability and control for all mission operations on the ground and during the transition to and from flight. There are no adverse dynamics occurring at any time, such as shimmy or porpoising.

Method of Compliance: Verification methods include analyses, tests and demonstration. Stability analysis, shimmy analysis and dynamic analysis verify adequate stability and control of the air vehicle during all phases of ground operation. Instrumented ground taxi and turning tests verify operational control and demonstrate no contact with the ground and other permanent ground structures.

References: JSSG-2009: A.3.4.1.1.2, A.4.4.1.1.2 Pitch Stability; A.3.4.1.1.7, A.4.4.1.1.7 Gear Stability

AFGS-87139: 3.2.1.2 Arrangement, 3.2.5.1 General

14 CFR 25.233

8.5.2.3 Wheel well clearances.

Criterion: For retractable gears, verify that sufficient clearance exists within the wheel well under all ground and flight conditions so that no part of the gear contacts the airframe or becomes stuck in the up position due to interference with any air vehicle structure or component.

Standard: Sufficient clearance is maintained between all landing gear components, air vehicle structure and air vehicle systems. Rotating parts do not unintentionally contact other components and systems over the landing gear's life including adverse wear effects. Loads from rotating parts do not exceed design requirements.

Method of Compliance: Verification methods include analyses, tests, inspections and demonstrations. Clearance analyses, system inspections and system checkouts on the air vehicle verify clearances between landing gear and structure. Simulator testing verifies clearances under air loads. Flight and ground demonstrations verify suitable clearances for all takeoff and landing operations, both for normal and emergency operations. Lab testing verifies that rotating parts, including grown tires, do not exceed design requirements and clearances. Clearances due to wear effects are verified by simulation or inspection of lead the fleet aircraft.

References: JSSG-2009: A.3.4.1.1.4, A.4.4.1.1.4 Retraction Clearances

AFGS-87139: 3.2.1.2 Arrangement and 3.2.1.3.b Clearances (retractable landing gears)

14 CFR 23.745

8.5.2.4 Dynamic stability for ground operation.

Criterion: Verify that the design of the landing gear system prevents the occurrence of unsafe dynamics, vibrations, or pitching motions for all operational phases of the air vehicle on the ground and during the transition to and from flight.

Standard: The air vehicle maintains an acceptable level of dynamic stability for all mission operations on the ground and during the transition to and from flight. There are no adverse dynamics occurring at any time, such as shimmy, gear walk, porpoising or yaw skids.

Method of Compliance: Verification methods include analyses and tests. Dynamic and stability analyses verify landing gear damping and stability for all ground operations, and are validated using component characterization, air vehicle ground vibration tests, and taxi tests. Flight testing verifies that all transitional operations to and from flight have no adverse vibration or instability.

References: JSSG-2009: A.3.4.1.1.2, A.4.4.1.1.2 Pitch Stability; A.3.4.1.1.7, A.4.4.1.1.7 Gear Stability; A.3.4.1.4.5.1, A.4.4.1.4.5.1 Steering characteristics

AFGS-87139: 3.2.1.2.b Arrangement; 3.2.1.4 Damping.

14 CFR 23.721-23.745, 25.721-25.738

8.5.2.5 Tip back.

Criterion: Verify that the air vehicle does not tip back when reverse braking or towing is done at the specified conditions.

Standard: Tip back of the air vehicle for all configurations (i.e., gross weights, adverse center of gravity locations and weapon loadings) does not occur when maximum braking (either air vehicle or tow vehicle) is applied with the air vehicle traveling in the aft direction at a speed of 5 miles per hour on a 3 degree slope.

Method of Compliance: Verification methods include analysis and ground demonstration. Analysis and ground demonstration verify the reverse braking and towing capability of the air vehicle for all aircraft configurations, gross weights, adverse center of gravity locations and weapon loadings.

References: JSSG-2009: A.3.4.1.2.2.1.3, A.4.4.1.2.2.1.3 Landing gear towing; and A.3.4.1.3.1.14, A.4.4.1.3.1.14 Empennage protection

14 CFR 23.509, 25.507, 25.509

8.5.2.6 Kneeling.

Criterion: Verify the landing gear kneeling capability allows for safe kneeling of the air vehicle.

Standard: For air vehicles that have kneeling capability, lowering and raising of the air vehicle is accomplished in a predictable and controllable manner, with no sudden or adverse movements.

Method of Compliance: Verification methods include analyses, tests and demonstrations. Design analysis verifies kneeling system operation and limits of operation. Air vehicle tests verify the design and the analysis for all required operational and environmental conditions.

Ground operational demonstrations verify that the kneeling system meets operators' requirements.

References: JSSG-2009: A.3.4.1.10, A.4.4.1.10 Specialized subsystems
AFGS-87139: 3.1.9 Specialized subsystems.

8.5.2.6.1 Kneeling procedures.

Criterion: Verify the servicing procedures for landing gear kneeling and unkneeling are safe and properly sequenced.

Standard: Servicing interfaces and kneeling system control are accessible to ground personnel and/or the pilot/operator as required by the design. All air vehicle movements are controllable at all times from the kneeling control station.

Method of Compliance: Verification methods include analyses, tests and demonstrations. Design analysis verifies safe kneeling system servicing and controls. Air vehicle demonstrations verify accessibility and that the air vehicle movements during kneeling are safe and controllable.

References: JSSG-2009: A.3.4.1.10, A.4.4.1.10 Specialized subsystems
AFGS-87139: 3.1.9 Specialized subsystems.

8.5.3 Landing gear structure.

References: JSSG-2009: A.3.4.1.1 Landing gear, A.3.4.1.3 General provisions
AFGS-87139: 3.2.2
14 CFR 23.721-23.745, 25.721-25.737

8.5.3.1 Prevention of crew station penetration.

Criterion: Verify that any structural failure of the gear does not result in penetration of the crew station (for manned air vehicles), fuel tanks, or any other bay that may ignite.

Standard: Landing gear structural failure modes do not result in catastrophic failure modes such as cockpit or cabin penetration, severed hydraulic lines or electrical cables, or fuel spillage.

Method of Compliance: Verification methods include analyses, inspections and demonstrations. Failure Modes Effects and Criticality Analysis (FMECA) shows that expected structural failures of the landing gear do not result in catastrophic failures. Functional checkouts and inspection of gear design, location and alignment verifies that expected structural failures of the landing gear do not result in catastrophic failures.

References: JSSG-2009: A.3.4.1.3.1.3, A.4.4.1.3.1.3 Failure Tolerance
AFGS-87139: 3.2.2.1.e General (limits on structural failure modes)
14 CFR 23.721 and 25.721 cover fuel spillage

8.5.3.2 Shock strut energy absorption.

Criterion: Verify the functionality of the shock strut to perform all its required suspension, stroking, and energy absorption for all ground operations, landing, and takeoffs with normal servicing and with acceptable levels of misservicing.

Standard: Landing gear energy absorption capability supports the air vehicle at all times for all the design missions. Static and dynamic loads generated during taxi, takeoff and landing under all air vehicle operational weights and environments with properly serviced and misserviced shock struts are considered and included.

Method of Compliance: Verification methods include analyses, tests, inspections and demonstrations. Shock strut energy analysis verifies that air vehicle loads are not exceeded for any shock strut pressure levels, including misserviced shock struts, and any air vehicle operational weights. Loads are validated by component test results. Checkout/inspection verifies that the gear can be serviced properly. Ground demonstration verifies that the gear performs as designed when serviced at the specified pressure levels. Flight testing validates the analysis and verifies the operational suitability of the shock strut.

References: JSSG-2009: A.3.4.1.3.1.8, A.4.4.1.3.1.8 Energy Absorption; 3.4.1.3.1.11, 4.4.1.3.1.11 Repeated Operation

AFGS-87139: 3.2.2.1 General, 3.2.2.2 Shock absorption

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14 CFR 23.721-23.745, 13.1-13.2.4, 23.1501, 23.1529, 25.721-25.737, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

8.5.3.3 Shock strut misservicing allowance.

Criterion: Verify that a misserviced shock strut safely supports all weapons loading, fueling and defueling, does not compromise takeoff and landings, and does not result in ground resonance.

Standard: Misserviced shock struts do not adversely affect dynamic energy absorption or adversely affect air vehicle structure. Sudden and adverse movements of the strut do not occur during weapons, fuel, and other loading events. During takeoff, landing and taxi events no damage occurs to the landing gear system or to the air vehicle structure as long as the pressure within the strut stays within the misservicing range.

Method of Compliance: Verification methods include analyses, tests, inspections and demonstrations. Shock strut energy analysis verifies that air vehicle loads are not exceeded for misserviced shock strut pressures and at all air vehicle operational weights. Ground demonstrations and inspection verify that the landing gear system maintains satisfactory attitudes during ground operations such as fueling, weapons loading, etc. Component testing verifies that the landing gear system performs as designed when misserviced within the specified range of pressures. Flight and ground air vehicle testing validate the analysis and verify the operational suitability of the shock strut.

References: AFGS-87139: 3.2.1.3 Clearances

MIL-T-6053 (Inactive for New Design)

MIL-L-8552

14 CFR 13.1-13.2.4, 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

8.5.3.4 Landing operating limits.

Criterion: Verify that, for both main and nose/tail landing gear, landing conditions (normal and emergency) are within the safe operating limits.

Standard: For all expected air vehicle operations, the sink rates and landing weights do not cause overloads of aircraft structures and systems. Landing gear rebound and gear dynamic characteristics are within safe operating limits.

Method of Compliance: Verification methods include analyses and tests. Energy analysis verifies the landing gear capability to handle all air vehicle landing weights and conditions, both normal and emergency including flat strut and flat tire operations. Drop testing verifies that design loads are not exceeded for all operational conditions (normal and emergency) and verifies load predictions for both static and fatigue conditions. Drop testing verifies the energy absorption curves and that metering pin and orifice design are acceptable.

References: JSSG-2009: A.3.4.1.3.1.7, A.4.4.1.3.1.7 Flat tire and flat strut operation; A.3.4.1.3.1.8, A.4.4.1.3.1.8 Energy absorption; A.3.4.1.3.1.11, A.4.4.1.3.1.11 Repeated operation
AFGS-87139: 3.6 Environmental Conditions; 3.2.2.1 General; and 3.2.2.2 Shock absorption
14 CFR 23.721-23.731, 23.473, 23.477, 23.479, 23.481, 23.483, 23.485, 25.721-25.731, 25.101, 25.511, 25.1583

8.5.3.5 Landing gear stability and shimmy prevention.

Criterion: Verify that dynamic stability is adequate and landing gear shimmy is not evident.

Standard: Verify that the landing gear design parameters for new and worn conditions suppress all divergent loads and forces at all operational ground speeds. Divergent loads and forces are controlled by either active or passive means in order to prevent detrimental oscillations induced by runway roughness, tire imbalance or design, brake vibrations and gear natural responses. The oscillation modes to be evaluated include fore and aft, torsional and vertical displacements.

Method of Compliance: Verification methods include analyses and tests. Shimmy analysis verifies sufficient shimmy damping at all ground operations. Ground vibrational tests verify the natural frequency sensitivities of the gear and air vehicle. Ground (taxi) and flight testing verify that all air vehicle operations meet vibrational requirements and are within prescribed shimmy and stability limits.

References: JSSG-2009: A.3.4.1.1.7, A.4.4.1.1.7 Gear Stability; A.3.4.1.4.5.1, A.3.4.1.4.5.1 Steering Characteristics
AFGS-87139: 3.2.1.2 Arrangement, 3.2.1.4 Damping
14 CFR 23.721-23.745, 25.721-25.737 - shimmy is not covered; the rest of the paragraphs imply coverage

8.5.4 Tire load and speed ratings.

Criterion: Verify that all mission and all ground handling conditions, including maximum air vehicle deceleration at the most critical center of gravity (CG) and gross weight, have a maximum expected tire load and speed below that demonstrated for the selected tire at its intended inflation pressure and maximum wear limit (MWL).

Standard: The tire design is compatible with all air vehicle performance requirements during taxi, turns, takeoff, and landing operations (including rolling over arresting gear cable). The tire design parameters account for all critical gross weights, CGs, and velocities such that the loads do not exceed aircraft structural or operational limits.

Method of Compliance: Verification methods include analyses and tests. Performance analysis determines the maximum expected tire load and speed profiles for all missions and ground handling conditions. Laboratory tests verify the structural and performance capability of the tire when tested at maximum expected tire load and speeds. Tests include material, strength, roll distance, cable bruise, service life, overload operations and speed/load/time profiles that represent air vehicle performance. Flight test verifies tire carcass integrity and simulated loads used for qualification are not exceeded in the field operations. Operational tests verify tire life and tread design (wet and dry stopping performance).

References: JSSG-2009: A.3.4.1.2.2, A.4.4.1.2.2 Ground handling; A.3.4.1.3.1.4, A.4.4.1.3.1.4 Strength; A.3.4.1.11.1.1, A.4.4.1.11.1.1 Air vehicle tire performance
AFGS-87139: 3.1.8 Ground handling (operations), 3.2.4.1 Tires
MIL-PRF-5041
14 CFR 23.473, 23.726, 23.733, 25.473, 25.726, 25.733

8.5.5 Wheel loads.

Criterion: Verify that the worst-case loads expected during operational missions on the nose/tail wheels and main gear wheels are not exceeded.

Standard: The tire/wheel combination supports all expected normal and emergency ground operations at all design mission conditions, including operation at hot and cold climates, altitudes, wet and dry, roll on rim without coming apart (i.e., non-frangible) for flat or blown tires, at all air vehicle gross weights and flight configurations.

Method of Compliance: Verification methods include analyses and tests. Air vehicle performance analysis predicts the worst case loads. Laboratory tests verify the structural and performance capability of the wheel/tire combination. Tests include strength, roll distance, service life, roll on rim, overload operation and speed/load/time profiles. Flight test and operational tests validate the analysis and component tests.

References: JSSG-2009: A.3.4.1.3.1.4, A.4.4.1.3.1.4 Strength; A.3.4.1.11.2.1, A.4.4.1.11.2.1 Air vehicle wheel performance; A.3.4.1.11.2.4, A.4.4.1.11.2.4 Nonfrangibility criteria (flat tire operation)
MIL-W-5013 (Inactive for New Design)
MIL-B-8584
AFGS-87139 paragraphs 3.1.8 Ground handling (operations) and 3.2.4.2 Wheels
SAE ARP1493
14 CFR 23.721-23.732, 25.721-25.732, 23.471-23.511, 25.471-25.511, 25.101 (see 13.1-13.2.4)

8.5.6 Wheel and tire over-pressurization protection.

Criterion: Verify that protection is incorporated to preclude wheel and tire overheating and over-pressurization.

Standard: The overheat and over-pressurization devices release tire pressure before the material in the wheel and/or tire is degraded or tire pressure reaches unsafe levels.

Method of Compliance: Verification methods include analyses, tests and inspections. Thermal analysis and inspection confirm overheat and over-pressurization protection, i.e., the fuse plug releases before the wheel is softened by brake temperature and that the pressure relief valve releases before overpressure exceeds explosive levels. Component testing verifies the capabilities and consistency of pressure release devices and their applicability for the particular design. Laboratory testing validates analysis and verifies performance of fuse plugs and over-pressurization devices.

References: JSSG-2009: A.3.4.1.11.2.3, A.4.4.1.11.2.3 Brake Overheat Capability; A.3.4.1.11.2.6, A.3.4.1.11.2.6 Pressure-release criteria; A.3.4.1.11.3.1, A.4.4.1.11.3.1 Air vehicle stopping and turn-around performance; and A.3.4.1.11.3.7, A.4.4.1.11.3.7 Temperature interface criteria

AFGS-87139: 3.2.4.2.c Wheel overheat capability; MIL-W-5013 (Inactive for New Design)
SAE ARP1493
14 CFR 23.731, 25.731

8.5.7 Brake assemblies

References: JSSG-2009: A.3.4.1.4.1, A.4.4.1.4.1; A.3.4.1.11.3, A.4.4.1.11.3
AFGS-87139: 3.2.3 and 3.2.4.3
MIL-W-5013 (Inactive for New Design)
SAE ARP1493
14 CFR 23.45, 23.55, 23.493, 23.735, 25.45, 25.55, 25.493, 25.735, 25.101

8.5.7.1 Brake energy capability.

Criterion: Verify that the energy, torque, and distance performance are at least equal to the levels required for the air vehicle when it is operated within its design limits.

Standard: The deceleration system stops the air vehicle within operational requirements, on all specified runways and lengths, etc. Brake performance meets defined dry and wet runway requirements.

Method of Compliance: Verification methods include analyses and tests. Air vehicle performance analyses determine system size and energy characteristics. Laboratory tests verify brake performance levels at all critical weights and speeds. Flight testing verifies compliance with the brake performance on various runway surfaces and conditions.

References: JSSG-2009: A.3.4.1.11.3.1, A.4.4.1.11.3.1 Air vehicle stopping and turn-around performance
MIL-W-5013 (Inactive for New Design)
AFGS-87139: 3.2.3.1.a and b Brake system (General)
SAE ARP1493
14 CFR 23.45, 23.55, 23.493, 23.735, 25.45, 25.55, 25.493, 25.735, 25.101

8.5.7.2 Brake redundancies.

Criterion: Verify that any failure of a hydraulic, electrical or mechanical component of the brake system or the loss of the primary operating power source does not prevent the air vehicle from stopping within the runway length needed to conduct the mission.

Standard: Single point failures in the brake assembly do not adversely affect the brake's capability to produce torque. An alternate means of providing power to the brakes is provided that is capable of stopping the air vehicle within the operational runway lengths, if the primary power source fails. The alternate brake performance meets dry and wet runway operational criteria for all specified distances and surfaces.

Method of Compliance: FMECA identifies safe and unsafe modes of operation in the brake system. Component testing verifies the FMECA results and brake redundancy. Air vehicle checkouts verify design functionality and integration. Laboratory testing verifies the performance of the deceleration systems for both normal and emergency or alternate modes. Flight testing verifies the performance of the deceleration systems normal mode.

References: JSSG-2009: A.3.4.1.11.3.3, A.4.4.1.11.3.3 Structural failure criteria; and A.3.4.1.11.3.4, A.4.4.1.11.3.4 Secondary braking capability (fail-safe)
AFGS-87139: 3.2.3.1.c Brake system, General; and 3.2.4.3 Brakes
MIL-W-5013 (Inactive for New Design)

SAE ARP1493
14 CFR 23.735, 25.735

8.5.7.3 Brake torque.

Criterion: Verify that the brakes provide sufficient torque to prevent wheel rotation with engine thrust at least equal to normal preflight levels.

Standard: Brake sizing is sufficient to provide static holding torque that prevents wheel rotation when end of runway run-up thrust is applied to the air vehicle.

Method of Compliance: Verification methods include tests and demonstrations. Laboratory tests establish brake holding torque capabilities. Air vehicle demonstrations at the design and operational levels verify that the brake prevents wheel rotation.

References: JSSG-2009: A.3.4.1.7, A.4.4.1.7 Restraint capability
MIL-W-5013 (Inactive for New Design)
MIL-B-8584
AFGS-87139: 3.2.3.1.b Brake System, General; and 3.2.4.3 Brakes
SAE ARP1493
14 CFR 23.735, 25.735

8.5.8 Brake control and anti-skid control.

References: JSSG-2009: A.3.4.1.4.1, A.4.4.1.4.1 Braking; A.3.4.1.4.4, A.4.4.1.4.4 Braking and skid control
AFGS-87139: 3.2.3, 3.2.4.3
MIL-W-5013 (Inactive for New Design)
SAE ARP1493
14 CFR 25.101, 23.45, 23.55, 23.735, 25.735

8.5.8.1 Brake control redundancies.

Criterion: Verify that there is a separate and independent method of stopping the air vehicle within the required distance when the primary stopping method is unavailable or compromised.

Standard: An alternate and independent means of stopping and controlling the air vehicle is provided when the primary means is unavailable. The level of control and stopping performance are equal to that provided by the normal system; if not equal, then as specified for reduced stopping performance. Manual braking is available to the pilot/operator.

Method of Compliance: Verification methods include analyses, tests and demonstrations. Ensure the FMECA addresses all modes of brake control system failure. Design analysis verifies the availability of a redundant and/or alternate means to provide stopping power. Brake system simulator testing confirms that there is a separate and independent method of stopping the air vehicle when the primary means is not available. Laboratory braking test verifies the performance of the secondary braking system. Air vehicle checkouts and ground testing verify system performance and proper functioning of the secondary system.

References: JSSG-2009: A.3.4.1.4.4.2, A.4.4.1.4.4.2 Alternate independent braking
MIL-B-8584
AFGS-87139: 3.2.3.2.a Brake actuation system; 3.2.4.3 Brakes
SAE ARP1493
14 CFR 23.735, 25.735

8.5.8.2 Braking control.

Criterion: Verify that the braking function can be maintained in a smooth and controllable manner for all normal and emergency operations.

Standard: Brake actuation forces can be applied in a predictable and proportional manner. The pilot/operator/autonomous system is able to apply varying input commands and achieve the expected output braking force from the commanded input. The following system parameters need to be considered for cockpit design: rudder pedal design, feel spring characteristics, and pedal force versus pedal travel. Non-cockpit designs include preprogrammed command conditions, switching commands, design logic, etc. System feedback requirements are established to determine varying brake operation commands.

Method of Compliance: Verification methods include tests and simulations. Simulators and mockups provide system force, travel and response assessments for the specified size range of pilots. Air vehicle checkouts verify function and command integration of the braking system. Air vehicle ground and flight tests verify controllability and suitability of the braking system for all required operations.

References: JSSG-2009: A.3.4.1.4.2, A.4.4.1.4.2 Directional Control; A.3.4.1.4.4.1, A.4.4.1.4.4.1 Braking control interface
MIL-B-8584
AFGS-87139: 3.2.3.1 General; 3.2.3.2 Brake actuation system; 3.2.3.3 Anti-skid brake control; 3.2.4.3 Brakes
SAE ARP1070
14 CFR 25.101, 23.45, 23.55, 23.735, 25.735

8.5.8.3 Parking brake.

Criterion: If a parking brake is required, verify that it provides holding power for the required time and conditions.

Standard: The parking brake provides sufficient torque to hold the air vehicle static for the operational design conditions and for the specified time required by the system performance specification.

Method of Compliance: Verification methods include tests and demonstrations. Simulator tests verify system design logic and functionality of the parking brake. Air vehicle demonstrations and tests verify performance of the parking brake.

References: JSSG-2009: A.3.4.1.9.5, A.4.4.1.9.5 Parking Brake
MIL-B-8584
AFGS-87139: 3.2.3.2.d Brake actuation system
SAE AS8584

8.5.8.4 Safe stopping performance.

Criterion: Verify safe stopping performance for all expected runway conditions (dry, wet, snow, ice, etc.) over all mission speed ranges and for all ground maneuvering conditions.

Standard: The brake system, in conjunction with the anti-skid system, will safely stop the air vehicle under all expected runway conditions from maximum braking speed to the lowest ground speed compatible with ground handling of the air vehicle system.

Method of Compliance: Verification methods include analyses, tests and simulations. Air vehicle performance analysis determines stopping performance capability for all specified operations, speeds and locations. Laboratory testing and simulation that use all system hardware and software as incorporated in the air vehicle and under specified environmental design conditions verify the stopping performance. Air vehicle checkouts verify proper functioning of the brake system, with and without failures, as integrated within the air vehicle control systems. Ground braking tests verify system operation for the specified runway conditions.

References: JSSG-2009: A.3.4.1.4.4.3, A.4.4.1.4.4.3 Skid control; A.3.4.1.11.3.1, A.4.4.1.11.3.1 Air vehicle stopping and turn-around performance
MIL-B-8584
AFGS-87139: 3.2.3.1 General; 3.2.3.3 Anti-skid brake control; 3.2.4.3 Brakes
SAE ARP1070
14 CFR 23.45, 23.55, 23.493, 23.735, 25.187, 25.45, 25.55, 25.493, 25.735

8.5.8.5 Anti-skid system.

Criterion: Verify that anti-skid system design can respond to any power interruptions or system malfunctions without compromising the ability to control the air vehicle.

Standard: The braking and deceleration system responds to an internal anti-skid malfunction or to external power interruption. The anti-skid self-correcting features switch to alternate braking mode in a safe and controllable manner. The change in controlling function is designed to provide for safe recovery of the air vehicle from any failure state.

Method of Compliance: Verification methods include analyses, tests and demonstrations. The FMECA identifies failures of the anti-skid system. Simulator testing verifies the modes of operation shown in the FMECA results. Air vehicle checkout verifies proper functioning of the anti-skid system as integrated within the brake control system. Flight and ground testing demonstrate the successful operation of the brake control/anti-skid systems and warnings/indications.

References: JSSG-2009: A.3.4.1.4.4.4, A.4.4.1.4.4.4 skid control with power interruption; A.3.4.1.4.4.5, A.4.4.1.4.4.5 anti-skid engagement and disengagement
AFGS-87139: 3.2.3.3 Anti-skid brake control; 3.2.4.3 Brakes
MIL-B-8584
SAE ARP1070

8.5.8.6 Locked wheel prevention.

Criterion: Verify that the anti-skid system precludes locked wheel/tire occurrences for all normal operating conditions.

Standard: The anti-skid control system prevents locked wheel conditions from occurring from touchdown to taxi speeds. The system controls braking forces to the extent that the tire is not flat spotted and the anti-skid and air vehicle deceleration performance requirements are still met.

Method of Compliance: Verification methods include analyses, tests and demonstrations. The brake design analysis indicates sufficient locked wheel protection for all braking operations. Braking simulator testing verifies locked wheel protection for all modes of air vehicle operations. Air vehicle system checkout verifies proper functioning of the anti-skid system with and without failures. Ground and flight testing verify installed aircraft performance.

References: JSSG-2009: A.3.4.1.4.4.3, A.4.4.1.4.4.3 Skid Control
MIL-B-8584
AFGS-87139: 3.2.3.3 Anti-skid brake control; 3.2.4.3 Brakes
SAE ARP1070

14 CFR 23.45, 23.55, 23.493, 23.735, 25.45, 25.55, 25.493, 25.735

8.5.8.7 Brake application characteristics.

Criterion: Verify that brake control power is equal and proportional to brake input command.

Standard: To produce repeatable and predictable braking actuation forces, input commands are proportional to output commands.

Method of Compliance: Verification methods include tests and demonstrations. Laboratory testing verifies that input commands and output braking forces are proportional as designed and brake release and running clearances are maintained. Air vehicle checkout verifies that air vehicle system operation and integration matches that which was tested. Ground and flight braking tests verify performance.

References: JSSG-2009: A.3.4.1.4.4.1, A.4.4.1.4.4.1 Braking Control Interface
MIL-B-8584
SAE ARP1070

8.5.8.8 Release of brakes.

Criterion: Verify that when brake command is removed, brakes return to brakes-off position and brake control power is not trapped or slow to release any brake.

Standard: When the input braking command is removed, the brake actuation system returns to a free-wheeling position to prevent any dragging brake events from occurring. Brake heat stack running clearances and consistent brake on pressure levels are maintained.

Method of Compliance: Verification methods include tests and demonstrations. Laboratory testing verifies that brakes are released and running clearances are maintained when input commands are removed. Air vehicle checkout verifies system operation and integration. Ground and flight braking tests verify performance.

References: JSSG-2009: A.3.4.1.4.4.1, A.4.4.1.4.4.1 Braking control interface
MIL-B-8584
AFGS-87139: 3.2.3.2 Brake actuation system; 3.2.3.3 Anti-skid brake control; 3.2.4.3 Brakes
SAE ARP1070

8.5.8.9 Brake control modes.

Criterion: Verify that all modes of brake operation are safe.

Standard: Brake system disconnect, switching or disengaging does not cause locked wheels/tire conditions. System failures or control changes are predictable and default to a state that is controllable. Single point failures have been identified and their consequences of failure have been eliminated or mitigated.

Method of Compliance: Verification methods include analyses, tests and demonstrations. The FMECA identifies degraded modes of operation. Ground and simulator testing verifies that the brake system functions safely in degraded and normal modes. Hardware and simulator testing verify that failures or control changes are predictable and result in a state that is controllable. Ground and flight tests verify performance.

References: JSSG-2009: 3.2.7.4.4.2, 4.2.7.4.4.2 Damage tolerant-fail safe evident subsystems and components; A.3.4.1.4.3, A.4.4.1.4.3 Emergency directional control; A.3.4.1.4.4.2, A.4.4.1.4.4.2 Alternative independent braking

MIL-B-8584
AFGS-87139: 3.2.3.1 General; 3.2.3.2 Brake actuation system; 3.2.3.3 Anti-skid brake control; 3.2.4.3 Brakes
SAE ARP1070

8.5.8.10 Anti-skid control system compatibility.

Criterion: Verify that the anti-skid control system is compatible with and continues to function in the installed environment and that heat buildup does not cause locked wheels on touchdown or during the landing roll.

Standard: Brake control system and anti-skid are integrated with the brake hardware and provide the required air vehicle and landing gear deceleration performance. The methods for the system controls for switch on/off and to alternate controls do not cause:

a. Locked wheels/tire conditions

b. Inadvertent operation without anti-skid

Method of Compliance: Laboratory and simulation testing verifies that all anti-skid operations are sufficient for all specified environmental conditions. Ground and flight testing verify anti-skid operations and control system compatibility with all operational energy levels and conditions.

References: JSSG-2009: 3.2.7.2, 4.2.7.2 Environment
MIL-B-8584
AFGS-87139: 3.2.3.1 General; 3.2.3.2 Brake actuation system; 3.2.3.3 Anti-skid brake control; 3.2.4.3 Brakes.
SAE ARP1070

8.5.8.11 Anti-skid coupling.

Criterion: Verify that there is no anti-skid coupling into the landing gear structure.

Standard: Normal, alternate and emergency braking do not induce any undesirable dynamics. Brake operations in each of the designed control systems including switching between systems do not induce any undesirable dynamics.

Method of Compliance: Verification methods include analyses and tests. Dynamic analysis shows no adverse gear loadings and undesirable dynamics due to anti-skid operations during all phases of brake operations. Laboratory testing validates the analysis. Air vehicle ground and flight testing shows no adverse loadings due to anti-skid operations during all phases of brake operations.

References: JSSG-2006: A.3.4.1.4.4.3, A.4.4.1.4.4.3 Skid Control; 34.2.7 Dynamic response during ground/ship-based operations; 4.4.2 Ground loading conditions
AFGS-87139: 3.2.1.4 Damping; 3.2.3.3 Anti-skid brake control

8.5.9 Directional control.

References: JSSG-2009: A.3.4.1.4.2, A.4.4.1.4.2 Directional control; A.3.4.1.4.5, A.4.4.1.4.5 Steering
AFGS-87139: 3.2.5
14 CFR 23.45, 23.497, 23.499, 23.745, 25.233, 25.45, 25.497, 25.499, 25.745

8.5.9.1 Backup for directional control.

Criterion: Verify that there is a primary and emergency (secondary) method to provide directional control during ground operations of the air vehicle for all operational missions and flight configurations.

Standard: Ground directional control of the air vehicle is maintained at all times during ground operations, including single point failure conditions. Systems that affect directional control of the air vehicle may include steering, brakes, flight control surfaces, and propulsion.

Method of Compliance: Verification methods include analyses, tests and demonstrations. The FMECA identifies single point failure conditions and degraded modes of operation. Ground and simulator testing verifies that the directional control system functions safely in degraded and normal modes. Air vehicle checkouts indicate proper functioning of the primary, secondary and emergency directional control systems. Air vehicle ground and flight testing verifies safe operation of the primary, secondary and emergency directional control systems.

References: JSSG-2009: A.3.4.1.4.2, A.4.4.1.4.2 Directional control; A.3.4.1.4.3, A.4.4.1.4.3 Emergency directional control
AFGS-87139: 3.2.5.1 General; 3.2.5.2 Nose gear steering system
MIL-S-8812
14 CFR 23.45, 23.497, 23.499, 23.745

8.5.9.2 Steering control system.

Criterion: Verify that the steering control system protects against steering failures, including hard-overs, and that system failures do not cause loss of control of the air vehicle.

Standard: All uncommanded steering events and hard-over commands are negated. The system disengages or corrects the command to the extent that the air vehicle remains in its original commanded direction or goes to a controllable configuration.

Method of Compliance: Verification methods include analyses, tests and demonstrations. FMECA identifies all steering and directional control failures (including hard-overs and uncommanded events). Component failure mode testing verifies performance of all components and switching logic within the steering system. Air vehicle checkouts verify proper functioning of the steering control system with and without failures. Ground and flight testing verifies safe operation for all steering and directional control failures.

References: JSSG-2009: A.3.4.1.4.5.2, A.4.4.1.4.5.2 Response to nose wheel steering failure; A.3.4.1.4.5.3, A.4.4.1.4.5.3 Emergency steering
AFGS-87139: 3.2.5.1 General; 3.2.5.2 Nose gear steering system
MIL-S-8812

8.5.9.3 Steering engagement.

Criterion: Verify that control of the air vehicle can be maintained during engagement or disengagement of the steering throughout all the operational speed ranges and conditions, even if it occurs from an operator/pilot commanded or a system uncommanded action.

Standard: During engaging and disengaging of the steering control function, the air vehicle maintains its previously commanded directional headings, or defaults to a controllable configuration (e.g., dynamically stable, free caster, self-centering).

Method of Compliance: Verification methods include analyses, tests and demonstrations. Design and failure analysis verify performance of the steering engage and disengage system. Simulator testing verifies control for the expected modes of operation and engagements. Air vehicle checkout and ground and flight testing of the normal, backup and emergency steering systems verify proper control of the aircraft during engagements and disengagements.

References: JSSG-2009: A.3.4.1.4.5.1, A.4.4.1.4.5.1 Steering Characteristics
MIL-S-8812
AFGS-87139: 3.2.5.1 General; 3.2.5.2 Nose gear steering system.

8.5.9.4 Steering capability.

Criterion: Verify that steering system operation during taxi, takeoff, and landing is sufficient to accomplish all the required ground maneuvering and parking, and is not sensitive to high-speed, ground rolling effects on directional control.

Standard: The steering system provides minimum radius turn capability required for ground operations (taxi and parking). Steering system safely accommodates high speed operations (takeoff and landings) by integrating steering system responses with the flight control system and providing damping and steering gain control as required to maintain directional control.

Method of Compliance: Analysis and ground, taxi and flight testing verify safe steering and directional control system performance.

References: JSSG-2009: A.3.4.1.4.5.1, A.4.4.1.4.5.1 Steering Characteristics
MIL-S-8812
AFGS-87139: 3.2.5.1 General; 3.2.5.2 Nose gear steering system.
14 CFR 23.45, 23.497, 23.499, 23.745, 25.233, 25.45, 25.497, 25.499, 25.745

8.5.10 Landing gear actuation control

References: JSSG-2009: A.3.4.1.5, A.4.4.1.5
AFGS-87139: 3.2.6
14 CFR 23.729, 25.729

8.5.10.1 Landing gear retraction and extension operation.

Criterion: Verify safe operation of landing gear retraction, extension, and emergency extension; and verify that there are adequate clearances and suitable geometry for components having relative motion.

Standard: The motion relationship and mechanical interface of the gear and door actuation and locking system are established for all modes of operation. Door sequencing during normal and emergency operations maintains all specified clearances and ensures that the gear can be extended for any expected set of adverse conditions.

Method of Compliance: Verification methods include analyses, tests, inspections, simulations and demonstrations. Solid modeling and/or inspection verifies adequate clearances for various combinations of free play, installation tolerances, rigging, misalignment, etc. Mock-up or simulators validate adequate clearances are maintained under the full range of motion and under all loading conditions. Air vehicle checkouts verify proper functioning of the gear through the gear's full range of motion. Flight testing verifies operation under air loads and ensures no contact with air vehicle structure and other components within the wheel well.

References: JSSG-2009: A.3.4.1.1.3, A.4.4.1.1.3 Extended clearances; A.3.4.1.1.4, A.4.4.1.1.4 Retraction Clearances; A.3.4.1.5.1, A.4.4.1.5.1 Retraction and extension actuation interface
AFGS-87139: 3.2.6.1 Retraction-extension system; 3.2.6.2 Actuation system indication.

14 CFR 23.729, 25.729

8.5.10.2 Prevention of gear extension.

Criterion: Verify that loss of doors, reversal of commands, or any single failures in the air vehicle power do not prevent gear extension. Verify that the emergency extension system is independent of the landing gear primary power source(s).

Standard: Loss of doors or fairings does not prevent extension of the gear. Gear extension capability is not lost due to a single failure of the door or its actuation. Changes in gear position command while in transit do not cause the gear system to jam, nor do they prevent the successful extension of the gears. The emergency extension system is independent of the landing gear primary power source(s).

Method of Compliance: Verification methods include analyses, tests and demonstrations. The FMECA identifies all failures and operational events that prevent extension. Design analysis shows sufficient capability to extend the gear, either by normal or emergency means. Air vehicle checkout and flight testing verify proper operation with different methods of extending the gear.

References: JSSG-2009: A.3.4.1.5.3, A.4.4.1.5.3 Single failure criteria; A.3.4.1.5.4, A.4.4.1.5.4 Actuation reversal; A.3.4.1.5.6, A.4.4.1.5.6 Operation with loss of door; A.3.4.1.5.7, A.4.4.1.5.7 Emergency extension
AFGS-87139: 3.2.6.1 Retraction-extension system; 3.2.6.2 Actuation system indication.
14 CFR 23.729, 25.729

8.5.10.3 Gear sequencing status.

Criterion: Verify that gear position indications are given to the pilot/operator for all gear sequencing events during any phase of mission operations.

Standard: The pilot or the operator has sufficient indications that the landing gear is in the last commanded position or of commanded/actual gear position disagreement.

Method of Compliance: Verification methods include analyses, tests, simulations and demonstrations. Design analysis verifies that all modes of operation and position indications are properly annunciated. Analysis addresses all normal and emergency conditions, and addresses all failure events as defined by the FMECA. Simulators/mock-ups verify sequencing events and gear position indications. Air vehicle checkouts and flight testing verify that proper gear position indications are given to the air crew or ground controller.

References: JSSG-2009: A.3.4.1.5.4, A.4.4.1.5.4 Actuation reversal; A.3.4.1.5.8.1, A.4.4.1.5.8.1 Gear position status indicators
AFGS-87139: 3.2.6.1 Retraction-extension system; 3.2.6.2 Actuation system indication
14 CFR 23.729, 25.729

8.5.10.4 Position warning system.

Criterion: Verify that the gear position warning system operates properly and allows the crew to override the warning systems.

Standard: Visual and audible warnings are provided to the pilot/operator indicating when the air vehicle is close to the ground and close to landing speeds without gear down. The pilot/operator has time to extend the gear before landing and indications are given that the gear is in a safe position to land.

Method of Compliance: Verification methods include analyses, test, simulation and demonstration. Design analysis verifies that appropriate integrated warnings, cautions and advisories are provided that address all normal and emergency conditions, and for all failure events as defined by the FMECA. Simulators/mock-ups confirm the logic analysis and validate the warnings and indications. Air vehicle checkouts verify proper installation and integration of the warning and indication system. Flight testing verifies correct functioning of the warning and indication system.

References: JSSG-2009: A.3.4.1.5.8.1, A.4.4.1.5.8.1 Gear position status indication

AFGS-87139: 3.2.6.1 Retraction-extension system; 3.2.6.2 Actuation system indication

14 CFR 23.729, 25.729

8.5.10.5 Gear position speed.

Criterion: Verify that the time to move the gear to the command positions is compatible with air vehicle performance requirements for takeoff, landing, and go-around.

Standard: For takeoff and go-around conditions, the gear is retracted before its design limit speeds are reached under maximum performance acceleration. Prior to landing, the gear has sufficient time to extend and lock.

Method of Compliance: Verification methods include analyses, tests, simulations, and demonstrations. Design analysis establishes gear retract/extend times in relation to air vehicle performance. Simulator mock-up testing supports analysis and gear times. Air vehicle checkout demonstrations and flight testing verify retract/extend times for all operational performance speeds and accelerations.

References: JSSG-2009: A.3.4.1.5.5.1, A.4.4.1.5.5.1 Retraction; A.3.4.1.5.5.2, A.4.4.1.5.5.2 Extension

AFGS-87139: 3.2.6.3 Retraction-extension time.

14 CFR 23.729, 25.729, 25.1515, 25.1583

8.5.10.6 Emergency extension.

Criterion: Verify that the emergency extension times are compatible with emergency landing requirements.

Standard: When the alternate method of extension is used, such as freefall or backup/emergency power, the gear achieves its final down and locked position at limit speeds before power is lost or interrupted and prior to touchdown.

Method of Compliance: Verification methods include analyses, test, simulations and demonstrations. The FMECA identifies all failures that could result in unsafe landing gear extension. For the emergency conditions defined by the analysis, the emergency extension times are compatible with air vehicle landing requirements. Simulator testing identifies emergency extend times and operation. Air vehicle checkouts verify installation and emergency extension performance. Flight testing validates the extend times and extension performance.

References: JSSG-2009: A.3.4.1.5.7, A.4.4.1.5.7 Emergency extension

AFGS-87139: 3.2.6.3 Retraction-extension time

14 CFR 23.729, 25.729, 25.1515, 25.1583

8.5.10.7 Gear position restraint.

Criterion: Verify that the gear is restrained in the final commanded positions for all ground and flight conditions required by all mission profiles.

Standard: Positive passive means are provided to maintain the gear in the final commanded position without the primary power source. Typical positive passive means include: over center locking mechanism, pins or locking detents, such that gears do not unlock due to power failure, leakage, or excessive deflection.

Method of Compliance: Verification methods include analyses, tests, simulations and demonstrations. Design analysis verifies gear locking mechanism maintains position under all expected loads resulting from any expected maneuver. Simulator tests and ground demonstrations verify gear position holding capability. Ground and flight testing under all expected mission loading and maneuvering verify position holding capability.

References: JSSG-2009: A.3.4.1.5.1, A.4.4.1.5.1 Retraction and extension actuation interface; A.3.4.1.5.9.1, A.4.4.1.5.9.1 Gear position restraint

AFGS-87139: 3.2.6.4 Position restraint

14 CFR 23.729, 25.729

8.5.10.8 Gear position restraint for ground operations.

Criterion: Verify that a positive secondary means is available to lock the gear and doors during ground operations to prevent retraction on the ground. Also verify that visual indicators are provided so the ground retention devices are removed prior to flight.

Standard: Mechanical locking devices are provided to prevent inadvertent gear and door retraction while the air vehicle is on the ground or during any maintenance event. Locking devices hold all of the gear and doors in position for all expected ground configurations and ground operations. A visual warning indicator is provided to indicate when a mechanical locking device is installed.

Method of Compliance: Verification methods include analyses, tests and demonstrations. Design analysis determines the suitability of the ground locking features of the gear and doors. Ground demonstration and testing under all expected loads and conditions verify position restraints and load carrying capability. The ground demonstration verifies the visual indication when a locking mechanism is installed.

References: JSSG-2009: A.3.4.1.5.1, A.4.4.1.5.1 Retraction and extension actuation interface; A.3.4.1.5.9.1, A.4.4.1.5.9.1 Gear position restraint

AFGS-87139: 3.2.6.4 Position restraint

8.5.10.9 Strength of gear position restraint for ground operations.

Criterion: Verify that no damage to the airframe, gear or any door structure results if power is supplied to retract the gears and/or doors while secondary ground lock devices are installed

Standard: Locking devices and the structures used to retain the devices can take the full retraction power and load without damage that would cause detrimental effects to the air vehicle.

Method of Compliance: Verification methods include analyses, tests and demonstrations. Design analysis verifies load capability. Air vehicle checkout verifies functionality and structural integrity of the restraining device, and that no damage to the airframe, gear or doors occurs.

References: JSSG-2009: A.3.4.1.5.10, A.4.4.1.5.10 Ground safety restraint; A.3.4.1.5.1, A.4.4.1.5.1 Retraction and extension actuation interface

AFGS-87139: 3.2.6.4 Position restraint

8.5.10.10 Fail-safe provisions.

Criterion: Verify the down-locking and up-locking fail-safe provisions of the landing gear.

Standard: The locks have fail-safe provisions to prevent jamming or failure modes which would result in complete loss of function. The locks maintain landing gear in its final commanded position and allow landing gear to be extended prior to landing.

Method of Compliance: The design analysis and the FMECA verify the performance of the locks with and without failures. Simulator/mock-up testing verifies strength and functionality of the locks. Flight testing verifies the gear position locking design.

References: JSSG-2009: 3.2.7.4.4.2, 4.2.7.4.4.2 Damage tolerant-fail safe evident subsystems and components; A.3.4.1.5.3, A.4.4.1.5.3 Single failure criteria

AFGS-87139: 3.2.6.1 Retraction-extension system; 3.2.6.2 Actuation system indication

14 CFR 23.729, 25.729

8.5.11 Auxiliary deceleration devices.

References: JSSG-2009: A.3.4.1.8, A.4.4.1.8

AFGS-87139: 3.2.7 Auxiliary deceleration devices

8.5.11.1 Air vehicle arrestment performance.

Criterion: Verify that the arresting system is capable of stopping the air vehicle at all the required design conditions (refused takeoffs (RTOs), fly-in engagements, brake overruns, etc.) without any damage to either the air vehicle or the arresting systems.

Standard: The arresting system is capable of stopping the air vehicle at all specified design conditions. Arrestment system engagements (e.g., barrier, cable) are defined by energy level, hook loads, air vehicle speeds and weights. The engagement limits are defined for on-center and off-center engagements. The engagement limits are set either by the air vehicle or the type of arrestment system; these limits are defined and documented.

Method of Compliance: Verification methods include analyses and tests. Design analysis verifies the arresting system engagement capability under all specified conditions. Flight testing supports the design analysis and verifies the installation, functionality and performance capability of the air vehicle arresting system and the arrestment system (e.g., barrier, cable) engagement limits.

References: JSSG-2009: A.3.4.1.8.1.1, A.4.4.1.8.1.1 Air vehicle arrestment performance; through A.3.4.1.8.1.8, A.4.4.1.8.1.8 Hook actuation criteria

MIL-A-18717

MIL-A-83136 (cancelled; for information only)

SAE ARP1538

8.5.11.2 Arresting hook system.

Criterion: Verify the safety of the following: hook load, hold-down, and damping forces; off-center engagement capabilities; lateral run-outs; cable compatibility; deck and runway compatibility and any other specific engagement provisions.

Standard: The arresting hook design minimizes the occurrence of the hook skipping over the cable and improves the ability of engaging the cable at the various cable and air vehicle positions (e.g., off center engagements, pitch, airframe dynamics at touchdown). Arrestments often cause violent hook and cable movements which can contact air frame structures. The system provides sufficient damping and protection to minimize any damage to the air vehicle.

Method of Compliance: Verification methods include analyses, tests and demonstrations. Design analysis verifies compliance at all the specified arrestment conditions. Air vehicle demonstrations confirm the safe performance of the system in engaging the cable. Flight testing verifies the installation, functionality and performance capability of the arresting system to stop the air vehicle and to minimize air vehicle and cable damage.

References: JSSG-2009: A.3.4.1.8.1.1, A.4.4.1.8.1.1 Air vehicle arrestment performance; through A.3.4.1.8.1.8, A.4.4.1.8.1.8 Hook actuation criteria

MIL-A-18717

MIL-A-83136 (cancelled; for information only)

AFGS-87139: 3.2.7.1 Arresting hook system

SAE ARP1538

8.5.11.3 Hook actuation.

Criterion: Verify that the hook can be deployed and, if applicable, retracted from the crew station in a timely manner and that a means is provided in the crew station to determine the position of the hook.

Standard: The pilot or the operator can deploy and, if applicable, retract the hook from the crew station in a timely manner to meet all normal and emergency conditions. Indications confirm that the arresting hook is in the last commanded position.

Method of Compliance: Verification methods include analyses and tests. FMECA identifies failures which would prevent deployment and, if applicable, retraction of the hook in a timely manner. Design analysis verifies compliance with operational conditions. Flight and ground testing verify the installation, functionality and performance capability of the arresting system and its indications.

References: JSSG-2009: A.3.4.1.8.6, A.4.4.1.8.6 Position indication; A.3.4.1.8.8, A.4.4.1.8.8 Hook actuation criteria

MIL-A-18717

MIL-A-83136 (cancelled; for information only)

AFGS-87139: 3.2.7.1 Arresting hook system

SAE ARP1538

8.5.11.4 Arresting hook system with tire failure.

Criterion: Verify, for all critical air vehicle conditions, that no part of the landing gear, air vehicle or stores snags the arresting cable when the air vehicle is rolling on rims after a tire failure.

Standard: Air vehicle roll-over does not cause cable dynamics with ready-for-use arresting cable system such that unintended cable contact occurs with the air vehicle. Nose and main gear rims diameters are large enough to preclude snagging cable (static or dynamic conditions). Projections in front of the rims do not snag the cable or cause the cable to travel over the top of the wheel and snag the strut(s).

Method of Compliance: Verification methods include analyses, test, inspections and demonstrations. Design analysis and component inspection verifies cable roll-over capability at all operational conditions. Flight testing and demonstration support the design analysis and the performance of the air vehicle while traversing cables.

References: MIL-A-18717

MIL-A-83136 (cancelled; for information only)

AFGS-87139: 3.2.7.1 Arresting hook system

SAE ARP1538

8.5.11.5 Drag chutes.

Criterion: Verify that the performance of drag chutes meets the specified deceleration requirements without any adverse loading or damage to air vehicle structure.

Standard: The design of the chute and its attachments and deployments meets all specified performance requirements and deployment of the drag chute does not cause damage to the air vehicle. The air vehicle speeds for deployment and the drag performance of the chute are defined. The method for releasing the chute is compatible with system operations.

Method of Compliance: Verification methods include analyses and tests. Design analysis verifies compliance at all specified operational conditions. Flight testing verifies the installation, functionality and performance capability of the drag chute system.

References: JSSG-2009: A.3.4.1.8.2.1, A.4.4.1.8.2.1 Air vehicle drag chute performance

AFGS-87139: 3.2.7.2 Drag Chutes

8.5.11.6 Auxiliary deceleration systems.

Criterion: As applicable to the air vehicle, verify the performance of thrust reversers, speed brakes, and/or other auxiliary deceleration systems; and verify that there is no adverse loading or structural damage to the air vehicle when these devices are used.

Standard: Auxiliary deceleration devices (alone or in combination with other deceleration devices) do not cause unacceptable air vehicle loadings or dynamics. Directional control of the air vehicle is maintained when these devices are in use for all specified operations, conditions, and expected environments.

Method of Compliance: Verification methods include analyses, tests and demonstrations. Design analysis verifies compliance at all operational and environmental conditions. Flight testing verifies the installation, functionality and performance capability of the thrust reversers and/or speed brakes and any other deceleration devices. Flight testing and demonstrations verify the absence of adverse effects on air vehicle control.

References: AFGS-87139: 3.2.7.1 Arresting hook system; 3.2.7.2 Drag chutes

8.5.11.7 Barrier operations.

Criterion: For barrier operations, verify that the landing gear does not cause damage to the barrier such that the barrier is unable to stop the air vehicle.

Standard: The landing gear design does not contain any protrusions or sharp edges of a non-frangible nature which would damage a barrier system (e.g., vertical net) beyond its ability to stop the air vehicle.

Method of Compliance: Verification methods include inspection, test, and analysis. Inspection of landing gear components verifies absence of protrusion or sharp edges which unacceptably damage the barrier. Ground testing of barrier materials which contact landing gear protrusions and sharp edges confirm that the barrier materials are not unacceptably damaged. Analysis of damaged barrier materials verifies that the barrier is acceptable for continued use.

References: AFGS-87139: 3.2.7.1 Arresting hook system; 3.2.7.2 Drag chutes

8.5.12 Ground handling.

References: JSSG-2009: A.3.4.1.2.2, A.4.4.1.2.2
AFGS-87139: 3.2.7
14 CFR 23.471-23.511, 25.471-25.519

8.5.12.1 Jacking provisions.

Criterion: Verify that safe jacking provisions are provided for all specified air vehicle gross weights, critical centers of gravity and environmental conditions.

Standard: Safe jacking provisions are provided on the fuselage and on each gear so that various maintenance actions can be accomplished. The provisions are capable of supporting the air vehicle at given weights and critical centers of gravity such that the maintainers can accomplish all required tasks within all required environmental conditions.

Method of Compliance: Verification methods include analyses and tests. Design analysis verifies jacking location and capability for all expected conditions, including wind gusts and wind direction. Air vehicle ground testing verifies jacking suitability for all environmental and maintenance conditions.

References: JSSG-2009: A.3.4.1.2.2.1.1, A.4.4.1.2.2.1.1 Axle jacking; A.3.4.1.2.2.1.2, A.4.4.1.2.2.1.2 Fuselage jacking
AFGS-87139: 3.2.8.1 Jacking
NATO STANAG 3098
14 CFR 23.507

8.5.12.2 Jacking interfaces.

Criterion: Verify that there is dimensional and physical compatibility between jacking interface points, both fuselage and axle, and jacks to permit safe jacking of the aircraft and to provide adequate clearance between jacks and adjacent aircraft components.

Standard: Jacking interfaces meet dimensional and physical tolerances to provide a stable platform for jacking. Jacking pads are located so that there is no interference between jacks and adjacent aircraft components. Fuselage jacking pads are located to allow safe operation of the landing gear system.

Method of Compliance: Verification methods include analyses, inspection and ground demonstration. Design analysis and inspection of drawings verify compliance with interface tolerances and clearances. Air vehicle ground demonstration verifies compliance with support equipment operation.

References: AFGS-87139: 3.2.8.1 Jacking
NATO STANAG 3098
SAE AS8091
14 CFR 23.507, 25.519

8.5.12.3 Towing.

Criterion: Verify that the air vehicle is capable of being safely towed in all specified directions, at all mission weights, under the required environmental conditions, on expected operational surfaces.

Standard: Towing provisions on the gears allow towing of the air vehicle at its maximum gross weight. The design accommodates all required tow vehicles/bars and the tow interface conforms to all service/international standards. Towing is limited by the capability of the powered steering system. Operational procedures for towing outside of powered steering limits are defined. Steering disconnects prevent damage to the steering system when operated outside the powered steering limits.

Method of Compliance: Verification methods include analyses and tests. Design analysis verifies towing capability and the towing interface at all specified conditions. Air vehicle ground testing and operational tests verify towing suitability for all environmental conditions and surfaces.

References: JSSG-2009: A.3.4.1.2.2.1.3, A.4.4.1.2.2.1.3 Landing gear towing; A.3.4.1.2.2.1.5, A.4.4.1.2.2.1.5 Towing interface
MIL-STD-805
AFGS-87139: 3.2.8.2 Towing
NATO STANAG 3278
NATO STANAG 4101
14 CFR 23.509, 25.509

8.5.12.4 Emergency towing.

Criterion: Verify emergency towing capability of the air vehicle to the maximum weight and load requirements.

Standard: When emergency towing provisions are provided on the gear, the towing loads and limits are defined. The attachment methods, interface and limitations are specified.

Method of Compliance: Verification methods include analyses, tests and demonstrations. Design analysis verifies emergency towing methods, interfaces and capability for all expected conditions. Air vehicle ground demonstrations and testing verify emergency towing capability for all expected environmental conditions and surfaces.

References: JSSG-2009: A.3.4.1.2.2.1.4, A.4.4.1.2.2.1.4 Emergency towing
AFGS-87139: 3.2.8.2 Towing
14 CFR 23.509, 25.519

8.5.12.5 Mooring.

Criterion: Verify that all mooring provisions are designed to accommodate all mission weights and environmental conditions and that these provisions are compatible with standard mooring patterns to ensure safety.

Standard: Mooring provisions are designed to accommodate all mooring conditions (e.g., maximum allowable cross-wind) that the vehicle encounters. The interface conforms to all specified interfaces and international standards.

Method of Compliance: Verification methods include analyses, tests and demonstrations. Design analysis verifies mooring capability and mooring interface for all expected conditions including wind gust and wind direction. Air vehicle ground demonstration and testing verify mooring provisions and interfaces for all expected environmental conditions and surfaces.

References: JSSG-2009: A.3.4.1.2.2.1.6, A.4.4.1.2.2.1.6 Mooring provisions
AFGS-87139: 3.2.8.3 Mooring
14 CFR 23.519, 25.519

8.5.12.6 Specialized systems.

Criterion: Verify that any specialized systems requirements and functional characteristics are safe for the operational mission conditions. (Examples of specialized systems are skis, skids, kneeling, crosswind positioning, and in-flight pressure control systems.)

Standard: The design criteria for any specialized systems that affect ground operation or control of the air vehicle are defined. Requirements for mission operation are consistent with specialized systems/equipment.

Method of Compliance: Verification methods include analyses and test. Design analysis and air vehicle ground testing verifies safe specialized system performance and operations for all expected missions including all specified environments and surfaces.

References: JSSG-2009: A.3.4.1.10, A.4.4.1.10 Specialized subsystems; A.3.4.1.10.1, A.4.4.1.10.1 Flotation gear; A.3.4.1.10.2, A.4.4.1.10.2 Snow ski gear
AFGS-87139: 3.2.9.1 General
14 CFR 23.737, 23.751, 23.753, 23.755, 23.757, 25.737, 25.753, 25.755

8.5.12.7 Failure modes and effects.

Criterion: Verify all known potential single-point failures are identified and are acceptable.

Standard: No single component or function failure results in loss of any one of the following: extend system, deceleration function, air vehicle support or directional control on the ground. Loss of primary landing gear functions/performance due to single-point failure is mitigated by an alternate means of accomplishing the function (preferably independent from the primary power and control).

Method of Compliance: Verification methods include analyses, tests and simulations. Design analysis and FMECA identify all possible failure events and list the alternate operational capabilities. Simulator, ground and flight testing verify acceptable alternate operation.

References: JSSG-2009: 3.2.7.4.4.1, 4.2.7.4.4.1 Safety and mission critical functions; A.3.4.1.3.1.3, A.4.4.1.3.1.3 Failure tolerance
AFGS-87139: 3.5 System safety
14 CFR 23.471-23.511, 25.471-25.519, 25.1309
AC 25-1309-1A

8.5.12.8 Turnover.

Criterion: Verify that the air vehicle does not turnover or ground loop for all mission, taxi and towing conditions that produce side-load.

Standard: The turnover loads do not exceed a 0.5g load at the critical center of gravity location for all possible gear configurations. Taxi and towing conditions include all expected turning speeds and turn radii, all possible strut/tire conditions at all air vehicle weights and ground configurations including crowned and sloped surfaces.

Method of Compliance: Verification methods include analyses, test, inspections and ground demonstrations. Design analysis and dimensional inspections verifies the air vehicle turnover angle and turn radius at turn off speeds. Air vehicle ground demonstration and test verify turn stability.

References: JSSG-2009: A.3.4.1.1.1, A.4.4.1.1.1 Gear Arrangement; A.3.4.1.1.2, A.4.4.1.1.2 Pitch Stability

AFGS-87139: 3.2.1.2 Arrangement

14 CFR 23.473, 23.477, 23.485, 25.473, 25.477, 25.485

8.5.12.9 Ground Foreign Object Damage (FOD).

Criterion: Verify that the landing gear and engine inlet geometry are designed to prevent possible foreign object damage and excessive water ingestion into the engines.

Standard: The location of the main and nose gear tires minimizes the throwing of debris, water, snow, and slush into the engine inlet, causing unacceptable degradation of engine performance. The design limits inlet exposure by establishing acceptable spray patterns and thrown object trajectories.

Method of Compliance: Verification methods include analyses and tests. Design analysis verifies compatibility of gear and inlet locations along with projected spray patterns for debris, water, snow and slush. Air vehicle ground tests verify that there is no excessive ingestion into the engines.

References: JSSG-2009: A.3.4.1.2.3, A.4.4.1.2.3 Ground FOD

AFGS-87139: 3.2.1.1 General; 3.2.1.2 Arrangement; 3.2.1.3 Clearances

8.5.12.10 Landing gear interfaces.

Criterion: Verify that the landing gear systems are compatible with air vehicle structure, weight, and balance, and with any other subsystems that interface with the landing gear system.

Standard: The arrangement and location of the gear and it's attach points support air vehicle weight and balances for specified mission operations and within specified environmental conditions. All interfaces with other systems are defined and controlled.

Method of Compliance: Verification methods include analyses and tests. Design analysis verifies that the gear supports the air vehicle at all weight and balance conditions, and interfaces with all other air vehicle systems as needed to complete specified missions. Laboratory and simulator testing verify interface compatibility. Air vehicle ground and flight testing verify compatibility with all interfaced systems.

References: AFGS-87139: 3.2.1.1 General; 3.2.1.2 Arrangement; 3.2.1.3 Clearances

14 CFR 23.471-23.511, 25.471-25.519

8.5.12.11 Landing gear system integrity.

Criterion: Verify the landing gear system's integrity for preventing uncommanded or unsafe effects in the event of single-point failures, dormant failures, or primary system loss of interfacing systems.

Standard: Single-point failures of interfacing systems do not adversely affect landing gear systems and components. The analysis and logic incorporated within the landing gear control system or interfacing system design prevents loss of critical landing gear function due to a single point failure(s) or dormant failure(s). Failure of externally provided power or governing control logic (e.g., electrical, hydraulic) does not prevent the air vehicle from maintaining controlled flight, safely landing and stopping.

Method of Compliance: Verification methods include analyses and tests. Design analysis and FMECA identify single point failures of the landing gear system. Solutions are documented for all unsafe conditions including dormant states of non-indicated failures. Laboratory, simulator and flight testing support the FMECA and verify the acceptability of alternate systems operation.

References: AFGS-87139: Appendix B
14 CFR 23.471-23.511; 25.471-25.519; 25.1309

8.5.12.12 Damage tolerance.

Criterion: Verify that the system and system components have damage tolerance capability to sustain partial failure or leakage before failure without jeopardizing safety.

Standard: Structure or components that have fail safe design criteria fail in a safe and predictable manner. The design limits undesirable failures and controls the method of failure. Maintenance procedures are provided for detecting failures for fail safe components.

Method of Compliance: Verification methods include analyses and test. Design analysis shows damage tolerance capability of individual components and FMECA shows primary failure modes for the system and components. Static, fatigue and system tests verify the fail safe design.

References: AFGS-87139: 3.2.2.1 General; 3.2.2.2 Shock absorption; 3.2.2.3 Tail bumpers
14 CFR 25.571, 25.1309

8.5.12.13 Failures and leakage.

Criterion: Verify that failures and leakage are evident in flight and/or during routine ground maintenance.

Standard: The landing gear system and its components are designed to an agreed to maintenance concept. Component failures of tires, wheels, brakes, gear structure, locks, latches, doors, etc. are detectable/inspectable, and serviceability criteria are established for the landing gear system to prevent the air vehicle from being operated unsafely.

Method of Compliance: Verification methods include analyses, tests and demonstrations. Design analysis identifies failure modes and establishes serviceability criteria. Inspection of maintenance procedures ensures that the air vehicle is not operated unsafely. Laboratory testing verifies leakage detection and isolation capability. Air vehicle checkout verifies the installation and application of failure logic. Air vehicle ground testing verifies failure and leak criteria and sufficient indications are provided.

References: AFGS-87139: 3.2.2.1 General; 3.2.2.2 Shock absorption; 3.2.2.3 Tail bumpers
14 CFR 25.571, 25.1309

8.5.12.14 Lift points.

Criterion: Verify that adequate and safe lift points are provided for the landing gear and arresting gear that require routine external ground crew movement utilizing hands, mechanical lifts, hoists, etc.

Standard: Proper landing gear and arresting gear moving and lifting locations and procedures are indicated and documented.

Method of Compliance: Verification methods include analyses and demonstrations. Design analysis establishes proper landing gear and arresting gear moving and lifting operations. Design analysis identifies where the landing gear and arresting gear are not to be loaded while on the ground or during ground maintenance events. Air vehicle demonstration verifies moving, lifting and maintenance procedures.

References: JSSG-2001: 3.4.3.2.1.6.1.3, 4.4.3.2.1.6.1.3

8.5.12.15 Operator interface.

Criterion: Verify that adequate crew/operator station information is available to provide notification of the landing and deceleration system operational conditions and state of functionality.

Standard: The crew/operator station provides the means to assess landing and deceleration systems operating conditions to the extent necessary for flight safety. The system provides warnings, cautions and advisories to operators and maintainers for hazardous failure conditions of equipment and controls of the landing and deceleration systems.

Method of Compliance: Verification methods include tests and inspections. Inspection of the design verifies provisions for the necessary monitoring of the system's operation and health. Integration tests, to include Failure Modes and Effects Tests (FMET), verify compatibility of landing and deceleration systems with the controls and monitoring systems. Ground tests of installed systems verify operating performance.

8.5.12.16 Technical manuals.

Criterion: Verify that flight and maintenance manuals include normal, back-up, and emergency operating procedures, limitations, restrictions, servicing, and maintenance information for all landing gear and deceleration systems.

Standard: Technical data describe the installed landing and deceleration systems, normal and emergency operation, operating procedures and limitations, restrictions, servicing, and maintenance requirements.

Method of Compliance: Verification methods include inspections and demonstrations. Technical data are verified by inspection of design documentation and technical manuals and by demonstration of technical manual procedures.

8.5.12.17 Qualification testing.

Criterion: Verify that all components, either individually or as part of a landing gear and deceleration subsystem, have passed qualification tests (e.g., proof, burst, vibration, acceleration, explosive atmosphere, pressure cycling, temperature cycling, fatigue) as required for airworthy performance.

Standard: Component analysis, component level testing and/or ground based simulator testing confirm sufficient verification for full airworthiness qualification. Safety of flight testing is used to confirm a limited amount of verification to permit initial flight test without fully qualified hardware. Life limits and restrictions are identified.

Method of Compliance: Landing gear and deceleration components are verified for expected usage and environmental conditions using analyses, simulator tests, component tests, and ground/flight tests. Inspection of design criteria documents establishes usage and environment (natural and induced) requirements. Component safety of flight and qualification analyses and tests verify requirements, capabilities and limitations. The following criteria are considered: life, temperature, ambient pressure, shock, vibration, acoustics, explosive atmosphere, proof and burst pressure, acceleration, gyroscopic moments, humidity and moisture, sand and dust, rain, salt fog, fungus, attitude, electromagnetic environments, material compatibility, foreign object damage, steam and gun gas ingestion and others (this is not an all-inclusive list) as derived from the air vehicle requirements that could affect safe usage of the equipment.

References: MIL-HDBK-516: 4.1.5
MIL-STD-810
MIL-STD-461
MIL-STD-464
DoDI 5000.02

8.5.12.18 Installation.

Criterion: Verify the safe installation of the landing gear and deceleration systems and their components.

Standard: The air vehicle installation meets all interfaces, functions, form, fit, and performance criteria as designed. Appropriate system and component checkout procedures are in place to determine form, fit and functions are as designed and perform as expected.

Method of Compliance: Verification methods include tests and demonstrations. The landing gear system demonstrations and tests verify the hardware and software functionality, to the maximum extent possible, on the air vehicle. Air vehicle checkout and acceptance procedures verify installed performance.

8.5.13 Parachute landing system.

8.5.13.1 Safe and reliable operation.

Criterion: Verify that parachute landing operations are safe and reliable.

Standard: The parachute landing system deployment method prevents the parachute from getting entangled with the air vehicle (e.g., flight control surfaces, propulsion systems) during all phases of recovery operation. For the design operational envelope, the parachute landing system controls the rate of descent, glide rate and oscillations to allow recovery of the air vehicle and onboard equipment with no damage beyond acceptable operating limits.

Method of Compliance: Verification methods include analysis and test. Analysis and testing are conducted to verify required reliability. Flight testing verifies the installation, functionality and performance capability (e.g., deployment time, parachute inflation characteristics, acceleration, descent rate and aircraft stability) of the parachute system throughout the defined deployment envelope.

References: JSSG-2010: 3.12 Deployable Aerodynamic Decelerator (DAD) System
ASTM F2316-08

8.5.13.2 Aborted landing.

Criterion: Verify that the air vehicle provides for aborting the normal landing procedure up to just prior to initiation of the parachute landing system deployment sequence and that a safe transition to normal flight can be continued.

Standard: When a parachute landing system is the primary means to recover the air vehicle after every flight, the air vehicle flight performance and handling qualities are adequate to provide for continued powered flight of the air vehicle up to the point of parachute deployment. Flight manual defines speeds, altitude and environmental conditions needed for the landing approach phase, abort, and continued flight.

Method of Compliance: Flight testing verifies that landing can be aborted just prior to deployment of the parachute landing system. Flight testing verifies that the aircraft can sustain controlled flight subsequent to the abort, within the defined operational envelope.

Reference: JSSG-2010: 3.12 Deployable Aerodynamic Decelerator (DAD) System

8.5.13.3 Load factors.

Criterion: Verify that the air vehicle and parachute landing system can sustain limit load factors due to parachute generated accelerations, impact shock absorption, recovery surface dragging, sacrificial elements, parachute extracting devices and parachute installation.

Standard: Installation and operation of the parachute landing system does not adversely affect the air vehicle's structure and equipment functionality beyond proposed limits. Static, dynamic and impact loads generated during parachute deployment, descent and landing are documented and sustainable. Parachute sizing and incorporation of impact attenuation subsystems (e.g., shock absorbers, landing bags and intentional crushable structure) are sufficient to recover the air vehicle within the operational envelope. Parachute components are designed with a 2.0 factor of safety. Parachute components which are reused do not adversely affect the ability to carry limit loads. Sacrificial elements (e.g., installation covers and doors) do not impact the air vehicle upon parachute deployment. The use of an extracting device (e.g., mechanical, pyrotechnics) does not cause any damage to the air vehicle and parachute landing system that impairs or jeopardizes a successful landing.

Method of Compliance: Verification methods include analyses and tests. Design analysis verifies aircraft and parachute loading conditions. Laboratory testing verifies that system and components can sustain design loads and maintain functionality for all expected conditions without deformation or damage beyond operational concept limits. Flight testing verifies the loads and impact effects consistent with design analysis and laboratory results.

References: JSSG-2010: 3.12 Deployable Aerodynamic Decelerator (DAD) System
ASTM F2316-08

8.5.13.3.1 Parachute deployment.

Criterion: Verify that sacrificial elements and parachute extracting devices within the parachute landing system do not compromise the airworthiness aspects of the air vehicle systems and their structural integrity.

Standard: Sacrificial elements (e.g., installation covers, doors) do not impact the air vehicle upon parachute deployment. The use of an extracting device (e.g., mechanical, pyrotechnics) does not cause damage to the air vehicle and parachute landing system that impairs or jeopardizes a successful landing.

Method of Compliance: Verification methods include test and demonstration. Demonstration and flight tests verify that extraction of the parachute does not cause unacceptable damage to the aircraft.

Reference: JSSG-2010: 3.12 Deployable Aerodynamic Decelerator (DAD) System

8.5.13.4 Minimization of dragging.

Criterion: Verify that the parachute landing system minimizes dragging of the air vehicle after landing.

Standard: Means are provided to minimize dragging of the air vehicle across the recovery surface (e.g., ground and water) due to winds and currents.

Method of Compliance: Demonstrations verify that the air vehicle is not dragged by the parachute across the recovery surface after landing.

Reference: JSSG-2010: 3.12 Deployable Aerodynamic Decelerator (DAD) System

8.5.13.5 Environmental exposure.

Criterion: Verify that the parachute landing system installation prevents damage or detrimental effects to system components from environmental conditions.

Standard: The parachute storage compartment and component design protect the parachute system in the packed condition from adverse internal and external environmental conditions (e.g., flight loads, electromagnetic interference, rain, humidity, and snow). For parachute landing system components located near the propulsion system, adequate cooling, shielding, and material selection are provided to prevent degradation of the parachute landing system which could impair or jeopardize a successful landing.

Method of Compliance: Verification methods include tests and demonstrations. Laboratory testing and demonstrations verify the absence of adverse effects due to operating environments.

References: JSSG-2010: 3.12.1.2 Stowed interface

8.6 Auxiliary power system/emergency power system(s) APS/EPS.

This covers auxiliary power units (both ground and in-flight use applications), airframe accessory gearboxes, engine starting system components, power-take-off (PTO) shafts, emergency power systems, and ram air turbines (RATs).

References: JSSG-2009: Appendix C
FAA TSO-C77
FAA AC 20-128

FAA AC 120-42A

14 CFR 23.901-23.1203, 25.901-25.1207

NOTE: 14 CFR Reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.

8.6.1 Suitability of components.

Criterion: Verify that system components are safe for the intended use and environment.

Standard: Component design and performance requirements, capabilities and limitations are established and substantiated.

Method of Compliance: Inspection of design criteria documents establishes usage and environment (natural and induced) requirements for life, temperature, ambient pressure, shock, vibration, acoustics, explosive atmosphere, proof and burst pressure, acceleration, gyroscopic moments, humidity and moisture, sand and dust, rain, salt fog, fungus, attitude, electromagnetic environments, material compatibility, foreign object damage, steam and gun gas ingestion and others as derived from the air vehicle requirements that could affect safe usage of the equipment). Component safety of flight and qualification analyses and tests validate requirements, capabilities and limitations.

References: JSSG-2009: Appendix C

FAA TSO-C77

8.6.2 System operation.

Criterion: Verify that the APS/EPS operates safely under installed operating conditions over the design envelope.

Standard: The control system ensures stable operation. The power, torque, speed, bleed pressure and temperature provided by the APS/EPS are within specified limits.

Method of Compliance: Inspection of control system design analysis verifies that phase and gain margins exist between all control loops to provide stable operation. The FMECA verifies safe system operation or termination following any combination of failures that have a probability of occurrence greater than one in ten million, or single control system failure. Inspection of the performance model verifies operability margins throughout the intended ground and flight envelopes, as applicable. Software verification and validation testing, control system integration tests, and vehicle integration tests verify proper operation. Aircraft ground tests and flight tests of the installed system and interfacing systems demonstrate intended operation.

References: JSSG-2009: Appendix C

FAA TSO-C77 4.4.1-4.5.2

14 CFR 23.901, 25.901, 25.903(f)

8.6.2.1 Safety features/shutdown systems.

Criterion: Verify that protective safety features (auto shutdown, etc.) are available and effective in protecting the equipment against hazardous malfunctions and conditions such as over-speed, over-temperature and inadvertent activation.

Standard: Protective safety features (auto shutdown, etc.) are available and effective in protecting the equipment against hazardous malfunctions and conditions such as over-speed, over-temperature and inadvertent activation.

Method of Compliance: Inspection of system safety documentation (FMECA) verifies safe system operation or termination following any combination of failures that have a probability of occurrence greater than one in ten million, or single control system failure. Software verification and validation testing, control system integration tests, and vehicle integration tests verify intended operation. All protective shutdown features are verified by test at the controller (via simulated inputs) and system levels.

References: JSSG-2009: Appendix C
FAA TSO-C77: 4.6.2

8.6.3 Functional and physical compatibility.

Criterion: Verify that the functional and physical compatibility of the integrated system are safe.

Standard: The integrated APS/EPS system maintains functional compatibility throughout all normal operating and flight conditions. Normal or abnormal operation of the APS/EPS system does not induce hazardous conditions to interfacing subsystems. Physical interfaces withstand the maximum combination of static and dynamic loading throughout defined flight and ground envelopes and environments. Safety critical interfaces are fault tolerant or fail safe. No single failure or combination of failures with probability greater than one in ten million causes loss of the air vehicle.

Method of Compliance: APS/EPS physical and functional interface requirements are verified by inspection of program documentation such as interface control and design documents. System interfaces are verified to be safe by analyses of worst case single failure operating and loading conditions (bending, torsional and gyroscopic loads, pressures, temperatures, vibratory, etc.). System interface critical analysis assumptions are verified by stress, thermal, pressure or vibration surveys during ground and flight tests as appropriate. Integrated system functional compatibility is verified by simulation, test and demonstration of system functionality at integration test facilities and on the air vehicle during ground and flight test. System physical and functional compatibility hazards and probability of air vehicle loss are verified by inspection of System Safety documentation.

References: JSSG-2009: Appendix C
FAA TSO-C77: 4.4.1-4.5.2 Sections 6 and 7
14 CFR 23.901, 25.901, 25.903(f)

8.6.4 Damage tolerance/containment.

Criterion: Verify that high-speed rotating components are designed to be damage tolerant, or that there are provisions for containment of failed parts. Also, verify that any potentially uncontained fragments do not damage safety of flight components or critical safety items, or injure personnel.

Standard: High-speed rotating components maintain damage tolerance for two times the inspection interval, in the presence of material, manufacturing, processing, and handling defects for the design service life and design usage specified in the model specification. In the absence of damage tolerant design, containment prevents safety of flight components or critical safety items damage due to liberated parts.

Method of Compliance: For damage tolerance approach: Inspection of material characterization data validates material properties used in failure mechanics analysis. Component development tests validate thermal and stress models. Design analysis of rotating components verifies adequate strength and fatigue life margins using minimum material properties. The FMECA verifies the control system's ability to prevent overspeed following any single or likely combination of failures. Disk burst and durability testing demonstrate adequate strength and life. Material and component manufacturing processes are validated by inspection. Trajectory and size analysis in an installed configuration verifies that loss of safety critical systems are extremely remote or less in the event of an uncontained failure.

For containment approach: Analysis of maximum energy burst verifies containment of fragments and includes assessment of failure modes that may result in axial movement of the rotating group. Containment tests verify containment of hazardous fragments.

References: JSSG-2009: Appendix C
FAA AC 20-128
FAA TSO-C77: 5.9, 6.6, 6.7, 6.8
14 CFR 23.903(b), 23.1461, 25.901(c), 25.1461

8.6.4.1 Power take-off anti-flail provisions.

Criterion: Verify that containment or other provisions preclude a failed power-take-off (PTO) system from causing secondary damage, due to flailing or whipping, to critical safety items (CSI) or to nearby safety of flight components/systems, including fuel and hydraulic lines.

Standard: Damage tolerance methodologies are applied to the design of all components of the installed PTO system, including flex couplings, shear sections, clutches and interfacing airframe mounted accessory drive (AMAD)/engine mounted accessory drive (EMAD) stub shafts. Containment of failed components with rotating parts provides protection against damage to neighboring critical systems or components.

Method of Compliance: Inspection of design criteria verifies containment, duration and operating parameters. Containment tests (generally component level) validate specified capability. For a non-containment solution, safety and other supporting analyses and tests verify that personnel and safety critical systems are safe in the event of a flailing or whipping shaft.

References: JSSG-2009: Appendix C
14 CFR 25.901 (c), 25.1167 (a), (c)

8.6.5 Vibration.

Criterion: Verify that APS/EPS equipment in the installed configuration is free of damaging vibrations at all operating conditions throughout the APS/EPS operational envelope.

Standard: Installed equipment withstands vibratory induced loads from startup to maximum operating speeds under any combined expected torsional and air vehicle maneuver induced loading. The system contains no natural (resonant) frequencies within the normal operating range or has damping provisions to prevent resonance damage or failure.

Method of Compliance: Inspection of design and models verify that the system (compressor, turbine, shafts, gear trains and other highly stressed parts) is free from vibration stresses that damage the system or other air vehicle systems throughout the operating envelope. Development tests validate analyses and models. Durability tests demonstrate the ability to withstand the vibratory stresses for the intended life.

References: JSSG-2009: Appendix C
FAA TSO-C77: 5.10
14 CFR 25.901(c), 25.903(f)

8.6.5.1 PTO balance and alignment.

Criterion: Verify, when applicable, that the PTO system is capable of operating safely when installed at the maximum allowable conditions of misalignment and imbalance.

Standard: Operating the PTO system (shaft, clutch, flex coupling, interfacing AMAD/EMAD stub shafts, etc.) with the maximum shaft imbalance and installation misalignment does not induce excess vibration or accelerated wear of system components.

Method of Compliance: Inspection of design criteria verifies that requirements for balance and alignment of the PTO shaft are addressed and tolerances established. Endurance testing in a suitable test fixture verifies safe operation at the maximum allowable imbalance and misalignment.

References: JSSG-2009: Appendix C
14 CFR 25.1167(a), (c)

8.6.6 Response to failures.

Criterion: Verify that the emergency power system (including the Auxiliary Power Unit (APU) or jet fuel starter when deemed flight essential) is capable of responding to failures and providing adequate levels of bleed air, shaft, electrical and/or hydraulic power in sufficient time to meet design requirements.

Standard: The emergency power system is capable of responding to failures and providing adequate levels of bleed air, shaft, electrical and/or hydraulic power in sufficient time to meet design requirements.

Method of Compliance: Inspection of program documentation and design analysis identify the APS/EPS sizing and performance requirements. Component tests verify the ability to start, operate, and endure the natural and induced environmental conditions (ambient temperature extremes, pressure, humidity, rain, sand and dust, etc.) and flight conditions (maneuvers, attitudes, negative "G", shock, etc.). Base level and simulated altitude chamber tests verify uninstalled performance and operability. Analysis and/or wind tunnel tests verify inlet and exhaust performance. Performance analysis (model) verifies installed performance throughout the operating and flight envelope. Integration tests (e.g., Vehicle Integration Facility) verify APS/EPS controller hardware/software compatibility with the air vehicle. Testing verifies sufficient start time design requirements. Installed system ground testing verifies proper operation and performance with air vehicle systems. Flight test results, including those of the inlet and exhaust systems, verify system starting, operability and performance and validate installed performance models.

References: JSSG-2009: Appendix C
FAA TSO-C77: 4.1, 4.4.1, 4.4.2, 4.4.3, 4.7
14 CFR 23.943, 25.901 (f), 25.943

8.6.7 Safety considerations.

8.6.7.1 Structural mounting.

Criterion: Verify that provisions for structural mounting adequately address safety.

Standard: Mounts withstand maximum combination of static and dynamic loading throughout defined flight and ground envelopes and environments. Structural mounts are corrosion resistant and fireproof (as governed by 8.4 of this document).

Method of Compliance: Inspection of design criteria verifies maximum static and dynamic mount loads including flight loads and loads that result from APU/EPU seizure, imbalance under a failed blade condition, and the critical vibration amplitudes and frequencies transmitted by the APU/EPU from the mounting points to the airframe through the normal operating range of the APU. Structural analysis verifies the ability to withstand specified limit loads without permanent deformation and ultimate loads without failure. Critical analysis assumptions are verified by stress, thermal, pressure or vibration surveys during ground and flight tests.

References: JSSG-2009: 3.2.7, 4.2.7, 3.2.7.4.4, 4.2.7.4.4, 3.2.7.5, and 4.2.7.5

MIL-HDBK-516: 8.4

FAA TSO-C77: 4.8, 5.1.3, 5.2.5

14 CFR 25.901(c), (d)

8.6.7.2 Wiring and plumbing support, routing, and clearances.

Criterion: Verify that provisions for wiring and plumbing support, routing, and clearances adequately address safety.

Standard: APS system wiring and plumbing are mounted/routed such that there is no interference or contact with neighboring components of the system or other (sub)systems and that no wear or chafing conditions exist. Positive clearances are maintained under all operational loadings . Electrical wiring is routed above flammable fluid lines to preclude leak impingement on wiring. Flammable fluids and oxidizers are separated from wiring by at least 1/2". Wiring (including connectors) and plumbing do not contain natural (resonant) frequencies within the system operating range, or have adequate damping provisions to prevent resonance damage or failure.

Method of Compliance: Inspection of design criteria verifies suitable support and clearance requirements. Inspection of drawings verifies proper installation that provides for adequate routing, support and clearance to preclude contact and chafing. Tests (vibration response) and analysis verify that plumbing lines are adequately damped. Unit durability tests verify life. Visual inspection of installed system verifies required support and clearance.

References: JSSG-2009: 3.3.8, 4.3.8

SAE ARP994, Tubing/Plumbing Routing - tubing and line support, routing and clearance requirements

SAE AS50881

14 CFR 23.993, 23.1017, 25.901(c), 25.993, 25.1017

8.6.7.3 Compartment drainage of system/components.

Criterion: Verify that provisions for compartment drainage of system/components adequately address safety.

Standard: APS/EPS drain and vent systems accommodate the combined maximum system leakage and ventilation flow rates. No allowable flight conditions inhibit the function to the extent that APS/EPS operation is adversely affected or a hazardous condition is created. Storage or expulsion of the fluids and vapors does not create a hazardous condition. These provisions are compatible with applicable fire protection certification criteria, standards and methods of compliance of 8.4 (this document).

Method of Compliance: Inspection of design verifies existence of provisions for drainage of flammable fluids and vapors within the APU which may occur during normal operation or abnormal events such as a false start. Aircraft manufacturing or system operational tests verify functional capability.

References: JSSG-2009: 3.3.8, 4.3.8
MIL-HDBK-516: 8.4
FAA TSO-C77: 5.27, 5.42, 5.52
14 CFR 25.1187

8.6.7.4 Cooling and ventilation of system/components.

Criterion: Verify that provisions for cooling and ventilation of system/components adequately address safety.

Standard: APS/EPS compartment cooling and ventilation provisions maintain the temperatures of system components, fluids, and structure within the temperature limits established for these components and fluids, underground and flight operating conditions, and after normal system shutdown. These provisions are compatible with applicable fire protection certification criteria, standards and methods of compliance of 8.4 (this document).

Method of Compliance: Temperature limit requirements are verified by inspection of design documentation. System thermal performance is verified by inspection of design analysis and thermal model simulations. APS/EPS compartment environments are verified by thermal surveys during ground and flight tests.

References: JSSG-2009: 3.3.8, 4.3.8
MIL-HDBK-516: 8.4
FAA TSO-C77: 5.3
14 CFR 23.1041-23.1045, 23.1103(a), 25.1041-25.1045, 25.1103(a)

8.6.7.5 Fire hardening of system/components.

Criterion: Verify that provisions for fire hardening of system/components adequately address safety.

Standard: Safety critical components withstand worst case temperatures and heat flux for the expected flammable fluids and operating conditions (e.g., for JP-8, 2000°F fire with a heat flux of 10 Btu/sec/ft^2). These provisions are compatible with applicable fire protection certification criteria, standards and methods of compliance of 8.4.

Method of Compliance: Analysis demonstrates material and component compliance with the established fireproof or fire-resistance air vehicle requirements. Laboratory component tests demonstrate compliance to the fire protection requirements when exposed to the required flame temperature and heat flux density for the required time (15 minutes for fireproof and 5 minutes for fire resistance).

References: JSSG-2009: 3.3.3, 4.3.3, 3.3.8, 4.3.8, G.3.4.7, G.4.4.7
MIL-HDBK-516: 8.4
FAA TSO-C77: 5.2
14 CFR 23.1181-23.1203, 25.1181-25.1207

8.6.7.6 Accessibility and servicing features.

Criterion: Verify that provisions for accessibility and servicing features adequately address safety.

Standard: Required installed APS/EPS system servicing, inspections, and maintenance activities can be accomplished and verified by the multivariate maintainer population. This includes access necessary to accomplish pre- or post-maintenance leak checks of high pressure fluid and pneumatic systems. Access accommodates the maintainer's anthropometric dimensions and strength limitations taking into consideration all environmental conditions and any required mission equipment (chemical protective gear, gloves, etc.).

Method of Compliance: Access for required servicing, inspections and maintenance requirements are verified by inspections of design documentation and virtual models that provide evidence that clearances, reach and weight are within the capability of the maintainer population. Physical mock-ups and technical publications (e.g., Technical Orders) verification demonstrations verify ability to accomplish and verify required tasks.

References: JSSG-2009: 3.2.6 and 4.2.6
14 CFR 23.901, 23.1021, 25.901, 25.1021

8.6.8 Flammable fluid ingestion/exhaust gas impingement.

Criterion: Verify that the inlet and exhaust hazards (i.e., velocities, temperatures, acoustics, exhaust by-products, etc.) to the ground/flight/passenger personnel, air vehicle subsystems, and air vehicle structure are acceptable.

Standard: APS/EPS is not susceptible to leakage from flammable fluid lines, fitting, or components entering the inlet air stream. Exhaust gases are transported off the air vehicle. Exhaust plume does not:

a. Impinge on aircraft structure or equipment to the extent that maximum temperatures are exceeded.
b. Impinge on or mix (except when designed) with any flammable fluid drainage or vapor discharge to the extent that the fluid/vapor auto ignition temperature is achieved or exceeded.
c. Impose an unavoidable hazard to flight/ground crew or impede a pre-flight/launch activity.

Acoustic emissions do not exceed established levels.

Method of Compliance: Inspection of design verifies that leakage from flammable fluid lines, fittings, or components cannot enter the intake air stream. Component and ground tests verify that the exhaust system prevents leakage of exhaust gas into the aircraft. Exhaust plume interaction with structure, fluid/vapor discharge, and flight/passenger/ground crew is validated by inspection of plume and thermal analysis and models. Design analysis verifies there is no plume attachment to the aircraft during in-flight operation. Flight tests validate the design analysis. Ground tests verify acoustical emission levels. Hazards are validated by inspection of system safety documentation.

References: JSSG-2009: Appendix C
FAA TSO-C77: 5.3.1, 5.3.3, 5.6
14 CFR 23.1091, 23.1103, 23.1121, 23.1123, 25.1091, 25.1103, 25.1121, 25.1123

8.6.9 Personnel hazards.

Criterion: Verify that personnel hazards are properly documented in the appropriate operator handbooks or manuals with normal and emergency procedures, limitations, restrictions, warnings, cautions and notes.

Standard: Technical data accurately describes personnel hazards (e.g., exhaust plumes, overspeed, over temperature). Operator handbooks or manuals identify all normal and emergency procedures, limitations, restrictions, warnings, cautions and notes. Warnings, cautions and notes are identified in such a manner as to attract attention and set them apart from normal text. When an unsafe condition is detected and annunciated, the operator's manual has clear and precise corrective procedures for handling the condition (see also 4.5 and 9.4, this document).

Method of Compliance: Review of the operating and support hazard analyses verifies that the potential hazards are identified. Inspection of operator handbooks or manuals verifies that they contain the appropriate normal and emergency procedures, limitations, restrictions, warnings, cautions and notes.

References: JSSG-2009: 3.3.3, 4.3.3
MIL-HDBK-516: 4.5, 9.4
14 CFR 23.1541, 23.1581(a)(2), 25.1541, 25.1581(a)(2)

8.6.10 Accessory drive system compatibility.

Criterion: Verify that compatibility of the accessory drive system with the air vehicle accessories and engine drive system is adequately evaluated for torsional vibrations and loads as well as possible misalignments.

Standard: Compatibility of the accessory drive system with the air vehicle accessories and engine drive system is adequately evaluated for torsional vibrations and loads as well as possible misalignments.

Method of Compliance: Design analysis verifies strength margins throughout drivetrain and absence of torsional modes within the operating range. Tolerance and flight load analysis establishes maximum misalignment. Accessory Drive Integration Lab tests and system alignment measurements verify installed performance. Installed ground tests verify operating performance.

References: JSSG-2009: 3.2.7, 4.2.7, 3.2.7.4.4, 4.2.7.4.4, 3.2.7.5, 4.2.7.5
14 CFR 25.1167

8.6.11 Failure modes and effects.

Criterion: Verify that all critical failure modes and hazards have acceptable risk levels.

Standard: No single failure or combination of failures with probability greater than one in ten million results in loss of an air vehicle. The severity of all hazards associated with the APS/EPS is reduced to an acceptable level or has risk accepted in accordance with MIL-STD-882.

Method of Compliance: APS/EPS critical failures modes, hazards and acceptability of risk are verified by inspection of System Safety documentation.

References: JSSG-2009: 3.3.3, 4.3.3
14 CFR 25.901 (c)
FAA TSO-C77: 5.1

8.6.12 Operator interface.

Criterion: Verify that the crew station provides for adequate control and monitoring of the system.

Standard: Crew/operator station provides means to control and assess APS/EPS operating condition to the extent necessary for flight safety. The system provides warnings, cautions and advisories to operators and maintainers for hazardous failure conditions of APS/EPS.

Method of Compliance: Inspection of design verifies provisions for the necessary control and monitoring of the system operation and health. Integration tests, to include Failure Modes and Effects Testing (FMET), verify compatibility of APS/EPS with cockpit/control station and monitoring system. Ground tests of installed system verify operating performance.

References: JSSG-2009, Appendix C
14 CFR 23.1141-23.1142, 23.1549, 25.1141-25.1142, 25.1549

8.6.13 Limits of operation.

Criterion: Verify that equipment service life, overhaul, and operating limits are safe and that life-limited components have a reliable means of tracking the limiting parameters.

Standard: Required maintenance actions are defined to ensure safe operation over the design service life. Component maintenance times are based on the parameter(s) that causes life degradation. A critical component tracking system has been established and defines the analysis procedures, serialization, data collection, and computer programs necessary to establish maintenance times of individual components based on accrual or parameter events.

Method of Compliance: Established lives and limits are verified by design analyses. Development tests validate critical calculated/modeled parameters such as stress and temperature spectrums. Durability/Accelerated Mission Testing validates established limits. Inspection of design and maintenance system verifies that provisions exist for tracking of critical components.

References: JSSG-2009: 3.2.7.4.4, 4.2.7.4.4, 3.2.7.6, 4.2.7.6

8.6.14 Technical manuals.

Criterion: Verify that the flight/operator and maintenance manuals include normal and emergency operating procedures, limitations, servicing, and maintenance information.

Standard: Technical data describes the installed APS/EPS, normal and emergency operation, operating procedures and limitations, servicing, and maintenance requirements.

Method of Compliance: Technical data is validated by inspection of design documentation and technical manuals and demonstration of technical manual procedures.

References: JSSG-2000: 3.6.2
14 CFR 23.1581-23.1585, G23.3-G23.4, 25.1581-25.1585, H25.3-H25.4

8.6.15 Failure of primary lubrication to the airframe mounted accessory drive (AMAD).

Criterion: Verify that, during a loss of the primary lubrication system, the AMAD gearbox continues to function and transmit the power required for safe flight until appropriate pilot action can be accomplished.

Standard: Airframe mounted accessory drive gearbox functions for at least 30 minutes after complete loss of the lubricant from the primary lubrication system and is in a condition such that the AMAD gearbox is still capable of transmitting the required power to maintain safe flight. The operational conditions are such that the loss of lubricant occurs at the most severe power condition and that the air vehicle can transition to cruise and land at the end of the thirty minute period. If an emergency lubrication system is used, any resulting attitude limitations during loss of lubricant operation are defined.

Method of Compliance: Two, thirty minute tests are conducted with teardown inspections. The AMAD gearbox lubrication system is starved at the system's supply side (downstream from the pump) and continues to scavenge. Operation is demonstrated for a thirty minute period at the most severe power condition.

Creditable run time starts at the point at which the cockpit low oil pressure warning would be displayed. For non-pressurized AMAD gearboxes, creditable run time starts when the oil being drained from the gearboxes ceases to flow in a steady stream. The AMAD gearbox is configured in an air vehicle attitude simulating the cruise power condition. For a vertical take-off and landing (VTOL) air vehicle, the test spectrum and attitudes are commensurate with expected field use. For AMAD's that contain a clutch, a thirty minute loss-of-lubrication overrunning test consistent with the loss-of-lubricant test spectrum above demonstrates the ability of continued safe operation.

8.6.16 Failure of AMAD mounted components.

Criterion: Verify that failure or seizure of any individual accessory mounted to the AMAD gearbox does not prevent the AMAD gearbox from powering flight critical equipment.

Standard: The AMAD gearbox provides power to drive certain subsystem components. In some cases, failure of the AMAD gearbox to provide power to select components is flight critical (either in normal operation or emergency operation). In those cases, failure or seizure of any individual accessory mounted to the AMAD gearbox does not prevent the AMAD gearbox from driving the flight critical equipment. A typical approach to meet this requirement incorporates a shear section into the shaft of accessories driven by the AMAD gearbox.

Method of Compliance: Flight critical equipment driven by the AMAD gearbox is identified by analysis. The ability of the AMAD gearbox to continue supplying adequate power to the flight critical equipment is verified by component level test.

8.7 Aerial refueling.

Equipment involved with boom, receptacle, drogue, and probe aerial refueling systems; including the interfaces with other air vehicle systems. Also included are those air vehicle systems/components, along with the aerial refueling system(s)/components, which are involved in the conduct of the aerial refueling process.

References: JSSG-2001: 3.1.1.1.1 (Aerial Refueling Envelope); 3.4.6.2 (Aerial Refueling

Interfaces)

JSSG-2009: Appendix E (Fuel Subsystem), Appendix F (Aerial Refueling) and Appendix G (Fire and Explosion Hazard Protection Subsystem)

JSSG-2010: 3.3 (Cockpit/Crew Station/Cabin); 3.4 (Alerting); 3.5 (Aircraft Lighting), 3.5.3.3/4.5.3.3

MIL-A-19736

ATP-3.3.4.2

NATO STANAG 3971

NOTE: 14 CFR Reference paragraphs listed in the following section are not necessarily sufficient to fully satisfy the corresponding criteria.

8.7.1 Aerial refueling operations.

Criterion: Verify that aerial refueling operations can be safely and successfully accomplished with the targeted tanker/receiver aerial refueling subsystem(s).

Standard: All applicable factors involved in aerial refueling operation are addressed including but not limited to: handling qualities, developed loads, electrical compatibility, visual cues, communication capabilities, formation awareness, material compatibility, fuel pressures, fuel flow rates, lighting, flammability hazards, fuel spray hazards, types of fuel to be carried/transferred, tanker/receiver separation distances during the aerial refueling process, and technical data. All applicable factors are evaluated with the air vehicle and each targeted tanker/receiver in each approved operational configuration (e.g., external stores, gross weight extremes, center of gravity limits, etc.) under expected operating conditions (e.g., night, day, instrument meteorological conditions (IMC), visual meteorological conditions (VMC), etc.).

"Targeted" clarification: The other vehicles that will interface with the subject air vehicle during the aerial refueling process are referred to as a "targeted" tanker/receiver, as applicable.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Systems engineering and system safety analyses verify aerial refueling capability and safety. Additionally, all criteria listed in 8.7 subparagraphs have been verified by methods defined for each respective criterion. Appropriate Aerial Refueling Standardized Technical Document Survey (NATO STANAG 3971, ATP-3.3.4.2, Part 5, Annex BA, Appendices 1 - 5) and an Aerial Refueling Technical Assessment (NATO STANAG 3971, ATP-3.3.4.2, Part 5, Annex Z, Appendix 2) have been obtained.

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2

MIL-A-19736

ATP-3.3.4.2

NATO STANAG 3971

8.7.1.1 Technical manuals.

Criterion: Verify that the operator and maintenance manuals for the air vehicle and the targeted tanker(s)/receiver(s) document safe operation of the aerial refueling systems.

Standard: The manuals identify the proper operator and maintenance instructions/information and placards noting restrictions and limitations in the use of the air vehicle's aerial refueling system(s) under all operating conditions (ground/in-flight; normal/emergency). Flight procedures address all applicable factors involved in aerial refueling operation including, but not limited to:

a. Day versus night.
b. With and without night vision goggle(s) (NVG).
c. Rendezvous methods.
d. Formation techniques.
e. Approved airspeed/altitude envelopes:
   (1) Tanker/receiver contacts.
   (2) Opening/extending system.
   (3) System in open/extended position.
   (4) Returning system to stowed/retracted position.
f. Receiver contact/closure rate limits (probe-drogue systems only) and receiver closure/fall back rate limits once engaged.
g. For boom systems, envelopes (elevation, roll/azimuth, extension) for receiver contact, receiver disconnect, and boom control limits.
h. Single versus multiple aircraft operations.
i. Fuel transfer restrictions (e.g., flow rates/delivery pressures).
j. Reverse aerial refueling.
k. Operational restrictions.

Method of Compliance: Verification methods include inspection and review of documentation. Aerial refueling procedures are identified and confirmed through inspection of appropriate documentation.

References: JSSG-2001: 3.1.1.1.1, 3.4.6.2.1, 3.4.6.2.2
ATP-3.3.4.2
NATO STANAG 3971

8.7.1.1.1 Life-limited components.

Criterion: Verify that for each aerial refueling system, all life-limited components that must function properly to maintain the flight safety of the air vehicle and/or the safe usage of the aerial refueling system during aerial refueling operations are identified.

Standard: The maintenance manuals identify limited-life aerial refueling system components that must function properly to maintain the flight safety of the air vehicle and/or the safe usage of the aerial refueling system during aerial refueling operations. Necessary processes are established which identify appropriate inspection intervals and/or life monitoring techniques (see also 16.3.2 of this document).

Method of Compliance: Verification methods include inspection and review of documentation. Inspection intervals and life monitoring methods are identified and confirmed through inspection of appropriate documentation.

References: AFI 63-101/20-101
MIL-HDBK-516: 16

8.7.1.1.2 Component wear/damage levels.

Criterion: Verify that appropriate inspection criteria for wear/damage are provided for the components in each aerial refueling system.

Standard: The maintenance manuals identify the acceptable levels for wear/damage on the components in each aerial refueling system. Wear/damage inspection criteria are provided for, but not limited to, receptacle doors, boom nozzles, probe nozzles, drogue struts/canopy, fuel reception couplings, aerial refueling hoses, and inadvertent boom strike structure surrounding receptacle installation.

Method of Compliance: Verification methods include inspection and review of documentation. Aerial refueling procedures are identified and confirmed through inspection of appropriate documentation.

Reference: AFI 63-101/20-101

8.7.1.2 Interface compatibility.

Criterion: Verify that there is dimensional, physical, electrical, and material compatibility between each aerial refueling interface and the targeted tanker's/receiver's aerial refueling interface to permit safe engagement procedures.

Standard: Engagements can be conducted in accordance with standard aerial refueling operations/procedures associated with targeted tanker/receiver. Aerial refueling system design meets physical and dimensional tolerances as well as electrical and material compatibilities associated with targeted tanker/receiver.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Verification of dimensional and physical interface characteristics is achieved by inspection of drawings, analysis of envelope, and both ground and flight demonstration of engagement throughout the contact envelope. Verification of electrical and material interface compatibility is achieved by laboratory tests and analyses of aerial refueling interface(s) on the air vehicle and interface(s) of targeted aerial refueling counterpart(s).

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2

NATO STANAG 3447 for probe equipped receivers and drogue equipped tankers dimensional guidance

NATO STANAG 7191 for receptacle equipped receivers and boom equipped tanker dimensional guidance

8.7.1.2.1 Fastener obstructions.

Criterion: Verify that all structural fastener heads around the receptacle are flush with the surrounding structural surface.

Standard: There are no raised fasteners to be damaged by or cause damage to the boom. Raised fasteners present a FOD hazard as a broken fastener could enter the fuel system through the receptacle.

Method of Compliance: Verification methods include inspection and review of documentation. Inspection of drawings and aircraft surface surrounding receptacle verifies structural fasteners are flush.

References: JSSG-2006: 3.3.11, 4.3.11

8.7.1.2.2 Interface clearances.

Criterion: Verify that adequate clearance has been provided around each aerial refueling subsystem's interface to permit safe and successful engagement/disengagement procedures with the interface of the appropriate tanker/receiver aerial refueling subsystem.

Standard: For probe/drogue aerial refueling subsystems, clearances comply with NATO STANAG 3447. For boom/receptacle aerial refueling subsystems, clearances comply with NATO STANAG 7191, ATP-3.3.4.5.

Method of Compliance: Verification methods include analysis, inspection and review of documentation. Inspection of drawings, dimensional analysis of each aerial refueling subsystem interface, and dimensional analysis of the area surrounding each aerial refueling subsystem interface verify that there is adequate clearance around each aerial refueling subsystem interface.

References: JSSG-2009: 3.4.6.2.3.2.2 and 4.4.6.2.3.2.2
ATP-3.3.4.5
NATO STANAG 3447
NATO STANAG 7191

8.7.1.3 Loads at the refueling interface.

Criterion: Verify that the aerial refueling system interface, its attachment to airframe structure, and the structure surrounding the interface can withstand the loads experienced during the aerial refueling process (e.g., engagement, disengagement, fuel transfer) without being damaged or creating FOD.

Standard: The aerial refueling system interface, its attachment to airframe structure, and the structure surrounding the interface can withstand the loads experienced during the aerial refueling process (e.g., engagement, disengagement, fuel transfer) without being damaged or creating FOD. Load applications include static and dynamic/fatigue conditions associated with normal and single failure operations for the entire life of the air vehicle, to include training requirements and operational employment (see also Section 5).

There are different sets of loads associated with the methods of aerial refueling.

a. Specific loads for boom and receptacle aerial refueling subsystems include:
   (1) Loads expected during normal engagements within the defined contact envelope and normal disengagements within the disconnect envelope.
   (2) Loads experienced when a single failure occurs in the latching mechanism of the receptacle and the boom nozzle must be forcibly pulled out of the receptacle at flight conditions.
   (3) Loads due to inadvertent boom strikes.
   (4) Loads experienced when the aerial refueling subsystem is in the "closed", "transition", and "open" positions.
b. Specific loads to be considered for probe and drogue aerial refueling subsystems include:
   (1) Loads expected during normal engagements/disengagements at the most severe receiver closure/fallback rates.
   (2) Loads experienced due to inadvertent/off-center engagements/disengagements.

(3) Loads experienced when a single failure occurs in the latching mechanism of the aerial refueling coupling and the probe nozzle must be forcibly pulled out of the coupling at flight conditions.

(4) Loads experienced due to failed/degraded hose reel response at the most severe receiver closure/fallback rates.

(5) Loads experienced from the acoustic/vibration environment when the aerial refueling subsystem is in the “stowed”, “transition”, and “extended” positions.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Critical points in the aerial refueling envelope have been defined based on the mission profiles and system design. Analysis and ground testing verify that the aerial refueling system and interfacing structure can withstand expected loads without being damaged or creating FOD. Flight testing of select critical points of the aerial refueling envelope validates the analysis.

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2
JSSG-2009: F.3.4.6.2.2.5, F.4.4.6.2.2.5, F.3.4.6.2.3.5, F.4.4.6.2.3.5
JSSG-2006: 3.4.1.6, 4.4.1.6; 3.5, 4.5; 3.6, 4.6
MIL-A-19736
MIL-HDBK-516: 5

8.7.1.4 Crewmember/operator cues.

Criterion: Verify that cues (visual or equivalent) are provided on the air vehicle to assist the crewmember(s)/operator(s)/automated system(s) of the targeted tanker(s)/receiver(s) and the crewmember(s)/operator(s)/automated system(s) of the air vehicle during the aerial refueling process under mission-defined environmental conditions. Likewise, verify that cues (visual or equivalent) provided on the targeted tanker/receiver air vehicle(s) can be viewed/received as intended by the appropriate air vehicle crewmember(s)/operator(s)/automated system(s), during the aerial refueling process under mission-defined environmental conditions.

Standard: Cues (visual or equivalent) are provided on the air vehicle to assist the crewmember(s)/operator(s)/automated system(s) of the targeted tanker(s)/receiver(s) and the crewmember(s)/operator(s)/automated system(s) of the air vehicle during the aerial refueling process under mission-defined environmental conditions. Cues (visual or equivalent) provided on the targeted tanker/receiver air vehicle(s) can be viewed/received as intended by the appropriate air vehicle crewmember(s)/operator(s)/automated system(s), during the aerial refueling process under mission-defined environmental conditions. Critical areas depend on the type of aerial refueling system and are identified below:

a. For boom subsystems, receiver positioning markings, aerial refueling boom markings showing inner/outer receiver contact limit and inner/outer fuel transfer limit positions, size and movement indicators (including lighting of) such as: wing tips, engine nacelle, horizontal/vertical stabilizers, etc.

b. For receptacle subsystems, boom lead-in markings in front of the receptacle, markings on objects which are located near the receptacle (e.g., antennae), size and movement indicators (including lighting of) such as: wing leading edge, engine nacelle, canopy, horizontal/vertical stabilizers, etc.

c. For drogue subsystems, receiver positioning markings and aerial refueling hose markings showing full trail, inner and outer fuel transfer range, and inner clearance limit positions (if applicable).

d. For probe subsystems, probe illumination.

Mission-defined environmental conditions include day, night, dusk, twilight, sun in and out of field of view (FOV), with and without NVIS, ambient moon lighting (waxing/waning) in/out of FOV, diverse backgrounds (snow, ocean, desert, populated city lights, foliage dominant, etc.), refueling in, above, and below clouds.

Method of Compliance: Verification methods include analysis, test, demonstration, and review of documentation. Crewmember(s)/operator(s)/automated system(s) evaluation from flight test/demonstration and/or ground simulation verify cues (visual or equivalent) provided on the targeted tanker/receiver air vehicle(s) can be viewed/received as intended by the appropriate air vehicle crewmember(s)/operator(s)/automated system(s), during the aerial refueling process under mission-defined environmental conditions.

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2
JSSG-2009: Appendix F
JSSG-2010: 3.3.2.1, 4.3.2.1

8.7.1.4.1 Marking durability.

Criterion: Verify that all markings used for aerial refueling are compatible with the expected environmental conditions and fluid exposures (fuel, hydraulic fluid, air vehicle cleaning solvents, etc.).

Standard: The aerial refueling markings do not degrade to the point of hindering the aerial refueling process or causing a hazard to flight/ground crews under any expected environmental conditions or fluid exposure (fuel, hydraulic fluid, air vehicle cleaning solvents, etc.).

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Criterion is verified by analyses and laboratory tests of material compatibilities prior to flight.

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2

8.7.1.4.2 Exterior lighting.

Criterion: Verify that exterior lights are provided on the air vehicle to assist the targeted tanker/receiver(s) crewmember(s)/operator(s)/automated system(s) and the air vehicle crewmember(s)/operator(s)/automated system(s) during the aerial refueling process.

Standard: Exterior lights are provided on the air vehicle to assist the targeted tanker/receiver(s) crewmember(s)/operator(s)/automated system(s) and the air vehicle crewmember(s)/operator(s)/automated system(s) during the aerial refueling process. Exterior lighting does not blind or create glare spots for the crewmembers(s)/operator(s)/automated system(s) on the targeted tanker/receiver(s) and air vehicle. Lighting required will vary depending on the systems being used for aerial refueling. Lighting to be considered includes, but is not limited to:

a. For receiver receptacle subsystems, receptacle/slipway illumination, illumination of the surface area immediately aft of the receptacle, wing leading edge illumination, and illumination of surface features possibly in the path of the boom.
b. For tanker boom subsystems, boom nozzle illumination, wing and underbody illumination, wing pod and engine nacelle illumination, and receiver pilot director lights.
c. For receiver probe subsystems, probe illumination.

d. For tanker drogue subsystems, drogue illumination, hose exit tunnel illumination, wing and underbody illumination, wing pod and engine nacelle illumination, and drogue subsystem status lights (see also 9.3, this document).

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Inspection of drawings and/or air vehicle verifies exterior lights are provided. Flight test(s)/demonstration(s) verify that exterior lights assist the aerial refueling process as intended.

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2
JSSG-2010: 3.5.3.3, 4.5.3.3
MIL-HDBK-516: 9.3

8.7.1.4.3 Exterior lighting effectiveness.

Criterion: Verify that the appropriate air vehicle crewmember(s)/operator(s)/automated system(s) can view/receive the exterior lights provided on the targeted tanker/receiver air vehicle(s), as intended, during the aerial refueling process.

Standard: Receiver(s) can view/receive information from targeted tanker(s) as presented through the use of exterior tanker lights. Tanker(s) can view/receive information from targeted receiver(s) as presented through the use of exterior receiver lights.

Lighting to be considered includes, but is not limited to: Receiver position, interface, formation, beacon, rendezvous, and status lights (see also 9.3 of this document).

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Flight test(s)/demonstration(s) verify that exterior lights assist the aerial refueling process as intended.

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2
JSSG-2010: 3.3.2.1, 4.3.2.1; 3.5.3.3, 4.5.3.3
MIL-HDBK-516: 9.3

8.7.1.4.4 Exterior lighting intensity.

Criterion: Verify that the intensity of each exterior aerial refueling light, or light group, can be independently varied to accommodate the needs of the targeted tanker/receiver crewmember(s) /operator(s)/automated system(s) and the air vehicle crewmember(s)/operator(s)/automated system(s).

Standard: Lighting intensity is variable in response to the differing requirements depending on environmental lighting conditions as well as tanker/receiver orientation. Variability of lighting provides optimum illumination of appropriate systems. Independently controllable lighting systems include, but may not be limited to: receptacle/slipway illumination, probe illumination, boom nozzle illumination, flood light illumination, wing and underbody illumination, wing pod and engine nacelle illumination, receiver pilot director lights, and tanker subsystem status lights (see also 9.3.2 of this document).

Method of Compliance: Verification methods include analysis, test, demonstration, and review of documentation. Adequacy of the exterior aerial refueling light or light group intensity is verified by analysis and evaluation of crewmember(s)/operator(s)/automated system(s) observations/data during ground and flight test and/or demonstration.

References: JSSG-2010: 3.5.3.3.1, 4.5.3.3.1; 3.5.3.5, 4.5.3.5
MIL-HDBK-516: 9

8.7.1.4.5 Night vision imaging system (NVIS) compatibility.

Criterion: Verify that exterior lights utilized during the aerial refueling process are compatible with NVIS or automated systems.

Standard: Exterior lights utilized during the aerial refueling process are compatible with NVIS or automated systems (see also 9.3.4, this document).

Method of Compliance: Verification methods include analysis, test, demonstration, and review of documentation. Analysis, ground and flight test/demonstration verify compatibility of all appropriate lights with NVIS and/or automated systems.

References: JSSG-2010: 3.5.3.3, 4.5.3.3
ATP-3.3.4.2
NATO STANAG 3971
MIL-HDBK-516: 9
14 CFR 23.951-23.1001, 25.951-25.1001

8.7.1.4.6 Environmental conditions for exterior lighting systems.

Criterion: Verify that all exterior lights used during the aerial refueling process are compatible with the expected environmental conditions and fluid exposures.

Standard: The illumination capability of the aerial refueling lights is not degraded to the point of hindering the aerial refueling process under any expected environmental conditions or fluid exposures (fuel, hydraulic fluid, air vehicle cleaning solvents, etc.). Fluid exposure does not compromise the integrity of the light such that a hazard to the air vehicle(s) or personnel is created.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Criterion is verified by analyses and laboratory tests of material compatibilities prior to flight. Inspection of lights throughout aircraft aerial refueling flight testing regime confirms analyses and lab test accuracy.

References: JSSG-2009: F.3.4.6.2.2.1.4, F.3.4.6.2.3.4
JSSG-2009: G.3.4.7.2, G.3.4.7.3

8.7.1.4.7 Viewing systems.

Criterion: Verify that any viewing system which is to be used by any crewmember/ operator/automated system during the aerial refueling process is designed to permit safe aerial refueling operations.

Standard: When viewing systems are to be used by any crewmember/operator/automated system in the tanker and/or receiver air vehicle during the aerial refueling process, each viewing system is designed such that it permits safe aerial refueling operations to be conducted. Design parameters to be considered include, but are not limited to: field of view, latency, depth perception, clarity, background effects, thermal signatures of tanker/receiver, blooming and glare effects, failure response, solar effects, and overlay considerations.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Analysis of technical data and evaluation of the system by crewmember(s)/operator(s)/automated system(s) during ground simulation, ground test, and flight test verify that each viewing system supports the conduct of safe aerial refueling operations.

References: MIL-HDBK-516: 9

8.7.1.5 Communication system.

Criterion: Verify that a communication system is provided which permits the timely exchange of all identified data/information between the crewmember(s)/operator(s)/ automated system(s) of the air vehicle and the crewmember(s)/operator(s)/automated system(s) of the targeted tanker/receiver air vehicle(s) during the aerial refueling process.

Standard: Communication system is provided which permits the timely exchange of all identified data/information between the crewmember(s)/operator(s)/automated system(s) of the air vehicle and the crewmember(s)/operator(s)/automated system(s) of the targeted tanker/ receiver air vehicle(s) during the aerial refueling process. Communication system is compliant with appropriate classified information transfer requirements.

Data/information includes but is not limited to: relative positioning, fuel offload amount, "breakaway" command, boom operator guidance, air vehicle call sign, receiver tail number, etc. (see also 9.2.8, this document).

Method of Compliance: Verification methods include test, demonstration and review of documentation. Adequate communication is verified by demonstration/test of communication system under operational restrictions/conditions.

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2
MIL-HDBK-516: 9
ATP-3.3.4.2
NATO STANAG 3971

8.7.1.6 Identification of fuels.

Criterion: Verify that the types of fuels to be transferred/received and any allowed deviations are identified.

Standard: Primary, alternate/restricted and emergency fuels have been identified and the fuel to be transferred/received does not adversely affect the aerial refueling system functions under all specified conditions (see also 8.3.2, this document).

Method of Compliance: Verification methods include analysis, test, demonstration and review of documentation. Aerial refueling system compatibility and performance with all specified air vehicle fuels to be transferred/received, under all specified flight and environmental conditions, are verified using analyses, simulator tests, component tests, and ground/flight tests.

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2
MIL-HDBK-516: 8.3

8.7.1.7 Delivery pressure and flow rate.

Criterion: Verify that the delivery pressure and flow rate of the transferred/received fuel are identified and are within all applicable tanker/receiver design limits during normal and single failure conditions.

Standard: Delivery pressure and flow rate of the transferred/received fuel have been identified and are within all applicable tanker/receiver design limits. Values are established that keep the maximum pressures (including transients) within proof pressure limits of the fuel tank structure and the aerial refueling, vent, and fuel systems when transferring at the maximum specified delivery fuel pressure and rate at normal and single failure conditions. Other considerations include: maximum flow capability of the vent and fuel system, flow induced static buildup, failure of tanker/receiver pressure regulation, simultaneous receiver refueling, tank overfill due to failure of control valve closure, tank overfill due to fuel line separation, and any other limiting factors.

Method of Compliance: Verification methods include analysis, test and review of documentation. Design analysis, ground tests, and flight tests verify delivery pressure and flow rate of the transferred/received fuel are within tanker/receiver design limits. Design analysis is used to identify the most critical pressure and flow rate conditions (including single failures).

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2
JSSG-2009: F.3.4.6.1.6, F.4.4.6.1.6
MIL-A-19736: 3.5.2.1, 3.8.7
ARSAG International Document number 00-03-01

8.7.1.8 Surge pressures.

Criterion: Verify that surge pressures generated during the aerial refueling process do not exceed proof pressure limits for the aerial refueling system(s) of any air vehicle involved in the aerial refueling process.

Standard: Surge pressures generated during the aerial refueling process (including those from single failures) do not exceed proof pressure limits for the aerial refueling system(s) of any air vehicle involved in the aerial refueling process. Surge pressure conditions include, but are not limited to the following:

a. With and without a single failure in the tanker/receiver system's pressure regulation/surge suppression feature(s).
b. Pump start-up surges (no flow to receiver).
c. All possible single/multiple receiver valve closures (manually or automatically activated) which could terminate flow into the receiver.
d. Flowing disconnects.
e. Single receiver and simultaneous receiver refueling (if applicable) scenarios.
f. Reverse aerial refueling scenarios (if applicable).
g. All possible tanker valve activations during fuel transfer.

Method of Compliance: Verification methods include analysis, test and review of documentation. Design analysis, ground tests, and flight tests verify surge pressures of the transferred/received fuel are within tanker/receiver design limits under the following conditions:

a. With and without a single failure in the tanker/receiver system's pressure regulation feature(s).

b. Pump start-up surges (receiver[s] not connected, receiver[s] connected but no flow to receiver and receiver[s] connected with an open flow path into receiver).
c. All possible receiver valve closures (manually or automatically activated) which could terminate flow into the receiver.
d. Flowing disconnects.
e. Single receiver and simultaneous receiver refueling (if applicable) scenarios.
f. Reverse aerial refueling scenarios. (if applicable).
g. All possible tanker valve activations during fuel transfer.

Design analysis is used to identify the most critical pressure and flow rate conditions (including single failures) when evaluating surge pressures.

References: JSSG-2001: 3.4.6.2.1; 3.4.6.2.2, 4.4.6.2.2
MIL-A-19736: 3.5.2.3
ARSAG International Document number 00-03-01

8.7.1.9 Fuel spray.

Criterion: Verify that any fuel spray resultant of the engagement/disengagement process between the aerial refueling interface(s) of the tanker/receiver(s) does not negatively affect the safe operation of the air vehicle(s) or personnel.

Standard: Any fuel spray resultant of the engagement/disengagement process between the aerial refueling interfaces of the tanker/receiver(s) does not cause hazards for the air vehicle(s) or personnel. Areas addressed include but are not limited to: engine inlet, ventilation inlets/outlets, air data sensors, antennae masts, low observable coatings/material, mission equipment, canopy, ignition sources, etc.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis of system design and review of flight test data verifies no hazards are caused by fuel spray resultant of the aerial refueling process.

References: JSSG-2001: 3.2.3, 3.3.10
JSSG-2009: F.3.4.6.2.2.2, F.4.4.6.2.2.2, F.3.4.6.2.3.2, F.4.4.6.2.3.2

8.7.1.10 Flight stability and handling qualities.

Criterion: Verify that satisfactory flight stability and handling qualities are achievable for the tanker/receiver aerial refueling interface within the specified aerial refueling envelope.

Standard: Satisfactory flight stability and handling qualities are achievable for each tanker/receiver aerial refueling interface within the specified aerial refueling envelope to accomplish the mission without significant increased crew member(s) workload (acceptable Cooper-Harper rating or equivalent as defined by the program). (Flight stability of an aerial refueling system interface has typically been an issue with both boom and drogue systems. Handling qualities have been an issue with boom systems). All flight conditions are addressed, including but not limited to: altitude, airspeed, weather (including turbulence), air vehicle maneuvering and interface transitioning to/from the stowed/extended positions.

Method of Compliance: Verification methods include analysis, test, simulation and review of documentation. Satisfactory flight stability and handling qualities of each aerial refueling interface are verified by design and/or simulation analysis and flight test data including crewmember evaluations.

References: JSSG-2001: 3.1.1.1.1, 3.3.11.1.1

8.7.1.11 Computer system integration.

Criterion: Verify that any aerial refuel system function which is supported by computer systems is compliant with Section 15.

Standard: Computer system hardware/software in each aerial refueling system is developed under appropriate processes which take into consideration the safety aspects of the aerial refueling process. The computer hardware/software development process adequately accommodates the criticality of the aerial refueling system function(s) and considers potential hazards to the tanker/receiver aircraft during the aerial refueling process in single/multi-receiver aerial refueling formations.

Method of Compliance: See Section 15.

References: JSSG-2008
MIL-STD-882
RTCA DO-178
RTCA DO-254

8.7.1.12 Equipment safing.

Criterion: Verify that any system on the air vehicle, which if active during the aerial refueling process could create a hazard to the targeted tanker/receiver(s) or to the crew/personnel of the targeted tanker/receiver(s), can be adequately inhibited/disengaged prior to the air vehicle entering the aerial refueling process.

Standard: Any system on the air vehicle, which if active during the aerial refueling process could create a hazard to the targeted tanker/receiver(s) or the crew/personnel of the targeted tanker/receivers(s) can be adequately inhibited/disengaged prior to the air vehicle entering the aerial refueling process. Such potential systems include, but are not limited to, radar, offensive, defensive countermeasure, pod jettisoning and aerial refueling hose jettisoning systems.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Analyses identify those air vehicle systems which, if permitted to be activated/engaged during the aerial refueling process, may be hazardous to the targeted tanker/receiver(s) and their crews/personnel. Analyses of these systems identify methods to inhibit/disengage the appropriate system(s) prior to air vehicle entering the aerial refueling process.

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2

8.7.1.13 Spatial clearance between participating vehicles.

Criterion: Verify that adequate clearance is provided between the air vehicle and the tanker/receiver(s) participating in the aerial refueling process.

Standard: Adequate clearance is provided between the air vehicle and the tanker/receiver(s) participating in the aerial refueling process. For probe-drogue systems, evaluation considers tanker/receiver and receiver/receiver (if applicable) clearance at each drogue system's contact, fuel transfer, and inner limit positions. Evaluations consider contact positions with hose empty and hose full of fuel. For boom-receptacle systems, evaluation considers tanker/receiver and receiver/receiver (if applicable) clearance at each boom system's contact, fuel transfer, and inner limit positions. Evaluations consider fuel transfers with the receiver positioned at the boom system's disconnect limits (elevation, lateral, and extension).

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis of spatial clearances, inspection of drawings and flight test documentation (photo/video) verify that there is adequate tanker/receiver and receiver/receiver (if applicable) clearance during the aerial refueling process.

References: JSSG-2001: 3.4.6.2.1, 3.4.6.2.2

8.7.2 Safe installation and operation.

Criterion: Verify that each aerial refueling system can be installed and operated (normal and single-failure conditions) without causing loss of the air vehicles (tanker and receiver[s]) or creating a potential hazard to personnel in the identified environment (induced and natural).

Standard: Normal operation or single failure conditions of the aerial refueling systems do not cause loss of the air vehicles or create potential hazards to personnel in identified environments including all flight and ground conditions. Areas addressed include but are not limited to: the hydraulic, environmental control, structure, fuel, and vehicle management systems.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis of the system, FMECA, inspection of drawings and ground/flight tests verify aerial refueling systems do not cause loss of the air vehicles or create potential hazards to personnel.

References: JSSG-2009: 3.2.7.4.4.1, 4.2.7.4.4.1; 3.2.7.4.4.2, 4.2.7.4.4.2; 3.3.8, 4.3.8

8.7.2.1 Minimization of hazards.

Criterion: Verify that the aerial refueling system has been designed to minimize the hazards from lightning, static electricity, fuel leaks, ignition sources, and ground potential.

Standard: The aerial refueling system is designed to minimize the hazards caused by direct lightning strikes, static electricity, fuel leaks, ignition sources, and ground potential (see also 8.3 and 8.4, this document).

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Analysis of design, Safety Hazard Analysis, inspection of drawings, and laboratory tests verify risks are within defined acceptable limits.

References: JSSG-2009: E.3.4.5.8.11, E.4.4.5.8.11; F.3.4.6.1.7, F.4.4.6.1.7; G.3.4.7.2, G.4.4.7.2; G.3.4.7.3, G.4.4.7.3; G.3.3.4.7.6, G.4.4.4.7.6
MIL-HDBK-516: 8.3, 8.4

8.7.2.1.1 Receptacle pressure box.

Criterion: For receptacle installations, verify that a pressure box is provided and any fluids that collect in this box do not migrate into adjacent compartments.

Standard: The receptacle installation has a pressure box below it to collect fluids, including fuel spray that may occur during aerial refueling. The pressure box prevents migration of the fluids or vapors to hazardous ignition zones or occupied areas.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. The criterion is verified by inspection of drawings which validate the presence of the pressure box. Fuel- and vapor-containment capabilities of the pressure box are verified by analysis and test.

References: JSSG-2009: 3.3.8, 4.3.8; F.3.4.6.2.2.4, F.4.4.6.2.2.4

8.7.2.1.2 Receptacle pressure box drainage.

Criterion: For receptacle installations, verify that the collected fluids within the pressure box are capable of being drained safely in ground and flight conditions.

Standard: The receptacle installation has a pressure box below it that allows safe drainage of fluids, including fuel spray that may occur during aerial refueling. Safe drainage occurs during ground and flight conditions.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Analysis, ground demonstration, flight test and post-flight inspections verify fluids which collect within the pressure box are capable of being drained without causing hazards to the air vehicle, other aircraft, or personnel.

References: JSSG-2009: 3.3.8, 4.3.8; F.3.4.6.2.2.3, F.4.4.6.2.2.3

8.7.2.1.3 Probe installation trough.

Criterion: For probe installations (retractable), verify that a probe trough is provided and any fluids that collect in this compartment do not migrate into adjacent compartments.

Standard: The probe installation has a trough (e.g., probe bay, probe compartment) below it to collect fluids, including fuel spray that may occur during aerial refueling. The probe trough prevents migration of the fluids or vapors to hazardous ignition zones or occupied areas.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. The criterion is verified by inspection of drawings which validate the presence of the probe trough. Fuel- and vapor-containment capabilities of the probe trough are verified by analysis and test.

References: JSSG-2009: 3.3.8, 4.3.8; F.3.4.6.2.3.3, F.4.4.6.2.3.3

8.7.2.1.4 Probe trough drainage.

Criterion: For probe installations (retractable), verify that the collected fluids within the probe trough are capable of being drained safely in ground and flight conditions.

Standard: The probe installation has a trough (e.g., probe bay, probe compartment) below it that allows safe drainage of fluids, including fuel spray that may occur during aerial refueling. Safe drainage occurs during ground and flight conditions.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Analysis, ground demonstration, flight test and post-flight inspections verify fluids which collect within the probe trough are capable of being drained without causing hazards to the air vehicle, other aircraft, or personnel.

References: JSSG-2009: 3.3.8, 4.3.8; F.3.4.6.2.3.3, F.4.4.6.2.3.3

8.7.2.1.5 Refueling pod ventilation.

Criterion: For aerial refueling pods, verify that there is adequate air flow/exchange within the pod to preclude the buildup of a flammable vapor within the pod.

Standard: Active ventilation provides at least 1 volumetric air change per minute for flammable leakage zones and 2 to 3 volumetric air changes per minute for fire zones.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis or test for flight and ground conditions verifies that adequate ventilation is provided to minimize flammability.

References: JSSG-2009: 3.3.8, 4.3.8

8.7.2.1.6 Refueling pod drainage.

Criterion: Verify that all fluids that can be collected within the pod are capable of being drained safely.

Standard: Collected fluids within the aerial refueling pod are capable of being drained without causing hazards to the air vehicle, other aircraft or creating a potential hazard to personnel.

Method of Compliance: Verification methods include analysis, test, demonstration and review of documentation. Analysis, drainage demonstration and flight test verifies collected fluids within the aerial refueling pod are capable of being drained without causing hazards to the air vehicle, other aircraft or creating a potential hazard to personnel.

References: JSSG-2009: 3.3.8, 4.3.8

8.7.2.1.7 Refueling pump dry run capability.

Criterion: Verify that a dry-run condition with an aerial refueling pump does not create a potential ignition source.

Standard: A dry-run condition with an aerial refueling pump does not create a potential ignition source during ground and flight operations.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Analysis of design, inspection of installation, and laboratory/ground/flight test verify that a dry-run condition with an aerial refueling pump does not create a potential ignition source.

References: JSSG-2009: 3.3.3, 4.3.3; F.3.4.6.1.7, F.4.4.6.1.7; G.3.4.7.23, G.4.4.7.23

8.7.2.1.8 Secondary barrier.

Criterion: Verify that there is a secondary liquid- and vapor-tight barrier between the aerial refueling fuel tanks and identified fire hazard areas/inhabited areas.

Standard: Dual vapor and liquid-proof barriers are installed between aerial refueling tanks and other zones on the aircraft that contain ignition sources (e.g., avionics bays, sensor bays) and inhabited areas. Provisions are made to allow detection of fuel leakage across the primary barrier.

Method of Compliance: Verification methods include analysis, test, demonstration and review of documentation. Analysis and component tests verify performance of the primary and secondary fuel and vapor tight barriers. Engineering test models verify performance of the fault isolation provisions to detect a failure of the primary fuel barrier. Ground demonstration verifies adequacy of the secondary barrier design to isolate and remove flammable vapors to a safe location.

References: JSSG-2009: E.3.4.5.6.11, E.4.4.5.6.11; F.3.4.6.1.6, F.4.4.6.1.6; F.3.4.6.1.7, F.4.4.6.1.7
MIL-HDBK-516: 8.4

8.7.2.1.9 Static discharge tolerance.

Criterion: Verify that each aerial refueling system can withstand the static discharge typically encountered during the engagement of tanker and receiver interfaces.

Standard: Each aerial refueling system involved in an engagement is designed to accommodate/dissipate the static discharge resultant of the electrical potential difference of the two aircraft.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis of design, inspection of drawings, and laboratory tests verify each aerial refueling system can withstand the static discharge encountered during the engagement of tanker and receiver interfaces.

Reference: JSSG-2001: 3.2.3

8.7.2.1.10 Lightning strike tolerance.

Criterion: Verify that each aerial refueling system, in the open/deployed position and in the closed/retracted position, is designed to withstand the appropriate lightning strike criteria.

Standard: Each aerial refueling system, in the open/deployed position and in the closed/retracted position, is designed to withstand lightning strikes without causing damage to air vehicle as appropriate, loss of air vehicle, or creating hazards to personnel.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Analysis of design, inspection of drawings, and laboratory tests verify each aerial refueling system, in the open/deployed position and in the closed/retracted position, is designed to withstand lightning strikes without causing damage to air vehicle or creating hazards to personnel.

References: JSSG-2001: 3.2.1, 3.3.10.1.1
JSSG-2009: G.3.4.7.6, G.4.4.7.6
14 CFR 23.954, 25.954

8.7.2.2 Air vehicle flight control/handling qualities.

Criterion: Verify that the flight control/handling qualities of the air vehicle are not adversely affected when the aerial refueling system is installed or operating under normal and single-failure conditions during all phases of flight.

Standard: The flight control/handling qualities of the air vehicle are not adversely affected when the aerial refueling system is installed or operating under normal and single-failure conditions during all phases of flight. Areas addressed include but are not limited to:

a. Receiver receptacle installations: the opening/closing of receptacle/slipway doors or the transition of roll-over installations during opening and closing.
b. Tanker boom subsystems: moving the boom from the “stowed” position and moving it throughout its control envelope (prior to receiver engagement and after a contact has been made).
c. Receiver probe installations: all positions and transitions between the “stowed” and “fully extended” positions.
d. Tanker drogue subsystems: all positions and transitions between the “stowed” and “fully extended” positions (with and without fuel in the hose).

Phases of flight include before, during and after aerial refueling operations (including landing).

For air vehicles with multiple aerial refueling systems, a single failure of each aerial refueling interface to operate properly is considered (see also 6.1, this document).

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Analysis of system design, ground and flight demonstration verify the flight control/handling qualities of the air vehicle are not adversely affected when the aerial refueling system is installed or operating under normal and single-failure conditions during all phases of flight (see also 6.1, this document).

References: JSSG-2001: 3.3.11.1.1.1
MIL-HDBK-516: 6.1

8.7.2.2.1 Flight control/handling qualities degradation.

Criterion: Verify that the flight control/handling qualities of the air vehicle are not degraded below safe limits, and the air vehicle can safely land when an aerial refueling system cannot be returned to its fully stowed configuration.

Standard: Flight control/handling qualities of the air vehicle are not degraded to the point of causing loss of air vehicle or creating hazards to personnel. The air vehicle can land when the system cannot be returned to its fully stowed configuration without causing loss of air vehicle or creating hazards to personnel.

Method of Compliance: Verification methods include analysis, demonstration and review of documentation. System design analysis, FMECA, and flight demonstration verify flight control/handling qualities of the air vehicle are not degraded to the point of causing loss of air vehicle or creating hazards to personnel when an aerial refueling system cannot be returned to its fully stowed configuration. For air vehicles with multiple aerial refueling systems, the analysis and flight demonstration are completed with each aerial refueling system.

References: JSSG-2001: 3.3.11.1.1.1

8.7.2.2.2 Ram air turbine failure.

Criterion: For aerial refueling pods, verify that any ram air turbine (RAT) failure mode does not degrade flight control/handling qualities of the air vehicle below acceptable limits.

Standard: Any RAT failure mode; including but not limited to failure to feather, failure to unfeather, and separation of blade(s); does not degrade flight control/handling qualities of the air vehicle to the point of causing loss of air vehicle or creating hazards to personnel. All phases of flight operation are addressed including landing.

Method of Compliance: Verification methods include analysis, test and review of documentation. System design analyses, FMECA, and laboratory tests verify any RAT failure mode does not degrade flight control/handling qualities of the air vehicle to the point of causing loss of air vehicle or creating hazards to personnel.

References: JSSG-2009: F.3.4.6.1.1, F.4.4.6.1.1; F.3.4.6.1.2, F.4.4.6.1.2

8.7.2.2.3 Jettison of stores/pods.

Criterion: Verify that when dictated by mission requirements, it is possible to safely jettison the aerial refueling stores/pods upon command by the aircrew/operator without resulting in unsafe flying qualities of the air vehicle.

Standard: The in-flight jettisoning of an aerial refueling store/pod can be safely accomplished when commanded by the tanker aircrew/operator. The jettison event does not result in damage to, or unsafe flying qualities of, the air vehicle.

Method of Compliance: Verification methods include analysis, test, and review of documentation. See 17.2.2 of this document. System design analyses, computational fluid dynamics (CFD) modeling, wind tunnel, and flight tests verify that the jettisoning of an aerial refueling store/pod does not result in damage to, or unsafe flying qualities of, the air vehicle. For air vehicles with multiple aerial refueling stores/pods, compliance verification is completed with each store/pod.

References: JSSG-2001: 3.3.11.1.1 through 3.3.11.1.3
JSSG-2009: F.3.4.6.1.1, F.4.4.6.1.1
MIL-HDBK-516: 17.2.2
MIL-STD-1797

8.7.2.2.4 Hose jettison function.

Criterion: For drogue aerial refueling systems, verify that any aerial refueling hose, or any portion of the hose, can be safely and timely jettisoned when commanded by the aircrew/operator without resulting in unsafe flying qualities of the air vehicle.

Standard: The in-flight jettisoning of an aerial refueling hose, or any portion of the hose (including coupling and drogue basket/canopy), can be safely and timely accomplished when commanded by the tanker aircrew/operator. The jettison event does not result in damage to, or unsafe flying qualities of, the air vehicle.

Method of Compliance: Verification methods include analysis, test, and review of documentation. System design analyses, CFD modeling, wind tunnel, and flight tests verify that the jettisoning of an aerial refueling hose, or any portion of an aerial refueling hose, does not result in damage to, or unsafe flying qualities of, the air vehicle. System design analyses, wind tunnel, and flight test verify acceptability of hose jettison sequence time. For air vehicles with multiple drogue aerial refueling systems, compliance verification is completed with each aerial refueling hose.

References: JSSG-2001: 3.3.11.1.1–3.3.11.1.3
JSSG-2009: F.3.4.6.1.1, F.4.4.6.1.1
MIL-STD-1797

8.7.2.3 Egress with unstowed equipment.

Criterion: Verify that in-flight egress, ground emergency egress, and assisted egress of any crewmember or passenger are not affected when the aerial refueling system cannot be returned to its fully stowed configuration.

Standard: In-flight egress, ground emergency egress, and assisted egress of any crewmember or passenger are not hindered when the aerial refueling system cannot be returned to its fully stowed configuration (see also 9.1.2 of this document).

Method of Compliance: Verification methods include analysis, demonstration and review of documentation. Analyses and demonstration verify in-flight egress, ground emergency egress, and assisted egress of any crewmember or passenger are not hindered when the aerial refueling system cannot be returned to its fully stowed configuration

References: JSSG-2009: F.3.4.6.1.1, F.4.4.6.1.1; F.3.4.6.1.2, F.4.4.6.1.2
MIL-HDBK-516: 9
14 CFR 25.1309

8.7.2.4 Built-in-test and fault isolation.

Criterion: Verify that built-in-test (BIT) and fault isolation provisions are available to appropriate crewmember(s)/operator(s)/maintenance personnel to ensure safe ground or in-flight operations under all configuration options.

Standard: Built-in-test (BIT) and fault isolation provisions are available to appropriate crewmember(s)/operator(s)/maintenance personnel during ground or in-flight operations under all configuration options without causing loss of air vehicle or creating hazards to personnel.

Method of Compliance: Verification methods include test, demonstration, inspection and review of documentation. Inspection of technical data verifies BIT and fault isolation capabilities are provided. Demonstration verifies BIT and fault isolation provisions are available/accessible to appropriate personnel. Testing verifies proper operation and indication of BIT and fault isolation capabilities.

References: JSSG-2009: F.3.4.6.2.2.2, F.4.4.6.2.2.2; F.3.4.6.2.3.2, F.4.4.6.2.3.2

8.7.3 Removal of aerial refueling hardware.

Criterion: Verify that the removal (due to maintenance action) of any hardware associated with an aerial refueling system does not adversely affect the safety of the air vehicle during all phases of flight.

Standard: Safety of the air vehicle during all phases of flight is not adversely affected by the removal (due to maintenance) of Group B hardware associated with an aerial refueling system. Group B hardware includes, but is not limited to, removable aerial refueling stores/pods, palletized aerial refueling systems, removable aerial refueling fuel tanks, boom-to-drogue adapters, and non-permanent probe installations.

Method of Compliance: Verification methods include analysis, demonstration and review of documentation. Analysis of system design and flight demonstration verify that the flight control/handling qualities of the air vehicle are not adversely affected by the removal of Group B hardware associated with aerial refueling systems. For air vehicles with multiple Group B hardware, the analysis and flight demonstration consider all possible configurations due to the different combinations of Group B removals.

Reference: JSSG-2001: 3.3.11.1.1.1

8.7.3.1 Group B removal effect on other-system interfaces.

Criterion: When Group B aerial refueling hardware is removed, verify that interfaces with other systems (e.g., electrical, hydraulic and fuel) are properly covered, sealed, isolated, etc., to preclude introducing a new leak or ignition source in the air vehicle.

Standard: Upon removal of Group B aerial refueling hardware, interfaces with other systems (e.g., electrical, hydraulic and fuel) are properly covered, sealed, isolated, etc., to preclude providing a new leak or ignition source in the air vehicle.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis of technical data verifies that interfaces have proper coverage, sealant and/or isolation. Component tests demonstrate that interfaces will not leak or be a source of ignition. Inspection of the air vehicle verifies that coverage, sealant and/or isolation are provided. Aircraft leak tests completed on fluid system interfaces confirm no source of leakage at interface.

References: JSSG-2009: F.3.4.6.1.5, F.4.4.6.1.5; G.3.4.7.3, G.4.4.7.3

8.7.3.2 Group B removal effect on air vehicle flying qualities.

Criterion: Verify that the air vehicle's flying qualities are acceptable when Group B aerial refueling hardware is removed.

Standard: The air vehicle's flying qualities are acceptable when Group B aerial refueling hardware is removed (see 6.1, this document).

Method of Compliance: Verification methods include analysis, demonstration and review of documentation. Analysis of system design and flight demonstration verifies that the flying qualities of the air vehicle are not adversely affected by the removal of Group B hardware associated with an aerial refueling system. For air vehicles with multiple Group B hardware, the analysis and flight demonstration evaluate all possible configurations due to the different combinations of Group B removals.

References: JSSG-2001: 3.3.11.1.1–3.3.11.1.3
JSSG-2009: F.3.4.6.1.5, F.4.4.6.1.5
MIL-STD-1797
MIL-HDBK-516: 6.1

8.7.3.3 Group B removal effect on operation of other systems.

Criterion: Verify that the removal of the Group B aerial refueling hardware does not adversely affect the operation of other systems (e.g., electrical, hydraulic, and fuel) on the air vehicle and/or on the targeted tanker(s)/receiver(s) during, and subsequent to, the aerial refueling process.

Standard: The removal of the Group B aerial refueling hardware does not adversely affect the operation of other systems on the air vehicle and/or on the targeted tanker(s)/receiver(s) during, and subsequent to, the aerial refueling process.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis and test of aerial refueling and other air vehicle systems validate that the removal of Group B hardware associated with an aerial refueling system does not affect the operation of other systems on the air vehicle and/or the targeted tanker(s)/receiver(s). For air vehicles with multiple Group B hardware, the analysis and test evaluate all possible configurations due to the different combinations of Group B removals.

References: JSSG-2001: 3.3.11.1.1–3.3.11.1.3
JSSG-2009: F.3.4.6.1.5, F.4.4.6.1.5
MIL-STD-1797

8.7.4 Design and performance requirements.

Criterion: Verify that each aerial refueling system, as installed, can meet its design and performance requirements when operated within the specified parameters.

Standard: The aerial refueling system, as installed, meets its design and performance requirements when operated within the specified parameters. Factors considered include: airspeed/altitude envelope, natural and induced environmental conditions, aerial refueling procedures/tactics, identified targeted tanker(s)/receiver(s), single failure modes and fault isolation capabilities of each aerial refueling system.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis, functional ground tests, and flight test verify that the aerial refueling system operates as required. Ground testing includes the operation of the system on the aircraft and the system while coupled to the targeted tanker/receiver air vehicle(s) or while coupled to a simulated tanker/receiver air vehicle. Flight testing includes the operation of the system on the aircraft and the system while coupled to the targeted tanker/receiver air vehicle(s).

References: JSSG-2009: F.3.4.6.1.5, F.4.4.6.1.5

8.7.4.1 Exposure of components to proof pressure.

Criterion: Verify that the plumbing/components in each aerial refueling system (as completely assembled and installed within the air vehicle) can withstand exposure to the specified proof pressure limit without resulting in fuel leakage and system performance degradation.

Standard: Plumbing/components in each aerial refueling system (as completely assembled and installed within the air vehicle) can withstand exposure to the specified proof pressure limit without resulting in fuel leakage and system performance degradation. Proof pressure is defined as: a minimum pressure in which the fuel system may function satisfactorily including pressure transients (surges) up to a value in which the aircraft can continually sustain throughout the life of the aircraft without any external leakage, failure and/or malfunction, or permanent deformation.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis and ground tests verify plumbing/components in each aerial refueling system (as completely assembled and installed within the air vehicle) can withstand exposure to the specified proof pressure limit without resulting in fuel leakage and system performance degradation.

References: JSSG-2009: F.3.4.6.1.3, F.4.4.6.1.3
ARSAG International Document No. 00-03-01

8.7.4.2 Functional modes.

Criterion: Verify that critical operational functions and functional modes are adequately provided in the aerial refueling system to ensure that the aerial refueling process can be conducted safely.

Standard: Critical operational functions and functional modes are provided in the aerial refueling system to conduct the aerial refueling process without causing loss of aircraft or creating hazards to personnel.

RECEIVERS:

a. Receptacle subsystems have, as a minimum, the operational function of DISCONNECT (initiates a disconnect from the boom subsystem), a RESET function (changes receptacle system from DISCONNECT status to READY status), the operational modes of NORMAL/OVERRIDE (signal amplifier modes), a "PRE-CHECK" function (verifies operation of refuel valves), a “through the boom” communication capability, the capability to transition the receptacle from its open/close positions, and a reverse aerial refueling capability (if applicable).
b. Probe subsystems have, as a minimum, probe extension/retraction function (if applicable) and a "PRE-CHECK" function (verifies functionality of refuel valves).

TANKERS:

a. Boom subsystems have, as a minimum, fuel transfer control, fuel pressure regulation, boom control, tanker internal fuel management (including unique fuel isolation, if applicable), manual/automatic DISCONNECT function, a “through the boom” communication capability, load alleviation capability, independent disconnect capability, aircrew/operator viewing capability (if applicable), capability to transition the boom from stowed/deployed positions and a reverse aerial refueling capability (if applicable).
b. Drogue subsystems have, as a minimum, fuel transfer control, fuel pressure regulation, hose extension/retraction function, hose response capability, tanker internal fuel management (including unique fuel isolation), hose jettison capability, aircrew/operator viewing capability (if applicable), and pod jettison capability (if applicable).

Method of Compliance: Verification methods include analysis, demonstration and review of documentation. Analysis of technical data verifies that functional modes have been provided. Ground and flight demonstrations verify that the functional modes permit aerial refueling to be conducted without causing loss of aircraft or creating hazards to personnel.

References: JSSG-2009: F.3.4.6.2.2.7, F.4.4.6.2.2.7; F.3.4.6.2.3.1.2, F.4.4.6.2.3.1.2

8.7.4.3 Control provisions.

Criterion: Verify that controls are provided and properly located for the appropriate crewmember(s)/operator(s) to activate and control those critical system functions that are required to conduct the aerial refueling process safely.

Standard: Controls are provided and properly located for the appropriate crewmember(s)/operator(s) to activate and control the critical system functions that are required to conduct the aerial refueling process safely. For aerial refueling system controls the following are provided:

RECEIVERS:

a. Receiver receptacle subsystems have, as a minimum, the following:
   (1) Press-to-Test (verify mode/status indicators properly working).
   (2) DISCONNECT (initiates a disconnect from the boom subsystem).
   (3) RESET (changes mode from DISCONNECT to READY).
   (4) Receptacle slipway lighting turns slipway lighting on/off and controls lighting intensity/mode.
   (5) Open and close receptacle doors.
   (6) Manual boom latch, if applicable.

b. Probe subsystems have, as a minimum:
   (1) A probe lighting control turns probe lighting on/off and controls lighting intensity/mode.
   (2) A probe extension/retraction control (retractable probe installations only.)

TANKERS:

a. Boom subsystems have, as a minimum, the following:
   (1) Aerial refueling pump activation.
   (2) Fuel transfer control.
   (3) Boom deployment/stowage.
   (4) Boom control.
   (5) Tanker internal fuel management.
   (6) Boom nozzle/receptacle DISCONNECT.
   (7) System status RESET.
   (8) Emergency contact (permits engagement with a failure in the boom/receptacle status signal system).

b. Drogue subsystems have, as a minimum, the following:
   (1) Aerial refueling pump activation (if applicable).
   (2) Fuel transfer control.
   (3) Hose extension/retraction.
   (4) Tanker internal fuel management.
   (5) Hose jettison capability.
   (6) Pod jettison capability (if applicable).

For controls of other systems (such as interior/exterior lighting, communication, and viewing systems) used during the aerial refueling process, refer to 9.2.1, 9.2.2, 9.2.4, and 9.2.5 (this document).

Method of Compliance: Verification methods include analysis, demonstration, inspection, simulation and review of documentation. Inspection and analysis of technical data and evaluation of the system by crewmember(s)/operator(s)/automated system(s) during ground simulation/mock-up and flight demonstration verify that controls are provided and properly located.

References: JSSG-2009: F.3.4.6.2.1.3, F.4.4.6.2.1.3
JSSG-2010: 3.2.14, 4.2.14
MIL-HDBK-516: 9.2

8.7.4.4 Display provisions.

Criterion: Verify that displays are provided and properly located for the appropriate crewmember(s)/operator(s) to indicate the necessary information to conduct the aerial refueling operation safely.

Standard: Displays are provided and properly located for the appropriate crewmember(s)/operator(s) to indicate all necessary information to conduct the aerial refueling operation safely; including Warnings, Cautions, and Advisories. For aerial refueling system displays the following, as a minimum, are provided:

RECEIVERS:

a. Receptacle subsystems have the standard refueling status indicators with the standard color code of lights; i.e., READY (Aviation white/light blue), CONTACT (Green), and DISCONNECT (Amber). Receptacle subsystems have an indicator for receptacle position (OPEN/CLOSED) and functional mode (NORMAL/OVERRIDE).
b. Probe subsystems have an indicator for probe position (EXTENDED/RETRACTED).

TANKERS:

a. Boom subsystems have an indicator for:
    (1) Fuel transfer rates and delivery pressures.
    (2) Boom position.
    (3) Load alleviation status (if applicable).
    (4) Boom flight control system mode (if applicable).
    (5) Boom nozzle load (if applicable).
    (6) Functional mode (NORMAL/OVERRIDE).
    (7) System status (READY, CONTACT, DISCONNECT).
b. Drogue subsystems have indicators for:
    (1) Subsystem operational status (i.e., ON/OFF, EXTEND, TRAIL, REWIND, STOWED).
    (2) Fuel transfer rates and delivery pressures (if applicable).
    (3) Ram air turbine speed (if applicable).
    (4) Fuel temperature (if applicable).
    (5) Hydraulic pressure (if applicable).

For displays of other systems used during the aerial refueling process, refer to 9.2.1 and 9.2.3 (this document).

Method of Compliance: Verification methods include analysis, demonstration, inspection, simulation and review of documentation. Inspection and analysis of technical data and evaluation of the system by crewmember(s)/operator(s)/automated system(s) during ground simulation/mock-up and flight demonstration verify that displays are provided and properly located.

References: JSSG-2010: 3.2.13, 4.2.13
MIL-HDBK-516: 9

8.7.4.5 Display lighting.

Criterion: Verify that display lights are variable intensity and, if applicable, NVIS compatible.

Standard: Display lights used during aerial refueling are of variable intensity and, if applicable, NVIS compatible. Detailed standards for display light control and intensity are included in 9.3.2 and 9.3.4 (this document) respectively.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Analysis of technical data and evaluation of the system by crewmember(s)/operator(s)/automated system(s) during ground simulation, ground test, and flight demonstration verify that display lights are of variable intensity and, if applicable, NVIS compatible.

References: JSSG-2010: 3.5.2.1.2, 4.5.2.1.2
MIL-HDBK-516: 9

8.7.5 Compatibility with other systems.

Criterion: Verify that the installation and operation of each aerial refueling system (normal/single-failure conditions) does not negatively affect the operation of other systems on the air vehicle or on the targeted tanker(s)/receiver(s) throughout the mission(s) of the air vehicle or the targeted tanker(s)/receiver(s).

Standard: Installation and operation of each aerial refueling system (normal/single-failure conditions) do not negatively affect the operation of other systems on the air vehicle or on the targeted tanker(s)/receiver(s) throughout the mission(s) of the air vehicle or the targeted tanker(s)/receiver(s). Examples include, but are not limited to: proper release of offensive weapons, release of defensive countermeasures, jettisoning of external stores, crew escape, air vehicle flight control systems, fuel management, etc.

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Ground tests, flight tests, and analysis of drawings and technical data verify that installation and operation of each aerial refueling system do not negatively affect operation of other systems.

References: JSSG-2009: F.3.4.6.1.1, F.4.4.6.1.1

8.7.5.1 Common fuel line leakage.

Criterion: If there are common fuel lines associated with an aerial refueling system and the air vehicle's fuel system and/or other aerial refueling system(s), verify that if leakage occurs from the common plumbing during system operation, no ground or flight hazards are created.

Standard: For air vehicles where there are common fuel lines associated with an aerial refueling system and the air vehicle's fuel system and/or other aerial refueling system(s), no ground or flight hazards are created if leakage occurs from the common plumbing during system operation. Consider, as a minimum, leakage due to a failure of the sealing mechanism at the single-point refueling adapter, at the pressure defueling adapter, or at the other aerial refueling system interface(s).

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis of technical data, FMECA, and ground testing verifies no ground or flight hazards are created if leakage occurs in the air vehicle fuel system and/or other aerial refueling system plumbing during aerial refueling operations.

References: JSSG-2009: F.3.4.6.1.6, F.4.4.6.1.6

8.7.5.2 Isolation for unique fuel.

Criterion: For tankers carrying a unique fuel for the designated receiver air vehicle(s), which cannot be utilized by the tanker's propulsion system(s), verify that there is adequate isolation of the aerial refueling system from the tanker's fuel system.

Standard: Tanker air vehicles, which carry unique fuel(s) for their targeted receiver air vehicle(s), provide adequate isolation of any unique fuel(s) from the tanker air vehicle's fuel system if the tanker air vehicle's own propulsion system(s) is(are) not compatible with the unique fuel(s).

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Analysis of technical data, inspection, and ground testing verify proper isolation of the aerial refueling system from the tanker's fuel system.

References: JSSG-2009: F.3.4.6.1.6, F.4.4.6.1.6

8.7.5.3 Data communication system.

Criterion: Verify that any data communication system provided on the air vehicle for aerial refueling purposes is compatible with:

a. the flight control system on the air vehicle,
b. other electrical systems on the air vehicle,
c. the flight control and electrical systems on the targeted tanker(s)/receiver(s), and
d. personnel (ground and aircrew).

Standard: Any data communication system provided on the air vehicle for aerial refueling purposes does not adversely affect the function of:

a. the flight control system on the air vehicle,
b. other electrical systems on the air vehicle,
c. the flight control and electrical systems on the targeted tanker(s)/receiver(s), and
d. personnel (ground and aircrew) (see also 9.2.7 and 9.2.8, this document).

Method of Compliance: Verification methods include analysis, test and review of documentation. Ground test, flight test and analysis of technical data verify that the data communication system does not adversely affect the function of:

a. the flight control system on the air vehicle,
b. other electrical systems on the air vehicle,
c. the flight control and electrical systems on the targeted tanker(s)/receiver(s), and
d. personnel (ground and aircrew).

References: JSSG-2001: 3.4.7.2.1, 3.4.7.2.2
MIL-HDBK-516: 9

8.7.5.4 Field of view.

Criterion: Verify that the field of view of the crew member(s)/operator(s)/automated system(s) is adequate during landing and during other critical flight phases when an aerial refueling system is installed, is operating, or fails to return to the fully stowed configuration.

Standard: The field of view is not obstructed by the following conditions: retractable probes remaining extended, receptacle doors remaining open, hoses extended, booms remaining extended and/or unstowed, fixed probes, stowed boom, etc. The preceding is not an exclusive list (see also Section 9.2.1.2)

Method of Compliance: Verification methods include analysis, demonstration and review of documentation. Analysis of models/simulation, ground and flight demonstration verify that the field(s) of view of the crew member(s)/operator(s)/automated system(s) is adequate during landing or other critical flight phases when an aerial refueling system is installed, is operating, or fails to return to the fully stowed configuration.

References: JSSG-2010: 3.3.2.1, 4.3.2.1
MIL-HDBK-516: 9

8.7.5.5 Effects of leaks on interfaced fuel systems.

Criterion: When the plumbing of the aerial refueling system interfaces with the fuel system plumbing of the air vehicle, verify that a leak in the aerial refueling system plumbing does not adversely affect the fuel system's fuel management functions (e.g., engine feed, thermal management, center of gravity control).

Standard: AR system interfaces with the air vehicle fuel system are identified. Failure modes have been assessed to show that a leak in the aerial refueling system plumbing does not adversely affect the fuel system's fuel management functions, including, but not limited to: engine feed, thermal management and center of gravity control. Leaks from the aerial refueling system do not prevent continuation of safe flight and landing.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis of technical data combined with ground testing verifies that when the plumbing of the aerial refueling system interfaces with the fuel system plumbing of the air vehicle, a leak in the aerial refueling system plumbing does not adversely affect the fuel system's fuel management functions.

References: JSSG-2009: F.3.4.6.1.1, F.4.4.6.1.1, F.3.4.6.1.5, F.4.4.6.1.5

8.7.5.6 Effects of electrical failure(s).

Criterion: Verify that electrical failures within the aerial refueling system do not adversely affect the air vehicle electrical system or any other system.

Standard: Failure modes associated with the aerial refueling system's electrical system have been assessed to show that the air vehicle's electrical system, or any other system, is not adversely affected. Failures in the aerial refueling electrical system do not prevent continuation of safe flight and landing.

Method of Compliance: Verification methods include analysis, test, inspection and review of documentation. Inspection of drawings, analysis, FMECA and ground test verify that electrical failures within the aerial refueling system do not adversely affect the air vehicle electrical system or any other system.

References: JSSG-2009: F.3.4.6.1.1, F.4.4.6.1.1

8.7.5.7 Operation with interfaced fuel/hydraulic systems.

Criterion: When aerial refueling (AR) components interface with the air vehicle fuel or hydraulic system, verify that pressures and temperatures within the fuel/hydraulic system remain within safe limits under normal aerial refueling operations and single-failure conditions.

Standard: AR system interfaces with the air vehicle fuel or hydraulic system are identified and failure modes assessed. Aerial refueling system pressures and/or temperatures remain within safe limits under normal and single failure conditions, and do not adversely affect the air vehicle operation. Typical components for consideration include, but are not limited to: RAT-driven pumps in aerial refueling pods, aerial refueling pumps, probe door actuation/retraction mechanisms, probe extension/retraction mechanisms, receptacle door actuation/retraction mechanisms, and receptacle latch actuation/retraction mechanisms.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis of technical data, FMECA, and ground test verify fuel/hydraulic system components that interface with the aerial refueling system operate within defined safe limits under normal aerial refueling operations and single-failure conditions.

References: JSSG-2009: F.3.4.6.1.1, F.4.4.6.1.1

8.7.5.8 Compatibility with vehicle fuel management functions.

Criterion: Verify that the off-loading of fuel through any tanker aerial refueling system at its maximum flow rate, and the on-loading of fuel through any receiver aerial refueling system at its maximum rate, does not adversely affect the air vehicle's fuel management functions (e.g., engine fuel feed and fuel center of gravity).

Standard: Proper fuel flow to each powerplant system, and the aircraft center of gravity, are not adversely affected by maximum off-load/on-load fuel flow rates (see also 8.3.7 and 8.3.8, this document).

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis indicates that engine fuel flow is not degraded and center of gravity limits are not exceeded for all in-flight fuel on-loading/off-loading conditions with each aerial refueling system (e.g., fuel dumping or refueling through each aerial refueling system). Ground calibration tests verify fuel gauging system accuracy during on-loading/off-loading conditions. Ground and flight tests verify the performance of the air vehicle computer management system and crewmember/operator control interfaces during on-loading/off-loading fuel scenarios.

References: JSSG-2009: E.3.4.5.5, E.4.4.5.5
MIL-HDBK-516: 8.3
14 CFR 23.1001, 25.1001

8.7.5.9 Fuel management with unstowed aerial refueling interface.

Criterion: Verify that fuel management functions (e.g., engine fuel feed and fuel center of gravity) are not adversely affected when the aerial refueling system is operated and when the aerial refueling interface fails to return to its fully closed/stowed condition.

Standard: Fuel management functions are not adversely affected when the aerial refueling system is operated and when the aerial refueling interface fails to return to its fully closed/stowed condition (see also 8.3.7 and 8.3.8 of this document).

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis indicates that engine fuel flow is not degraded and center of gravity limits are not exceeded for all in-flight fuel on-loading/off-loading conditions with each aerial refueling system (e.g., fuel dumping or refueling through each aerial refueling system). Ground calibration tests verify fuel gauging system accuracy during on-loading/off-loading conditions. Ground and flight tests verify the performance of the air vehicle computer management system and crewmember/operator control interfaces during on-loading/off-loading fuel scenarios.

References: JSSG-2009: E.3.4.5.5, E.4.4.5.5
MIL-HDBK-516: 8.3
14 CFR 23.1001, 25.1001

8.7.5.10 Vehicle landing with unstowed aerial refueling interface.

Criterion: Verify that the air vehicle can land safely when any aerial refueling system interface cannot be returned to its fully closed/stowed condition.

Standard: The air vehicle can land safely when any aerial refueling system interface cannot be returned to its fully closed/stowed condition.

Method of Compliance: Verification methods include analysis, test and review of documentation. Analysis and flight tests verify that the air vehicle can be properly configured for a landing (e.g., landing gear system in down/lock position) when any aerial refueling interface cannot be returned to its fully closed/stowed condition.

References: JSSG-2009: F.3.4.6.1.1, F.4.4.6.1.1
14 CFR 23.1001, 25.1001

8.7.5.11 Hose jettison hazards.

Criterion: Verify that no safety hazards are created by the jettisoning of an aerial refueling hose, or a portion of the hose.

Standard: No safety hazards are created by the jettisoning of an aerial refueling hose, or a portion of the hose. Conditions to be considered include, but are not limited to: the hose or any sprayed fuel contacts the air vehicle, and fuel leakage within the store/pod (see 8.4, this document, for evaluation of fire hazards).

Method of Compliance: Verification methods include analysis, test, demonstration, inspection and review of documentation. Analysis, ground/flight test and inspection indicate that no safety hazards are created by the jettisoning of an aerial refueling hose, or a portion of the hose (see 8.4, this document, for evaluation of fire hazards).

References: JSSG-2009: G.3.4.7.2, G.4.4.7.2; G.3.4.7.3, G.4.4.7.3
MIL-HDBK-516: 8.4

8.7.5.12 Fuel jettison.

Criterion: Verify the jettisoning of fuel through an aerial refueling system meets the fuel jettisoning requirements of 8.3 and 8.4 (this document).

Standard: See 8.3 and 8.4 (this document).

Method of Compliance: See 8.3 and 8.4 (this document) for fuel jettisoning and fire hazards.

References: JSSG-2009: G.3.4.7.2, G.4.4.7.2; G.3.4.7.3, G.4.4.7.3
MIL-HDBK-516: 8.3, 8.4

8.7.5.13 Stores integration.

Criterion: Verify that the aerial refueling stores/pods meet the requirements of 17.2 (this document).

Standard: See 17.2 (this document).

Method of Compliance: See 17.2 (this document).

References: JSSG-2009: G.3.4.7.2, G.4.4.7.2; G.3.4.7.3, G.4.4.7.3
MIL-HDBK-516: 17.2

8.8 Mechanisms.

Mechanisms include equipment involved in the securing, fastening, and mechanizing of air vehicle doors, hatches, canopies, ramps, weapon launchers, etc. Such equipment includes items such as locks, latches, bearings, hinges, linkages, indicators, and actuators. Mechanical actuation subsystems that provide motion and position locking functions for stowable and deployable surfaces such as folding wing panels, folding rotor blade systems, folding tail rotors/pylons, air scoops, air vents, and weapons bay doors in ground and air applications for both operational and maintenance purposes are also included. Equipment that is mechanical in form, fit, and function, but not covered by any other system-level requirements should be included herein.

8.8.1 Functionality.

Criterion: Verify that all safety of flight critical mechanisms perform their allocated air vehicle functions under their specified operating environments and conditions.

Standard: Safety of flight critical mechanisms maintain functionality while subjected to their intended operating environments, and load conditions do not prevent a loss of function.

Method of Compliance:

a. The component sizing and operating characteristics are determined analytically based on specified missions.
b. Test selection, test methods and test conditions reflect the expected operating environment(s) for individual components and subsystems. Mechanical systems are designed for safe and durable operation in accordance with the damage tolerance and

durability requirements of the cited aircraft structures specification.

c. Full scale functional test mock-up duplicating the air vehicle installation and interfaces, and system control verify system performance, rigging, installation and indication requirements at the expected loads and structural attachments.
d. System components are laboratory tested to life and performance requirements.
e. Checkouts on the air vehicle verify installation, rigging, normal and emergency functionality, and performance.

References: JSSG-2009 (Appendix I) I.3.4.9.1, I.3.4.9.4
ADS-51-HDBK

8.8.2 Effects of jam loads.

Criterion: Verify that damage or permanent deformation to latches or support structures does not result from the most critical jam load condition.

Standard: Latches, locks, linkages and the rigging have sufficient strength and rigidity to withstand all actuator stall loads resulting from a jam load condition, without adverse deflection or deformation. The system is designed to prevent jamming or blocking by cargo, baggage, or foreign objects in the open or closed position. The design prevents system damage that causes subsequent improper operation. When the system function is linked to the lock system, any damage to the system actuation linkage or support structure does not cause the system and locks to lose their related synchronization.

Method of Compliance:

a. The sizing and operating characteristics are determined analytically. Analysis is used to determine conditions where the mechanical linkage exerts the greatest force due to the available mechanical advantage on the critical parts of the system.

b. Integration of the mechanical systems is demonstrated and tested in a mock-up simulating the expected loads and structural attachments. Testing validates the integrity and durability of the mechanisms. Demonstrations verify that the system cannot be jammed or blocked by cargo, baggage, or foreign objects in the open or closed position. Demonstration verifies that the system will withstand jam loads at any point in the system without detrimental deformation. All jam load tests are conducted on the full scale article in conjunction with the latch and lock jam load tests. Jam load tests are accomplished on every critical part of the system.

References: JSSG-2009 (Appendix I) I.3.4.9.1, I.3.4.9.4

8.8.3 Effects of mechanism failure.

Criterion: Verify that the failure of any mechanism does not cause the loss of control of the air vehicle or prevent continued safe flight and landing.

Standard: Failure of mechanism (e.g., loss of a door, failure of mechanical system) does not rupture hydraulic lines, tear electrical cables, or disable any additional systems which make the aircraft unsafe for continued flight or landing.

Method of Compliance: Inspection of the aircraft drawings and analysis of the failed mechanism verify that damage will not occur to the flight critical components such as control surfaces and engines. A Failure Modes, Effects and Criticality Analysis (FMECA) predicts the consequence of hydraulic, electrical or mechanical failures or loss upon door separation or mechanical failure.

References: JSSG-2009: (Appendix I) I.3.4.9.1, I.3.4.9.4

8.8.4 Independence from flight controls.

Criterion: Verify that inadvertent loosening or opening of air vehicle doors, door latches, locks, or fasteners does not restrict the operation of any flight control system.

Standard: In flight operation of any mechanical system and doors does not interfere with or affect the operation of any flight control surface, nor compromise the flying qualities necessary to maintain safe flight. The integrity of the flight controls is maintained at all times to avoid compromising the aircraft flight safety regardless of the state of the mechanical mechanisms and their components.

Method of Compliance: Design analysis and inspection of the aircraft drawings ensure the independence of flight controls from the mechanical systems. A FMECA predicts the consequences of inadvertent loosening or opening of the mechanical components.

References: JSSG-2009: (Appendix I) I.3.4.9.1.3, I.3.4.9.4, I.3.4.9.3

8.8.5 Fail-safe latching.

Criterion: Verify that no single failure allows any latch to open inadvertently.

Standard: The latching system employed is designed to hold the doors closed in the event of a single failure within the system, to include hinges. The latching system is fail-safe. Maximum possible relative deflection between the aircraft structure, doors, and the latching system do not cause unlatching under any ultimate design loading condition. Locking and latching systems are separated so that a single malfunction cannot cause the hazardous actuation of both the locking and latching actuators.

Method of Compliance: Failure modes of the latching system are determined by analysis. Critical loading conditions are identified by structural analysis. Structural tests and demonstrations are conducted to ascertain that no door opening will occur subsequent to a single latch system or hinge failure.

References: JSSG-2009: (Appendix I) I.3.4.9.1.3, I.3.4.9.4

8.8.6 Interrelation of latching and locking systems.

Criterion: Verify that any locking system is incapable of locking or indicating it is locked unless all the latches are properly latched in the fully secured position.

Standard: The latching system is independent of the locking system so that any inadvertent unlatching attempt does not cause unlocking. There is no possibility of an out of sequence door locking action producing a false indication of a locked door. There is no indication of a locked condition other than when the locking action is fully completed.

Method of Compliance: Verify by analysis and demonstration that the latching system is independent of the locking system so that any inadvertent unlatching attempt will not cause unlocking. Verify by demonstration that the locking system is incapable of locking or indicating it is locked unless the latches are in the fully secured position and the locking action is completed. Verify by analysis and demonstration that the locking system is independent of the latching system and that inadvertent unlocking does not cause unlatching. Verify by analysis and demonstration that inadvertent latching system activation does not cause unlocking or unlatching with the locking system engaged.

References: JSSG-2009: (Appendix I) I.3.4.9.1, I.3.4.9.4

8.8.7 Door pressurization interlock.

Criterion: Verify that all air vehicle doors, whose inadvertent opening would present a probable hazard to continued safe flight and landing, have provisions to prevent depressurization (or inadvertent pressurization) of the air vehicle to an unsafe level if the doors are not fully closed, latched, and locked.

Standard: The door latches cannot be unlocked unless the air vehicle has been depressurized. The latching system incorporates an interlock that senses fuselage air pressure differential to prevent unsafe unlocking. The system also guards against unsafe pressurization before doors are latched and completely locked.

Method of Compliance: Verify by analysis and demonstration that the locking system is incapable of unlocking at unsafe pressurization levels. Verify by testing on a full scale test model that a completely assembled lock and latching system will not unlock under unsafe pressurization levels, even when the locking system receives a command to unlock. Demonstration verifies that the system prevents depressurization when all doors are secured and compartments are pressurized. Demonstration verifies that the system prevents pressurization before doors are secured. All probable failure modes are tested on a full scale test article. Testing ensures that the pressurization prevention system will hold the locks in the closed position when the fuselage is pressurized and the locks are energized to open.

References: JSSG-2009: (Appendix I) I.3.4.9.1, I.3.4.9.4

8.8.8 Door status monitoring and indication.

Criterion: Verify that the indication system continuously monitors and provides an unsafe indication when the door, latching, or locking system is unsecured, and provides a safe indication when the system is secured.

Standard: The safe or unsafe status of the doors is continuously presented to the aircrew and ground operators. The system also assists in trouble shooting in the event of a malfunction. Indicator sensors directly sense the position of doors, latches and locks without the use of sensor targets. Mechanical indicators use positive mechanical linkage for extension and retraction. The indication system is designed such that the deflection of the aircraft structure under all ground and flight load conditions does not cause false indications.

Method of Compliance: Analysis and demonstration verify that each indication system will continuously monitor and provide an unsafe indication when either the door, latching or locking system is unsecured and will provide a safe indication when the systems are secured. All malfunctions that could give a false indication are included. Particular emphasis is placed on those malfunctions that could give a safe indication for an unsafe condition. Inspection of aircraft drawings and demonstrations on a full scale article verify that the sensors will only respond to actual door system components position. Flight and ground test verify that the indication system will not report false indications due to the deflection of the aircraft structure under all ground and flight load conditions.

References: JSSG-2009: (Appendix I) I.3.4.9.1, I.3.4.9.4

8.8.9 Emergency door operation.

Criterion: Verify that the door control systems are designed for emergency operation by means of manual actuation of the door/drive sequence.

Standard: The door system can be manually operated in the event of a control or primary power source failure.

Method of Compliance: Analysis and test on the full scale test article or production aircraft demonstrates that the system can be manually sequenced or opened in an emergency. Tests include the event where normal system operation opens the doors partially and manual operation is required to complete the operating cycle.

References: JSSG-2009: (Appendix I) I.3.4.9.1.9, I.3.4.9.4.11

8.8.10 Door seals.

Criterion: Verify that all door seals prevent rain or water leakage into the air vehicle during all flight and ground operations and while the air vehicle is parked and depressurized under storm conditions.

Standard: All seals are air tight when pressurized, and protect against water when the aircraft is unpressurized. The seals exclude water at all times with the doors or canopy closed.

Method of Compliance: Analysis and seal testing verifies that the seals will have satisfactory performance when pressurized and unpressurized. Rain storm tests verify that there are no leaks in the aircraft.

Reference: JSSG-2009: (Appendix I) I.3.4.9.1.10

8.8.11 Environmental conditions.

Criterion: Verify that all actuation subsystems are able to be locked and unlocked, provide for folding, unfolding, and deploying, and can be folded, unfolded, and deployed within a wind environment that encompasses atmospheric and weather-induced conditions, wind-over-deck from carrier vessel movement, and downwash and jetwash conditions caused by other vehicles expected in the operational ground/deck environment.

Standard: The mechanical subsystem is able to operate and complete all its functional actions (to include locking) under all expected mission and environmental conditions. Worst case conditions include operations in the air and on the ground.

Method of Compliance: The design is verified by analysis. Component and system load testing verifies operation at worst case conditions. Testing up to design limits are conducted on the ground and in flight as applicable.

References: JSSG-2009: (Appendix I) I.3.4.9.4; I.3.4.9.4.1, I.4.4.9.4.1

8.8.12 Locking of structural load path mechanisms.

Criterion: Verify that mechanisms which provide a structural load path incorporate redundant means of locking the mechanism in position.

Standard: Mechanical systems are designed for safe and durable operation in accordance with the damage tolerance and durability requirements of the cited aircraft structures specification. Particular attention is paid to safety of flight and critical single load path systems. These items are designed to have redundant means of locking the mechanism in position.

Method of Compliance: Analysis, test and demonstration verify the locking function. The verification methods are consistent with the approach taken with respect to the airframe structure specification and are integrated within the air vehicle structural test programs. Where fail-safe criteria is used, inspection and maintenance procedures detect unsafe conditions.

References: JSSG-2009: (Appendix I) I.3.4.9.4, I.3.4.9.4.2, I.4.4.9.4.2

8.8.13 Locked or unlocked condition.

Criterion: Verify that the locked-or-unlocked condition of mechanisms with sensors is displayed in the cockpit, on aircraft, and in all remote operator control locations during ground operations.

Standard: Safe or unsafe status of the mechanisms are continuously presented to the aircrew, ground operators or maintenance personnel. The system also assists in trouble shooting in the event of a malfunction.

Method of Compliance: FMECA documents probable failures and system indications associated with the failures. Testing on the full scale article and control station, as applicable, verifies that the conditions of mechanisms with position sensors are properly displayed. Testing includes all the malfunctions that could give a false indication as determined by the analyses. Particular emphasis is placed on those malfunctions that could give a safe indication for an unsafe condition.

References: JSSG-2009: (Appendix I) I.3.4.9.4, I.3.4.9.4.3, I.4.4.9.4.3

8.8.14 Actuation power and control.

Criterion: Verify that, when applicable, a means is provided for controlling utility actuation. Where possible, include a separate means for "motion" and "locking" control.

Standard: The actuation power and control for moving the mechanism to its commanded position is independent from the power and control used to hold the mechanism in its initial and final commanded state.

Method of Compliance: The design and operating characteristics are verified by analysis. System components are laboratory tested to the performance requirements. Full scale functional tests duplicating the system power and system control verify system performance, rigging, installation and indication requirements. Demonstrations on the air vehicle validate mechanical system installation, rigging, functionality, and performance. Normal and emergency functions are demonstrated and verified.

References: JSSG-2009: (Appendix I) I.3.4.9.4, I.3.4.9.4.4; I.4.4.9.4.4

8.8.15 Safety devices for manual operation.

Criterion: Verify that actuation subsystems that have a provision for manual operation include safety devices to prevent injury to maintainers in case of inadvertent application of power during a manually powered operation, and incorporate a controlled deployment speed at a specified safe rate.

Standard: The design for deployment of mechanisms is safe when air vehicle power is off. Safety devices provide retention capability to keep mechanism in the locked and hold position for all cases when power or forces are applied to unlock and move the mechanism. Actuation subsystem has a reduced or controlled speed for maintenance operations.

Method of Compliance: The design is substantiated by analysis. Component and system load testing verifies safe operation with locking/hold devices installed. Ground checkouts on the air vehicle up to design limit loads and deployment speeds validate the safe operation.

References: JSSG-2009 (Appendix I) I.3.4.9.4; I.3.4.9.4.5; I.4.4.9.4.5

8.8.16 Utility actuation systems with ground power.

Criterion: Verify that utility actuation subsystems are capable of operating from the ground power supplied to the air vehicle as well as air vehicle supplied power.

Standard: Control, actuation, indication and functional performance parameters are the same when either ground power or air vehicle power is used to activate the mechanical system. There is no change in how the system responds, nor in how the controls or indication logic acts.

Method of Compliance: Analysis and testing verifies that the mechanical system operates correctly (including indication system) with either air vehicle power or with ground power as applicable. FMECA substantiates probable failures and system indications associated with the failures.

References: JSSG-2009: (Appendix I) I.3.4.9.4; I.3.4.9.4.6; I.4.4.9.4.6

8.8.17 Actuation time.

Criterion: Verify that all actuation subsystems are able to perform their specified function within the specified safe time and cycle. Also specify allowable intervals between actuation cycles as well as total cycles expected during the application lifetime.

Standard: The system actuation cycle is compatible with the air vehicle operational requirements. The time between initiation of the command to the completion of the action is within the design allowable. The time between successive operations of the same cycle is not degraded and can be consistently repeated, for the design service life.

Method of Compliance: The design is verified by analysis of components and systems. Component and system tests verify actuation rates, cycle times and interval times to be completed as required. Full scale checkouts on a simulator or on the air vehicle verify system installation, rigging, control, and functional performance. Air vehicle flight and ground tests demonstrate compatibility with air vehicle performance requirements.

References: JSSG-2009: (Appendix I) I.3.4.9.4; I.3.4.9.4.7; I.4.4.9.4.7

8.8.18 Actuation without damage.

Criterion: Verify that utility actuation subsystems incorporate some means to prevent damage to adjacent movable surfaces (e.g., flaps) during folding and unfolding operations.

Standard: The actuation system control has interlocks or logic that will prevent actuation power or movement when other mechanical surfaces or flight control surfaces are in a position to be damaged or compromised.

Method of Compliance: The design is verified by analysis of components and systems. Component and full scale system tests verify actuation logic and control to the extent that no actuation power is applied or movement occurs when other surfaces are in the way. Full scale checkouts on the air vehicle verify system interlock and control logic meet design requirements.

References: JSSG-2009: (Appendix I) I.3.4.9.4; I.3.4.9.4.8; I.4.4.9.4.8

8.8.19 Actuation subsystem attachment location.

Criterion: Verify that the actuation subsystem attachment is not an integral part of the air vehicle structure, such as a wing rib, but is a replaceable attachment designed so that, in case of an overload or fatigue failure, the attachment fails in lieu of a structural component failure on the primary air vehicle.

Standard: No structural failure of the mechanical system actuation system and its attachment fitting causes damage to air vehicle structure. Replacement of mechanical system attachment does not require the replacement of major structure such as bulk head, keel beams, etc.

Method of Compliance: Analysis and inspection of drawings verify that mounting and attachment fittings are designed to be replaceable without major structural effects. The design loads and ultimate loads are verified by analysis. Laboratory testing verifies that system components meet design limit loads and ultimate loads.

References: JSSG-2009: (Appendix I) I.3.4.9.4; I.3.4.9.4.9; I.4.4.9.4.9

8.8.20 Mechanism clearances.

Criterion: Verify that clearance is provided in the deployed or stowed position and during the deployment operation to prevent damage to the surface, attached equipment, and to other areas of the air vehicle.

Standard: When stationary or in motion, adequate clearance is maintained between the mechanism and all other air vehicle and ground equipment for all expected operational conditions including all air vehicle maintenance. There should be no contact between the mechanism and air vehicle structure or ground systems.

Method of Compliance: The design is verified by analysis of components and systems, and accounts for worn states, loading and natural and induced environmental conditions of various components. Component and system tests verify clearances between air vehicle structure and systems. Full scale checkouts on a simulator or on the air vehicle verify system installation, rigging, and clearances. Air vehicle flight and ground tests demonstrate compatibility with air vehicle and ground equipment clearance requirements.

References: JSSG-2009: (Appendix I) I.3.4.9.4; I.3.4.9.4.10; I.4.4.9.4.10

8.8.21 Manual actuation provisions for ground operations.

Criterion: Verify that utility actuation mechanisms used during ground operations have a purely manual backup available for motive power and locking and unlocking purposes if the primary mode of operation is automatic or powered (or both). Verify that subsystems used for purely in-flight applications also have means incorporated to allow controlled activation for ground maintenance actions.

Standard: There are means to provide accessibility to mechanism by the maintainers. There can be an alternate non-power means to open doors or provide access to the mechanisms on the air vehicle, while on the ground and when being serviced by the maintainers.

Method of Compliance: Inspections of design drawings and maintenance documentation verify the ability to open and operate mechanisms without power for maintenance action. Non-power access is demonstrated on the air vehicle. Demonstrations are used to verify all ground operation capabilities for activating subsystems used for in-flight applications.

References: JSSG-2009: Appendix I: 3.4.9.4; 3.4.9.4.11; 4.4.9.4.11

8.8.22 Clear display of locked/unlocked status.

Criterion: Verify that the locked-unlocked condition of mechanisms used during ground operations is displayed visually, externally, by purely mechanical, nonelectric means.

Standard: A visual or a mechanical means is provided to confirm the status of mechanisms and is readily visible to the maintainers. The system is a backup for the primary indicating system.

Method of Compliance: The design and operating characteristic are verified by analysis. Full scale functional test mock-up duplicating the air vehicle installation and interfaces, and system control verifies system performance, rigging, installation and indication requirements. Demonstrations on the air vehicle verify installation, rigging, functionality, and performance. Demonstration verifies normal and emergency functions.

References: JSSG-2009: (Appendix I) I.3.4.9.4.13; I.4.4.9.4.13

8.8.23 Securing of air vehicle doors on the ground.

Criterion: Verify that for ground operation with power off, means are provided to hold the air vehicle doors in the open or closed position, and that manually operated hold-open latches are provided to secure doors in the open position, incorporate a lock, and are located in an area where personnel can access safely. Verify that subsequent power operation of the doors, with these means left in place, will not result in damage.

Standard: When the air vehicle is unpowered, doors remain in the position they were in when power was removed. Manual repositioning of the doors is possible and allows ground personnel to latch or secure the doors in the open and locked position. Those manual locking mechanisms are safely accessible for maintenance personnel. Locking mechanisms and structure used to retain the door can take the full actuation power and loads if applied without damage to, and without detrimental effects to, the air vehicle.

Method of Compliance: Inspection of design documentation verifies that means are provided to lock doors in the desired positions when power is removed. Demonstration on an aircraft verifies that doors remain in either open, closed, or partially open position when power is removed. Demonstration is used to show that manual locks or latches safely secure the doors in the desired positions, and that the mechanisms are safely accessible to applicable personnel. Testing of the power operation of the doors with locking mechanism engaged is conducted to verify that no damage to airframe, doors, locking mechanisms, or actuators occurs.

References: JSSG-2009: (Appendix I) I.3.4.9.1.c, I.3.4.9.1.13

8.8.24 Aborted and resumed operation of controls.

Criterion: Verify that the controls automatically stop the sequence in the event a malfunction or failure occurs part way through a cycle, and in the event of a power interruption, doors do not change position, and the door controls go to the stop position and remain in the stop position upon resumption of power.

Standard: In the event of a malfunction or a failure, the door controls automatically stop the sequence and physically stop the door movement at any time in the cycle. The controls are capable of stopping door movement at any time in the cycle and have the door remain in the stop position until commanded by the operator. In the event of a power interruption, the doors go to the stop position and remain in the stop position upon resumption of power. The door controls do not require reprogramming upon resumption of power.

Method of Compliance: The design is verified through inspection of air vehicle documents. Analysis and demonstration verifies that the door controls are provided such that the aircrew can operate the controls quickly and safely without danger of damaging the air vehicle. A FMEA is created to predict the consequence of hydraulic, electrical, pneumatic or mechanical failures. Demonstration of the door control system capability to react to these situations on a full-scale article verifies the design.

References: JSSG-2009: (Appendix I) I.3.4.9.1.2, I.3.4.9.1.9.a, I.3.4.9.1.9.d

8.8.25 Operator sequencing of controls.

Criterion: Verify that the controls are capable of stopping or reversing door movement at any time in the cycle at the option of the operator by selecting the appropriate control option.

Standard: The door will move to the last commanded position at any time in the control sequence. Commanded changes in door position during the cycling sequence do not cause jamming nor prevent the door from obtaining the last commanded position.

Method of Compliance: FMECA verifies safe operation for all commanded door positions. Design analysis verifies that jamming will not occur. On aircraft testing verifies that door movement matches commanded position.

References: JSSG-2009: (Appendix I) I.3.4.9.1.9a

8.8.26 In-flight actuation prevention for ground only systems.

Criterion: Verify that locking mechanisms incorporate a means of operational command interrupt to prevent in-flight actuation of ground-only operating systems, that all mechanical and powered locks and actuators are designed to prevent undesired surface positioning in flight, and that the "fold" sequence requires two separate, deliberate actions in the case of flight critical surfaces.

Standard: Locking features are used to prevent inadvertent use of ground-only systems while in flight. The locking features are positive, do not depend on any power source to remain engaged, and are not accessible during flight conditions. A means of operational command interrupt is incorporated to prevent actuation of ground-only systems while in flight. The control and lock subsystem is shielded against electromagnetic interference (EMI), and the “fold” sequence requires two separate deliberate operator actions in the case of flight critical surfaces such as wings and rotor blades.

Method of Compliance: The design is verified through inspection of air vehicle documents. Analysis and demonstration verify that the ground-only systems cannot be operated in-flight.

References: JSSG-2009: (Appendix I) I.3.4.9.4.2

8.8.27 Prevention of inadvertent actuation.

Criterion: Verify that positive locking provisions are incorporated to prevent inadvertent actuation of a mechanism after a safety device such as a fuse or thermal switch is activated and which do not depend on any power source to remain engaged.

Standard: Positive locking provisions, once engaged, remain engaged even after a safety device is activated or when a power source is removed.

Method of Compliance: Positive locking provisions are verified by inspection of drawings, analysis and on-aircraft test.

Reference: JSSG-2009: (Appendix I) I.3.4.9.4.2

8.8.28 Strength of removable surface securing devices.

Criterion: Verify that removable surface securing devices, if specifically permitted by the Government, have strength equal to or exceeding that of the air vehicle.

Standard: Removable surface securing devices are only used in lieu of integral locks when specifically authorized by the Government. These devices are capable of withstanding rough handling without damage and have strength equal to or exceeding that of the air vehicle. The removable devices are such that one man can secure the removable surface in winds up to 60 knots from any direction.

Method of Compliance: Analysis and inspection of drawings verify that mounting and attachment fittings are designed to be replaceable without major structural effects. Laboratory testing verifies that system components meet design limit loads and ultimate loads. The design loads and ultimate loads are verified by analysis. On air vehicle demonstrations verify installation, functionality, and performance.

References: JSSG-2009: (Appendix I) I.3.4.9.4.12

8.8.29 Performance of bearings.

Criterion: Verify that airframe bearings are capable of safely joining mechanical elements; transmitting design loads through the full range of the system operating parameters; permitting rotation, misalignment, or both while maintaining a specified dimensional relationship between the joined elements; and reducing friction and wear.

Standard: Airframe bearings' strength meets the static loading conditions without deformation and fracture. The airframe bearings are designed to operate under the dynamic loading conditions over the intended range of motions.

Method of Compliance: Analysis and testing verify bearings' ability to operate under the static and dynamic loading conditions over the intended range of motions.

References: JSSG-2009: (Appendix I) I.3.4.9.2
MIL-HDBK-1599

8.8.30 Life limit of bearings.

Criterion: Verify that each flight safety critical bearing has defined safe life limits established to operate in worst case environmental conditions.

Standard: Bearings will operate for the defined life limit under load and in specified environmental conditions. A safe life ensuring a probability of failure less than 1 x 10E-7 per flight hour is established.

Method of Compliance: Analysis is used to verify the worst case environmental conditions. Analysis and component testing verify the integrity and durability of the bearings. One uncontaminated bearing is tested to establish a baseline life under a representative load and motion spectrum. A sample of bearings is tested with that same spectrum and worst case environmental contamination conditions for that type of bearing (e.g., plain lined, rolling element, or elastomeric). Results of testing are analyzed to determine bearing's safe life.

References: JSSG-2009: (Appendix I) I.3.4.9.2, I.3.4.9.2.1
MIL-HDBK-1599

8.8.31 Endurance of mechanisms.

Criterion: Verify that all Safety of Flight critical mechanisms have sufficient endurance to preclude adverse safety effects throughout their service life.

Standard: The mechanism is able to operate and complete all functional actions for four (4) times the Endurance Life Limit under all expected mission, environmental extremes and contaminated conditions simultaneously (e.g., cycles, vibrations, loads, temperature, contamination).

Method of Compliance: The design is verified by analysis to show positive margin for four (4) times the Endurance Life Limit. Mechanism testing verifies successful completion of two (2) times the Endurance Life Limit without degradation of performance or wear exceeding wear tolerances.

References: JSSG-2009: (Appendix I) I.3.4.9.4

8.8.32 No binding or jamming of flight critical mechanisms.

Criterion: Verify that all safety of flight critical mechanisms do not cause binding or jamming with surrounding structure or any portion for the system under any combination of temperature effects, air loads, landing loads, structural deflections, tire condition, landing gear condition, buildup of manufacturing tolerances or wear.

Standard: Sufficient clearance is maintained to prevent jamming of mechanisms with surrounding structure and system. The following minimum clearances are used after all combined adverse effects are accounted for:

¼-inch between elements which move in relation to each other and which are connected to or are guided by different structural or equipment elements.

½-inch between elements and aircraft structure and equipment to which the elements are not attached.

Method of Compliance: The design is verified by analysis to show that the minimum clearance in worst-case conditions is not exceeded. Static clearances are verified through inspection and evaluation of installation mock-ups and the air vehicle. Dynamic operation critical clearances are actively monitored during endurance testing and are verified during ground and flight demonstrations.

References: JSSG-2009: B.3.4.2.1.17, B.4.4.2.1.17
SAE AS94900: 3.6.2.11

8.9 External cargo hook systems (rotary wing).

8.9.1 Cargo hook system operation does not adversely affect air vehicle safety.

Criterion: Verify that the cargo hook system operation in normal, automatic, and emergency modes does not adversely affect safety of the air vehicle system.

Standard: The air vehicle maintains an acceptable level of dynamic stability for all mission operations on the ground and during flight whenever the cargo hook system is in operation. There are no adverse effects that damage the air vehicle or harm personnel at any time the cargo hook system is used.

Method of Compliance: Dynamic and stability analyses verify that the cargo hook system operation does not adversely affect all ground and flight operations and are validated using component characterization and air vehicle ground demonstrations tests. Flight testing verifies that all transitional operations (air-to-ground and visa-versa) and inflight operations have no adverse vibration or instability effects.

References: 14 CFR Parts 27, 29

8.9.2 Pilot/operator control of cargo hook system.

Criterion: Verify that the cargo hook system cockpit switches and indicators provide for normal, automatic, and emergency release of cargo.

Standard: The pilot or the operator has sufficient control and indications of the cargo hook system operation. Control and indication provisions allow release of the cargo as commanded for normal and emergency operations. The indications provide an accurate representation of the status of the cargo and of any malfunctions. Safe or unsafe status of the cargo is continuously presented to the aircrew/ground operators. The system also assists in trouble shooting in the event of a malfunction. The sensors only respond to the system components and not to sensor targets which could hang up and give a false indication. Mechanical indicators use positive mechanical linkage for hold or release, and deflection of the aircraft structure under all ground and flight load conditions does not cause false indications.

Method of Compliance: Analysis and demonstration verifies that the cargo hook system operates correctly and provides proper status indication with air vehicle power and/or ground station power. Testing, such as the life cycle tests, regression tests and performance tests are conducted to include all malfunctions that could give a false indication. Test verify all malfunctions that could give a safe indication for an unsafe condition. FMECA substantiates probable failures and system indications associated with the failures

Reference: 14 CFR 133 Amendment No. 133-11; 133 Amendment No. 133-9 (Rotorcraft External-Load Operations)

8.9.3 Securing of cargo.

Criterion: Verify that the cargo can be hooked safely to the hook and that the manuals contain the maximum and minimum loads for safe movement of cargo.

Standard: The cargo hook system and the associated structure used to retain the cargo can take the full ground and flight loads without damage to and without any detrimental effects to the air vehicle and the cargo. Sufficient documentation and instructions to properly retain the cargo in position and to release it is provided so as not to cause and overloads throughout the operational missions

Method of Compliance: Air Vehicle performance analysis predicts the worst case loads. Laboratory tests verify the structural and performance capability of the cargo hook system and structural attachment combination. This includes material selection, strength, service life, overload operation and cargo release profiles that supports the air vehicle performance and operations. Flight test and operational tests validate the analysis and component tests.

Reference: 14 CFR: 133 Rotorcraft External-Load Operations, subpart D-Airworthiness Requirements, sec.133.45

8.9.4 Electromagnetic compatibility.

Criterion: Verify that the electromagnetic environment of the air vehicle is compatible with safe loading and release of cargo.

Standard: Cargo hook operation is able to complete all its functional actions under all expected mission and electromagnetic conditions. Worst case conditions are to be designed for operations in the air and on the ground.

Method of Compliance: The design is substantiated by analysis. Component and system load testing is conducted at worst case conditions. Ground and air vehicle flight testing up to design limits are conducted on the ground and in flight as applicable.

Reference: 14 CFR 27.865 (Part 27 Airworthiness Standards: Normal Category Rotorcraft, subpart D-Design and Construction)

8.9.5 Structural load capacity for cargo.

Criterion: Verify that the air vehicle structure can support all loads imposed by the external transport of cargo during operational usage.

Standard: The Operational Concept dictates the structural requirements based on a defined external loads envelope and worst-case flight conditions. The aircraft's structural limits for flight operations exceed external loads envelope by an acceptable margin.

Method of Compliance: Analysis and structural testing of subsystems or complete structures are performed as necessary. Structural testing verifies analytical results such that an acceptable margin of safety is attained for the design condition.

References: 14 CFR 27.865, 29.865

8.9.6 Technical manuals.

Criterion: Verify that the external cargo hook and supporting structure limits are defined and are published in all applicable operator and maintenance manuals.

Standard: Unless otherwise specified the cargo hook and supporting structure have a limit load factor of 2.5 times the rated or working load capacity. The hook support structure is capable of withstanding the rated capacity to 15 degrees with the vertical forward and lateral and 30 degrees with the vertical to the rear.

Method of Compliance: The rated capacity of the cargo hook and support structure throughout their defined range of movement is verified through analysis and testing.

References: 14 CFR 27.865, 29.865

8.9.7 Effect of load movement.

Criterion: Verify that air vehicle flight performance/control is not adversely affected by load movement experienced during external load operations and the emergency jettison of external cargo.

Standard: The air vehicle can perform external load operations and emergency jettisons throughout the defined external cargo envelope at the required airspeeds without adverse effects on performance/control or the airframe.

Method of Compliance: Aircraft stability is verified through analysis and testing with a range of loads and airspeeds.

References: 14 CFR 27.865, 29.865

8.10 External rescue hoist (rotary wing).

8.10.1 No adverse effects on safety.

Criterion: Verify that the external rescue hoist system does not adversely affect safety of personnel or the air vehicle system.

Standard: The air vehicle maintains an acceptable level of dynamic stability for all mission operations on the ground and during flight whenever the hoist system is in operation. There are no adverse effects that would damage the air vehicle or harm personnel at any time the hoist system is used.

Method of Compliance: Dynamic and stability analyses verify that the hoist system operation does not adversely affect all ground and flight operations and are validated using component characterization and air vehicle ground demonstrations tests. Flight testing verifies that all transitional operations (air-to-ground and visa-versa) and inflight operations have no adverse vibration or instability effects.

8.10.2 Operation under all load conditions.

Criterion: Verify that the hoist system operates safely under rated and emergency loading conditions.

Standard: The design of the hoist system allows for safe operation at its maximum and minimum loading conditions, as specified for normal and emergency missions.

Method of Compliance: The design is substantiated by analysis of components and systems. Component and system tests verify operation, loads and times to be completed as required. Full scale checkouts on a simulator or on the air vehicle verify system installation, rigging, control, and functional performance. Air vehicle flight and ground tests demonstrate compatibility with air vehicle performance requirements.

8.10.3 Electromagnetic compatibility.

Criterion: Verify that the electromagnetic environment of the air vehicle is compatible with safe operation of the rescue hoist.

Standard: The hoist operation is able to complete all its functional actions under all expected mission and electromagnetic conditions. Worst case conditions are to be designed for operations in the air and on the ground.

Method of Compliance: The design is substantiated by analysis. Component and system load testing is conducted at worst case conditions. Ground and air vehicle flight testing up to design limits are conducted on the ground and in flight as applicable.

8.11 Fast rope insertion/extraction systems (FRIES) (rotary wing).

8.11.1 Insertion and extraction of personnel.

Criterion: Verify that H-bar and FRIES bar provides for the safe insertion and extraction of personnel into and out of the air vehicle.

Standard: The design of the H-bar and FRIES bar system allows for safe operation at its maximum and minimum loading conditions, as specified for normal and emergency missions. The system allows for the safe insertion and extraction of personnel for all expected mission profiles.

Method of Compliance: The design is substantiated by analysis of components and systems. Component and system tests verify operation, loads and times to be completed as required. Full scale checkouts on a simulator or on the air vehicle verify system installation, rigging, control, and functional performance. Air vehicle flight and ground tests demonstrate compatibility inserting and extracting personnel within air vehicle performance requirements.

8.11.2 Structural safety margin.

Criterion: Verify that the back-up structure possesses adequate structural margins of safety for the safe insertion and extraction of personnel.

Standard: The design of the air vehicle back-up structure has the capability to support the FRIES at all times for all the design missions. Static and dynamic loads generated during taxi, takeoff, flight and landing under all air vehicle operational weights and operational environments are considered.

Method of Compliance: Air Vehicle performance analysis predicts the worst case loads. Laboratory tests verify the structural and performance capability of the FRIES system and back-up structure. This includes material selection, strength, service life, overload operation and speed/load/time to insert/extract profiles that support the air vehicle performance and operations. Flight test and operational tests validate the analysis and component tests.

9. CREW SYSTEMS.

The crew systems area consists of the following elements: pilot-vehicle interface, aircrew station (accommodations, lighting, furnishings, and equipment), human-machine interface, Unmanned Aircraft System/Remotely Operated Aircraft (UAS/ROA) control station (operator accommodations, lighting, and equipment), the life support system, the emergency escape and survival system, the transparency system, crash survivability, and air transportability.

TYPICAL CERTIFICATION SOURCE DATA

1. Escape system requirements and validation.
2. Crew station layout/geometry review.
3. Human factors.
4. Failure modes, effects, and criticality analysis (FMECA).
5. Life support system requirements and validation.
6. Crash survivability requirements and validation.
7. Lighting system design, analysis, test reports.
8. Transparency integration.
9. Air transportability, cargo, and airdrop systems.
10. Load analyses.
11. Aeroservoelastic analyses.
12. Test plans.
13. Test reports.
14. Proof test results.
15. Simulation test, modeling and results.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

(NOTE: For subsystems that use computer systems and software, see Section 15 for additional specific criteria, standards and methods of compliance.)

References: JSSG-2010 Crew Systems
FAA AC 20-41A
FAA AC 20-60

9.1 Escape and egress systems.

This element provides the means whereby the occupant(s) can leave the air vehicle and/or control station during in-flight, water, and ground emergencies.

9.1.1 Escape system safety compatibility.

Criterion: Verify that any escape system is compatible with the air system, and that all occupants can safely egress from the aircraft and/or control station.

Standard: An escape system or means of emergency escape is incorporated within the air vehicle for both ground and ditching conditions, and in-flight conditions if specified. (An escape system may include ejection seats, escape capsules, escape path clearance systems, emergency exits, and ground egress aids used to perform the functions of escape, survival, and recovery of air vehicle occupants.) Automated ejection seats, escape capsules or modules function to separate the aircrew from the aircraft and recover them to the earth. Escape system functionality, including operation of escape path clearance systems, does not induce a probability of incapacitating major injury greater than 5% throughout the required performance envelope. Means of emergency egress (e.g., use of explosive components for egress, sharp edges, hot metal percussion) does not cause serious injury or hinder required procedures for evacuation. For systems that allow one or a portion of the aircrew to eject independently, the ability to sustain flight and for remaining aircrew to subsequently eject is not precluded.

Applied and inertial forces during escape do not exceed a 5% human incapacitating injury probability for speeds up to at least 350 knots equivalent air speed (KEAS) for legacy aircraft and 450 KEAS for aircraft in development unless otherwise specified or limited by air vehicle speed capability.

Recovery decent rates with oscillation dampening devices deployed do not exceed a total velocity of 24ft/sec at sea level (SL) on a standard day. The maximum resultant deceleration, stabilization, and recovery opening loads experienced by the aircrew during escape do not exceed:

25g at 450 KEAS or less and 8000 ft mean sea level (MSL) and below

35g above 450 KEAS and 8000 ft MSL and below

20g at 450 KEAS or less and 8000 to 18000 ft MSL

30g above 450 KEAS and 8000 to 18000 ft MSL

Canopies and hatches do not present a risk of collision with any ejectee of the aircraft during the escape and recovery sequence from straight and level flight conditions.

Head and neck loads (neck tension, compression, shear force and combined neck moment and loads) that may be experienced during escape do not exceed injury level criteria for the anthropometric range of aircrew.

Accelerations imposed on an ejection seat occupant do not exceed limits indicated below for the Dynamic Response Index (DRI), Multi-Axis Dynamic Response Criteria (MDRC), and Dynamic Response Radical (DRR) criteria as defined in 3.11.4.1 and B.4.1.1.5.2 of JSSG-2010. (NOTE: MDRC is referred to as the Biodynamic Response Index in B.4.1.1.5.2.b.).

Note that Control Stations may not have powered or automated egress system(s).

Method of Compliance: Inspection of engineering drawings verifies the escape system has all components necessary to allow aircrew escape. System level performance as integrated into the aircraft is verified by testing throughout the designated envelope with extreme permutations of crew anthropometry and mass properties. System level testing (such as sled tests and canopy jettison/fracture tests) using instrumented articulating dummies verifies that exposure to acceleration levels and other loads, forces, environments, and impacts do not exceed injury criteria and injury probability levels. Emergency egress demonstrations with human subjects verify the ability to safely operate required systems and egress the air vehicle. System level testing, analysis, and subsystem level test and demonstration verify integration and compatibility with the air vehicle and other subsystems (e.g., structural testing/analysis, electromagnetic compatibility testing, power/electrical system tests, software verification testing, aerodynamic analysis).

References: JSSG-2010-3: 3.3.4

JSSG-2010-7: 3.7.3.5.3

JSSG-2010-11: 3.11.7, 3.11.7.2 and 7.3.3.3.5.3

9.1.1.1 Escape system reliability.

Criterion: Verify that the systems and subsystems of the escape system have a designed and demonstrated reliability sufficient for use.

Standard: Ejection seats, capsules, modules, and escape path clearance systems have a minimum demonstrated reliability of 90% with a 90% confidence interval at the system level. Minimum design reliability at the system level is 98%. Subsystems including Cartridge Actuated Devices and Pyrotechnic Actuated Devices (CAD/PAD) have demonstrated reliability that supports the system design level for the environments specified.

Method of Compliance: Sufficient reliability and confidence level is verified by analysis and system level escape system testing. Ejection seat reliability is verified by qualification with 22 consecutively successful tests. Air vehicle escape system level tests (such as sled tests) verify integration of previously qualified ejection seats, with at least eight (8) system level ejections conducted unless otherwise specified. Reliability of CAD/PAD devices is verified by subsystem level testing, completed prior to system level tests.

References: JSSG-2010
MIL-C-83124
MIL-C-83125
MIL-C-83126

9.1.2 Escape exits and routes.

Criterion: Verify that escape exits and escape routes are provided in appropriate sizes and numbers for emergency evacuation to permit timely and complete egress of occupants. For manned aircraft this includes landing and ditching.

Standard: Crew station, aircraft and control station interior design permits all occupants to egress the aircraft and/or control station within the specified time. Multi-place, cargo, transport aircraft and control station exits and sizes have twice the capacity for the maximum number of occupants to egress in the specified time. The crew and passenger areas of aircraft have emergency means to allow for complete abandonment in the specified time during ground egress or ditching of the air vehicle, with the landing gear extended as well as retracted, considering the possibility of the air vehicle being on fire, and at maximum seating capacity.

For fighter aircraft: Crew members are able to egress the aircraft within 30 seconds.

For multi-place and cargo aircraft: All crew members are able to egress the aircraft within 60 seconds using only half the exits.

For transport aircraft the following apply:

a. For aircraft with 25 passengers or less: All passengers and crew are able to egress the aircraft within 45 seconds using only half the exits.
b. For aircraft with greater than 25 passengers: All passengers and crew are able to egress the aircraft within 90 seconds using only half the exits.
c. The 90 second evacuation criteria is not applicable for patients on aeromedical evacuation missions.

For ditching fixed wing aircraft egress times are double those for ground egress.

NOTE: For Navy multi-place, cargo and transport aircraft, FAA 14 CFR regulations may apply.

NOTE: For definitions of multi-place, cargo and transport aircraft, see Section 3.

For rotary wing aircraft the following apply:

a. For aircraft with non-crashworthy fuel cells: All crew members are able to egress in 20 seconds using only one-half the exits.
b. For aircraft with crashworthy fuel cells: All crew members are able to egress in 30 seconds using only one-half the exits.
c. For all aircraft, all crew and passengers are able to egress in 45 seconds using only one-half the exits.

For control stations not in permanent structures: All occupants are able to egress within 60 seconds using only one-half the exits. Maximum number of occupants permitted in the control station at any one time is posted.

If the control station is occupied while being transported in or on another vehicle such as an aircraft the egress requirements of the platform are not violated (e.g., a control station trailer is being transported by a C-17 and is occupied. The occupants of the control station are able to egress the control station and aircraft within the required time for the aircraft).

For control stations in permanent structures: The egress time is in accordance with local building codes.

Method of Compliance: Testing, inspection, demonstration, and time study analyses documents verify that the appropriately equipped (mission representative) aircrew and passengers can egress the aircraft and control station from that combination of half the exits which results in the most restrictive configuration. An emergency egress demonstration from the vehicle, control station, or a high fidelity mockup is used to verify egress capability and time required under both day and night lighting conditions. For transport aircraft, participants have no prior practice or rehearsal for the demonstration. For control stations located inside of permanent buildings, compliance is shown by a certificate of occupancy from the local building inspector.

References: JSSG-2010
USAAVSCOM TR 89-D-22E
AMCP 706-203
14 CFR 23.803, 25.803, 29.803

9.1.3 Emergency exit markings.

Criterion: Verify that emergency exits have operating instructions and markings, both internally and externally.

Standard: Emergency exits are clearly marked and have readily apparent, discernable operating instructions for use by operators, crewmembers and/or passengers internally, and are marked with relevant markings for external rescue.

For control stations located inside of permanent buildings, emergency egress exits and routes are in accordance with local building codes.

Method of Compliance: Inspection of emergency exits or engineering drawings verifies instructions and markings. Demonstrated utility and discernability have been documented during emergency egress and rescue demonstrations with simulated or actual anticipated lighting conditions.

For control stations located inside of permanent buildings, compliance is shown by a certificate of occupancy by the local building inspector.

References: JSSG-2001: 3.3.10.2.3
JSSG-2010: 3.8, 4.8; 3.9, 4.9; 3.11, 4.11; 3.12, 4.12; 3.13, 4.13; 3.14, 4.14

MIL-STD-1472

14 CFR 23.803-23.815, 25.801-25.819, 23.1411, 23.1415, 25.1411, 25.1415, 23.813, 25.813, 25.1423; Part 25, Appendix F and Appendix J

9.1.4 Ground/ditching emergency egress devices.

Criterion: Verify that devices for ground emergency egress assist (doors, slides, descent reels, life rafts, etc.) and their deployment mechanisms (handles, actuators, etc.) meet safety requirements.

Standard: Ground emergency egress devices can be safely used by the intended crew/operator and passenger populations, without unacceptable risk of major injury. Deployment handles/actuators capable of creating a flight safety or injury hazard are designed to prevent inadvertent actuation during normal operations and incidental contact. The safety requirements of each individual emergency ground egress assist device bound and include the application requirements of the system into which the device is being incorporated. This includes the number and intended anthropometric range of occupants, the ground egress time requirements of the system, the operational environmental requirements of the system, and applicable physical and power integration requirements of the system.

Method of Compliance: Safety of emergency egress devices is verified by system testing and analysis. Qualification testing confirming compliance with specified requirements for each device verifies safe operation. Analysis, inspection, and demonstration of capability when integrated into the host platform verify system level safety. Emergency egress demonstrations verify the ability to operate and use emergency egress devices without unacceptable major injuries.

References: JSSG-2001: 3.3.10.2.3

JSSG-2010: 3.8, 4.8; 3.9, 4.9; 3.11, 4.11; 3.12, 4.12; 3.13, 4.13; 3.14, 4.14

USAAVSCOM TR 89-D-22E,

14 CFR 23.803-23.815, 25.801-25.819, 23.1411, 23.1415, 25.1411, 25.1415

9.1.5 Ground/ditching emergency processes and procedures.

Criterion: Verify that ground/ditching emergency egress and rescue processes and procedures exist, are incorporated in system documentation, and are implemented in training.

Standard: Flight and training manuals incorporate required emergency procedures. System training and syllabus documentation includes instruction for emergency egress. Documentation of required passenger briefings includes emergency egress instructions. Rescue procedures and processes are documented for ground rescue personnel. (Ground emergency egress includes aircraft with and without automatic emergency escape systems. The process includes the design of the aircraft to permit timely egress of the aircraft including disconnection of restraint systems and personal equipment as well as training systems for aircrew, and ground/water rescue personnel.) Procedures are documented that inform and enforce the ground/ditching egress procedures for aircrew, operators, passengers and rescue personnel. The procedures are distributed to training groups, aircrew, operators and rescue personnel.

Method of Compliance: Documentation of egress/rescue processes and procedures, including flight manuals, training manuals/syllabus, and rescue procedures are verified by inspection. Demonstration, test, and analysis documentation verify that the design of the ground/ditching egress process and procedures provide timely egress for aircrew, operators and passengers with high fidelity mockups, actual personal equipment, and aircraft hardware. Demonstration and analysis verify effectiveness of processes for rescue personnel including canopy, hatch, and/or door removal by external actuation or cutting. Inspections verify that procedures exist in documented form for egress training for aircrew, operators, passengers and rescue personnel and are distributed to all organizations that either operate the aircraft or could possibly support it.

References: JSSG-2001: 3.3.10.2.3
JSSG-2010: 3.8, 4.8; 3.9, 4.9; 3.11, 4.11; 3.12, 4.12; 3.13, 4.13; 3.14, 4.14
14 CFR 23.803-23.815, 25.801-25.819, 23.1411, 23.1415, 25.1411, 25.1415

9.1.6 Emergency egress/rescue equipment.

Criterion: Verify that egress equipment exists to aid escape in the event exits are blocked, damaged, or when exit opening actuation fails.

Standard: Creation of necessary exits in aircraft transparencies and designated aircrew compartment surfaces can be performed by using either onboard devices (e.g., crash axe, canopy penetrator) and/or ground rescue tools (e.g., fire rescue axe, powered saw). Depending on the operational concept of the aircraft, the egress equipment exists either on the aircraft and/or with organizations where the aircraft could operate. If applicable, onboard egress equipment exists in every compartment where an occupant could be under landing and takeoff conditions.

Method of Compliance: Emergency egress/rescue demonstrations, test, and analysis documentation verify that exits can be created in aircraft transparencies and designated aircrew compartments with either onboard devices or ground rescue tools.

References: No information available in current JSSG.
14 CFR 121.309, 121.310

9.2 Crew stations, control stations and aircraft interiors.

Crew station (accommodations, lighting, furnishings and equipment): This element provides the crewmember with crew or control station geometry covering workspace size and arrangement as specified by the anthropometric requirements, internal and external visibility and situational awareness necessary to perform the specified missions safely, cockpit/area illumination (primary, secondary, night vision imaging systems (NVIS), laser eye protection (LEP), utility and emergency lighting), thermal and acoustic protection, and storage facilities. Additionally, for manned air vehicles, other elements include sanitary facilities, cockpit finish and trim, instrument panel and consoles, and protection from cockpit generated reflections (glareshields). It may also cover boarding arrangements such as ropes or ladders. Crew and passenger accommodations may also be covered. This element also covers UAS/ROA control station requirements, where appropriate.

References: 14 CFR 23.771-23.775, 25.771-25.773, 23.803-23.815, 23.1411, 23.1415, 25.801-25.819, 25.1411, 25.1415

9.2.1 Crew station arrangement.

Criterion: Verify that all controls and displays are arranged and located so that they are completely functional and visible and that cockpit or operator station geometry (including seats) accommodates the specified multivariate flight and mission crew population.

Standard:

a. Crew or operator station controls, displays, geometry, and human interfaces accommodate the physical attributes, body dimensions, and capabilities of the intended user population. Critical flight information can be obtained, and control inputs can be made to sustain flight under all operational conditions.

b. The geometry, design, and layout of controls, displays, and seating are compatible with human perception capabilities, and do not cause fatigue, distraction, or discomfort resulting in performance degradation or human error.

Method of Compliance:

a. Mockup evaluations and crew-in-the-loop flight or mission simulations with mission equipped human subjects representative of the intended anthropometric range demonstrate the ability to obtain required flight information, and to make necessary and accurate control inputs.

b. Crew-in-the-loop flight or mission simulations demonstrate that accommodation features do not produce risk of error sufficient to cause loss of control or the inability to sustain flight.

References: JSSG-2001 typical anthropometric dimensions and ranges considered acceptable to accommodate the US pilot population

JSSG-2001: guidance on controls and displays

JSSG-2010

MIL-STD-1472: 5.6, design criteria and features recommended to provide human accommodation

AFRL-HE-WP-TR-2002-0118

ENFC-CSB-08-01

14 CFR 23.777, 25.777, 27.777, 29.777

9.2.1.1 Controls and display readability.

Criterion: Verify that all displays are readable, from all crewmember (or operator/controller) eye positions, under the full range of ambient conditions.

Standard: Displays are constructed, arranged and mounted so as to not adversely affect information transfer due to reflection, while minimizing reflection of instruments and consoles in windshields and other enclosures. Displays are located so that they are readable from all operator and/or crew member positions, under all expected illumination conditions (i.e., from full darkness to direct sunlight).

Method of Compliance: Mockup evaluations and crew-in-the-loop flight or mission simulations with mission-equipped human subjects representative of the intended anthropometric range are utilized to demonstrate the ability to obtain required flight information. Physical measurements and demonstration/simulations under various lighting conditions expected for the actual operational environment take into account both extremes for ambient illumination and any extreme viewing conditions that can be anticipated.

References: JSSG-2010 3.1, 4.1; 3.2, 4.2; 3.3, 4.3; 3.4, 4.4; 3.5, 4.5; 3.14, 4.14

MIL-STD-1472: 5.2 addresses visual displays of various types

AFRL-HE-WP-TR-2002-0118

ENFC-CSB-08-01

14 CFR 23.777, 25.777, 27.777, 29.777

9.2.1.2 Interior and exterior fields of view.

Criterion: Verify that the interior and exterior fields of view are sufficient to safely perform all flight and mission-critical functions.

Standard: The interior and exterior fields of view are optimized relative to the intended anthropometric population such that all required flight and mission-critical functions and tasks (e.g., take-off, landing, and aerial refueling) are achievable and can be safely conducted throughout all aircraft operating envelopes and intended natural and induced environments.

A sufficient exterior field of view (including electronically transmitted information) is provided to permit the pilot/operator to safely maneuver and control the aircraft within its operating limits while also providing, from the same eye position, an unobstructed interior view of flight instruments and other critical components and displays.

Method of Compliance:

a. A cockpit, crew station or control station mockup, using production representative components and geometries to the maximum extent possible, is used to verify the quality and extent of interior and exterior fields of view/visual access.

b. Analysis of rectilinear plots verifies the total envelope (plus and minus 180 degrees in azimuth and plus and minus 90 degrees in elevation) of each operator's unobstructed vision (clear vision area). Flight simulators and flight test assessments verify sufficient visibility to safely conduct all flight tasks.

References: JSSG-2001: 3.4.3.1.7 and 3.4.3.1.8, 2. interior and exterior vision, respectively.

JSSG-2010: 3.1, 4.1; 3.2, 4.2; 3.3, 4.3; 3.4, 4.4; 3.5, 4.5; 3.14, 4.14

JSSG-2010: 4.3.2, rectilinear plots

JSSG-2010-3: 3.3.2, rectilinear plots

14 CFR 23.771-23.781, 25.771-25.781

9.2.2 Controls and display usability.

Criterion: Verify that all controls are properly designed and can be operated through their complete range of travel without interference with other controls, structures, or crewmembers' bodies; and that all emergency action controls are reachable, by the appropriately restrained operator; or by the aircrew member from a restrained shoulder position in all air vehicle attitudes and throughout the complete range of "g" force loads.

Standard: Controls are operable by the full range of aircrew and operator populations as defined by anthropometric requirements while wearing all applicable clothing and equipment ensembles. Controls can be fully actuated without travel restrictions under all combinations of operating conditions and flight equipment use and locations.

Method of Compliance: The range of anthropometric requirements for critical body dimensions is incrementally verified using zone techniques and high fidelity modeling, mockups and/or simulation. The evaluation(s) includes subjects wearing applicable clothing and equipment. Anthropometric evaluations verify ability to operate controls throughout the full range of travel.

References: JSSG-2001: 3.4.3.1.1, typical anthropometric dimensions and ranges considered acceptable to accommodate the US pilot population

JSSG-2010: 3.1, 4.1; 3.2, 4.2; 3.3, 4.3; 3.4, 4.4; 3.5, 4.5; 3.14, 4.14

JSSG-2010-3: 4.3.3, Table VI, definition and application of zones

14 CFR 23.771-23.781, 25.771-25.781

9.2.3 Aircrew alerting systems.

Criterion: Verify that the master caution and warning systems' displays are located in the prime visual signal area and that all warning and caution situations are displayed and/or conveyed to the aircrew or operator in a fashion that permits recognition in sufficient time to take actions necessary for safe flight.

Standard:

a. The aircrew alerting system provides feedback of all events, conditions, and situations which could present a hazard to the safety of the occupants, endanger human life, or cause substantial damage to the aircraft. The alerting system is activated upon the occurrence of the condition. Warnings and cautions are not masked or obscured by other displayed information.

b. Master cautions and warnings are located within a 30 degree cone centered on the pilot/operator's normal line of sight and are of sufficient magnitude to ensure rapid detection. All visual warnings, cautions, and advisories are in accordance with MIL-STD-411.

c. All aural warnings, cautions, and advisories are in accordance with MIL-STD-411 and MIL-STD-1472. Aural alerts are used in conjunction with visual alerts to direct attention to a critical change in system or equipment status and alert the pilot and/or operator of a critical action(s) that must be taken.

d. The aircrew alerting system is prioritized by urgency into warnings, cautions, and advisories categories. Warnings are presented at the top of the aircrew alert display, followed by cautions and then advisories. When multiple alerts are present, the relative alert priorities are readily and easily detectable by the pilot and/or operator. Aural alerts are prioritized so that only one aural alert is presented at a time and an active aural alert should finish before another aural alert begins. An active aural alert is interrupted by higher urgency level alerts if the delay to annunciate the higher-priority alert affects the timely response of the pilot and/or operator.

Method of Compliance:

a. Flight simulations and mockup evaluations demonstrate the capacity of the alerting systems to garner attention in sufficient time to take appropriate actions.

b. Location of visual alerting system components is verified by inspection and analysis of crew station layout drawings and mockups as well as inspection and physical measurements of display hardware.

c. The completeness of the alerting system, including the alert priority approach and methodology, is verified by subsystem integration testing, human use analysis, failure and degraded modes analysis, and crew system simulation and documentation.

References: JSSG-2010: 3.1, 4.1; 3.2, 4.2; 3.3, 4.3; 3.4, 4.4; 3.5, 4.5; 3.14, 4.14
MIL-STD-411
MIL-STD-1472
MIL-STD-1787
14 CFR 23.1321-23.1322, 25.1321-25.1322

9.2.4 Emergency markings.

Criterion: Verify that emergency action controls are properly marked.

Standard:

a. Emergency controls, or controls that serve an emergency function, are clearly marked as to the method of operation. Only emergency controls are designated in emergency markings and are consistent throughout the air vehicle and control stations.

b. Emergency switches, buttons, and small handles or levers have a striped background. Large handles or levers are striped on the handle or lever. Emergency controls are marked with alternate stripes of orange-yellow and black compliant with FED-STD-595. The orange-yellow stripe is three times the width of the black striping and the stripes are applied at a 45 degree angle from the vertical, rotated clockwise. For night operation, emergency markings appear as illuminated stripes identical to the orange-yellow background striping. Commercial derivative aircraft may conform to 14 CFR for emergency control markings, if approved by the procuring activity.

c. Red compartment lighting is not permitted in new air vehicles. If red compartment lighting exists on a legacy system, an orange-yellow and black striped border, in accordance with FED-STD-595, is used to outline functional groups involving emergency or extremely critical operations.

Method of Compliance: Proper marking of emergency action controls is verified by inspection and analysis of program documentation including cockpit, crew and operator station layout drawings or mockups, as well as inspection of hardware, manufacturing drawings and engineering drawings.

References: JSSG-2010
JSSG-2010-11
MIL-STD-1472
MIL-STD-2161
STANAG 3230
SAE AS18012

9.2.5 Emergency controls.

Criterion: Verify that, if appropriate, the design allows each crewmember, in an emergency, to operate all essential controls.

Standard:

a. Ejection seat equipped aircraft: Ejection controls (automatic and/or manual) are readily accessible and activation is possible with either hand. Provisions are incorporated to guard against accidental activation of ejection system/controls.

b. All aircraft: Controls and switches necessary for emergency actions can be operated under all flight conditions, and crewmember restraint positions. Required safety equipment to be used by the crew in an emergency is readily accessible. The controls are located and arranged, with respect to the crewmember's seats, so that there is full and unrestricted movement of each control without interference from the cockpit structure or the clothing of the flight crew when seated with the seat belt and shoulder harness fastened. Provisions are incorporated to guard against accidental activation of emergency systems or controls.

c. Control Stations: Controls and switches necessary for emergency actions can be operated and can be reached by all the intended anthropometric population. Required safety equipment to be used by the operator(s) in an emergency is readily accessible. The controls are located and arranged so that there is full and unrestricted movement of each control without interference from the control station structure and the operator(s) . Provisions are incorporated to guard against accidental activation of emergency controls. These requirements are met with all mission appropriate gear and restraints (e.g., seatbelts, harnesses).

d. Stowage provisions for required safety equipment are furnished and arranged so that the equipment is directly accessible and its location is obvious.

Method of Compliance: Operation of the controls is verified by inspection and analysis of cockpit, crew and operator station layout drawings and mockups as well as inspection and physical measurements of the control hardware. Operation by the intended anthropometric population, wearing applicable clothing and equipment, is incrementally verified by test using zone techniques and high fidelity integrated modeling and/or simulation. Demonstrations verify the ability to operate controls across the range of crewmember capabilities and throughout the full range of travel.

References: JSSG-2010
MIL-STD-1472
AFRL-HE-WP-TR-2002-0118
ENFC-CSB-08-01

9.2.6 Interior finishes, components and equipment.

Criterion: Verify that all interior finishes, components, and equipment are made with flame resistant materials. This includes, but is not limited to lavatories, galleys, and areas that are not continuously occupied.

Standard: Any combustible materials used are burn resistant and have low smoke generation properties.

The materials prevent post-crash fire and/or protect aircraft and/or control station occupants from fire which cannot be prevented. This applies to interior components including:

a. Ceiling and wall panels (excluding lighting lenses and windows).

b. Partitions (excluding transparent panels needed to enhance cabin safety).

c. Galley structure, including exposed surfaces of stowed carts and standard containers and the cavity walls that are exposed when a full complement of such carts or containers is not carried.

d. Cabinets and cabin stowage compartments.

For control stations located inside of permanent buildings, refer to local fire and building codes.

Method of Compliance: Analysis verifies that materials are burn resistant and have low smoke generation. Testing (including finishes or decorative surfaces applied to the materials) verifies that materials meet the applicable test criteria prescribed in 14 CFR or other government-approved equivalent methods.

References: JSSG-2010-7: 3.7.3.4
14 CFR 25.791, 23.853, 25.854, 25 Appendix F

9.2.7 Communication systems.

Criterion: Verify that a system exists such that the flight deck and/or operator(s) can effectively and efficiently communicate with other personnel, to include other aircrew members; support, launch and recovery personnel; and military and/or civilian airspace controllers.

Standard: A means is provided to alert the aircrew in a timely manner and to give time-critical feedback of all events, conditions, and situations which could present a hazard to the safety of the occupants, endanger human life, or cause substantial damage to the aircraft. An intercom system is accessible for immediate use at any crew station and provides two way communication between all crew compartments. The intercom systems are capable of operation independent of any public address system.

Method of Compliance: Functionality of communication systems is verified by system demonstration.

References: JSSG-2010-4
14 CFR 121.319

9.2.8 Speech intelligibility.

Criterion: Verify that all audio communication systems have speech intelligibility of sufficient quality to ensure safe and effective aircraft system operation.

Standard: All critical audio communications paths are to be evaluated using the Modified Rhyme Test (MRT), in accordance with ANSI/ASA S3.2.

Critical communication paths may include but are not limited to:

a. Pilot/operator audio communications with ground personnel or mission personnel.
b. Pilot/operator communications with Air Traffic Control.
c. Pilot/operator with another external air vehicle pilot/operator.
d. Pilots to aircrew and passengers.

An 80% (91% for Army) score on the modified rhyme test (MRT) conducted in accordance with ANSI/ASA S3.2 is considered adequate for all operational military aircraft communication paths essential to safety of flight.

In support of initial ground testing and first flight predictive measures of speech intelligibility including the Articulation Index (AI), Speech Transmission Index (STI), and Speech Intelligibility Index (SII) may, at the discretion of the airworthiness authority, be used to predict communication performance for some environments.

Method of Compliance: Speech intelligibility is verified by testing. Verify with talkers and listeners in the worst case noise environments where communications are required. Speech intelligibility scores cannot be combined for different personnel locations and flight conditions. Predictive measures are not used for full airworthiness compliance.

References: MIL-STD-1472
MIL-STD-1474
ANSI/ASA S3.2
ANSI/ASA S3.5

9.3 Air system lighting.

This element involves the following: Lighting environments and mechanisms (e.g., NVIS, LEP) allowing crewmembers to see information from displays and instruments, to operate controls, to move safely throughout and emergency egress the compartment, to see other vehicles in formation and during aerial refueling, and to perform all other mission-critical functions where sight is necessary.

References: FAA AC 20-30A

FAA AC 20-30B

14 CFR: 23.1381-23.1401, 25.1381-25.1403

9.3.1 Lighting system illumination.

Criterion: Verify that lighting systems exist to illuminate everything in or on the air system that needs to be seen by crew, wing men, passengers, maintainers, and ground support personnel, regardless of ambient lighting conditions.

Standard: The lighting system provides adequate illumination for the anticipated range of aircrew and operator tasks throughout all environmental lighting conditions. Tasks include normal ingress and emergency egress for all occupants within the cockpit, control station and crew station. Adequate lighting to ensure the safety of aircrew, operators, passengers and maintainers is provided for the cargo compartment, loading and ramp areas, passageways, passenger seating area(s), avionics bays, auxiliary power plant compartment and all flight critical maintenance areas. Illumination is sufficient for exterior visibility and tasks to be accomplished by external aircrews and ground support personnel, including, but not limited to, aerial refueling operations, formation flights and carrier operations (e.g., deck operator, angle of attack lights).

Method of Compliance: Photometric and radiometric performance are verified by direct measurement. Lighting Mockup, System Integration Laboratory (SIL), and aircraft evaluations are used to test and evaluate the adequacy of the lighting system, both internal and external to the cockpit, control station and crew stations.

References: JSSG-2010-5

MIL-STD-1472

MIL-STD-3009: 4.2.2, Table I, criteria for the operator station lighting system

MIL-L-006730 (cancelled, for information purposes only)

MIL-L-85762

14 CFR 23.1381-23.1401; 25.1381-25.1403

9.3.2 Lighting controllability and uniformity.

Criterion: Verify that the lighting is fully controllable and uniform and does not produce unacceptable glare, shadows, or reflections.

Standard:

a All devices that emit or transmit light within the flight deck, control station or other crew compartments, and are related by function or area, are attached to the aircraft power via a common dimmer control.

b. At any given luminance level, lighting components within a lighting subsystem (primary instrument panel, secondary instrument panel, primary console, secondary console, warning, caution and advisory signals, utility, and compartment) provide luminance such that the average luminance ratio between lighted components is not greater than 2 to 1. For displays, luminance variation does not exceed 30 percent.

c. Reflections from the canopy, windshields, and windows are minimized and reflections that affect the outside vision of the pilot and crewmembers are not sufficient to result in a hazard. Specular reflections resulting from aircraft lighting sources do not obscure the displayed information when viewed from the pilot's and crewmembers' design eye position(s).

d. Reflections and glare from control station windows and lighting are minimized and do not affect the display and control readability.

e. The lighting system is designed and installed so as to prevent the leakage of stray light and shield all illumination sources from direct view.

Method of Compliance:

a. Dimmability control is verified by lighting mockups and aircraft and control station demonstrations.

b. Average luminance ratio is verified by measurements in a lighting mockup, control station or aircraft with each lighting subsystem independently energized to half brightness and maximum brightness and the contrast ratio between the brightest and dimmest lighting component of the subsystem. Visual inspection determines the brightest and dimmest lighting component of that subsystem. Display luminance (L) variation is determined by measuring the brightest and dimmest portion of a display at a given setting and applying the following formula: (Lmax - Lmin)/Lmax. The test is conducted at both high and low dimmer settings.

c. Acceptability of specular reflections is verified under dark ambient conditions by unaided eye inspections at full bright lighting levels for each lighting subsystem. Any evidence of foreign matter, cracks, scratches, bubbles, delamination, warps or stray light is considered as cause for rejection.

d. For control stations, acceptability of specular reflections is verified by unaided eye inspections over the expected range of ambient conditions.

e. Prevention of light leakage and stray light is verified by visual inspection of the lighting sources as installed.

References: JSSG-2010-5

14 CFR 23.1381-23.1401; 25.1381-25.1403

9.3.3 Operation in commercial airways.

Criterion: Verify that the lighting allows the air vehicle to operate in commercial airways without restriction.

Standard: Air vehicle exterior lighting complies with all applicable regulations of 14 CFR, JSSG-2010-5 and MIL-L-85314.

a. Taxi and landing lights are installed and provide sufficient light for night operations.

(1) Taxi lights have a minimum intensity value of 50,000 candelas (cd) with a minimum beam spread of 10 degrees in the vertical plane and 40 degrees in the horizontal.

(2) Landing lights have a minimum intensity value of 300,000 candelas (cd) with a minimum beam spread of 8 degrees in the vertical plane and 14 degrees in the horizontal.

(3) For exterior lighting systems that combine taxi and landing lights, the intensity and beam spread of the landing lights of paragraph 1b are met.

b. The position light system is installed in accordance with 14 CFR and the air vehicle type (e.g., FAR 23.1385-1397, 27.1385-1397).

c. The riding (anchor) light required for water operations is installed in accordance with 14 CFR (e.g., FAR 23.1399, 27.1399).

d. An anti-collision light system is installed in accordance with MIL-L-85314. Flashing characteristics, intensity, and the field of coverage are in accordance with 14 CFR (e.g., FAR 23.1401, 27.1401).

Method of Compliance:

a. Landing and taxi light performance is verified by geometric and photometric analysis in addition to demonstration of coverage, aimability, and minimized glare to the crew. Light intensity is verified by direct measurement of intensity in candelas.

b. Position light location and chromaticity lighting requirements are verified by inspection, analysis and test per 4.5.3.2.1 of JSSG-2010-5. Position light distribution and intensity are verified by inspection, analysis, and test per 4.5.3.2.2 of JSSG-2010-5 requiring direct measurement of intensity in candelas.

c. Riding light conspicuity and visual interference are verified by inspection and analysis.

d. Anti-collision lights are verified by inspection, analysis and test of the aircraft configuration as it applies to the position of the lights, conspicuity, flashing characteristics, field of coverage and visual interference. Anti-collision light intensity is verified by direct measurement of intensity in candelas.

References: JSSG-2010-5

MIL-L-85314

14 CFR 23.1383-23.1401; 25.1383-25.1403; 27.1383-25.1401; 29.1383-29.1403

9.3.4 Lighting for flight-critical tasks.

Criterion: Verify that lighting and illumination exists for crewmembers to perform all flight-critical tasks and that lighting systems are NVIS and laser eye protection (LEP) compatible, if applicable.

Standard:

a. A lighting system with sufficient luminance is provided so as not to degrade crew and/or operator performance throughout the anticipated range of flight-critical tasks. Aircrew members and/or operators are able to rapidly and accurately obtain required crew and/or control station information without vision enhancing devices. During day operations, illuminated visual signals and cockpit, crew station, and/or control station displays that are related to flight-critical tasks are readable in the full range of anticipated ambient lighting conditions in accordance with MIL-L-85762 and MIL-STD-3009.

b. Instruments and their collocated controls (if applicable) that are used during flight-critical tasks are readable and discernible. The visibility of any graduations, numerals, pointers, or other specific markings is not restricted. Luminance uniformity is maintained throughout the entire range of luminance control. At any given luminance level, lighting components within a lighting subsystem provide luminance such that the average luminance ratio between lighted components is not greater than two to one.

c. Displays are located so that they are legible from the operator or crew member position, under all expected illumination conditions from full darkness to direct sunlight (up to 10,000 fc), with adequate luminance, contrast and lighting balance. At any given luminance level, displays provide luminance such that the luminance variation between the brightest and dimmest areas is not greater than 30 percent and the luminance range does not degrade the operator(s) or aircrews ability to perform any flight critical tasks.

d. The crew and/or control station lights do not cause direct or indirect glare or reflection that interfere with the aircrew member and/or operator's interior and exterior aided or unaided vision.

e. The crew station and air vehicle lighting does not degrade aircrew visibility while using night vision devices or laser eye protection devices, and is sufficient to maintain flight and conduct safety critical tasks. The lights do not have a direct or indirect effect on the image intensification capabilities of the NVIS. NVIS lighting is compliant with MIL-L-85762 and MIL-STD-3009.

Method of Compliance: Specified levels for luminance, chromaticity, and daylight contrast of electronic and/or electro-optical displays are agreed to in the lighting test plan and approved by the airworthiness lighting technical expert during the certification basis review.

a. Sufficient luminance is verified by direct measurement using calibrated photometric equipment that verifies specified levels required by MIL-L-85762, MIL-STD-3009 and JSSG-2010-5.

b. Sufficient daylight contrast is verified by direct measurement using calibrated photometric equipment that verifies specified levels required by MIL-L-85762.

c. Chromaticity is verified by direct measurement using calibrated colorimetric equipment that verifies specified levels required by MIL-STD-3009.

d. Readability and discernibility of instruments is verified by lighting mockup or laboratory (SIL) and aircraft/control station demonstrations with human subjects, in addition to inspections of installed equipment and testing (i.e., making instrumented measurements).

e. Non-interference with interior and exterior aided and unaided vision is verified by lighting mockup or laboratory (SIL) and aircraft/control station demonstrations with human subjects, in addition to inspections of installed equipment and testing.

f. LEP compatibility is verified by lighting wavelength analysis and mockup/aircraft demonstrations indicating visibility is acceptable to conduct flight critical tasks.

g. NVIS radiance is verified by direct measurement using calibrated radiometric equipment that verifies specified levels required by MIL-STD-3009.

h. NVIS compatibility is verified by analysis of visual acuity comparison data using the system level verification testing methods for NVIS compatibility as described in MIL-STD-3009 and using methods and procedures of MIL-L-85762.

References: JSSG-2010
JSSG-2010-5
MIL-STD-3009
MIL-L-85762
MIL-HDBK-87213
14 CFR 23.1381-23.1401; 25.1381-25.1403

9.4 Human performance.

This element provides the means for the crewmembers (including operators) to monitor and control the system flight path management, navigation, caution, warning, advisory, communications, identification, propulsion, and mission and utilities subsystems. It covers presentation of emergency checklists and procedures. It encompasses the location and arrangement of the primary flight display suite, crew workload, situation awareness, and spatial disorientation aspects.

References: MIL-STD-1472

14 CFR 23.1311-23.1322; 25.1321-25.1322

9.4.1 Functional operations and workload.

Criterion: Verify that all functional operations can be safely performed including tasks performed by aircrew, operators, and maintainers. Verify that all normal and emergency procedures can be accomplished within acceptable workload limits.

Standard: Aircrew, operator and maintenance tasks are defined and can be accomplished within the capabilities of the personnel without undue risk of injury, loss of situational awareness and loss of vehicle.

Method of Compliance: All aircrew, operator and maintainer tasks are defined and documented by function and task analysis. Workload analysis and human in the loop simulation and/or flight test, using fully trained and qualified operators and maintainers, verify that trained personnel can perform the task in a safe manner.

References: JSSG-2010: 3.1, 4.1; 3.2, 4.2

JSSG-2010-1 - Handbook 3.2.1 and 4.2.1 for Method of Compliance. Table II of the document provides a list of Figures of Merit

MIL-STD-46855

14 CFR 23.1311-23.1322, 25.1321-25.1322

9.4.1.1 Primary flight display suites.

Criterion: Verify that the primary flight display suite provides the necessary information to the pilot(s) and operator(s) to enable all basic and unique flight maneuvers to be performed safely, in both normal and emergency conditions.

Standard:

a. Flight symbology presents the information needed for all flight maneuvers to include takeoff, navigation, and landing. All crew stations from which a pilot or operator is to control an air vehicle have at least one complete set of primary flight reference (PFR) or primary flight display (PFD) data. All PFR displays or PFDs provide full-time presentation of critical flight data in accordance with MIL-STD-1472, MIL-STD-411, and MIL-STD-1787 for both fixed wing and rotary wing air vehicles (e.g., MIL-STD-1787 Table I (fixed wing)).

b. Head-up displays (HUD), head-down displays (HDD) and helmet mounted display (HMD) symbology and information presentation are designed in accordance with MIL-STD-1787, MIL-STD-1472 and MIL-STD-411. If the HUD or HMD is designated as the PFR or PFD, then a head down, supplementary PFR or PFD is, as a minimum, selectable with a single control input from the pilot or operator.

Method of Compliance:

a. New PFR or PFD designs (or significant deviations from baseline designs) are verified by simulation and flight testing, including, but not limited to unusual attitude recovery (UAR); basic flight maneuvers; and mission demonstrations. Air Force PFR displays are endorsed by the Air Force Flight Standards Agency. All Navy PFDs are approved and certified by the airworthiness technical authority and SMEs identified by the NAVAIR Human Systems Chief Engineer. All Army PFDs are approved by the technical authority of the AED Crew Stations subject matter experts (SMEs).

b. Compliance with MIL-STD-1787, MIL-STD-1472 and MIL-STD-411 symbology design is verified through analysis of hardware, engineering design drawings and documents related to the pilot vehicle interface as well as through inspection and demonstration during simulation and flight test. Selectability of supplemental PFR or PFD is verified by mockup demonstration and functional testing.

References: MIL-STD-411

MIL-STD-1472

MIL-STD-1787

Air Force Flight Standards Agency white paper (Single Medium Flight Instrument Display Endorsement Process)

14 CFR 23.1311-23.1322, 25.1321-25.1322

9.4.2 Relevant documentation.

Criterion: Verify that all relevant documentation is not in conflict with systems descriptions and procedures (normal and emergency) and actual system performance; that emergency procedures are clear; and that corrective actions do not create other hazardous situations.

Standard: Operating instructions, flight handbooks, checklists, and flight/performance management and planning systems documentation provide accurate and relevant information that is not in conflict with system descriptions and procedures (normal and emergency). Required performance parameters are clearly stated. All technical documentation is validated; all emergency procedures and corrective actions are identified and do not create other hazardous situations.

Method of Compliance: Operating instructions, flight handbooks, checklists, and flight/performance management and planning systems documentation are verified by documentation reviews and demonstration of system performance. Emergency procedures are identified and documented and are compared to results from the subsystem integration testing, human use analysis, and failure and degraded modes analysis, with no inconsistencies found to exist. Analysis verifies that corrective actions do not create other hazardous situations.

References: JSSG-2010: 3.1, 4.1; 3.2, 4.2

MIL-DTL-7700

14 CFR 23.1581-23.1589; 25.1581-25.1587

9.4.3 External visibility and transmitted visual indications.

Criterion: Verify that external visibility and transmitted visual indications are sufficient for the aircrew and operators to maintain flight; conduct all necessary flight tasks; avoid ground or flight obstacles; and command, control and monitor all associated emergency procedures and maneuvers to ensure safe operation in military and civilian airspace.

Standard: External visibility and transmitted visual information allow all flight tasks to be conducted. No unsafe blind spots exist from posts, canopy bow, windshield frames, head up display (HUD) supports, etc. and no parallax exists from remote camera sensors that can introduce hazardous conditions.

Method of Compliance: The total vision envelope is verified by inspection of engineering drawings (including vision plots), a review of computer vision analyses, mock-ups, and first article demonstrations. Human factors evaluations with aircraft and control stations or representative mockups verify visibility for the intended mission equipped user population. Flight simulations and initial flight tests verify the ability to maintain flight and conduct necessary tasks.

References: JSSG-2010: 3.1, 4.1; 3.2, 4.2
JSSG-2010-2: 3.2.13.3, 3.2.13.5
14 CFR 23.1581-23.1589; 25.1581-25.1587

9.4.4 Crew system interface.

Criterion: Verify that the crew system interface (physical, graphical, perceptual, etc.) is designed to reduce the potential for, and minimize the consequences of, a crew-induced error, and provides a simple means to correct an error.

Standard: Crew Systems interfaces are designed in accordance with human engineering principles. The intended crew population can conduct flight critical tasks with low risk of error. Errors which jeopardize flight safety can be quickly corrected with a minimal number of steps.

For UAS, there are clear indications to inform the operator(s) which vehicle(s) are under their control and which vehicle(s) are being monitored.

Method of Compliance: Design in accordance with human engineering principles is verified by review and analysis of human engineering design approach and methodology documentation (e.g., crew station working group minutes, Human Engineering Design Approach – Operator (HEDAD-O)). The crew system interface is verified by subsystem integration testing, human use analysis, failure and degraded modes analysis, and crew system simulation and documentation.

Reference: MIL-STD-1472

9.4.5 Technical manual completeness.

Criterion: Verify that technical manuals, technical orders and publications are accurate and complete for all tasks that may have flight safety effects.

Standard: Technical manuals, technical orders and publications are evaluated with respect to usefulness and accuracy in the areas of job instructions (how to perform maintenance tasks), training, and job performance aids (fixed procedures and troubleshooting).

Method of Compliance: Technical manuals, technical orders and publications are verified by demonstration and inspection.

Reference: TO 00-5-3 Technical Manual, Methods and Procedures, AF Technical Order Life Cycle Management, Chapter 9 “Quality Assurance”

9.5 Life support systems.

This element provides breathing and anti-“g” provisions, as appropriate; and natural, induced, and combat hazard protection. This includes chemical biological protection, laser protection, cold water immersion protection, head protection, noise protection, altitude protection (pressure suits), protection from rapid decompression, etc.

9.5.1 Life support functionality.

Criterion: Verify that the air vehicle integrated life support systems (e.g., high altitude, "g" protection, ocular protection, and breathing) are fully functional and accessible within the flight envelope.

Standard: The life support and personal protective equipment are designed, tested, and installed as part of an overall system. The life support and personal protective equipment supports the intended personnel in the operational envelope of the air vehicle. The life support and personal protection system could include: chemical/biological (CB) protection, “g” protection, ballistic protection, personal altitude protection, thermal stress protection, flame and heat protection, smoke and toxic fumes protection, head protection, eye protection and augmentation devices, hearing protection and communication devices, clothing and accessories.

Method of Compliance: Life support system integration and functionality is verified by a combination of testing, inspections, demonstrations, and analyses, accomplished from the standpoint of the overall system performance and installation. System verification by inspection includes examination of hardware samples, components, and on-aircraft system checkout. Verification by demonstration includes mockups and simulations in the areas of human factors and cockpit compatibility and pilot acceptability. Verification by test includes centrifuge using live subjects, altitude chamber testing, sled and windblast testing to verify ejection compatibility, live parachute jumping, water immersion tests using live subjects, chemical/biological verification of the specified threat. Analysis is used to verify specific aspects of the system where testing is not appropriate or possible. System validation is demonstrated by the system functional review so that more detailed analysis and inspections can progress to meet design review milestones.

References: JSSG-2010: 3.6, 4.6; 3.9, 4.9; 3.10, 4.10; 3.13, 4.13
JSSG-2010-9: 3.9.1, 4.9.1
14 CFR 23.1301, 23.1441, 25.1301, 25.1441

9.5.2 Life support physiology.

Criterion: Verify that the system satisfies the physiological requirements of the occupants during mission, escape, and survival.

Standard: The pilot, operator and air crew are provided sufficient provisions and protection to sustain life and maintain vehicle control under natural and induced environmental conditions for the intended mission of the aircraft. This includes environmental effects that degrade human physical and cognitive capabilities. Provisions are incorporated to ensure:

a. Core body temperature can be maintained at or below 100.4 °F.
b. Breathing gas pressures and concentrations are in accordance with physiological requirements.
c. Ocular protection against foreign matter, irritants, or laser threats that may be present.
d. Protection from chemical or biological threats.
e. Consciousness can be maintained during “g” loads.
f. Ambient noise environment is characterized and protection is identified if necessary.
g. Humidity levels are acceptable (see also 8.2).

The above is not to be considered an exclusive list.

In addition, for an in-flight escape capability, physiological protective features incorporated ensure:

a. Impact protection from flying debris.

b. Flame protection to ensure the maximum skin temperature does not exceed 107.6 °F.

c. Flotation and drowning prevention for an unconscious crewmember.

d. Physiological protection from cold weather/water survival to 32 °F for 2 hours, maintaining a core temperature in excess of 96.8 °F and skin/foot temperature in excess of 60 °F.

The above is not to be considered an exclusive list.

Method of Compliance: Physiological requirements are verified by human testing in mockups, simulators and production representative systems to ensure that physiological needs are met, vehicle control can be maintained and the mission can be accomplished.

References: JSSG-2010: 3.6, 4.6; 3.9, 4.9; 3.10, 4.10; 3.13, 4.13
JSSG-2010-9: 3.9.1, 4.9.1
AFOSHSTD 48-20
14 CFR 23.1301, 23.1441, 25.1301, 25.1441

9.5.3 Life support interfaces.

Criterion: Verify that the operation of the life support system is not degraded by, and does not degrade, the normal or failure modes of operation of subsystems in which it interfaces (e.g., controls and displays, escape systems, communication, environmental management system (EMS))

Standard: The life support system is designed such that total aircraft and/or control station performance and capability are not compromised and hazards are minimized. Interface with aircraft occupants allows crew members and passengers to properly use the life support equipment and successfully perform other essential flight duties and operations. Design limits are specified for the life support subsystem where there is interface with other aircraft and/or control station subsystems so that proper equipment may be selected and accountability is provided should adjustments to these limits be required. No operational mode of the life support system degrades other aircraft and/or control station systems sufficiently to cause an unsafe condition. No normal or emergency operational mode for aircraft and/or control station subsystems causes a life support system failure or condition that can injure occupants, fail to meet physiological needs, or prevent sustained flight.

Method of Compliance: The life support system's interface with other air vehicle subsystems is verified to ensure that the operation of any of the systems interfacing with the life support system does not result in the degradation of the system involved. Verification includes inspection of the hardware components, demonstrations using mock-ups and simulations, on-aircraft and/or control station system check-outs, and/or ground/flight tests. Analysis is used to verify specific aspects of the system where other methods of verification are not appropriate or possible. A Failure Modes Effects and Criticality Analysis (FMECA) also identifies potential failure mode causes, to include those that could be induced by life support system or subsystem operations.

References: JSSG-2010: 3.6, 4.6; 3.9, 4.9; 3.10, 4.10; 3.13, 4.13
JSSG-2010-9

14 CFR 23.1301, 23.1441, 25.1301, 25.1441

9.5.4 Emergency oxygen.

Criterion: Verify that emergency oxygen is available for all occupants of the air vehicle.

Standard: The emergency oxygen system(s) provides a supply of breathing gas to all crewmember and passengers in the event of an emergency where the flow of oxygen from the primary system is interrupted or stopped. It is desirable for the system to activate automatically and alert the crewmembers that it is activated. The duration of the supply is maximized to the greatest extent possible, and as a minimum, supplies enough oxygen to allow the crew and passengers to safely descend from the aircraft's maximum altitude to below 10,000 feet MSL.

Method of Compliance: Emergency oxygen system capabilities are verified by inspection of drawings, demonstrations in mockups, and analysis of test data from system qualification tests. Emergency oxygen system operation to maximum aircraft altitude is verified by analysis of data from the oxygen system qualification program, including altitude chamber man rating tests.

References: JSSG-2001: 3.3.10.2.2

JSSG-2010: 3.7, 4.7; 3.13, 4.13

9.5.4.1 Emergency oxygen–escape.

Criterion: Verify sufficient emergency oxygen is available during high altitude escape.

Standard: A sufficient emergency oxygen supply to each crewmember is available for use during high altitude escape. This system is an integral part of the ejection seat or part of the parachute system. Emergency oxygen flow is automatically initiated and supplied to crewmembers at ejection. The duration of the supply is maximized to the greatest extent possible, but as a minimum, supplies enough oxygen to allow the crew to safely descend from the maximum altitude within the escape system envelope.

Method of Compliance: Oxygen requirements are verified by system man rating consisting of initial simulated human exposures to operational environments, followed by human testing in mockups and simulators (including altitude chamber testing) to ensure that physiological needs are met. Emergency ejection actuation and supply are verified by sled tests.

9.5.5 Life raft operation.

Criterion: Verify that each life raft has obviously marked operating instructions. Ensure that approved survival equipment is marked for identification and method of operation and that emergency flotation and signaling equipment are installed so that they are readily available to the crew and passengers.

Standard: For air vehicles with extended overwater operations, life rafts of a rated capacity and buoyancy to accommodate the occupants of the airplane are available. The buoyancy and seating capacity of the rafts accommodate all the occupants of the airplane in the event of a loss of one raft with the largest rated capacity (unless excess rafts of enough capacity are provided). At least one pyrotechnic signaling device is included with each life raft. Each life raft has obviously marked operating instructions. Approved survival equipment is marked for identification and method of operation. Stowage provisions for the required survival equipment is conspicuously marked to identify the contents and facilitate easy removal of the equipment.

Method of Compliance: Verification testing is accomplished from the standpoint of the overall system performance and installation. It consists of inspections, analyses, demonstrations, and tests of normal and emergency operations for all intended air vehicle occupants. The existence of markings and instructions are verified by air vehicle and article inspections. Floatation accessibility is verified by mockup demonstrations and functional tests of floatation deployment and inflation systems.

References: JSSG-2010-9: 3.11.7.3
14 CFR 25.1561, 23.1561, 23.1415, 121.339

9.5.6 Life raft release.

Criterion: Verify that each life raft to be released automatically or by a crewmember is attached to keep it in place alongside the air vehicle until the raft is afloat on water. Verify that this attachment is sufficiently weak to break away from the air vehicle before submerging the fully occupied life raft to which it is attached.

Standard: Each life raft capable of release is attached to the airplane by a line that will keep it alongside the airplane. The line holds the raft near the aircraft but releases if the airplane becomes totally submerged and cannot submerge a fully occupied raft.

Method of Compliance: Manual and automatic life raft deployment selection is verified by demonstration in a cockpit mockup, inspection of drawings, or by similarity with legacy systems. Verification of the physical characteristics of the aircraft flotation system is verified by a combination of analyses, inspections, demonstrations, and tests, as necessary, to ensure all specified requirements have been met. Attachment line release is verified by floatation system and lanyard load tests.

References: 14 CFR 25.1561, 23.1561, 23.1415
FAA TSO C70a

9.5.7 Firefighting equipment and protection

Criterion: Verify that the air vehicle system is equipped with breathing and eye protection equipment, fire-fighting equipment, and fire extinguishers appropriate for the expected use.

Standard: If required, the air vehicle system is equipped with breathing and eye protection equipment to protect the crew from the effects of smoke, carbon dioxide or other harmful gases, or an oxygen deficient environment. Crewmembers are protected from these effects while combating fires within the control station. If required, fire extinguishers and other fire fighting equipment are conveniently located and readily accessible by the crew (see also 8.2, 8.4, and section 14).

Method of Compliance: Inspection of operator/crew equipment provisions and the air vehicle system configuration verifies availability and accessibility of fire protection equipment. Inspections, analyses, and demonstrations verify that normal and emergency operations can be safely accomplished.

References: JSSG-2001
JSSG-2010
JSSG-2010-9: 3.9.3
MIL-HDBK-516: 8.2, 8.4 and section 14
14 CFR 25.851, 29.851

9.6 Transparency integration.

This element provides the aircrew and operator with exterior vision capability in accordance with system requirements. It may consist of a flat transparency window, a windscreen, enclosures for flight critical remote camera systems and sensors and/or a canopy system. It also may include the transparency/canopy frame, canopy actuator, canopy latch/locking system, etc.

9.6.1 Transparency system integration with the escape system.

Criterion: Verify that canopies and associated support structure, as well as the actuation, latching, and locking mechanisms, are compatible with the air vehicle escape system to permit safe egress and escape in the event of an emergency.

Standard: The transparency system mates with the escape system in a fashion that does not degrade the capabilities of either system or impose a hazardous situation for the crew member or maintenance person.

At least, the following interface areas have been considered and addressed, as applicable:

a. Canopy thrusters, removers, or rockets.
b. Explosive assemblies (shielded mild detonating cord, flexible linear shaped charge assemblies, etc.).
c. Energy transmission (electrical connections, tubing, etc.).
d. Canopy lanyards.
e. Aerodynamic decelerators.
f. Ejection through the canopy.
g. Canopy breakers.
h. Canopy/seat clearance and canopy/helmet clearance.
i. Jettisoned canopy trajectory (external path clearance with aircraft and seat hardware/crew member).
j. Canopy/seat sequencing.
k. Seat adjustment range.
l. Ejection clearance envelope
m. Ingress/egress (normal and emergency).
n. Pitot clearance with transparency.
o. Canopy seals (remain intact during jettison.
p. Canopy locking mechanism.
q. Noise.
r. Power rescue saw.
s. Training hoods/vision restriction device.

Method of Compliance: Transparency system compatibility is verified by a combination of flight tests, computer modeling, inspections of engineering drawings, demonstrations, and qualification tests (including sled tests) to allow the integration aspects of an escape system to be evaluated from an engineering standpoint, an operational standpoint, and a human factors standpoint.

Seat adjustment range and ejection clearance envelope are verified by inspection of engineering drawings and demonstrations using full scale functional mockups or simulators. Other escape system interface requirements are verified by analysis, inspection of documentation, and qualification test programs, as applicable.

References: JSSG-2010-14: 3.14, 4.14
JSSG-2010-11
MIL-STD-1474
14 CFR 23.775, 25.775, 27.775, 29.775

9.6.2 Transparency system survivability.

Criterion: Verify that the transparency systems (windshields, canopies, windows and enclosures for flight critical remote camera systems and sensors) meet survivability requirements for bird-strike impact.

Standard:

a. Transparency systems and all supporting structure withstands, without penetration, the impact of a four-pound bird at the lesser of 600 Knot True Airspeed (KIAS) or the air vehicle maximum operational true airspeed which can be achieved at altitudes up to 7000 feet and at the most adverse temperatures.

b. Impact at the specified airspeed and bird weight does not result in deflections or material failures sufficient to cause incapacitating crewmember injury or loss of the air vehicle.

c. Unmanned aircraft systems equipped with remote camera systems and sensors used for primary flight tasks remain operable after impact. Impact does not degrade exterior visibility to the extent that maintaining control of the air vehicle cannot be accomplished. If exterior visibility has been degraded to the extent that the remote camera system cannot be used to maintain control of the air vehicle, an alternative method for control (e.g., instrument flight, air vehicle transitions to a pre-determined and expected state and mode) is available.

Method of Compliance:

a. Structural analysis verifies that maximum stresses due to a bird strike are below material allowables.

b. Full scale bird strike tests at worst case impact locations verify no transparency or backup structural failure is sufficient to cause loss of the air vehicle, or crew member incapacitation, or loss of remote camera system functionality.

c. Remote camera system enclosure external visibility is verified by inspection after full scale bird strike tests have been conducted. Hazard analysis and technical documentation address process and procedures that are instituted when the air vehicle has lost the ability to provide remote camera imaging data to the operator.

References: JSSG-2010-14

USAF Structures Bulletin EN-SB-12-002, Methodology to establish bird strike design criteria.

ASTM F330

14 CFR 23.775, 25.775, 27.775 and 29.775

9.6.3 Transparency system structural/thermal capabilities.

Criterion: Verify that the structural/thermal capability of the transparency system, including any remote sensing/camera system, is adequate for all loads and flight conditions.

Standard: Transparency system, including any remote sensing/camera system does not fail when exposed to maximum thermal and structural load stresses that may be experienced in operational conditions.

Method of Compliance: Structural analysis verifies stresses within material allowables. Coupon or full scale transparency tests verify thermal and flight load capabilities.

References: JSSG-2010-14: 3.14, 4.14

14 CFR 23.775, 25.775, 27.775, 29.775

9.6.4 Transparency system shape compatibility.

Criterion: Verify that the transparency system shape is compatible, and does not interfere, with crewmember and equipment positions and motions used during normal and emergency conditions.

Standard: The transparency system is shaped so as to minimize contact with crew member equipment and systems used in the cockpit during design missions and normal and emergency crew member positions and movements.

Crew member equipment considered includes helmets, visors, anti-drown devices, breathing system components, chemical defense equipment, flash blindness protection, night vision systems, helmet mounted displays, head or helmet position tracking systems, vision restriction devices, helmet mounted sights, etc., and combinations of this equipment as required by the system's design missions.

Crew member motions considered includes normal and emergency ingress and egress, check-six, landing, use of specialized cockpit equipment, transferring equipment from one crew member to another, inertial reactions to accelerations, etc.

Method of Compliance: Verification is performed as a demonstration. However, testing is performed to evaluate the extent of any scratching or crazing, or the activities or positions that may cause contact. Analysis or inspection is used to provide preliminary estimates of the potential for problems with crew systems contact, but is not the sole basis for evaluating this integration. Verification addresses each item of crew member equipment and each anticipated crew member activity to ensure adequate integration with the transparency system.

References: JSSG-2010-14: 3.14, 4.14
14 CFR 23.775, 25.775, 27.775, 29.775

9.6.5 Optical characteristics of the transparency system.

Criterion: Verify that the optical characteristics of the transparency systems (e.g., windshield, canopy, windows, and enclosures for flight critical remote camera systems and sensors) are compatible with the critical optical systems used by the crewmember and/or operator and provide an effective and safe optical environment for the crewmember and/or operator.

Standard:

a. Transparency systems optical characteristics do not cause distortion, obscurity, reflections, or reduced transmittance sufficient to render vision or flight critical sensors or systems ineffective for critical optical zones. Critical optical zones for transparencies systems meet the following limits:
   (1) Haze less than 4%.
   (2) Optical distortion as measured by grid line slope in accordance with ASTM F2156 and results are better than 1:12.
   (3) Binocular disparity, if applicable, is less than 2.0 mrads eye convergence and less than 1.0 mrads eye divergence, and less than 2.0 mrads of dipvergence.
   (4) Binocular magnification disparity, if applicable, is less than 2%.
   (5) Transmittance is at least 65% both visible and NVIS, from Design Eye Point at the installation angle for fighter aircraft and at least 60% other aircraft platforms.
   (6) No birefringence, reflections, crazing or minor optical defects rendering critical optical zones ineffective.

b. If multiple sensors are installed, the sensors do not cause debilitating distortion, multiple images, binocular disparity, or false parallax and provide an accurate and interpretable visual representation of the external scene view to the pilot or operator.

c. Transparency system optical characteristics allow the pilot or operator to maintain sufficient visual capability under all relevant operational lighting conditions (including NVIS lighting) to maintain vehicle control and safe flight.

d. Transparency system optical characteristics do not contribute to pilot or operator loss of situational awareness, susceptibility to pilot errors, or an inability to make flight critical decisions that could result in loss of the air vehicle.

Method of Compliance:

a. Transparency system optical characteristics are verified by optical test of coupon samples and representative first articles, as appropriate, in accordance with JSSG-2010-14.

b. Lighting mockup evaluations, flight simulations, and flight testing verify that the pilot and/or operator visibility is sufficient in all relevant operational lighting conditions (including NVIS lighting) to maintain vehicle control and perform critical tasks, such as sustaining flight, aerial refueling and unmanned aircraft system operation. NVIS compatibility of transparencies is verified by testing in accordance with MIL-L-85762.

c. System level visual capability is verified by human engineering demonstration and analysis using high fidelity flight simulators, flight test vehicles and/or control stations to demonstrate adequate situational awareness is maintained, and pilot/operator can make flight critical decisions

References: JSSG-2010-14
MIL-L-85762
ASTM D1044
ASTM F733
ASTM F735
ASTM F2156
14 CFR 23.773, 23.775, 23.773, 25.775, 27.773, 27.775, 29.773, 29.773

9.6.6 Canopy deployment power.

Criterion: Verify that necessary deployment power is available under normal and emergency conditions and that there is no interference with manual actuation of the canopy when air vehicle or external power is not available.

Standard: An alternate or secondary power source is provided that will operate the canopy. A manual system is provided for ingress and egress with all aircraft power off and for canopy operation when primary actuation system is not available. An external means is provided to enable a ground rescue crew to manually open the canopy.

Method of Compliance: Deployment power availability and manual capabilities are verified through system demonstrations, subsystem testing, and vehicle functional tests.

References: JSSG-2010-14
14 CFR 23.775, 25.775, 27.775, 29.775

9.6.7 Transparency system integration with the environmental management system.

Criterion: Verify that the environmental management system interface provides necessary defogging, pressurization, heating, cooling, humidity control, and ventilation of the transparency system under normal and emergency conditions.

Standard:

a. Provisions are incorporated to sufficiently remove rain, snow, ice, and fog from transparencies, within the operational limits of the air vehicle, such that adequate visibility and sensor operation is maintained to enable the pilot, operator and/or crewmember to obtain necessary information and situational awareness to sustain flight; avoid obstacles; make flight critical decisions; and land the air vehicle.
b. The subsystems used to remove rain, snow, ice, or fog do not expose transparencies to temperatures, fluids or other conditions that obstruct pilot, operator and/or crewmember vision or degrade sensor operation to the extent that the conditions listed above cannot be accomplished.

Method of Compliance:

a. System tests in simulated flight conditions verify the capability of removing fog, ice, snow, or rain from the transparency. Testing is accomplished in an environmental chamber that simulates potential operational conditions. Air vehicle flight tests verify the system capabilities under actual flight conditions.
b. Material and transparency coupon tests with exposure to rain, snow, ice, or fog removal systems verify the capability to maintain adequate light transmittance and optical qualities.

References: JSSG-2010-14
14 CFR 23.775, 25.775, 27.775, 29.775

9.7 Crash survivability

This element provides the pilot, crew, and passengers with protection/procedures in the event of a crash scenario. It covers crash rescue procedures, fire protection, equipment containment, smoke protection, emergency lighting and seating.

References: JSSG-2001: 3.3.10.2.2
JSSG-2010: 3.7, 4.7; 3.13, 4.13
USAAVSCOM TR 89-D-22A, Aircraft Crash Survival Design Guide, December 1989
14 CFR 23.561, 23.562, 25.561, 25.562, 25.563, 27.561, 27.562, 27.563, 29.561, 29.562, 29.563

9.7.1 Seating system load capabilities.

Criterion: Verify that seating system load capabilities are commensurate with the air vehicle type for aircrew and passengers and that the design of the floor and load paths to the seat attachments is capable of sustaining the loads of the seat system in applicable crash load conditions.

Standard: The seating and restraint system has been designed to hold in place an occupant for design static and dynamic loading. The seating and restraint system including structural attachment to the aircraft withstands static loads defined in SAE AS8049, table 4, and dynamic load defined in 5.3 with a maximum weight occupant (250 lbs unless otherwise specified). For military ejection seat equipped aircraft, the dynamic forward ±15 degrees off axis "g" load capability is 40 g's. The loading directions are specific to airframe type and orientation of the seat.

Method of Compliance: Analysis and test documentation show that the seat and restraint system with associated aircraft structure meet the standard with the seated occupant. Static and dynamic load capabilities are verified by testing defined in SAE AS8049, 5.1 and 5.3.

References: JSSG-2001: 3.3.10.2.2

JSSG-2010: 3.7, 4.7; 3.13, 4.13

SAE AS8049

14 CFR 23.561, 23.562, 25.561, 25.562, 25.563

9.7.2 Seating stroke clearance envelopes.

Criterion: Verify that the stroke clearance envelope for energy absorbing seats is clear of structures and equipment that could impede seat stroke.

Standard: Stroke volume for both the functioning of the seat and the occupant is provided in the aircraft installation for the impact velocity environment specified for the aircraft.

Method of Compliance: Stroke clearance envelope is verified by dynamic seat tests, analysis and documentation inspection, indicating the occupied stroke volume for the design impact velocity of the aircraft and that volume exists and is unobstructed in the aircraft design.

9.7.3 Restraint systems loads.

Criterion: Verify that restraint systems are designed to restrain the occupant properly for the escape system environment and the crash loading of the seat.

Standard: The occupant is kept in position with respect to support of the seating system under both inertial and applied loads (such as aerodynamic pressure). The restraint system prevents "submarining" or translation of the pelvis under the lap belt. The shoulders are restrained to align the thoracic and lumbar spine with primary ejection seat catapult loads and vertical crash loads. Torso restraint holds occupant under aerodynamic and parachute opening shock loads. Leg restraints prevent the major injuries due to adduction of the femur. Restraint systems in forward facing seats limit dynamic overshoot of reaction loads into the seating structure during required crash loads.

Method of Compliance: Analysis and test documentation show that the restraint system properly restrains the occupant. Dynamic crash load tests verify restraint integrity and body restraint. Ejection sled tests and parachute jump tests verify escape system restraint capability.

References: JSSG-2001: 3.3.10.2.2

JSSG-2010: 3.7, 4.7; 3.13, 4.13

14 CFR 23.561, 23.562, 25.561, 25.562, 25.563, 27.561, 27.562, 27.563, 29.561, 29.562, 29.563

9.7.4 Occupant strike envelope.

Criterion: Verify that the strike envelope of the occupant during crash loads are kept free of objects that are risks to survival or may cause serious injury that renders the crewmember unable to perform post-crash egress functions.

Standard: There are no objects in the crew station that would cause major injury within the throw distance of restrained occupants during design crash loads. Torso and head motion do not contact surfaces, edges, corners, or structures/equipment with sufficient velocity to cause injury.

Method of Compliance: Analysis and test documentation shows that occupant body translation is determined for design crash loads and that no objects in the crew station that would cause major injury are within that translation volume. Analytical models of human body motion under crash load conditions verify that no strike hazards exist.

References: JSSG-2001: 3.3.10.2.2

JSSG-2010: 3.7, 4.7; 3.13, 4.13

14 CFR 23.561, 23.562, 25.561, 25.562, 25.563, 27.561, 27.562, 27.563, 29.561, 29.562, 29.563.

9.7.5 Post crash operational exits.

Criterion: Verify that the exits are post-crash operational up to the design crash loads.

Standard: Aircraft exits designated for ground egress by aircraft occupants will function after exposure to the design crash loads of the aircraft platform. Function is defined by the exit opening.

Method of Compliance: Mechanical and structural analysis, test, and demonstration show that the exit functions up to design crash loads.

References: JSSG-2001: 3.3.10.2.2

JSSG-2010: 3.7, 4.7; 3.13, 4.13

14 CFR 23.561, 23.562, 25.561, 25.562, 25.563, 27.561, 27.562, 27.563, 29.561, 29.562, 29.563

9.7.6 Items of mass.

Criterion: Verify that, under emergency landings, ditching, and crash loads, items of mass do not cause serious injury to occupants or prevent escape.

Standard: Ultimate loads for structural installations are considered for normal and emergency operations/conditions. Installed equipment in passenger compartments is provided with a restraining means to protect passengers during an emergency landing. Items exceeding a defined mass located in a manner that could result in injury to personnel or prevent egress are analyzed and designed to withstand loading in all potential directions without failure. Installation/mounting provisions shock load mounts or restraints are sufficient to prevent injury to personnel under the following crash load conditions; Longitudinal 9.0 forward, 1.5 aft; Lateral 1.5 right and left; Vertical 4.5 down, 2.0 up.

Method of Compliance: Documentation exists of analyses and/or testing of aircraft component installations for static and dynamic reactions using the aircraft system level crash condition requirements. Analysis and test verify that items of high mass are properly restrained and do not cause a hazard to aircrew.

References: JSSG-2001: 3.3.10.2.2

JSSG-2010: 3.7, 4.7; 3.13, 4.13

14 CFR 23.561, 23.562, 25.561, 25.562, 25.563, 25.787, 25.789, 23.787, 25.801, 25.1411, 25.1421

9.7.7 Personnel ditching provisions.

Criterion: Verify that ditching provisions, including flotation devices for all occupants, are installed on all air vehicles without assisted escape systems.

Standard: For aircraft with overwater missions, ditching provisions are installed on all air vehicles without assisted escape systems. This would include one life preserver for each occupant. For extended overwater operations, an aircraft has enough life rafts of a rated capacity and buoyancy to accommodate the occupants of the airplane. Unless excess rafts of enough capacity are provided, the buoyancy and seating capacity of the rafts accommodates all the occupants of the airplane in the event of a loss of one of the largest rated capacity. Approved survival equipment is attached to each life raft. There is an approved survival type emergency locator transmitter for use in at least one life raft.

Method of Compliance: Verification is accomplished from the standpoint of the overall system performance and installation. It consists of inspections, analyses, demonstrations, and tests of normal and emergency operations for all intended air vehicle occupants. Inspection of the vehicle configuration verifies availability of flotation devices. Device floatation and buoyancy characteristics are verified by tests in ocean or fresh water environments.

References: JSSG-2001: 3.3.10.2.2

JSSG-2010: 3.7, 4.7; 3.13, 4.13

14 CFR 23.561, 23.562, 25.561, 25.562, 25.563, 27.561, 27.562, 27.563, 29.561, 29.562, 29.563.

9.7.8 Pre-crash warning system.

Criterion: Verify that pre-crash warning between aircrew and all compartments is possible without aircrew or occupants leaving their seating position.

Standard: For troop and passenger carrying aircraft, the system provides a warning method or system that enables pilots, in the event of potential or impending mishap, to quickly and clearly convey a crash warning to aircraft occupants so that they can prepare for impact.

Pre-crash warning displays are unambiguous and redundant (visual and auditory, for example).

Pre-crash warnings do not cause confusion or induce panic.

When visual and auditory displays are used in conjunction with each other, the auditory warning devices supplement or support the visual displays (MIL-STD-1800, cancelled).

Pre-crash warnings are audible, readable and intelligible at all passenger seats, lavatories, and crew seats and work stations.

Means of activating the warning are accessible for immediate use from each crew station in the pilot compartment.

Method of Compliance: Pre-Crash warning systems are verified by inspection of drawings and passenger emergency egress demonstration tests. System functional tests verify the ability to activate the warning system from seated positions and the ability to convey a warning indication to all crew and passengers.

References: JSSG-2001: 3.3.10.2.2

JSSG-2010: 3.7, 4.7; 3.13, 4.13

9.7.9 Occupiable volume reduction in rotary wing aircraft.

Criterion: Verify that, for rotary wing air vehicles, occupiable volume reduction resulting from design crash loads provides reasonable protection against occupant injury.

Standard: When subjected to the design crash loads parameters, the rotary wing airframe provides containment of the occupants with no more than 15% reduction in volume and the prevention of intrusion into the occupant strike zone of injurious structures or objects. The mounting of engines, transmissions, fuel cells, rotor masts, and other high mass objects are designed to prevent their displacement in a manner that would be hazardous to the occupant volume. The transmission and rotor hub does not displace in a manner hazardous to the occupant volume during the following impact conditions: rollover about the aircraft's pitch or roll axes, main rotor obstacle strike that occurs within the outer 10% of the blade span assuming the obstacle is an 8-inch cylinder, ultimate load factors for high mass items around the occupant volume commensurate with the crash parameters of the airframe.

Method of Compliance: Structural test and analysis and crash load tests verify that the design meets occupant volume requirements.

References: JSSG-2001: 3.3.10.2.1, 4.3.10.2.1
JSSG-2010-7: 3.7.3.2.1
14 CFR 27.562

9.7.10 Emergency crew extraction mechanisms.

Criterion: Verify that mechanisms used for emergency crew extraction and for firefighting are properly marked and can be operated while wearing personal protective equipment.

Standard: When provided, crew extraction devices and fire fighting equipment are conspicuously marked and identifiable in normal and emergency lighting conditions. Aircrew training incorporates methods of operation and/or methods are marked on or near the device. Limits and restrictions for use as well as safety devices (such as those used for handheld fire extinguishers) are clearly marked. Devices can be unstowed or deployed while wearing personal and emergency flight equipment appropriate to the aircraft. Devices can be used and effective while being used by aircrew in personal and emergency flight equipment appropriate to the aircraft. Emergency controls and actuation mechanisms for fire fighting or extraction can be accessed and utilized with protective gloves.

Method of Compliance: Emergency egress and rescue demonstrations verify the ability to operate required mechanisms. Inspection, demonstration and human factors analysis documentation verify existence of markings and the ability of rescue personnel and aircrew to operate devices.

References: JSSG-2001: 3.4.3, 4.4.3
JSSG-2010-9: 3.9.5, 4.9.5
JSSG-2010-13: 3.13.6, 4.13.16
MIL-STD-1472: 5.5, 5.6
14 CFR 25.811

9.8 Lavatories, galleys, and areas not continuously occupied

This element addresses air vehicle compartments, control stations and areas that may be accessible to operators, crew, passengers or maintainers, but that may not be occupied at all times during flight.

9.8.1 Combustible material containment.

Criterion: Verify that food service carts, refuse carts, and waste containers used to receive any combustible materials contain a fire ignited within.

Standard: The sustenance and waste management components and plumbing is installed to minimize fire hazards. The sustenance and waste management system is installed on the aircraft such that the operational envelope of the components does not violate the operational envelopes of any other aircraft subsystem, and the cabling, wiring, and plumbing routing between aircraft subsystems. Refuse containers include self-closing covers and prevent the spread of wastepaper fires beyond the container interior. All systems are designed to limit the spread of any fire.

Designated fire containment areas (such as identified in SAE AS1426) are constructed of fire resistant material; openings for ventilation, entry, or other use is minimized; either self-closing openings or placards are employed to advise that the opening must be kept closed when not in use; and use of wiring, hoses, or other equipment within that space is minimized.

Method of Compliance: The adequacy of the refuse containers' placement and operation is verified by inspections. The ability of the dry waste containers to prevent the spread of wastepaper fires beyond the container interior is analyzed and tested. The ability of the disposal receptacle to contain those fires under all probable conditions of wear, misalignment, and ventilation expected in service is demonstrated by test.

References: JSSG-2000: 3.1.7.2
JSSG-2001: 3.4.5, 3.4.6
MIL-HDBK-516, Section 5

9.8.2 Smoke and fire detectors.

Criterion: Verify that all aircraft and/or control station compartments have separate and approved smoke and/or fire detectors to alert the crew at the pilot, operator or flight engineer station for both in-flight and ground operations; that each aircraft and/or control station compartment has dedicated hand fire extinguishers; and that if unoccupied cargo holds are present, fire protection and fire detection/suppression requirements are met.

Standard:

a. Hand fire extinguishers.
   (1) The following minimum number of hand fire extinguishers are conveniently located and evenly distributed in passenger compartments.
      (a) At least one hand fire extinguisher is conveniently located in the pilot and/or operator compartment(s).
      (b) At least one readily accessible hand fire extinguisher is available for use in each baggage compartment that is accessible to crewmembers in flight.
      (c) At least one hand fire extinguisher is located in, or readily accessible for use in, each galley.
   (2) Each hand fire extinguisher is approved.

b. Built-in fire extinguishers. If a built-in fire extinguisher is provided:
   (1) Each built-in fire extinguishing system is installed so that:
      (a) No extinguishing agent likely to enter personnel compartments will be hazardous to the occupants; and
      (b) No discharge of the extinguisher can cause structural damage.
   (2) The capacity of each required built-in fire extinguishing system is adequate for any fire likely to occur in the compartment where used, considering the volume of the compartment and the ventilation rate.

c. Lavatory fire protection.
   (1) Each lavatory is equipped with a smoke detector system or equivalent that provides a warning light in the cockpit and/or control station(s) or provides a warning light or audible warning to the crew.
   (2) For manned aircraft, each lavatory is equipped with a built-in fire extinguisher for each disposal receptacle for towels, paper, or waste, located within the lavatory. The extinguisher is designed to discharge automatically into each disposal receptacle upon occurrence of a fire in that receptacle.

d. Cargo or baggage compartment smoke or fire detection systems.
   (1) The detection system provides a visual indication to the flight crew within one minute after the start of a fire.

(2) The system is capable of detecting a fire at a temperature significantly below that at which the structural integrity of the airplane is substantially decreased.

(3) There are means to allow the crew to check in flight, the functioning of each fire detector circuit.

Method of Compliance: Aircraft, control station and engineering drawing inspections verify that smoke detectors, fire extinguishers, and fire protection/detection/suppression systems are installed. System and subsystem functional tests and analyses verify the ability to detect or suppress fires under all specified operating configurations and conditions.

References: JSSG-2010-7: 3.7.3.4

JSSG-2009: Appendix G, paragraph 3.4.7.9

14 CFR 25.855, 25.857, 25.858, 25.859, 25.854

9.8.3 Intercom/ public address system.

Criterion: Verify that the fire alarm and intercom/public address (PA) system can be heard in all lavatories, galleys, and all other compartments.

Standard: The fire alarm, intercom and/or public address system is intelligible at all passenger seats, lavatories, flight attendant seats, work stations and control stations. System volume is sufficient to be detected in all compartments, during all normal flight noise levels. Alarm and intercom or PA systems are capable of functioning independently of any required crewmember interphone system. Alarm and intercom or PA systems are accessible for immediate use from at least two flight crewmember stations in the pilot compartment. For control stations located inside of permanent buildings, fire alarm and intercom/PA systems are in accordance with local building codes.

Method of Compliance: Test and analysis of fire alarm, intercom, and public address systems verify functionality under all approved operating configurations and conditions. Subsystem integration testing and crew system simulation testing verify the ability of crew, operators and passengers to hear alarms and understand intercom/PA communications. For control stations located inside of permanent buildings, compliance is shown by a certificate of occupancy from the local building inspector.

9.8.4 Safe operation under aircraft environmental exposures.

Criterion: Verify that all equipment installed in lavatories, galleys, and other areas can be safely operated in the aircraft environment and is designed to withstand all potential aircraft environmental exposures, including rapid decompression, without creating a safety hazard.

Standard: All structural elements have sufficient strength, rigidity, and durability to resist accelerations and inertia loads for a safe installation on the aircraft without permanent deformations, loss of rigidity, or loss of proper structural functioning for the specified usage. Structural integrity is consistent with strength requirements for the aircraft.

Sustenance and waste management equipment is made of quality parts, does not include sharp corners, uses adequate retention and latches, and does not create hazardous noise levels.

The sustenance and waste management equipment is designed to withstand, without degradation, exposure to the natural and induced environments of an equipment life cycle . Equipment, including enclosed chambers, assemblies, and pressure vessels can withstand rapid decompression at maximum aircraft altitudes without structural failures, deformations, or material releases that can cause injury or create a flight safety hazard.

Method of Compliance: Analyses, demonstrations, inspections, and tests are used to verify the sustenance and waste management system is properly designed. Safe operation is verified by system tests in actual or simulated flight environments. Structural analysis is accomplished to ensure that adequate installation strength is provided. Decompression tests verify ability of equipment to safely withstand rapid pressure changes.

9.8.5 Occupant entrapment.

Criterion: Verify that occupants cannot become trapped in lavatories, galleys, and other compartments during emergency evacuation situations, and that emergency lighting is available to aid egress.

Standard: All lavatory doors are designed to preclude anyone from becoming trapped inside the lavatory. If a locking mechanism is installed, it is capable of being unlocked from the outside without the aid of special tools. Each enclosed cabin with passenger accommodations has at least one adequate and easily accessible external door.

Enclosed spaces, such as lavatories and compartments, have emergency lighting to permit the occupants to perform flight safety critical functions and escape during a loss of electrical power to the normal space lighting. The lavatory and all enclosed spaces have ceiling-mounted emergency lighting that produces illumination on the floor and the door handle. The lighting automatically operates upon loss of power.

For control stations located inside of permanent buildings, lavatories and emergency lighting are in accordance with local building codes.

Method of Compliance: Verification is by inspection of drawings and emergency egress demonstrations. Lighting system tests and analysis verify functionality for all approved operating configurations and conditions.

For control stations located inside of permanent buildings, compliance is shown by a certificate of occupancy from the local building inspector.

10. DIAGNOSTICS SYSTEMS

TYPICAL CERTIFICATION SOURCE DATA

1. Failure modes, effects and criticality analysis (FMECA).
2. Acceptance test procedures.
3. Preflight test results.
4. Built-in-test software.
5. Flight test plan.
6. Testability analysis reports.
7. BIT demos reports.
8. Test and evaluation master plan (TEMP).
9. Failure report and corrective action system (FRACAS) data.
10. Test reports.
11. System safety analysis report.
12. Flight and Maintenance Manuals.
13. Failure modes and effects analysis (FMEA).

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

10.1 Failure modes.

10.1.1 Identification and detection.

Criterion: Verify that critical functional failure modes are identified and detection methods are incorporated.

Standard: Critical failures are detected and displayed in a timely manner by the system to enable actions (by system and/or operator) that prevent loss of the aircraft or personnel injury.

Method of Compliance: Critical failures are identified in a Failure Mode, Effects and Criticality Analysis (FMECA), and the detection and the timely display of those failures is verified by a combination of analysis and test.

References: JSSG-2000: 3.3.2
JSSG-2001: 3.3.7 and 3.3.7.1
SAE AIR4845 details the FMECA process.
14 CFR 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

10.1.2 Timely reporting.

Criterion**:** Verify that all critical functional failures, including built-in-test (BIT) features, are linked to the warning caution and advisory message indicators and function.

Standard: All critical functional failures activate a visual and/or aural indication in sufficient time to enable the operator or pilot to take necessary action.

Method of Compliance: The timely linkage of critical failures to the warning, caution and advisory indication is verified by conducting component, subsystem, system analysis, simulation and tests. FMECA and Failure Modes and Effects Analysis (FMEA) data along with time lines for timing and latency demonstrate compliance.

References: JSSG-2000: 3.3.2
JSSG-2001: 3.3.7 and 3.3.7.1
SAE AIR4845
14 CFR 23.1301, 23.1309, 23.1351, 25.1301, 25.1309 and 25.1351

10.2 Operation.

10.2.1 Safety of flight parameters.

***Criterion*:** Verify that the operation of air vehicle and ground diagnostic systems is proper for all safety of flight parameters.

Standard: On-board and ground diagnostic systems measure the appropriate safety of flight parameters.

Method of Compliance: The appropriate safety of flight parameters are verified by analysis and test of on-board and ground diagnostics components, subsystems, and systems.

References: JSSG-2000: 3.3.2
JSSG-2001: 3.3.7, 3.3.7.1, 3.4.4.1.6
MIL-HDBK-2165 addresses testability and the extent to which a system supports fault detection and fault isolation.
14 CFR 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

10.2.1.1 Critical parameter calibration.

***Criterion*:** Verify that critical parameter values can be measured within the established tolerances and that operation and calibration procedures are defined.

Standard: Critical parameters that need to be detected and measured by diagnostics have tolerances, accuracy and test accuracy ratio (TAR) defined. The calibration of the diagnostic sensors is specified with traceability to the National Institute of Standards and Test (NIST). Operation procedures are defined in operators and maintenance manuals.

Method of Compliance: The tolerances, accuracy and TAR of the critical parameters are verified by analysis and test. The calibration of the diagnostic sensors is verified by a Calibration Measurement Requirements Summary (CMRS) which shows traceability to NIST standards. All manuals have undergone quality assurance review by the contractor, and final versions of the manuals have been verified by the Government.

References: JSSG-2000: 3.3.2
JSSG-2001: 3.3.7, 3.3.7.1
14 CFR 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

10.2.2 Diagnostics system safety.

***Criterion*:** Verify that measures are taken to ensure that the diagnostic system itself does not induce undetected failures or otherwise damage the air vehicle system.

Standard: Diagnostic hardware and software are designed to be minimally invasive, and failures of the diagnostic sensors or software do not affect the safe operation of the air vehicle system.

Method of Compliance: Fail safe operation of the air vehicle system in response to a diagnostic system failure is verified by a combination of analysis, component, subsystem, and system tests. Diagnostic hardware and software design are verified by inspection of design documentation. Non-permanent diagnostic equipment is verified to be safe.

References: JSSG-2000: 3.3.2

JSSG-2001: 3.3.7, 3.3.7.1

14 CFR 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

10.2.3 Safety systems health reporting.

Criterion**:** Verify functionality of safety systems that provide protection against catastrophic failures prior to potential need of the safety system.

Standard: Air vehicle safety systems are checked by built-in-test and/or their health is monitored to verify functionality prior to the safety systems being activated.

Method of Compliance: A combination of engineering analysis, component, subsystem, and system testing verifies that critical safety systems are checked and their status is reported to the pilot/operator.

References: JSSG-2000: 3.3.6

JSSG-2001: 3.3.7, 3.4.4.1.6

14 CFR 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

10.2.4 Operation and maintenance manuals.

Criterion**:** Verify that all operator and maintenance manuals containing diagnostic systems are complete and accurate.

Standard: Operation and maintenance manuals reflect the appropriate engineering data to ensure diagnostic systems address safety of flight parameters.

Method of Compliance: All manuals have undergone quality assurance review by the contractor, and final versions of the manuals have been verified by the Government.

References: JSSG-2000: 3.6.2

14 CFR 23.1301, 23.1309, 23.1351, 25.1301, 25.1309, 25.1351

11. AVIONICS

Avionics certification criteria apply to manned air vehicle avionics, as well as airborne and ground segment avionics for UAS.

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria.
2. Design studies and analyses.
3. Design, installation, and operational characteristics.
4. Design approval and system compatibility tests.
5. Simulation tests and modeling results.
6. Component and system level qualification and certification tests.
7. Electromagnetic environmental effects.
8. Hazard analysis and certification.
9. Failure Modes and Effects Analysis (FMEA).
10. Avionics flight-critical hardware and software.
11. Avionics preliminary design review (PDR) and critical design review (CDR) open items.
12. Avionics integration tests and results.
13. Avionics/electronics integrity program documentation.
14. Flight test simulation plan.
15. System/subsystem self-test design and capabilities.
16. Acceptance test plans, procedures, and results.
17. Qualification test plans, procedures, and results.
18. Functional Configuration Audit (FCA) and Physical Configuration Audit (PCA) data.
19. Test reports.
20. Environmental analysis and test results.
21. Diminishing manufacturing sources plan.
22. Obsolete parts plan.
23. Failure Modes, Effects and Criticality Analysis (FMECA)

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

(NOTE: For subsystems that use computer systems and software, see Section 15 for additional specific criteria, standards and methods of compliance.)

11.1 Avionics architecture.

11.1.1 Avionics subsystems architecture.

11.1.1.1 Air data system.

Criterion: Verify for the air data subsystem (including provision for displaying primary flight parameters) that the number and type of sensors, data processors, data busses, controls and displays, and communication devices are adequate for safety of flight considerations.

Standard: The air data system provides vehicle and/or operator(s) with all needed air data information with sufficient accuracy and reliability to satisfy safety of flight requirements. The specific requirements are defined in program detailed design information. No single or dual air data system component failure results in the propagation (or absence) of information resulting in an adverse safety of flight condition (for Army; see also 14.2 of this document). Air data system external sensors are installed with sufficient separation and redundancy to ensure a single event (such as a bird strike or a lightning attachment) does not degrade air data system performance (for Army; see also 14.2 of this document). Air data system performance meets air vehicle Vertical Separation Minimums (VSM), Reduced Vertical Separation Minimums (RVSM), and Vertical Navigation (VNAV) requirements (as applicable). RVSM and VNAV performance matrices are tailored to the specific needs of the program.

Method of Compliance: Performance of Air Data safety of flight components is verified through analysis and laboratory test. Air Data System safety of flight redundancy and performance are validated through system level analysis, simulation and test. Safety Hazard Analysis verifies that all air data system related failures have acceptable risk levels. Safe operation of the air vehicle following air data system failures is verified using FMECA. Laboratory based failure mode tests verify acceptable performance for single and dual failure operation. On-aircraft ground testing verifies performance and redundancy of the air data system safety critical functions. Flight testing verifies air data system level performance.

References: JSSG-2005: 3.2.1.8.1
MIL-HDBK-516: 14.2
MIL-STD-882
MIL-STD-1787: 4.1.1
MIL-HDBK-87213: 3.1
GATOMC2 Communications, Navigation and Surveillance/Air Traffic Management (CNS/ATM) RVSM, Barometric Vertical Navigation (BARO VNAV), Area Navigation Vertical Navigation (RNAV VNAV), Performance Matrices provide CNS/ATM related air data system safety guidance. Contact GATOMC2 for current applicable performance matrices and current supporting civil documents.
RTCA DO-200
RTCA DO-236, guidance on CNS/ATM related air data system requirements:
SAE ARP4761
SAE ARP5580
14 CFR 23.1301, 23.1309, 23.1323, 23.1325, 23.1326, 25.1301, 25.1309, 25.1323, 25.1325, 25.1326
FAA AC 27-1
FAA AC 29-2
FAA AC 91-85

11.1.1.2 Propulsion system instrumentation.

Criterion: Verify that propulsion system instrumentation, with the ability to monitor performance, fuel status, and integrity of the system, is provided.

Standard: The propulsion system provides the vehicle and/or operator(s) with all needed propulsion system information with sufficient accuracy and reliability to satisfy safety of flight requirements. The system displays engine power indication (RPM, temperature, percent thrust, or other parameter(s) as appropriate for the engine type) at all times. The system displays fuel quantity remaining, along with any necessary fuel location or balance information, at all times. Power and fuel indications may be replaced/obscured by other display data if: sufficient automatic monitoring of these parameters is provided to ensure that the pilot or operator will always be notified of impending abnormal or dangerous situations; and presentation of detailed status and trend information is always available with only one control action. Power and fuel status information are available after any single point failure.

Method of Compliance: Required system displays are verified through inspection of the design. Testing verifies the accuracy of the information displayed. FMECA verifies that power and fuel status information are available after any single point failure.

References: JSSG-2005: 3.2.1.8 (Control and displays)
MIL-STD-1787: 4.1.1 provides guidance on displayed information
MIL-HDBK-87213: 3.1
RTCA DO-186
RTCA DO-200
RTCA DO-219
SAE ARP4761
SAE ARP5580
FAA AC 20-138
FAA AC 20-145
14 CFR 23.1301, 13.1305, 23.1309, 25.1301, 25.1305, 25.1309
FAA AC-27-1 and FAA AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.1.1.3 Display of parameters.

Criterion: Verify that air vehicle and vehicle management system parameters are displayed as required for safe flight.

Standard: The system continuously displays any aircraft parameter(s) defined to be important to flight safety. This may include landing gear status, cabin pressure, hydraulic system pressure, oxygen status, etc, as well as items specific to aircraft type, e.g., swing wing position, tilt rotor position, etc. These indications may be replaced/obscured by other display data if: sufficient automatic monitoring of these parameters is provided to ensure that the pilot or operator will always be notified of impending abnormal or dangerous situations; and presentation of detailed status information is always available with only one control action. Air vehicle or vehicle management system parameters required for safe flight continue to be available after any single point failure.

Method of Compliance: Required system displays are verified through inspection of the design. Testing verifies the accuracy of the information displayed. FMECA verifies that air vehicle or vehicle management system status information required for safe flight is available after any single point failure.

References: JSSG-2005: 3.2.1.8 (Control and displays)
MIL-HDBK-87213: 3.1 provides display system guidance.
SAE ARP4761
SAE ARP5580
RTCA DO-200
14 CFR 23.1301, 23.1307, 23.1309, 25.1301, 25.1307, 25.1309, 25.1351d
FAA AC 20-138
FAA AC 20-145
FAA AC 27-1
FAA AC 29-2

11.1.1.4 Communication subsystem.

Criterion: Verify for the installed communication subsystem that the number and type of sensors, data processors, data busses, controls and displays, and communication devices are adequate for safety of flight considerations, including integrity and continuity of service throughout the intended missions.

Standard: Requirements for voice and data communications systems (including communications requirements for air traffic coordination) are defined and documented for military and civilian air traffic coordination and communication. Minimum safety of flight communication range is specified. The communication subsystem installed performance meets these requirements. As a minimum, the following apply:

a. Voice communications are intelligible. A Modified Rhyme Test (MRT) score meets the specified requirements at the specified range.

b. Data communications bit error rate (BER) is specified and sufficient to preclude loss of data that would adversely affect safety of flight.

c. System provides sufficient link margin and antenna coverage to preclude loss of signal that would adversely affect safety of flight. Antenna nulls do not adversely affect safety of flight.

d. When safety of flight instrumentation telemetry is used, appropriate safety of flight data are made available to coordinators. Bit error rate of safety of flight data is specified and sufficient to preclude loss of data that would adversely affect safety of flight.

e. The safety of flight information transmitted via a communications system is received and displayed without degradation and does not cause a misinterpretation of the intended information. Safety critical Information Exchange Requirements (IER) and nodes are identified and substantiated. Interfaces with safety critical nodes (as identified in the IER matrix) are interoperable.

f. No single point failure results in an adverse safety of flight condition.

Method of Compliance: Verification methods include analyses, test, and inspection of documentation. Analyses, laboratory, open-air, ground and aircraft testing verify installed system performance. Safety Hazard Analysis verifies that all communication system related failures have acceptable risk levels.

a. Voice intelligibility is verified via statistical analysis and testing via a Modified Rhyme Test, per MIL-STD-1472.

b. Data bit error rates are verified via analysis, laboratory, open-air, and aircraft testing.

c. Link margins are verified via analysis, laboratory, open-air, and aircraft testing. Antenna coverage is verified via analysis, laboratory, open-air, and aircraft testing.

d. Instrumentation telemetry is verified via analysis, laboratory, open-air, and aircraft testing.

e. Interoperability certifications are obtained from Joint Interoperability Test Command (JITC).

f. A failure modes and effects analysis (FMEA) and a quantitative probability analysis of the installed communications system are performed to verify that there is no single point failure that adversely affects safety of flight.

References: JSSG-2005: 3.2.1.6, 4.2.1.6
MIL-HDBK-87213: 3.1 Electronically/Optically Generated Airborne Displays
MIL-STD-188-141
MIL-STD-188-181
MIL-STD-188-182
MIL-STD-188-242
MIL-STD-188-243
MIL-STD-882
MIL-STD-1472 Human Engineering: 5.3.1.8.1, guidance in conducting Modified Rhyme Testing
STANAG 4591
AFI 11-202V3: 2.16
CJCSI 6212.01 (Interoperability and IERs)
RTCA DO-186
RTCA DO-200
RTCA DO-219
RTCA DO-297
SAE ARP4761
SAE ARP5580
14 CFR 23.1301, 23.1309, 25.1301, 25.1309
FAA AC 20-138
FAA AC 20-140
FAA AC 20-170
FAA AC 27-1
FAA AC 29-2
FAA TSO C153

11.1.1.5 Navigation subsystem.

Criterion: Verify for the navigation subsystem that the number and type of sensors, data processors, data busses, controls and displays, and communication devices are adequate for safety of flight considerations, including performance, integrity, availability, and continuity of service requirements for long range reference, local area reference, and landing/terminal reference.

Standard: The navigation system provides the vehicle and/or operator(s) all needed navigation information with sufficient accuracy and reliability to satisfy safety of flight requirements. The amount, quality and refresh rate of information needed for safety of flight are defined in the design information. No single navigation subsystem component failure causes the propagation (or absence) of information resulting in an adverse safety of flight condition (for Army; see also 14.2 of this document). Navigation subsystem performance, integrity, availability and continuity of service meets air vehicle Required Navigation Performance (RNP), Vertical Navigation (VNAV), Basic Area Navigation (BRNAV), Precision Area Navigation (PRNAV) requirements (as applicable). RNP, VNAV, BRNAV, and PRNAV performance matrices are tailored to the specific needs of the program.

Method of Compliance: Performance of the navigation system safety of flight components is verified through analysis and laboratory test. Navigation System safety of flight redundancy and performance are validated through system level analysis, simulation and test. Safety Hazard Analysis verifies that all navigation system related failures have acceptable risk levels. Safe operation of the air vehicle following any single navigation system component failure is verified using FMECA. Laboratory based failure mode tests verify acceptable performance for single failure operation. On aircraft ground testing verifies performance and redundancy of the navigation system safety critical functions. Flight testing verifies previous analysis and testing. For example, when a Kalman filter is used in an integrated navigation system, a representative subset of operational flight profiles is chosen via analysis to demonstrate direct compliance to performance requirements as well as validate navigation system analysis simulations. Once validated these navigation system simulations are used to verify performance for all other operational flight profiles not directly tested.

References: JSSG-2005: 3.2.1.5, 4.2.1.5
MIL-HDBK-516: 14.2
MIL-STD-882
MIL-HDBK-87213: 3.1
AFI 11-202V3: 2.6.2
RTCA DO-236 for CNS/ATM related navigation system requirements
RTCA DO-200: 2.3.2, 2.3.3, 2.3.5, and 2.4.1 (RNP Data Processing)
SAE ARP4761
SAE ARP5580
FAA AC 20-138

11.1.1.6 Surveillance subsystem.

Criterion: Verify for the surveillance subsystem, to include detection and action/response functionality, that the number and type of sensors, data processors, data busses, controls and displays, and communication devices are capable of meeting safety of flight performance, including integrity, continuity of service, relative positioning, trajectory, timing and intent information.

Standard: Requirements for surveillance systems (including requirements for air traffic coordination and Sense and Avoid (SAA)) are defined and documented for military and civilian air traffic coordination and surveillance. The surveillance subsystem installed performance meets these requirements. As a minimum, the following apply:

a. IFF Mark XII/XIIA capabilities are implemented and certified in accordance with the DoD International AIMS program office technical standards (e.g., AIMS 97-1000 and AIMS 03-1000).

b. Mode Select (S) and related capabilities are implemented in accordance with FAA and International Civil Aviation Organization (ICAO) performance requirements, as applicable.

c. Traffic Alert and Collision Avoidance System (TCAS) capabilities are implemented in accordance with FAA and ICAO performance requirements, as applicable. Use of TCAS capabilities for formation/station keeping does not create an adverse safety of flight condition.

d. Additional sensors for SAA (e.g., optical, radar, Automatic Dependent Surveillance-Broadcast (ADS-B)) are implemented in accordance with their applicable requirements.

e. No single point failure results in an adverse safety of flight condition. (for Army: see also 14.2, this document)

Method of Compliance: Analysis, laboratory, open-air, and aircraft testing verify installed system performance. Safety Hazard Analysis verifies that all surveillance system related failures have acceptable risk levels.

a. AIMS certification is obtained.

b. A FMEA and a quantitative probability analysis of the TCAS II equipment, Mode S transponder, and altitude information source are performed resulting in no single point critical safety of flight failures.

NOTE: If commercial or commercial derivative aircraft, then FAA experimental type certification is achieved prior to first flight and complete type certification is achieved prior to production.

References: JSSG-2005: 3.2.1.6, 4.2.1.6
MIL-HDBK-516: 14.2
MIL-STD-882
MIL-HDBK-87213: 3.1 Electronically/Optically Generated Airborne Displays
DoD AIMS 97-1000/DoD AIMS 03-1000 provide the requirements for AIMS certification.
AFI 11-202V3: 5.4.2
RTCA DO-181
RTCA DO-185
RTCA DO-200
RTCA DO-212
RTCA DO-297
SAE ARP4761
SAE ARP5580
14 CFR 23.1301, 23.1309, 25.1301, 25.1309
FAA AC 20-131
FAA AC 20-138
FAA AC 20-170
FAA AC 27-1
FAA AC 29-2
FAA TSO C151
FAA TSO C153

11.1.2 Redundancy.

Criterion: Verify that redundancy is incorporated such that failure of any single sensor, connection, processor, or display unit does not result in loss of safety-critical data or display of unsafe or misleading data.

Standard: Potential failure modes, required diagnostic capability, and the effects on system safety are defined and documented. Failure modes identified, including degradation/loss due to single point failures; generation of corrupt data; memory upset conditions; blank cockpits/operator stations; and processor, system, and subsystem resets, are prevented using a combination of diagnostics capability (acceptable fault detection accuracy), fault isolation, real time principles such as Rate Monotonic Scheduling (RMS) and data stream cross check. The probability of presenting Hazardously Misleading Information (HMI) to the pilot/operator is found to be consistent with the type and mission of the aircraft.

Method of Compliance: Potential failure modes are verified by inspection of the FMEA. Laboratory and flight testing under worst case loaded conditions verify that no failure modes exist that result in unsafe flight conditions. Analysis shows probability of HMI is consistent with the type and mission of the aircraft.

References: JSSG-2005: 3.2.1.4.1, 3.2.1.8, 4.2.1.8, 4.2.1.4.1
MIL-STD-882
SAE ARP4761
SAE ARP5580
SAE ARP4761: 4.2 FMEA, 4.4 CCA, 4.4.2 PRA, 4.4.3 CMA
14 CFR 23.1309, 23.1311, 23.1331, 25.1309, 25.1331 plus any appropriate advisory circular(s)
FAA AC-27-1 and FAA AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.1.3 Data buses.

11.1.3.1 Flight critical functioning.

Criterion: Verify that data buses have sufficient redundancy, reliability, and integrity to meet system safety requirements and to preclude loss of flight-critical functioning.

Standard: Loss of flight critical functionality and the effects on system safety are defined and documented. Air vehicle/system/subsystem end to end timing and latency are documented and acceptable for normal and fully loaded conditions of all bus components (e.g., networks, switches, hubs) and interfaces for each function. Bus retries, network data error rates, message size, non-blocking operation, numbers of priorities, and level of compliance with rate monotonic scheduling are documented.

Method of Compliance: Loss of flight critical functioning documented in FMEA, analysis, and simulation. Underlying real time principles are identified (e.g., RMS based, deterministic, stochastic) and documented. Bus retries, network data error rates (e.g., 10^-12), message size, numbers of priorities, level of RMS compliance are appropriate by design. Laboratory and flight testing under fully loaded conditions verify that no loss of flight critical functioning occurs.

References: JSSG-2005: 3.2.2, 4.2.2
MIL-STD-882
SAE ARP4761
SAE ARP5580
14 CFR 23.1301, 23.1309, 25.1301, 25.1309 plus any appropriate advisory circular(s)
FAA AC 27-1 and FAA AC 29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.1.3.2 Display of unsafe or misleading information.

Criterion: Verify that data bus performance precludes display of unsafe or misleading information to the operator or maintainer.

Standard: Data bus performance supports system latency requirements, including the primary flight display latency criterion contained in 11.1.4, of this document. Integrity of data transmitted on the bus supports system integrity requirements, including the hazardously misleading information criterion contained in 11.1.2 of this document.

Method of Compliance: Analysis documents the timing and latency of buses, including latency in the presence of single point failures. Analysis and testing documents the latency, bit error rate and other parameters that define bus integrity. FMEA and testing verify results.

References: JSSG-2005: 3.2.2, 4.2.2
MIL-STD-882
SAE ARP4761
14 CFR 23.1301, 23.1309, 25.1301, 25.1309 plus any appropriate advisory circular(s)
FAA AC 27-1 and FAA AC 29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.1.3.3 Undetected failure modes.

Criterion: Verify that the design precludes undetected failure modes.

Standard: Undetected failure modes in all architecture elements (e.g., processors, buses, memory) are defined, assessed, and compensated for as required to ensure safe operation. Undetected failures include undetected hardware and interface failures (i.e., hard and intermittent) as well as failures due to priority inversions, lack of real time support (e.g., lack of rate monotonic scheduling), unpredictable software execution (e.g., unknown execution timeline), and timing anomalies

Method of Compliance: Undetected failure modes are verified by inspection of the FMEA, timeline, and latency data. Laboratory and flight testing verify that no undetected failure modes exist that result in a safety of flight condition.

References: JSSG-2005: 3.2.2, 4.2.2
SAE ARP4761
SAE ARP5580
14 CFR 23.1301, 23.1309, 25.1301, 25.1309 plus any appropriate advisory circular(s)
FAA AC 27-1 and FAA AC 29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.1.4 Deterministic operation.

Criterion: Verify that the overall avionics system operates in a deterministic or bounded manner and limits latency of any time-critical data, including primary flight data, as needed to support all safety-critical functions.

Standard: Avionic system/subsystem deterministic, real time operation, and latency (aircraft and avionic level end to end timing and latency) are defined, assessed, and documented. The avionic system and subsystems are compliant with real time principles based on Rate Monotonic Scheduling (RMS) and other mathematically based principles. Latency of a Primary Flight Display (PFD) presentation used for real-time control of an aircraft does not exceed 100 ms, unless characteristics or design of the system mitigate the effects of latency.

Method of Compliance: Avionic system/subsystem real time operation and latency are defined and documented. Laboratory, ground and flight testing verify that no deficiencies result in a safety of flight condition.

References: JSSG-2005: 3.2.1.3, 4.2.1.3

11.1.5 Modes of operation.

11.1.5.1 Undetected failure modes.

Criterion: Verify that undetected failure modes (failures not automatically detected by diagnostics) do not result in unsafe system operation.

Standard: Undetected failure modes are defined (e.g., failure condition, timing, performance, graceful degradation) and documented for normal, backup, and emergency modes.

Method of Compliance: Undetected failure modes are shown to be safe and verified by inspection of FMEA, analysis, and test data. Testing (e.g., bench, SIL, ground, flight) establishes that each mode is safe and predictable.

References: JSSG-2005: 3.3.5, 4.3.5; 3.2.1.3.2, 4.2.1.3.2
SAE ARP4761
SAE ARP5580
FAA AC 20-145
14 CFR 23.1301, 23.1309, 23.1329, 23.1335, 25.1301, 25.1309, 25.1329, 25.1335
FAA AC 27-1 and FAA AC 29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.1.5.2 Timing/latency anomalies.

Criterion: Verify that all normal, backup, and emergency modes of operation are safe for the integrated system. Verify that timing or latency anomalies do not result in unsafe system operation.

Standard: Timing (e.g., priorities, margins, bounded timelines) and latency anomalies for normal, backup, and emergency modes are assessed, documented and shown to meet safety of flight requirements.

Method of Compliance: Timing (e.g., priorities, bounded timelines) and latency anomalies for normal, backup, and emergency modes are verified by FMEA, analysis, and testing. Laboratory, ground and flight testing under fully loaded conditions verify that no timing or latency anomalies degrade safety of flight.

References: JSSG-2005: 3.3.5, 4.3.5; 3.2.1.3.2, 4.2.1.3.2
SAE ARP4761
SAE ARP5580
FAA AC 20-145
14 CFR 23.1301, 23.1309, 23.1329, 23.1335, 25.1301, 25.1309, 25.1329, 25.1335
FAA AC 27-1 and FAA AC 29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.1.5.3 Interface/interconnect failures.

Criterion: Verify that interface/interconnect failures do not result in unsafe system operation.

Standard: All interface and interconnection failures for normal, backup, and emergency modes, including transition between modes, are defined, documented and determined to be safe.

Method of Compliance: All failures and mode transitions are compatible with safety of flight requirements and verified by FMEA, analysis, and testing. Laboratory and system level testing establish that each failure is safe.

References: JSSG-2005: 3.3.5, 4.3.5; 3.2.2.2, 4.2.2.2; 3.2.2.3, 4.2.2.3
SAE ARP4761
SAE AR 5580
14 CFR 23.1301, 23.1309, 23.1329, 23.1335, 25.1301, 25.1309, 25.1329, 25.1335 plus any appropriate advisory circular(s)

11.1.6 Diagnostics.

Criterion: Verify that the avionics system integrated diagnostics provides the fault coverage, low false alarm rates, fault isolation, and fault detection needed to detect bad data and failed components that would degrade safe operation.

Standard: The diagnostic system parameters are derived from operational requirements and the system specification. Fault coverage, False alarm rates, Fault Isolation (FI) and Fault Detection (FD) standards are normally specified as percentages which are based on current technology, criticality of the system being diagnosed, and sound engineering and economic principles.

Method of Compliance: A combination of simulation, design analysis and testing is required to mature the diagnostic system. A discreet event to verify the diagnostic parameters is not practical. Maturation of the diagnostics is accomplished by carefully documenting all system testing, failures and corrective actions to determine if the diagnostic system meets the specified requirements.

References: JSSG-2005: 3.2.1.3.2, 4.2.1.3.2
14 CFR 23.1309, 25.1309
FAA AC 27-1 and FAA AC 29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.2 Avionics subsystems

11.2.1 Critical information.

11.2.1.1 Legibility of primary flight displays.

Criterion: Verify that primary flight information is provided to the crew at all times and is fully legible in all mission environments, including full sunshine on displays, sun in the eyes, and total darkness.

Standard: Primary Flight Reference (PFR) information is provided in accordance with sections 4 and 5 of MIL-STD-1787. PFR data is considered legible when it is presented on a display meeting all the following criteria. Variations on these criteria may be acceptable where data is provided showing equivalent or better legibility in all environments.

a. Display produces symbols with maximum luminance of at least 700 cd/m² for clear canopy type aircraft, 500 cd/ m² for aircraft with an opaque overhead area and 200 cd/m² for crewstations with a controlled lighting environment.

b. Displays which will be used with Night-Vision Imaging System (NVIS) produce symbols with maximum luminance of at least 10 cd/m² in NVIS mode.

c. Displays which will be used with NVIS have controlled radiance in compliance with MIL-STD-3009, table III.

d. Display is dimmable to a max luminance of 0.1 cd/m² for crewstations where out-the-window vision is required, dimmable to 20 cd/m² for crewstations where out-the window vision is not required.

e. Contrast of all critical data is at least 3.0 in an illumination environment of: 108,000 lux with a 6800 cd/m² glare source for clear canopy type aircraft, 86,000 lux with a 6800 cd/m² glare source for aircraft with an opaque overhead, or 640 lux with a 3400 cd/m² glare source for a crewstation with a controlled lighting environment (e.g., indoor UAV/ROA control station).

f. Attitude indicator is at least 75 mm wide.

g. Critical alpha-numeric characters (e.g., airspeed, altitude and heading) subtend at least 24 minutes of arc vertically.

h. Viewing angle is sufficient to allow viewing from the full range of pilot seating positions.

i. Display has sufficient resolution, uniformity, refresh rate and update rate to present the PFR in highly dynamic situations with no objectionable smear, jitter, jerking or other artifacts.

Method of Compliance: Display capabilities sufficient to continuously display primary flight information are verified by analysis. Legibility and balance of the entire installed system are verified by a lighting demonstration of the complete cockpit or control station. Legibility of individual display units is verified by review of specifications and test. Pilot or operator evaluation of the real aircraft system in flight demonstrates that all parts of the system perform correctly in the installed environment under real dynamics.

References: JSSG-2005: 3.2.1.8, 4.2.1.8; 3.2.1.8.1, 4.2.1.8.1
MIL-HDBK-516: 9
MIL-STD-1472
MIL-STD-1787: 4, 5
MIL-STD-3009
MIL-HDBK-87213: 3.1.1 provides guidance on legibility of displays; 3.2.1.6 provides guidance on verification of displays in high ambient lighting environments.
AFI 11-202V3: 2.6, 2.6.1, 2.6.1.1, 2.6.1.2, 2.6.1.2.1 provide Air Force instructions on PFRs.
14 CFR 23.1301, 23.1309, 23.1311, 23.1321, 23.1351, 25.1301, 25.1309, 25.1321, 25.1351 plus any appropriate advisory circular(s)
FAA AC-27-1 and FAA AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.2.1.2 Accuracy.

Criterion: Verify that accuracy of flight-critical information meets safety of flight requirements.

Standard: Altitude, air speed, vertical velocity (or angle-of-attack), pitch, roll and heading data are sufficiently accurate to satisfy safety of flight requirements under all operational flight conditions/environments, profiles, specified geographic locations and with any single failure of a component. The specific requirements for data accuracy and reliability are defined in program detailed design information.

Method of Compliance: Accuracy is validated through system level analysis, simulation and test. Safety Hazard Analysis (SHA) verifies that critical information related failures do not degrade accuracy below acceptable risk levels. Laboratory based failure mode tests verify acceptable performance for single failure operation. On aircraft ground testing verifies the accuracy of critical information. Flight testing verifies previous analysis and testing.

References: MIL-STD-882
MIL-HDBK-87213: 3.2.1.25.4.1 and Appendix A
SAE ARP4761
14 CFR 23.1311, 23.1323, 23.1325, 23.1326, 23.1327, 25.1323, 25.1325, 25.1326, 25.1327
FAA AC-27-1 and FAA AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.2.1.3 Warnings, cautions, and advisories.

Criterion: Verify that cautions and warnings are legible in all mission environments and are provided in an organized, prioritized system, and that the presentation of high-priority information is not masked by older or lower priority warnings and cautions.

Standard: Cockpit and control station Warnings, Cautions and Advisories (WCAs) meet the luminance and contrast requirements of MIL-STD-411. Where the operator is in a controlled ambient indoor lighting environment, WCAs are presented on a display capable of 200 cd/m² peak luminance. WCAs are presented and prioritized in accordance with MIL-STD-411. No probable failure of the WCA system results in a "safe" indication while an unsafe condition requiring pilot or operator action exists.

Method of Compliance: Luminance and contrast throughout the mission lighting environment is verified by test of each WCA display device. Legibility and balance of the entire installed system is verified by a lighting demonstration of the complete cockpit or control station. Performance of each warning and caution function and performance of prioritization schemes in the presence of worst-case multiple system failures is verified by FMECA and by testing.

References: JSSG-2005: 3.2.1.8.5, 4.2.1.8.5
MIL-STD-411
MIL-HDBK-516: 9
MIL-HDBK-87213
14 CFR 23.1311, 23.1322, 25.1322.
FAA AC-27-1 and FAA AC-29-2 provide guidance on helicopter equipment, primarily in subpart "F"

11.2.1.4 Symbology.

Criterion: Verify that instruments and symbols used to display flight-critical information employ accepted formats, directions, etc.

Standard: Instruments and symbols used to display airspeed, altitude, attitude, heading, and any other parameters considered essential to flight are in accordance with MIL-STD-1787 and MIL-HDBK-87213 in the areas of, but not limited to, shape and scaling, direction of motion, and color.

Method of Compliance: Primary Flight Reference (PFR) presentations are analyzed against the requirements and guidance in MIL-STD-1787 and MIL-HDBK-87213 and tested in manned simulations, mockups, and/or the actual aircraft or control station, to verify that flight instrument standards and conventions are followed. Assessment by an independent team of pilots or operators (e.g., the Air Force PFR endorsement process) is used to assess any new or unique approaches.

References: MIL-HDBK-516: 9
MIL-STD-1787: 4.2 and Appendix A
MIL-HDBK-87213
14 CFR 23.1321, 23.1541, 25.1321, 25.1541
FAA AC 23-1311-1: Section 9
FAA AC-27-1 and FAA AC-29-2 provide guidance on helicopter equipment, primarily in subpart “F”

11.2.1.5 BIT features.

Criterion: Verify that BIT features of equipment alert the flight crew of flight-critical equipment status.

Standard: All flight-critical failures identified through a FMECA are linked to a caution and warning function and message indicator (appropriate visual and/or aural indicators) to warn the flight crew or operators of impending or failed functions. The information is provided to the crew and/or operators to enable them to determine the failed function in a timely manner to take appropriate action.

Method of Compliance: A combination of analysis and test is utilized to ensure that the critical functional failures tied to the caution and warning indications activate the indication, and necessary information is displayed to the crew or operator. FMECA and FMEA data along with time lines for timing and latency demonstrate compliance.

References: JSSG-2005: 3.2.1.3.2, 4.2.1.3.2
SAE ARP4761
SAE ARP5580
14 CFR 23.1309, 25.1309
FAA AC-27-1 and FAA AC-29-2 provide guidance on helicopter equipment, primarily in subpart “F”

11.2.2 Reliability/redundancy of controls.

Criterion: Verify that controls have adequate redundancy and/or reliability to maintain control of all safety-critical functions.

Standard: Avionic subsystem controls such as those for controlling avionic modes and system function are defined, (e.g., redundancy, robust reliability, timelines, latency) documented and determined to be safe and predictable. The design includes redundant data presentation, power, and operator control for all safety of flight parameters and functions.

Method of Compliance: Avionic system control functionality is verified by inspection of design documentation, analysis and FMEA. Laboratory, ground and system level testing establishes that control functionality is safe and predictable.

References: JSSG-2005: 3.2.1.8.6, 4.2.1.8.6
SAE ARP4761
SAE ARP5580
14 CFR 25.777
FAA AC-27-1 and FAA AC-29-2 provide guidance on helicopter equipment, primarily in subpart “F”

11.2.3 Safety and flight critical control functions.

11.2.3.1 Control function integrity.

Criterion: Verify that the integration of off-board system command and control, automatic/semi-automatic (man-in-the-loop) landing, formation, guidance, and other control used for safety and flight critical functions ensures safety of flight integrity and continuity of service throughout the intended missions.

Standard: Requirements for data link communication systems (including but not limited to link availability, integrity, reliability, continuity of service) are defined and documented. The data link subsystems' installed performance meets these requirements throughout the operational environment. As a minimum, the following apply:

a. The data communications bit error rate is sufficient to preclude loss of data (to include safety of flight data) that would adversely affect safety of flight.
b. The system provides sufficient link margin, bandwidth, latency, throughput and antenna coverage to preclude loss of signal that would adversely affect safety of flight. Antenna nulls do not adversely affect safety of flight. For Army, system latency demonstrates both line of sight (LOS) and beyond line of sight (BLOS) to ensure it does not adversely affect safety.
c. When safety of flight instrumentation telemetry is used, appropriate safety of flight data are made available to coordinators. Bit error rate of safety of flight data is specified and sufficient to preclude loss of data that would adversely affect safety of flight.
d. Contingency systems and procedures are defined, documented, and verified. Safety of flight critical data links are redundant, include backup data link systems, and/or have contingent flight path/route management (e.g., automatic return-to-base) capabilities.
e. Switchover of the command and control data link does not lead to an unsafe condition. Handover procedures are positive, controlled and result in a safe evolution.
f. For Army, requirements are specified according to the criticality of the function and the class of airspace of the intended operation.

Method of Compliance: Analysis, laboratory, open-air, and aircraft testing verify installed system performance to include:

a. Data bit error rate.
b. Link margin analysis, bandwidth, latency, throughput and antenna coverage.
c. Instrumentation telemetry safety of flight data and bit error rate.
d. Contingency systems and procedures.
e. Switchover of command and control data link and handover procedure safety.
f. For Army, compliance is determined by the criticality of the function.

References: JSSG-2005: 3.2.2, 4.2.2
14 CFR 23.1301, 23.1309, 25.1301, 25.1309
FAA AC 20-140

11.2.3.2 Control function information display.

Criterion: Verify that the integration of off-board system command and control, automatic/semi-automatic (man-in-the-loop) landing, formation, guidance, and other control used for safety and flight critical functions ensures that hazardously misleading information is identified, and precludes display of such information to the operator.

Standard: Requirements for display of data linked information are defined and documented.

The display's installed performance meets these requirements. The safety of flight information that is transmitted via a data link is received and displayed, as appropriate, without degradation or misinterpretation of the intended information.

Method of Compliance: All data links that handle safety of flight information are verified by analysis, laboratory, and aircraft testing for installed system performance. The criteria of 11.2.3.1 and 11.1.3 are satisfied. A FMEA analysis and a quantitative probability analysis of the installed data link system are performed resulting in no single point critical safety of flight failures.

References: JSSG-2005: 3.2.2, 4.2.2
SAE ARP4761
SAE ARP5580
14 CFR 23.1301, 23.1309, 25.1301, 25.1309
FAA AC 20-140

11.2.4 Operational environment.

Criterion: Verify that each subsystem (including any off-the-shelf equipment) and the overall system operates throughout the required operational environment without imposing a safety of flight risk. This verification typically includes environmental qualification and/or analysis.

Standard: Applicable climatic, shock and vibration environments are specified in the system specification.

Method of Compliance: Verify proper operation of the avionic subsystem by analysis and test to demonstrate that it can actually provide required performance within the envelope of possible operational environments as required in the system specification without imposing a safety of flight risk.

References: JSSG-2005: 3.2, 4.2.3
MIL-HDBK-516: 12, 13
MIL-STD-810 can be used as guidance in selection and tailoring of appropriate requirements for specified environments. It provides guidance and test methods for verification.
FAA AC-23.1309-1
FAA AC 25.1309-1

11.2.5 Electrical power quality.

Criterion: Verify safe avionics subsystem operation with required power characteristics.

Standard: Applicable avionics subsystem equipment utilizes electric power in accordance with MIL-STD-704 (for Army only, in accordance with MIL-STD-704, Aircraft Electric Power Characteristics, ADS-37A-PRF, Electromagnetic Environmental Effects (E^3) Performance Verification Requirements and/or program requirements or the system specification). The avionics subsystem equipment specification also specifies the type of electric power to be utilized and the detailed performance required during normal, abnormal, emergency, starting and transfer operation of the aircraft electric system.

Method of Compliance: Verify proper operation of the avionics subsystem by test to demonstrate that the equipment provides required performance within the envelope of possible conditions present within the electrical power system. Equipment testing is used to demonstrate avionics subsystem compatibility with the electric power characteristics of MIL-STD-704 (for Army only, in accordance with MIL-STD-704, Aircraft Electric Power Characteristics, ADS-37A-PRF, Electromagnetic Environmental Effects (E^3) Performance Verification Requirements and/or other required documents).

References: JSSG-2005: 3.2.2.5, 4.2.2.5
MIL-HDBK-516: 12
MIL-STD-704
ADS-37A-PRF
14 CFR 23.1351, 25.1351, 27.1351, 29.1351

11.3 Air vehicle avionics.

11.3.1 Avionics air vehicle installation.

Criterion: Verify that the avionics equipment installation, including arrangement and crashworthiness, is adequate for safety of flight.

Standard: Applicable climatic, shock and vibration environments are specified in the system specification to address the equipment installation. The hardware meets crashworthiness and is retained in the aircraft in a manner that does not result in additional injury to the crew. The safety of flight equipment is mounted in such a manner that it is easily accessible and visible by the crew to prevent a safety of flight risk in normal and emergency conditions.

Method of Compliance: Verify proper operation/installation via analysis, demonstrations, and tests of the avionic subsystems to demonstrate that it can provide required performance and safety within the envelope of possible operational environments as required in the system specification without imposing a safety of flight risk.

References: MIL-HDBK-516: Section 9
MIL-STD-810 provides guidance on environmental qualification.
MIL-HDBK-87213: 3.2.3 provides guidance on environmental requirements for cockpit display equipment.

11.3.2 Necessary limitations.

Criterion: Verify that flight manual and maintenance manual limits are adequate to conduct safe flight, including emergency operations.

Standard: Flight and maintenance manuals contain all necessary limits to ensure safe flight including all limitations established as a result of all other airworthiness criteria assessments. All emergency operations are documented.

Method of Compliance: All manuals have undergone a quality assurance review by the contractor and are verified by the government. An independent group of pilots, operators and maintenance experts conduct reviews of all flight and maintenance manuals to ensure all limitations and emergency operations are clearly identified and easily understood.

References: JSSG-2005: 3.2.2, 4.2.2
MIL-HDBK-516: 4, 16
MIL-PRF-63029
14 CFR 23.1501, 25.1501, 27.1501, 29.1501
FAA AC 27-1: Subpart G
FAA AC 29-2

11.3.3 Antenna performance.

11.3.3.1 Flight critical functionality.

Criterion: Verify that installed antenna performance and patterns for safety/flight-critical transmitting and receiving systems provide adequate gain and coverage to ensure flight-critical functionality is retained.

Standard: Requirements for systems' link margins and antenna coverage necessary for safety of flight are defined and documented. The subsystems' installed performance provides sufficient link margin and antenna coverage to preclude loss of signal that would adversely affect safety of flight. Antenna nulls do not adversely affect safety of flight.

Method of Compliance: Analysis, laboratory, open-air, and aircraft testing verify installed system performance and antenna coverage. For USAF and Army, antenna system coverage testing for safety of flight systems has 360 degrees spherical coverage.

Reference: JSSG-2005: 3.3.5, 4.3.5

11.3.3.2 Information integrity and assurance.

Criterion: Verify that installed antenna performance and patterns for safety/flight-critical transmitting and receiving systems provide adequate gain and coverage to ensure unsafe information is not displayed to the operator or maintainer.

Standard: Requirements for information integrity and assurance are defined and documented. Displayed safety of flight information obtained using antenna based systems is not degraded or altered to cause an unsafe condition.

Method of Compliance: Analysis, laboratory, open-air, and aircraft testing verify installed system performance. Criteria of 11.2.3.1, and 11.1.4 are satisfied. An FMEA and a quantitative probability analysis of the installed system are performed resulting in no single point critical safety of flight failures.

References: JSSG-2005: 3.3.5 and 4.3.5
SAE ARP4761
SAE ARP5580
14 CFR 23.1309

11.3.3.3 Availability.

Criterion: Verify that installed antenna performance and patterns for safety/flight-critical transmitting and receiving systems provide adequate gain and coverage to ensure adequate availability and continuity of service for safety of flight operations.

Standard: Requirements for antenna based systems are defined and documented. The subsystems' installed performance meets these requirements. Systems provide sufficient link margin and antenna coverage to preclude loss of signal that would adversely affect safety of flight. Antenna nulls do not adversely affect safety of flight.

Method of Compliance: Analysis, laboratory, open-air, and aircraft testing verify installed system performance. Link margins are verified through analysis, laboratory, open-air, and aircraft testing. Antenna coverage is verified with analysis, laboratory, open-air, and aircraft testing.

References: JSSG-2005: 3.3.5, 4.3.5
14 CFR 23.1309

12. ELECTRICAL SYSTEM

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria.
2. Design studies and analyses, including electrical loads analysis.
3. Failure modes, effects, and criticality analysis (FMECA).
4. Hazard analyses.
5. Functional operations test results.
6. Performance test results.
7. Installation and operational characteristics.
8. Component and system qualifications.
9. Flight manual, flight test procedures, and limitations.
10. Wiring diagrams, which may include information regarding:
    a. Wire types, wire sizes and current/voltage carried, wire identification, circuit breaker sizes and part numbers.
    b. Harness diameters including modified harnesses.
    c. Connector and accessories part numbers and identification.
    d. Clamping and part numbers.
    e. Miscellaneous parts identification and part numbers-nuts, bolts, washers, terminal lugs, environmental splices/shield terminations.
11. 3D routing diagrams with several views and pictures.
12. Visual assessment of the design implementation and installation.
13. Component and system qualifications.
14. Installed equipment list.
15. Diminishing manufacturing sources plan.
16. Obsolete parts plan.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

(NOTE: For subsystems that use computer systems and software, see Section 15 for additional specific criteria, standards and methods of compliance.)

12.1 Electric power generation system.

Definition: For airborne, shipborne, ground applications, or UAS/UAV/ROA/RPV fixed location or portable control stations the electric power generating system is defined as including electrical power sources, main power buses, transmission cables and associated control, regulation and protective devices.

Summary Description: Good design practice and electrical compatibility principles applicable to aircraft electrical power systems are particularly emphasized by/in the associated commercial and DoD referenced documents listed below. This list should not be considered to be an exclusive list.

References: For guidance/principles regarding aspects of assuring effective and proper electric power generation system design, integration and compatibility:

MIL-HDBK-299
MIL-HDBK-454
MIL-STD-464
MIL-HDBK-704
MIL-STD-704
MIL-STD-1399-300
MIL-STD-1683
MIL-E-7016
MIL-STD-7080
AFGS-87219
ADS-51-HDBK: Chapter/Section 4-8.6
SAE AS1831
SAE AS50881
ARINC Report 609
NFPA 70

12.1.1 Power quantity.

Criterion: Verify that sufficient power is available to meet the power requirements during all modes of operation, mission profiles, failure conditions and malfunction recovery procedures. Verification of sufficient power requires consideration of all sources, and includes evaluating battery rate(s) of discharge.

Standard: Electrical load demand for each mission requirement is defined both without and with critical failures. Power supply capacity exceeds load demand for all operating conditions, including transient and probable failure conditions to include multiple power source failures for all combinations of failure conditions.

In the event of a complete loss of the primary electrical power generating system, battery capability exists for providing thirty minutes (or more, if so specified) of electric power to those loads which are essential to continued safe flight and landing. This time period includes the time required for operator/pilot recognition and corrective load shedding action.

Method of Compliance: The Electrical Loads Analysis properly documents the power requirements and conditions anticipated on the aircraft. Qualification, simulator, ground and flight tests verify that adequate power is available for all operating conditions. Failure conditions are analyzed in the Failure Modes, Effects and Criticality Analysis (FMECA). Analysis of the architecture verifies sufficient electrical flow paths for normal and abnormal conditions.

Analysis of Electrical Loads Analysis substantiates the ability of the backup system components to power required equipment and systems. System tests are successfully performed, including battery tests under actual load conditions using a non-new, nominally aged battery to reflect end-of-service-life rated capacity.

References: For guidance/principles regarding design and operation of safe electrical generation systems:

JSSG-2009: H.3.4.8, H.4.4.8, H.3.4.8.4, H.4.4.8.4.
MIL-HDBK-454
MIL-STD-464

MIL-PRF-21480

AFGS-87219

ADS-51-HDBK: Chapter/Section 8-7

For guidance/principles regarding/affecting the integrated design and operation of backup power within aircraft electrical systems:

JSSG-2009: H.3.4.8, H.4.4.8, H.3.4.8.5, H.4.4.8.5.

MIL-E-7016

AFGS-87219

14 CFR 23.1351-23.1367, 25.1351-25.1363.

12.1.1.1 Notification of battery discharge.

Criterion: Verify that there is a means to notify the crew if an electrical malfunction is causing the continuous discharge of any safety of flight battery system.

Standard: The electrical system is designed to provide crew and operator notification for any system malfunction that results in a continuous discharge mode of operation of any battery used in a flight critical/emergency battery system.

Method of Compliance: Verification methods include analysis, test, and inspection of documentation. Verify that crew/operator receives notification for any system malfunction that results in a continuous discharge mode for any safety of flight batteries. Verify notification includes voltage and current of the battery system so that battery capacity can be evaluated.

References: JSSG-2009: H.6.3.2.

MIL-PRF-8565

MIL-PRF-81757

MIL-PRF-29595

12.1.2 Safe operation of generation system.

Criterion: Verify that the operation of the electric power generation system and its component parts is safe, including adequate implementation of cooling provisions, status/failure indications, and mechanical/thermal disconnect (as applicable) of generators, converters, inverters, batteries, etc.

Standard:

a. Each installed system is free of hazards in its own operation, in its effects on other parts or components of the aircraft, and in its use and interaction with operating, passenger and servicing personnel.
b. Provisions are included to allow operators and flight crew members to selectively disconnect electrical power sources from the system.
c. Status and failure indications are provided in a clear manner for operating and maintenance personnel.
d. Generator(s) withstand(s) operational parameters, including overload applications for five seconds and five minutes in accordance with 3.4.8.2 of MIL-PRF-21480 or equivalent applicable specification(s) for the type(s) of equipment(s) being utilized.
e. Means are provided for electro-mechanical/thermal disconnect of generators under all stressing conditions.
f. Means are provided to contain parts in the event of a failure.

Method of Compliance: Verification methods include analysis, test, demonstration, and inspection of documentation.

a. FMECA verifies that the system is free of hazards in its own operation.
b. Analysis of design documentation verifies proper disconnects are provided.
c. Performance of the status/failure indications are verified by analysis, test and demonstration.
d. The generator(s) capability is(are) verified by tests with no degradation in performance.
e. Provisions for electro-mechanical/thermal disconnect are verified by test.
f. Analysis of design documentation verifies parts are contained in the event of a failure.

References: For guidance/principles regarding design and operation of safe electrical generation systems:

JSSG-2009: H.3.4.8, H.4.4.8, H.3.4.8.4, H.4.4.8.4

MIL-HDBK-454

MIL-STD-464

MIL-PRF-7032

MIL-PRF-7115

MIL-PRF-21480

MIL-E-85583

AFGS-87219

ADS-51-HDBK: Chapter/Section 8-7

14 CFR 23.1351-23.1367, 25.1351-25.1363.

12.1.3 Safe operation of integrated electrical power system.

Criterion: Verify that operation of the integrated electrical power system for normal and emergency modes is safe. This includes use of actual or simulated drives and loads, all flight and control configurations, transition between modes, bus switching, load shedding, fault condition operation (detection, clearing, and reconfiguration), and assurance that no single fault affects more than one power source.

Standard: Proper function of electric power sources is maintained whether connected in combination or independently. No malfunction or failure of any electric power source or bus impairs the ability of any remaining source or bus to supply circuits essential for safe operation. Load management, fault detection/protection and bus switching arrangements maintain safe delivery of electric power.

Method of Compliance: Verification methods include analysis, test, and inspection of documentation. Operation of the integrated system during normal and emergency modes is verified with analysis of the engineering design, Electrical Loads Analysis, and FMECA. Proper functioning of the integrated system is verified by system level tests including on-aircraft testing using documented test procedures for checkout.

References: For guidance/principles regarding/affecting design and operation of safe integrated electrical systems:

JSSG-2009: H.3.4.8, H.4.4.8, H.3.4.8.4, H.4.4.8.4, H.3.4.8.5, H.4.4.8.5

MIL-STD-464

MIL-E-7016

AFGS-87219

ADS-51-HDBK: Chapter/Section 8-7

14 CFR 23.1351-23.1367; 25.1351-25.1363

12.1.4 Power quality.

Criterion: Verify that required power quality is maintained for all operating conditions and load combinations.

Standard: The electrical power system provides the required electric power quality (in accordance with MIL-STD-704 and for Army only ADS-37A-PRF) to each load circuit and load combination under all operating conditions. Operation of other aircraft systems does not degrade power quality below minimum acceptable levels.

Method of Compliance: Verification methods include test and inspection of component qualification documentation. Component qualification and aircraft system level tests verify that power quality levels are maintained at the input terminals of the power utilization equipment for all electrically powered aircraft systems operating under all operating conditions and load combinations.

References: For guidance/principles regarding/affecting design and operation of electrical systems to provide compatible and predictable electric power quality:

JSSG-2009: H.3.4.8.1, H.4.4.8.1

MIL-STD-464

MIL-HDBK-704 for test methods and procedures for verification of power quality.

MIL-STD-704

MIL-STD-1399-300

AFGS-87219

ADS-37A-PRF

ADS-51-HDBK: Chapter/Section 8-7

14 CFR 23.1351-23.1367; 25.1351-25.1363.

12.1.5 Uninterruptible power.

Criterion: Verify that independent, uninterruptable power sources, including power control panels, are available to satisfy requirements of essential redundancy for flight-critical functions after failure of the primary power system and there is no single-point failure (including circuit boards) anywhere in the power system. This verification includes examination to assure that loss of primary electric power to a control station does not cause loss of control of its associated aircraft.

Standard:

a. Uninterruptible power is provided, as appropriate, for flight-critical functions and all other essential loads.
b. When necessary to avoid loss of associated aircraft, the control station and other flight critical functions are provided with uninterruptible power.

Method of Compliance: Verification methods include analysis, test, demonstration and inspection of documentation. Engineering evaluation of systems design, evaluation of Electrical Loads Analysis, and systems level tests verify that electric power is reliably delivered to essential systems and equipment under both normal and adverse operating conditions. Evaluation of FMECA shows that single point failures are precluded by the system design.

References: For guidance/principles regarding/affecting design and operation of electrical systems for uninterruptible electric power:

JSSG-2009: H.3.4.8, H.4.4.8
MIL-E-7016
AFGS-87219
NAVSEA TM-S9310-AQ-SAF-010
14 CFR 23.1351-23.1367; 25.1351-25.1363

12.1.6 Battery charging.

Criterion: Verify that, if batteries are employed for SOF backup power, adequate charging methods and checks are provided and installation provisions for all batteries are safe.

Standard:

a. Safe battery cell temperatures and pressures are maintained during any probable charging and discharging conditions and under the most adverse cooling conditions likely to occur in service.
b. No explosive or toxic gases emitted by any battery in normal operation or as the result of any probable malfunction in the battery subsystem, accumulate in hazardous quantities within the aircraft.
c. Any corrosive fluids or gases which escape from the battery do not damage surrounding structures or adjacent essential equipment.
d. Each battery installation has provisions to prevent any hazardous effect on structure or essential systems caused by the maximum amount of heat the battery can generate during a short circuit of the battery or of its individual cells.
e. Battery charging systems are designed to automatically control the charging rate of the battery in order to prevent overheating.
f. Nickel cadmium battery installations, including charging systems, are designed for safe operation.
g. Lithium battery (both rechargeable and non-rechargeable) safety requirements are defined in NAVSEA TM-S9310-AQ-SAF-010.
h. Lithium batteries are not connected to the aircraft electrical power by any means, charged or recharged using aircraft electrical power, unless they have been tested and passed the requirements of MIL-STD-704 in accordance with test procedures of MIL-HDBK-704.
i. All batteries that have internal electronics and that are connected directly to the power bus have been tested and passed the requirements of MIL-STD-704 in accordance with test procedures of MIL-HDBK-704.

Method of Compliance: Verification methods include analysis, test, demonstration, and inspection.

a. Bench and aircraft level testing verifies battery cell temperatures and pressures.
b. Analysis and test verify that means exist to remove or safely contain any gases.
c. Analysis, test and inspection verify that means exist to contain any fluids.
d. Analysis and test verify that the design precludes damage from possible battery overheating.
e. Analysis and subsystem tests verify proper operation of battery equipment/charger(s).
f. Analysis, test and inspection verify proper operation of battery equipment/charger(s) and embedded electronics.
g. Analysis and test verify safe application of the lithium batteries in every application. For

Navy only, Naval Ordnance Safety Security Activity (NOSSA) approval is required for all Lithium Batteries.

References: For guidance/principles regarding/affecting the integrated design and operation of battery subsystems within aircraft electrical systems:

JSSG-2009: H.6.3.2

AFGS-87219

NAVSEA TM-S9310-AQ-SAF-010

14 CFR 23.1351-23.1367; 25.1351-25.1363

12.1.6.1 Lithium batteries.

Criterion: Verify that, if Lithium batteries are employed, the batteries safely operate when supplied MIL-STD-704 power. Verify that adequate charging methods and checks are provided and installation provisions for the batteries are safe.

Standard:

a. Safe battery cell temperatures and pressures are maintained during any probable charging and discharging conditions and under the most adverse cooling conditions likely to occur in service.
b. No explosive or toxic gases emitted by any battery in normal operation, or as the result of any probable malfunction in the battery subsystem, accumulate in hazardous quantities within the aircraft.
c. Any corrosive fluids or gases which escape from the battery do not damage surrounding structures or adjacent essential equipment.
d. Each battery installation has provisions to prevent any hazardous effect on structure or essential systems caused by the maximum amount of heat the battery can generate during a short circuit of the battery or of its individual cells.
e. Battery charging systems are designed to automatically control the charging rate of the battery in order to prevent overheating.
f. Lithium battery (both rechargeable and non-rechargeable) safety requirements are defined in NAVSEA TM-S9310-AQ-SAF-010.
g. Lithium batteries, with or without embedded electronics, are not connected to the aircraft electrical power by any means, charged or recharged using aircraft electrical power, unless they have been tested and passed the requirements of MIL-STD-704 in accordance with test procedures of MIL-HDBK-704.

Method of Compliance: Verification methods include analysis, test, demonstration, and inspection.

a. Bench and aircraft level testing verifies battery cell temperatures and pressures.
b. Analysis and test verify that means exist to remove or safely contain any gases.
c. Analysis, test and inspection verify that means exist to contain any fluids.
d. Analysis and test verify that the design precludes damage from possible battery overheating.
e. Analysis and subsystem tests verify proper operation of battery equipment/charger(s).
f. Analysis, test and inspection verify proper operation of battery equipment/charger(s) and embedded electronics.
g. Analysis and test verify safe application of the lithium batteries in every application. For Navy only, Naval Ordnance Safety Security Activity (NOSSA) approval is required for all lithium batteries.

References: For guidance/principles regarding/affecting the integrated design and operation of battery subsystems within aircraft electrical systems:

JSSG-2009: H.6.3.2

AFGS-87219

NAVSEA TM-S9310-AQ-SAF-010

14 CFR 23.1351-23.1367; 25.1351-25.1363.

12.1.7 Subsystem limitations.

Criterion: Verify that any subsystem limitations are defined and included in the appropriate manuals.

Standard: Published aircraft operating limitations are defined in operators and maintenance manuals. These items are identified in such a manner as to attract attention and set them apart from normal text.

Method of Compliance: Verification methods include analysis, test results, and inspection of documentation. Component/subsystem/system level test, FMECA and Electrical Loads Analysis define limitations. Technical manuals (e.g., Technical Orders, Flight Manuals, Operator's Manuals, NATOPS) describe limitations.

References: For guidance/principles affecting/providing awareness of limitations of aircraft electrical systems:

JSSG-2009: H.3.4.8, H.4.4.8

MIL-E-7016

14 CFR 23.1301, 23.1309; 25.1301, 25.1309

12.1.8 Procedures.

Criterion: Verify that suitable normal and emergency operating procedures are included in the appropriate manuals.

Standard: Published normal and emergency operating procedures are defined in operators and maintenance manuals. Operator handbooks or manuals identify all applicable restrictions, warnings, cautions, advisories and notes. These items are identified in such a manner as to attract attention and set them apart from normal text. When an unsafe condition is detected and annunciated, the appropriate manuals have clear and precise corrective procedures for handling the failure.

Method of Compliance: Verification methods include analysis, test results, demonstration, and inspection of documentation. Inspection verifies that the FMECA defines abnormal modes and that appropriate procedures are included in the flight manuals. Engineering and operational personnel demonstrations verify suitability of procedures. Tests using operating procedures are completed successfully. Appropriate manuals (e.g., Technical Orders, Flight Manuals, Operator's Manuals, NATOPS) include correct operating criteria (e.g., altitude limitation, electrical loading) and describe normal and emergency operating procedures.

References: JSSG-2009, H.3.4.8 and H.4.4.8 for guidance/principles regarding/providing awareness of operating characteristics and procedures for aircraft electrical systems

14 CFR 23.1301, 23.1309; 25.1301, 25.1309

12.1.9 Start and reversion to safe state.

Criterion: Verify that the system powers up in a safe state and upon loss of power or power transient/fluctuation the system remains in a known safe state or reverts to a known safe state.

Standard: Verify that the electrical system will provide appropriate power-on, initiated, and continuous built-in-test (BIT), fault detection, indication, isolation capability, and fault alarm rates. Verify the power recovery capability of the electrical system in accordance with MIL-STD-704. When applicable, software and BIT contained within the electrical system provide the capability to ascertain the operational readiness of the electrical system and to accomplish appropriate failure detection and failure isolation. Provisions include fault protection/trip coordination, source protection, bus isolation, fault trip coordination, reset, shut down, and restart.

Method of Compliance: Verification methods include analysis, test, and inspection of documentation. Analysis of design and inspection of FMECA, system hazard analysis, and subsystem hazard analysis verify that the system will operate properly. System level tests performed under normal and adverse conditions verify proper system response.

References: For guidance/principles regarding design with knowledge of the states of aircraft electrical systems:

JSSG-2009: H.3.4.8.4, H.3.4.8.5.

MIL-STD-464

MIL-HDBK-704

MIL-STD-704

MIL-HDBK-2084

AFGS-87219

14 CFR 23.1351-23.1367; 25.1351-25.1363, 25.1309, 25.1529.

12.2 Electrical wiring system, including power distribution.

This element involves all wiring and wiring components (connectors, circuit breakers, etc.) for the purpose of transmitting signals and/or electrical energy throughout the air vehicle and for UAVs/ROAs/RPVs, and also includes the portable or fixed location control station safety of flight-related wiring system.

Good design practice; fundamental requirements and guidance of basic practice for electrical wiring systems are outlined in SAE AS50881 or its predecessor, MIL-W-5088. MIL-STD-464 (5.10 and 5.11) contains requirements for electrical bonding and grounding. NFPA 70 may be applicable for ground applications and systems/subsystems. Other specification(s) may apply for shipboard and ground mobile applications. The preceding should not be considered to be an exclusive list.

References: For guidance/principles regarding design of aircraft electrical wiring systems:

MIL-HDBK-299

MIL-HDBK-419

MIL-HDBK-454

MIL-STD-464

MIL-STD-1310

MIL-STD-1683

MIL-STD-7080

AFGS-87219

ARINC Report 609
SAE ARP1870
SAE AS50881
NFPA 70

12.2.1 Selection of components.

Criterion: Verify that appropriate electrical wiring (conductor material and coating and insulation system), electrical system components, and support devices in the design are suitable for the physical environment in each area of the system, and that the electrical wiring system installation is safe regarding shock hazard protection for personnel.

Standard: Electrical wiring, electrical system components, and support devices comply with physical environment and bonding/grounding requirements of SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Data may include, but are not necessarily limited to, wiring diagrams (including routing diagrams) and data, installed equipment list(s), E^3 test report(s), qualification data (including system, subsystem and parts level), flight manuals, flight test procedures, operational limitations, operational test results, installation and operational characteristics, performance test results, visual assessments, hazard analyses, FMECA, design criteria, design data/studies/analyses (including Electrical Loads Analyses) and production line test results. Visual inspection/assessment can be used to confirm/generate design documentation.

References: For guidance/principles regarding design and selection of aircraft electrical system components:

JSSG-2009: H.6.3.1
MIL-W-5088 (Inactive for New Design)
MIL-HDBK-299
MIL-HDBK-454
MIL-STD-1683
MIL-STD-7080
SAE AS50881
NFPA 70
14 CFR 23.1365; 25.1353
AC 43.13-1B with Change 1 — Acceptable Methods, Techniques and Procedures — Aircraft Inspection and Repair.

12.2.2 Ampacity.

Criterion: Verify that wiring is sized properly for the required current handling capability and voltage drop.

Standard: Wire sizes comply with requirements of SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis of the design verifies that wire sizing is sufficient for its associated voltage and current. Visual inspection/assessment can be used to confirm/generate design documentation.

References: For guidance/principles regarding proper selection/sizing of aircraft electrical system wiring components:

JSSG-2009: H.6.3.1

SAE AS50881

NFPA 70

14 CFR 23.1365; 25.1353

12.2.3 Circuit protection.

Criterion: Verify that proper circuit protection is provided for wiring associated with power distribution throughout its entire run, including circuits contained in or exiting from any electronic enclosures performing intermediate power switching or distribution functions.

Standard: Circuit protection complies with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including drawings, documents and assembled product verify proper circuit protection.

References: For guidance/principles regarding design and selection of aircraft wiring protection:

JSSG-2009: H.3.4.8.5 and H.4.4.8.5

MIL-HDBK-454

MIL-STD-7080

SAE AS50881

NFPA 70

12.2.4 Circuit isolation.

Criterion: Verify that redundant circuits provided for safety are sufficiently isolated.

Standard: Redundant circuits are isolated in compliance with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including drawings, documents, FMECA and assembled product verify sufficient isolation of redundant circuits.

References: For guidance/principles regarding provision of isolation for aircraft electrical circuits:

JSSG-2009: H.6.3.1

SAE AS50881

NFPA 70

14 CFR 23.1301, 23.1309; 25.1301, 25.1309

12.2.5 Avoidance of single point failures.

Criterion: Verify that design precludes single-point failures related to wiring when redundant functions are integrated within an electronics enclosure.

Standard: Design complies with good engineering practice to avoid single point failures, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including drawings, documents, FMECA and assembled product verify the absence of single point failures.

References: For guidance/principles relating to design of equipment to minimize single point failures in redundant circuits:

JSSG-2009: H.6.1, H.6.3.1

MIL-HDBK-454, Guideline 69

SAE AS50881

NFPA 70

14 CFR 23.1301, 23.1309, 23.1351-23.1367; 25.1301, 25.1309, 25.1351-25.1363, 25.1529

14 CFR SFAR No. 88

12.2.6 Sufficiency of design.

Criterion: Verify that the design of the wiring system installation, including connectors, is adequate for all planned operating conditions.

Standard: Wiring system installation complies with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including drawings, documents, FMECA and assembled product verify that the wiring system is appropriate for all anticipated operating conditions.

References: For guidance/principles regarding good engineering design of wiring system installations:

JSSG-2009: 3.3, 3.3.4; E.4.4.5.1.3; E.3.4.5.1.11, E.4.4.5.1.11; E.3.4.5.8.7, E.4.4.5.8.7; E.3.4.5.8.11, E.4.4.5.8.11; G.3.4.7.2; G.3.4.7.6, G.4.4.7.6; H.6.1; H.6.3.1.

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14 CFR 23.1301, 23.1309, 23.1351-23.1367; 25.1301, 25.1309, 25.1351-25.1363, 25.1529

AC 43.13-1B with Change 1 - Acceptable Methods, Techniques and Procedures — Aircraft Inspection and Repair

SFAR No. 88—Fuel Tank System Fault Tolerance Evaluation Requirements

12.2.6.1 Prevention of ignition.

Criterion: Verify that wiring in areas containing explosive vapors and/or flammable fluids is protected to prevent potential ignition sources which could result from installation, operational environment, aging and/or deterioration of the wiring.

Standard: Wiring in explosive vapor areas is protected in compliance with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including drawings, documents, FMECA and assembled product verify protection and suitability of the wiring system. Inerting may assist in providing additional protection.

References: For guidance/principles regarding wiring design principles/practice for prevention of ignition sources:

JSSG-2009: 3.3; 3.3.4; E.4.4.5.1.3; E.3.4.5.1.11, E.4.4.5.1.11; E.3.4.5.8.7, E.4.4.5.8.7; E.3.4.5.8.12, E.4.4.5.8.11; G.3.4.7.2; G.3.4.7.6; G.4.4.7.6; H.6.1; H.6.3.1.

MIL-STD-810G: Method 5.11.5

SAE AS50881

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14 CFR 23.1351-23.1367; 25.1351-25.1363, 25.1309, 25.1529

SFAR No. 88—Fuel Tank System Fault Tolerance Evaluation Requirements.

12.2.6.2 Faults in safety critical wiring.

Criterion: Verify that failure (either open circuit fault or shorted/crossed-circuits fault) within a wiring harness that includes safety-critical wiring does not cause loss of, or unacceptable degradation to, any safety-critical functions.

Standard: Wiring harnesses comply with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Inspection and analysis of design, including drawings, documents, FMECA and assembled product verify a failure within the wiring harness does not cause loss or degradation of safety critical functions.

References: For guidance/principles leading toward good design practice and minimization of loss of safety-critical functions:

JSSG-2009: H.6.1, H.6.3.1

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14 CFR 23.1351-23.1367; 25.1351-25.1363, 25.1309, 25.1529

SFAR No. 88—Fuel Tank System Fault Tolerance Evaluation Requirements

12.2.6.3 Wiring separation.

Criterion: Verify that the wiring design and installation procedures maintain positive separation of wiring from all fluid or gas carrying lines, flight controls or other mechanical controls, and heat sources (taking into account movement caused by dynamic G loading, thermal effects and vibration); and that electrical power wiring is routed separately from flight control and avionics wiring.

Standard: Wire installation complies with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including drawings, documents, FMECA and assembled product verify that positive wiring separation is maintained.

References: For guidance/principles regarding the fundamentals of sound design for effective separation of wiring from other subsystem components:

JSSG-2009: 3.3.8; B.3.4.2.1.17; H.6.3.1; M.6.3.1
SAE AS50881
NFPA 70
TM 55-1500-323-24 (Army only)

12.2.6.4 Chafing.

Criterion: Verify that the routing design and installation procedures are such that the installation of wiring is free from chafing conditions.

Standard: Wire installation complies with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including installation and routing drawings, documents, and assembled product verify that no conditions exist which will lead to chafing.

References: For guidance/principles regarding the prevention of wire/cable/harness chafing:
JSSG-2009: 3.3.8; A.3.4.1.5.8.1; B.3.4.2.1.17; H.6.3.1; L.3.4.12; M.6.3.1
SAE AS50881
NFPA 70
TM 55-1500-323-24 (Army only)

12.2.6.5 Wiring support.

Criterion: Verify that wiring design provides primary and secondary support for the wiring throughout the installation.

Standard: Wiring support complies with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including drawings, documents, and assembled product verify proper support of wiring.

References: For guidance/principles regarding the provision of proper support for wiring:
JSSG-2001: 4.3.10.1.1
JSSG-2009: 3.2.6; 3.2.7.2; H.6.3.1; H.6.3.2.
SAE AS50881
NFPA 70

12.2.6.6 Avoidance of damage.

Criterion: Verify that wiring design provides for routing and installation to minimize the risk of damage to wiring by cargo, crew and maintenance personnel.

Standard: Wiring support complies with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including processes, drawings, documents, FMECA and assembled product verify that wiring and its installation are suitably protected.

References: For guidance/principles leading toward maintainable design(s):

JSSG-2001: 3.1.5, 3.3.10.2.2, 4.1.5, 4.4.8

JSSG-2009: H.6.3.1

SAE AS50881

NFPA 70

12.2.6.7 Maintainability.

Criterion: Verify that maintainability is a factor in the design and installation procedures for wiring and components, including that all wiring and components are properly identified and that the identification does not adversely affect the performance or life of the wiring or components.

Standard: Maintainability characteristics of wiring installation comply with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including processes, drawings, documents, FMECA and assembled product verify that wiring installation is maintainable.

References: For guidance/principles leading toward maintainable design(s):

JSSG-2009: 6.4.1

SAE AS50881

NFPA 70

12.2.6.8 Bonding and grounding.

Criterion: Verify that all equipment and equipment racks are designed for proper electrical bonding and grounding.

Standard: Bonding and grounding comply with standards as defined in MIL-STD-464C, 5.11 and 5.12 inclusive.

Method of Compliance: Verification methods include analysis, test, and inspection. Analyses, tests and inspections verify proper bonding and grounding values. Documentation establishes appropriate bonding values to be maintained throughout system life, via drawings, specifications, maintenance manuals, etc.

References: For guidance/principles regarding the provision of proper electrical bonding:

JSSG-2001: 3.2.1, 4.2.1: 3.3.10.1.1, 4.3.10.1.1

JSSG-2009: 3.3; 3.3.4; E.4.4.5.1.3; E.3.4.5.1.11, E.4.4.5.1.11; E.3.4.5.8.7, E.4.4.5.8.7; E.3.4.5.8.11, E.4.4.5.8.11; G.3.4.7.2; G.3.4.7.6; G.4.4.7.6

MIL-HDBK-419

MIL-HDBK-454

MIL-STD-464C: A5.11, A5.12

MIL-STD-1310

SAE ARP1870

12.2.6.9 Care in modification.

Criterion: Verify that addition of a modification into existing wiring installations does not create cracking or conditions for chafing or other degradation of existing wiring insulation.

Standard: Wire installation complies with good design practice, as defined in SAE AS50881 for aircraft and NFPA 70 for ground stations. Other specification(s) may apply for shipboard and ground mobile applications.

Method of Compliance: Verification methods include analysis and inspection. Analysis and inspection of design, including processes, drawings, documents, FMECA and assembled product, verify that the wiring installation is free of conditions that can lead to chafing or other wiring/harness degradations.

References: For guidance/principles regarding the prevention of wire/cable/harness chafing:

JSSG-2009: 3.3.8; A.3.4.1.5.8.1; B.3.4.2.1.17; H.6.3.1; L.3.4.12; M.6.3.1

SAE AS50881

NFPA 70

TM 55-1500-323-24 (Army only)

13. ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E^3)

TYPICAL CERTIFICATION SOURCE DATA

1. E^3 design criteria, analysis, and tradeoff studies.
2. Results of E^3 modeling and simulation.
3. E^3 failure modes, and effects, and criticality analyses.
4. Electromagnetic hazard analyses.
5. Equipment/subsystem E^3 qualification reports.
6. Details of installation and operation.
7. System E^3 qualification tests.
8. Flight and operational manuals, and flight test procedures, and limitations.
9. Safety-of-flight (SOF) certifications.
10. Authorized radio frequency allocations.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

The document references in this section are based on the versions of documents which were current at the time of preparation of this material. On that basis, paragraph and section/subsection numbers were matched with their corresponding titles as listed below. It should be recognized that when referenced documents are updated/revised, paragraph/section/subsection numbers sometimes will change. It is expected that the users of this document will be familiar with most or all of the referenced documents and be able to recognize and assess such changes. It is incumbent on the users of this document to be certain that when verifying compliance with its intent, the appropriate referenced documents, including correct paragraphs/sections/subsections, are utilized.

References: MIL-STD-461: Section 5: Detailed Requirements

MIL-STD-464: (section numbers listed below are for the sections as contained in MIL-STD-464C; for cases where other versions of the document may apply, corresponding applicable sections/requirements are utilized)

5.1 Margins; 5.2 Intra-system electromagnetic compatibility (EMC); 5.3 External RF EME; 5.5 Lightning; 5.6 Electromagnetic pulse (EMP); 5.7 Subsystems and equipment electromagnetic interference (EMI); 5.8 Electrostatic charge control; 5.9.3 Hazards of electromagnetic radiation to ordnance (HERO); 5.11 Electrical bonding; 5.11.3 Mechanical interfaces; 5.11.3.c: 2.5 milliohms or less across individual faying interfaces within the equipment, such as between subassemblies or sections; 5.15 EM spectrum supportability

MIL-STD-2169: This standard is classified (see section 2 for requesting copies).

ADS-37A-PRF: 4.1 Electromagnetic Environmental Effects Integration Analysis (E^3IA)

DoDI 4650.01

DoDI 6055.11

NAVSEA OP 3565

TO 31Z-10-4

DD Form 1494

IEEE Std C95.1

RTCA DO-160: Section 18 Audio Frequency Conducted Susceptibility- Power Inputs; Section 19 Induced Signal Susceptibility; Section 20 Radio Frequency Susceptibility (Radiated and Conducted); Section 21 Emission of Radio Frequency Energy; Section 22 Lightning Induced Transient Susceptibility

SAE ARP5412

SAE ARP5583: Section 5 Routes to HIRF Compliance; Section 7 Compliance for Level A Systems

13.1 Component/subsystem E^3 qualification.

13.1.1 Flight/safety critical equipment requirements.

Criterion: Verify that all flight-critical and safety-critical equipment comply with all electromagnetic environmental effects requirements, including lightning susceptibility, that are appropriate for the system application; or verify that appropriate flight restrictions are imposed.

Standard: All equipment and subsystems comply with the conducted and radiated emissions and conducted and radiated susceptibility requirements of MIL-STD-461, section 5, MIL-STD-464, 5.5 or equivalent requirements from industry/commercial standards such as RTCA DO-160, sections 18 through 22 and SAE ARP5412.

Method of Compliance: Verification methods of MIL-STD-461, section 5 or equivalent verification methods from industry/commercial standards such as RTCA DO-160, sections 18 through 22 (for Army, Section 22 only) demonstrate that the equipment complies with the emissions and susceptibility requirements.

References: MIL-STD-461: section 5

MIL-STD-464: 5.5

SAE ARP5412

RTCA DO-160: sections 18 through 22

13.1.2 Non-flight-critical/non-safety-critical equipment requirements.

Criterion: Verify that all non-flight-critical and non-safety-critical equipment comply with the conducted and radiated emissions and susceptibility requirements (including external electromagnetic environments), and do not affect the safe operation of flight-critical and safety-critical equipment.

Standard: All equipment and subsystems comply with the conducted and radiated emissions and conducted and radiated susceptibility requirements of MIL-STD-461, section 5 or equivalent requirements from industry/commercial standards such as RTCA DO-160, sections 18 through 21 (for Army, industry/commercial standards are non-applicable).

Method of Compliance: Verification methods of MIL-STD-461, section 5 or equivalent verification methods from industry/commercial standards such as RTCA DO-160, sections 18 through 21 (for Army, industry/commercial standards are non-applicable) demonstrate that the equipment complies with the emissions and susceptibility requirements.

References: MIL-STD-461: section 5

RTCA DO-160: sections 18 through 21

13.1.3 Non-flight-critical/non-safety-critical equipment transient susceptibility requirements.

Criterion: Verify that all non-flight-critical and non-safety-critical equipment comply with transient susceptibility requirements that include consideration of indirect effects levels derived from the external lightning environment, and does not affect the safe operation of flight-critical and safety-critical equipment.

Standard: The indirect effect requirements are defined based on the lightning environment in 5.5 of MIL-STD-464 or an equivalent environment such as in SAE ARP5412 Aircraft Lightning Environment and Related Test Waveforms (for Army, SAE ARP5412 is non-applicable). While in flight, the equipment withstands the indirect effects of lightning (current and voltage transients).

Method of Compliance: Analysis defines the indirect effects on the equipment. The test levels are derived from the aircraft level analysis and the test waveforms are defined in 5.5 of MIL-STD-464 or an equivalent industry/commercial standard such as RTCA DO-160, section 22.

References: MIL-STD-464: 5.5
RTCA DO-160: section 22
SAE ARP5412

13.2 System-level E^3 qualification.

13.2.1 Mutual electromagnetic compatibility of equipment and subsystems.

Criterion: Verify that all equipment and subsystems exhibit mutual electromagnetic compatibility.

Standard: Intra-system electromagnetic compatibility (EMC) is required at the air system level to demonstrate that equipment and subsystems are capable of providing safety of flight in conjunction with other equipment and subsystems which are required to operate concurrently.

Method of Compliance: For the entire system: system level EMC test and analysis of the test results (e.g., see MIL-STD-464, 5.2).

Reference: MIL-STD-464: 5.2

13.2.2 Mutual compatibility of antenna-connected and other equipment.

Criterion: Verify that antenna-connected equipment is mutually compatible and is not degraded beyond its operational requirements, by any other on-board and off-board equipment to a level that would affect safety.

Standard: Intra-system electromagnetic compatibility (EMC) is required at the air system level to demonstrate that equipment and subsystems are capable of providing safety of flight in conjunction with other equipment and subsystems which are required to operate concurrently.

Method of Compliance: For the entire air system: system level EMC test and analysis of the test results (e.g., see MIL-STD-464, 5.2).

Reference: MIL-STD-464, 5.2

13.2.3 Compatibility of air system with electromagnetic environment.

Criterion: Verify that the air system is electromagnetically compatible with its intended external radio frequency (RF) electromagnetic environment.

Standard: Air system equipment can safely operate in the external RF electromagnetic environment defined in 5.3 of MIL-STD-464 or an equivalent RF external electromagnetic environment such as the one defined in SAE ARP5583, sections 5 and 7 (SAE ARP5583 is non-applicable for Army).

Method of Compliance:

a. For the entire air system: system high level RF pulse testing and analysis of the test results, or:

b. For the entire air system: system shielding effectiveness testing and analysis of the test results, or:

c. For the entire air system: a combination of system high level RF pulse and shielding effectiveness testing and analysis of the test results.

References: MIL-STD-464: 5.3

SAE ARP5583: sections 5 and 7

13.2.4 Lightning effects.

Criterion: Verify that the air system has met all requirements for lightning, either direct (physical) or indirect (electromagnetic) effects and that any potential for ignition of fuel vapors is eliminated.

Standard: During flight, the air system can withstand the direct effects of lightning when exposed to the external lightning environment of 5.5 of MIL-STD-464 or an equivalent environment such as in SAE ARP5412 (SAE ARP5412 is non-applicable for Army). Also during flight, the air system can withstand the indirect effects of lightning which include current and voltage transients coupled to the wiring and air system equipment. The indirect effect requirements are determined by an aircraft level analysis when the aircraft is exposed to the external lightning environment defined in 5.5 of MIL-STD-464 or an equivalent environment such as in SAE ARP5412 (SAE ARP5412 is non-applicable for Army). The requirement for eliminating the potential for ignition of fuel vapors is achieved by eliminating possible ignition sources and reducing flammability when the air system is exposed to the external lightning environment of 5.5 of MIL-STD-464 or an equivalent environment such as in SAE ARP5412 (SAE ARP5412 is non-applicable for Army). The elimination of ignition sources can be accomplished by:

a. Inerting fuel tanks or,

b. If tanks are not inerted:

   (1) Providing electrical insulation for the tank's fasteners.

   (2) Electrically bonding the lines and wires penetrating the fuel tanks to the dry part of the fuel tank structure or interrupting the low electrical conductivity of these lines inside the fuel tanks using line isolators.

Method of Compliance:

Lightning Direct Effects:

a. Coupon testing to demonstrate no puncture of aircraft skin/structure. This includes full scale testing of radomes and canopies.

b. Fuel tanks:

   (1) If fuel tanks are not inerted, electrical bonding measurements of lines and wiring penetrating fuel tanks, or via validated electrical bonding process specifications.

   (2) If fuel tanks are inerted, verify by measuring the oxygen content of the tanks.

Lightning Indirect Effects:

a. Air system level analysis.
b. Tests using high level pulse or low level continuous wave (CW) techniques and analysis of the test results.

References: MIL-STD-464: 5.5
SAE ARP5412

13.2.5 EMP protection.

Criterion: Verify that the air system meets the requirements for electromagnetic pulse (EMP) protection, if applicable.

Standard: The air system can withstand the effects of the electromagnetic pulse (EMP) when exposed to the classified environment of MIL-STD-2169.

Method of Compliance: Air system level EMP coupling analysis or air system level testing and analysis of the test results.

References: MIL-STD-464: 5.6
MIL-STD-2169

13.2.6 Electrostatic charge.

Criterion: Verify that the system is able to control and dissipate the build-up of electrostatic charges caused by particle impingement, fluid flow, air flow, and other tribolectric charge-generating mechanisms to avoid ordnance hazards, personnel shock hazards and to control p-static interference or damage to electronics.

Standard: Control of electrostatic charging ensures that all structural surfaces are at least mildly conductive, that all components are electrically bonded, and that an electric path to earth ground is provided. A one ohm static bond is the accepted industry standard.

Method of Compliance: Verification is accomplished by bonding measurements or by validated bonding assembling/process specifications. A measurement of 1 ohm is typically specified, but for most applications resistive paths of up to 10E6 ohms are sufficient to dissipate the charge buildup.

Reference: MIL-STD-464: 5.8

13.2.7 Hazards of electromagnetic radiation.

Criterion: Verify that sources of electromagnetic radiation pose no Hazard of Electromagnetic Radiation to Personnel (HERP), Hazard of Electromagnetic Radiation to Fuel (HERF), and Hazard of Electromagnetic Radiation to Ordnance (HERO), and that the appropriate manuals include safe criteria regarding distance from on-board and off-board transmitters to personnel and fuel sources.

Standard:

a. HERP: The criteria to protect personnel from the electromagnetic radiation from aircraft emitters is defined in DoDI 6055.11 (see also IEEE STD C95.1a).
b. HERF: Fuel cannot be inadvertently ignited by radiated electromagnetic fields from aircraft emitters or by the external RF electromagnetic environment defined in 5.3 of MIL-STD-464 or an equivalent RF external electromagnetic environment such as the one defined in SAE ARP5583, sections 5 and 7 (SAE ARP5583 is non-applicable for Army).
c. HERO: Electrically initiated devices (EIDs) used in ordnance and other parts and equipment of the aircraft cannot be inadvertently actuated during or experience

performance degraded characteristics after exposure to the radiated electromagnetic fields from aircraft emitters and by the external RF electromagnetic environment defined in MIL-STD-464, 5.9.3 or an equivalent RF external electromagnetic environment such as the one defined in SAE ARP5583, sections 5 and 7 (SAE ARP5583 is non-applicable for Army), and the effects of the lightning environment defined in MIL-STD-464, 5.5 or an equivalent environment such as in SAE ARP5412 (SAE ARP5412 is non-applicable for Army). EIDs are required to demonstrate 16.5 dB of safety margin no fire stimulus to the above external environments for safety assurances and 6 dB margin for EIDs where there are consequences other than safety.

Method of Compliance:

a. HERP: Verification is accomplished by measurements of the RF generated by the on-board emitters and analysis based on the methodology of Protection of DoD Personnel from Exposure to Radiofrequency Radiation and Military Exempt Lasers, DoDI 6055.11 (see also IEEE STD C95.1a). The following publications also provide guidance and methodology for assessing RF Hazards: (Air Force) Electromagnetic Radiation Hazard TO 31Z-10-4; (Navy) Electromagnetic Radiation Hazard NAVSEA OP 3565.

b. HERF: Verification is accomplished by inspection and analysis based on the methodology of TO 31Z-104 and NAVSEA OP 3565 for calculating hazard distance from RF emitters.

c. HERO: Verification is accomplished by testing of the EIDs and associated circuitry to the margins defined in MIL-STD-464, 5.1; to the external RF electromagnetic environment defined in MIL-STD-464, 5.9.3; and by analysis by using NAVSEA OP 3565, Volume 2 or an equivalent RF electromagnetic environment such as the one defined in SAE ARP5583, sections 5 and 7 (SAE ARP5583 is non-applicable for Army). Also, verification is accomplished by testing of the EIDs and associated circuitry to the effects of the lightning environment defined in MIL-STD-464, 5.5 or an equivalent environment such as in SAE ARP5412 (SAE ARP5412 is non-applicable for Army).

References: MIL-STD-464: 5.1, 5.5, 5.9.3 and 5.15
DoDI 6055.11
TO 31Z-10-4
NAVSEA OP 3565
IEEE STD C95.1a
SAE ARP5583: sections 5 and 7
SAE ARP5412

13.2.8 Electrical bonding.

Criterion: Verify that the air system electrical bonding is adequate to ensure safe system operation.

Standard: Electrical bonding is required for the control of the electromagnetic effects environments, and it is specified in accordance with the characteristics of the materials used. The air system bonding requirements are defined in MIL-STD-464, 5.11 (for Army, only 5.11.3c with 2.5 milli-ohms or less per faying surface lifetime).

Method of Compliance: Verification is accomplished by bonding measurements or by validated bonding assembly/process specifications backed by empirical/test data.

Reference: MIL-STD-464: 5.11

13.2.9 Electromagnetic spectrum licensing and certification.

Criterion: Verify that the air system meets the electromagnetic spectrum licensing requirements in accordance with DoD, national, and international regulations and has received electromagnetic spectrum certification.

Standard: Spectrum certification denotes the supportability of an electronic system or spectrum dependent equipment in accordance with MIL-STD-464, 5.15, for operation in a designated frequency band to avoid interference with other system or equipment and for compliance with the national and international spectrum certification regulations cited in DoDI 4650.01, Policy and Procedures for Management and Use of the Electromagnetic Spectrum.

Method of Compliance: Verification of supportability is accomplished via compliance with MIL-STD-464, 5.15. Certification is achieved through submittal and approval of DD Form 1494, Application for Frequency Allocation (EL-CID), which contains the information on the operating characteristics of the spectrum dependent equipment.

References: DoDI 4650.01

DD Form 1494 (use of Equipment Location-Certification Information Database (EL-CID) is required).

14. SYSTEM SAFETY

TYPICAL CERTIFICATION SOURCE DATA

1. System Safety Program Plan (SSPP).
2. Preliminary Hazard Analysis (PHA).
3. Subsystem Hazard Analyses (SSHA) (fault hazard analyses or fault tree analyses).
4. System Hazard Analyses (SHA) (including hardware, software and human system integration causal factors).
5. Operating and Support Hazard Analysis (O&SHA).
6. Test hazard analyses.
7. Occupational Health Hazard Assessment (HHA).
8. Specialized analyses such as a sneak circuit analyses and software hazard analyses.
9. Modification documentation (for correction of safety deficiencies).
10. Component/system test results (waivers/deviations and equipment conditional usage documents).
11. Minutes of system safety group meetings (open items).
12. Minutes of system safety program reviews (open items).
13. Engineering change proposals (safety related).
14. Hazard identification, evaluation and correction-tracking system files.
15. Safety Assessment Reports (SARs).
16. Test plans and test results.
17. Test temporary engineering orders (not previously included in any safety analyses).
18. Failure Modes, Effects, and Criticality Analysis (FMECA)/Failure Modes and Effects Analysis (FMEA).
19. Hazard risk index.
20. MIL-STD-882, System Safety Program Requirements.
21. Test review board reports.
22. Safety review board reports.
23. Flight readiness review reports.
24. Safety requirements traceability matrix (both hardware and software).
25. Software System Safety Program Plan (SwSSPP).
26. Functional Hazard Analysis or Assessment (FHA).
27. System of Systems Hazard Analysis.
28. Safety Critical Functions/Safety Critical Items list.
29. Systems Engineering Plan (SEP).
30. Proof of Risk Acceptance.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

14.1 System safety program.

14.1.1 System safety process.

Criterion: Verify that an effective system safety program is implemented that mitigates risks/hazards attributed to hardware, software, and human system integration and that the safety program documents and tracks the risks/hazards of the design/modification.

Standard: The system safety program meets the minimum mandatory requirements of MIL-STD-882 (e.g., system safety approach has been documented; hazards have been identified; hazards have been assessed; hazards have been mitigated; residual risks are at an acceptable level; residual risk has been accepted by appropriate authority; and hazards and residual risk have been tracked), and the system safety requirements are incorporated into the technical and programmatic documents. The Programmatic Environmental Safety and Health Evaluation (PESHE) includes all hazards identified for the program.

Method of Compliance: Verification method includes inspection of documentation. Effectiveness of the system safety program is verified by inspection of technical and programmatic documents to verify: system safety approach has been documented; hazards have been identified; hazards have been assessed; hazards have been mitigated; residual risks are reduced; residual risk has been accepted by appropriate authority; and hazards and residual risk have been tracked. Inclusion of Environmental Safety and Occupational Health (ESOH) hazards in PESHE is verified by inspection.

References: MIL-STD-882

DoDI 5000.2, Enclosure 3, Table E3.T1 (details of PESHE content and relation to system safety)

SAE ARP4754

SAE ARP4761

14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.1.1.1 System safety requirements.

Criterion: Verify that the system safety program incorporates system safety into all aspects of systems engineering throughout all acquisition phases.

Standard: System safety requirements are incorporated into the system technical and programmatic documents. System safety requirements, analyses, time lines and other milestones are in synchronization with the rest of the program schedules.

Method of Compliance: Verification method includes inspection of documentation. Incorporation of system safety requirements into the systems technical documents, programmatic documents and operating procedures is verified by inspection. Integration of system safety requirements, analyses, time lines and other milestones is verified by inspection of programmatic documents.

References: MIL-STD-882

SAE ARP4754

SAE ARP4761

14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.1.1.2 System safety analysis and assessment.

Criterion: Verify that appropriate system safety analysis and assessment tasks are accomplished for all programs, including temporary and permanent modifications.

Standard: System, subsystem, component and software safety analyses and assessments are accomplished for all programs, including temporary and permanent modifications. Design and operational/maintenance procedures do not have an unacceptable negative effect on system safety or on the mishap risk baseline.

Method of Compliance: Verification method includes inspection of documentation. Accomplishment of appropriate system, subsystem, component and software safety analyses and assessments for all programs, including temporary and permanent modifications is verified by inspection, and any changes do not have an unacceptable negative effect on system safety or on the mishap risk baseline.

References: MIL-STD-882
SAE ARP4754
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.1.1.3 Hazard/risk tracking and risk acceptance.

Criterion: Verify that hazards/risks are tracked and residual risks documented.

Standard: Hazard/risk tracking and residual risk documentation and acceptance are planned, documented and accomplished in accordance with MIL-STD-882. Risks are presented and accepted at the appropriate level and risk acceptances are documented in a hazard tracking system.

Method of Compliance: Evidence of the closed loop hazard tracking system and the risk acceptance processes is verified by inspection of safety program documentation.

References: MIL-STD-882
SAE ARP4754
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars.

14.1.1.4 System safety program implementation.

14.1.1.4.1 Flight safety.

Criterion: Verify that the system safety program addresses flight safety.

Standard: Single point failures that result in loss of aircraft or system do not occur at an unacceptable rate (e.g., improbable or lower probabilities in accordance with MIL-STD-882). Safety design deficiencies uncovered during flight mishap investigations or in deficiency reports (e.g., Materiel Deficiency Reports (MDRs), Quality Deficiency Reports (QDRs)) are assessed and residual risks identified. Flight hazard risks for the system do not exceed threshold limits that are established for the program.

Method of Compliance: Verification methods include analysis and inspection of documentation. Evidence of a flight safety process is verified by: review of all hazards associated with single point failures to document their elimination or reduction of risks to an acceptable level; by inspection of design deficiencies identified in flight safety reports and deficiency reports (e.g., MDRs, QDRs) to assure they are assessed and resolution actions are tracked to closure; by analysis that actual flight mishap rates comply with pre-set program threshold limits.

References: MIL-STD-882
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars.

14.1.1.4.2 Foreign Object Damage (FOD) prevention.

Criterion: Verify that the system safety program addresses ground/industrial safety (foreign object damage prevention).

Standard: Ground/Industrial safety requirements are established for activities at the plant to minimize the risk of Foreign Object Damage (FOD) or undetected damage to the assembled air vehicle and all required support equipment.

Method of Compliance: Verification method includes inspection of documentation. Evidence of an established FOD prevention program is verified by review of FOD program documents and inspection of reports, or on-site certification by the Defense Contract Management Agency (DCMA) that an acceptable FOD program exists.

References: MIL-STD-882
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars.

14.1.1.4.3 Explosives and ordnance safety; non-nuclear munitions.

Criterion: Verify that the system safety program addresses explosives and ordnance safety; non-nuclear munitions.

Standard: Requirements for system safety processes and analyses are established in accordance with MIL-STD-882 to support weapons testing, certification, and obtainment of explosive hazard classifications.

Method of Compliance: Verification method includes inspection of documentation. Safety program requirements for explosives and ordnance safety are verified by inspection of system safety program analysis data.

References: MIL-STD-882
DoD 6055.9-M
AR 40-10
TB 700-2/NAVSEAINST 8020.8/TO 11A-1-47
14 CFR Section 1309 of Parts 23, 25, 27, 29 and related advisory circulars.

14.1.1.4.4 Range safety.

Criterion: Verify that the system safety program addresses range safety.

Standard: The system safety program is responsive to test range safety requirements and official requests for safety analysis information.

Method of Compliance: System safety program support for range safety is verified by inspection of system safety process documentation.

References: MIL-STD-882
RCC 323 Range Safety Criteria for Unmanned Air Vehicles
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars.

14.1.1.4.5 Nuclear safety.

Criterion: Verify that the system safety program addresses nuclear safety.

Standard: The nuclear safety program adheres to the four key DoD Nuclear Weapon System Safety Design Standards for hardware and software.

Method of Compliance: Verification method includes inspection of documentation. Evidence that a process is in place to incorporate the four key nuclear safety design requirements into the safety analyses, program functional baselines and other design requirements is verified by inspection of program safety documents and functional baselines.

Reference: DoDD 3150.02

14.1.1.4.6 Radiation/LASER (light amplification by stimulated emission of radiation) safety.

Criterion: Verify that the system safety program addresses radiation/laser safety.

Standard: Key design requirements for radiation/laser safety are established including: protective housing; safety interlocks; remote interlock connector; key control/arming device; emission indicator; beam stop/attenuator; location of controls; viewing optics; scanning safeguard; manual reset; labeling requirements; laser classification; hazard evaluation; protective eyewear; laser area control; and informational requirements.

Method of Compliance: Verification method includes inspection of documentation. Evidence of a process to establish the key safety design requirements for radiation/laser safety is verified by inspection of safety analyses, design specifications and program functional baselines.

References: MIL-STD-882

MIL-HDBK-828

MIL-STD-1425

ANSI Z136.1 (now owned by LIA) for definitions of key laser safety design requirements

14.1.1.4.7 Test safety and support.

Criterion: Verify that the system safety program addresses test safety and support.

Standard: System safety organization actively participates in test planning and post-test reviews to analyze all test-related hazards and recommended corrective actions to ensure hazard closeout or mitigation. Appropriate system safety requirements criteria are incorporated into the test program for validation and verification.

Method of Compliance: Verification method includes inspection of documentation. System safety support of the test and evaluation process and incorporation of safety requirements criteria are verified by inspection of the system safety program plan, test-related hazard analyses and the Test and Evaluation Master Plan (TEMP).

References: MIL-STD-882

SAE ARP4754

14 CFR Section 1309 of Parts 23, 25, 27, 29 and related advisory circulars.

14.1.1.4.8 Software safety.

Criterion: Verify that the system safety program addresses software safety.

Standard: See 14.3 (this document) and subparagraphs.

Method of Compliance: Methods of Compliance for Software Safety are contained in 14.3 (this document) and subparagraphs.

References: Refer to 14.3 of this document.

14.1.1.4.9 Material changes/deficiencies.

Criterion: Verify that the system safety program addresses materials.

Standard: Risks associated with use of new/alternate/substituted/hazardous materials or material deficiencies do not exceed the hazard baseline set for the program.

Method of Compliance: Verification method includes inspection of documentation. Evidence of a material safety process is verified by inspection of program safety documentation and safety analyses. Cumulative risks of identified hazards do not exceed the program's hazard baseline.

References: MIL-STD-882
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars.

14.1.1.4.10 Failure Modes and Effects Testing (FMET) and Built-In-Test (BIT).

Criterion: Verify that the system safety program addresses FMET and BIT.

Standard: System safety participates in all tests/test planning on parts and assemblies that establish failure modes and rates, and conducts safety analyses on all built-in test equipment to assure that integration into a system does not induce hazards which exceed the hazard baseline set for the program.

Method of Compliance: Verification method includes inspection of documentation. Evidence of system safety support of FMET and BIT evaluations is verified by inspection of the system safety program documents, test documents and the hazard tracking data base.

References: MIL-STD-882
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars.

14.1.1.4.11 Fail-safe design.

Criterion: Verify that the system safety program addresses fail-safe design.

Standard: Design ensures that the system remains inherently safe. A single failure causes the system to revert to a state which will not cause a mishap. Flight hazard risks for the system do not exceed threshold limits that are established for the program.

Method of Compliance: Verification method includes inspection of documentation (e.g., safety analyses, technical documentation, testing documentation, hazard tracking data base). Design documentation verifies: inherent system safety; that a single failure will not cause the system to revert to a state which will result in unacceptable risk of a mishap; and that flight hazard risks for the system do not exceed the threshold limits established for the program.

References: MIL-STD-882
SAE ARP4754
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars.

14.1.1.4.12 Safety assessment of support equipment.

Criterion: Verify that the system safety program addresses support equipment.

Standard: Design related hazards and interfaces of support equipment with aircraft and control stations are included in system safety analyses. Identified safety hazards are resolved or risks reduced to an acceptable level before first test use or first operational use of the support equipment.

Method of Compliance: Verification method includes inspection of documentation. The incorporation of design safety requirements for support equipment into technical document baselines/safety documents and the elimination or control of their associated safety risks is verified by inspection of technical documents baselines, safety process documentation, safety analyses and the closed loop hazard tracking system.

References: MIL-STD-882

SAE ARP4761

14 CFR Section 1309 of Parts 23, 25, 27, 29 and related advisory circulars.

14.2 Safety design requirements.

14.2.1 Hazard identification/control/resolution process

Criterion: Verify that a systematic process is employed that provides for hazard identification, hazard control requirement generation and implementation, and residual risk assessment.

Standard: A process is in place to identify and characterize hazards, devise corrective actions, and assess residual risks. A System Safety Group is established to implement the process

Method of Compliance: Verification method includes inspection of documentation. Evidence of a hazard identification/control/resolution process is verified by inspection of safety process documentation and review of safety analyses and system safety group proceedings.

References: MIL-STD-882

SAE ARP4754

14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.2.2 Mitigation of mishap risks.

Criterion: Verify that the design is free from unacceptable mishap risk, including risks to third parties.

Standard: Unacceptable risks to personnel or equipment are eliminated or controlled in accordance with MIL-STD-882. Mishap risk determination, including risk to third parties, reflects the current configuration and maturity of the system. Mishap risk acceptability is based on the intended airspace operations, including rules and restrictions for such airspaces.

Method of Compliance: Verification method includes inspection of documentation. Evidence of a process to mitigate hazards with "unacceptable" mishap risk is verified by inspection of system safety documents, technical documents, test documents, programmatic documents, safety hazard tracking database and the residual risk acceptance process.

References: MIL-STD-882

SAE ARP4754

SAE ARP4761

14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars.

14.2.3 Single point failure assessment.

Criterion: Verify that no single-point failure unacceptably affects the safety of the system.

Standard: The risks of all hazards associated with single point failures do not exceed the hazard baseline set for the program. Residual risk is accepted in accordance with MIL-STD-882.

Method of Compliance: Verification method includes inspection of documentation. Evidence that the risks of all single point failure hazards do not exceed the hazard baseline set for the program and that the residual risk has been accepted is verified by inspection of the safety analyses for single point failures and the relevant data in the closed loop hazard tracking system.

References: MIL-STD-882
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.2.4 Subsystem protection.

Criterion: Verify that the design adequately protects the power sources, controls, and critical components of redundant subsystems.

Standard: Power sources, controls, and critical components of redundant subsystems are separated/shielded per the general safety requirements of MIL-STD-882.

Method of Compliance: Verification method includes inspection of documentation. Inspection of safety analyses/assessments and associated documentation verifies that power sources, controls, and critical components of redundant subsystems are separated/shielded per the general safety requirements of MIL-STD-882.

References: MIL-HDBK-516: Section 12
MIL-STD-882
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.2.5 Human factors.

Criterion: Verify that all aspects of human factors are addressed and unacceptable human factors safety issues/risks are resolved in the design process.

Standard: Establish human factors design requirements interface with system safety to minimize the probability of human error and satisfy the intent of MIL-STD-882.

Method of Compliance: Verification method includes inspection of documentation. The standard to establish human factors requirements and identify safety issues/risks related to human factors and reduce them to an acceptable level is verified by inspection of safety documentation, safety analyses and program functional baselines.

References: MIL-STD-882
MIL-STD-1472
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.2.6 Human error.

Criterion: Verify that the system is produced/manufactured ensuring risk reduction of failures or hazards potentially created by human error during the operation and support of the system.

Standard: System design minimizes risk created by human error in the operation and support of the system.

Method of Compliance: Verification method includes inspection of documentation. Evidence that a process is in place to reduce the mishap risks associated with human error to acceptable levels is verified by inspection of safety documents and analyses and review of the closed loop hazard tracking system.

References: MIL-STD-882
MIL-STD-1472
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.2.7 Environmental conditions.

Criterion: Verify that the system design is within acceptable risk bounds over worst-case environmental conditions.

Standard: Safety risks due to system exposure/operation in required environmental conditions are defined and verified to be within acceptable limits.

Method of Compliance: Verification method includes inspection of documentation. Evidence that the safety risk minimization process addresses effects of worst-case environmental conditions on the design is verified by review of safety analyses and environmental/climatic test results/reports.

References: MIL-STD-810
MIL-STD-882
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29 and related advisory circulars.

14.2.8 Assembly/installation hazards.

Criterion: Verify that personnel exposure to hazards during the installation process, including hazards due to locations of systems in the air vehicle, is at an acceptable risk level.

Standard: A safety process is in place to prevent errors in assembly, installation, or connections which could result in a safety hazard or mishap for the system.

Method of Compliance: Verification method includes inspection of documentation. Design and procedural safety requirements acceptability is verified by inspection and approval of system safety documentation and requirements. Evidence of acceptability/approval is provided by inspection of equipment installation, operation and maintenance process documentation.

References: MIL-STD-882
SAE ARP4754
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.2.9 Safety design process.

Criterion: Verify that the system design isolates hazardous substances, components, and operations from other activities, areas, personnel, and incompatible material.

Standard: A safety design process is in place to isolate hazardous substances, components, and operations from other activities, areas, personnel, and incompatible materials.

Method of Compliance: Verification method includes inspection of documentation. The standard to assure that hazardous substances, components and operations have been identified and corrective measures taken (e.g., separation, shielding, isolation), and/or risks reduced to an acceptable level for the program, is verified by review of safety analyses and program technical documentation.

References: MIL-STD-882
SAE ARP4754
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29 and related advisory circulars

14.2.10 Analysis of changes or modifications.

Criterion: Verify that a system safety change analysis is accomplished on changed or modified equipment or software.

Standard: All changes/modifications to existing systems do not:

a. create new hazards;
b. affect a hazard that had previously been resolved;
c. increase the risk of any existing hazards;
d. adversely affect any safety-critical component.

Method of Compliance: Verification method includes inspection of documentation. Inspections of system safety change analyses on changed or modified equipment or software***.*** Verify that no changes/modifications to existing systems will cause any of the following:

a. create new hazards;
b. affect a hazard that had previously been resolved;
c. increase the risk of any existing hazards;
d. adversely affect any safety-critical component.

References: MIL-HDBK-516: 14.3.3, 15.2.4, and 15.6.4 (this document)
MIL-STD-882
SAE ARP4754
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.2.11 Assess safety of operational contingencies.

Criterion: Verify that the system provides and implements operational contingencies in the event of catastrophic, critical and marginal failures or emergencies involving the system.

Standard: In the event of catastrophic, critical and marginal failures or emergencies the system provides and implements operational contingencies by transitioning to a pre-determined and expected state and mode.

Method of Compliance: Verification method includes inspection of documentation. Inspections of safety analyses *v*erify which catastrophic, critical, marginal failures, and other system emergencies require operational contingencies. Inspections of design documentation verify that, in the event of the identified failures or emergencies, the system provides and implements operational contingencies by transitioning to a pre-determined and expected state and mode. Inspection of system safety documentation verifies that operational contingencies have been approved.

References: Unmanned Systems Safety Guide for DOD Acquisition
SAE ARP4754
SAE ARP4761
14 CFR Section 1309 of Parts 23, 25, 27, 29 and related advisory circulars.

14.2.12 Safety assurance for special military modes of operation.

Criterion: Verify that special military modes of operation when inactive do not reduce the UAS below threshold safety levels.

Standard: Special military modes of operation of UAS (e.g., weapons or stores arming and release or operation of electromagnetic spectrum emitters) when inactive (e.g., a jammer in standby mode) meet probability of failure and design and development assurance requirements through physical/functional segregation and design.

Method of Compliance: Verification method includes inspection of documentation. Inspections of programmatic, system safety and software safety documents.

Criterion: Verify that special military modes of operation of UAS (e.g., weapons or stores arming and release or operation of electromagnetic spectrum emitters) when inactive (e.g., a jammer in standby mode) meet probability of failure and design and development assurance requirements through physical/functional segregation and design.

References: MIL-STD-882
SAE ARP4754
SAE ARP4761
STANAG 4671, section U19
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars.

14.3 Software safety program.

NOTE: Software safety is additionally verified through Section 15 of this document.

14.3.1 Comprehensive approach to software safety.

Criterion: Verify that a comprehensive software safety program is integrated into the overall system safety program.

Standard: A comprehensive software safety program is integrated into the system safety program by ensuring the following:

a. Adequate planning for software safety tasks;

b. Adequate planning for analysis, traceability and testing is documented in safety management plans and test plans;

c. Active participation of software safety in engineering processes/events (i.e., peer review, change boards, deviation processing etc.);

d. Inclusion of software safety in the software development process and products;

e. System safety allocates safety requirements to software safety in a timely manner;

f. System/software hazard analyses substantiate that no single point failure caused by software results in loss of aircraft or system;

g. Software causes of and mitigations for the system hazards are identified and integrated into the system safety process (i.e., hazard reports, hazard tracking system etc.);

h. Software safety recommends system safety requirements to system safety in a timely manner;

i. Systems engineering receives the final software safety input from system safety in a timely manner;

j. Software integrity levels are established and enforced for the program in accordance with prescribed industry standards;

k. Safety designated functions and their associated safety designated software are identified and analyzed;

l. Test plans and procedures include testing of software safety functional requirements and design requirements.

NOTE: The preceding should not be considered to be an all-encompassing exclusive list, and may be expanded depending on program scope and complexity.

Method of Compliance: Verification method includes inspection of documentation. Verify by inspection of program safety, software safety, and software documentation that the comprehensive software safety program has been integrated into the system safety program in a manner which meets the standard.

References: MIL-STD-882
JSSSEW JSSSEH
AMCOMR 385-17, AMCOM Software System Safety Policy
RTCA DO-178
RTCA DO-254
RTCA DO-278
SAE ARP4754
SAE ARP4761
NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.3.2 Planning/accomplishing software safety analyses and assessments.

Criterion: Verify that the software safety program requires that appropriate software safety-designated analyses be performed as part of the software development process and verify accomplishment of related assessment tasks.

Standard: A tailored set of analyses and assessments (or equivalent) required by the references of 14.3 (this document) is planned for and accomplished.

Method of Compliance: Verification method includes inspection of documentation. Verify by inspection of system safety, software safety, and software documentation that the tailored set of analyses and assessments (or equivalent) required by the references of 14.3 (this document) are planned for and accomplished.

References: MIL-STD-882
JSSSEW JSSSEH

RTCA DO-178
SAE ARP4761
NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.3.2.1 Performance of software safety analyses.

Criterion: Verify that the required software safety analyses preparation is accomplished.

Standard: The types and quantities of required software safety analyses are prepared and provided in accordance with planning for software safety. Software safety analyses and assessments include the tailored documentation required by the references of 14.3 (this document).

Method of Compliance: Verification method includes inspection of documentation.

Criterion: Verify by inspection that the delivered software safety analyses for the program have a complete systems view, including identification of software hazards, and associated software risks.

References: MIL-STD-882
JSSSEW JSSSEH
RTCA DO-178
SAE ARP4761
NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.3.2.2 Performance of software safety traceability analyses.

Criterion: Verify that the required software safety traceability analyses are accomplished.

Standard: System safety requirements allocated to software are refined using appropriate analyses to allocate the system safety requirements to the software requirements, and bi-directional traceability to the identified hazard(s) is accomplished. Appropriate analyses include the tailored documentation required by the references of 14.3 (this document).

Method of Compliance: Verification method includes inspection of documentation. Verify by inspection of system safety, software safety and program documentation that the bi-directional software safety traceability analyses amongst requirements, design, implementation, verification, and hazard have been accomplished.

References: MIL-STD-882
JSSSEW JSSSEH
AMCOM REG 385-17, AMCOM Software System Safety Policy
RTCA DO-178
SAE ARP4761
NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29 and related advisory circulars.

14.3.3 Evaluation of software for elimination of hazardous events.

Criterion: Verify that the design/modification software is evaluated to ensure controlled or monitored functions do not initiate hazardous events or mishaps in either the on or off (powered) state.

Standard: The software as designed or as modified does not initiate hazardous events in either the on or off (powered) state.

Method of Compliance: Verification methods include analysis, test, and inspection of documentation. Verify that a system safety assessment is accomplished which includes evaluation of software and identification of anomalous software control/monitoring behavior to assure the software as designed or as modified does not initiate relevant hazardous events.

References: MIL-STD-882
JSSSEW JSSSEH
RTCA DO-178
NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars.

14.3.4 Commercial off-the-shelf software integrity level confirmation.

Criterion: Verify that Commercial Off-the-Shelf (COTS) and reuse software (which includes application software and operating systems) are developed to the necessary software integrity level.

Standard: The software criticality level for COTS and reuse software functions has been determined and their development has been confirmed to be at the required software integrity level as defined by software and/or safety planning.

Method of Compliance: Verification methods include inspection of documentation. Verify by inspection of program, system safety, software safety and software engineering documentation that the software criticality level for COTS and reuse software by function is determined. Verify that the software is developed to the required software integrity level as defined by software and/or safety planning.

References: MIL-STD-882
JSSSEW JSSSEH
AMCOMR 385-17, AMCOM Software System Safety Policy
RTCA DO-178
SAE ARP4754
NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29 and related advisory circulars
FAA AC 20-148

14.3.5 Identification of safety designated/significant software.

Criterion: Verify that software elements which perform functions related to system hazards have been identified and handled as safety designated/significant software.

Standard: Safety functions identified as system hazards are allocated to software functions. Software elements (e.g., CSCI, CSC, CSU, data, interfaces) related to each of those software functions are identified and assigned an appropriate safety criticality as defined by the system safety planning documentation. The software elements are handled (labeled, tracked, implemented, tested, etc.) as defined by the system safety planning documentation.

Method of Compliance: Verification method includes inspection of documentation. Verify by inspection of system safety and software safety documentation that safety related software functions have been identified. Verify by inspection of program, system safety and software safety documentation that the identified safety related software elements are handled (labeled, tracked, implemented, tested, etc.) as required by software/safety planning based on their safety criticality levels.

References: MIL-STD-882
JSSSEW JSSSEH
AMCOMR 385-17, AMCOM Software System Safety Policy
RTCA DO-178
SAE ARP4754
NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.3.5.1 Assignment of criticality levels.

Criterion: Verify that each safety designated software function is assigned an appropriate criticality level.

Standard: For each of the software elements (e.g., CSCI, CSC, CSU, data, interfaces), the software functions implementing those elements are assigned an appropriate criticality level. If a software function contains multiple software elements, the function is assigned a criticality level equal to the criticality level of the highest element.

Method of Compliance: Verification method includes analysis and inspection of documentation. Verify that the appropriate level of criticality is assigned to each software function.

References: MIL-STD-882
JSSSEW JSSSEH
AMCOMR 385-17, AMCOM Software System Safety Policy
RTCA DO-178
SAE ARP4754
NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.3.5.2 Testing to criticality levels.

Criterion: Verify that each safety designated software function is tested commensurate with its assigned criticality level.

Standard: Each safety designated software function is tested to the level required by its assigned criticality level. The testing requirements for the software criticality levels are documented in the system safety planning documents.

Method of Compliance: Verification method includes inspection of documentation. Verify that the appropriate level of testing for designated safety software has been performed and required results were achieved.

References: MIL-STD-882
JSSSEW JSSSEH
AMCOMR 385-17, AMCOM Software System Safety Policy
RTCA DO-178
SAE ARP4754

NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.3.6 Software safety test analyses.

Criterion: Verify that the appropriate software safety test analyses have been planned and performed.

Standard: Software safety test analyses (e.g., nominal and functional requirements base testing/analysis, structural coverage analysis, hazard mitigation testing analysis, failure modes and effects testing analysis) planning and other documentation are formally documented and are kept under configuration management control. Software safety test analyses activities are also executed; results are recorded using formal procedures and are kept under configuration control.

Method of Compliance: Verification method includes inspection of documentation. Verify by inspection of the safety plans that software safety testing and test analyses have been adequately documented and planned. Verify by analysis of the documented hazards that the hazards associated with software and computer components have been eliminated or controlled to the acceptable level of risk as required by the system/software safety plan. Verify by inspection of the test reports that the software safety test results have been analyzed and approved/accepted.

References: MIL-STD-882
JSSSEW JSSSEH
AMCOMR 385-17, AMCOM Software System Safety Policy
RTCA DO-178
SAE ARP4754
NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

14.3.7 Structural coverage analysis.

Criterion: Verify that software safety planning adequately plans for structural coverage analysis and that the planned analysis is accomplished.

Standard: Adequate structural coverage analysis for the software criticality level is accomplished; results are recorded using formal procedures and are kept under configuration management.

Method of Compliance: Verification method includes inspection of documentation. Verify by inspection of the test plans that adequate structural coverage analysis is planned for and documented. Verify by inspection of structural coverage analysis results that adequate structural coverage testing and analysis were achieved.

References: MIL-STD-882
JSSSEW JSSSEH
AMCOMR 385-17, AMCOM Software System Safety Policy
RTCA DO-178
NATO AOP-52
14 CFR Section 1309 of Parts 23, 25, 27, 29; and related advisory circulars

15. COMPUTER SYSTEMS AND SOFTWARE

TYPICAL CERTIFICATION SOURCE DATA

1. Safety Critical Function (SCF) Thread Analysis.
2. System/subsystem and safety requirement documents.
3. System Processing Architecture (SPA) integration plan(s).
4. SPA architectural drawings/diagrams.
5. SPA design descriptions.
6. SPA Interface Control Documents (ICDs).
7. Hardware requirements specifications.
8. Software requirements specifications.
9. Hardware and software ICDs and bus ICDs.
10. Hardware development process documentation.
11. Software development plans (SDPs) and/or software development integrity master plan (SDIMP).
12. Configuration management plans and data.
13. Quality assurance plans and audits.
14. Failure Modes Effects Analysis (FMEA) and/or Failure Modes, Effects and Criticality Analysis (FMECA) (or equivalent).
15. Failure Modes and Effects Testing (FMET) plans, procedures and reports (or equivalent).
16. Various technical analyses and studies (e.g., common mode analysis, Single Event Upset (SEU) vulnerability analysis, latency analysis, Built-In-Test (BIT) coverage analysis, interface coupling analysis, transient analysis, source data analysis, safety interlock design analysis, traceability analysis, reports from code analysis tools)
17. Hardware diagrams and drawings.
18. Software design documents.
19. Design review minutes.
20. Safety interlock design thread analysis.
21. Detailed software process guidelines such as software coding standards, prohibited coding techniques.
22. Software integration plan(s).
23. Hardware and software test plans, procedures, and reports.
24. Software regression testing policy at software and system level.
25. Computer resources utilization analyses and metrics (e.g. processor throughput, data bus throughput, memory utilization, memory throughput).
26. Version description documents for each software configuration item.
27. Software/Operational Flight Program (OFP) build plans.
28. Software load process and procedures.
29. Validation evidence for verification tools and models.
30. Reports from problem report databases (system and software level).
31. Technical manuals (e.g., Technical Orders, Flight Manuals, Operator's Manuals, NATOPS).

32. Ground and flight test plans and reports.
33. Flight clearance process documentation.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

References: In addition to VCMS systems, JSSG-2008 Appendix A provides useful guidance for all airborne computer resources involved in safety critical processing. Consequently in reading the reference information contained in JSSG-2008 it may be useful to interpret VCMS to mean any aircraft system involved in safety critical processing. JSSG-2008 Appendix A references to requirements (i.e., 3.x.y paragraphs) should also be understood as referencing the corresponding verification paragraphs (i.e., 4.x.y).

15.1 System processing architecture (SPA).

15.1.1 Safety critical functions (SCFs).

Criterion: Verify that the system's safety critical functions (SCFs) have been identified and documented.

Standard: All SCFs have been identified based on the program safety definitions and the criticality of the functions implemented on the air system.

Method of Compliance: Verification methods include analysis, and inspection of documentation. Verify that all air system functions have been identified. Verify that all SCFs from the complete list of air system functions are identified and documented. Verify that documentation identifies the analysis method used to determine SCFs.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III.1.a); 3.1.2.1 for establishing safety criticality along with CNS/ATM safety performance references in the Electronic Systems Center (ESC) developed Generic Performance Matrices (10E-5 to 10E-7 hazard rates depending on flight phase)

MIL-STD-882: 4.3.2 of MIL-STD-882E addresses the identification of hazards; Task 208 - Functional Hazard Analysis

DoD JSSSEH: 4.1.3, 4.3.6, and appendix C.3.4 - identify and explain the purpose of a Safety Critical Functions list for software

USAF Weapon System Software Management Guidebook: 3.8; G.2.3; G.2.4; G.2.5; G.3.1; G.4.1

NASA-STD-8719.13B: 4.0 safety-critical software determination

IEEE Std 1228-1994: 4.4.1.b; 4.4.3.c.4

FAA AC 23.1309-1E, Para 16; and FAA AC 25.1309-1A, Para 8a; both address identification of critical functions in performing a Functional Hazard Analysis (FHA)

FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: A.3.3

15.1.2 SPA requirements.

Criterion: Verify that the System Processing Architecture (SPA) safety requirements are fully defined and documented.

Standard: Safety and performance requirements are allocated to the architecture. The SPA is defined. An analysis of the SPA is performed to address attributes such as functional requirements, processing demands, timing criticalities, data flow, interfacing elements, and fault tolerance. Federated and integrated elements of the SPA are identified.

Method of Compliance: Verification methods include analysis and inspection. Verify that the analysis of the SPA is complete and is documented. Analysis determines if the SPA supports program safety and performance requirements. Ensure all technical and safety SPA risks are appropriately mitigated/captured.

References: JSSG-2008 Appendix A: 3.1.7 - 3.1.12 System Architecture, Unique Function Integration, Failure Immunity and Safety, Failure Transients, Integration Management, Redundancy; 3.3.1 Processing Architecture

MIL-STD-882: Task 203 of MIL-STD-882 E (see also MIL-STD-882D: A.4.3.1; A.4.3.2 Safety Performance Requirements; A.4.3.3 Safety Design Requirements)

DoD JSSSEH: 4.3.5 addresses defining safety requirements for software systems

USAF Weapon Systems Software Management Guidebook: G.2.1; G.2.2; G.2.3

NASA-STD-8719.13B: 4.4.2 software safety requirements designated; 6.2.2.2.f

RTCA DO-178: 2.1 of RTCA DO-178C addresses how system design drives safety related requirements that flow to software (see also RTCA DO-178B: 2.1.1)

SAE ARP4754A: 4.1.6

FAA AC 20-115C: provides guidance on the use of RTCA DO-178C, RTCA DO-330, RTCA DO-331, RTCA DO-332, RTCA DO-333 (NOTE: FAA AC 20-115B was the companion guidance issued with RTCA DO-178B)

DOT/FAA/AR-07/48: A.6

15.1.3 SPA redundancy.

Criterion: Verify that the SPA employs redundancy to preclude the loss of safety critical processing in the event of a single failure or data channel loss and supports fault tolerance requirements.

Standard: The SPA has employed redundancy and fault tolerance to preclude the loss of SCFs due to the occurrence of single point failures or data channel loss. The SPA does not contain any components (e.g., digital hardware, interfaces, software components/modules, and operating system/executive) whose failures defeat the redundancy mechanization.

Method of Compliance: Verification methods include analysis and testing of the SPA. Verify through analysis and testing, including Failure Modes and Effects Test (FMET), that a single point failure does not result in the loss of SCF. Verify techniques such as the following are employed to preclude the existence of single point failures: voting schemes, Cross Channel Data Links (CCDL) mechanization, data bus management, and input/output signal management approach. Verify that the SPA fault tolerance and redundancy management mechanization is capable of handling all single failures.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III.1.b & e) 3.1.9; 3.1.11; 3.1.12; 3.3.1 for further guidance concerning redundancy, system and processing architectures

MIL-STD-882: 4.3.4 of MIL-STD-882E, risk mitigation through design choices;

Task 208.2.1.h (see also MIL-STD-882D - A.4.3.3.1.1.a Unacceptable Conditions; A.4.4.6.1 Testing for a Safe Design)

DoD JSSSEH: C.8.4 Safety Tools & Training; E.6.2 Memory Checks - address identifying single point failures

USAF Weapon Systems Software Management Guidebook: 3.8; G.2.3; G.2.6; G.3.1

NASA-STD-8739.8: 7.3.1

FAA CAST-24: 2.1 safe flight after single failure

IEEE Std 1220-2005: 6.5.12 assess failure modes, effects, and criticality

FAA AC 20-156: Aviation Databus Assurance

FAA AC 23.1309-1E: 17.c.4 FMEA may be necessary to determine functional redundancy; 17.d.3 failure conditions

FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: A.1.3; A.3.1 redundancy, error-correcting memory, voting

15.1.4 SCF threads.

Criterion: Verify that all SPA supported SCF threads have been identified, documented and completely traced, and that all Safety Supporting Elements (SSEs) of the SPA have been identified.

Standard: All SCF threads have been traced from the SPA to the component level. All SSEs, Safety Supporting Software Elements (SSSEs), Safety Supporting Hardware Elements (SSHEs) and non-SSEs have been identified and documented. Automating the SCF thread tracing capability allows for repeatability and expansion of analysis.

Method of Compliance: Verification methods include analysis, and inspection of documentation. Verification includes functional thread analysis for each SCF from the SPA to the SSEs, SSSEs, SSHEs, and components. Ensure SSEs, SSSEs, SSHEs, and components are appropriately identified, labeled and traced to each SCF they support. Ensure non-SSEs are identified and documented. Verify the sufficiency of coverage and repeatability of the functional thread analysis conducted on the SCFs.

References: JSSG-2008 Appendix A: 3.1.8; 3.1.9; 3.1.11.3; 3.1.12

MIL-STD-882: 4.3.2 of MIL-STD-882E addresses the identification of hazards; Task 208 - Functional Hazard Analysis

DoD JSSSEH: 4.1.3, 4.3.4.2, 4.3.6, 4.3.7.2.3, and appendix C.3.4 - identifies and explains the purpose of an SCF list for software

USAF Weapon Systems Software Management Guidebook: G.2.1; G.2.2; G.2.3

NASA-STD-8719.13B: 4.0 Safety-Critical Software Determination

RTCA DO-178: For RTCA DO-178C: 2.1 System Requirements Allocation to Software; 2.3 System Safety Assessment; 2.3.2 Failure Condition Categorization; 2.3.3 Software Level Definition; 2.3.4 Software Level Determination; 4.4 Software Life Cycle Environmental Planning (see also RTCA DO-178B: 2.1; 2.2.1; 2.2.2; 2.2.3)

RTCA DO-254: 2.0; 2.1.1

IEEE 12207.2-1997 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 5.3.2.1 Guidance 2 - trace requirements down to components

FAA AC 20-115C

FAA AC 20-152: provides guidance for the use of RTCA DO-254

FAA AC 25.1309-1A: 8a (see also FAA AC 23.1309-1E: Para 16) addresses identification of critical functions in performing a Functional Hazard Analysis (FHA)

FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: 4.2

15.1.5 Probability of loss of control and hazard mitigations.

Criterion: Verify that the SPA is designed to meet Probability of Loss of Control (PLOC), Probability of Loss of Aircraft (PLOA), SCF processing, hazard mitigations, and reliability requirements.

Standard: Proper levels of redundancy, sufficient cross checks, and hazard mitigations are incorporated in the SPA to ensure safety critical components accommodate failures while achieving safety/PLOC/PLOA and fail-operational/fail-safe requirements. Program PLOC and PLOA numbers are specified in system documents. SPA hardware components are designed to meet specified reliability requirements. For Air Force, aircraft designed to operate in all classes of air space are expected to achieve a PLOC of 10E-7.

Method of Compliance: Verification method includes analysis. The analysis covers the design of all hardware and software elements of the SPA.

References: JSSG-2008 Appendix A: 3.1; 3.1.2; 3.1.8; 3.3.1; 3.3.2; 3.1.11; 3.1.12

MIL-HDBK-217: Reliability Predictions of Electronic Equipment

MIL-STD-882: For MIL-STD-882E, 4.3.4; 4.3.6; Task 101; Task 103.2.8.a; Task 203.2.3; Task 204.2; Task 301.2.b; Task 303 (see also MIL-STD-882D - 4.3; A.4.4.3)

DoD JSSSEH: 4.3.8; 4.4.2.8; 4.4.4; C.9.3

USAF Weapon Systems Software Management Guidebook: G.2.6

NASA-STD-8719.13B: 6.2.2.2.b hazard identification

RTCA DO-254: 2.3.1; 6.3.2; 10.3.1; 10.3.2.2

IEEE Std 1228-1994

SAE AS94900: 3.1.1.3 quantitative flight safety requirements

FAA AC 20-152

15.1.6 SPA interfaces.

Criterion: Verify that all SSEs of the SPA that interface (physically or functionally) with other processing elements (SSEs or non-SSEs) continue safe operation in the event there is a data channel failure or data corruption with the interfacing elements.

Standard: The SPA physically and functionally separates SSEs from non-SSEs to maintain safe system operation. Failure of non-SSEs or the loss or corruption of data channels does not affect SSEs. All interfaces which handle data associated with SCFs have been identified (baselined and documented) as safety critical. SSE interfaces are designed to ensure data/calculation/system-timing dependencies do not impede system performance in any operational mode or degrade architectural safety coverage.

Method of Compliance: Verification methods include analysis, interface testing, and inspection of documentation. The documentation is inspected for completeness in identifying all SSE and non-SSE interfaces. Verify through analysis (e.g., common mode) that the SPA requirements and design physically and functionally separate SSEs from non-SSEs. Verify through testing that non-SSEs do not affect SSEs. Testing of these interfaces addresses interface performance (e.g., interface loading, handshaking/protocols, timing/data/calculation/system dependencies) for all operational modes and failure modes to ensure safe system operation.

References: JSSG-2008 Appendix A: 3.1.7.1 provides for basic partitioning of the architecture (hardware and software); 3.1.7.2 gives guidance regarding "system arrangement" (architecture design); 3.1.7.3 directly addresses isolation of less critical elements to prevent their failure from affecting critical functions, 3.1.8; 3.1.11, 3.14.4, 3.2.2.6, and 3.3.1 provide guidance for integrating safety critical VCMS systems with non-safety critical processing elements

MIL-STD-882: For MIL-STD-882E, Task 208; B.2.2.5.a (see also MIL-STD-882D - A.4.3.3.b & d)

DoD JSSSEH: 3.5; 4.3.6.2; 4.4.1.1; D.3.3

USAF Weapon Systems Software Management Guidebook: G.3.1

NASA-STD-8719.13B: 6.1.1.5

RTCA DO-254: 2.3.1

ARINC Specification 653

FAA AC 20-152

FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: 4.3.2 software fault isolation; A.1.15 isolation of safety-critical functions from non-critical functions

DOT/FAA/AR-99/58: Partitions in Avionics Architectures

15.1.7 Computer System Integrity Levels (CSILs).

Criterion: Verify that all SCFs are fully allocated to elements within the SPA and that each element is assigned a Computer System Integrity Level (CSIL) based on the criticality of support that it provides to the SCF.

Standard: The CSILs are defined. Each SPA element has an appropriately assigned CSIL and the corresponding process is applied to all components of the element. All SCFs have been allocated to SSEs. Functional design assurance levels and CSILs are not lowered through alternative design techniques (e.g., the use of redundancy, monitoring, or other techniques is not an acceptable justification for lowering a CSIL).

Method of Compliance: Verification methods include analysis, and inspection of documentation. Inspection of process documentation verifies that CSILs are defined. Inspect all SCFs and thread analysis documentation. Verify that the analysis has identified all elements of the SPA and that the associated CSIL has been determined. Ensure all SSEs are assigned a CSIL based on the criticality of support that is provided to the SCF.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III.1.c); 3.2.2.2.7 (Requirements Lessons Learned); 3.3.2; 3.5.7

JSSG-2008 Appendix B: 4.1.5; 4.1.8.5; A14.1.3

MIL-STD-882: (see also MIL-STD-882D)

DoD JSSSEH: 4.2; 4.2.1.3.1; 4.2.1.4; 4.2.1.5; 4.3.3; 4.4; C.1.6.2; E.1.2; E.1.3.3; G.2.2

USAF Weapon Systems Software Management Guidebook: 3.8; G.2.2; G.2.3; G.2.6; G.3.1

RTCA DO-178: 2.3; 2.3.2; 2.3.3; 2.3.4 (see also RTCA DO-178B: 2.1.1; 2.2.2;

2.2.3)

RTCA DO-254: 2.1.1; 2.2

IEEE Std 1012-2012: Sec 5 software integrity levels

SAE ARP4761: 3.4 references RTCA DO-178 for software and hardware assurance levels; B.3.3.d

SAE ARP4754: 5.2

FAA AC 20-115C

FAA AC 20-152

15.1.8 CSIL processes.

Criterion: Verify that every CSIL has a corresponding development process defined and applied and that each process is adequate to support the safety requirements of the classification.

Standard: CSILs are identified and documented. For each CSIL, ensure the program process and planning documentation or applicable integrity program plans clearly define and document appropriate processes, and that those processes are applied. The defined development and test processes support safety requirements and CSILs. All SSEs, SSSEs, and SSHEs are designed, developed, integrated and tested to appropriate CSILs.

Method of Compliance: Verification methods include analysis, and inspection of process documentation. Ensure CSILs are identified and documented. Verify through analysis the adequacy of the CSIL processes. Verify that appropriate CSIL processes are documented and followed.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III.1.c); A.3.2.2.2.7 (Requirements Lessons Learned); A.3.3.2; A.3.5.7

JSSG-2008 Appendix B: B.4.1.5; B.4.1.8.5; B.A14.1.3

MIL-STD-882: (see also MIL-STD-882D)

DoD JSSSEH: 4.2; 4.2.1.4; 4.2.1.5; 4.3.3; 4.4; C.1.6.2; E.1.2; G.2.2

USAF Weapon Systems Software Management Guidebook: 3.8; G.2.2; G.2.3; G.2.6; G.3.1

RTCA DO-178: For RTCA DO-178C: 2.3; 2.3.2; 2.3.3; 2.3.4 (see also RTCA DO-178B: 2.1.1; 2.2.2; 2.2.3)

RTCA DO-254: 2.1.1; 2.2

IEEE Std 1012-2012: Sec 5 software integrity levels

SAE ARP4754: 4.1.2 development assurance levels

SAE ARP4761: 3.4 references RTCA DO-178

FAA AC 20-115C

FAA AC 20-152

15.1.9 Data flow and control flow

Criterion: Verify that interfaces (control and data flow) supporting SPA SSEs are clearly defined and documented.

Standard: All SSE interfaces which handle control and data associated with safety critical functions have been clearly defined and documented. Interface requirements for safety are defined and accounted for throughout the development process (e.g., drive specific test processes). Safety critical interfaces are designed to ensure data/calculation/system-timing dependencies do not impede system performance in any operational mode or degrade architectural safety coverage.

Method of Compliance: Verification methods include analysis, and inspection of documentation. The documentation is inspected for completeness in identifying and defining all SSE and non-SSE interfaces. Inspect test process documentation to ensure safety interfaces are fully verified. Analysis verifies interface dependencies do not impede system performance and safety.

References: JSSG-2008 Appendix A: 3.0 Vehicle Control and Management Systems/Flight Control Systems section (IX.6); 3.0 Computer Resources section (III.1.d.2); 3.1.7.1 provides guidance for identifying subsystem interfaces and ensuring sufficient data communication timing margins; 3.5.7 discusses the application of integrity processes in the design of system interfaces from both the hardware and software standpoint

JSSG-2008 Appendix B: A8.6.1.3; A14.1.4.2

DoD JSSSEH: 4.3.6.3.2; 4.3.7.3.2; 4.3.7.3.2.2; 4.3.7.3.2.3; E.4.6

USAF Weapon Systems Software Management Guidebook: 3.6; 3.6.1; 3.11; F.2.2; F.4.2; F.5.2; F.6.2; F.7; G.2.2; G.2.4

IEEE Std 1012-2012: 8.3 Activity table V&V Task (2) Interface Analysis

IEEE Std 1220-2005: 4.8; 5.2.1.1; 5.2.1.2

IEEE 12207.0-1996 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 5.3.4.1.b external interfaces to the software item must be documented

SAE EIA SEB6-A: 3.2.1

CMU/SEI-2010-TR-033, CMMI for Development Ver. 1.3: SP 2.3 Requirements Development - identify interface requirements

15.1.10 Physical and functional separation.

Criterion: Verify that physical and functional separation between SSEs and non-SSEs are accounted for in the SPA.

Standard: Partitioning schemes and operating systems utilized to separate SSEs from non-SSEs are developed and tested at the highest CSIL supported. Partitioning schemes ensure partitioning breaches are prevented and that derived requirements are defined to ensure partitioning integrity is maintained.

Method of Compliance: Verification methods include analysis and test. Analysis ensures the effectiveness of partitioning schemes. Analysis (e.g., Failure Modes Effects Analysis (FMEA)) and testing (e.g., Failure Modes and Effects Testing (FMET)) verify that techniques employed for separation are effective and safe. Systems integration tests are conducted on the SPA at the highest CSIL of the SSEs residing within. These tests verify that the non-SSEs do not affect the safe operation of the system. Ensure the testing of all elements, the SPA, and computer system interfaces is commensurate with their CSILs.

References: JSSG-2008 Appendix A: 3.1.7.1 provides for basic partitioning of the architecture (hardware and software); 3.1.7.2 gives guidance regarding "system arrangement" (architecture design); 3.1.7.3 directly addresses isolation of less critical elements to prevent their failure from affecting critical functions; 3.1.8, 3.1.11, 3.14.4, 3.2.2.6, and 3.3.1 provide guidance for integrating safety critical VCMS systems with non-safety critical processing elements

MIL-STD-882: For MIL-STD-882E: Task 208; B.2.2.5.a (see also MIL-STD-

882D: A.4.3.3.b & d)

DoD JSSSEH: 3.5; 4.3.6.2; 4.4.1.1; D.3.3

USAF Weapon Systems Software Management Guidebook: 3.6; 3.6.1; 3.11; F.2.2; F.4.2; F.5.2; F.6.2; F.7; G.2.2; G.2.4

NASA-STD-8719.13B: 6.2.2.2.e isolation of safety-critical from non-safety critical design elements

RTCA DO-178: For RTCA DO-178C: 2.3; 2.4.1; 2.5.5.b; 11.1.b (see also RTCA DO-178B: 2.3.1)

RTCA DO-254: 2.3.1

RTCA DO-255

ARINC Specification 653

FAA AC 20-152

FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: A.1.15 isolation of safety-critical functions from non-critical functions

15.1.11 Notification of loss of critical processing.

Criterion: Verify that the operator is notified upon the loss of flight critical processing capability or redundancy in flight critical processing.

Standard: Flight critical processing systems have been identified. Built-In-Test (BIT) detects loss of redundant processing capabilities for flight critical systems. Operator is alerted to the loss of flight critical processing or the loss of redundancy in a flight critical processing system either through the notification of the functional loss/degradation that results, or the loss of redundant processing capacity. The annunciation of loss or degraded processing is properly prioritized. Unless a more stringent requirement is specified, latency time from detection to annunciation for flight critical alerts is no more than 100ms.

Method of Compliance: Verification methods include test, demonstration, and inspection. Inspection of safety documentation identifies flight critical processing systems. Verify that proper annunciations have been designed into the system by inspecting requirements, design documentation and flight manuals. Test and/or demonstration verify the annunciations and proper prioritization to the operator when loss of flight critical processing or loss of redundancy occurs. Verify using FMET and system performance testing that the system BIT and response characteristics are acceptable and latency requirements are met.

References: JSSG-2008 Appendix A: 3.1.11.2 pilot notification of modes; 3.1.12 Redundancy; 3.2.2.5.1.4 Annunciations/Warnings

MIL-STD-882: For MIL-STD-882E: 4.3.4.d; B.2.2.5.a (see also MIL-STD-882D - 4.4.c; A.4.3.3.1.2.i)

DoD JSSSEH: 3.6.2; E.1.3.1; E.6.1; E.8.4; E.9.1.1; E.9.6; E.9.7; E.9.8; E.11.11

FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: A.4.2 all anomalies, faults, and failures should be reported to operator in real time

15.1.12 Uninterruptable power.

Criterion: Verify that the electrical power quantity and quality for the SPA(s) are sufficient to maintain continuous operation.

Standard: Power mechanization maintains dedicated/uninterruptible power of sufficient quality for safety critical applications in the presence of failures. Safety critical architectures provide dedicated/uninterruptible power sources. Redundancy (alternate power sources or battery) achieves safety requirements. Compliance with the following criteria from section 12 is also achieved: 12.1.1 (sufficient power), 12.1.5 (uninterruptable power).

Method of Compliance: Verification methods include analysis, testing, and inspection. Verify independent power sources through the inspection of design documentation. The analysis covers the power mechanization scheme which supports flight critical/safety critical processing to verify design adequacy and establish verification test requirements. Extensive FMET, system integration and software testing verifies the fault tolerance of the design. Method of Compliance verifications associated with identified section 12 criteria are met.

References: JSSG-2008 Appendix A: 3.2.2.2.2 and 3.2.2.2.5 give extensive guidance on aircraft primary and secondary power system support to safety critical equipment

MIL-HDBK-516: Section 12

DoD JSSSEH: 3.5; 4.3.7.2.2; E.4

USAF Weapon Systems Software Management Guidebook: G.3.4

RTCA DO-254: 5.1.2; 6.1 Note 2

SAE AS94900: 3.1.1.5 transient electrical power effects

FAA AC 20-152

FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: A.2 computer system power

15.2 Design and functional integration of SPA elements.

15.2.1 Functional coupling.

Criterion: Verify that SSEs avoid unnecessary coupling.

Standard: The SPA design mechanization accounts for the dependencies of data/parameters utilized by the safety critical processing elements within the SCF threads. The SSE interdependencies (e.g., data, control, functional, and hardware) of the SCF thread satisfy the SCF requirements (e.g., latency, processing, and data). Data coupled to these threads are defined in terms of criticality and requirements are in place to avoid unnecessary coupling. Only SSE data and control required to satisfy the SCF processing requirements are coupled between the SSEs. Unnecessary coupling is avoided by eliminating non-essential elements in a SCF thread.

Method of Compliance: Verification methods include analysis, test, demonstration, and inspection. Inspection of SCF threads is performed to ensure that unnecessary coupling does not exist. Process documentation is reviewed to verify that processes are in place to ensure unnecessary coupling is eliminated. Essential coupling, processing rates, associated allowable latencies, and transient limitations required for safety critical data are analyzed, tested and demonstrated. Verify all data requirements for SSEs are defined.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III.3.a); 3.1.14.6 addresses designing software to be invulnerable to errors; 3.1.5.1 gives guidance on data latency issues; 3.1.7 gives overall architecture design guidance along with specific data latency discussions in Lessons Learned subparagraph I

JSSG-2008 Appendix B: A14.3.1

DoD JSSSEH: 4.3.7.3.2.7; 4.4.1.5; D.6.1; E.3.19

NASA-GB-8719.13: 4.6 design for weak coupling

RTCA DO-178: For RTCA DO-178C: 6.3.4.d; 6.4.4.d; 6.4.4.2.c; 11.8; 12.1.1.c (see also RTCA DO-178B)

FAA AC 20-115C

DOT/FAA/AR-07/48: 5.3 data and control coupling tools, also calls attention to DO-178B; 6.13 control of data coupling

15.2.2 Functional autonomy and critical data sources.

Criterion: Verify that safe functional autonomy is achieved by ensuring that SSEs do not rely on single source safety critical data or non-safety critical data to support SCFs.

Standard: All data sources for SSEs are identified. Safety critical data are identified. The SSEs are designed to preclude reliance on single source safety critical data or from non-safety critical sources for safety critical applications.

Method of Compliance: Verification methods include analysis and test. FMEA and FMET verify that loss of non-safety critical data or a safety critical source will not cause loss of SCF.

References: JSSG-2008 Appendix A: 3.1.11.3 addresses single source data concerns; 3.3.1 contains guidance addressing redundant data path management, data validity and reasonableness; 3.1.7.3 and 3.1.8 provide guidance for interfacing between safety and non-safety critical subsystems

DoD JSSSEH: 4.3.7.2.4; 4.3.7.3.2.2; 4.3.7.3.2.4

USAF Weapon Systems Software Management Guidebook: 3.8; G.2.3.f; G.4.1

NASA-GB-8719.13: 7.4.1 segregate safety-critical data from other data

IEEE Std 1012-2012: 5.0 altering of critical data

FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: A.3.1 protection against single system failure

15.2.3 Integration methodology.

Criterion: Verify that the integration methodology used for the SPA SSEs is defined, documented, and provides complete verification coverage of SCFs at all levels, for each flight configuration release.

Standard: The entire SPA is developed, integrated and verified using a defined, documented, and proven process which includes complete test coverage (requirements, functions, failure conditions, mission validation) at all levels. Verification methodology includes end-to-end testing of SCF threads. SSEs, along with non-SSEs, are developed and tested individually; then integrated to form a SPA or multiple SPAs. Multiple SPAs may be integrated to form the system. Software residing on a SPA or multiple SPAs forms a build. Each build, for planned flight release, has all the safety critical functionality necessary to ensure safe flight. The integration methodology identifies conditions (adequacy of partitioning, decision points, areas of testing) for which a subset of testing is permissible in lieu of complete testing. Regression process addresses adequacy of partitioning, the areas of change, other areas affected by the change(s), and core testing required independent of the change(s) (comprehensive verification of SCFs that are supported by modified SSEs).

Method of Compliance: Verification method includes inspection of integration planning and test documentation. Inspection of integration plans and process documentation verifies that the integration methodology has been implemented, and provides complete verification coverage. Verify that the SSEs of the SPA are clearly identified such that any dependencies that safety critical systems (e.g., vehicle management system) have on other systems are addressed.

Ensure integration plans show a reasonable build-up approach. Verify that the test documents reflect all levels of testing throughout all levels of the architecture/system. Verify the plans and results of end-to-end SCF testing.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III) - Assessment Criteria; 4.0 Verification section; 4.3 addresses processing element verification; 3.3.1 addresses integration; 4.1.14.4, 4.2.2.2, and 4.5.7 specify a buildup approach in verification and testing

DoD JSSSEH: 2.5.5.2; 4.3; 4.4.1.1; 4.4.1.6; 4.4.2.2; 4.4.2.12; 4.4.2.13; 4.4.2.14; C.9.7; F.5.3

USAF Weapon Systems Software Management Guidebook: 3.1.3; 3.6; 3.8; 3.12.3.b.2; F.11.2; G.3.1; G.3.4; G.4 and subparagraphs; Appendix I

NASA-STD-8719.13B: 5.8 closed-loop tracking and resolution of discrepancies

NASA-GB-8719.13: Chapter 9 discrepancy reports

IEEE Std 1012-2012: 8.5 Activity table

IEEE 12207.2-1997 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 5.3.10 system integration CIs

IEEE Std 15288-2008: 6.4.5 integration process

CMU/SEI-2010-TR-033, CMMI for Development Ver. 1.3: Product Integration section

ARINC Specification 653

15.2.4 Critical discrepancies.

Criterion: Verify that safety critical hardware and software discrepancies identified are safely corrected or mitigated.

Standard: The system development process identifies and applies a discrepancy reporting process for software/hardware/system/laboratory/air vehicle/control segment/support segment problems, which documents/corrects/mitigates all safety critical faults at all testing levels. Typical areas to include: software (i.e., requirements, design, coding), hardware anomalies, test case inconsistencies, simulation anomalies, and lab/tool problems. A discrepancy review board is established which evaluates problem reports for safety effect, prioritization and urgency of correction required; and documents approved discrepancy mitigations and resolutions. If used for problem mitigation, operational safety restrictions (e.g., flight envelope, operating modes, fleet grounding) are documented in the flight clearance, flight manual or equivalent documentation.

Method of Compliance: Verification method includes inspection of discrepancy reporting processes, discrepancy documentation, and technical manuals (e.g., Technical Orders, Flight Manuals, Operator's Manuals, NATOPS). Ensure that safety critical discrepancies are documented, appropriate restrictions are imposed when necessary, and details of the corrective/mitigation action are reviewed.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III.5.i.5 and III.5.j); 3.3.8 provides guidance under lessons learned for tracking and mitigating software discrepancies

JSSG-2008 Appendix B: A14.5.9.5; A14.5.10

MIL-STD-882: Task 304 of MIL-STD-882E

DoD JSSSEH: 4.2.2; E.13.1

USAF Weapon Systems Software Management Guidebook: F.9.2; G.6

RTCA DO-178: For RTCA DO-178C: 2.2.2.d; 7.1.c; 7.2.3; 8.3.d; 11.14; 11.17; 11.20.k (see also RTCA DO-178B)

FAA AC 20-115C

15.2.5 Simulations, models and tools.

Criterion: Verify that simulators, models, and tools used in the development, integration, and testing of software and hardware supporting SCFs have been appropriately qualified and validated.

Standard: All simulators, models, and tools used for design, development, integration, and test have been identified and a qualification and validation approach has been defined. Each simulator, model, and tool is identified as off-the-shelf (commercial or government), modified, or developed for the application, and has been adequately qualified (for Navy, accredited) and validated for its intended use to the appropriate qualification level. Verification tools do not mask safety issues within products they are used to verify.

Method of Compliance: Verification methods include analysis, test, and inspection. Verify that the qualification/validation (for Navy, accreditation) approach is defined and documented. Inspect tool documentation to ensure all simulators, models, and tools have been identified, highlighting how they are used and if they are off-the-shelf, modified, or newly developed. Analyses and tests verify the effectiveness (accuracy and fidelity) of the output performance for all simulators, models, and tools. Analyses and tests ensure verification tools do not mask product problems.

References: JSSG-2008 Appendix A: 4.0 Verification Guidance, Verification section item 4 - Analysis of requirements paragraph and the Laboratory Tests section item 3.b.2; 3.1.5 Requirement Guidance; 4.1.5.1 Verification Lessons Learned; 4.2.2.2.6 Verification Lessons Learned; 4.2.2.5 Verification Lessons Learned; 4.3.4 Verification Lessons Learned; 3.3.6.3; 4.7.1 Verification Lessons Learned

JSSG-2008 Appendix B: 4.3.6; A3.1.7; A14.5.5

DoD JSSSEH: 3.11; 3.12.3; F.3.3.k; G.1; G.4.4; G.4.7; Appendix I

DA PAM 5-11: VV&A of Army Models and Simulations

NASA-STD-7009: 4.0 and various subparagraphs

RTCA DO-178: 12.2 of RTCA DO-178C (see also RTCA DO-178B)

RTCA DO-254: 11.4

FAA AC 20-115C

FAA AC 20-152

DOT/FAA/AR-07/48: 5.0

15.2.6 Safety interlocks.

Criterion: Verify that interlocks provide safe engagement and disengagement of air system modes for flight and ground operations.

Standard: All SPA safety interlocks have been identified and defined. The specifics of how each safety interlock is used by each SSE is documented. The safety interlocks include those required for engagement, switching, and disengagement, of single or multiple modes (including ground or flight conditions). Safety interlocks safely control (enable/prevent) mode engagement based on ground or flight parameters and to prevent engagement of incompatible modes.

Method of Compliance: Verification methods include analysis, test, demonstration, and inspection. Inspection of design documentation ensures that safety interlocks have been identified and defined. Verify that safety interlocks prevent the engagement or disengagement of system modes that are incompatible or could create a hazard or undesirable situation. Verification includes end-to-end testing of the interlock design through the use of laboratory testing/demonstration, ground and flight testing.

References: JSSG-2008 Appendix A: 3.0 Vehicle Control and Management System/Flight Control Systems section (II.2.h, III.2.j, IV.2.f, IX.8, and IX.9); 3.0 Computer Resources section (5.d.6); 3.1.7.3 addresses system operation and interfacing; 3.1.11.2 mode compatibility; 3.1.13.1 pre-flight interlocks; 3.1.13.3 post-flight interlocks; 3.1.14.7 interlocks to prevent flight crew error

JSSG-2008 Appendix B: A3.2.2.2.8; A3.2.3.2.10; A3.2.4.2.6; A3.2.9.8; A14.5.4.6

DoD JSSSEH: 4.3.7.2.1 safety interlocks; 4.3.7.3.1 using process flow analysis to verify interlocks; 4.4.2.8 fault insertion testing of interlocks; 4.4.2.10; 4.4.4; D.6.6; E.3.5; E.3.18; E.4.4; F.1.1-F.1.3

USAF Weapon Systems Software Management Guidebook: G.4.3

FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: A.5

15.2.7 Single event upset (SEU) susceptibility.

Criterion: Verify that the SPA is designed to ensure that SEUs do not cause unsafe conditions.

Standard: Areas of the envelope susceptible to SEU effects are identified. SPAs/SSEs supporting SCFs that have SEU susceptibility are identified. Detection, correction, and prevention techniques are employed to mitigate hazards and the loss of SCFs.

Method of Compliance: Verification methods include analysis and test. Analysis ensures acceptable level of coverage protection across the design. Testing ensures BIT mechanisms can detect SEU data corruption and the system can employ mitigating corrections. Testing verifies the effectiveness of shielding techniques.

References: JSSG-2008 Appendix A: 3.1, 4.1 no single failure; 3.1.7.3 addresses failure propagation; 3.1.9 maintain control after single failure; 3.1.11.1 requirement prohibiting single or dissimilar combination failure; 3.1.13.2 in flight fault detection; 3.1.14.1 invulnerability to natural environments; 3.1.14.3 invulnerability to induced environments; 3.1.17 memory protection for computations supporting critical functions; 3.3.2 processing hardware; 3.3.5 growth and reserves

NASA-NPR-7150.2 Rev A: 2.2.12.f and i (also see note on item f)

RTCA DO-178: For RTCA DO-178C: 4.5 Note 2; 11.1 (see also RTCA DO-178B)

RTCA DO-254: 2.3.1; 2.3.3; 3.1; 3.3.2.1

FAA AC 20-115C

FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: A.1.4

DOT/FAA/AR-07/48: 6.16.2

15.2.8 Security techniques.

Criterion: Verify that security techniques used are implemented safely.

Standard: Security requirements have been applied to the processing architecture to protect SCFs. For identified security vulnerabilities, ensure that security techniques incorporated into the design have been implemented such that they do not have a compromising effect on SCFs. For Army and Navy, the SPA contains features to prevent unauthorized control of or access to the system (e.g., change or add data, limits, or information) that could result in loss of the air vehicle or other component/s of the air system.

Method of Compliance: Verification methods include analysis, test, and inspection. Verify that security processes have identified potential security vulnerabilities. Verify that vulnerability mitigation techniques have been implemented, analyzed, and tested to ensure that SCFs are not compromised.

References: JSSG-2008 Appendix A: 3.1.14.5 directly addresses unauthorized modification and tampering with components; 3.1.14.6 invulnerability to software error; 3.1.16 security; 3.3.1 processing architecture; 3.3.7 establishes requirement for tracing security requirements

AFPAM 63-1701: provides guidance for implementation of Systems Security Engineering

IEEE 12207.0-1996 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 6.4.2.4.d; 6.4.2.5.d design/code implements security and this is verified by rigorous methods

15.3 Processing hardware/electronics.

15.3.1 Safety supporting hardware element (SSHE) performance.

Criterion: Verify that all safety supporting hardware elements (SSHEs) are safe.

Standard: SPA SSHEs are identified. SSHE performance meets SPA processing requirements. SSHEs are of mature/proven technology with safety critical application heritage. SSHEs are designed to detect failures. These SSHEs may include but are not limited to the following: circuit cards, internal and external buses, signals/discretes, interfacing subsystems, feedback loops, cockpit/control station input/output (I/O), and Cross Channel Data Links, processors, FPGA, ASICs, backplanes, data storage devices, connectors, and power supplies. SSHEs are designed with reliable components and meet system reliability requirements.

Method of Compliance: Verification methods include analysis, test, and inspection. Inspection verifies that the SSHEs of the SPA are identified/defined. Hazard analysis ensures hazards are traced to applicable SSHEs. Verify through analysis and/or test that SPA SSHEs and applicable components have the following performed as appropriate:

a. Acceptable level of burn-in time completed without failure.
b. Supplier acceptance testing (e.g., parts screening, sample lot acceptance testing).
c. Failure Modes, Effects and Criticality Analysis (FMECA) performed.
d. Electronic components supporting safety critical applications are tested to safety critical standards.
e. FMET on hardware supporting SCFs.
f. Qualification testing required for expected flight envelopes.

Inspection and analysis ensure that all testing conducted at vendor and prime developer facilities adequately verifies hardware performance.

References: JSSG-2008 Appendix A: 3.3.1, 3.4.1, and 3.4.5 cover components and parts pedigree; 3.1.11.11.2 addresses integrity of signal transmission

MIL-HDBK-217: Reliability Predictions of Electronic Equipment

MIL-STD-882: (see also MIL-STD-882D)

DoD JSSSEH

RTCA DO-254

RTCA DO-255

SAE ARP4761-1996

FAA AC 20-152

FAA TSO-C153: Appendix 1 section 4.f design assurance of hardware elements

15.3.2 Separation of safety critical hardware components.

Criterion: Verify that all safety critical electronic components are physically and functionally separated from non-safety critical items. If not separated, verify that the non-safety critical items are developed and qualified to the same CSIL as the safety critical components/SSHEs with which they are integrated.

Standard: All SSHE components are designed, developed, integrated and tested to appropriate CSILs. Electronic hardware of SSHEs is physically separate from non-safety critical electronic components. Non-safety critical electronic components that are integrated with the electronic hardware of an SSHE are designed, developed, integrated and tested to the CSIL of the SSHE.

Method of Compliance: Verification methods include analysis, test, and inspection. Verify through inspection of hardware design documentation that safety critical electronic components of SSHEs and non-safety critical electronic components are identified/documented. Analysis, test, and inspection of design documentation verify that the SSHE components are physically and functionally separated from non-safety critical components. Verify through inspection of documentation identifying CSIL designations for hardware that non-safety critical electronic components, which are integrated with the electronic hardware of an SSHE, are designed, developed, integrated and tested to the CSIL of the SSHE. Analyses (e.g., FMECA) and tests (e.g., FMET) verify that non-safety critical components do not affect the safe operation of SCFs.

References: JSSG-2008 Appendix A: 3.3.1 lessons learned addresses systems partitioning; 3.1.7.3 addresses isolation of less critical elements to prevent their failure from affecting critical functions

RTCA DO-254: 2.3.1; 2.3.2; 3.1

FAA AC 20-152

15.3.3 Data bus redundancy.

Criterion: Verify that SSHEs have redundant buses that are physically separated.

Standard: Buses which carry safety critical data are identified as safety critical. These buses are redundant, implemented with proper redundancy management, bus control, and are physically separated (run through separate connectors, wiring harnesses, etc.).

Method of Compliance: Verification methods include analysis, test, and inspection of design documentation. Verification of safety critical buses and physical separation is through analysis and/or inspection of SPA drawings and other documentation. Analysis and/or inspection identifies the safety critical bus controller(s). Testing verifies the redundancy management and bus control functionality.

References: JSSG-2008 Appendix A: 3.3.1, 3.4.1, and 3.4.5 cover components and parts pedigree; 3.1.11.11.2 addresses integrity of signal transmission

MIL-STD-882: B.2.2.5.a (see also MIL-STD-882D - A.4.3.3.d)

SAE AS94900: 3.4.5.1; 3.4.5.2

15.3.4 Environmental qualification.

Criterion: Verify that all hardware processing elements are capable of safely operating within planned operational environments.

Standard: All processing elements have been identified. The environmental requirements (e.g., Environmental Criteria Document) have been defined for natural and induced environmental conditions expected for air system locations/envelopes/operational environments. All processing hardware meets defined environmental requirements and component integrity standards (e.g., MIL-STD-1796 and MIL-STD-810). Refer to 4.1.5 Standard of this document for natural and induced environmental qualification requirement details.

Method of Compliance: Verification methods include analysis and test. Verify that environmental life requirements are met by hardware processing elements through test and analysis. All processing elements are qualified to defined environmental requirements, and those requirements reflect current environments expected.

References: JSSG-2005 Appendix A: A.3.2.3 product integrity of avionic units

JSSG-2008 Appendix A: 3.0 Vehicle Control and Management System/Flight Control Systems section (III.2.n); 4.0 Laboratory Tests section (3.a and Component Tests subsection); 4.1 Analysis and Test sections; 3.1.6 Reliability; 3.1.7.2 System Arrangement; 3.1.14.1 invulnerability to natural environments; 3.1.14.2 and various subparagraphs address electromagnetic effects; 3.1.14.3 invulnerability to induced environments; 3.1.15 design operational usage; 3.2.3.3 packaging and mounting; 3.3.2 processing hardware; 3.3.2.3 processing components; 3.4 Requirement Guidance item h component construction; 3.4.2 Durability

MIL-HDBK-217: Reliability Predictions of Electronic Equipment

MIL-STD-461: Electromagnetic Compatibility

MIL-HDBK-516: Section 4

MIL-STD-810: Environmental Engineering Considerations and Laboratory Tests

MIL-STD-1796: Avionics Integrity Program

RTCA DO-160

IEEE Std 1012-2012: 8.2 Activity 7.a.1

CMU/SEI-2010-TR-033, CMMI for Development Ver. 1.3: Validation section SP 2.1 (pg. 398) product should perform as expected in operational environment

FAA AC 23.1309

FAA AC 25.1309

15.4 Software development processes.

15.4.1 Software processes.

Criterion: Verify that the software development process for Safety Supporting Software Elements (SSSEs) is fully documented (e.g., Software Development Plan (SDP), Software Safety Plan (SSP)), followed, and is sufficiently suitable to produce software supporting SCFs.

Standard: Identify all SSSEs via a documented SCF thread analysis and flow down of system safety requirements. SSSEs adhere to a rigorous development process which is suitable, comprehensive, well defined, documented and consistently applied. The processes and activities are applied to all software intended for use (e.g., new development, commercial-off-the-shelf/government-off-the-shelf (COTS/GOTS), reuse, legacy, firmware). The processes and associated life cycle activities are based on a development standard that represents a high integrity process for safety critical software. The development process is documented in an SDP (or set of SDPs) that addresses all activities required for the developing organizations. The activities are identified to support the SSSE requirements, design, code, integration, test and release of products. The SDP may reference other documents and data as part of identifying all processes and related activities (e.g., coding standards, system safety plan, risk management plan, configuration management plan, and quality assurance plan). Development processes for SSSEs and non-SSSEs may be addressed in the same SDP.

Method of Compliance: Verification method includes inspection of process and product documentation. Verify that the SSSEs are identified and documented. Verify that the SSSE development processes address the following areas and the defined processes are followed:

a. Functional analysis (e.g., SCF thread analysis).
b. SCF testing methodology.
c. Quality Assurance.
d. Configuration Management.
e. Coding standards.
f. System Safety.
g. Peer reviews.
h. Software test methodology (unit level, software integration, software requirements, etc.).
i. Regression test methodology.
j. Verification/qualification environment (e.g., system integration laboratory).
k. FMET.
l. Risk management.
m. Software Review Board composition.
n. Traceability.
o. Manpower.
p. Metrics.
q. Software discrepancy reports.
r. Change impact analysis.
s. SSSE architecture support of SPA.
t. Requirement definition and allocation.
u. Software engineering environment.
v. Software reuse.
w. Areas of auto code.

References: JSSG-2008 Appendix A: 3.1.14.6, 3.2.4.6, 3.3.6 and 3.3.7 including various subparagraphs of each provide guidance regarding software design and development for safety critical systems

DoD JSSSEH

USAF Weapon Systems Software Management Guidebook

RTCA DO-178: (see also DO-178B)

SAE 12207.1-1997: 6.17 software development process

IEEE Std 1228-1994 Software Safety Plans

FAA AC 20-115C

15.4.2 Traceability.

Criterion: Verify that each SSSE has sufficient bidirectional traceability established for requirements (performance and interface), design, source code, and test data.

Standard: Bidirectional traceability exists from the system level to the element requirement level. Sufficient SSSE bidirectional traceability also exists from the SSSE requirements to the detailed design, and to the source code and all levels of test. SCF bidirectional traceability exists both vertically (system level to the lowest software level) and horizontally (across the system/software). Requirements supporting SCFs are identified (e.g., tagged as safety critical). Bidirectional traceability of all software ensures that unwanted or unapproved code is not present (e.g., unused code, malicious code).

Method of Compliance: Verification methods include analysis and inspection of documentation. Verify that requirements have full bidirectional traceability from the system level to the software requirements. Verify that bidirectional traceability also exists for the software design and source code. Full SCF bidirectional traceability (both vertically and horizontally) from the system level to the software design level is verified through inspection of traceability data. Verify through bidirectional traceability that requirements and functions are coupled to all levels of testing. Verify that requirements supporting SCFs are tagged. Verify that no unwanted code exists.

References: JSSG-2008 Appendix A: 3.0 Vehicle Control and Management System/Flight Control Systems section (I.6); 3.0 Computer Resources section (III.5.i.1); 3.1.14.6; 3.2.4.6; 3.3.6 and various subparagraphs; 3.3.7 and various subparagraphs

MIL-STD-882: For MIL-STD-882E: Task 106.2.m; B.2.2.5.b

DoD JSSSEH: 4.2.1.5; 4.2.1.6.2; 4.2.1.7; 4.2.1.8.2; 4.3.4.2; 4.3.5.3; 4.3.6.3.3; C.6.3; C.6.5; C.6.7; C.6.8; C.8.4

USAF Weapon Systems Software Management Guidebook: 3.6; 3.6.1.l.3; 3.8; 3.11.c; G.2.4

NASA NPR 7150.2 Rev A: 3.1.1.4 bidirectional traceability between software requirement and higher-level requirement; 3.3.6; 3.4.8

NASA STD 8719.13: 5.7

RTCA DO-178: For RTCA DO-178C: 3.3; 4.4.2; 5.2.2; 5.5; 6.3.1; 6.3.2; 6.3.4; 6.4.4.1; 6.4.4.2; 6.5; 8.3; 11.21 (see also RTCA DO-178B)

IEEE Std 1012-2012: 9.4 Activity 3 software traceability analysis

IEEE 12207.0-1996 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): G.4.n

CMU/SEI-2010-TR-033, CMMI for Development Ver. 1.3: Requirements Management section SP1.4 (pg. 345) maintain bidirectional traceability of requirements

FAA AC 20-115C

15.4.3 Configuration management.

Criterion: Verify that the configuration/change control management process is fully documented, followed, and is sufficiently suitable to control software supporting SCFs.

Standard: Configuration management/change control processes are defined and documented for all hardware, software, and firmware. HWCIs (Hardware Configuration Items) and CSCIs (Computer Software Configuration Items) are defined and the associated criticality to supported

SCFs is identified. The configuration/change control management process ensures that the physical and functional characteristics of a HWCI/CSCI are identified, documented, and verified. The Configuration Management (CM) process identifies means to record the specific configurations of HWCI/CSCI and establishes baselines for each CI (Configuration Item). Processes are defined/documented to control changes to a HWCI/CSCI baseline and its associated documentation throughout the life cycle of all HWCIs/CSCIs under CM control.

Method of Compliance: Verification method includes inspection of process documentation, product configuration data, and quality assurance reports. Verify that the configuration management/change control process maintains the integrity of hardware and software configurations. Verify that all configurations are properly documented.

References: JSSG-2008 Appendix A: 3.0 Vehicle Control and Management System/Flight Control Systems section (I.6, III.5.i.1); 3.0 Computer Resources section (I.7, II.2, II.5.m, III.2, III.5.a & m); 3.1.11.8 Requirement Guidance; 3.3.7 Requirement Guidance item h; 3.1.14.6

JSSG-2008 Appendix B: 4.3.11; 4.4.5; A8.3.1

MIL-STD-882: For MIL-STD-882E: 4.3.8; Task 101.2.3

DoD JSSSEH: 2.5.3.2.5; 2.5.4; 4.3.7.3.2.6; C.1.6.1.2; C.6.6; C.11.3; D.6.9; E.2.1; E.3.4; E.12.4; E.12.5

USAF Weapon Systems Software Management Guidebook: 3.11; Appendix A

MIL-HDBK-61

RTCA DO178: For RTCA DO-178C: 7.0 and subparagraphs; 11.4; 11.18; 12.1.5 (see also RTCA DO-178B)

IEEE Std 828-2005

IEEE Std 1012-2012: 7.5 Activity

IEEE Std 1074-1997: A.1.2.2 plan CM; A.5.2 software CM activities also references IEEE-Std-828

IEEE 12207.0-1996 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 6.2 CM process

CMU/SEI-2010-TR-033, CMMI for Development Ver. 1.3: Configuration Management (pg. 137)

SAE EIA-649

FAA AC 20-115C

NASA STD 0005: 4.3.15 hardware and software change control

15.5 Software architecture and design.

15.5.1 Software architecture.

Criterion: Verify that the software architecture and design are defined, properly implement the system/software requirements, and are safe.

Standard: Computer system software architecture is defined. System level requirements are allocated to the subsystem and software requirements. All software and associated safety requirements are defined and allocated to software components. Software architecture is consistent with the software functional requirements; especially functions that ensure system integrity (e.g., partition schemes). The software architecture and design mechanizations implement proven techniques and are safe. The software architecture is compatible with the target hardware architecture.

Method of Compliance: Verification methods include analysis, test, and inspection of documents. Inspection of software architecture design documentation ensures that the software architecture is defined. Analysis and test of the software architecture and design mechanization ensures software/system requirements are properly allocated, are met, and provide a safe implementation for the applications supported. Analysis ensures software design supports overall software architecture and does not conflict with system integrity requirements.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (II.5.d); 3.1.5.1 gives guidance on data latency issues; 3.3.4 addresses synchronization, deterministic execution, and frame rate issues

DoD JSSSEH: 4.3.3; 4.3.6.3.2; 4.3.7.1

USAF Weapon Systems Software Management Guidebook: F.4; Appendix I

RTCA DO-178: For RTCA DO-178C: 5.0 and various subparagraphs; 6.0 and various subparagraphs including 6.3.3 Reviews and Analyses of Software Architecture; 11.7; 11.10 (see also DO-178B)

IEEE 12207.0-1996 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 5.3.5 software architectural design

IEEE 12207.1-1997 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 6.12 software architecture description

ARINC Specification 653

FAA AC 20-115C

15.5.2 Software control structure and execution rates.

Criterion: Verify for each SSSE that the execution rates provided by the executive/control structure (considering priority assignments and interrupt design) are consistently obtainable and sufficient to safely provide the required performance for all SCFs supported.

Standard: SSSE flow and execution is deterministic and all processes meet their deadlines under all conditions. Frame rates are compatible with real time system performance requirements and support execution rate requirements. SPA mechanization including priority task assignments, interrupt structure and overall processing control structure is sufficient for safety critical requirements/function processing. The executive structure or operating system is designed, developed, integrated and tested to its corresponding CSIL.

Method of Compliance: Verification methods include analysis, test, and inspection. Analysis verifies execution rates directly correlate to required frame rates and allowable data latencies. Inspection of documentation verifies that the executive structure or operating system was developed as safety/flight critical. Software development lab tests verify that executive control structure meets required execution rates under fully loaded, worst case timing conditions.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III.5.d.1 & 2, III.5.i.6); 3.3.1 establishes timing and control allocations based on operational requirements; 3.3.4 addresses synchronization, deterministic execution, and frame rate issues; 3.3.6.1 Requirement Guidance provides restrictions on coding for executive control functionality

DoD JSSSEH: 4.3.7.3.2.3; 4.3.7.3.2.5; D.6.4; D.6.8; E.4.6; E.5.1.1; E.5.3; E.9.5; E.10.2; E.10.4

USAF Weapon Systems Software Management Guidebook: G.3.1

RTCA DO-178: (see also RTCA DO-178B)

IEEE Std 1012-2012: 9.1 Activity table V&V Task (2) hardware and software allocation analysis (timing, response time, frequency, etc.)

IEEE 12207.2-1997 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 6.4.2.5.b

FAA AC 20-115C

15.5.3 Software architecture attributes and performance.

Criterion: Verify that the software architecture and design, including the initialization, synchronization, timing, data flow, control flow, interrupt structure, and data structures for all SSSEs are safe and sufficient to support the required processing performance for all SCFs supported.

Standard: The software architecture and design, software functional control flow mechanization and data structures are suitable and compatible with the system/subsystem SCF processing without unacceptable latencies. Source code matches the data and control flow defined in software architecture. Real-time architectures are designed to meet processing requirements. All tasks and interrupts are defined and prioritized. Tasks and interrupt mechanizations are appropriately implemented. Software/data initialization and synchronization requirements are defined and meet specified performance.

Method of Compliance: Verification methods include analysis, test, and inspection. Inspection ensures source code matches the data and control flow defined for the software architecture. Analysis and test verify processing performance requirements for SCFs are supported by the software architecture. Items analyzed include processor/data initialization, synchronization of data and channels, overall flow of the software architecture/design implementation, data dependencies, task prioritization and interrupt structure.

References: JSSG-2008 Appendix A: 3.0 Vehicle Control and Management System/Flight Control Systems section (IX.7); 3.0 Computer Resources section (III.5.d.2 and 5); 3.1.11 Integration Management; 3.1.12.1 Requirement Guidance address synchronization of cross channel data links; 3.1.7 gives overall architecture design guidance along with specific data latency discussions in Lessons Learned subparagraph l; 3.1.5.1 gives guidance on data latency issues; 4.1.17 Lessons Learned regarding asynchronous operation; 3.2.4.6 Software Safety; 3.3.4 addresses synchronization, deterministic execution and frame rate issues

DoD JSSSEH: 4.3.3; 4.3.6.3.2; 4.3.7.1; 4.3.7.3.2.1; 4.3.7.3.2.3; 4.3.7.3.2.5; D.6.4; D.6.8; E.4.6; E.5.1.1; E.9.5; E.10.2; E.10.4

USAF Weapon Systems Software Management Guidebook: G.3.1, F.4, Appendix I

NASA NPR 7150.2 Rev A: 2.2.12.a

NASA-GB-8719.13: 4.6 initialize all unused memory; initialize software into a known safe state; 7.4.1 document initialization and synchronization; 11.4.3 support for synchronization

RTCA DO-178: For RTCA DO-178C: 5.2.2; 6.3.3.b and c; 6.3.4; 6.4.2.2; 6.4.3.a and b; 11.7; 11.10 (see also RTCA DO-178B)

IEEE Std 1012-2012: 9.2 Activity 1.a.4 validate flow of data satisfies functionality and performance requirements

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DOT/FAA/AR-07/48: 6.4.2; 6.10

DOT/FAA/AR-99/58: 3.2 synchronization of bus clock

15.5.4 Dynamic operation.

Criterion: Verify that the following are designed to safely operate under all dynamic conditions anticipated: mode inputs, operational flight modes, failure monitoring and detection techniques, failure management functions, redundancy management, voting schemes, self-checks, built-in-tests, safety interlock mechanizations, SCF interfaces, health status interfaces, reconfiguration capabilities, and switchover of command and control data links.

Standard: The SSSE designs account for all dynamic conditions anticipated for the system. Ensure the transient effects of mode switching and condition changes are acceptable and do not introduce unacceptable hazards. Switchover of command and control data links does not result in loss of control. Flight test features and software hooks for laboratory testing cannot be activated in any unintended flight mode. Design techniques employed in the software, hardware, and computer system architecture mechanization of the system do not introduce unacceptable hazards. Typical areas to address are the techniques for detecting, monitoring, isolating, and accommodating failures; the entire redundancy management/fault tolerance scheme (from the lowest level through the system level); the techniques for assessing self-health; the techniques employed for determining other channels and external dependent subsystem/system health status; the voting scheme mechanization; the flow of all mode unique inputs through the system; and the safe implementation of internal/functional/subsystem/system interfaces throughout all dynamic conditions/modes/envelopes expected. NOTE: “SCF interfaces” refers to SSSE interfaces supporting SCFs.

Method of Compliance: Verification methods include analysis, test, and inspection of test plans. Verification testing includes extensive system/subsystem integration tests, and FMET at various levels. Analyses and tests ensure the system is safe under all expected dynamic conditions and modes throughout the design envelope. Verify through inspection that test plans cover the testing of all dynamic conditions expected.

References: JSSG-2008 Appendix A: 3.0 Vehicle Control and Management System/Flight Control Systems section (III.2.j, IX.9); 3.0 Computer Resources section (III.5.d.3); 3.1.4 addresses survivability; 3.1.5.2 addresses mode transitions; 3.1.5.7 addresses sensitivity analysis; 3.1.7.2 discusses overall system arrangement issues affecting invulnerability and failure immunity; 3.1.12 addresses redundancy management; 3.3.1 lessons learned provides guidance regarding fault management and systems partitioning; 3.3.2 provides guidance regarding failure propagation and redundancy

JSSG-2008 Appendix B: A14.5.4.3

DoD JSSSEH: 4.3.7.2.1; 4.3.7.3.2.4; 4.4.1.3; 4.4.2.8; E.3.17; E.3.18; E.4.4; E.7.8; E.9.1.1; E.13.2

USAF Weapon Systems Software Management Guidebook: 3.8; G.2.2; G.2.3; G.2.5; G.2.6.e; G.3.1; G.4.1; G.4.3

NASA-GB-8719.13: 7.4.2 fault-tolerant design; 11.8.3.1 mode identification and reconfiguration

FAA CAST-24: 2.2

SAE ARP1834: 3.3.5.2 fault response; 5.4.c

SAE ARP4761: D.11.1.3.3 latent failure management

SAE AS94900: 3.1.3.3.e-f; 3.3.2-3.3.5

DOT/FAA/AR-07/48: 3.7.3; 4.3 health monitoring and fault management; A-9 health monitoring and recovery

15.5.5 Failure management and redundancy management.

Criterion: Verify the safe operation of Built-In-Test (BIT), redundancy management, and failure management algorithms.

Standard: For each subsystem's first failure instance, BIT is designed to detect, and the subsystem isolates and accommodates, 100% of the safety critical failures. For subsystems supporting safety critical functions that have been determined to require three (3) or more channels of redundancy, the subsystem is designed to detect and accommodate 95% of second like safety critical failures. The BIT redundancy management/failure management functionality meets specified safety requirements (e.g., PLOC). The BIT implementation is compatible with the levels of redundancy, redundancy management mechanizations, and failure management mechanizations employed. The system design addresses acceptable transient levels, prevention of propagation of failures, and re-admittance of failed elements.

Method of Compliance: Verification methods include analysis, test, demonstration, and inspection. Testing includes system integration testing with actual flight hardware, FMET, ground test, and flight test. A combination of analysis, demonstration, flight test, and inspection verifies meeting detection, isolation, and accommodation requirements such that, given a failure, the system will continue to perform its SCFs. System/subsystem integration testing and FMET ensure that the design accommodates transient levels, prevention of propagation of failures, and re-admittance of failed elements.

References: JSSG-2008 Appendix A: 3.0 Vehicle Control and Management System/Flight Control Systems section (IX.8 and IX.9); 3.0 Computer Resources section (III.5.d.6 and III.5.i.4); 4.1 Lessons Learned address certain BIT issues; 3.1.4 addresses survivability; 3.1.7.2 discusses overall system arrangement issues affecting invulnerability and failure immunity; 3.1.11.11.2 BIT testing of data connections; 3.1.12 addresses redundancy management; 3.1.13 (Requirement Guidance a.2) defines types of BIT and a list of typical items tested; 3.3.1 lessons learned provides guidance regarding fault management and systems partitioning; 3.3.2 provides guidance regarding failure propagation and redundancy; 3.3.6.2 establishes guidance for CSCI failure detection and execution of BIT

JSSG-2008 Appendix B: A14.5.4.3

DoD JSSSEH: 4.3.7.2.1; 4.3.7.3.2.4; 4.4.1.3; 4.4.2.8; E.3.17; E.3.18; E.4.4; E.7.8; E.9.1.1; E.13.2

USAF Weapon Systems Software Management Guidebook: 3.8; G.2.2; G.2.3; G.2.5; G.2.6.e; G.3.1; G.4.1; G.4.3

NASA-STD-8739.8: 7.3.1

15.5.6 Digital system failures.

Criterion: Verify that the SSSEs are adequately designed to detect and accommodate digital system failures.

Standard: The computer system architectural design, through techniques employed in the software and associated hardware, is fault tolerant. Typical digital system areas to address are initialization, reconfiguration, processor halt detection, transient suppression, overflow protection, anti-aliasing, saturation protection, memory protection and utilization, self-check, and protection techniques against failure propagation to preclude safety hazards. Protection techniques to consider include but are not limited to processor error detection and recovery, watchdog monitor implementation, and frame over-run protection.

Method of Compliance: Verification methods include analysis, test, and inspection of design documentation. Complete software testing is accomplished from the unit level to the system level. Digital hardware FMEA and FMET verify that the system's design is able to detect and accommodate digital system failures. Verify that the design mitigates, to acceptable levels, hazards due to digital hardware failures. Verify, through analysis and test, that data and real time processing integrity are maintained.

References: JSSG-2008 Appendix A: 3.0 Vehicle Control and Management System/Flight Control Systems section (IX.8); 3.0 Computer Resources section (III.5.d.6); 3.1.11.9, 3.1.12.1 gives detailed guidance for redundancy management; 3.1.13, 3.1.17, and 3.3.2.1 provide guidance for integrity and BIT checks often implemented in software; 3.3.6.2 provides guidance for robust integrated CSCI design

DoD JSSSEH: 3.6.1.3; 4.3.4.2; 4.3.7.3.2.6; 4.4.1.1; 4.4.1.3; 4.4.2.9; D.6.8; E.1.3.2; E.3.15; E.4.5; E.4.6; E.5.1; E.5.1.1; E.6; E.6.1; E.6.2; E.7; E.8.2; E.11.11; E.13.5

USAF Weapon Systems Software Management Guidebook: 3.8; G.2.5; G.2.6; G.3.3; G.4.1

RTCA DO-178: For RTCA DO-178C: 2.4.3; 5.2.2; 6.3.4; 6.4.2.2; 6.4.3 (see also RTCA DO-178)

SAE ARP1834: fault/failure analysis for digital systems

NASA-NPR 7150.2 Rev A: 2.2.12.e-h

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15.5.7 Restart and reset capabilities.

Criterion: Verify that SSSE designs have the necessary provisions to restart and/or reset the system safely while in flight.

Standard: The system SSSEs are designed in conjunction with the digital hardware to reset/restart the computer system safely without inducing unacceptable effects (e.g., transients). Aspects of the design include channel/data resynchronization, the systems interrupt structure, the system reinitialization, re-check of system health, and reconfiguration to safe states. The design of flight critical functions accommodates transient time limits dependent on the air system's inherent stability/safety margins, envelope, and flight maneuvers before unrecoverable departure.

Method of Compliance: Verification methods include analysis and test. Testing is accomplished at all levels (from software to integrated system) and includes FMET. Analysis coupled with test verifies that the reinitialization and reconfiguration capability, channel/data resynchronization, and system's interrupt structure meet the system reset/restart safety requirements. System integration tests ensure all safety related state transitions meet required timelines, are stable, secure, and do not result in loss of safety critical data.

References: JSSG-2008 Appendix A: 3.0 Vehicle Control and Management System/Flight Control Systems section (IX.7); 3.0 Computer Resources section (III.5.d.5); 3.1.12.1 discusses redundancy management support for restart; 4.1.13.2 provides lessons learned in verification of in-flight monitoring capability; 3.1.17 provides guidance regarding failure propagation of computational failures; 3.2.4.6 addresses software support for failure recovery; 3.3.2.2 discusses microprocessor timing and synchronization; 3.3.4 details issues surrounding synchronization rates

DoD JSSSEH: F.5.3; F.3.1

NASA-NPR 7150.2 Rev A: 2.2.12.a

DOT/FAA/AR-07/48: 4.3 restart LRU without affecting other applications

15.5.8 Unsafe techniques.

Criterion: Verify that SSSEs do not utilize or include unsafe techniques or attributes (e.g., patches, de-activated code, lab test functionality).

Standard: Program process documents identify the prohibition of unsafe techniques. Code does not implement unsafe techniques. Unsafe techniques/attributes include the patching of object code, the existence of de-activated or flight test unique software, dead code, training system software hooks, lab unique functionality, the reuse of software with unknown or questionable pedigree, undocumented functions, dynamic memory allocation, unverifiable source code statements and structures, alteration of source code to achieve verification, and any other unsafe techniques identified through established policy by the respective armed services.

Method of Compliance: Verification methods include analysis, test, demonstration, and inspection of process and design documentation. Verify, by analysis and inspection of processes and code, that unsafe techniques are not employed. Perform testing and demonstration on the software product to ensure that employed techniques and attributes do not adversely affect SCFs.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III.1.d); 3.1.8 addresses integration of unique functions; 3.3.7 contains guidance on software change control; 3.3.8 prohibits patches in certified software

DoD JSSSEH: 4.3.6.3.2; 4.3.7.3.2.6; D.6.6; E.1.4.2; E.2.4; E.4.6; E.11.1.1; E.11.11; E.11.12; E.12.1

USAF Weapon Systems Software Management Guidebook: 2.1.1; G.3.1

NASA-GB-8719.13: H.5 check for dead code

RTCA DO-178: For RTCA DO-178C: 4.2.h; 5.2.4; 5.4.2; 6.4.4.3.c and d; 11.7; 11.10.k (see also RTCA DO-178B)

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FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: A.10.4

15.5.9 Resource capacity.

Criterion: Verify that there is sufficient capacity and design margin for all processors, data channels (I/O, buses, etc.), and data storage devices.

Standard: The system is designed to accommodate the software implementation with enough capacity (throughput, memory, bus, and I/O capacity) to complete all critical software tasks. Each processing component is designed with enough capacity that any limits (e.g., in major and minor frames) are not reached (for Air Force, exceeded) under peak/worst-case, full loading. Systems analysis develops throughput, memory, bus, and I/O utilization allocations. For Air Force, the throughput capacity of each processing core (e.g., a single core of a multi-core processor) and bus loading capacity does not exceed 90% utilization under peak/worst-case, fully loaded conditions. For Army, processing rates and margins do not reach the peak/worst-case, full loading rates and margins contractually specified for the life cycle phase. For Army, at no time during the life cycle do the processing rates and margins degrade to an unacceptable level.

Method of Compliance: Verification methods include analysis and test. Throughput is measured as a series of benchmarks of the implemented system. Throughput allocations are verified in test under peak/worst-case, fully loaded conditions. Analysis and test verify that all processing and data channel rates are acceptable. Analysis verifies that load image size does not exceed available memory.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III.5.c.3 and III.5.f); 3.1.14.6 contains guidance for worst case throughput and I/O spare; 4.1.18 Lessons Learned provides historical example of throughput issues; 3.3.5 contains guidance regarding reserve capacity; 3.5.7 establishes performance parameters for computing resource margin

DoD JSSSEH: 4.3.8; 4.4.2.5; E.13.11

USAF Weapon Systems Software Management Guidebook: 3.8.b; G.3.1; G.3.3

NASA-NPR 7150.2 Rev A: 5.3.1.e computer resource utilization

NASA-GB-8719.13: 6.6.6 timing, throughput and sizing analysis

RTCA DO-178: 6.3.2.c of RTCA DO-178C (see also RTCA DO-178B: 6.3.2.c)

RTCA DO-255: 2.6.1; 2.6.2; 2.6.3; 2.6.4; 2.6.5

IEEE Std 1012-2012: 9.2 Activity 1.c.1.iv

IEEE 12207.2-1997 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 5.3.2 guidance for computer hardware resource utilization

SAE EIA-632-1999: Table C.16.d

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FAA Guide to Reusable Launch and Reentry Vehicle Software and Computing System Safety: A.1.2

DOT/FAA/AR-07/48: 6.7 throughput limits conveyed; 7.1 worst-case execution times

15.5.10 Safety Supporting Software Elements (SSSE) performance.

Criterion: Verify that all SSSEs provide acceptable performance and safety.

Standard: All performance and safety requirements are identified, documented, and traceable to software specifications. Software requirements and interfaces are accurate, consistent, unambiguous, stated in quantifiable terms with tolerances, sufficiently detailed, and verifiable. Ensure that the implementation satisfies the performance and safety requirements. Performance deficiencies have been identified and fully documented. The design implementation has not introduced unacceptable hazards.

Method of Compliance: Verification methods include analysis, test, and inspection of requirements. Analysis and inspection are performed to determine proper flow down of system and safety requirements to the software specification. Hazard analysis is performed to ensure no new or unacceptable risks have been introduced by the design. Analyze discrepancy reports to determine failure trending and disposition. All performance and safety requirements are tested/verified.

References: JSSG-2008 Appendix A: 3.1.14.6, 3.2.4.6, 3.3.6 and subparagraphs, and 3.3.7 and subparagraphs provide guidance regarding software design and development for safety critical systems

MIL-STD-882: (see also MIL-STD-882D)

DoD JSSSEH

USAF Weapon Systems Software Management Guidebook

RTCA DO-178: (see also RTCA DO-178B)

IEEE Std 1228-1994: Annex - Discussion of Software Safety Analyses

IEEE 12207 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): provides industry best practice software development guidance

SAE EIA 632-1999: Requirement 16.c

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15.6 Software qualification and installation.

15.6.1 Software test methodology.

Criterion: Verify that each SSSE is tested and integrated in a multi-level approach from the software component level to the integrated system level and that there is adequate test coverage at each level of testing.

Standard: The system is integrated and verified using an established, documented and proven process which includes thorough testing of SCFs with complete test coverage at all levels. Levels include:

a. Unit testing.
b. Component testing.
c. CSCI testing on target hardware.
d. CSCI integration testing.
e. Subsystems testing.
f. Systems integration testing, including operator-in-the-loop testing.
g. SCF Thread Testing.
h. Iron bird testing.
i. Flying test bed testing.
j. Air vehicle level testing.
k. Ground testing.
l. Flight testing.

Types of testing include:

a. Requirements coverage.
b. Failure condition testing (out-of-bounds, off-nominal and robustness).
c. Regression testing (required at all levels for software modification/revisions).

Every flight release build has all the safety critical functionality necessary to ensure safe flight.

Method of Compliance: Verification methods include analysis and inspection of documentation. Inspection of planning and test documentation ensures adequacy of the verification approach for all levels of testing. Verify design dependencies of the SPA are identified in planning documentation and are coupled to the overall test coverage strategy. Verify that build plans show a reasonable build-up approach. Inspection ensures test documents reflect all levels and types of testing executed for each level of the architecture. Verify all functionality is in place to support SCFs and safe flight. Test coverage analysis verifies that no gaps exist in the test coverage. Test coverage analysis is performed on all levels of testing of the system and its SCFs.

References: JSSG-2008 Appendix A: 3.0 Vehicle Control and Management System/Flight Control Systems section (IX); 3.0 Computer Resources section (III.5.i.2); 4.1.14.4, 4.2.2.2, and 4.5.7 buildup approach in verification and testing; 4.3 processing element verification; 3.3.1 integration

DoD JSSSEH: 4.4.2

USAF Weapon Systems Software Management Guidebook: Appendix C.o.(3); F.3.3; G.4.8

RTCA DO-178: (see also RTCA DO-178B)

IEEE 12207.0-1996 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 5.3.8 software integration; 6.4.2.6

SAE 12207.1-1997: 6.18

IEEE 12207.2-1997 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 5.3.8

SAE ARP4754: 4.6.3 electronic hardware/software integration

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15.6.2 Full qualification of software.

Criterion: Verify that all SSSEs released for flight have been fully qualified.

Standard: For each SSSE, identify the associated CSCI(s). Qualification is performed with the final configuration of each CSCI for flight release on its target hardware in the required test environment. All identified CSCIs are qualified with 100% of the software requirements having been tested/verified on the flight release configuration.

Method of Compliance: Verification methods include analysis, test, and inspection of process documentation. Inspection verifies that 100% requirements testing (or other approved verification method, if required) is planned for SSSEs. Verify that SSSEs have 100% of their requirements tested/verified for every CSCI version release for flight. Analysis and inspection verify that all failed requirements have been dispositioned to assure safe flight. Ensure formal qualification test reports are submitted for each CSCI.

References: JSSG-2008 Appendix A: 3.1.11.4 100% validation of I/O; 4.3 processing element verification; 4.3.6 Verification Rationale - software fulfills requirements; 6.3 Test Verification Review (TVR) and First Flight Readiness Review (FFRR)

DoD JSSSEH: 4.4; 4.4.1.1; 4.4.1.2; 4.4.1.3; 4.4.1.4; 4.4.1.6; 4.4.2

USAF Weapon Systems Software Management Guidebook: 3.8; G.4.3; G.4.8

RTCA DO-178: For RTCA DO-178C: 5.5.b.1; 6.1.b-e; 6.3.1; 6.3.2; 6.3.3; 6.4.a; 6.4.3; 6.4.4 (see also RTCA DO-178B)

IEEE 12207.0-1996 (s/s by ISO/IEC 12207:2008(E); IEEE Std 12007-2008): 5.3.9 software qualification testing

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15.6.3 Software build process.

Criterion: Verify that the software build process for SSSEs is safe.

Standard: A sound, repeatable process is defined and implemented for building the air system's software load images. The build process addresses equipment, security, time required (nominal versus emergency release), safety, and configuration management. The process ensures that the build product is not corrupted, is compatible (hardware and software), and is complete. The scope of the build process includes executables and data files. All air system loadable and non-loadable software elements are identified.

Method of Compliance: Verification methods include analysis, test, and inspection of build process documentation. The software load image build process is verified to ensure that the generated products are complete, compatible, and are not corrupt. Configuration and process documents are reviewed for completeness to ensure that all CSCI developers' products are included, and version descriptions/configuration data are identified (e.g., unique CSCI constraints, sizing information, load image link data, data files). Verify the correctness and completeness of the compatibility matrix through analysis and test. Ensure that the process for generating build products is reliably repeatable. Verify that the build process addresses all air system loadable and manufacturer/depot loaded software and data files.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (III.5.l); 4.3 discusses verification of integrated processing capabilities; 3.2.2.2 discusses subsystem integration; 3.3.1 provides guidance for integrated architecture design; 3.3.6 addresses breaking down complex software into manageable CSCIs; 3.3.8 addresses software certification of hardware compatibility

DoD JSSSEH: 4.3.6.3.2; 4.4; 4.4.1.6

USAF Weapon Systems Software Management Guidebook: 3.6.2; G.3.2; G.3.5.e and f

RTCA DO-178: For RTCA DO-178C: 5.4; 5.4.2.a; 7.2.7; 7.5; 11.4.b.9; 11.16 (see also RTCA DO-178B)

IEEE Std 828-2005: 3.3.7

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15.6.4 Software load compatibility.

Criterion: Verify that adequate configuration management controls are in place to ensure proper and functionally compatible software loading for the intended use on the air system.

Standard: Multiple versions and configurations of hardware and software in support of varying missions (e.g., service related) are carefully controlled. A matrix is established to identify compatibility for software and hardware configurations. A means for checking the correct software configuration (executables and data files) for loading is provided. CM controls preclude loading an incorrect software version onto the air system.

Method of Compliance: Verification method includes inspection of configuration management process documents. Verify that configuration management controls are in place to prevent incorrect version selection and loading of incompatible or incorrect configurations.

References: JSSG-2008 Appendix A: 3.1.16 provides guidance regarding OFP version control and integrity; 3.3.7 addresses software change control; 3.3.8 addresses software certification of hardware compatibility

DoD JSSSEH: 4.3.6.3.2; 4.4.3; D.6.9; E.2.1; E.2.5.1; E.3.4; E.12.5

USAF Weapon Systems Software Management Guidebook: 3.11; G.3.5.h; Appendix I.g.(11)

RTCA DO-178: For RTCA DO-178C: 7.0.b; 7.1.a, f-i; 7.2; 7.2.1; 7.2.2; 7.2.7.d; 7.5; 8.3.f and i; 11.4.b.7-9; 11.16; 11.22 (see also RTCA DO-178B)

SAE 12207.1-1997: 6.24 provide instructions for linking and loading data

SAE AS94900: 3.1.5.3.10

ARINC REPORT 667-1: 1.5.1; 1.5.6; 1.8.1.1

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DOT/FAA/AR-07/48 : 5.2 configuration management tools

15.6.5 Software load process.

Criterion: Verify that the software loading and load verification processes for all software are safe and correct.

Standard: A sound, repeatable process is used to load software and associated data files onto the air system, ensuring all software load images have been properly loaded onto the corresponding hardware. The process ensures the loaded software and data files are correct, have not been corrupted, have not compromised compatibility (hardware and software), and are completely loaded.

Method of Compliance: Verification methods include test and inspection. Verify through inspection that the software loading and load verification process is defined and implemented. Verify through test that the correct software load images and data files are consistently loaded by the software load process onto the air system. The correct loading of all manufacturer/depot loaded software (box loadable) is verified through inspection and test. Verify that systems utilized to load software have been configured to prevent unauthorized use.

References: JSSG-2008 Appendix A: 3.0 Computer Resources section (II.5.g); 3.3.2 and 3.3.2.3 provides guidance for single point OFP load and verification; 3.3.8 addresses software certification of hardware compatibility; 3.1.14.6 discusses system invulnerability to software errors

DoD JSSSEH: D.6.6; E.1.3.2; E.6.2, E.7.7; E.9.8; E.12.3

USAF Weapon Systems Software Management Guidebook: G.3.2; G.5.1

RTCA DO-178: For RTCA DO-178C: 2.5.1; 2.5.5; 5.4; 6.3.5; 7.1.h; 7.2.1.d; 7.2.7.d; 7.4; 8.3.g; 11.4.b.8; 11.10.g; 11.16 (see also RTCA DO-178B)

IEEE-Std-1012-2012: 9.8 Activity verify and validate software install

SAE AS94900: 3.1.5.3.10.e

ARINC REPORT 667-1: 1.9.3; 1.9.4

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16. MAINTENANCE

TYPICAL CERTIFICATION SOURCE DATA

1. Maintenance manuals/checklists (equivalent or supplement to –2 TOs).
2. Inspection requirements (equivalent or supplement to –6 TOs).
3. Life-limited/time replacement plan/list.
4. System Safety Hazard Analysis (SSHA).
5. Failure modes, effects, and criticality analysis (FMECA).
6. Maintenance records (including failure report and corrective action system (FRACAS)).
7. TO 00-5-1.
8. Test reports.
9. Test plans.
10. COMNAVAIRFORINST 4790.2 (Series).
11. OPNAVINST 4790.2J.

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

16.1 Maintenance manuals/checklists.

16.1.1 Servicing instructions.

Criterion: Verify that servicing instructions are provided for all systems that require servicing; e.g., fuel, engine oil, hydraulic systems, landing gear struts, tires, oxygen, escape system, etc.

Standard: All servicing information is provided for those subsystems that require servicing, including, as a minimum, fluid levels that require constant checking and servicing.

Method of Compliance: Servicing information is verified by showing traceability from support analysis. Servicing information has undergone a quality assurance check, and the check and the content of servicing information have been verified by the government.

References: JSSG-2000: 3.6.1, 3.6.2

JSSG-2001: 3.1.5

14 CFR 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563; Part 23, Appendix G; Part 25, Appendix H, Instructions for Continued Airworthiness

16.1.2 Cautions and warnings.

Criterion: Verify that cautions and warnings are included in maintenance manuals, aircrew checklists, and ground crew checklists.

Standard: Warning and Caution notes are used when alternative design approaches cannot eliminate a hazard per MIL-STD-882. All required Cautions and Warnings are prominently displayed in the pilot or operator’s checklist and the maintenance personnel's manuals and technical orders.

Method of Compliance: Operator and maintenance actions requiring Cautions and Warnings are verified by review of the Failure Modes Effects Criticality Analysis (FMECA) and from the System Safety Hazard Analysis. The proper wording and placement of Cautions and Warnings per MIL-STD-38784 and MIL-DTL-85025 is verified by a review of the checklists and maintenance manuals.

References: JSSG-2000: 3.6.1, 3.6.2

MIL-STD-882: A.4.3.3.i

MIL-STD-38784: 3.2, A.3.2, A.3.3, A.3.4, A.3.5.

MIL-DTL-85025

14 CFR 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

16.1.3 Maintenance checklists.

Criterion: Verify that maintenance checklists are available for critical maintenance tasks, such as fuel and oxygen servicing procedures, towing procedures and restrictions, jacking procedures, engine operation during maintenance, lifting procedures, integrated combat turn procedures, etc.

Standard: Maintenance checklists are developed in accordance with applicable service's procedures (e.g., 2.4.3, 2.4.3.1, 2.4.3.1.1, 2.4.3.2 of USAF TO 00-5-1, Air Force Technical Order System, COMNAVAIRFORINST 4790.2) for preparing maintenance publications.

Method of Compliance: The maintenance checklists developed are verified by showing traceability from the support analysis, and are verified by the Government.

References: JSSG-2000: 3.6.1, 3.6.2

JSSG-2001: 3.1.5

USAF TO 00-5-1, Air Force Technical Order System, 2.4.3, 2.4.3.1, 2.4.3.1.1, 2.4.3.2

COMNAVAIRFORINST 4790.2

14 CFR 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

16.1.4 Support equipment.

Criterion: Verify that support equipment does not adversely affect the safety of the air vehicle system.

Standard: The support equipment used to perform maintenance functions on the air vehicle system is safe to operate and cannot adversely affect the safety of the air vehicle system.

Method of Compliance: The safety of the support equipment is verified by review of the System Safety Hazard Analysis and through individual testing of the support equipment and compatibility testing with the air vehicle system.

References: JSSG-2000: 3.6.1, 3.6.2

JSSG-2001: 3.1.5

14 CFR 23.1501, 23.1529, 25.1501, 25.1503-25.1533, 25.1529, 25.1541, 25.1543, 25.1557, 25.1563

16.1.5 Removal procedures.

Criterion: Verify that maintenance manuals incorporate procedures for system/component removal.

Standard: For each level of maintenance, procedures for authorized system/subsystem/ component removal and installation are adequately covered in the appropriate maintenance manuals.

Method of Compliance: The removal and installation instructions have undergone a quality assurance check, and the check and the content of removal and installation instructions have been verified by the Government.

References: JSSG-2000: 3.6.1, 3.6.2
JSSG-2001: 3.1.5
14 CFR Part 23, Appendix G; Part 25, Appendix H

16.1.6 Operational testing.

Criterion: Verify that maintenance manuals require system operational testing for normal/emergency system operation when systems are affected by removal/replacement of components.

Standard: Operational tests are performed to ensure system performance when components are removed/replaced that are critical to the operation of the air vehicle system.

The maintenance manuals detail the operational tests required to ensure safe system performance following removal/replacement of air vehicle system components.

Method of Compliance: Verify by analysis, test, and demonstration that the maintenance manuals contain the operational test(s) required to ensure safe system performance following the removal/replacement of air vehicle system components. Testing instructions have undergone a quality assurance check, and the check and the content of operational testing instructions have been verified by the Government.

References: JSSG-2000: 3.6.1, 3.6.2
JSSG-2001: 3.1.5
14 CFR Part 23 Appendix G; Part 25, Appendix H

16.1.7 Troubleshooting procedures.

Criterion: Verify that maintenance manuals provide adequate troubleshooting procedures to correct expected system/component failures.

Standard: Maintenance manuals provide troubleshooting instructions and identify items (e.g., support equipment, supplies, tools) needed to correct expected system/component failures.

Method of Compliance: The maintenance manuals are verified to contain troubleshooting procedures for those systems/components that are expected to fail as part of the normal operation of the air vehicle system.

References: JSSG-2000: 3.6.1, 3.6.2
JSSG-2001: 3.1.5
14 CFR Part 23, Appendix G; Part 25, Appendix H

16.1.8 Non-destructive inspections.

Criterion: To ensure continued airworthiness, verify that in-service, non-destructive inspection techniques, inspection intervals, damage limits and detailed repair procedures have been developed and documented in the technical manuals.

Standard: Non-destructive inspection (NDI) techniques and repair procedures address damage that occurs during normal operations (e.g., erosion, delamination, corrosion, as well as battle damage). Inspection intervals are identified in accordance with 16.2.4. Damage limits are documented in maintenance and technical documentation. Repair procedures identify all materials, processes, tools, equipment, facilities, and training necessary to complete the repairs. Structural substantiation is provided demonstrating that completed repairs maintain structural integrity and return the system to a positive margin of safety for strength and fatigue life.

Method of Compliance: Verification methods include inspection and review of NDI documentation, repair procedures, and relevant structural substantiation. Documentation is reviewed to verify that damage limits, inspection intervals, and necessary materials, processes, tools, equipment, facilities, and training are identified. Structural substantiation is reviewed to verify that positive margins of safety for strength and fatigue life are maintained.

16.2 Inspection requirements.

16.2.1 Preflight checklists.

Criterion: Verify that ground crew work cards for preflight inspection are coordinated with the aircrew checklists.

Standard: Preflight checklists that are used by the ground crew and the aircrew or operator are consistent and well-coordinated with operators' manuals.

Method of Compliance: Preflight checklists are verified by analysis, test and demonstration for consistency of content and continuity between the air and ground crew documentation.

References: JSSG-2000: 3.6.1, 3.6.2
JSSG-2001: 3.1.5
MIL-DTL-85025
14 CFR 23.1501, 23.1529

16.2.2 Special inspection procedures.

Criterion: Verify that special inspection procedures are available for unusual or specified conditions (e.g., exceeding operating limits; severe vibration; engine stall; foreign object damage (FOD) to engine or structure; excessive loss of fluid; conditions requiring fluid sampling and analysis; severe braking action, hard landing, and running off runway; air vehicle subject to excessive G loads or maneuvers outside the specified flight envelope; lost tools; emergency procedures implemented; dropped objects or parts; sudden stoppage inspection in event of compressor stall).

Standard: Special inspection procedures have defined exceedance parameters (e.g., temperatures, speeds, G loads, vibration) and corresponding durations. Acceptable damage criteria are established which clearly delineate serviceability or repair requirements. Maintenance levels and personnel authorized to perform the required inspections are identified. Special inspection procedures provide troubleshooting instructions and identify items (e.g., support equipment, supplies, tools) needed to perform the inspections.

Method of Compliance: Verify by analysis, test, and demonstration that instructions are documented for special inspections. Special inspection procedures have undergone quality assurance checks, and the checks and the content of the special inspection procedures have been verified by the Government.

References: JSSG-2000: 3.6.1, 3.6.2
JSSG-2001: 3.1.5
MIL-PRF-5096: 3.2.2.3.1 gives guidance regarding special inspections after a specific occurrence
14 CFR 23.1501, 23.1529

16.2.3 Life-limited parts.

Criterion: Verify that life-limited parts and replacement intervals are identified using relevant operational data.

Standard: All known life-limited parts and their replacement intervals are identified in maintenance documentation. Replacements intervals are based on operational data whenever possible. Prior to fielding, replacement intervals are based on available analyses and test data.

Method of Compliance: The identification of life-limited parts is verified by the review of maintenance documentation. Replacement intervals are traceable to appropriate source data such as the FMECA, reliability and maintainability predictions, and reliability/fatigue testing results, and the life-limited parts are identified in the appropriate technical data.

References: JSSG-2000: 3.6.1, 3.6.2

JSSG-2001: 3.1.5

MIL-PRF-5096: 3.2.2.4 gives guidance regarding flying time related or time change items

14 CFR 23.1501, 23.1529

16.2.4 Inspections and intervals.

Criterion: Verify that all required inspection intervals are identified using relevant operational data.

Standard: All features of the air vehicle system requiring periodic inspection (to include NDI) are identified in maintenance documentation. Inspection intervals are based on operational data whenever possible. Prior to fielding, inspection intervals are based on available analyses and test data.

Method of Compliance: All required inspections and corresponding intervals are verified by the review of maintenance documentation. Inspection intervals are traceable to appropriate source data such as the FMECA, reliability and maintainability predictions, and reliability/fatigue testing results.

References: JSSG-2000: 3.6.1, 3.6.2

JSSG-2001: 3.1.5

MIL-PRF-5096: 3.2.1.1.1 gives guidance regarding frequency of maintenance items.

14 CFR 23.1501, 23.1529

17. ARMAMENTS AND STORES INTEGRATION

A store is any device intended for internal or external carriage, mounted on air vehicle suspension and release equipment, which may or may not be intended to be for in-flight separation from the air vehicle. Stores include missiles, rockets, bombs, nuclear weapons, mines, fuel and spray tanks (permanently attached and/or detachable), torpedoes, sonobuoys, dispensers, pods (refueling, thrust augmentation, gun, electronic countermeasures, etc.), targets, decoys, chaff and flares, and suspension equipment.

TYPICAL CERTIFICATION SOURCE DATA

1. User requirements and design requirements and validation results.
2. Design studies and analyses.
3. Design, installation, and operational characteristics.
4. Component and functional level safety of flight, qualification and certification tests.
5. Electromagnetic environmental effects.
6. Plume ingestion/propulsion compatibility tests and plume/gun gas impingement test.
7. Failure modes, effects, and criticality analysis/testing (FMECA/FMET).
8. Hazard analysis and classification including explosive atmosphere analysis/test.
9. Safety certification program.
10. Computational, theoretical and/or semi-empirical prediction methods.
11. Configuration: aerodynamic design and component location.
12. Wind tunnel test results and correction methods.
13. Mathematical representation of system dynamics.
14. Loads analysis, wind tunnel and flight test results.
15. Flutter, mechanical stability, aeroelastic, aeroservoelastic and modal analyses, wind tunnel and flight test results.
16. Performance analysis.
17. Environmental compatibility analysis and tests including gun fire vibration analysis/test.
18. Interface control documents.
19. Store separation models, wind tunnel and flight test results.
20. Flight manual.
21. Flight test plan and test results.
22. MIL-HDBK-1763, Aircraft/Stores Compatibility: Systems Engineering Data Requirements and Test Procedures.
23. MIL-HDBK-244, Guide to Aircraft/Stores Compatibility.
24. MIL-STD-1760, Aircraft/Store Electrical Interconnection System.
25. MIL-STD-8591, Airborne Stores, Suspension Equipment and Aircraft-Store Interface (Carriage Phase).
26. SEEK EAGLE engineering data.
27. ANSI Z136.1 (now owned by LIA), American National Standard for Safe Use of Lasers
28. Nuclear Certification Impact Statement (NCIS).
29. Aircraft monitor and control (AMAC) and surveillance tests.
30. Nuclear safety analysis report (NSAR).
31. Mechanical compatibility data.

32. Electrical compatibility data.
33. Certification requirements plan (CRP).
34. Operational flight program (OFP) source code.
35. Systems integration lab data/results.
36. Cooling analysis and ground/flight test results.
37. MIL-STD-1530, Aircraft Structural Integrity Program (ASIP)
38. ASC/EN Stores Integration practice.
39. Human factors to consider.
40. Crew egress paths to consider.
41. Aircraft weight and balance.
42. Environmental analysis and test results.
43. Store drawings including store mass properties (STAMP sheet).
44. Safety assessment report.
45. Airworthiness qualification plan (AQP) (Army unique).
46. Airworthiness qualification specification (AQS) (Army unique).

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

17.1 Gun/rocket integration and interface.

References: MIL-HDBK-244A: 5.1.10

MIL-HDBK-1763: 4.1.4.7, 4.1.4.10; Appendix A, Test 161 Gun Firing Test; Appendix A, Test 162 Rocket/Missile Firing Test; Appendix B, Test 272 Launch Test or Weapons Survey and Demonstrations; Appendix B, Test 273 Gun Firing Test

MIL-STD-331

ADS-44-HDBK

ADS-62-SP

ADS-65-HDBK

FAA: No applicable reference available for any of the criteria in this section.

17.1.1 Gun/rocket induced environments.

Criterion: Verify that environment induced by gun/rocket operation is compatible with the air vehicle's limitations for muzzle blast and overpressure, recoil, vibroacoustics, cooling, egress, human factors, and loads of the air vehicle.

Standard: Gun/rocket operation is compatible with the aircraft's prescribed limits for overpressure, Vibration/Acoustics, and ammunition feed/ejection. No catastrophic or negative effects with respect to safety of flight and/or the aircrew are caused by misfire handling and gun jams.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Verification is accomplished by initial installation testing, qualification testing, physical fit checks, static ground fire testing, Systems Integration Laboratory (SIL), safety analysis, safe separation test certification, Non-Nuclear Munitions

Safety Board (NNMSB) certification, Weapon System Explosive Safety Review Board (WSESRB) concurrence, and live fire testing during Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). Loading of aircraft is verified by Validation/Verification (Val/Ver) testing.

References: MIL-HDBK-244: 5.1.9.1; 5.1.9.2; 5.1.9.2.4; 5.1.10 inclusive

17.1.2 Gas and plume hazards.

Criterion: Verify that gun/rocket gases and plume do not create safety of flight hazards for the air vehicle, air and ground crew.

Standard: Gases or particulates from gun/rocket plume during operation do not cause engine flameout, stalling, and/or damage. Rounds do not fuze/detonate until they are at a safe distance from the air vehicle.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Verification is accomplished by initial installation testing, qualification testing, physical fit checks, static ground fire testing, Systems Integration Laboratory (SIL), safety analysis, safe separation test certification, Non-Nuclear Munitions Safety Board (NNMSB) certification, Weapon System Explosive Safety Review Board (WSESRB) concurrence, and live fire testing during Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). Loading of aircraft is verified by Validation/Verification (Val/Ver) testing.

17.1.2.1 Sensor hazards.

Criterion: Verify munitions gases and plume do not create an unsafe condition by obscuring primary sensor or weapons designation systems (e.g., laser, radar, etc.) when employing munitions.

Standard: Sensor, target acquisition and designation response to blast effects, debris, and weapons' rate of fire does not degrade sensor and weapons designation system performance to an unacceptable level.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Verification is accomplished by initial installation testing, qualification testing, physical fit checks, static ground fire testing, Systems Integration Laboratory (SIL), safety analysis, safe separation test certification, Non-Nuclear Munitions Safety Board (NNMSB) certification, Weapon System Explosive Safety Review Board (WSESRB) concurrence, and live fire testing during Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E).

References: MIL-HDBK-244
ADS-44-HDBK
ADS-62-SP
ADS-65-HDBK

17.1.3 Gas impingement.

Criterion: Verify that munitions gas impingement does not cause unacceptable erosion of air vehicle structure/skin or any other flight essential systems.

Standard: Gases from munitions operation do not ablate transparencies, erode fuselage surfaces, obscure/ablate faces of sensors or degrade any other flight essential systems (e.g., antenna, air data system etc.) beyond acceptable limits.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Verification is accomplished by initial installation testing, qualification testing, physical fit checks, static ground fire testing, safety analysis, safe separation test certification, Non-Nuclear Munitions Safety Board (NNMSB) certification, Weapon System Explosive Safety Review Board (WSESRB) concurrence, and live fire testing during Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E).

References: MIL-HDBK-244
ADS-44-HDBK
ADS-62-SP
ADS-65-HDBK

17.1.4 Explosive gas accumulations.

Criterion: Verify that the gun/rocket gas ventilation/purge system prevents accumulation of any explosive gas mixture.

Standard: Gases from gun/rocket operation do not accumulate beyond prescribed allowable toxic and/or explosive concentrations.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Verification is accomplished by initial installation testing, qualification testing, static ground fire testing, safety analysis, and live fire testing during Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E).

Reference: MIL-HDBK-244

17.2 Stores integration.

References: JSSG-2001: 3.3; 3.4.2.1.5; 3.4.2.2 for the testing methodology; 10.1.1
STANAG 3899
MIL-HDBK-244
MIL-STD-331
MIL-STD-464
MIL-STD-1289
MIL-STD-1760
MIL-HDBK-1760
MIL-HDBK-1763
MIL-STD-8591
ADS-44-HDBK
ADS-45-HDBK

17.2.1 Store clearance.

Criterion: Verify that the stores/air vehicle interface does not create unsafe conditions during ground and flight operations and that no unsafe environment is created for maintenance personnel.

Standard: Clearance between store and surroundings (such as Alternative Mission Equipment (AME), racks, and launchers) is sufficient to allow for stores loading, aircraft/munitions servicing, in flight vibration and deployment without contacting air vehicle, AME and other stores. Stores loading/unloading procedures are defined and documented.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Stores/air vehicle interface is verified by test in accordance with STANAG 3899, MIL-HDBK-1763, MIL-STD-1289 and MIL-STD-8591. Safe separation certification, Non-Nuclear Munitions Safety Board Certification, and Weapon System Explosive Safety Review Board (WSESRB) concurrence are achieved. Loading of aircraft is verified by Validation/Verification (Val/Ver) testing. Stores loading/unloading procedures are verified by demonstration using the stores loading manual.

References: MIL-STD-1289
MIL-HDBK-1763
MIL-STD-8591
STANAG 3899
ADS-44-HDBK
ADS-45-HDBK

17.2.2 Safe separation.

Criterion: Verify that the stores separate safely from the air vehicle throughout the air vehicle/store launch or jettison flight envelope.

Standard: Stores can be jettisoned throughout the vehicle/store employment flight envelope without inducing dangerous aerodynamic loads and moments, engine damage, propeller damage, store-aircraft collision, damage to any aircraft surface, or damage or interference to critical control functions.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Safe separation is verified by Computational Fluid Dynamics (CFD) models, wind-tunnel testing, safe separation flight testing, and requirements of MIL-STD-1289 and guidance specified in MIL-HDBK-244 and MIL-HDBK-1763. For USAF only, SEEK EAGLE certification is used.

References: MIL-STD-1289
MIL-HDBK-244
MIL-HDBK-1763

17.2.3 Store, suspension and release equipment structural integrity.

Criterion: Verify that the store or suspension and release equipment and air vehicle are structurally capable of operating safely in the air vehicle/store carriage flight envelope.

Standard: No additional clarification required (see also the Certification Standard under 5.1.6 of this document).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Store and suspension/release equipment structural integrity are verified by Finite Element Models (FEM), Computational Fluid Dynamics (CFD) models, wind-tunnel testing, captive carriage flight testing, ejection/jettison testing and requirements of MIL-STD-8591. For USAF only, SEEK EAGLE certification is used.

References: MIL-HDBK-1763: Test 131, Aircraft Stores Suspension Equipment Structural Integrity Ground Test
MIL-STD-8591

17.2.4 Electrical interfaces.

Criterion: For all required store configurations, verify that electrical interfaces do not cause unsafe stores operation or interactions with the air vehicle.

Standard: Aircraft electrical/logical interfaces are defined and prevent unintended release/launch/jettison and detonation of the stores.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Aircraft electrical/logical interfaces are verified by System Integration Laboratory test, EMI/EMC test, Hazards of Electromagnetic Radiation to Ordnance (HERO) test, flight test and requirements of MIL-HDBK-244.

References: MIL-HDBK-244
MIL-STD-1760
SAE AS5726 Interface for Micro-munitions

17.2.5 Store induced environments.

Criterion: Verify that the environment induced by the stores on the air vehicle, and by the air vehicle on the store during carriage and launch/separation/jettison for the cleared usage, does not adversely affect safety of flight of the air vehicle.

Standard: Store carriage, jettison or launch do not cause safety of flight problem by inducing dangerous aerodynamic loads and moments, engine damage, store-aircraft collision, damage to any aircraft surface, excessive load on aircraft ECS, damage to or interference with critical control functions.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Compatibility of air vehicle and stores environments is verified by Computational Fluid Dynamics (CFD) models, wind-tunnel testing, captive carriage flight testing, ejection/jettison testing, and requirements of MIL-HDBK-1763, MIL-STD-8591 and MIL-STD-1289. For USAF only, SEEK EAGLE certification is used.

References: MIL-STD-1289
MIL-HDBK-1763
MIL-STD-8591
ADS-44-HDBK

17.2.6 Safe store operations.

Criterion: Verify that the stores operations do not adversely affect any safety aspect of the flight control of the air vehicle.

Standard: Store carriage, jettison or launch do not cause safety of flight problems by inducing dangerous aerodynamic loads and moments, engine damage, store-aircraft collision, damage to any aircraft surface, excessive load on aircraft ECS, damage to or interference (e.g., physical or EMI/EMC) with critical control functions.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Verification is accomplished by physical fit and function, loading/installation procedures, aeroelastic ground vibration test, wind tunnel tests, effects of aircraft on captive stores/suspension equipment, effects of stores/suspension equipment on aircraft, environmental vibration tests, aeroacoustic test, HERO test, EMI/EMC, ballistic tables, temperature extremes and thermal test, SIL, and DT&E/OT&E. For USAF, SEEK EAGLE Certification will also be used.

References: MIL-HDBK-244
MIL-STD-1289

MIL-HDBK-1763

17.2.7 Store configurations.

Criterion: Verify that all stores configurations for the air vehicle are documented in the flight manuals.

Standard: The flight manual includes all stores configurations, safe available ripple selections, safe release envelopes and flight limits, proper loading procedures, appropriate store checklists, correct employment data for operational employment planning.

Method of Compliance: Verification methods include test, demonstration, inspection and review of documentation. Verification is accomplished by safe separation certification, NNMSB certification, WSESRB concurrence, Val/Ver of technical publications (e.g., flight manuals, maintenance manuals) accomplished by maintainers to ensure proper loading/unloading procedures, and ground test during DT&E/OT&E to verify all store configurations.

17.2.8 Malfunctioning stores.

Criterion: Verify that malfunctioning stores can be turned off or released if required to protect the air vehicle.

Standard: The air vehicle system has the capability to command/control/power down malfunctioning stores.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Verification is accomplished to include SIL/avionics tests and DT&E/OT&E to ensure the stores management system controls and conditions the stores properly and jettisons malfunctioning stores if necessary.

References: MIL-HDBK-244

MIL-STD-1760 for the electrical/logical interface

17.2.9 Lost link.

Criterion: Verify that a lost-link condition during a weapons engagement is considered and hazards are minimized and/or mitigated.

Standard: In the event of unexpected loss or corruption of command and control link the weapon system transitions to a predetermined state and mode (see the Certification Standard under 4.1.6).

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Verification is accomplished by analysis (e.g., fault tree analysis, system safety analysis), SIL/avionics tests, and ground and flight demonstrations and tests.

References: ADS-44-HDBK

17.3 Laser integration.

17.3.1 Crew exposure.

Criterion: Verify that the crew and maintenance personnel are not exposed to laser radiation (direct and reflected) in excess of maximum permissible exposure limits in order to ensure safe conditions.

Standard: The laser system and support equipment are designed to the lowest hazard classification and minimize the accessibility of the crew and maintenance personnel to hazardous emissions. Laser training procedures are defined for aircrew and maintenance personnel. Laser operational procedures are defined by the operator's manual.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Minimum crew and maintenance personnel exposure to laser radiation is verified by analyses (e.g., laser safety analysis), laser characteristics tests, laser control system (e.g., power on, weight on wheels) inspection/demonstration, accessibility checks, wire verification, ground test equipment checks, loading procedures checks, identification of safety equipment and inspection of training procedures.

References: MIL-STD-1425, for the safety design requirements of laser systems

MIL-HDBK-828

AR 11-9

AFOSH STD 48-139

ANSI Z136.1 (now owned by LIA), for the safety design requirements of laser systems

21 CFR Part 1040, Performance Standards for Light-emitting products

17.3.2 Induced environment.

Criterion: Verify that the induced environment resulting from laser operation is compatible with the air vehicle's limitations for vibroacoustics, thermal loads, and structural loads of the air vehicle.

Standard: Compatibility of laser operation is designed to meet vibration, acoustics, thermal and structure loads of the air vehicle.

Method of Compliance: Verification methods include analysis, test, demonstration, and review of documentation. Laser operation compatibility is verified by analyses (e.g., structural, stress, mechanical load, electrical load, acoustical), explosive environment test and ground and flight demonstrations/tests.

References: MIL-STD-1425, for the safety design requirements of laser systems

MIL-HDBK-828

AR 11-9

AFOSH STD 48-139m

ANSI Z136.1 (now owned by LIA), Safe Use of Lasers, for the safety design requirements of laser systems.

21 CFR Part 1040, Performance Standards for Light-emitting products.

17.3.3 Chemical exhaust.

Criterion: Verify that laser chemical and exhaust gases do not create safety of flight hazards for the air vehicle.

Standard: Exhaust gases or chemicals produced by laser operation do not exceed the concentrations defined as safe minimum values in any part of the aircraft or attached structures/pods.

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, inspection and review of documentation. Exhaust gas and chemical concentrations acceptability are verified by analyses/tests (e.g., concentration, thermal, flight, ground).

References: MIL-STD-1425, for the safety design requirements of laser systems

MIL-HDBK-828

AR 11-9

AFOSH STD 48-139

ANSI Z136.1 (now owned by LIA), for the safety design requirements of laser systems

21 CFR Part 1040, Performance Standards for Light-emitting products

17.3.4 Operation and direction.

Criterion: Verify that a means is provided for the crew and maintenance personnel to determine when the laser is operating and discern the direction of the beam.

Standard: The laser is boresighted to the prescribed alignment limit, the sighting display accurately points the laser to within prescribed limits (milliradians or microradians) and the aircraft and/or control station display clearly indicates when and where the laser is firing.

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, and review of documentation. Laser boresighted alignment, pointing accuracy and display are verified by installation tests, SIL testing, and ground and flight demonstrations/tests.

References: MIL-STD-1425, for the safety design requirements of laser systems

MIL-HDBK-828

AR 11-9

AFOSH STD 48-139

ANSI Z136.1 (now owned by LIA), for the safety design requirements of laser systems.

21 CFR Part 1040, Performance Standards for Light-emitting products.

17.3.5 Latching.

Criterion: Verify that laser operation and direction is controllable only by the crew and maintenance personnel and does not latch on (radiating).

Standard: The crew or operator maintains full control of the firing and pointing of the laser at all times. The laser does not fire unless activated by crew or operator and will immediately cease firing at command from crew, operator, or by system design.

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, and review of documentation. Verification is accomplished by initial installation tests, SIL testing, ground and flight test, and laser operating procedures.

References: MIL-STD-1425, for the safety design requirements of laser systems

MIL-HDBK-828

AR 11-9

AFOSH STD 48-139

ANSI Z136.1 (now owned by LIA1), for the safety design requirements of laser systems.

21 CFR Part 1040, Performance Standards for Light-emitting products.

17.3.6 Airframe contact.

Criterion: Verify that the laser beam cannot unintentionally contact any part of the airframe, rotor system, or payload/stores.

Standard: The laser software and/or hardware inhibitor (laser masking) control the laser field of regard so that the beam will not strike any part of the aircraft or any peripherals (i.e., stores, sensors etc.). Laser energy is not reflected back into the eyes of the pilot, operator, crew, or personnel.

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, and review of documentation. Verification is accomplished by initial installation tests, SIL testing, ground and flight test, and laser operating procedures.

References: MIL-STD-1425
ADS-62-SP
ADS-65-HDBK

17.3.7 Ground lasing.

Criterion: Verify that the laser cannot inadvertently lase when the aircraft is on the ground.

Standard: The laser is controlled during ground operations to preclude inadvertent laser firing. Methods for preventing inadvertent laser firing include, but are not limited to, procedures for ground crew, redundant hardware (e.g., interlocks, interlock switches/weight on wheels), and software (e.g., armament, sensor).

Method of Compliance: Verification methods include analysis, test, simulation, demonstration, and review of documentation. Verification is accomplished by initial installation tests, SIL testing, ground and flight test, and laser maintenance and operating procedures.

References: MIL-STD-1425
ADS-62-SP
ADS-65-HDBK

17.4 Safety interlocks.

Criterion: Verify that appropriate safety lockout and interlocks are in place to assure that unsafe armament and/or store operation does not take place.

Standard: Verify safety interlocks will prevent unplanned/inadvertent firing/initiation of armament and/or stores.

Method of Compliance: Verification methods include analysis, test, demonstration, simulation, inspection and review of documentation. Verification is accomplished by initial installation testing, qualification testing, physical fit checks, static ground fire testing, Systems Integration Laboratory (SIL), safety analysis, safe separation test certification, Non-Nuclear Munitions Safety Board (NNMSB) certification, Weapon System Explosive Safety Review Board (WSESRB) concurrence, and live fire testing during Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). Loading of aircraft is verified by Validation/Verification (Val/Ver) testing.

References: MIL-HDBK-244
ADS-62-SP
ADS-65-HDBK

18. PASSENGER SAFETY

The passenger safety section addresses technical requirements in the area of passenger carrying air vehicles as they pertain to safety. This area covers seat belts, stowage compartments, ditching, emergency exits, emergency evacuation, seating arrangements, emergency lighting, signs, fire extinguishers, smoke detection, lavatories, fire protection, and physiological requirements. Safety requirements for crew stations normally used for aircrew and mission essential personnel are located in section 9, Crew Systems.

TYPICAL CERTIFICATION SOURCE DATA

1. Federal Aviation Regulations
2. FAA Airworthiness Directives and Advisory Circulars
3. Joint Service Specification Guide
4. Cabin/crew station layout/geometry
5. Crash survivability requirements and validation
6. Escape system requirements and validation
7. Life support system requirements and validation
8. Tech data package

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

18.1 Survivability of passengers.

18.1.1 Passenger seating and restraint systems.

Criterion: Verify that seats with restraints are provided for each passenger that do not cause serious injury in an emergency landing. Verify each seat/restraint system is designed to protect each occupant during an emergency landing provided the restraints are used properly.

Standard* (Air Force)*: The seating and restraint system including structural attachment to the aircraft has been designed to a hold in place an occupant for design static and or dynamic loading. The loading directions and magnitudes are specific to airframe type and orientation of the seat, and meets requirements of SAE AS8049 with a 250 lb occupant.

There are enough seat and restraint systems for all passengers. Restraints apply body loads in a distributed fashion and location that do not cause major injury, (such as internal organ damage or skeletal fractures), and allow occupants to emergency egress after landing.

Method of Compliance* (Air Force)*: Analysis, test, inspection documentation shows that the seating restraint system meets crash load requirements and that there are seat and restraint systems for all passengers. Static and dynamic loads are verified by tests defined in SAE AS8049, with maximum weight occupants (250 lbs if not otherwise specified).

References: JSSG-2010-7: 3.7.3.2.2
SAE AS8049
14 CFR 25.785, 23.2, 23.562, 23.785, 25.562

18.1.2. Restraint system release point.

Criterion: Verify that each restraint system has a single-point release for passenger evacuation.

Standard* (Air Force)*: All passenger restraint systems have a single point release for the restraint system of each occupant.

Method of Compliance* (Air Force)*: Inspection and demonstration documentation exists to show that each passenger seat and restraint system has a single point release system for the restraint system.

References: JSSG-2010-7: 3.7.3.2.2
14 CFR 25.785, 23.2, 23.562, 23.785

18.1.3 Stowage compartment structure.

Criterion: Verify that, if stowage compartments are present, they are designed to contain the maximum weight of its contents and the critical load conditions in an emergency landing. The contents should not become a hazard to passengers due to shifting, such as under emergency landing conditions.

Standard* (Air Force)*: Stowage compartments are designed to restrain the specified cargo weight to a minimum of 9 G fwd, 1.5 G aft, 1.5 G laterally, 2 G up , and 4.5 G down or to other levels of restraint as may be determined from results of trade studies and analyses.

Method of Compliance* (Air Force)*: Fixed or removable equipment located in a manner wherein failure could result in injury to personnel or prevent egress is secured to levels of restraint commensurate with aircraft crash load factors. Structural test and analysis verify the capability to withstand maximum content weights. Testing and analysis with simulated landing and in-flight load conditions verify that contents do not cause injury or other passenger hazards.

References: MIL-A-8865B
At the time of publication of this document, no information was available in the current JSSGs
14 CFR 25.561, 25.787, 25.789, 23.787

18.1.4 External doors.

Criterion: Verify that each passenger carrying area has at least one external door that is operable from the inside and outside, is located to avoid hazardous external areas, and is inspected to ensure it is locked in flight.

Standard* (Air Force)*: Each compartment that will have a passenger restraint and seating system installed has an egress exit with a hatch or door that can be operated by an occupant from the inside, or by ground rescue personnel from the outside of the fuselage. The door or hatch is located away from hazardous areas of the aircraft (such as in close proximity to propellers, or jet engine inlets/outlets), and are not located in areas likely to be blocked after an emergency gear up landing. Inspection procedures and/or detection systems exist to ensure doors are fully locked in flight.

Method of Compliance* (Air Force)*: Inspection of engineering drawings and the air vehicle configuration verify that each passenger compartment with a seat and restraint system has an external exit with a door that can be opened internally and externally, and that there is clear indication of a locked or unlocked condition. Analysis and demonstration verify the ability to operate doors internally and externally. Inspection of vehicle configuration and documentation verifies that exit locations are away from hazardous areas around the aircraft. Documentation exists to show training and information for passengers to safely egress the aircraft.

References: JSSG-2010-7: 3.7.5.3.1
14 CFR 25.783

18.1.5 Exit locking mechanisms.

Criterion: Verify that exits are lockable, simple to open, and do not open in flight unless mission requirements necessitate this function.

Standard* (Air Force)*: All exits are lockable by aircrew trained to do so. All exits are uncomplicated to open such that no training is required for operation. All exits will stay locked and closed in passenger compartments when the aircraft is inflight unless mission needs allow the opening and use of exits inflight.

Method of Compliance* (Air Force)*: Analysis, demonstration and inspection documentation verifies that all exits in passenger areas are lockable by aircrew, simple to open without training, and will stay locked in flight when not opened for mission need. Human factors analysis and demonstration verify the expected passenger population's abilities to operate exits.

References: JSSG-2010-7: 3.7.5.3.1
14 CFR 25.813, 25.809, 23.807, 25.813

18.1.6 Provisions for passenger evacuation.

Criterion: Verify that each non-over-wing exit higher than 6 feet off the ground has a means to assist passengers to the ground. Provisions should exist for evacuees to be assisted to the ground from the wing when the exit opens to the wing.

Standard* (Air Force)*: For each exit that is not over the wing and is more than 6 feet above the ground when the aircraft is on level ground with landing gear down, a means for rapid and safe decent to the ground is provided for passengers that requires no training to use with assistance from aircrew. For exits opening to wing areas, provisions are incorporated to safely assist passengers from the wing surface to ground level.

Method of Compliance* (Air Force)*: Analysis, inspection and demonstration documentation verify which exits are more than 6 feet above the ground, that non-over-wing exits of that set have a means for passenger descent, and that these descent devices can be used without passenger training but with the assistance of aircrew members. Emergency egress demonstrations using non-trained personnel, representative of the expected passenger population verify the ability to safely exit and descend to the ground.

References: JSSG-2010-7: 3.7.5.3.2
JSSG-2010-13: 3.13.5
14 CFR 25.810, 121.31a

18.1.7 Exit weight and actuation.

Criterion: Verify that the weight of each passenger exit, if removable, and its means of opening, is conspicuously marked.

Standard* (Air Force)*: The means of opening and weight of each removable passenger exit hatch or door is clearly marked on the hatch or door.

Method of Compliance* (Air Force)*: Inspection and engineering drawing documentation verify that each hatch door is clearly marked with its means of opening and weight.

References: JSSG-2010-13: 3.13.5
14 CFR 25.811

18.1.8 Emergency lighting system.

Criterion: Verify that an emergency lighting system, independent of the main lighting system, provides sufficient illumination and guidance for passenger and crew emergency evacuation, including illumination of each exit and its exterior surrounding. Verify that energy to supply lighting allows complete egress of all passengers and crew before diminishing.

Standard* (Air Force)*: The lighting system provides adequate illumination for normal ingress and emergency egress for all occupants within the cockpit/crewstation. Illumination is sufficient for exterior visibility and tasks to be accomplished by external aircrews. Adequate lighting for aircrew and passenger safety is provided for the passageways and exits. The energy required for emergency lighting is sufficient to allow for the egress of all passengers and aircrew.

Method of Compliance* (Air Force)*: Illumination is verified by direct measurement. Lighting mockup, system integration laboratory, emergency egress demonstrations and aircraft evaluations in night time lighting conditions demonstrate the adequacy of the lighting system, both internal and external to the cockpit/crewstations as well as the duration of the emergency lighting.

References: JSSG-2010-13: 3.13.5
MIL-PRF-85676
14 CFR 25.812, 23.812, 25.1351, 25.1353, 25.1355, 25.1357, 25.1363

18.1.9 Emergency exit signs.

Criterion: Verify that emergency exit signs are installed and that each seated passenger is able to recognize at least one emergency exit sign.

Standard* (Air Force)*: Emergency exit lighting signs are provided that are powered integrally and operate independently of the main lighting system so that the lighting will be available when aircraft power is not. Exit location indications are also apparent when not lighted under normal flight conditions. There are a sufficient number of signs and they are located so that all passengers can locate an emergency exit based upon the viewing of one of the signs during adverse conditions that may occur during a crash such as the presence of smoke and water.

Method of Compliance* (Air Force)*: Verification is by inspection of engineering drawings and emergency egress demonstrations. Test and analysis of lighting systems verify functionality for all approved operating configurations and conditions. 14 CFR 25.812 applies to aircraft requiring FAA certification.

References: JSSG-2010-13: 3.13.5
14 CFR 25.812, 23.812, 25.811

18.1.10 Public address system power.

Criterion: Verify that a public address system is installed that is powerable when the air vehicle is in flight or stopped on the ground, including after the shutdown or failure of all engines and auxiliary power units.

Standard* (Air Force)*: A public address system is powerable when the aircraft is in flight or stopped on the ground, after the shutdown or failure of all engines and auxiliary power units, or the disconnection or failure of all power sources dependent on their continued operation, for:

a. A time duration of at least ten minutes, including an aggregate time duration of at least five minutes of announcements made by flight and cabin crewmembers, considering all other loads which may remain powered by the same source when all other power sources are inoperative; and

b. An additional time duration in its standby state appropriate or required for any other loads that are powered by the same source and that are essential to safety of flight or required during emergency conditions.

Method of Compliance* (Air Force)*: Test and analysis of public address systems verify that they work as required for all approved operating configurations and conditions.

References: At the time of publication of this document, no information was available in the current JSSGs
14 CFR 25.1423

18.1.11 Public address system accessibility.

Criterion: Verify that the public address system is accessible for immediate use by all aircrew, is capable of functioning independently of any required crewmember interphone system, and is intelligible at all passenger seats, aircrew seats, and workstations.

Standard* (Air Force)*: The public address system is accessible for immediate use from each of two flight crewmember stations in the pilot compartment. The system is capable of operation within three seconds from the time a microphone is removed from its stowage, and is intelligible at all passenger seats, lavatories, and flight attendant seats and work stations. The system is designed so that no unused, unstowed microphone will render the system inoperative. The system is capable of functioning independently of any required crewmember interphone system and is readily accessible to the crewmember designated to make announcements.

Method of Compliance* (Air Force)*: Test and analysis of the public address system verifies operation and functional requirements for all approved operating configurations and conditions.

References: JSSG-2010-13: 3.13.5
14 CFR 25.1423

18.1.12 Marking of safety equipment controls.

Criterion: Verify that each safety equipment control to be operated in an emergency, such as controls for automatic life raft releases, is plainly marked to show its method of operation.

Standard* (Air Force)*: Each safety equipment control to be operated by the crew in emergency, such as controls for automatic life raft releases, is plainly marked as to its method of operation. Each life raft has obviously marked operating instructions. Approved survival equipment is marked for identification and method of operation. Illustrations and pictoral representations are used to convey operation of critical safety controls where passenger language abilities vary or are unknown. Emergency controls have alternate stripes of 0.75-in. wide orange-yellow, color 13538 (see FED-STD-595), and 0.25-in. wide black, color 37038 (see FED-STD-595).

Method of Compliance* (Air Force)*: Safety equipment control markings are verified by inspection and functional demonstration. Human factors analysis verifies the ability of control makings to be clearly discerned.

References: JSSG-2010-11: 3.11.7.3
FED-STD-595
14 CFR 25.1561, 23.1561, 23.1415

18.1.13 Marking of safety equipment storage.

Criterion: Verify that each location, such as a locker or compartment, that carries fire extinguishing, signaling, or other life-saving equipment is marked accordingly. Verify that stowage provisions for required emergency equipment are conspicuously marked to identify the contents and facilitate easy removal of the equipment.

Standard* (Air Force)*: Each location, such as a locker or compartment, that carries any fire extinguishing, signaling, or other life-saving equipment is marked accordingly. Stowage provisions for required emergency equipment are conspicuously marked to identify the contents and facilitate easy removal of the equipment.

Method of Compliance* (Air Force)*: Markings indicating stowage locations of life saving equipment are verified by vehicle and engineering drawing inspection. The ability to discern markings for passenger identification and removal is verified by human factors analysis and demonstration.

References: JSSG-2010-11: 3.11.7.3
14 CFR 25.1561, 23.1561, 23.1415

18.1.14 Flotation devices.

Criterion: Verify that readily accessible individual flotation devices are provided for each occupant if the air vehicle flies missions over water.

Standard* (Air Force)*: For aircraft with over water missions, there is at least one approved floatation device for each occupant. Each passenger has ready access to a floatation device such as a removable seat floatation cushion or under seat life preserver stowage location. Stowage provisions are conspicuously marked to identify the contents and facilitate easy removal of the equipment.

Method of Compliance* (Air Force)*: Availability and stowage provisions of approved floatation devices is verified by inspection of the vehicle interior configuration and engineering drawings. Demonstrations verify the ability of passengers to access floatation devices. Emergency egress demonstrations verify the ability of each passenger to access a floatation device during emergency evacuation. Functionality of floatation devices and the ability to deploy, inflate or provide buoyancy is verified by floatation testing with human subjects.

References: 14 CFR 25.1411, 25.1415

18.1.15 Emergency equipment.

Criterion: Verify that the air vehicle is outfitted with equipment to deal with in-flight, ground, and ditching emergencies.

Standard* (Air Force)*: The aircraft is equipped with emergency equipment to deal with in-flight, ground, and ditching emergencies, tailored for the intended mission of the aircraft. This equipment may include emergency and floatation equipment, hand-held fire extinguishers, crash ax, megaphones, medical kits and supplies, automatic external defibrillators, portable oxygen supply systems, means for emergency evacuation, specialized tools or fracturing equipment, survival aids and equipment, weapons, communication equipment, signaling and locator devices, and portable lights.

Method of Compliance* (Air Force)*: Emergency equipment provisions are verified by vehicle configuration, engineering drawing, and mission equipment list inspections. Functional capabilities of equipment are verified by test for their intended purpose. Testing and verification should be accomplished from the standpoint of the overall system performance and installation.

It may consist of inspections, analyses, demonstrations, and tests of normal and emergency operations for all intended air vehicle occupants.

References: JSSG-2010-11

14 CFR 121.309, 121.310

18.2 Fire resistance.

18.2.1 Ignition source isolation.

Criterion: Verify that sources of ignition are located and/or designed to prevent contact with cargo.

Standard* (Air Force)*: The cargo compartment design and location is suitable for transport of flammable cargo under all operational conditions. Ignition sources are protected or cargo is prevented from contact with any compartment structure containing potential ignition sources. Cargo transport manuals incorporate any size restrictions necessary to preclude possible contact with an ignition source. The cargo compartment is free of any heat, flame, or electrical discharge sources in the vicinity of the transported cargo. All components within the cargo compartment are certified for operation in an explosive atmosphere.

Method of Compliance* (Air Force)*: Sources, locations, and configurations of possible ignition sources are verified by vehicle and engineering drawing inspections. The inability of components and systems to ignite flammable materials, and to preclude ignition of an explosive atmosphere is verified by system testing. Cargo clearances and preventive means of contacting ignition sources is verified by engineering drawing and cargo loading manual inspections, and by cargo loading demonstration.

References: At the time of publication of this document, no information was available in the current JSSGs

AFMAN 24-204(I) identifies flammability limits for transported cargo

14 CFR 25.787, 25.789, 23.787

18.2.2 Oxygen equipment installation.

Criterion: Verify that oxygen equipment and lines are not located in any designated fire zone; are protected from heat that may be generated in, or escape from, any designated fire zone; are not routed with electrical wiring; and are installed so that escaping oxygen cannot cause ignition of grease, fluid, or vapor accumulations present in normal operation or as a result of failure or malfunction of any system.

Standard* (Air Force)*: Oxygen equipment and lines are not located in any designated fire zone, are protected from heat that may be generated in, or escape from, any designated fire zone, and are installed so that escaping oxygen cannot cause ignition of grease, fluid, or vapor accumulations that are present in normal operation or as a result of failure or malfunction of any system. The functional and operational installation requirements for aircraft oxygen systems effectively limit fire and explosion hazards associated with survivable crashes. Oxygen system lines do not run in close proximity parallel with hydraulic fluid (or other flammable fluid/gas) lines, or in common conduits or bundled with electrical wiring. Insulation and routing paths for oxygen lines minimizes ignition hazards.

Method of Compliance* (Air Force)*: The location and routing of oxygen lines for criteria compliance is verified by inspection of engineering drawings and models. Heat protection is verified by temperature measurement in testing and by thermodynamic analysis. Identification and acceptability of ignition/explosive hazards is verified by a Failure Mode and Effects Criticality Analysis and a System Safety Hazard Analysis. The functional requirements are verified by review of design analysis, modeling and simulation.

References: JSSG-2010-7: 3.7.3.4, 3.10, 4.10
14 CFR 25.869

18.3 Physiology requirements of occupants.

18.3.1 Oxygen.

Criterion: Verify that air vehicles flying above 10,000 feet mean sea level (MSL) are capable of providing supplemental oxygen from the air vehicle, or from a stand-alone system, and are capable of delivering it to each passenger.

Standard* (Air Force)*: For each passenger, the minimum mass flow of supplemental oxygen required at various cabin pressure altitudes is not less than the flow required to maintain, during inspiration and while using oxygen equipment (including masks) provided, the following mean tracheal oxygen partial pressures:

a. At cabin pressure altitudes above 10,000 feet up to and including 18,500 feet, a mean tracheal oxygen partial pressure of 100 mmHg when breathing 15 liters per minute, Body Temperature, Pressure, Saturated (BTPS) and with a tidal volume of 700cc with a constant time interval between respirations.
b. At cabin altitudes above 18,500 feet up to and including 40,000 feet, a mean tracheal oxygen partial pressure of 83.8 mmHg when breathing 30 liters per minute, BTPS, and with a tidal volume of 1100cc with a constant time interval between respirations.
c. There is an individual dispensing unit for each passenger for whom supplemental oxygen is to be supplied. Units are designed to cover the nose and mouth and are equipped with a suitable means to retain the unit in position on the face.
d. For a pressurized airplane designed to operate at flight altitudes above 25,000 feet (MSL), the dispensing units for passengers are connected to an oxygen supply terminal and are immediately available to each occupant wherever seated. At least two oxygen dispensing units are connected to oxygen terminals in each lavatory. The total number of dispensing units and outlets in the passenger section exceeds the number of seats by at least ten percent. For operations above 30,000 feet, the dispensing units for passengers are automatically presented to each occupant before the cabin pressure altitude exceeds 15,000 feet.

Oxygen quantities are sufficient for the duration of time that passengers may be exposed to the cabin altitudes indicated.

Method of Compliance* (Air Force)*: The existence of a supplemental oxygen system and availability to each passenger is verified by vehicle configuration and engineering drawing inspections, and by mock up demonstration. The ability of oxygen systems to provide necessary oxygen quantities, duration, and flow rates is verified by analysis and system test in simulated altitude environments, (such as altitude chamber testing).

References: JSSG-2010-10: 3.10.1, 4.10.1
14 CFR: 23.1441, 23.1443, 23.1445, 25.1447, 23.1449, 23.1450, 25.1439, 25.1441, 25.1443, 25.1445, 25.1449, 25.1450, 25.1453

18.3.2 First aid.

Criterion: Verify that emergency medical kit(s) capable of providing medical support for the designed mission are installed in the air vehicle.

Standard* (Air Force)*: For treatment of injuries, medical events, or minor accidents that might occur during the designated mission of the aircraft, each passenger-carrying aircraft has an approved first-aid kit(s) and an approved emergency medical kit.

Method of Compliance* (Air Force)*: Installation and availability of emergency medical kits is verified by air vehicle and engineering drawing inspections. Adequacy of medical kit contents is verified by inspection of kit configurations, and specified content requirements for mission needs.

References: At the time of publication of this document, no information was available in the current JSSGs

14 CFR 121.309, 121.339, 121.310

19. MATERIALS.

(This section is applicable for Navy and Marine Corps aircraft only. This section is not required for Air Force or Army aircraft. Materials criteria, standards and methods of compliance are addressed throughout this document. If section 19 is used, the using aircraft or rotorcraft system office should tailor out the materials related criteria throughout the rest of the document as non-applicable, since these criteria may be in conflict with section 19.)

Materials comprise the entire flight vehicle including air vehicle structure, air vehicle subsystems, propulsion systems, electrical power systems, mission systems, crew systems, and armament/stores systems.

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria.
2. Materials properties data and analysis.
3. Environmental effects data and analysis.
4. Galvanic compatibility data and analysis.
5. Effects of defects data and analysis.
6. Hazardous materials data.
7. Material trade study results.
8. Design of experiments results.
9. Statistical process control data.
10. Nondestructive inspection (NDI) criteria.
11. NDI plan and records.
12. NDI probability of detection data.
13. Preproduction verification test data.
14. First article destructive test data.
15. Wear and erosion data.
16. Material specifications.
17. Process specifications.
18. Finish specifications.
19. Metallic materials properties development and standardization (MMPDS-08).
20. SAE CMH-17-2 Composite Material Handbook (volume 2) Materials and Properties.
21. Material safety data sheets.
22. Contractor policies and procedures.
23. Quality records.
24. Defect/failure data.
25. Fracture control plan.
26. Fracture critical parts list .

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

The following criteria, standards and methods of compliance apply to all air systems and represent the minimum requirements necessary to establish, verify, and maintain an airworthy design.

19.1 Properties and processes.

19.1.1 Material property evaluation.

Criterion: Verify that the material property evaluations are performed using a combination of recognized and standardized analyses, tests, inspections, and examinations.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: JSSG-2006: A.3.2.19, A.4.2.19
MIL-HDBK-1587
MMPDS-08
14 CFR 23.603, 23.613, 25.603, 25.613

19.1.2 Material property certification.

Criterion: Verify that the material properties are certified as specification compliant and that specification properties are represented as minimum values achievable using standardized processes.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: JSSG-2006: A.3.2.19.1, A.4.2.19.1
MMPDS-08
CMH-17
14 CFR 23.603, 23.613, 25.603, 25.613

19.1.3 Material design value.

Criterion: Verify that the material design allowable properties are represented as statistical values that account for product form and size, production representative processing, manufacturing variability, effects of defects, final assembly interfaces, environmental exposure, and repair.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: JSSG-2006: A.3.2.19.1, A.4.2.19.1
MMPDS-08
CMH-17
14 CFR 23.613, 25.613

19.1.4 Material specification properties.

Criterion: Verify that the likelihood and consequence of failure are accounted for when a material specification property is less than its corresponding material design allowable property.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: 14 CFR 23.603, 23.613, 25.603, 25.613
MMPDS-08

19.1.5 Environmental effects.

Criterion: Verify that the material property degradation due to the environment (e.g.,, moisture absorption; chemical, solvent, fuel, and lubricant exposure; hydrolytic instability; thermal exposure; electromagnetic radiation; wear; and erosion) is accounted for.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: JSSG-2001: 3.2.2, 4.2.2; 3.2.3, 4.2.3

JSSG-2006: A.3.2.16, A.4.2.16; A.3.11.1; A.4.11.1.2.1, A.3.11.2, A.4.11.2; A.3.11.3, A.4.11.3; A.3.11.4, A.4.11.4

JSSG-2009

MIL-STD-1568

MIL-HDBK-1587

14 CFR 23.609, 23.613, 25.609, 25.613

19.1.6 Critical process capability.

Criterion: Verify that critical process capability is demonstrated and that procedures for identifying, monitoring, and controlling critical process variation are in place.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: JSSG-2006: A.3.2.19.2, A.4.2.19.2; A.3.11.1; A.4.11.1.2.1

14 CFR 23.605, 25.605

19.1.7 Critical material and process integrity.

Criterion: Verify that critical material and process integrity are established.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: JSSG-2006: A.3.2.19.2, A.4.2.19.2

14 CFR: 23.605, 25.605

19.1.8 Damage repair.

Criterion: Verify that the maximum size and severity limits for damage requiring repair do not exceed repair capability.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: JSSG-2006: A.3.2.28, A.4.2.28

14 CFR 23.611

19.1.9 Material failure modes.

Criterion: Verify that insidious failure modes (e.g., hydrogen embrittlement, crack bifurcation) are understood and accounted for.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

Reference: 14 CFR 23.609

19.2 Corrosion.

19.2.1 Corrosion prevention and control practices.

Criterion: Verify that adequate corrosion prevention and control practices are in place for uniform surface corrosion, pitting, galvanic, crevice, filiform, exfoliation, inter-granular, fretting, high temperature oxidation (hot corrosion), corrosion fatigue, stress corrosion cracking and microbially induced corrosion.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

19.2.2 Corrosion prevention systems.

Criterion: Verify that corrosion prevention systems remain effective during the service life, including the mitigation of environmentally assisted cracking. Specific corrosion prevention and control measures, procedures, and processes are to be identified and established commensurate with the operational and maintenance capability.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

19.2.3 Non-metallic corrosion control.

Criterion: Verify that adequate prevention and control practices are in place for non-metallic materials degradation as a result of the degradation processes described in 19.2.1.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

19.2.4 Protective finishes.

Criterion: Verify that the finish systems provide adequate corrosion protection for specific parts, surfaces of similar and dissimilar materials, and attaching parts and fasteners. Identify/specify all surface treatments, inorganic and organic coatings, and other protective finishes to be used and their application.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: JSSG-2001: 3.2.3, 4.2.3
JSSG-2006: A.3.2.20, A.4.2.20; A.3.11.2, A.4.11.2
MIL-STD-889
MIL-STD-1568
MIL-STD-7179
14 CFR 23.603, 23.609, 25.603, 25.609

19.3 Non destructive inspection (NDI).

19.3.1 Defect characterization and detection.

Criterion: Verify that specific defect types, sizes, and locations critical to material integrity are characterized and assessed for probability of detection.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

19.3.2 NDI assessment criteria.

Criterion: Verify that NDI accept/reject criteria are validated and correlated with 'effects of defects' testing.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

19.3.3 NDI manuals.

Criterion: Verify that the nondestructive inspection manuals are developed and that each of the methods is valid.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

19.3.4 Inspection intervals.

Criterion: Verify that initial and recurring inspection intervals are defined where applicable.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: JSSG-2006: A.3.11.6, A.4.11.6
MIL-HDBK-6870
14 CFR 23.611

19.4 Wear and erosion.

19.4.1 Wear and erosion prevention.

Criterion: Verify that adequate wear and erosion practices are in place for wear mechanisms (abrasive, fretting, corrosive, and thermal wear) and erosion mechanisms (impinging fluid, solid particles). Specific wear and erosion prevention practices, measures, procedures, and processes are to be identified and established commensurate with the operational and maintenance capability.

Standard: To be provided by the procuring agency.

Method of Compliance: To be provided by the procuring agency.

References: JSSG-2006: A.3.2.28, A.4.2.28; A.3.11.4, A.4.11.4
14 CFR 23.609

20. AIR TRANSPORTABILITY, AIRDROP, MISSION/TEST EQUIPMENT AND CARGO/PAYLOAD SAFETY

TYPICAL CERTIFICATION SOURCE DATA

1. Design criteria
2. Design studies and analyses
3. Design, installation, and operational characteristics
4. Design approval and system compatibility tests
5. Component and system level qualification and certification tests
6. Electromagnetic environmental effects
7. Hazard analysis and certification
8. Failure modes and effects analysis
9. Avionics integration tests and results
10. System/subsystem self-test design and capabilities
11. Qualification test plans, procedures, and results
12. Ground test results
13. FCA and PCA data
14. Flight manual
15. Software development plan
16. Software development and product specifications
17. Software test plans, test procedures, and test reports
18. Software configuration control/management plan and procedure
19. Flight test reports
20. Environmental analysis and test results

CERTIFICATION CRITERIA, STANDARDS AND METHODS OF COMPLIANCE

20.1 Air transportability and airdrop.

Air transportability and airdrop are aircraft capabilities that enable an aircraft to perform cargo transport as a prime mission. Cargo includes objects and transported and airdroppable personnel (e.g., passengers and parachutists). These capabilities involve primary and secondary aircraft structure, size and shape of the cargo carrying compartment, and aircraft interactions with the cargo mass and weight, especially if cargo is airdropped during flight.

20.1.1 Air vehicle structure.

Criterion: Verify that the air vehicle structure can support all loads (internal or external, as applicable) imposed by the transported items during operational usage.

Standard: The Operational Concept identifies applicable transported items (e.g., cargo, baggage, stowed equipment) and dictates range of structural requirements. Structural interfaces are calculated from worst case loading/flight conditions with the cargo floor and related systems. The aircraft's allowable structural limits for ground and flight operations exceed the identified cargo loads by a margin acceptable to the Program Office (see Section 5 for applicable design requirements.)

Method of Compliance: Analysis and structural testing of subsystems or complete structures is performed. Structural testing verifies analytical results such that an acceptable margin of safety is attained for the design condition.

References: JSSG-2000: 3.1.7.2
JSSG-2001: 3.4.5, 3.4.6
MIL-HDBK-516: Section 5

20.1.2 Clearances.

Criterion: Verify that clearance exists for aircrew, support personnel and passengers during flight-critical and ground and flight emergency functions.

Standard: Dimensional data are compared on largest cargo items and internal aircraft dimensions. Cargo is considered in worst possible position as allowed by aircraft structure and weight and balance limits. Compared clearances meet or exceed accepted anthropometric requirements for passageways.

Method of Compliance: Acceptable clearance exists for aircrew and support personnel access during ground operations and flight of all required cargo items. Acceptable clearance exists for passenger egress on flights required to carry passengers. NOTE: Passenger egress clearances may be different from aircrew and support personnel access clearances.

References: JSSG-2000: 3.1.7.2
JSSG-2001: 3.4.5, 3.4.6
MIL-STD-1472 defines anthropometric data.
MIL-STD-1791 illustrates the minimum acceptable aircrew access clearances for C-130 aircraft.
AFI 11-2C-130 Vol 3, addendum A, defines C-130 passenger safety aisle requirements.

20.1.3 Cargo loading limits.

Criterion: Verify that cargo-loading manuals include operating limits such as shear, bending, crushing, or puncture load limits such that the cargo does not impart excessive loads into the air vehicle structure during any phase of the loading process.

Standard: Individual cargo items are accepted for flight based on measurable data such as wheel loads, overall weight, or load density. Cargo loading manuals define the overall parameters needed to approve cargo for structural interface with the aircraft. Cargo loading manuals consider and define all dimensional or load bearing limits that would damage the aircraft if exceeded by one or more individual cargo items. As backed by structural test reports and analyses, cargo loading limits are included in tabular or graphical form in the aircraft's cargo loading manual (AF TO 1C-XX-9, NATOPS, Army Operator Manual (-10), Army Maintenance Manual (-23, App G), etc.). Manuals list limits in generic terms of max compartment loads, axle loads, puncture loads, etc. in lieu of specific cargo item identification.

Method of Compliance: Existence of required information is verified by inspection of cargo loading manuals and supporting structural test or analysis data.

References: TO 1C-XX-9, the aircraft loading manuals include cargo loading limits in the desired formats.

Applicable DoD Operator's and Maintenance Manuals

20.1.3.1 Restraint system structure.

Criterion: Verify that cargo hook and restraint systems and the respective backup structural load limits are sufficient. Verify that limits are included in applicable operators and maintenance manuals.

Standard: Cargo floor tiedown rings and backup structure have strength levels equal to or in excess of the tiedown devices and are capable of withstanding specified loads. Unless otherwise specified, tiedown devices have a minimum ultimate strength capability 1.5 times the rated or working load capacity. Individual tiedown rings that can be used by more than one tiedown device and can be subject to forces in more than one direction within the hemisphere above the floor plane can withstand total applied loads. Repair of tiedown rings is included in the maintenance manuals. The structural integrity of the cargo hook assembly, the restraint system, the attachment hardware, and supporting airframe withstands the prescribed loads for the subject aircraft. Limitations are explained in the operator manuals (see also Section 5 for further details).

Method of Compliance: Through analysis and component testing, the attachment hardware, pan assemblies, and supporting airframe structure are verified to withstand pulling forces greater than the rated capacities of the restraint system. Ring assemblies are tested in vertical up, lateral, and longitudinal directions plus other directions as dictated by the analysis.

References: Structural Design Criteria for subject aircraft

JSSG-2000: 3.1.7.2

JSSG-2001: 3.4.5, 3.4.6

MIL-DTL-25959

MIL-PRF-27260

20.1.4 Aircraft weight and balance limits.

Criterion: Verify that the aircraft, with positioned cargo, meets required aircraft operations weight and balance requirements.

Standard: Overall weight, size and center of gravity (CG) location and other restrictions for cargo are compatible with aircraft structural, weight and balance limits. Loading locations (e.g., fuselage station, frame station) are specified if required to satisfy CG and structural limits. Repositioning is considered for cargo that can be moved within the confines of the compartment.

Method of Compliance: Aircraft weight and balance limits are verified by analysis, simulation, flight testing and any combination of methods, conducted at critical and extreme points of the aircraft gross weight, cargo locations and operating envelope.

References: Flight and cargo manuals applicable to each type of craft and Military Branch.

JSSG-2000: 3.1.7.2

JSSG-2001: 3.4.5, 3.4.6

20.1.5 Restraint system function during aerial delivery operations.

Criterion: Verify that the aircraft cargo restraint system meets the restraint specifications for the aircraft and also permits conduct of cargo delivery operations (e.g., air transport, combat offload, airdrop). The restraint system may be required to be compatible with standard DoD cargo and restraint systems.

Standard: For flight, loaded cargo items are secured against movement in all six degrees of freedom. Restraint criteria, specified for each type of aircraft, exceed cargo weight by static factors in order to secure cargo for crash and other severe flight conditions. For example, in USAF aircraft, the forward restraint criteria for crash is 3 x cargo weight or 3G's. Procedures and restrictions exist such that all restraints are applied before the aircraft begins ground movement and removal of the restraints are not accomplished until after the aircraft parks, except in the case of combat offload, emergency conditions and airdrop operations. Combat offload is permitted only with palletized loads, through release of the aft restraints while the aircraft is slowly rolling on the ground. Combat offload does not cause the aircraft to lose ground steering authority.

Method of Compliance: The ability to maintain restraint is verified by structural analysis and test of restraining systems, and by compatibility when interfacing with standard DoD pallets/platforms, restraint devices, and other applicable cargo delivery systems. The system has the restraint capacity to the specified level of force in the forward, aft, lateral and vertical up direction, applied in each direction separately.

References: Aircraft Specific Requirements, if different from USAF standards

JSSG-2000: 3.1.7.2

JSSG-2001: 3.4.5, 3.4.6

MIL-STD-1791, restraint criteria for transported cargo

MIL-A-8865, restraint criteria for transported cargo

20.1.6 Capacity and quantity of cargo restraint provisions.

Criterion: Verify that restraints afford sufficient capacity and are provided in sufficient quantity to restrain the transported items safely.

Standard: The quantity and capacity of restraint devices on board are sufficient to restrain the entire payload capacity of the aircraft to the specified level of force in the forward, aft, lateral and vertical up directions. Restraint devices are of an approved type and are stowed throughout the aircraft when not in use.

Method of Compliance: Through analysis and demonstration, the quantity of restraint devices is shown to be sufficient to restrain various mass quantities of cargo items. The strength level of the restraints is of a standard or otherwise approved value.

References: JSSG-2000: 3.1.7.2

JSSG-2001: 3.4.5, 3.4.6

MIL-DTL-25959, standard restraint devices

MIL-PRF-27260, standard restraint devices

20.1.7 Manuals.

Criterion: Verify that all operator and maintenance manuals (e.g., TO's) are accurate and provide cargo preparation, handling, carriage, and normal and emergency procedures necessary for safe ground and flight operations.

Standard: Aircraft Technical Orders, Operator's Manuals, Maintenance Manuals, Field Manuals, etc., provide a level of instruction that permits ground crew and air crew members to prepare and load cargo without damage to the aircraft and without confusion on part of the reader. Procedures are accurate and consistent with handling, carriage, and delivery capabilities.

Method of Compliance: Demonstrate draft copies of the operator, maintenance and loading manuals may be successfully used by properly trained crewmembers to perform necessary functions.

References: JSSG-2000: 3.1.7.2
JSSG-2001: 3.4.5, 3.4.6

20.1.8 Cargo compartment dimensions.

Criterion: Verify that cargo compartment dimensions allow enough room to load, transport, and/or airdrop required items safely.

Standard: For manned aircraft, the cargo compartment loading envelope provides a minimum of six inches clearance around the outside of the largest defined cargo item or defined operating space. For unmanned aircraft, the minimum cargo compartment clearance may be less than six inches, provided the size allows loading, unloading, restraint, airdrop, combat offload of the largest defined cargo item, or defined operating space. Cargo entrance geometry permits loading cargo with an underbelly clearance of at least one inch. Aircrew access and passenger escape envelopes are outside (but not overlapping) the cargo compartment loading envelope.

Method of Compliance: Selected cargo loading demonstrations and analysis of loaded cargo via drawings indicates the clearance envelope is maintained throughout the loading and flight activities.

References: Systems Specifications
JSSG-2009: Appendix J
MIL-STD-1791

20.1.9 Cargo or CG movement in flight

Criterion: Verify that air vehicle flight safety is not hazardously affected by movements in CG of airdrop loads or by load and CG movement experienced during external load operations.

Standard: Flight safety is maintained during airdrop of the designated payload weight at the required airspeeds (see also Section 6). Air vehicle can ground load the specified payload weight without adverse movement of the airframe. Stability struts for ground loading are permitted to satisfy this requirement.

Method of Compliance: Analysis and test verify flight safety during airdrop of the designated payload weight at required airspeeds. Stability and control analyses and testing performed in Section 6 demonstrate the ability to maintain safe flight during the exit of the heaviest payloads. Loading demonstrations verify that the air vehicle has sufficient stability in ground mode to present a stable platform for loading operations.

References: Systems Specifications
JSSG-2009: Appendix J
MIL-STD-1791

20.1.10 Personnel airdrop system structure.

Criterion: Verify that air vehicle personnel airdrop systems can withstand the loads imposed by personnel during airdrop and possible malfunctions of personnel airdrop equipment.

Standard: Air vehicle subsystem components and supporting structure such as anchor cables, jump platforms, air deflectors, seating, floor structure, retrieval winches, retrieval cables, etc. are designed to withstand loads imposed by airdrop and retrieval of the specified numbers and weights of paratroopers and personnel recovery systems (e.g., parachute and deployment bags). The static line support system must withstand a minimum of 3,600 lb x 1.5 safety factor (5,400 lbs static) caused by a towed parachutist. Airdrop and retrieval components are designed to handle a single towed jumper weighing the maximum allowable single jumper weight (including equipment) and specified number of deployment bags consistent with the subject aircraft, if not otherwise specified, when operated by the minimum crew size required by the operational concept.

Method of Compliance: Analysis of structural loads verified with instrumented results from flight testing demonstrates the aircraft structure and subsystems are not adversely affected by personnel airdrop and retrieval operations under a worst case scenario.

References: Systems Specifications

JSSG-2009: Appendix J

ASC-TM-ENE-77-1

Refer to the appropriate design criteria report for the subject aircraft to obtain the maximum allowable retrieval weight and cone angle

20.1.11 Towed jumper retrieval capability.

Criterion: Verify that the air vehicle provides the capability to safely recover a towed jumper.

Standard: The air vehicle has a capability to retrieve a hung paratrooper without injury using onboard equipment operated by the available aircrew. On-board equipment is readily available to permit this operation without extensive delay.

Method of Compliance: Flight testing results demonstrate the capability exists for a single aircrew member (unless otherwise specified) to readily retrieve a maximum weight towed mannequin plus the maximum towed parachute bag(s) minus one, using the onboard equipment. Flight testing results encompass a range of dummy weights to verify no adverse effects during retrieval into the aircraft exit way.

20.1.12 Personnel airdrop operations.

Criterion: Verify that, for personnel airdrop, acceptable risk levels exist to avoid paratrooper collision, adverse vortex interaction, and adverse multi-ship formation effects induced by the air vehicles.

Standard: The air vehicle provides an airdrop capability for specified numbers of paratroops to deliver them within defined drop zone regions both in single ship and mass formations. The air vehicle has systems for safe exit and indicators to allow the jumpers to stand by, proceed and abort the airdrop. For centerlining, the aircraft paratrooper trajectory (from exit to stabilization) is not worse than the C-141 aircraft Cumulative Distribution Function (CDF) Curve. There is no interaction between the paratrooper and the forward aircraft vortices within a formation element. High altitude entanglements or low altitude interaction with vortices from forward aircraft, between elements, are avoided within acceptable operational risk.

Method of Compliance: Testing, modeling, and analyses demonstrate that air vehicle induced effects on streams of jumpers present no increase in risk beyond that acceptable to the user. Multi-ship drop formations are determined to minimize interactions to an acceptable level of risk.

References: C-141 CDF Curve

C-17 High Altitude Entanglement Test Procedures

20.1.13 Cargo jettison capability.

Criterion: Verify for airdrop or jettisonable cargo, that the loaded items can be safely jettisoned during flight.

Standard: Airdrop or jettisonable cargo within specified limits does not adversely affect the aircraft or personnel.

Method of Compliance: The capability to airdrop the specified types and sizes of cargo is defined and substantiated through analysis and flight testing. The ability to jettison items of palletized cargo is demonstrated and documented. Extensive flight testing defines the range of hardware items and the required parameters necessary to perform preplanned airdrop and unplanned jettisoning of cargo loads. The range of testing includes maximum and minimum weights, locations, airspeeds, and other limitations as needed for technical input into the operational manuals.

References: Systems Specifications
JSSG-2009: Appendix J
MIL-STD-1791

20.1.14 In-flight movement

Criterion: Verify that necessary in-flight movement or operation of transported items and mission equipment does not adversely affect aircraft flight systems or cause injury to aircrew and passengers.

Standard: Movement or operation of non-fixed equipment or transported items during flight will not cause the aircraft to exceed limits (e.g., weight and balance) nor impose a risk to personnel (if applicable) within the aircraft. Items that may be moved in flight do not create a hazardous environment or fail in a fashion that causes flight or injury risks when accidentally dropped (e.g., during loading, installation, or removal).

Method of Compliance: Analysis and testing verify that operation or movement of equipment does not put the air vehicle out of established balance limits if it is relocated or used anywhere within operational possibilities. Transported equipment which, in a dynamic situation, could impose risks to personnel is only moved in a manner that affords control of the object at all times. Items with components or materials that could pose a hazard are drop tested to verify safety of possible post drop configurations and any release of hazardous materials.

References: Systems Specifications
JSSG-2009: Appendix J
MIL-STD-1791

20.1.15 Mission-specific equipment installation.

Criterion: Verify that in-flight operation of mission-specific personnel and cargo equipment (e.g., cargo hooks, rescue slings and hoists, H-bar and fast rope insertion/extraction system (FRIES) bar does not adversely affect safety of the air vehicle system.

Standard: Mission specific equipment, installation design, and functional interfaces to the air vehicle are assessed for potential adverse impact to air vehicle structure, weight and balance, flying qualities, electromagnetic compatibility, power quality/delivery to flight critical equipment, and potential for fire and explosion. The presence/function of these items is shown not to increase the probability of loss of the air vehicle.

Method of Compliance: Hazard analysis and/or test data is provided which verifies that no additional safety hazards to the air vehicle are induced by the installation and function of mission specific equipment.

20.2 Mission/test equipment operations and installation.

20.2.1 In-flight operations.

Criterion: Verify that the following items do not adversely affect the primary SOF functionality (such as structural capability, flying and handling qualities, electronic compatibility) of the air vehicle:

a. Special non-SOF mission or test equipment and software including instrumentation and wiring.
b. Non-SOF mission-specific equipment and software.
c. Nonessential mission equipment (hardware and software).
d. Carry-on/carry-off equipment that will be operated in flight.

Standard: Non-SOF equipment, installation design, and functional interfaces to the air vehicle are assessed for potential adverse impact to air vehicle structure, weight and balance, flying qualities, electromagnetic compatibility, power quality/delivery to flight critical equipment, and potential for fire and explosion. The presence/function of these items is shown not to increase the probability of loss of the air vehicle.

Method of Compliance: Hazard analysis and/or test data is provided which verifies that no additional safety hazards to the air vehicle are induced by the installation and function of non-SOF equipment.to the air vehicle are induced by the installation and function of non-SOF equipment.

20.2.2 Installation safety.

Criterion: Verify that carriage of cargo or payload does not adversely affect safety of the air vehicle system.

Standard: Cargo and/or payload, installation design, and functional interfaces to the air vehicle are assessed for potential adverse impact to air vehicle structure, weight and balance, flying qualities, electromagnetic compatibility, power quality/delivery to flight critical equipment, and potential for fire and explosion. The presence/function of these items is shown not to increase the probability of loss of the air vehicle.

Method of Compliance: Hazard analysis and/or test data is provided which verifies that no additional safety hazards to the air vehicle are induced by the installation and function of cargo and/or payload.

References: JSSGs corresponding to the appropriate item and/or installations under consideration.

14 CFR sections corresponding to Structural and Installation requirements; and systems as applicable, i.e., Electrical.

21. NOTES

21.1..Intended use.

This tri-service handbook provides guidance to be used in determining the airworthiness of all manned and unmanned, fixed and rotary wing air systems.

21.2 Subject term (key word) listing.

Airdrop
Air transportability
Armament
Avionics
Computer systems
Crew systems
Diagnostic systems
Electrical systems
Electromagnetic environmental effects
Flight technology
Foreign object damage
Maintenance
Materials
Propulsion systems
Safety
Stores
Structures
Systems engineering
System safety
Unmanned aircraft systems

21.3 Changes from previous issue.

Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

APPENDIX A

AIRWORTHINESS CERTIFICATION CRITERIA POINTS OF CONTACT

A.1 SCOPE

A.1.1 Scope.

This appendix provides points of contact for the Airworthiness Certificaiton Criteria contained within this document.

A.2 Points of contact.

A.2.1 U.S. Air Force

ALFCMC/EN-EZ Engineering Directorate
2145 Monahan Way, Bldg 28
Wright Patterson Air Force Base Ohio 45433-7017

Email: USAF.Airworthiness.Office@us.af.mil

A.2.2 U.S. Army

U.S. Army Aviation & Missile Research Development & Engineering Center
Aviation Engineering Directorate (AED)
RDMR-AE
Bldg 4488 Martin Rd., C-100
Redstone Arsenal, AL 35898-0001

Phone: 256-313-8400
Fax: 256-313-3196
Email: AEDFrontOffice@amrdec.army.mil

Website: http://www./amrdec.army.mil/AMRDEC/Directorates/AED.aspx

A.2.3 U.S. Navy

USN & USMC Airworthiness Office
Naval Air Systems Command, Headquarter (AIR-4.0P)
Building 460
22244 Cedar Point Road
Patuxent River, MD 20670-1163

Airworthiness Global Customer Support Team
Tel: (301)-757-0187
Email: airworthiness@navy.mil

Website: https://airworthiness.navair.navy.mil

A.2.4 Federal Aviation Administration (FAA)

For commercial derivative aircraft (CDA), contact the FAA Military Certification Office:

FAA Military Certification Office
ACE-100M
8200 East 34th Street North
Building 1000, Suite 1005
Wichita, KS 67226

Phone: 316-350-1580
FAX: 316-350-1592

CONCLUDING MATERIAL

Custodians:
Army – AV
Navy - AS
Air Force - 11

Preparing activity:
Air Force - 11

(Project No. SESS-2014-015)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.dla.mil.