DEPARTMENT OF THE AIR FORCE
Headquarters Air Force Life Cycle Management Center
Engineering Directorate
Wright-Patterson AFB OH 45433-7101

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AIRWORTHINESS CIRCULAR

Small Unmanned Aircraft Systems (SUAS) Airworthiness Assessments

PURPOSE:
This Airworthiness (AW) Circular (AC) provides an acceptable method for conducting AW assessments when identified as appropriate in Airworthiness Bulletin (AWB)-350, Unmanned Aircraft Systems.

ATTACHMENT:
SUAS Airworthiness Assessment Template

BACKGROUND:
The SUAS Airworthiness Assessment Template (Atch 1) is derived from the Range Commander's Council publication RCC 323-99, *Range Safety Criteria for Unmanned Air Vehicles- Rationale and Methodology Supplement*. This Tri-Service document serves as a basis for similar assessments by other Service and civil airworthiness authorities.

PROCESS:
For each SUAS, the preparer will complete Attachment 1 and provide all relevant information in each section about the design and operation. References to other documents (i.e., operator manuals, system safety documents, previous similar submissions to other DoD Airworthiness Authorities) may be cited for brevity as long as the reviewer can easily and accurately access the relevant information. Once Sections 1-5 are complete, the preparer will document specific hazards, assess initial severity and probability levels, identify any risk mitigation procedures, and determine residual risks in Section 6.

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Attachment 1

SUAS Airworthiness Assessment Template

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SUAS Airworthiness Assessment

of

[SUAS Make/Model]

for

[Project/Program Title]

Prepared By: **Date:**

[Preparer]

Reviewed By: **Date:**

[Reviewer]

Approved: **Date:**

[TAA or DTA]

CONTENTS:

INTRODUCTION:

An airworthiness assessment was conducted on the [*insert system name*] and the results are captured in this report.

This report is focused on hazards that may result in the following consequences:

- Unmanned Air Vehicle (UAV) crashes which may result in death or injury, or damage to property.
- Mid-air collision between UAV and other aircraft causing death or injury, or damage.

This document also describes the following:

- Key system vulnerabilities have been identified
- Safeguards are adequate for these system vulnerabilities
- Deficiencies or inadequacies of the proposed safeguards have been recognized

This list of topics is not intended to be all-inclusive. Please replace all red font with assessment information.

1. PROGRAM INFORMATION

1.1. Program/Project Name:
1.2. Program/Project POC: *Name, Office, Phone (DSN or commercial), email*
1.3. Program Objective:
1.4. Previous AW Approval(s):
1.5. Operating Environment:
___Flight Test
___Operational
___Other
1.6. Operator:
___USAF
___Contractor
___Both
1.7. Airspace:
___DoD Test or Training Range
___Other DoD Controlled Airspace
___FAA COA
___Other Airspace: ______________________
1.8. References used in this document:
1.8.1. [list as applicable]

2. UAS INFORMATION

2.1. General Description
2.1.1. Model/Nomenclature:
2.1.2. Manufacturer:
2.1.3. Air Vehicle Type:
___Fixed Wing
___Rotary Wing
___Multi-rotor
___Other: ______________________

2.1.4 Replacement cost of UAV:
2.2. UAV Physical Characteristics *Insert picture(s) and/or 3-view drawing*
2.2.1. Length
2.2.2. Wingspan
2.2.3. Max Weight
2.2.4. Empty Weight
2.2.5. Material Composition
2.2.6. Structural Elements
2.3. Flight Envelope/Performance
2.3.1. Cruise Speed
2.3.2. Max Speed

2.3.3. Max Altitude/Ceiling
2.3.4. Max Endurance
2.3.5. Max Range
2.3.6. Glide Ratio (L/D)

2.4. Weather Limitations.

2.4.1. Winds. *List headwind, crosswind and gust limits for:*

2.4.1.1. Flight
2.4.1.2. Launch
2.4.1.3. Recovery

2.4.2. Temperature
2.4.3. Precipitation

2.5. Avionics. *Describe accuracy, latency and redundancy in the avionics system.*

2.5.1. Datalinks
2.5.2. Air Data Systems
2.5.3. Navigation Sources
2.5.4. Navigation Modes

2.6. Propulsion and Power. *Describe power rating, power requirements, circuit protection and redundancy in the propulsion and power system.*

2.6.1. Engine/Motor

2.6.1.1. Make/Model
2.6.1.2. Engine Type/Fuel
2.6.1.3. Power Rating
2.6.1.4. Power Requirements

2.6.2. Electrical Generation/Distribution

2.6.2.1. Electrical Loads Analysis
2.6.2.2. Load Shedding
2.6.2.3. Battery Backup Capacity

2.7. Air Vehicle Computer Processing.

2.7.1. Architecture: *Describe the air vehicle computer processing architecture and interfaces with flight critical components. Identify any Contractor Off-the-Shelf (COTS), modified COTS, or Government Off-the-Shelf (GOTS) computer hardware and/or software that execute flight critical and safety critical functions for the air vehicle.*

2.7.2. Design: *Describe any unique flight modes, redundant processing, and monitoring implemented in the air vehicle design.*

2.7.3. Development Process: *Describe the procedures used to develop, integrate, and verify computer-supported functionality.*

2.8. Ground Control Station (GCS). *Provide a description of the GCS (i.e., manufacturer/model, fixed vs mobile, datalink architectures, UAV control method, Air Traffic Control (ATC) communications, backup GCS). Describe any unique user interfaces or configuration files tailored for the ground station.*

2.9. Lasers. *Describe any lasers (i.e., class, power) installed on the platform and include any Laser System Safety Review Board approvals.*

2.10. Lithium batteries. *If used, list type, size, chemistry, and any certifications (i.e., UL3030, US Navy TM S9310).*

2.11. Launch Method. *Describe the launching method.*

2.12. Recovery Method. *Describe the recovery method.*

2.13. Safety Hazard Keepout Zones. *Provide launch, recovery keepout zones for ground operations and flight.*

2.14. Manual Control. *Describe conditions under which manual piloting is allowed.*

2.15. Controls and Displays. *What indication does the Operator have that they are in control of the aircraft? How accurately can the Operator determine the attitude and position of the aircraft? What alarms, warnings, cautions or advisories does the system provide to the operator (for example, low fuel or battery, failure of critical systems, departure from operational boundary)?*

3. CAUSES OF LOSS OF CONTROL

3.1. Loss of Command Links. *Describe the UAS functions that satisfy these questions: What happens when command link is lost? How does vehicle respond if link is never re-established? How does the vehicle recognize that loss of command link has occurred? How does the UAS operator at the ground control station recognize loss of command link has occurred? Is there a backup command transmitter and receiver? What is the effect of Electromagnetic Interference on the command and control system?*

3.2. Loss of Vehicle Position Information. *Describe the UAS functions that satisfy these questions: What are the sources of vehicle navigation position information to the UAS operator? Are there redundant sources so the UAS operator can tell if there is a discrepancy? If the UAS operator loses primary position information, is control also lost? Does the UAS operator have access to any external sources of position information that could serve as a backup (radar, transponder, binoculars)? How does the vehicle autopilot respond to loss of primary internal navigation source? Is there a backup? What are the indications in the ground station to the UAS operator?*

3.3. Loss of Flight Reference Data. *Describe the UAS functions that satisfy these questions: What are the onboard sources of position, attitude, heading, altitude, and airspeed information to the UAS operator and/or autopilot? How does the vehicle autopilot respond to loss of primary attitude source? Is there a backup? What are the indications to the UAS operator?*

3.4. Unresponsive Flight Controls. *Describe any potential failure modes and corresponding mitigations. How does the system respond to an actuator failure, including stuck throttle, and what indications alert the operator that a failure has occurred?*

3.5. Loss of Propulsion. *Describe the UAS functions that satisfy these questions: What happens to the vehicle when propulsion stops? Will sufficient velocity and electrical power remain for "controlled ditch" or "dead stick landing"? Can the engine be* *restarted in flight? Is the propulsion system affected by environmental conditions (temperature, icing, dust, etc.)? What are the limits? Are the limits and failure modes confirmed by test data? Are limits considered in test plan? How is fuel volume or fuel utilization monitored?*

3.6. Loss of Electrical Power. *Describe the UAS functions that satisfy these questions: What happens when primary electrical power is lost? Is there a separate battery bus? What does battery bus power? Does automatic system load shedding occur if power is reduced? Are there "essential busses" for reduced power operations? Are all flight essential systems on an essential bus? Is there a battery power available time limit associated with loss of electrical power? How long? What if the UAS is too far from base to get back before power runs out? Does flight termination system (FTS) activate if battery backup fails (i.e., fails "safe")? How is backup battery checked prior to takeoff? Safety backup system battery lifetime is a critical issue. How do you know how much emergency battery power is left? Is battery usage data available on telemetry? Is a battery use log kept?*

3.7. Loss of Ground Control Station. *Describe the UAS functions that satisfy these questions: What is the source of electrical power for the ground control station? Is there an un-interruptible backup power source? What happens if electrical power is lost? Do backup command transmitter and emergency systems have adequate protection from loss of electrical power? If power to the ground station is lost, does it affect the air vehicle performance? Do all flight parameters get reset to zero? If a ground station processor crashes, what is the system response?*

4. **COMMON SAFEGUARDS**

This section describes the capabilities inherent to this system and mitigation procedures.

4.1. Degraded modes of flight. *What failures or conditions will cause the flight to be aborted (i.e., precautionary return to base)?*

4.2. Return Home Modes. *Describe the Return Home Mode and what triggers it. Does Return Home Mode work without GPS?*

4.3. Containment and Geofence. *Does the system have "Geofence" capability? If so, describe. Describe UAS containment procedures and methods of containment in requested area in the event of a "fly-away"*

4.4. Flight Termination System. *Is a FTS installed? Describe the FTS. Can FTS be self-activated, if so, what causes self-activation of the flight termination system? Electrical power loss? Loss of flight critical function? Loss of FTS signal? What are the criteria for activation of the FTS or flight termination maneuver? Does FTS activate if battery backup fails (i.e., fails "safe")? Does FTS operate on an independent battery circuit?*

4.5. Fail Safe Mode. *Is there a "fail safe" mode? What conditions cause it to activate? What happens when it is activated (engine shut off, flight controls to "turn" or "tumble")? Is there a specified time delay between what triggers fail safe mode and actions taken to cause the vehicle to stop flying?*

4.6. In Flight Restarts. *Can the system be restarted in flight? What conditions would lead to a restart? How long does it take to return to full capability? Does it return in the same state or revert to a set of defaults? Can the air vehicle maintain flight during the restart?*

4.7. Collision Avoidance. *How is the risk of mid-air collision with manned aircraft mitigated? How does the UAS Operator "see and avoid" other aircraft that may be nearby (radar, transponder, visual)?*

4.8. Parachute. *Does the UAS have a parachute recovery system? How is it activated? At what altitude will the chute deploy and what is the impact and drift rate? Is there a minimum deployment altitude? Are there altitude, airspeed, or attitude limits on deploying the parachute?*

4.9. Other. *Include any other safeguards not addressed above.*

5. **VEHICLE SAFETY HISTORY AND RELIABILITY** *Include references to existing documentation for the below items.*

5.1. System Flight History: *Include flight hours (from Original Equipment Manufacturer (OEM) or by operator if COTS) and operating environments (i.e., company range, DoD Test and Training ranges, operational locations)*

5.2. System Safety Program: *How does the program/OEM track mishap history?*

5.3. System Safety Hazard Analysis: *How does the program/OEM identify Mishap History and Corrective Actions?*

5.4. Failure Modes Effects Analysis, Mean Time Between Failure: *If known or available*

5.5. Hazardous Materials: *Are there hazardous materials in the system (flammable, toxic, energy storage, ordnance)? Can a crash start a fire?*

6. RISK ASSESSMENT

6.1. Severity Categories, Probability Levels and Risk Assessment Matrix per AWB-150.

Table 6.1. Severity Categories

Description	Severity Category	Mishap Result Criteria
Catastrophic	1	Could result in one or more of the following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M.
Critical	2	Could result in one or more of the following: permanent partial disability,injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.
Marginal	3	Could result in one or more of the following: injury or occupational illness resulting in one or more lost work day(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M.
Negligible	4	Could result in one or more of the following: injury or occupational illness not resulting in a lost work day, minimal environmental impact, or monetary loss less than $100K.

Table 6.2. Probability Levels

Description	Level	Specific Individual Item	Fleet or Inventory
Frequent	A	Likely to occur often in the life of an item.	Continuously experienced.
Probable	B	Will occur several times in the life of an item.	Will occur frequently.
Occasional	C	Likely to occur sometime in the life of an item.	Will occur several times.
Remote	D	Unlikely, but possible to occur in the life of an item.	Unlikely, but can reasonably be expected to occur.
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced in the life of an item.	Unlikely to occur, but possible.
Eliminated	F	Incapable of occurence. This level is used when potential hazards are identified and later eliminated.	Incapable of occurence. This level is used when potential hazards are identified and later eliminated.

Table 6.3 - Risk Assessment Matrix

Probability \ Severity	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A)				
Probable (B)				
Occasional (C)				
Remote (D)				
Improbable (E)				
Eliminated (F)	Eliminated			

Legend: Risk Acceptance Authority (RAA) per organizational RM policy		
	High	*[insert RAA]*
	Serious	*[insert RAA]*
	Medium	*[insert RAA]*
	Low	*[insert RAA]*

6.2. Risk Assessment

Assessment information documented in the previous sections is used to identify hazards and associated severities using Table 6.1 based on the repair or replacement cost of the air vehicle. Probabilities of individual hazards occurring are then qualitatively assessed using Table 6.2. It is important to develop viable mitigating actions where possible to reduce the risk level to the lowest possible. The resulting residual risks are summarized in Table 6.4 with a detailed analysis presented in Table 6.5 (examples included).

If historical mishap data is available and risks are aggregated at the system level, use the equation below to determine the Aggregate Probability of Mishap. The Quantitative Probability Level is determined by finding the range associated with the Aggregate Probability of Mishap per flight hour (FH) or Sortie / 10 in AWB-150, Table 2: Quantitative Probability Level Thresholds. (The division by 10 is appropriate to transform the Quantitative Probability Level Thresholds table from dealing with individual hazard types to handling the aggregate risk to the system.)

Aggregate Probability of Mishap per FH or Sortie = (Total Aircraft Losses + 1) / Total FH

The Risk Assessment Matrix in Table 6.3 is used to determine appropriate risk acceptance authorities (RAAs) based on residual risk levels. The residual risk from each hazard is used to set the overall risk level to be accepted for the intended usage of the system. The overall risk level will be no lower than the highest residual risk level from any of the hazards. The requiring activity determines the appropriate RAAs in accordance with DoD and AF policy.

Table 6.4 –Example Risk Summary

Hazard	Residual Risk
GENERAL	
Lithium Battery Fire/Explosion	3-E, MED
Unsuccessful Launch	3-E, MED
Unsuccessful Recovery	4-E, LOW
LOSS OF CONTROL	
Loss of Command Link	4-D, LOW
Loss of Vehicle Position Information	4-D, LOW
Loss of Flight Reference Data	4-E, LOW
Control surface failure	3-E, MED
Loss of Propulsion	4-D, LOW
Loss of Aircraft Power	4-E, LOW
Loss of Ground Station	Eliminated
SAFEGUARD FAILURES	
Airspace violation	4-E, LOW
Mid-air Collision	4-E, LOW
MISHAP HISTORY	3-C. MED

Table 6.5 – Example Risk Assessment

HAZARD	CAUSE	EFFECT	INITIAL RISK	MITIGATION	RESIDUAL RISK
GENERAL					
Lithium Battery Fire/Explosion	Damage; inappropriate storage or charging of batteries	Loss of A/C	3-C	Pre-flight procedure checks battery health; Mx manual describes proper storage and charging procedures	3-E
Unsuccessful Launch	Propulsion failure during launch	Loss of lift and impact with ground	3-D	Pre-flight procedure checks engine functionality; displays provide health and status, vertical speed indicator	3-E
Unsuccessful Recovery	Net capture failure	Impact with ground at high speed	4-D	Displays provide landing point deviations, vertical speed indicator; ground observers provide cross check	4-E
LOSS OF CONTROL					
Loss of Command Link	Complete failure of primary and secondary radios or tracking antenna	A/C executes Lost Comms flight plan	4-C	Lost Comms plan returns A/C home along pre-programmed route. Flight Termination conditions are set during pre-flight.	4-D
Loss of Vehicle Position Information	Lost/degraded GPS	A/C reverts to magnetometer, gyros and IMU; returns home	4-C	Displays provide health and status; Emergency procedures reduce probability of loss of A/C.	4-D
Loss of Flight Reference Data	Improper pitot-static assembly	Uncontrolled loss of aircraft	3-C	Warnings/Caution in Mech Ops Manual and positive Pre-flight checks reduce risk of in-flight failure.	4-E
Control surface failure	Stuck controller	Uncontrolled loss of aircraft	3-C	Positive Pre-flight checks reduce risk of in-flight failure.	3-E
Loss of Propulsion	Mechanical failure	Controlled loss of aircraft-Loss of altitude	4-C	Displays provide health and status; Emergency procedures sufficiently reduce probability of loss of A/C..	4-D
Loss of Alternator or PMU	Mechanical failure	Uncontrolled loss of aircraft	4-D	Emergency procedures sufficiently reduce probability of loss of A/C including VTOL landing.45-60 min backup battery for control surfaces	4-E
Loss of Ground Station	Electrical failure	Loss of UAV C2	3-D	Handoff to backup control station on separate electrical circuit	Eliminated
SAFEGUARD FAILURES					
Airspace violation	Autopilot failure results in fly-away	Fuel exhaustion and belly landing	4-D	Autopilot mfr has mature SW development process (10+ yrs) incorporating bug fixes from operational events	4-E
Mid-air Collision	Loss of situational awareness and/or anti-collision lights	Loss of A/C	4-C	Operations under FAA COA w/ airspace de-confliction, use of observers	4-E
MISHAP HISTORY	**FLIGHT HOURS**	**MISHAPS**	**MISHAP RATE**	**REPLACEMENT VEHICLE COST**	**MISHAP RISK**
Make/Model	20,000	10	5.5E-04	$500k	3-C