Structures Bulletin

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Subject: Factor of Uncertainty for Unmanned Air Vehicles (UAV)

Background:

There has been debate regarding the use of a reduced factor of uncertainty for UAV's in accordance with Joint Service Specification Guide (JSSG) – 2006, paragraph 3.2.12. The intent of this bulletin is to interpret and clarify the JSSG language in order to provide guidance for UAV programs.

Discussion:

A 1.5 factor of uncertainty (formerly known as factor of safety) historically has been used to determine ultimate loads for the design of airframe elements subject to deterministic structural design criteria. This factor has been accepted in U.S. design practice and has been fundamental in providing a balance between design efficiency and acceptable risk levels for aircraft safety with regards to structural integrity. The factor compensates for various issues that may result from the design, manufacturing and sustainment processes. These include but are not limited to the following:

- Use of nominal tolerances versus allowed minimal blueprint tolerances in structural analysis.
- Use of B-basis material allowables.
- Inaccuracies in the structural analysis not uncovered during development and full-scale testing. This includes untested structure, scale-up effects from component testing, and testing without environmentally conditioned test articles.
- Production variability occurring during standard aerospace industry fabrication, manufacturing and assembly processes.
- Variability inherent during implementation of quality control processes.
- Inadvertent pilot commanded load exceedances occurring during operations.
- Inherent flight limiter overshoots within vehicle management flight control laws.

A reduced factor of safety was derived for guided missiles in the 1950s thru a consolidated effort by the Air Force, Navy and Army. Specifically, this was limited to a subset of the overall design loading conditions and consisted of a factor of safety equivalent to 1.25 for free flight conditions of the missile other than during the initial free flight after separation from the launch platform/launcher. The 1.5 factor was maintained for all other conditions including captive flight, launching, jettison, ejection, transportation, handling and other non-flight conditions. Missile strength and rigidity requirements, including the reduced factor, were formally published in Specification MIL-M-8856; General Specification for Structural Integrity for Guided Missiles, originally dated 22 June 1959. This specification was directly applicable to guided missiles including cruise missiles.

Structural requirements were consolidated into the Joint Service Specification Guide for Aircraft Structures; JSSG-2006. Paragraph 3.2.12 defines the requirement for Ultimate Loads. The Requirement *Rationale* recommends a factor of uncertainty of 1.5. The Requirement *Guidance* for this paragraph states that a factor of uncertainty for unmanned aircraft has been 1.25, except that a factor of 1.5 has been used when a failure of the structure could result in injury to personnel or damage to or loss of the carriage and launch equipment. This statement seemingly has been misinterpreted from MIL-M-8856 and should only be applicable to guided missiles and perhaps extrapolated to expendable unmanned air vehicles.

The 1.5 factor of uncertainty has been the primary design criteria linked to providing the accepted probability of structural failure leading to loss of aircraft of less than 10^{-7}. It is important to note that the factor of uncertainty was not intended to function independently but in concert with many other structural design and operational requirements. Probability of structural failure will be sensitive to the number of significant design parameters and their statistical distribution. A robust building block approach, as defined in MIL-STD-1530, is a critical component in characterizing capabilities and ensuring historical risk levels are achieved during the design and validation phases of a development program. Tailoring of standard design criteria and requirements must entail a detailed quantification, to include substantial statistical data, of the design, manufacturing, and operating intricacies and variations that the requirements were meant to account for, including reductions in the factor of uncertainty. The impacts from tailoring structural criteria and development activities must be evaluated not on an individual basis but on a system level aspect.

Unmanned air vehicles are not immune to the typical issues addressed by standard structural design criteria and development processes, especially those accounted for by use of the 1.5 factor of uncertainty. Current unmanned program requirements provide evidence that these air vehicles are not expendable and are expected to be operational for many years. Furthermore, payload requirements drive weapon system costs to be prohibitive with regard to expendability. Standard deterministic criteria (including a FS = 1.5) should be followed unless a system level probabilistic analysis, based on substantial statistical data, addressing all tailored requirements is completed which defines the overall probability of structural failure and is approved by the appropriate approving authority as defined in MIL-STD-882D.

Recommendation:

1. Non-expendable unmanned air vehicles should follow standard deterministic design criteria including the use of a 1.5 factor of uncertainty.

2. The following change should be incorporated into the Requirement Guidance for paragraph 3.2.12 Ultimate Loads in the JSSG-2006:

   Was:

   The value for manned aircraft has been 1.5. The value for unmanned aircraft has been 1.25, except that a factor of 1.5 has been used when a failure of the structure could result in injury to personnel or damage to or loss of the carriage and launch equipment.

   Is:

   The value for manned and non-expendable unmanned aircraft has been 1.5. The value for guided missiles has been 1.25 for some of the free flight conditions and 1.5 for all other conditions (Reference MIL-M-8856B for detailed criteria for guided missiles).

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