AC 20-146A Methodology for Dynamic Seat Certification by Analysis for Use in Part 23, 25, 27, and 29 Airplanes and Rotorcraft

- Presented to: *Use of Dynamic Analysis Methods in Aircraft Certification Workshop*
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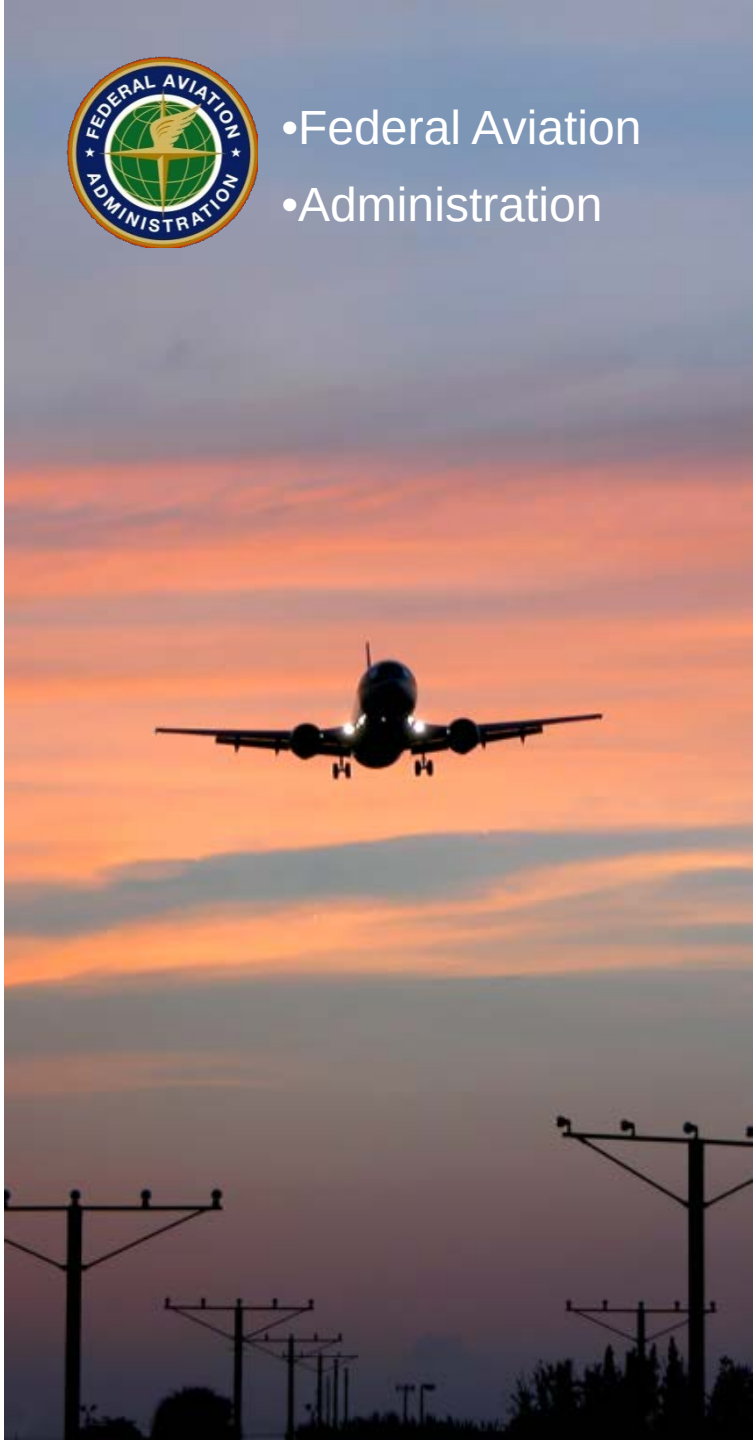
- Federal Aviation
- Administration



Overview

- **The advisory circular (AC) sets forth an acceptable means, but not the only means, for demonstrating compliance with Title 14, Code of Federal Regulations (14 CFR) 23.562, 25.562, 27.562, and 29.562, as well as Technical Standard Order (TSO) TSO-C127a, and TSO-C127b.**

Overview

- **AC 20-146 was signed on May 19, 2003 and is superseded**
- **Revision A was signed on 29 June, 2018 and is available for use**
  - Intended as a minor revision with an eye on a future, more significant revision/creation of a general M&S AC

Document Outline

1. Purpose
2. Applicability
3. Cancellation
4. Background
5. Related Publications
6. Definitions
7. Verification of Explicit Codes
8. Computer Model Validation
9. Application of Computer Modeling in Support of Dynamic Testing
10. Application of Computer Modeling Instead of Dynamic Testing
11. Seat Certification and Coordination Process
12. Documentation Requirements for Compliance
13. Appendix 1: Occupant Trajectory and HIC
14. Appendix 2: Load Time Histories

Revision A Highlights

- **Language clean up**
- **Added Verification Section**
- **Removed list of codes**
- **Added reference SAE ARP 5765 Rev A**
  - v-ATD calibration
- **Added reference to ASME V&V 10**
- **Revised acceptance criteria**
  - Building block approach
  - Updated Appendices A and B
  - Some new acceptance levels
    - HIC and Lumbar Load

Applicability

- **For:**
  - Aircraft manufacturer not using a TSO approved seat [e.g. GA and rotorcraft]
  - Seat manufacturer
  - Manufacturer installing a TSO approved seat
- **Uses:**
  - Establish critical seat installation/configuration
  - Changes to a compliant seat

Verification

- **Original AC discussed FE stability, time step, and mass scaling in section 6 [Definitions]**
- **New section provides more details on code and calculation verification**
  - Code verification is the process of determining that the numerical algorithms are correctly implemented in the computer code and of identifying errors in the software
  - Calculation verification, also called solution verification, is the process of determining the solution accuracy of a particular calculation

Validation

- **References SAE ARP 5765A for v-ATD calibration**
- **General Validation Acceptance Criteria**
- **Application-Specific Validation Criteria**
  - Building block approach
- **Discrepancies**
- **Computer Hardware and Software**
  - Configuration control

Validation - General

- **Engineering judgment and ACO-Applicant communication are vital**
- **Validate parameters that are relevant to the application of the model**
- **Model extrapolation should be limited to conditions similar to the model validation conditions**
- **"V&V cannot prove that a model is correct and accurate for all possible scenarios, but rather accumulate evidence that the model is or is not sufficiently accurate for its intended uses." – ASME V&V 10.2 [draft]**

8.3 Application-Specific Validation Criteria

- **The applicant should validate relevant parameters to the application of the model. The applicant and the ACO should identify and agree on the validation criteria specific to the application, and the certification plan should list those criteria. The applicant and the ACO should negotiate any additional validation criteria not listed in this AC. The following paragraphs provide guidance on the validation parameters to consider; however, the final levels should be coordinated with the ACO. If no acceptable rationale is available to make this determination, then the details listed in the following paragraphs may be followed:**

8.3.2.1 Structural Response – Internal Loads

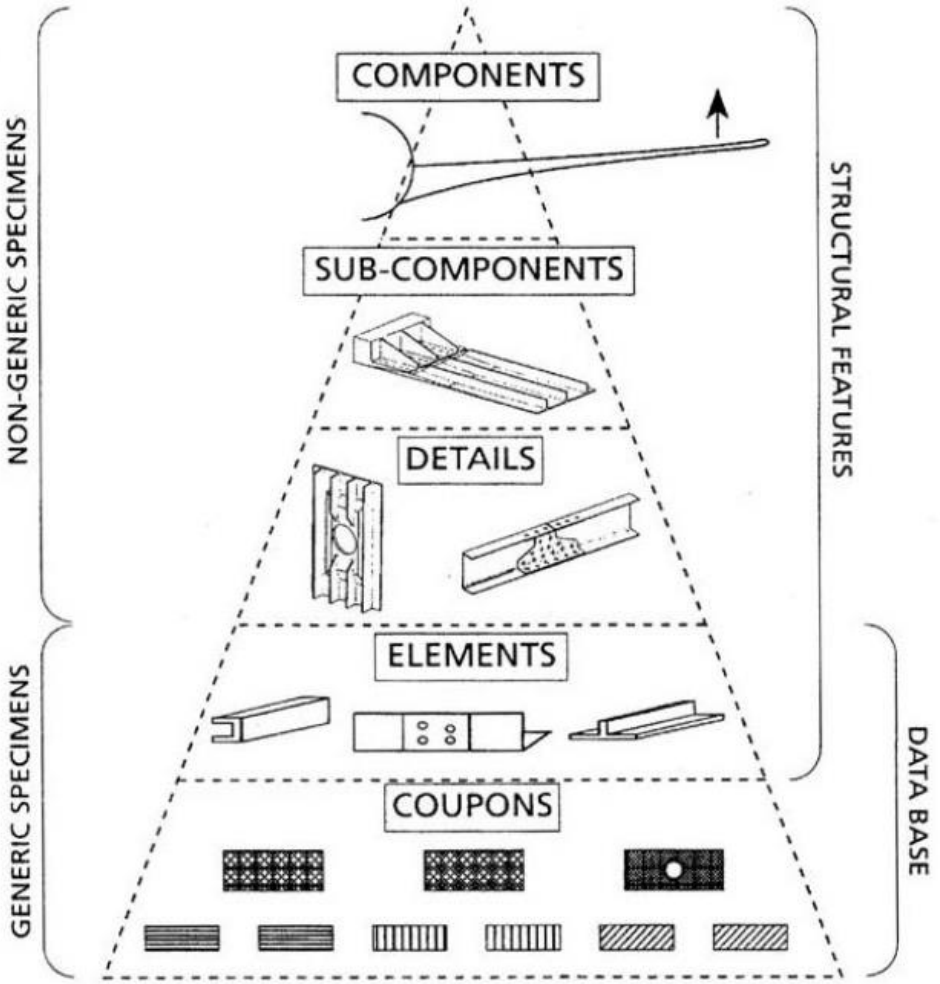
- **The peak critical floor reaction loads between the analysis and test data should correlate to within 10 percent unless a different level of correlation was determined prior to the initiation of any program.**

- **Other subsections in 8.3 do not include the red text, but the intent was to follow that (per preamble of 8.3)**

Model Conservatism

- **“Conservative simulation results are encouraged, but not required”**
- **Can use conservative inputs**
  - More stringent sled pulse
  - Conservative material properties
    - May need to run more than one simulation
- **Can use conservative limits**
  - Similar to HIC and lumbar load “factor of safety”

Building Block Approach



Model Tuning

- **“The ad hoc adjustment of model parameters to bring the model into better agreement with experimental outcomes is counterproductive and strongly discouraged. In some references, this selective model tuning is also called model calibration. Here, we make a clear distinction between the ad hoc tuning of a few select parameters vs. model calibration. Model calibration is the systematic process of minimizing the difference between model predictions and calibration measurements with the goal of improving model parameter estimates. While selective “model tuning” may result in better agreement between the experiment and the model, the overall predictive capability of the model may be compromised, leading the model to produce the right answer for the wrong reasons.” – ASME V&V 10.2 [draft]**
- **If parameter estimation is required, do it on sub-models and lock in those parameters for the higher level models.**

Validation – HIC

- **To account for testing uncertainty**
  - Assuming variance of ± 200 HIC points
  - 95% confidence of meeting regulation if test HIC is ≤ 890
- **Only original designs with test response ≤ 890 eligible [previous limit was 700]**
- **Model should be within 100 HIC units**

- **This is essentially a factor of safety / attempt to address some uncertainty**

HIC – Model Use Limits

- For modified configuration/installation, only model predictions ≤ 890 eligible
- Extrapolation limit a function of the degree of conservatism seen in validation
- For model that under-predicts the test result, the predicted HIC must not exceed 890 minus the magnitude of the under-prediction.

	Validation	Model Use
Model under predicts	Test = 850, Model = 800	Model = 840 or less
Model over predicts	Test = 850, Model = 900	Model = 890 or less

Validation - Lumbar Load

- **To account for testing uncertainty**
  - Assuming variance of ±125 lb
  - 95% confidence of meeting regulation if test load is ≤ 1430 lb
- **Only original designs with test response ≤ 1430 lb eligible**
- **Model should be within 10%**

- **This is essentially a factor of safety / attempt to address some uncertainty**

Lumbar Load – Model Use Limits

- **For modified configuration/installation, only model predictions ≤ 1430 lb eligible**
- **Extrapolation limit a function of the degree of conservatism seen in validation**
- **For model that under-predicts the test result, the predicted load must not exceed 1430 pounds minus the magnitude of the under-prediction.**

	Validation	Model Use
Model under-predicts	Test = 1400, Model 1350	Model ≤ 1380 lb
Model over-predicts	Test = 1400, Model 1450	Model ≤ 1430 lb

Application in Support of Testing

- **Determination of worst-case seat design**
- **Determination of worst-case seat installation**
- **Determination of occupant strike envelope**
  - Potential for head strike
  - Determine items required in test setup

Application Instead of Testing

- **Seat System Modification**
  - Modification of a certified seat configuration
- **Seat Installation Modification**
- **Limitation**
  - Changes to seat-floor attachment structure require a new series of dynamic tests

Certification and Coordination Process

- **FAA Coordination**
- **Certification Plan**
- **Technical Meeting**
- **“The document, referred to as the certification plan, should be developed in conjunction with the seat design evaluation phase and approved by the FAA as early in the certification process as possible.”**

Documentation Requirements

- **Validation and Analysis Report (VAR)**
- **Purpose of Model**
  - Modeling in support of or instead of testing
  - List 14 CFR or TSO requirements
- **Validation Criteria**
- **Overview of Seating System**
- **Software and Hardware Overview**
- **Description of Model**
  - Discuss assumptions with rational support

Documentation Requirements

- **Result Interpretation**
  - Energy Balance
    - Hourglass modes
  - Data Output [Frequency]
  - Data Filtering
  - Ultimate Margin of Safety

Appendix 2

- **Test-Simulation Comparison Methodology**
- **Objective, quantitative comparison of time histories**
- **Comparison of the peaks**

Conclusion

- **AC 20-146a is released and ready for use**
- **Change 1 being coordinated now – later presentation**