Methodology for Dynamic Seat Certification by Analysis

Presented to: CBA Workshop

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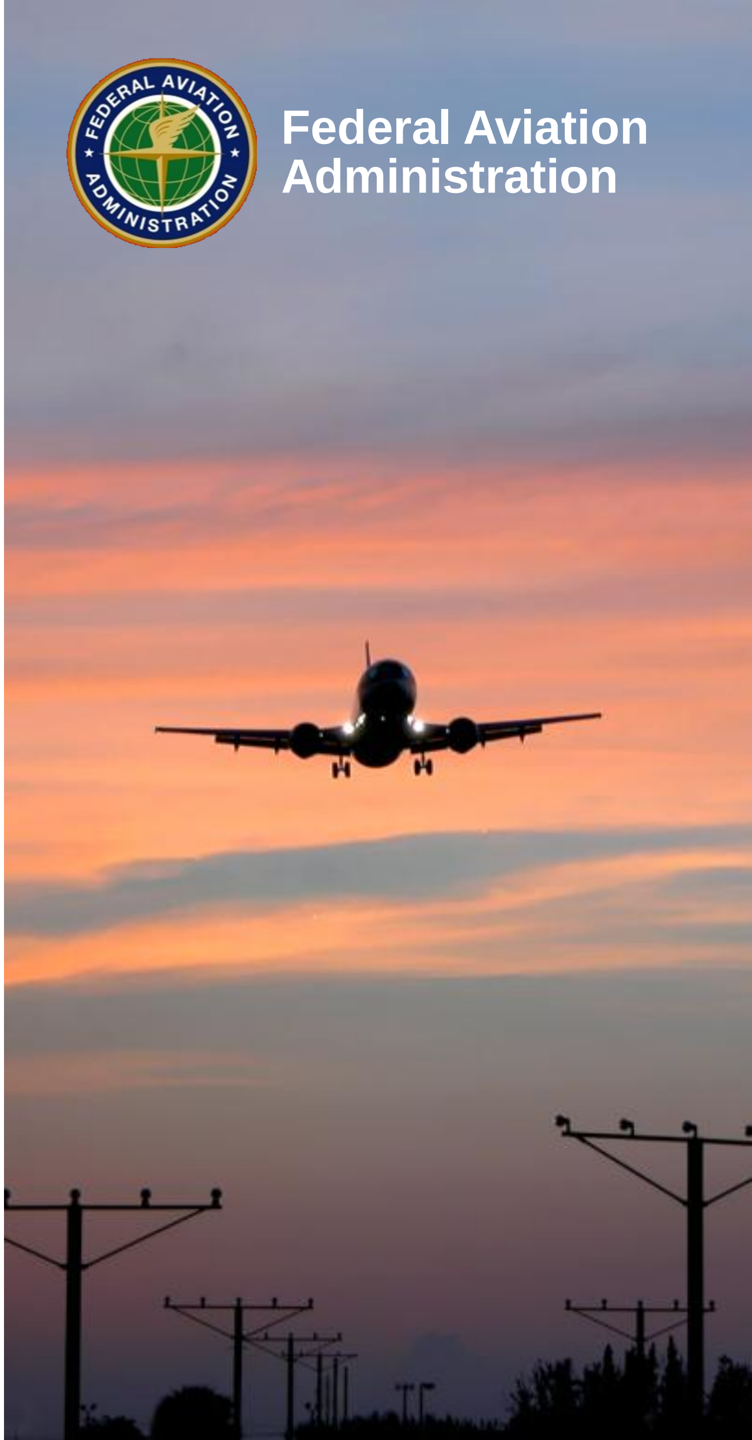


Nomenclature

- **Analysis – computer modeling representing the physical test - a prediction**
- **Verification – are the equations being solved correctly - math**
- **Validation – are the right equations being used - physics**
- **Calibration – adjusting values to improve agreement with test data**
- **Adequacy – is the level of agreement acceptable for our intended use**

Certification by Analysis

AC 20-146: Methodology for Dynamic Seat Certification by Analysis for use in Parts 23, 25, 27, and 29 Airplanes and Rotorcraft

(1) Purpose

- **AC 20-146 was signed on May 19, 2003 and is available for use**
- **Provides guidance on demonstrating compliance to 14 CFR §§ xx.562 or TSO-C127/C127a using computer modeling**
  - How to validate
  - Under what conditions the model may be used
- **Use of this AC will be evolutionary as both the industry and the FAA "get smart" on transient finite element modeling**
- **Not mandatory**

(4) Applicability

- **For:**
  - Aircraft manufacturer with seat as part of the type design and not using a TSO approved seat
  - Seat manufacturer building to the TSO
  - Manufacturer installing a TSO approved seat
- **Uses:**
  - Establish critical seat installation/configuration
  - Compliance to 2x.562
    - Changes to a baseline design
    - Compliant seat

(6) Definitions

- **Seating Configuration**
  - Aircraft interior floor plan, defines seating positions
- **Seating/Restraint System**
  - Seat structure, cushion, harness, attachments
- **Family of Seats**
  - Group of seat assemblies with similar designs
- **Load Path**
  - Components that carry the load
- **Baseline Seat**
  - 1st seat designed and manufactured within a new family of seats

(6) Definitions

- **Computer Modeling**
  - MADYMO
  - MSC/DYTRAN
  - LS-DYNA3D
  - Equivalent codes
- **Hybrid III if:**
  - FAA Hybrid III or similar modification
  - SAE AS8049A are satisfied

(6.1) Stability

- **Transient explicit FE codes – direct integration**
- **Pay attention to time step**
- **Select $\Delta t <$ critical**
- **A part of verification**
  - Code verification
  - Calculation verification
    - Temporal Convergence Accuracy
    - Spatial Convergence Accuracy

(7) Validation

- **Engineering judgment and ACO-Applicant communication are vital**
- **Validate parameters that are relevant to the application of the model**
  - Lumbar load not critical in many horizontal tests
  - Restraints may become slack during download test
  - Lateral floor loads are often small compared to horizontal and vertical

What is important in a physical sled test?

(7) Validation (cont'd)

- Validate against dynamic tests
- Validation and model use conditions should be similar
- Consider accuracy of test data
- Occupant trajectory should match test data
- Applicant and ACO should agree on application specific validation

(7.1.1.1) Validation – Occupant Trajectory

- **Translation and rotation of the dummy**
  - With respect to Seat Reference Point (SRP, CRP)
  - Head path, pelvic displacement, torso disp.
  - Head strike is key portion of head path
    - Position and Velocity (angular velocity)

(7.1.1.2) Validation – Structural Response

- **Critical floor reaction loads**
  - Load path from occupant to restraint to floor
  - Peak and time history should correlate
- **Structural deformation in critical members**

(7.1.1.3) Validation – Restraint Systems

- **Restraint load peak and time history**
- **Belt payout or permanent elongation**
  - If seen in dynamic tests
- **Although belt loads affect occupant trajectory, each should be evaluated independently**

(7.1.1.4) Validation – Head Injury Criteria (HIC)

- **Modeling may be used in lieu of testing if (not exhaustive list):**
  - Head path shows no contact
  - Impact surfaces are identical and original HIC < 700
  - Rigid structure tested is replaced with a less rigid structure (equivalent head velocity)
  - Tested HIC < 700 and simulation HIC within 50 units, as long as predicted HIC < 700, can be a different impact surface
  - Conservative HIC predictions are preferred

(7.1.1.5&7.1.1.6) Validation – Spine & Femur Loads

Spine Loads

- **Spine load should be correlated if design change is expected to affect this parameter**
  - I.e. seat cushion change
- **Correlate within 10%**

Femur Loads (Part 25)

- **If ACO and applicant determine there is a risk, peak femur load should be correlated**

(7.1.3) Validation – Hardware/Software

- **Certification modeling should be performed on the same hardware and software platform as that used for validation**

- **The software should be verified**
  – By end-user or vendor (more common)

(7.2) Validation Documentation

- **Applicant is entitled to documentation from the FAA stating that a model has been validated [for intended use]**
- **Possible inclusions:**
  - FAA acceptance statement
  - Identification of software versions and hardware platforms used
  - Description of limitations *
  - Configuration control of the model

(8) Application in Support of Testing

- **Not an exhaustive list**
- **Determination of worst-case seat design**
  - ID critically loaded structures
  - Selection of critical seat tracking positions
  - Evaluation of restraint system
  - Evaluation of yaw condition
  - Number of seat places occupied
  - Selection of worst-case seat cushion build-up

(8) Application in Support of Testing

- **Determination of worst-case seat installation**
  - Over-spar vs. non over-spar configurations
  - Installation location which effects restraint anchor positions
- **Determination of occupant strike envelope**
  - Potential for head strike
  - Determine items required in test setup

(9) Application in Lieu of Testing

- **Seat System Modification**
  - Modification of a certified seat configuration
    - Consider ultimate margin of safety
- **Seat Installation Modification**
  - HIC compliance
- **Limitation**
  - Changes to seat-floor attachment structure require a new series of dynamic tests

(10.2) Certification Plan – Applicant's Role

a. Acquaint FAA personnel with project
b. Discuss details of the project
c. Identify compliance paragraphs
d. Negotiate use of computer modeling
e. Establish means of compliance
f. Establish validation criteria
g. Prepare & obtain FAA ACO approval of certification plan

(10.3) Technical Meeting - Certification Plan Document

a. Description of seat to be modeled
b. Description of software
c. Description of compliance
d. Description of material data sources
e. Validation methods
f. Interpretation of Results
g. Substantiation documentation

(11) Documentation Requirements

- **Validation and Analysis Report (VAR)**
  - Provide documentation of validation criteria and the analytical results

11.1: Purpose of Model
  - Modeling in support of or in lieu of testing
  - List 14 CFR requirements

11.2: Overview of Seating System
  - Seat Structure
  - Restraint System
  - Unique Energy Absorbing Features

(11) Documentation Requirements

11.3: Software and Hardware Overview

- Define hardware (type & platform)
- Define software (type & version)

11.4: Description of Model

- Assumptions with support
- Finite element models & limitations
- Material models and source of data
- Constraints
- Load application
- Occupant model (include release number)
- General analysis control parameters

(11) Documentation Requirements

11.5: Analytical Result Interpretation

- Energy Balance
  - Hourglass modes
- Data Output
  - Channel class 1000
- Data Filtering
  - SAE J211
- Ultimate Margin of Safety

$MS_{ultimate}$ = 100 * ([Ultimate Strength / Ultimate Load] – 1)

Appendix 2: Load Time History

- **Peak Load within 10%**
- **Phasing**
- **General shape is represented**
  - "Does the comparison **look** reasonable?"
- **Conservative is better**
- **Unloading portion is less important then loading and peak**

Good Correlation

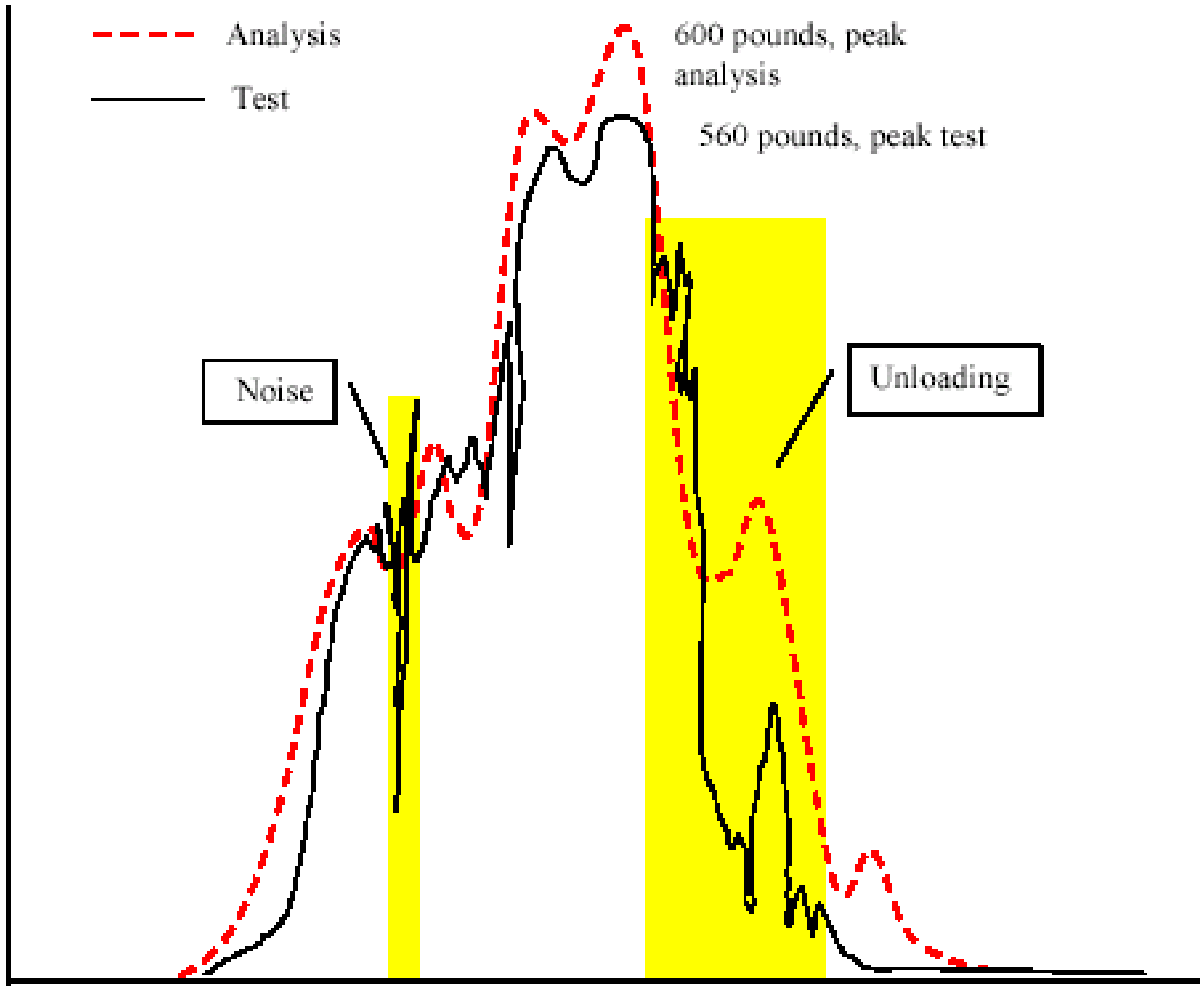
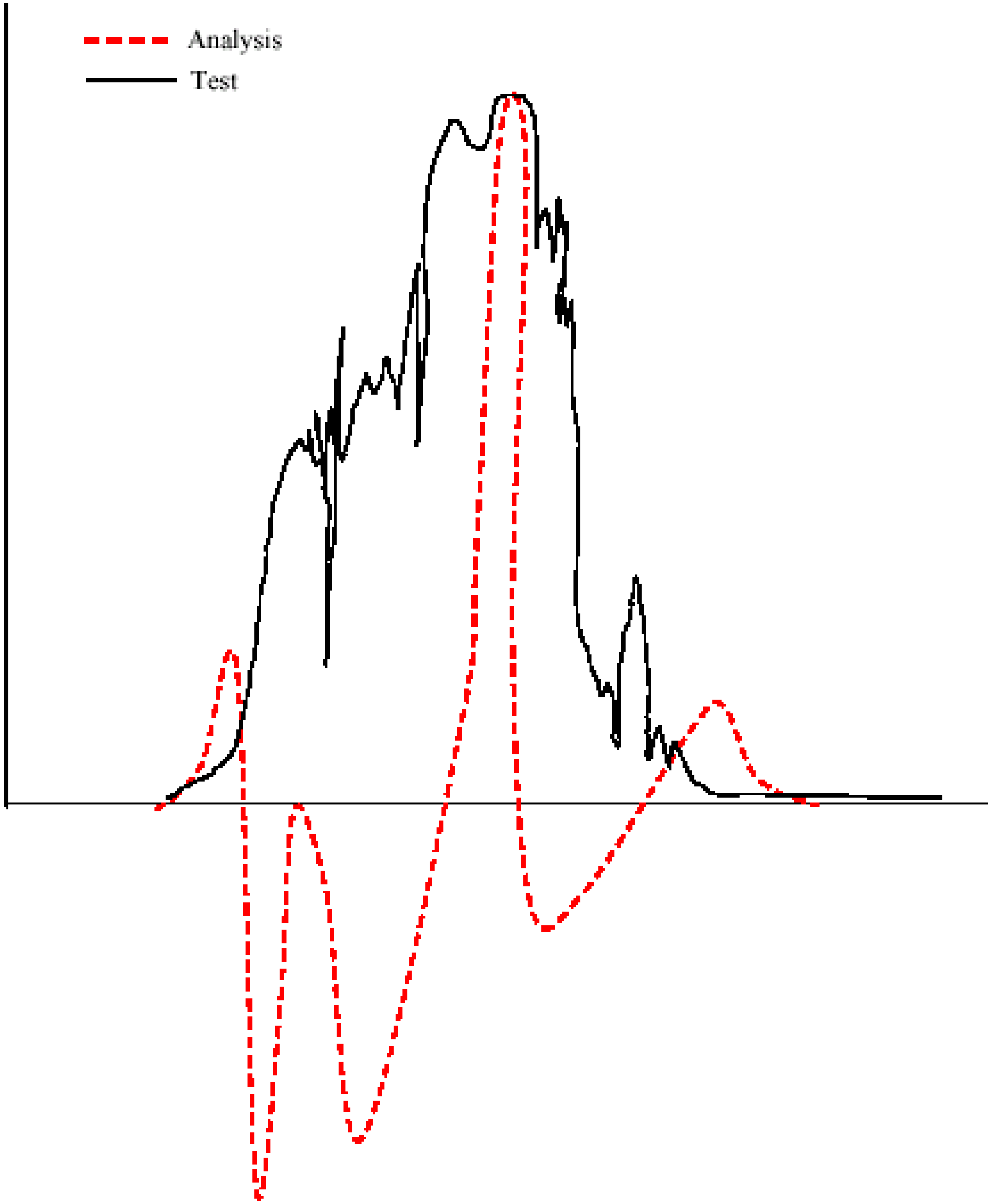


Figure 5 – Hypothetical Load vs. Time (Good correlation)

Poor Correlation



Appendix 1: Occupant Trajectory

Hypothetical Example

Part 25: 16 g, horizontal test

Occupant impact into bulkhead covered with ethafoam

See AC for details

Conclusions

- **Current AC flexible**
  - Discuss with the ACO on validation and usage
- **Provides some details**
  - Software and models
- **Lacks other details**
  - What is considered valid
- **Places restrictions**
  - HIC <700
- **Released almost 10 years ago**