Aircraft Seat Certification by Analysis from a Regulatory Perspective

Presented to: SAFE Chapter One

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Disclaimer

- Certification approvals are based on federal regulations, official FAA policy, and certification engineers – not research opinions
Background

• Federal regulation requires OEMs to demonstrate safety of aircraft components
  – Typically through physical testing
  – NHTSA has similar requirements for automobiles
  – FHWA has similar requirements for roadside safety equipment

• Cost vs. volume vs. injuries prevented is complex

• Congressional mandate to evaluate streamlining certification
  – HR 1000 Section 757
Crashworthiness Requirements

• No specific dynamic requirement for airplane level crashworthiness
• Demonstrate equivalent level of safety
• Impact conditions up to 30 ft/sec
• Passenger load
  – 2/3
  – Maximum
• Requirements on the seat performance
Dynamic Impact Standards

• Requirements on the seat performance

• Developed from
  – Accident data
  – Parametric studies
  – Existing guidelines
  – FAA/NASA research

• Provide occupant safety metrics

• Typically met through testing
  – Modeling and simulation is an option
Dynamic Impact Standards
– Test 1

• Combined Vertical/Longitudinal
  – Velocity change not less than 35 fps
    • Vertical 30.3 fps
    • Longitudinal 17.5 fps
    • Peak Deceleration 14 G’s minimum
  – Rise time = 0.08 sec
  – Floor deformation
    • None
  – Evaluates spinal loads and injury
Dynamic Impact Standards – Test 2

• **Longitudinal**
  – Velocity change not less than 44 fps
    • Peak deceleration 16 G’s minimum
  – Rise time = 0.09 sec
  – Floor deformation
    • 10° pitch
    • 10° roll
  – Assess occupant restraint system
  – Assess seat structural performance
## Dynamic Impact Standards

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- Corresponding injury metrics
  - HIC, Lumbar load, structural requirements

14 CFR 2X.562
Factors in Crash Survivability

• Demonstrate up to 30 ft/s vertical
  – Retention of items of mass
  – Maintenance of occupant emergency egress paths
  – Maintenance of acceptable acceleration and loads experienced by the occupant
  – Maintenance of survivable volume

• Provides structural envelope for seat performance
Occupant Focus

• Four factors – prevention of injury to occupants
• Relate to space and energy management around the occupant
• Can be met by occupant/seat interface
  – Assumes a minimum amount of energy management input
Modeling & Simulation

• Can be used for new designs
• Will require demonstration of ELOS
  – Demonstrate factors
• Will require testing to support validation
  – Drop Test
  – Components
Crashworthiness “Inside-Out Method”

• Phase 0: Define Occupant Injury Limits | FAR *.562 |

• Phase I: Develop and validate occupant ATD numerical models |CBA I Part I: Experimental and Computational| SAE ARP 5765 |

• Phase II: Define Modeling and Certification by Analysis Processes of Aerospace Seat Structures and Installations |AC 20-146|CBA I Part II: Experimental and Computational| SAE ARP 5765 |

• Phase III: Define Crashworthiness Requirements for Aircraft Structures |CBA II : Computational and Experimental/Accident Data Analysis|

• Phase IV: Define Structural CBA Methodology |CBA II : Computational and Experimental Procedures|
Modeling & Simulation

• **AC 20-146**  
  – Methodology for Dynamic Seat Certification by Analysis

• **SAE ARP 5765**  
  – Analytical Methods for Aircraft Seat Design and Evaluation  
    • Numerical Dummy Validation  
    • Best Practices Guide

• **Guidelines for other aircraft items**
16G Frontal Test
Sled Test Video
Sled Test Video
Sled Test Video
Horizontal Test
Combined Vertical/Horizontal
Modeling & Simulation

• Potential to reduce testing costs
  – Reduce the number of program tests, number of failures

• FAA policy allows computer modeling to support / be used in lieu of testing
  – Other federal agencies have similar policies (FHWA, FDA, etc)

• Advisory Circular 20-146: Seat Certification by Analysis [guidance material] - 2003
  – An acceptable means to show compliance to Federal Regulation
  – High-level guidance on the validation of seat models
Section 4: V-ATD Validation

Validity of V-ATDs based on 2pt, 3pt, 4pt (Test condition 1 & 2)

- Mass and Geometry
- Pelvis Shape
- Dynamic response
- Defines compliance criteria
- Provides specifications and performance criteria

How to evaluate the accuracy of seat models?

- Defines min set of test parameters and data needed to evaluate the degree of correlation between the model and the physical test,
- provides procedures for quantitative comparison of test and modeling results.

Section 5: System Validation

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Section 6: Testing & Modeling Best Practice

Provides current best test & modeling practices that have been found to improve the efficiency and validity of computer models

Appendix: Methodology for comparison of Test and Simulation Waveforms

Appendix B & C: Data set for Hybrid II and Hybrid III.

Appendix D: Sample V-ATD calibration report.
Physical Testing

- Certification testing is deterministic
  - Limited to point validation?

- Industry typically considers every test to be a certification test
  - Extra costs related to certification requirements
  - Limit instrumentation to only what is required
  - No repeat tests on same hardware
  - Uncontrolled parameters in test setup
Certification by Analysis Issues

• Requirement Definition
• Prediction of Failures
• Uncertainty Quantification
• One-sided Pass/Fail Criteria
Issue: Requirement Definition

• Industry wants a procedure to follow that will be acceptable to the FAA
  – Physical Test: Run these tests, results < limits = pass
  – M&S: Build model, results < limits = pass

• FAA has limited experience with M&S for seats
• FAA relies on companies to follow appropriate (modeling) techniques - V&V

• The FAA has proposed to work closely with applicants to increase the chance of success
Issue: Prediction of Failures

• **Deterministic testing**
  – Multiple possible failure modes
  – Repeatability of failure modes?

• **AC: validate to a passing test**
  – Provide confidence in ability to predict failure?

• **Tests on seats occasionally fail; industry has shown an interest in modeling these scenarios**
  – Hardware changes in parts that failed

• **Modification to Policy**
Issue: Uncertainty Quantification

- Policy (unintentionally) disincentives industry from running repeated tests
  - A second test resulting in a pass is of no value, while a fail requires a structural modification

- Test Repeatability (test procedure, ATDs)
  - Data mostly from researchers
  - Testing procedures different between certification tests and tests for model development/validation

- Building block approach
- Sensitivity analysis
Issue: One-sided Pass/Fail Criteria

- P/F criteria is “do not exceed”
- Error metrics typically do not factor in conservatism

Effect on extrapolation
- If my model under/over predicts (as seen in validation), should I adjust outcomes to account, or limit use of the model
  - Positive validation => acceptable for intended use

AC limits use to cases where results are not close to limits
- Seat designs tend to be close to limits
Good Points in FAA Approach

• FAA interested in pursuing CBA
  – Flexibility

• AC has documentation requirements
  – Detail level is needed

• AC recommends engineering judgment

• AC advocates early communication

• Healthy skepticism
  – “Prediction is hard, especially about the future!”
Path Forward

• **Industry Best Practices**
  – Common for all aspects of seat design/testing

• **Advisory Circular update**

• **Working closely with industry for initial certification programs**

• **FAA Research and Training**
  – Improve testing procedures/data collection
  – Certification Engineers are not necessarily M&S experts
Related Documents

• **AC 20-146**
  - http://rgl.faa.gov/
  - Click Advisory Circulars
  - Search for 20-146

• **SAE ARP 5765 (Published October 2012)**
  - http://standards.sae.org/arp5765