# Crash Dynamics Summary

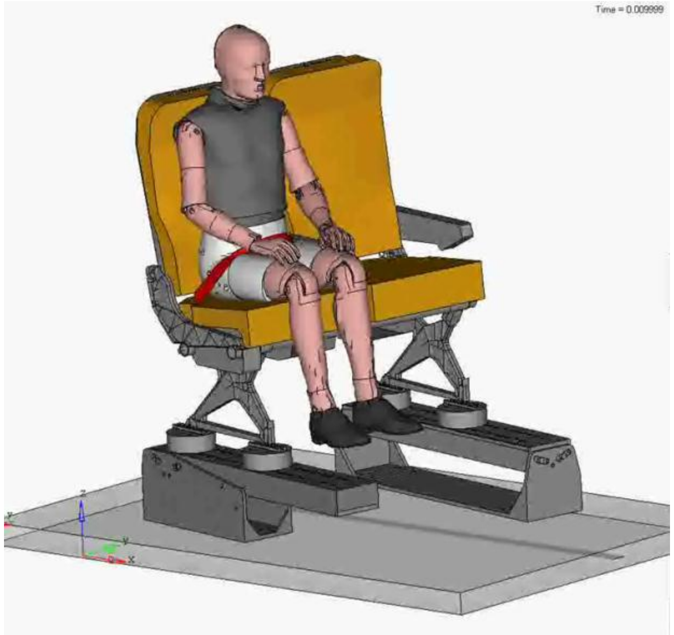
*Presented to: FAA/EASA/Industry Composite Transport Fatigue, Damage Tolerance, Maintenance and Crashworthiness Workshop*

*By: Joseph Pellettiere, Chief Scientific and Technical Advisor for Crash Dynamics*

*Date: 19 May 2011*

# Overview

- **History**
  - Provide basis of regulations
- **Modeling and Simulation**
  - How to apply M&S to regulations



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## Modeling and Simulation


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# Crashworthiness Requirements

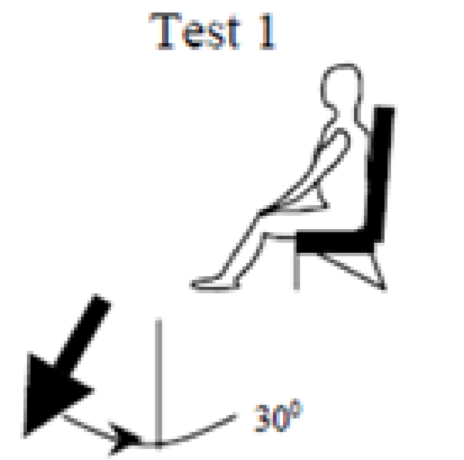
- **No specific dynamic requirement for airplane level crashworthiness**
- **Demonstrate equivalent level of safety**
- **Impact conditions up to 30 ft/sec**
- **Passenger load**
  - 2/3
  - Maximum
- **Requirements on the seat performance**

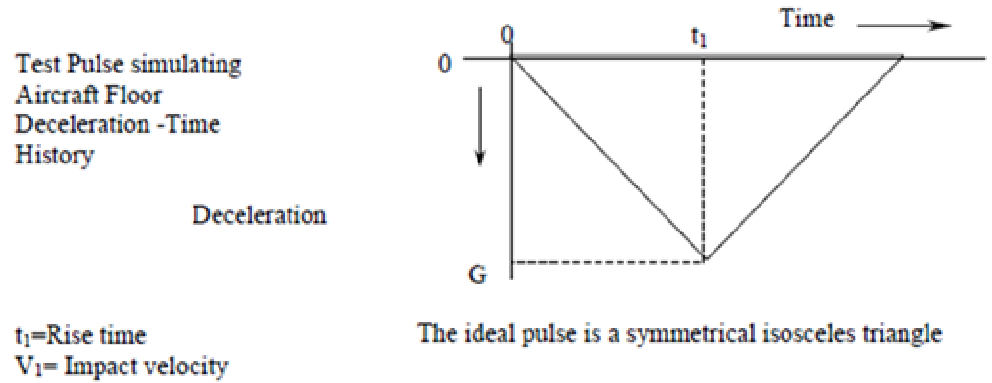
# Dynamic Impact Standards

- **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

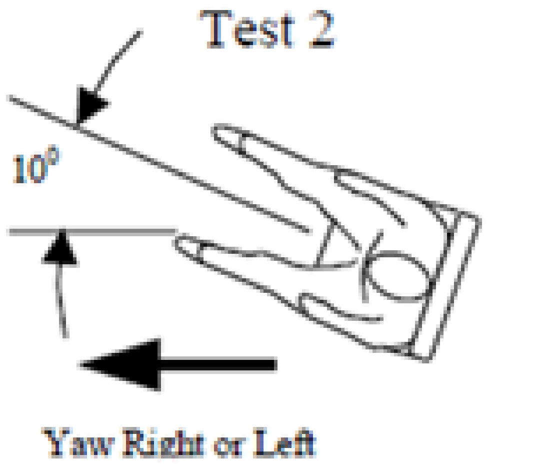
- **Combined Vertical/Longitudinal**
  - Velocity change not less than 35 fps
    - Vertical 30.3 fps
    - Longitudinal 17.5 fps
    - Peak Deceleration 14 G's minimum
  - Rise time = 0.08 sec
  - Floor deformation
    - None
  - Evaluates spinal loads and injury

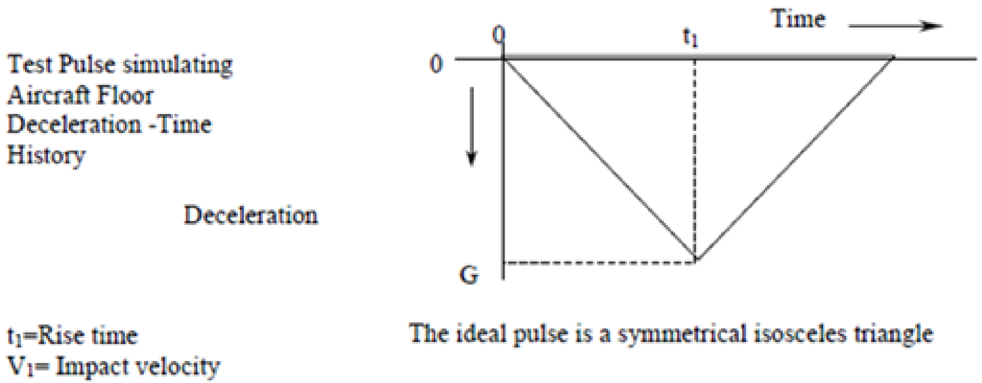


# Dynamic Impact Standards – Test 2

- **Longitudinal**
  - Velocity change not less than 44 fps
    - Peak deceleration 16 G's minimum
  - Rise time = 0.09 sec
  - Floor deformation
    - $10^{o}$ pitch
    - $10^{o}$ roll
  - Assess occupant restraint system
  - Assess seat structural performance



# Factors in Crash Survivability

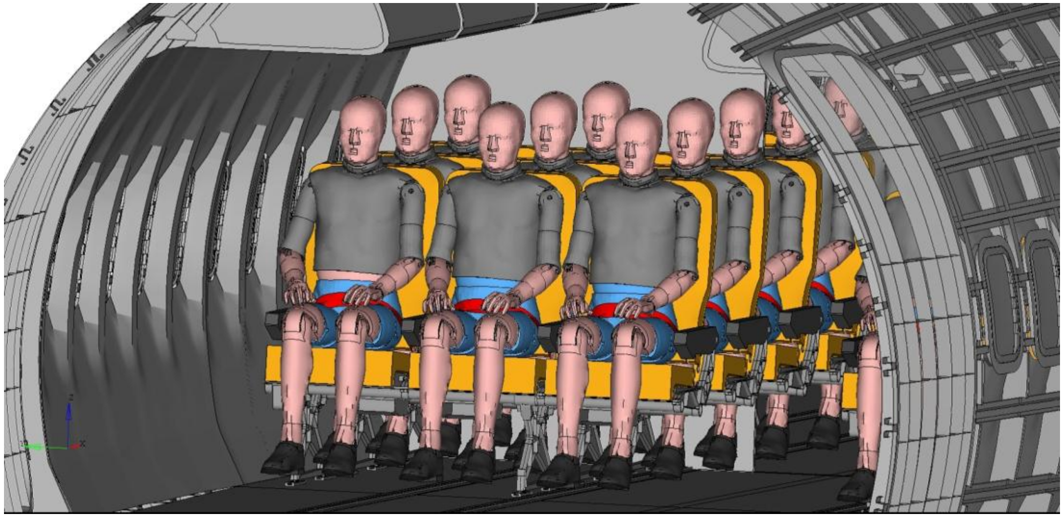
- Retention of items of mass
- Maintenance of occupant emergency egress paths
- Maintenance of acceptable acceleration and loads experienced by the occupant
- Maintenance of survivable volume

# Occupant Focus

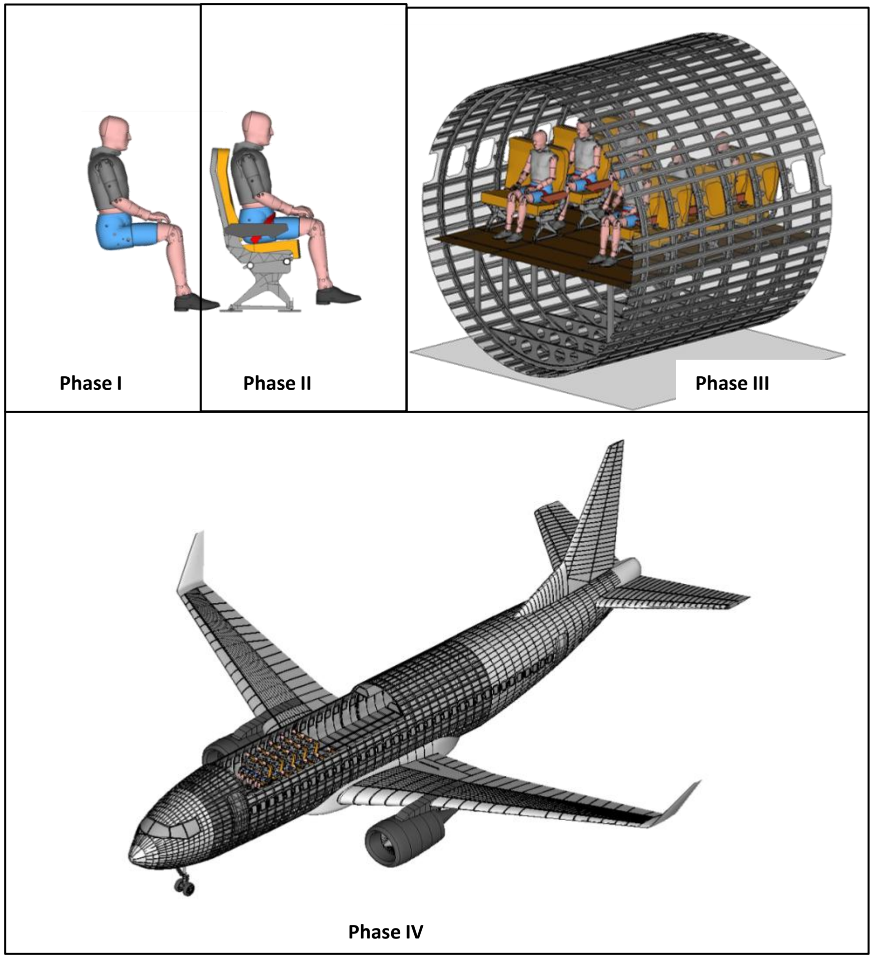
- **Four factors – prevention of injury to occupants**
- **Relate to space and energy management around the occupant**
- **Can be met by occupant/seat interface**
  - Assumes a minimum amount of energy management input

# 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**

# AC 20-146

- **Purpose: Acceptable means to demonstrate compliance with computer analysis validated by DYNAMIC TESTS**
- **23/25/27/29.562**
- **Defines**
  - Minimum validation guidelines
  - Minimum documentation requirements
  - Conditions for use
  - Limitations

# Modeling in Support of Dynamic Testing

- **Determination of worst-case for a seat design**
- **Determination of worst-case scenario for seat installation**
- **Determination of occupant strike envelope**
- **Seat system modification**
- **Seat installation modification**
  - Does not include seat-floor attachment

# Validation Acceptance

- **Validation against Dynamic Tests**
- **Use consistent with validation conditions**
- **Correlation demonstrated with**
  - Occupant trajectory
  - Floor loads
  - Restraint system loads
  - Head Injury Criterion (HIC)
  - Spine load
  - Femur compressive load

# Documentation Requirements

- Validation and Analysis Report
- Background and description of seat
- Description of model
- Assumptions
- Conditions and analysis parameters
- Analytical results

# SAE ARP 5765

**Provide a quantitative method to measure and evaluate the degree of correlation between a model and a physical test, and to provide best modeling practices to improve the accuracy and predictability of seat analyses**

# SAE ARP 5765 Outline

- **v-ATD Calibration**
  - Establish v-ATD performance criteria
- **Seat System Verification and Validation**
  - How to evaluate the accuracy of seat models
- **Seat Modeling Best Practice Guide**
  - Testing
  - Modeling
- **Appendices**
  - Test-Simulation Comparison Methodology
  - Dataset for Hybrid II
  - Dataset for FAA-Hybrid III

# v-ATD Calibration

- **Industry lacked multiple v-ATDs that produced accurate results in aviation-specific scenarios.**
- **Goal: define the process for ensuring that v-ATDs match the anthropometry and kinematic performance of a physical ATD for aviation-specific applications**
  - Component Response (head, chest, knee, etc.)
  - Pelvic Shape Evaluation (cushion interaction)
  - Dynamic Response
    - Forward Facing (FF) 2pt, FF 3pt, FF 4pt, Download
  - Appendices B & C: NIAR Test Information

# System Validation

- **Ensure that the system (v-ATD, restraints, seat, etc.) behaves in a predictable manner**
- **Verification**
  - Code
  - Calculation
- **Validation**
  - Materials
  - Component Test
  - Sensitivity Analysis
- **Documentation**

# Best Practices: Testing

- **Provide guidance for things to consider during test setup so that the necessary information is collected to support modeling**
- **Modifications to typical test protocols to collect quality data for modeling**
  - Consistent ATD positioning
    - Joint locations, pelvic angle
  - Belt information (material props, lengths, pre-tension)
  - Tips for photometric analysis
    - H-pt
    - Knee

# Best Practices: Modeling

- **Information needed to build aircraft specific models**
  - Global Parameters
  - Physical Discretization
  - Material Definition (metals, foam, plastic)
  - Contact Definition
  - Load Application
  - Initial Conditions (ATD positioning, pitch and roll)
  - Output Control

# Summary

- Occupant safety through seat testing
- M&S can be used for seat certification
- Can support full airframe crashworthiness
- Testing will still be required