SAE ARP 5765: Analytical Methods for Aircraft Seat Design and Evaluation

Presented to: IAFCSRC

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Date: 26 October 2010

Background

- **AC 20-146: Methodology for Dynamic Seat Certification by Analysis for Use in Parts 23, 25, 27, and 29 Airplanes and Rotorcraft**
  - Signed in May 2003; allows simulation results to be used in support of seat certification
  - Provides high-level guidance on the validation of seat models
  - Defines the conditions under which computer modeling can be used in support of certification

SAE SEAT Committee

- **Industry group that defines industry best practices (includes FAA & Academia)**
  - Aviation Standard (AS)
  - Aviation Recommended Practice (ARP)
  - Aviation Information Reports (AIR)
- **SAE ARP 5765: Analytical Methods for Aircraft Seat Design and Evaluation**
  - Being developed by a working group within the SEAT committee
  - Started in 2007

ARP 5765: Goal

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 (95% complete)

- **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

Dynamic Response

- **Original component tests specified considering an automotive interior**
- **Need to evaluate the ATD performance for conditions likely in aircraft seat tests**
  1. FF 2pt belt: extreme flail envelope
  2. FF 3pt belt: torso twist
  3. FF 4pt belt: submarining
  4. Download: vertical crash vector

Channel Description	Forward Facing 2-Point Belt	Forward Facing 60 Deg 2-Point Belt	Forward Facing 3-Point Belt	Forward Facing 4-Point Belt
Sled Ax	X	X	X	X
Upper Neck Fx *			X	X
Upper Neck Fy *			X	
Upper Neck Fz *			X	X
Upper Neck Mx *			X	
Upper Neck My *			X	X
Chest Ax (CFC 180)			X	X
Lumbar Fz		X		
Lumbar My		X		
Right Lap Belt Load	X		X	X
Left Lap Belt Load	X		X	X
Right Shoulder Belt Load				X
Left Shoulder Belt Load			X	X
Seat Pan Fx	X	X	X	X
Seat Pan Fz	X	X	X	X
Seat Pan My	X	X	X	X
Head CG X Position	X	X	X	X
Head CG Z Position	X	X	X	X
H-point X Position	X		X	X
H-point Z Position	X	X		
Knee X Position	X			X
Knee Z Position	X			X
Ankle X Position	X			
Ankle Z Position	X			
Shoulder X Position			X	X
Shoulder Z Position			X	X
Opposite Shoulder X Position			X	
Opposite Shoulder Z Position			X	
Head Angle	X			X
Pelvis Angle	X	X		X

* FAA-Hybrid III only

Comparison of Test-Sim Curves [Appendix A]

- **Input:**
  - Consistent units
  - Appropriate sampling rates
    - 10 kHz for electronic instrumentation
    - 1 kHz for photometric
  - Equal time lengths.

- **Duration: onset of the test pulse through significant system response, often dummy motion, as seen in the physical test.**

Comparison of Test-Sim Curves

Electronic Data [Forces, Moments, Accelerations]

- **Error on the Peak**

$$Error = \frac{\left|Peak_{Test} - Peak_{Sim}\right|}{\left|Peak_{Test}\right|} * 100\%$$

- **Shape Error - Sprague and Geers Comprehensive Error**

* Sprague MA and Geers TL. A Spectral-Element Method for Modeling Cavitation in Transient Fluid-Structure Interaction. International Journal for Numerical Methods in Engineering. 60 (15), 2467-2499. 2004.

Comparison of Test-Sim Curves

Motion Data [Position, Angle]

- **Coordinate Transformation**
- **Error on the Peak***

$$Error = \left| Peak_{Test} - Peak_{Sim} \right|$$

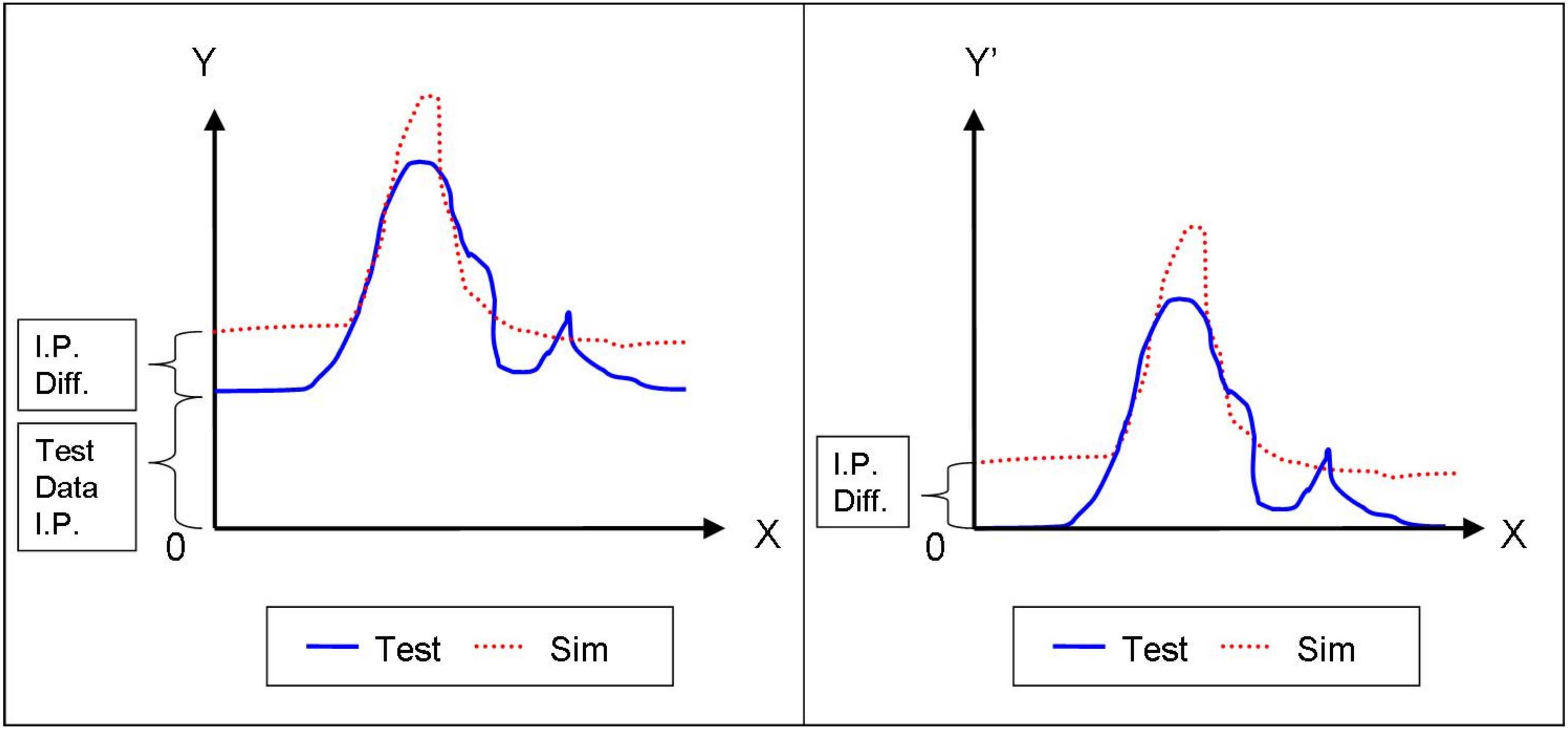
- **Shape Error - Sprague and Geers Comprehensive Error**

* Sprague MA and Geers TL. A Spectral-Element Method for Modeling Cavitation in Transient Fluid-Structure Interaction. International Journal for Numerical Methods in Engineering. 60 (15), 2467-2499. 2004.

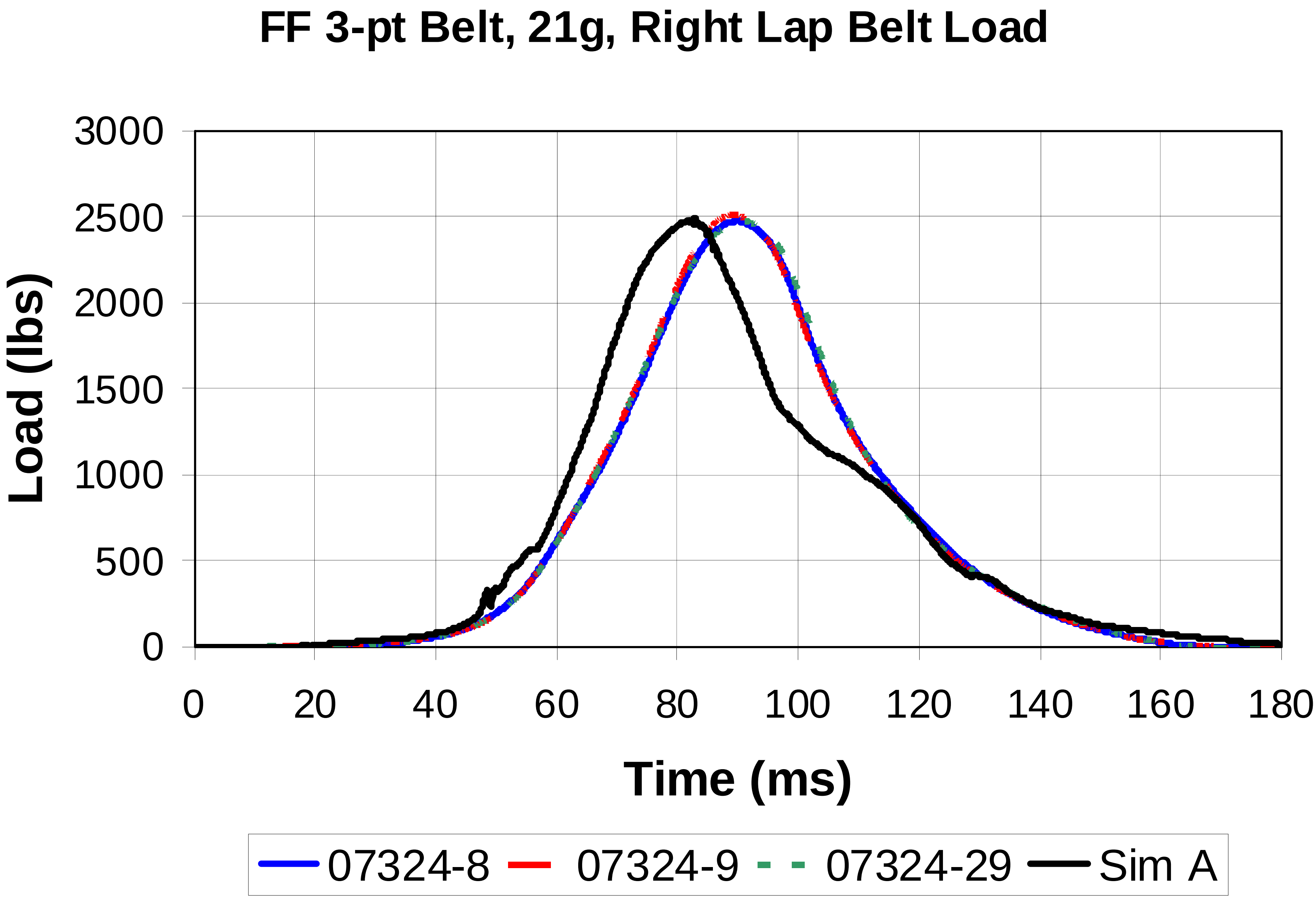
Comparison of Test-Sim Curves

Motion Data [Position, Angle]

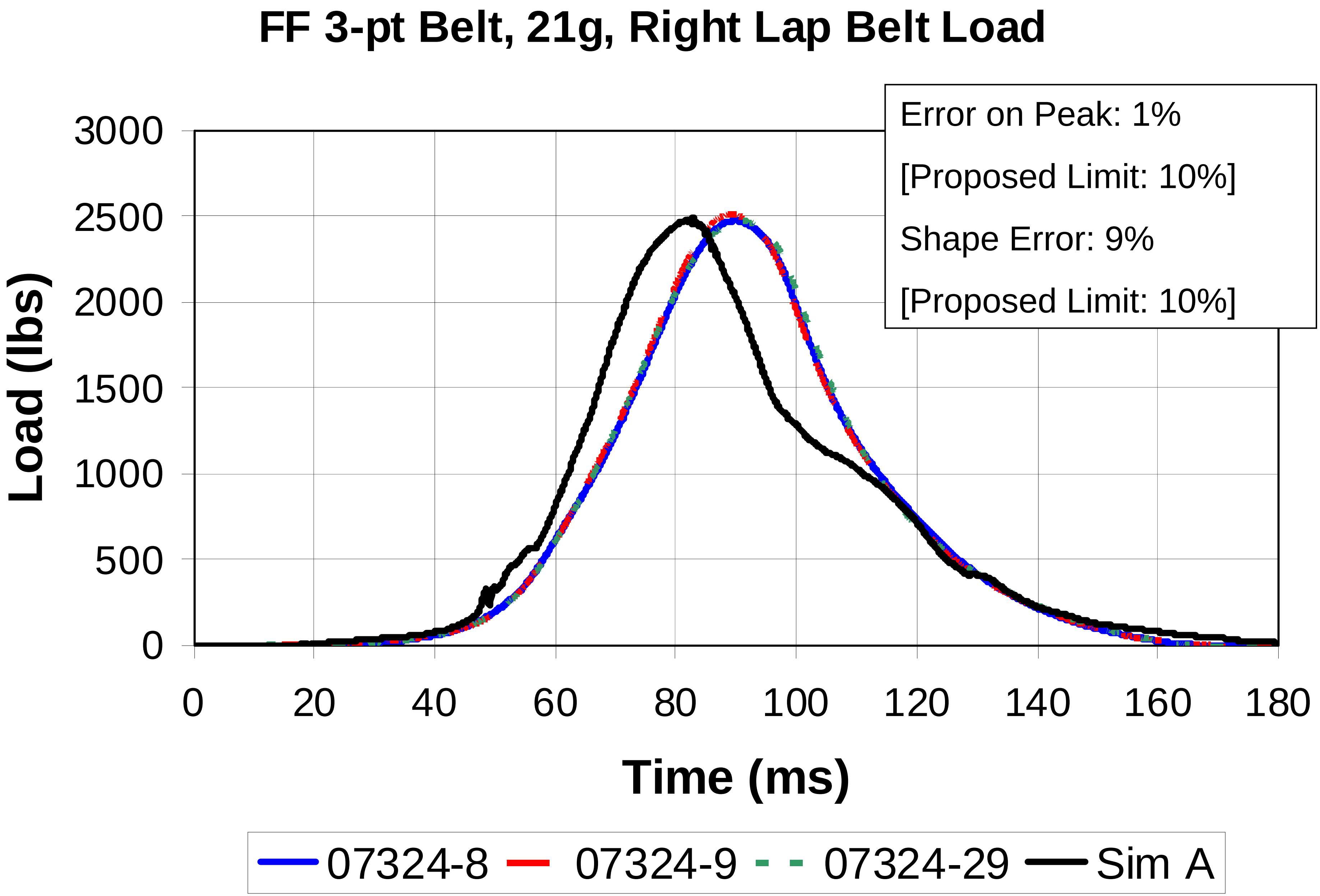
- **Coordinate Transformation**



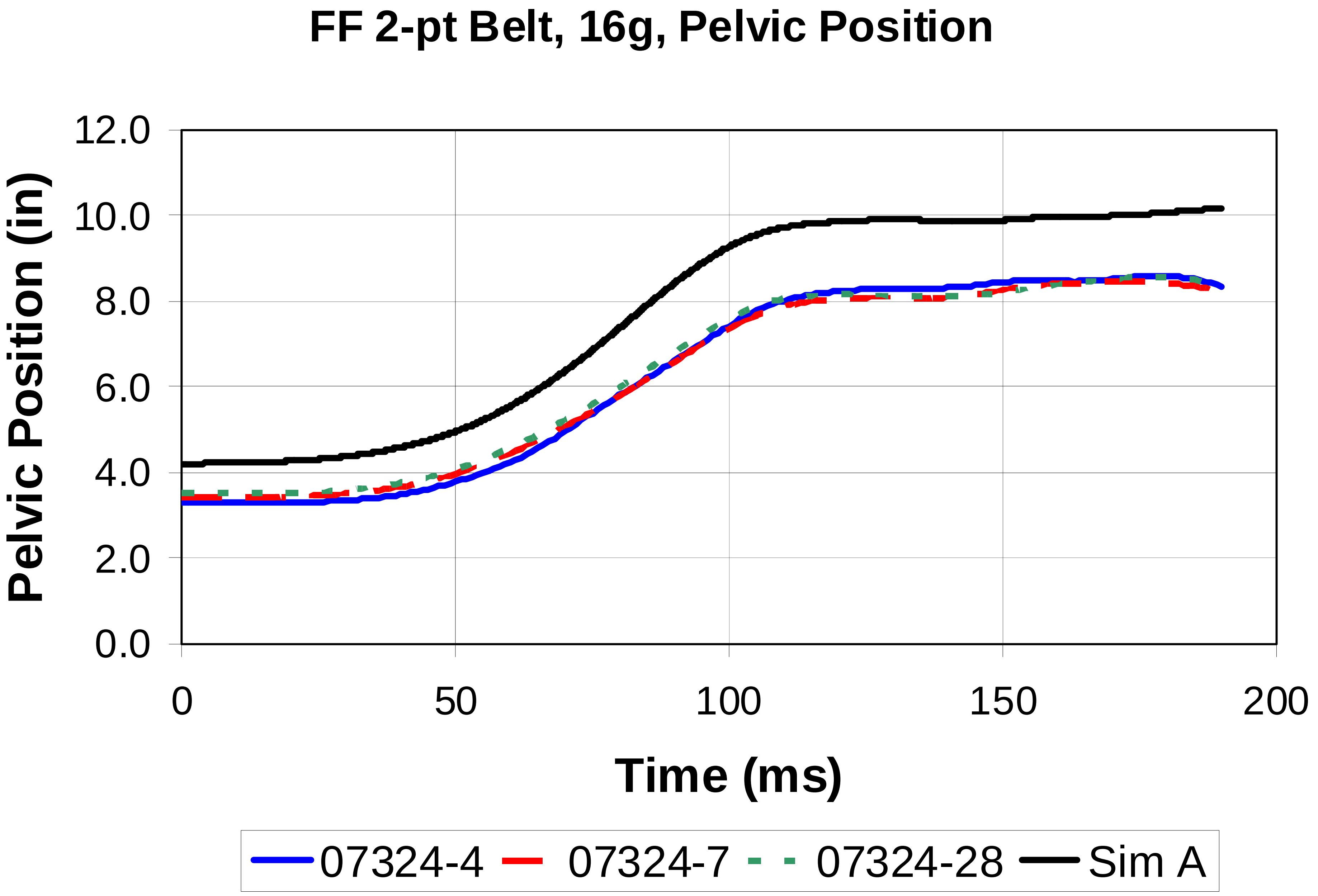
Example Data: Lap Belt Load



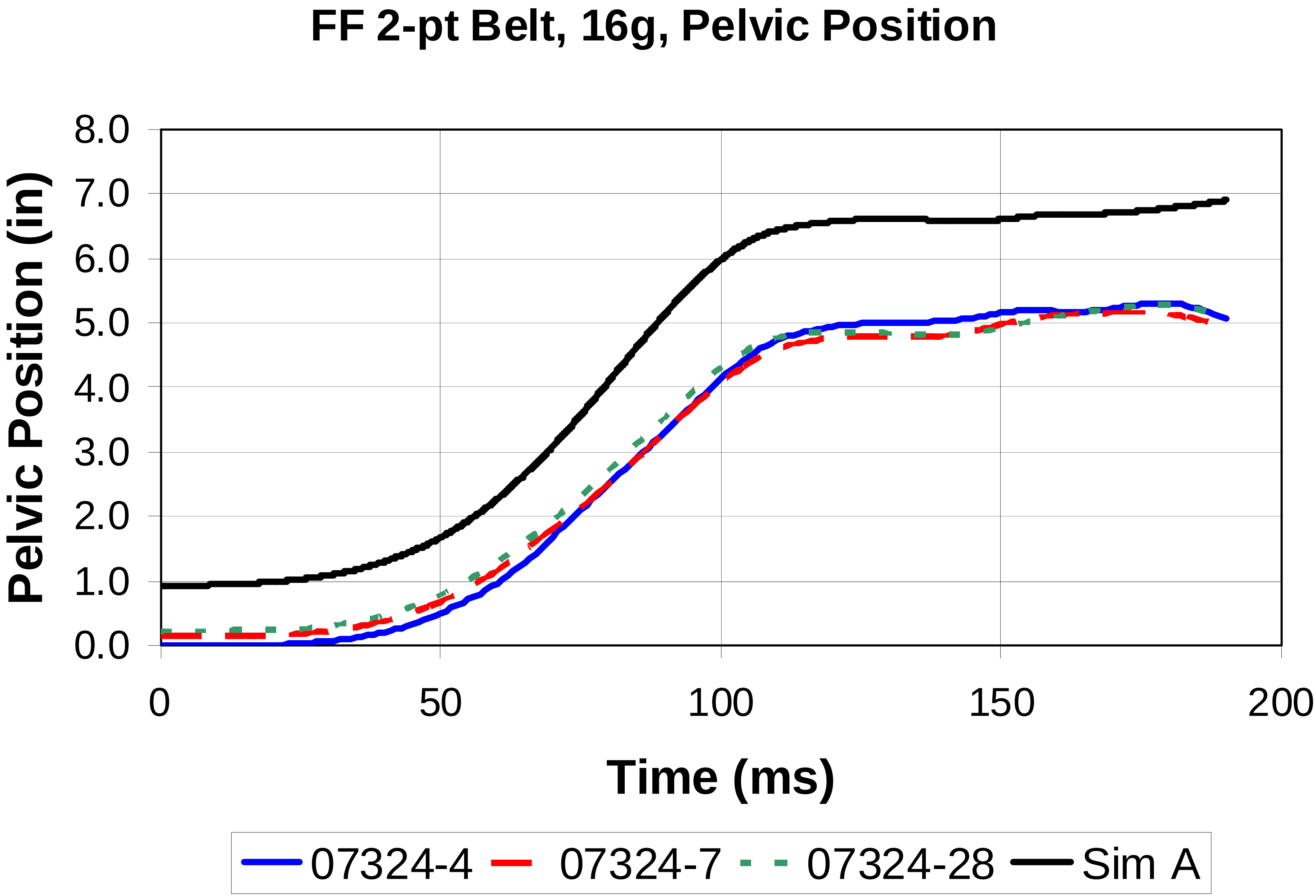
Example Data: Lap Belt Load



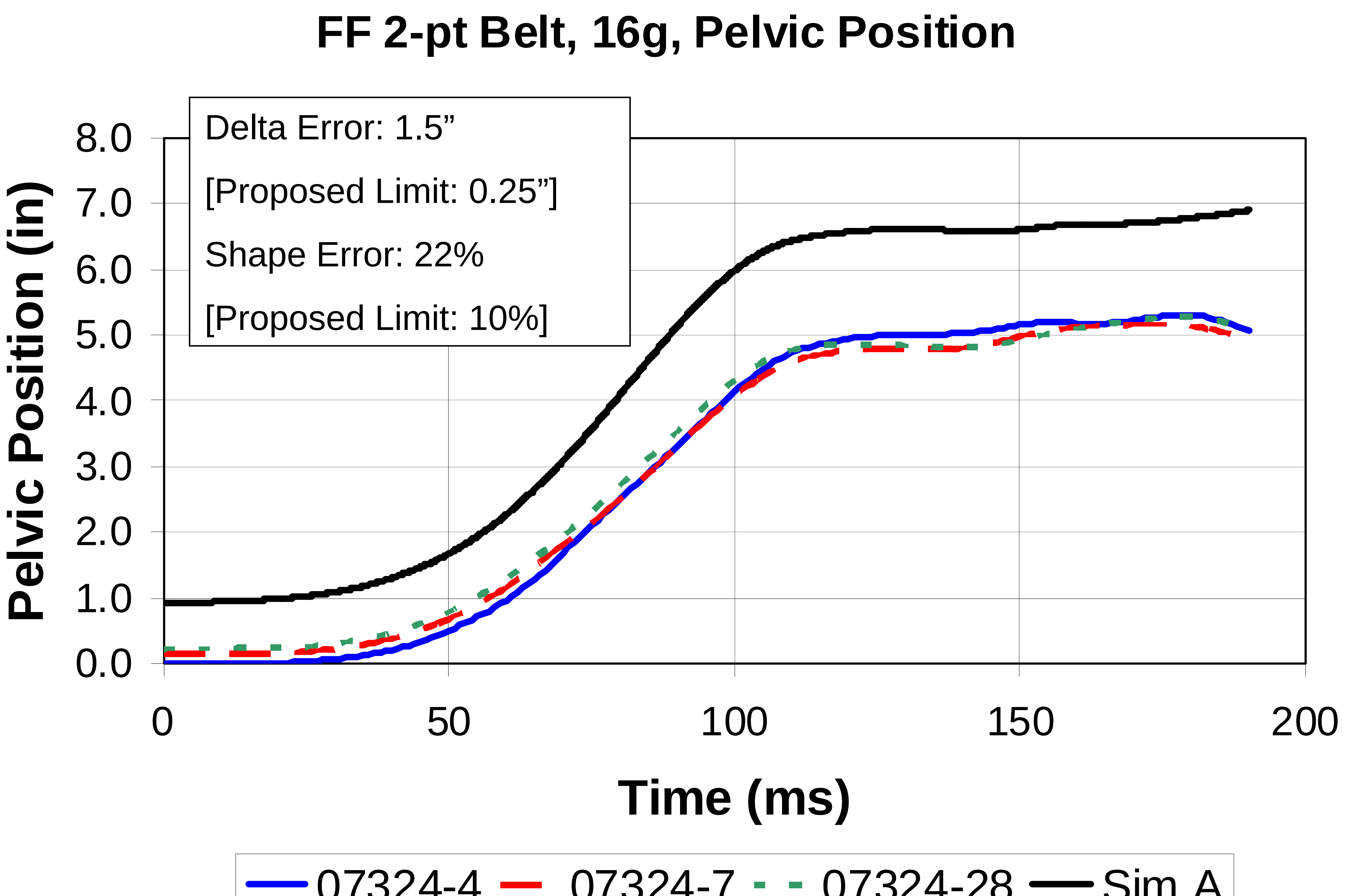
Example Data: Pelvic X Motion



Example Data: Pelvic X Motion - Offset



Example Data: Pelvic X Motion - Offset



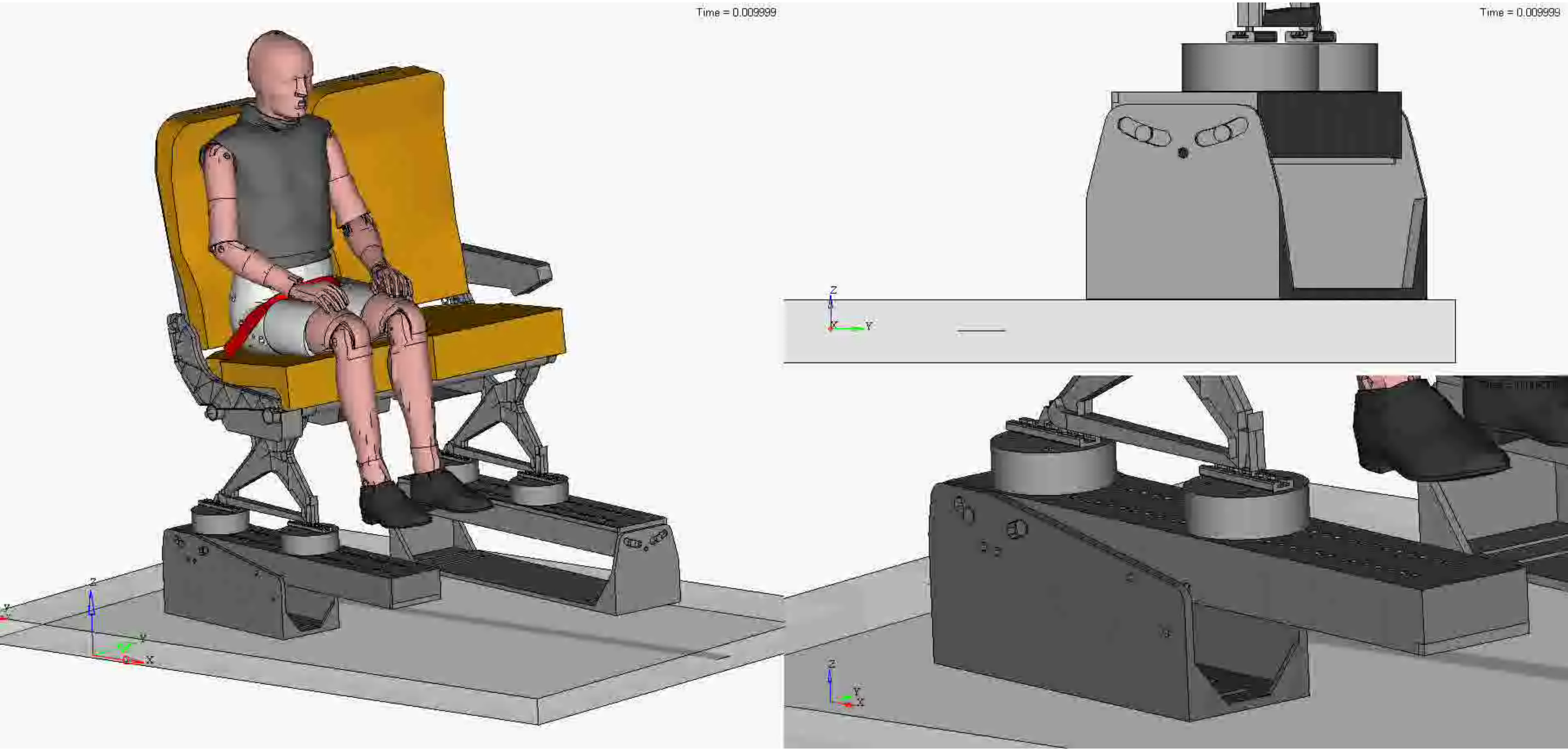
Best Practices: Modeling (60% complete)

- **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

Challenges in Finite Element Simulation

- **Determining the proper degree of fidelity required in the model**
  - **Fittings/Joints**
  - **Interface between seats and aircraft attachment**
  - **Restraints**
- **Cushion Models**
- **Floor Deformation**
- **Permanent Deformation**
- **Material Characterization**
- **Failure Criteria**

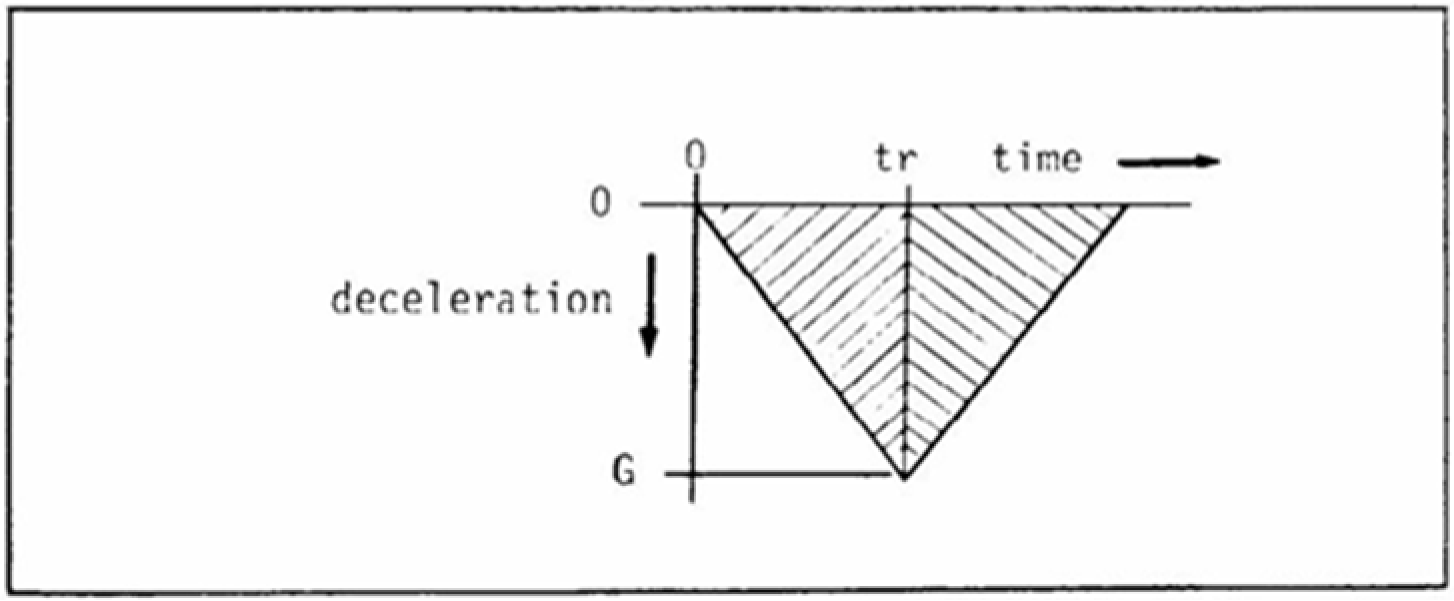
Simulated Pitch and Roll



Video courtesy of NIAR

Load Application – Sled Pulse

- **R&D – use Factor of Safety**
- **Validation – match physical test**
- **Certification – ideal pulse or typical pulse for your facility**



Load Application – Sled Pulse

							Calculated	
Part	**Seat**	**Orient**	**Vel**	**G's**	**RT**	**2*RT**	$\frac{1}{2}\ \Delta\nabla$	$\Delta\nabla$
			ft/s		**ms**	**ms**	**ft/s**	**ft/s**
23	**Crew**	**Horz**	**42**	**26**	**50**	**100**	***20.93***	***41.86***
23	**Crew**	**Vert**	**31**	**19**	**50**	**100**	***15.30***	***30.59***
23	**Pass**	**Horz**	**42**	**21**	**60**	**120**	***20.29***	***40.57***
23	**Pass**	**Vert**	**31**	**15**	**60**	**120**	***14.49***	***28.98***
25	**All**	**Horz**	**44**	**16**	**90**	**180**	**23.18**	**46.37**
25	**All**	**Vert**	**35**	**14**	**80**	**160**	**18.03**	**36.06**
27/29	**All**	**Horz**	**42**	**18.4**	**71**	**142**	**21.03**	**42.06**
27/29	**All**	**Vert**	**30**	**30**	**31**	**62**	***14.97***	***29.94***

* Italic/Red: Calculated Velocity < Required Velocity

Best Practices: Testing (95% complete)

- **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

System Validation (10% complete)

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

Future Work

- v-ATD Calibration: finalize limits, evaluate current v-ATDs
- System Validation: refine and evaluate process
- Best Practices: develop and refine content
- ES-2?

Contact Information

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- **www.sae.org/servlets/works/committeeHome.do?comtID=TEASEAT**