Certification by Analysis

Gerardo Olivares

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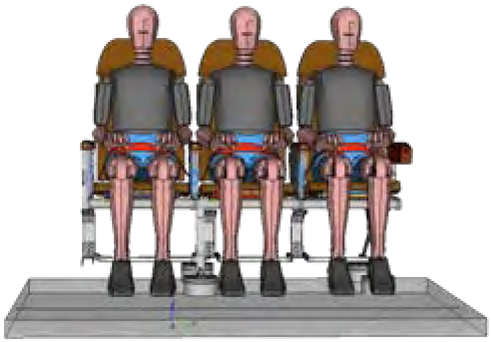
WICHITA STATE UNIVERSITY

The Joint Advanced Materials and Structures Center of Excellence

Certification by Analysis

- Motivation and Key Issues
  - Aircraft manufacturers are under strong pressure to reduce costs and development cycles. The development of aircraft interiors is driven by individualized customer demands, increasingly complex products and ever shorter innovation cycles. To remain competitive in today's market, aircraft manufacturers must conduct research in the development of state-of-the-art computational tools and processes in order to reduce the amount of physical testing, certification costs and product development cycles.



- Objective
  - Provide a document of best practices so that Industry and FAA personnel can gain an understanding of the fundamental modeling methods, develop an appreciation of the modeling problem areas, and limitations of current numerical models.

- Technical Approach
  - **Phase I** Numerical ATD / **Phase II** Seat Structure/Materials

FAA Sponsored Project Information

- Principal Investigators & Researchers
  - G.Olivares PhD, PI
  - K. S. Raju PhD (High Strain Rate Material Testing)
  - J. Guarddon, S. Patrick, V. Yadav
- FAA Technical Monitor
  - Allan Abramowitz
- Other FAA Personnel Involved
  - Rick Dewesse (CAMI)
  - David Moorcroft (CAMI)
- Industry Participation
  - Weber Aircraft, Contour Seating ,B/E Aerospace, SICMA, Schroth Safety Products, AMSAFE, TASS/TNO-MADYMO, Altair-Radioss, FTSS, ESI-Pamcrash, MSC, Cessna, Airbus NA, Hawker/Beechcraft, SAE Seat Committee

AC 20-146 - Scope

- This document defines the acceptable applications, limitations, validation processes, and minimum documentation requirements involved when substantiation by computer modeling is used to support a seat certification program.
- Computer modeling analytical techniques may be used to do the following, provided all pass/fail criteria identified in §§ 23.562, 25.562, 27.562, or 29.562 are satisfied:
  - Establish the critical seat installation/configuration in preparation for dynamic testing.
  - Demonstrate compliance to §§ 23.562, 25.562, 27.562, or 29.562 for changes to a baseline seat design, where the baseline seat design has demonstrated compliance to these rules by dynamic tests. Changes may include geometric or material changes to primary and non-primary structure.

Certification by Analysis I

- **Phase I: Numerical Anthropometric Test Dummies:**
  - Literature review and numerical tools survey
  - Sled testing – Rigid Seat (Series I [23 Sled Test] and II [30 Sled Tests])
    - Test variability studies – Establish corridors for validation criteria
    - ATD Validation reference database
  - Validation criteria:
    - Validation metrics methods: review and evaluation
    - Identify data channels required, and tolerance levels for model validation
  - Simulation studies:
    - Survey numerical ATD database availability
    - Preliminary evaluation of numerical ATDs with sled test data for part 23.562 and 25.562 dynamic requirements
    - Stochastic and/or DOE numerical model evaluation
  - Comparison HII vs. HIII FAA ATD performance

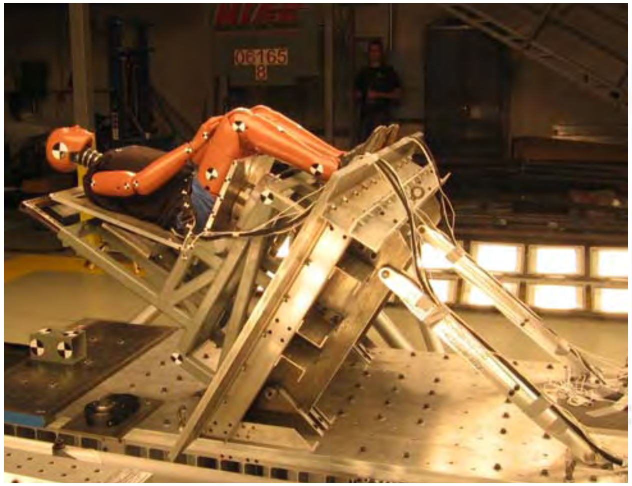
NIAR Sled Series 1 Numerical ATD Validation Reference Data

TEST NUMBER	ATD Serial#	BELT TYPE	TEST ANGLE (deg)	LOADING	SEAT TYPE	BELT MATERIAL	CRASH PULSE
06165-1	FAA HYB III 290	2	0	16g	Rigid	100% Polyester	25.562
06165-2	FAA HYB III 290	2	0	16g	Rigid	100% Polyester	25.562
06165-3	HYB II 698	2	0	16g	Rigid	100% Polyester	25.562
06165-4	HYB II 698	2	0	16g	Rigid	100% Polyester	25.562
06165-5	HYB II 698	2	60	14g	Rigid	100% Polyester	25.562
06165-6	HYB II 698	2	60	14g	Rigid	100% Polyester	25.562
06165-7	FAA HYB III 289	2	60	14g	Rigid	100% Polyester	25.562
06165-8	FAA HYB III 289	2	60	14g	Rigid	100% Polyester	25.562
06165-9	EMPTY	-	0	16g	Rigid	-	25.562
06165-10	HYB II 656	3	0	16g	Rigid	100% Polyester	25.562
06165-11	HYB II 656	3	0	16g	Rigid	100% Polyester	25.562
06165-12	FAA HYB III 289	3	0	16g	Rigid	100% Polyester	25.562
06165-13	FAA HYB III 289	3	0	16g	Rigid	100% Polyester	25.562
06165-14	FAA HYB III 289	4	0	16g	Rigid	100% Polyester	25.562
06165-15	FAA HYB III 289	4	0	16g	Rigid	100% Polyester	25.562
06165-16	EMPTY	-	0	16g	Rigid	-	25.562
06165-17	HYB II 656	4	0	16g	Rigid	100% Polyester	25.562
06165-18	HYB II 656	4	0	16g	Rigid	100% Polyester	25.562
06165-19*	HYB II 655	2	60	14g	Cushioned	100% Polyester	25.562
06165-20	HYB II 655	2	60	14g	Cushioned	100% Polyester	25.562
06165-21	FAA HYB III 289	2	60	14g	Cushioned	100% Polyester	25.562
06165-22	FAA HYB III 289	2	60	14g	Cushioned	100% Polyester	25.562
06165-23**	FAA HYB III 290	2	60	14g	Cushioned	100% Polyester	25.562

NIAR Sled Series 2 Numerical ATD Validation Reference Data SAE ARP 5765

TEST NUMBER	ATD	BELT TYPE	TEST ANGLE (deg)	LOADING	SEAT TYPE	BELT MATERIAL	CRASH PULSE
07324-1	HYB II	2	0	16g	Rigid	100% Nylon	25.562
07324-4	HYB II	2	0	16g	Rigid	100% Nylon	25.562
07324-7	HYB II	2	0	16g	Rigid	100% Nylon	25.562
07324-10	HYB II	2	60	19g	Rigid	100% Nylon	23.562
07324-11	HYB II	2	60	19g	Rigid	100% Nylon	23.562
07324-12	HYB II	2	60	19g	Rigid	100% Nylon	23.562
07324-2	HYB II	3	0	21g	Rigid	100% Nylon	23.562
07324-8	HYB II	3	0	21g	Rigid	100% Nylon	23.562
07324-9	HYB II	3	0	21g	Rigid	100% Nylon	23.562
07324-3	HYB II	4	0	21g	Rigid	100% Nylon	23.562
07324-5	HYB II	4	0	21g	Rigid	100% Nylon	23.562
07324-6	HYB II	4	0	21g	Rigid	100% Nylon	23.562
07324-16	FAA HYB III	2	0	16g	Rigid	100% Nylon	25.562
07324-17	FAA HYB III	2	0	16g	Rigid	100% Nylon	25.562
07324-18	FAA HYB III	2	0	16g	Rigid	100% Nylon	25.562
07324-13	FAA HYB III	2	60	19g	Rigid	100% Nylon	23.562
07324-14	FAA HYB III	2	60	19g	Rigid	100% Nylon	23.562
07324-15	FAA HYB III	2	60	19g	Rigid	100% Nylon	23.562
07324-19	FAA HYB III	3	0	21g	Rigid	100% Nylon	23.562
07324-20	FAA HYB III	3	0	21g	Rigid	100% Nylon	23.562
07324-24	FAA HYB III	3	0	21g	Rigid	100% Nylon	23.562
07324-21	FAA HYB III	4	0	21g	Rigid	100% Nylon	23.562
07324-22	FAA HYB III	4	0	21g	Rigid	100% Nylon	23.562
07324-23	FAA HYB III	4	0	21g	Rigid	100% Nylon	23.562
07324-25	FAA HYB III	3	0	21g	Rigid	100% Nylon	23.562
07324-26	HYB II	4	0	21g	Rigid	100% Nylon	23.562
07324-27	HYB II	4	0	21g	Rigid	100% Nylon	23.562
07324-28	HYB II	2	0	16g	Rigid	100% Nylon	25.562
07324-29	HYB II	3	0	21g	Rigid	100% Nylon	23.562

FAR §§ **.562: Emergency Landing Conditions

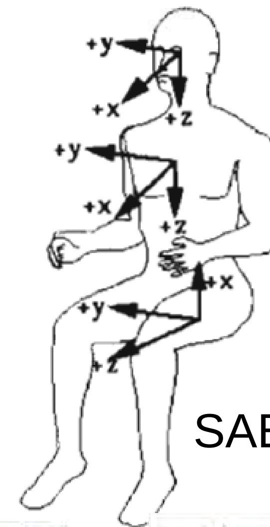


DYNAMIC TEST REQUIREMENTS	PART 23	PART 25	PART 27
TEST 1			
Test Velocity - ft/sec	31 (9.5 m/sec)	35 (10.7 m/sec)	30 (9.2 m/sec)
Seat Pitch Angle - Degrees	60	60	60
Seat Yaw Angle - Degrees	0	0	0
Peak Deceleration - G's	19/15	14	30
Time To Peak - sec	0.05/0.06	0.08	0.031
Floor Deformation - Degrees	None	None	10 Pitch/10 Roll
TEST 2			
Test Velocity - ft/sec	42 (12.8 m/sec)	44 (13.4 m/sec)	42 (12.8 m/sec)
Seat Pitch Angle - Degrees	0	0	0
Seat Yaw Angle - Degrees	±10	±10	±10
Peak Deceleration - G's	26/21	16	18.4
Time To Peak - sec	0.05/0.06	0.09	0.071
Floor Deformation - Degrees	10 Pitch/10 Roll	10 Pitch/10 Roll	10 Pitch/10 Roll
COMPLIANCE CRITERIA			
HIC	1000	1000	1000
Lumbar Load - lb	1500 (6675 N)	1500 (6675 N)	1500 (6675 N)
Strap Loads - lb	1750[1]/2000[2] (7787N[1]/8900N[2])	1750[1]/2000[2] (7787N[1]/8900N[2])	1750[1]/2000[2] (7787N[1]/8900N[2])
Femur Loads - lb	N/A	2250	N/A

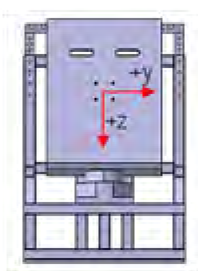
[1] - passenger [2] – pilot

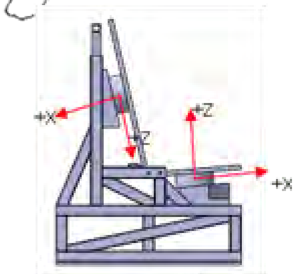
Test Data Channels and Polarities Overview

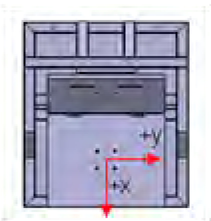
Channel Description	Channel Units	Hybrid II	Hybrid III
Sled acceleration	G's vs Sec	√	√
Head X acceleration	G's vs Sec	√	√
Head Y acceleration	G's vs Sec	√	√
Head Z acceleration	G's vs Sec	√	√
Upper neck force X direction	Lbf vs Sec		√
Upper neck force Y direction	Lbf vs Sec		√
Upper neck force Z direction	Lbf vs Sec		√
Upper neck moment about X axis	In-lbf vs Sec		√
Upper neck moment about Y axis	In-lbf vs Sec		√
Upper neck moment about Z axis	In-lbf vs Sec		√
Torso X acceleration	G's vs Sec	√	√
Torso Y acceleration	G's vs Sec	√	√
Torso Z acceleration	G's vs Sec	√	√
Lumbar load X direction	Lbf vs Sec	√	√
Lumbar load Z direction	Lbf vs Sec	√	√
Lumbar moment about Y axis	In-lbf vs Sec	√	√
Pelvis X acceleration	G's vs Sec	√	√
Pelvis Y acceleration	G's vs Sec	√	√
Pelvis Z acceleration	G's vs Sec	√	√
Left femur compression load	Lbf vs Sec	√	√
Right femur compression load	Lbf vs Sec	√	√
Lap strap left side tension load	Lbf vs Sec	√	√
Lap strap right side tension load	Lbf vs Sec	√	√
Shoulder left strap tension load	Lbf vs Sec	√	√
Shoulder right strap tension load	Lbf vs Sec	√	√
Joint shoulder straps tension load	Lbf vs Sec	√	√
Seat back X reaction force	Lbf vs Sec	√	√
Seat back Y reaction force	Lbf vs Sec	√	√
Seat back Z reaction force	Lbf vs Sec	√	√
Seat pan X reaction force	Lbf vs Sec	√	√
Seat pan Y reaction force	Lbf vs Sec	√	√
Seat pan Z reaction force	Lbf vs Sec	√	√
Seat pan X reaction moment	In-lbf vs Sec	√	√
Seat pan Y reaction moment	In-lbf vs Sec	√	√
Seat pan Z reaction moment	In-lbf vs Sec	√	√
Head trajectory in the X-Z plane	Inch vs Inch	√	√
Chest trajectory in the X-Z plane	Inch vs Inch	√	√
Torso trajectory in the X-Z plane	Inch vs Inch	√	√
Knee trajectory in the X-Z plane	Inch vs Inch	√	√



SAE J211-1



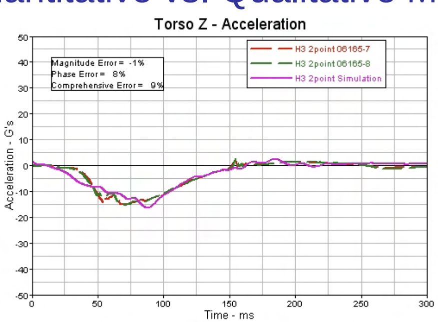




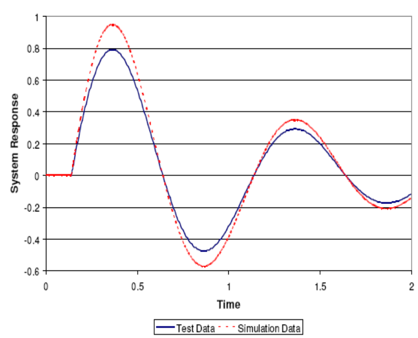
Validation Metrics

- Computable measures are needed that can **quantitatively** compare experimental and computational results over a series of parameters to **objectively** assess computational accuracy over the traditional qualitative graphical comparison
- Applications:
  - Quantify repeatability of test results (Establish physical test variability corridors)
  - Numerical model quality evaluation
- Four validation metrics methods currently under evaluation:
  - Sprague & Geers validation metric
  - Weighted Integration Factor validation metric
  - Quick Rating from MADPost Software (includes 3 different metric evaluations)
  - Mod Eval Software (includes 4 different metric evaluations)
  - Relative Error method

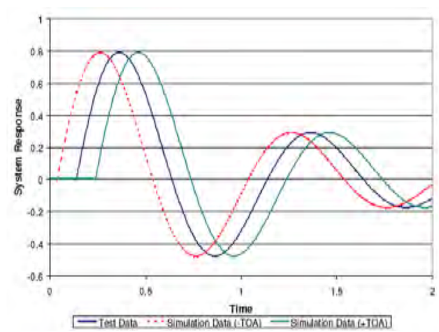
Quantitative vs. Qualitative Methods



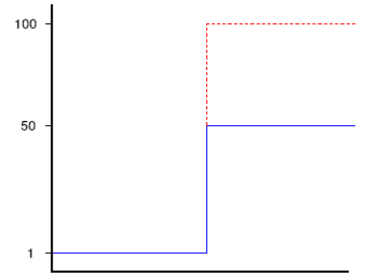
Magnitude Error



Phase Error



Area Under Curve Error



Validation Metric Selection

- The following error metrics will be defined in SAE ARP 5765:
  - Magnitude Error using Relative Error
  - Shape Error using Sprague and Geers
  - The error metric for motion data is different for Magnitude Error using a simple difference error metric on the most significant peak
- Since these metrics compare only two sets of data and there are three sets to compare, the following method is used:
  - Test 1 vs test 2 = Δ1
  - Test 1 vs test 3 = Δ2
  - Test 2 vs test 3 = Δ3
  - The highest value from Δ1 through Δ3 is used
  - Note that the biasing of these metrics do not have a significant effect on the results when the errors are small; thus, for test data uncertainty measurement, it does not have a considerable influence in what order the curves are compared since errors are generally small

Validation Metric – Shape Error (Sprague & Geers)

$$\vartheta_{bb} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} b^2(t)dt$$

$$\vartheta_{cc} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} c^2(t)dt$$

$$\vartheta_{bc} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} b(t)c(t)dt$$

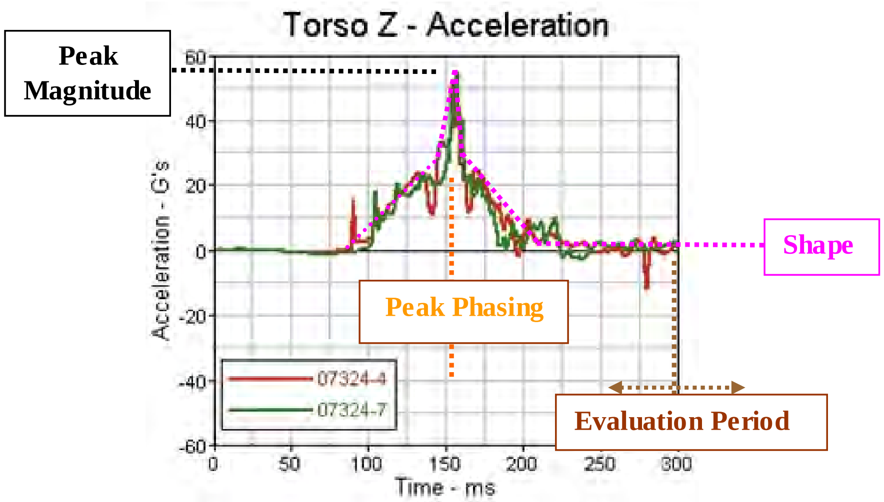
$$P = \frac{1}{\pi}\cos^{-1}\left(\vartheta_{bc} / \sqrt{\vartheta_{bb}\vartheta_{cc}}\right)$$

$$M = \sqrt{\vartheta_{cc} / \vartheta_{bb}} - 1$$

$$C = \sqrt{M^2 + P^2}$$

Where;

t1<t<t2 evaluation period
b(t) = reference data
c(t) = data to compare
P = phase error
M = magnitude error
C = shape error (S&G score)



Validation Metric – Peak Magnitude Error

- Relative Error Metrics used for Magnitude Error (accelerations and forces):

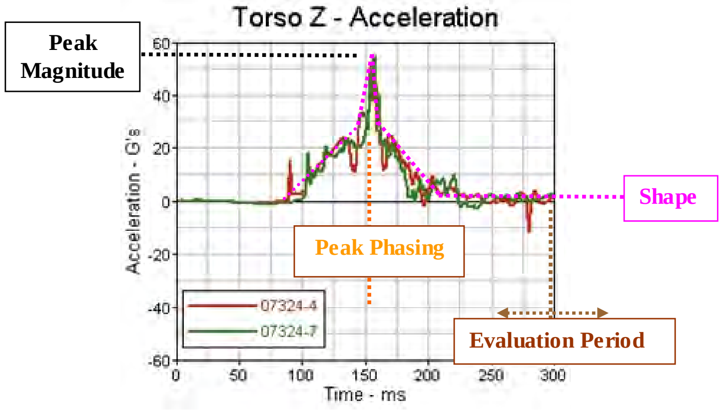
$$\textbf{Mag. Error (\%)} = \frac{Maxg(t) - Maxf(t)}{Maxf(t)}$$

Maxf(t) = Peak or maximum magnitude value (positive or negative) in reference data

Maxg(t) = Peak or maximum magnitude value (positive or negative) in candidate solution or data to compare

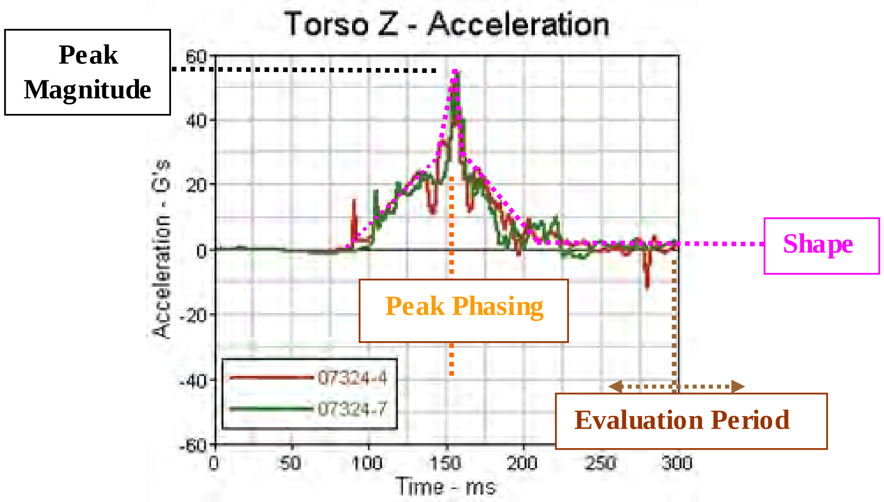
- Simple Difference used for Magnitude Error (Motion data only):

$$\textbf{Mag. Error} = |Maxg(t) - Maxf(t)|$$



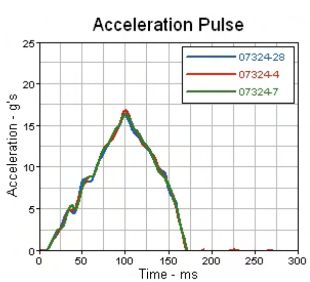
Validation Metric - Evaluation Period

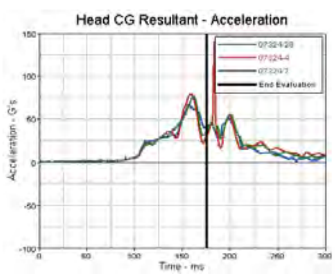
Configuration NIAR Sled Series 07324	Accelerometer Signals	Load Cell Signals	Position
2 Point Restraint - 0 degree HII	175 ms	200 ms	175 ms
3 Point Restraint - 0 degree HII	180 ms	180 ms	180 ms
4 Point Restraint - 0 degree HII	150 ms	150 ms	150 ms
2 Point Restraint - 60 degree HII	125 ms	125 ms	125 ms
2 Point Restraint - 0 degree HII	175 ms	200 ms	175 ms
3 Point Restraint - 0 degree HII	180 ms	180 ms	180 ms
4 Point Restraint - 0 degree HII	150 ms	150 ms	150 ms
2 Point Restraint - 60 degree HII	125 ms	125 ms	125 ms

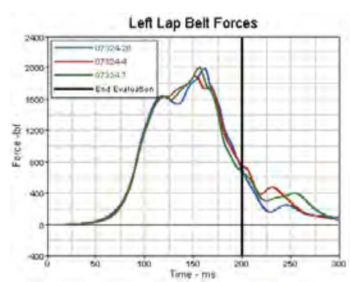


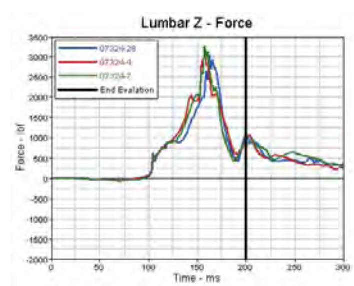
Example Error Metric – Test Data HII 2 Point Belt Configuration

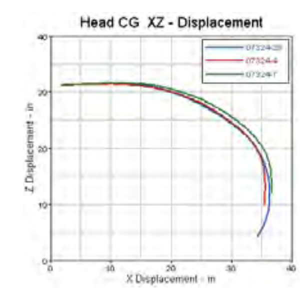
H2 2pt 0deg 16g					
	Mag. Error	Shape Error		Mag. Error	Shape Error
Sled Ax	3%	2%	Right Lap	5%	6%
Head Ax	7%	23%	Lumbar Fx	16%	11%
Head Ay	102%	86%	Lumbar Fz	7%	9%
Head Az	18%	7%	Lumbar My	21%	9%
Head Ar	19%	7%	Seat Back Fx	3%	8%
Torso Ax	47%	29%	Seat Back Fy	36%	65%
Torso Ay	19%	65%	Seat Back Fz	35%	24%
Torso Az	8%	14%	Seat Pan Fx	18%	11%
Torso Ar	8%	15%	Seat Pan Fy	61%	77%
Pelvic Ax	18%	16%	Seat Pan Fz	17%	13%
Pelvic Ay	16%	59%	Seat Pan Res	18%	12%
Pelvic Az	21%	23%	Seat Pan Mx	39%	77%
Pelvic Ar	15%	15%	Seat Pan My	12%	10%
Left Femur	5%	14%	Seat Pan Mz	98%	121%
Right Femur	66%	18%	Head CG X Excursion	1	2%
Left Lap	6%	2%	Head CG Z Excursion	1	1%



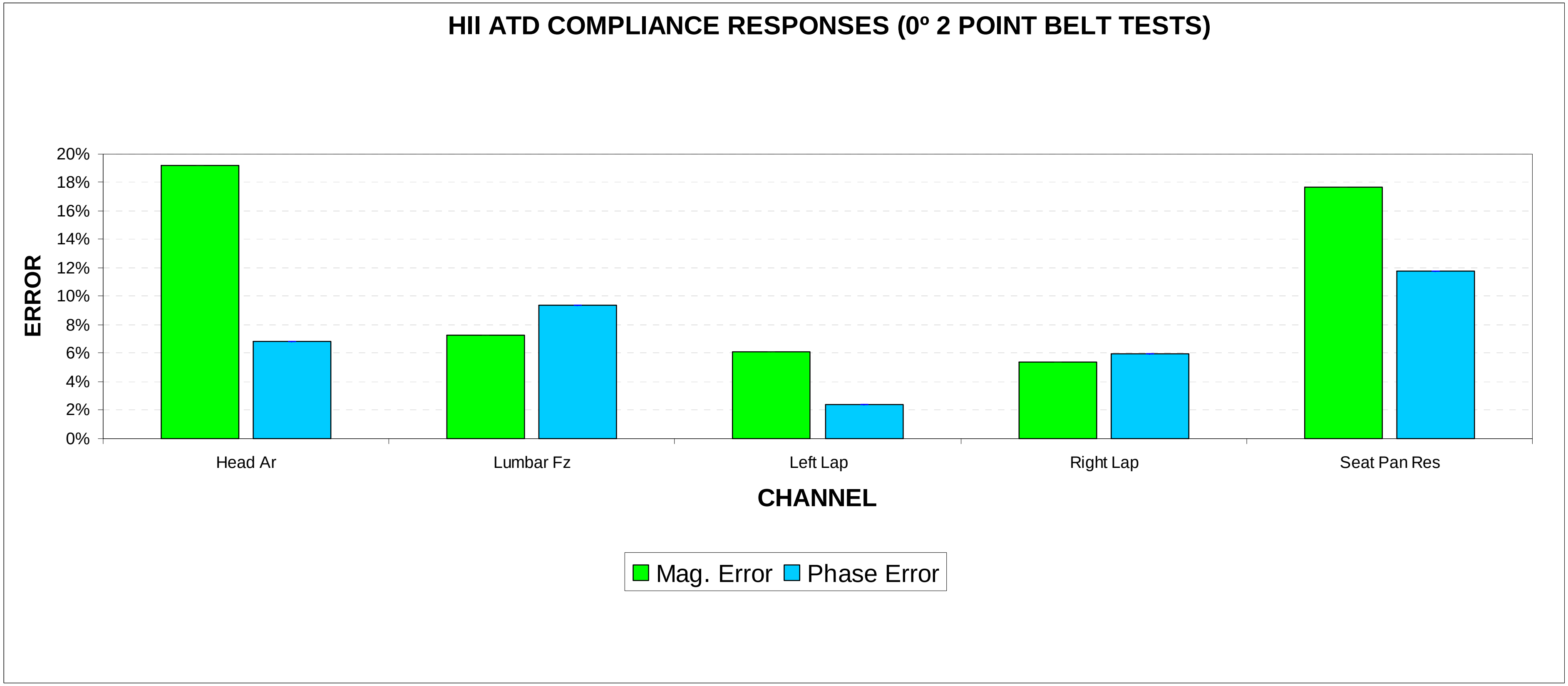








Example Error Metric – Test Data HII 2 Point Belt Configuration



Conclusions CBA Phase I

- Reference Sled Tests completed and available to numerical ATD developers and SAE ARP 5765 working group.
- Validated HII and HIII FAA numerical models will be available at the end of the year from all the major FE and Multibody Solvers.
- HII and HIII FAA test repeatability studies completed ([2, 3 and 4 point restraints] [0 and 60 deg Test Conditions] [Dynamic conditions FAR 23.562 and 25.562])
- Data will be published in CBA Phase I FAA report.
- Validation metrics and validation criteria will be defined in SAE ARP 5765.
- Develop testing protocols and data requirements to validate computer models. Plans to propose addendum to AC 20-146 or to include protocol in ARP 5765. Data will be published in CBA Phase I FAA report.
- Comparison of HII and HIII FAA performance for typical aerospace applications will be published CBA Phase I in FAA report.[2, 3 and 4 point restraints] [0 and 60 deg Test Conditions] [Dynamic conditions FAR 23.562 and 25.562].

Certification by Analysis II

- **Phase II: Aerospace Seat Material Modeling Requirements and Material Database:**
  - Literature review: Material data, testing protocols
  - Survey of materials used in aerospace seating applications
  - Review of material data required for numerical analysis:
    - Material Models: Structural components, cushions, and webbing
    - Strain rate definition for typical structural components
  - Computational FE Studies for various aerospace seat configurations
  - Experimental Studies for various aerospace seat configurations
    - Test repeatability
    - Comparison studies with computational solutions
  - Component Testing Protocols: Metallic components, seat cushions, and belt webbing
  - Material Database:
    - Physical testing // Component Testing Variability
    - Validation material models: Physical Testing vs. Simulation

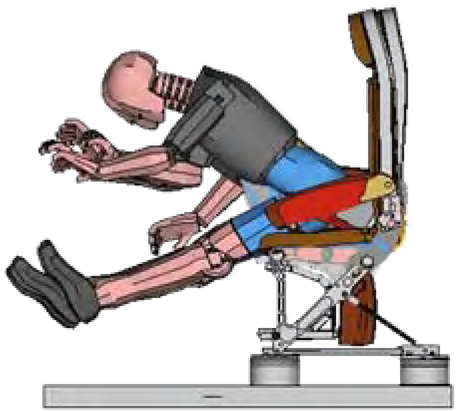
Material Survey: Aluminums

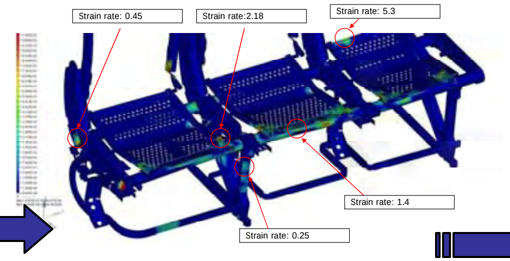
ALUMINUM		
Material Designation	**Material Form**	**Material Specification**
7075 T6	Sheet	AMS-4045 AMS-QQ-A-250/12
	Rolled/Drawn Bar	AMS-QQ-A 225/9
	Extrusion Bar	AMS-QQ-A 200/11
7075 T651	Plate	AMS-4045
2024 T3	Sheet	AMS-4037 AMS-QQ-A-250/4
	Rolled/Drawn Bar	AMS-4086 AMS-QQ-A-225/6
	Extrusion Bar	AMS-QQ-A-200/3
2024 T351	Rolled/Drawn Bar	AMS-4120
	Plate	AMS-4037
2024 T3511	Extrusion Bar	AMS-4165
2014 T6	Sheet	AMS-4029
	Bar	AMS-4121
2014 T651	Plate	AMS-4029
6061 T6	Rolled/Drawn Bar	AMS-4117
6061 T6511	Extrusion Bar	AMS-QQ-A-200/8
6082 T6	Sheet	BS EN 1386
6082 T6	Plate	BS EN 1386
7020 T6	Extrusion Tube	BS EN 755-2
L114 T6	Tube	BS L114(1971)
L168 T6	Bar	BS L168(1978)
5251 H22	Sheet	BS EN 485-2

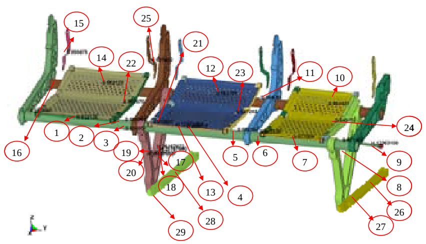
Material Survey: Steels

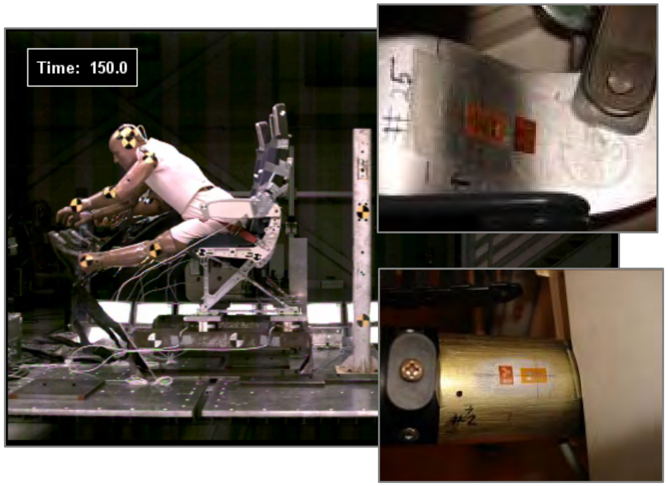
STEEL		
Material Designation	**Material Form**	**Material Specification**
AISI 4130	Tube	AMS 6361 AMS-T-6736
	Bar	AMS-S-6758
17-4PH	Bar	AMS 5643 (H900, H1025, H1150)
S-154	Bar	BS 154(1976)
X2CrNi19-11, 1.4306, C or H(304S11)	Sheet	BS EN 10028-7
C30E, 1.1178, +N(080M30)	Bar	BS EN 10083-1
	Sheet	BS EN 10083-2

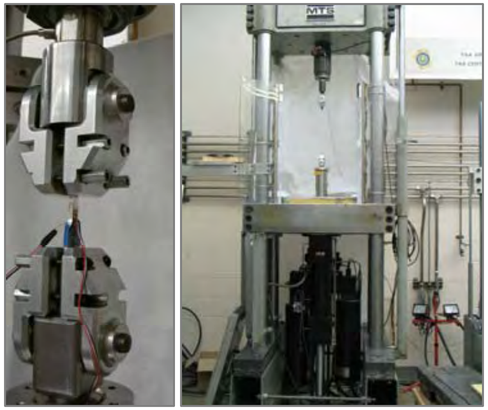
Strain Rate Specifications - Development Process

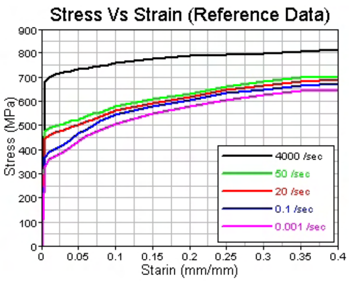








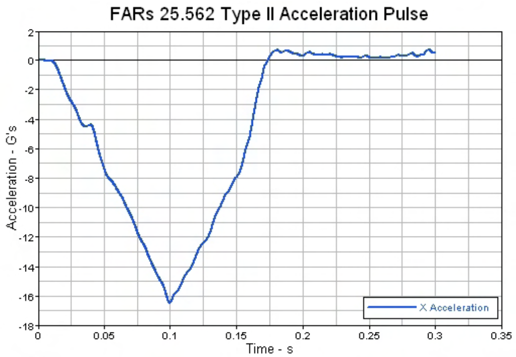




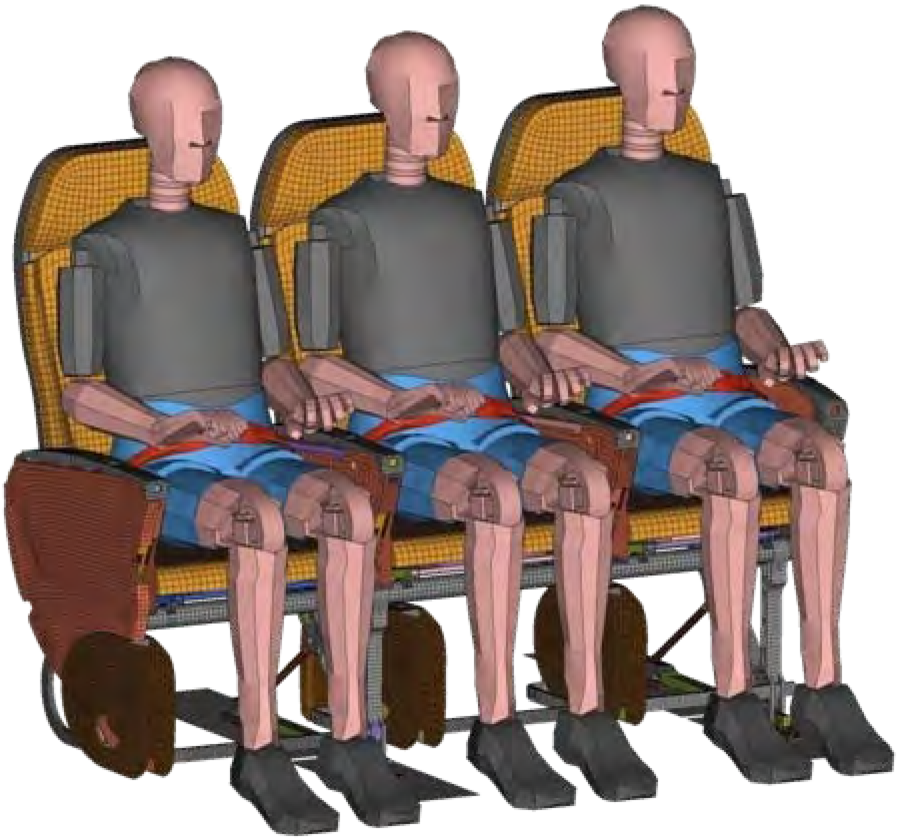
Material Database

Reference Test : Seat Type A

- Four 25.562 Dynamic Tests will be conducted with a typical aircraft seat configuration:
  - Two repetitions: FAR 25.562 0 deg no pitch, roll or yaw (Note one baseline test is completed).
  - Two repetitions: FAR 25.562 60 deg
- Purpose:
  - Identify strain rate range for various seat components
  - Baseline comparison with FE simulation model
  - Physical testing repeatability studies

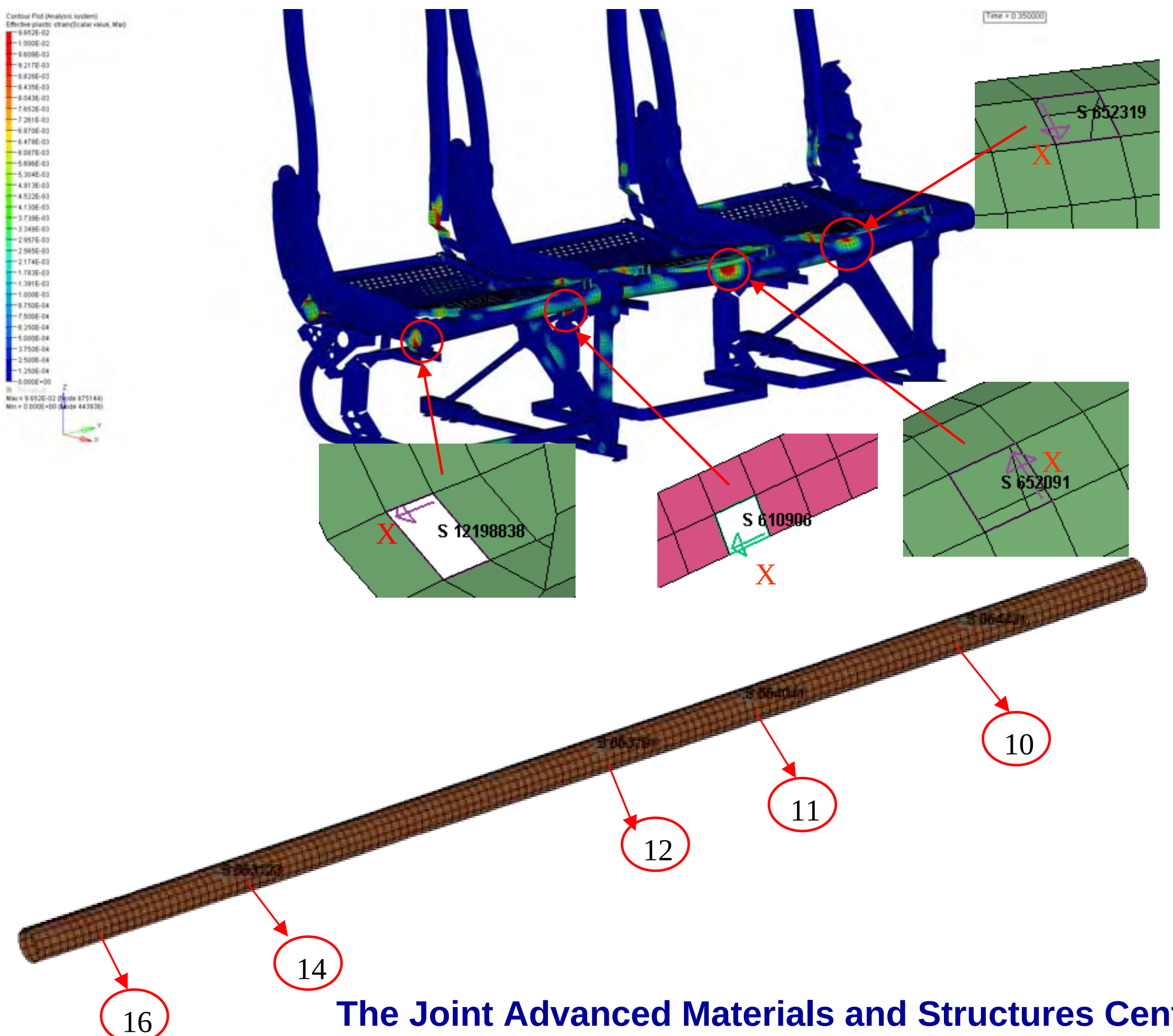


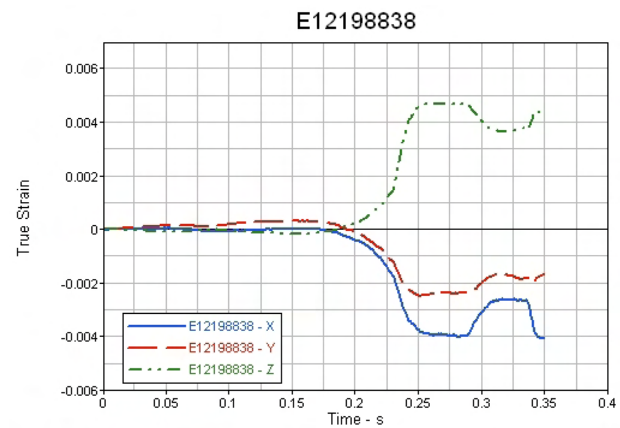
Reference Computational Model: FE Model Overview

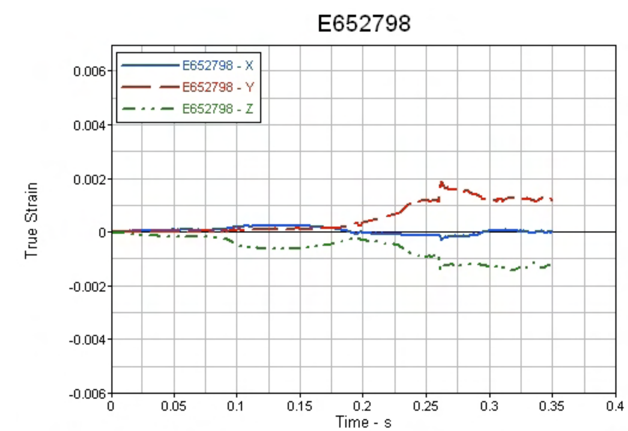


- Detail finite element model seat structure and occupants.
- Purpose:
  - Define strain gauge locations and instrumentation for physical testing
  - Identify strain rate for various seat components
  - Baseline comparison with physical system
  - Numerical model predictability
  - Study numerical model accuracy with quasi-static material data

Plastic Deformation - Identify Strain Gauge Location and Orientation

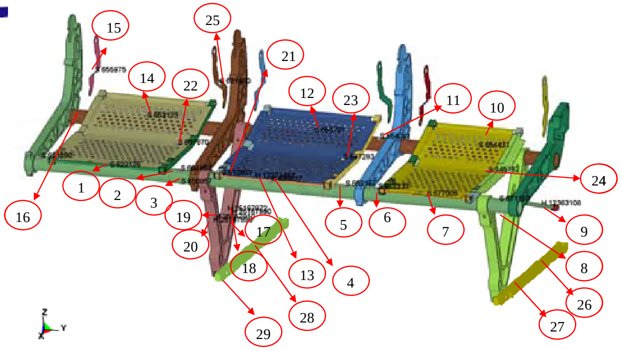


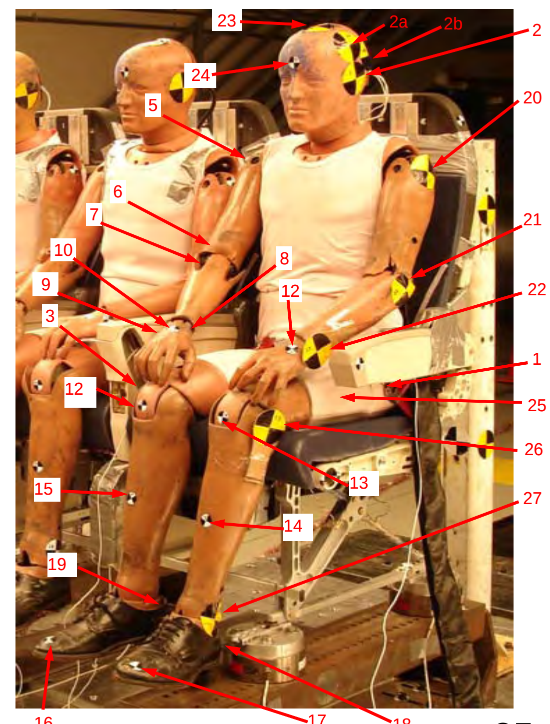




Reference Sled Test Data Channels – FAR 25.562 Pulse

# Channels	Channel Description	Channel Units
1	Sled acceleration	G's vs Sec
3	Head X acceleration	G's vs Sec
3	Head Y acceleration	G's vs Sec
3	Head Z acceleration	G's vs Sec
3	Torso X acceleration	G's vs Sec
3	Torso Y acceleration	G's vs Sec
3	Torso Z acceleration	G's vs Sec
3	Lumbar load X direction	Lbf vs Sec
3	Lumbar load Z direction	Lbf vs Sec
3	Lumbar moment about Y axis	In-lbf vs Sec
3	Pelvis X acceleration	G's vs Sec
3	Pelvis Y acceleration	G's vs Sec
3	Pelvis Z acceleration	G's vs Sec
3	Lap strap left side tension load	Lbf vs Sec
3	Lap strap right side tension load	Lbf vs Sec
4	Floor Attachments X interface loads	Lbf vs Sec
4	Floor Attachments Y interface loads	Lbf vs Sec
4	Floor Attachments Z interface loads	Lbf vs Sec
34	Strain Gauges	Strain vs Sec
4	Head trajectory in the X-Z plane	Inch vs Inch
	Torso trajectory in the X-Z plane	Inch vs Inch
	Knee trajectory in the X-Z plane	Inch vs Inch

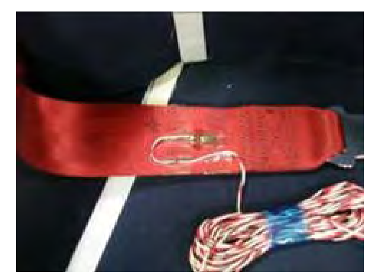




Reference Sled Test – Sample Instrumentation

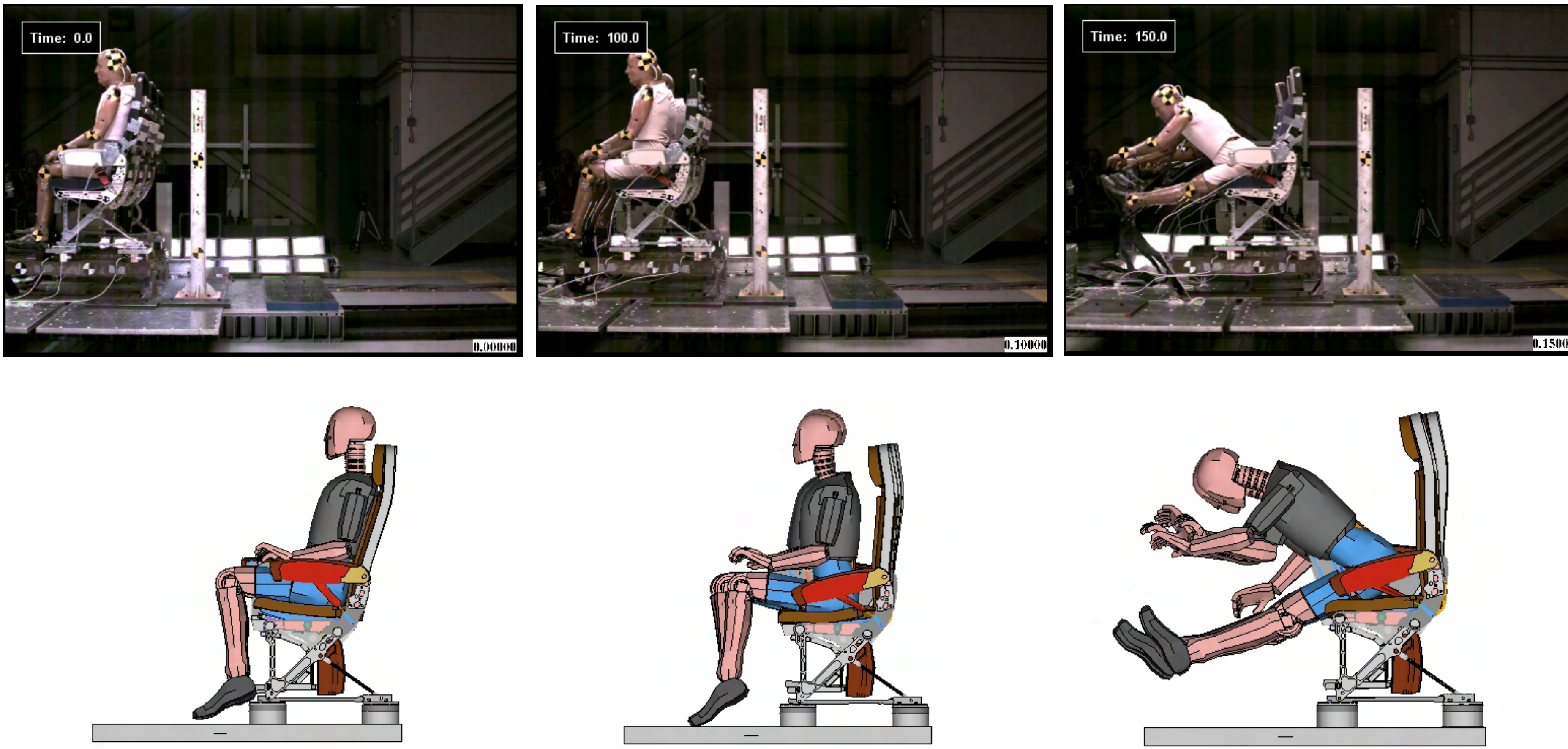
RIGHT SEAT

CENTER SEAT



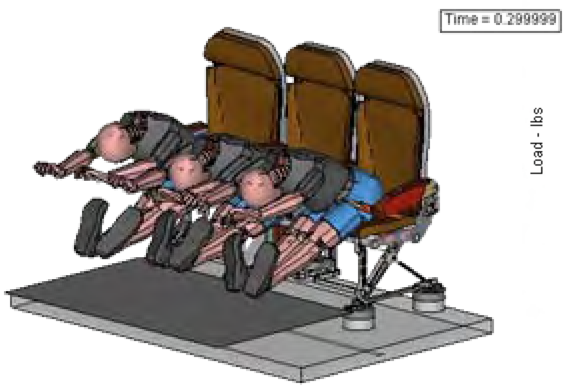
LEFT SEAT

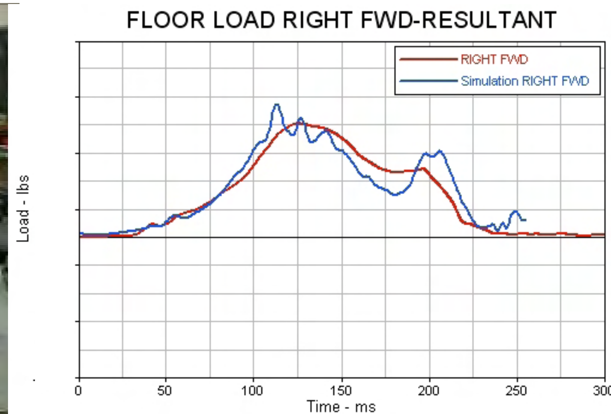
Comparison Simulation and Sled Test - Kinematics

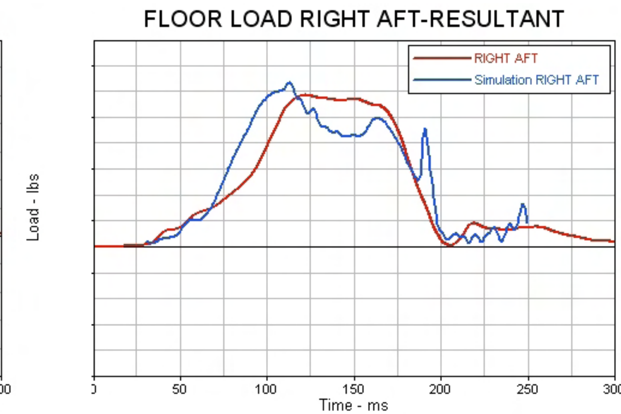


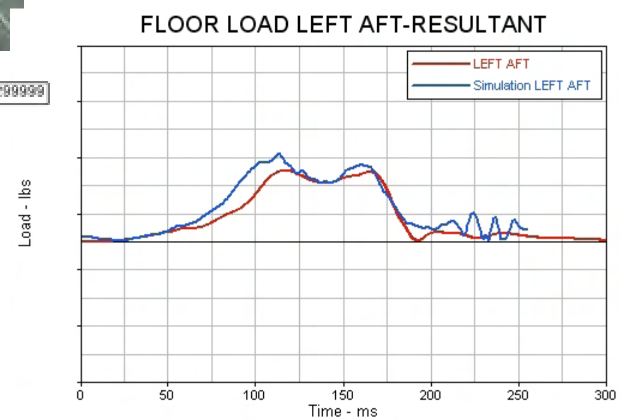
Front | Top | Left Of.

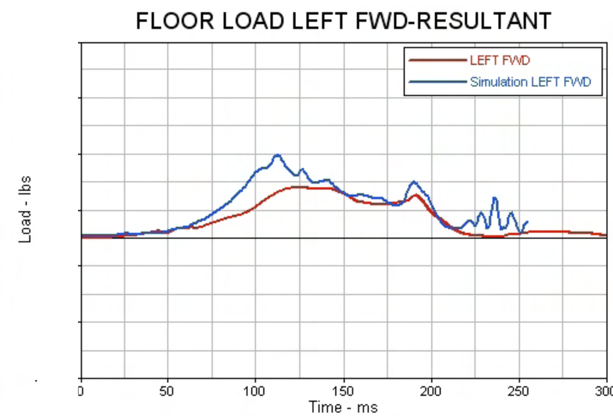
Comparison Simulation and Sled Test – Floor Loads



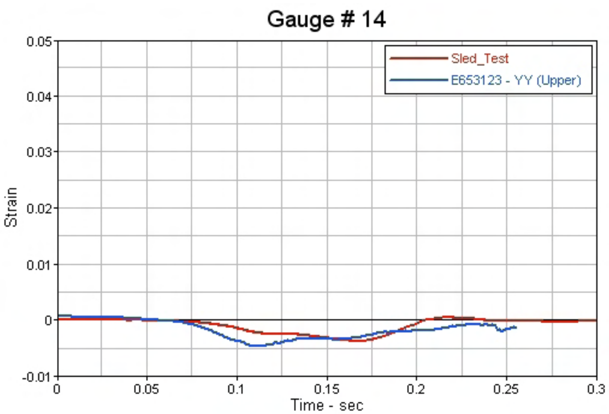


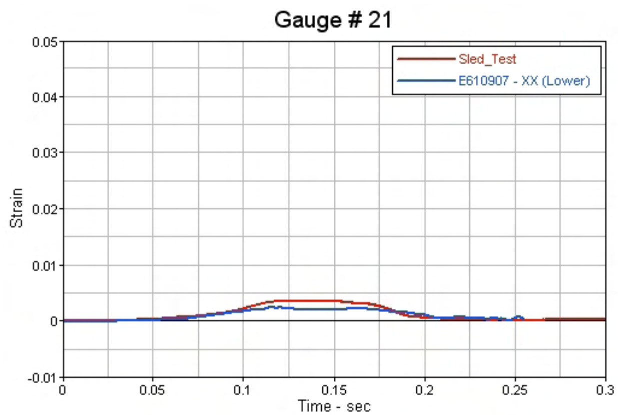


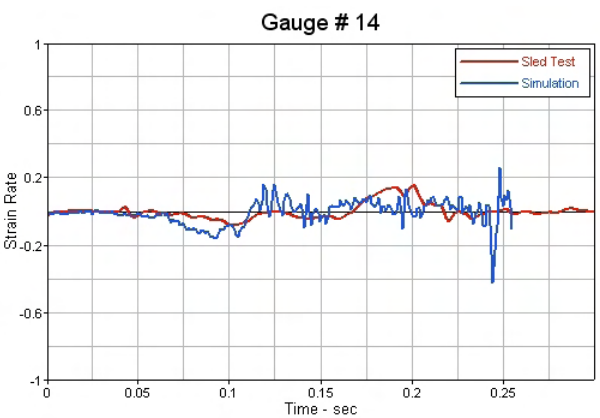


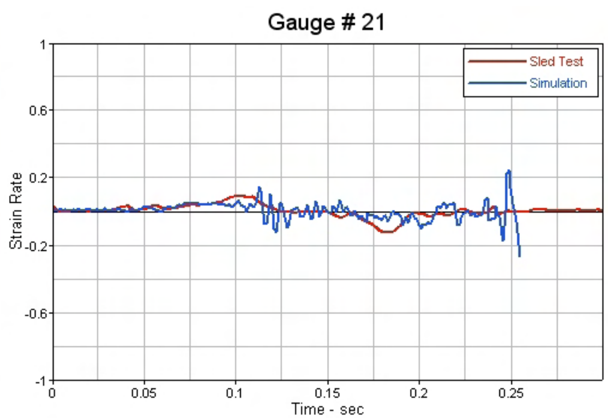


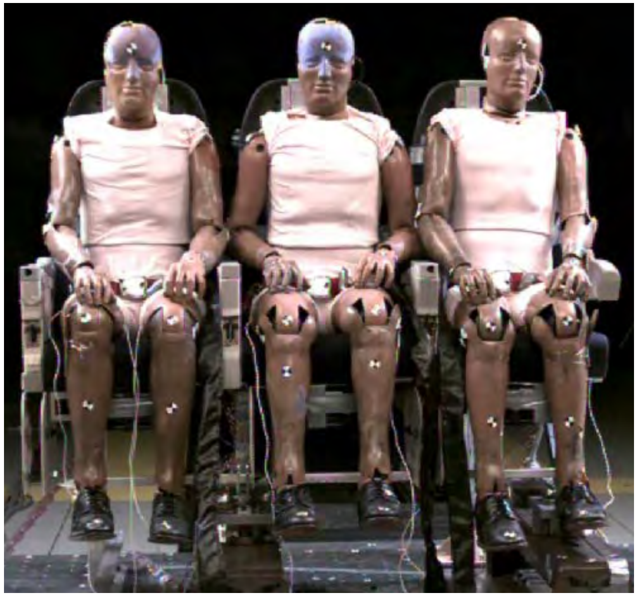
Comparison Simulation and Sled Test – Strain and Strain Rate





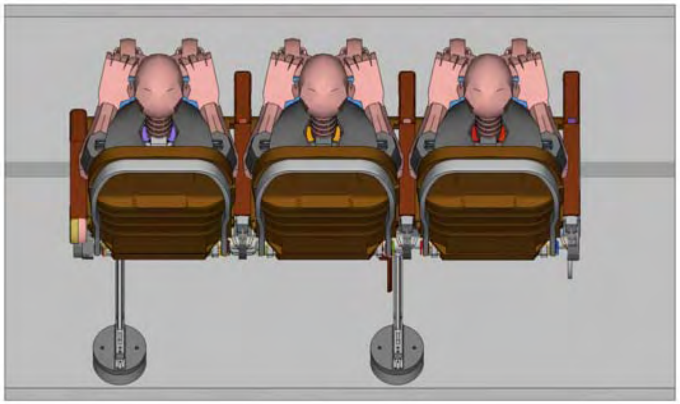


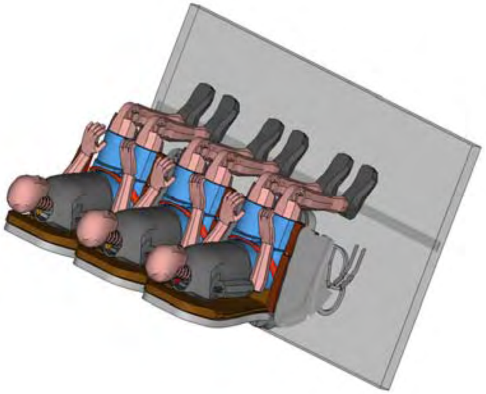


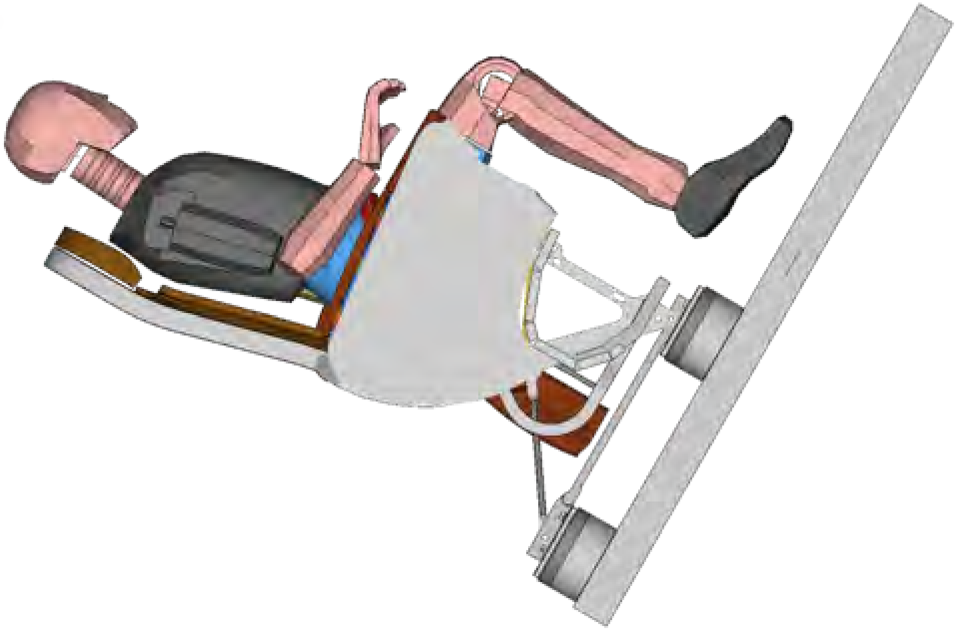


Strain rate bellow 1 /s
Data analysis ongoing

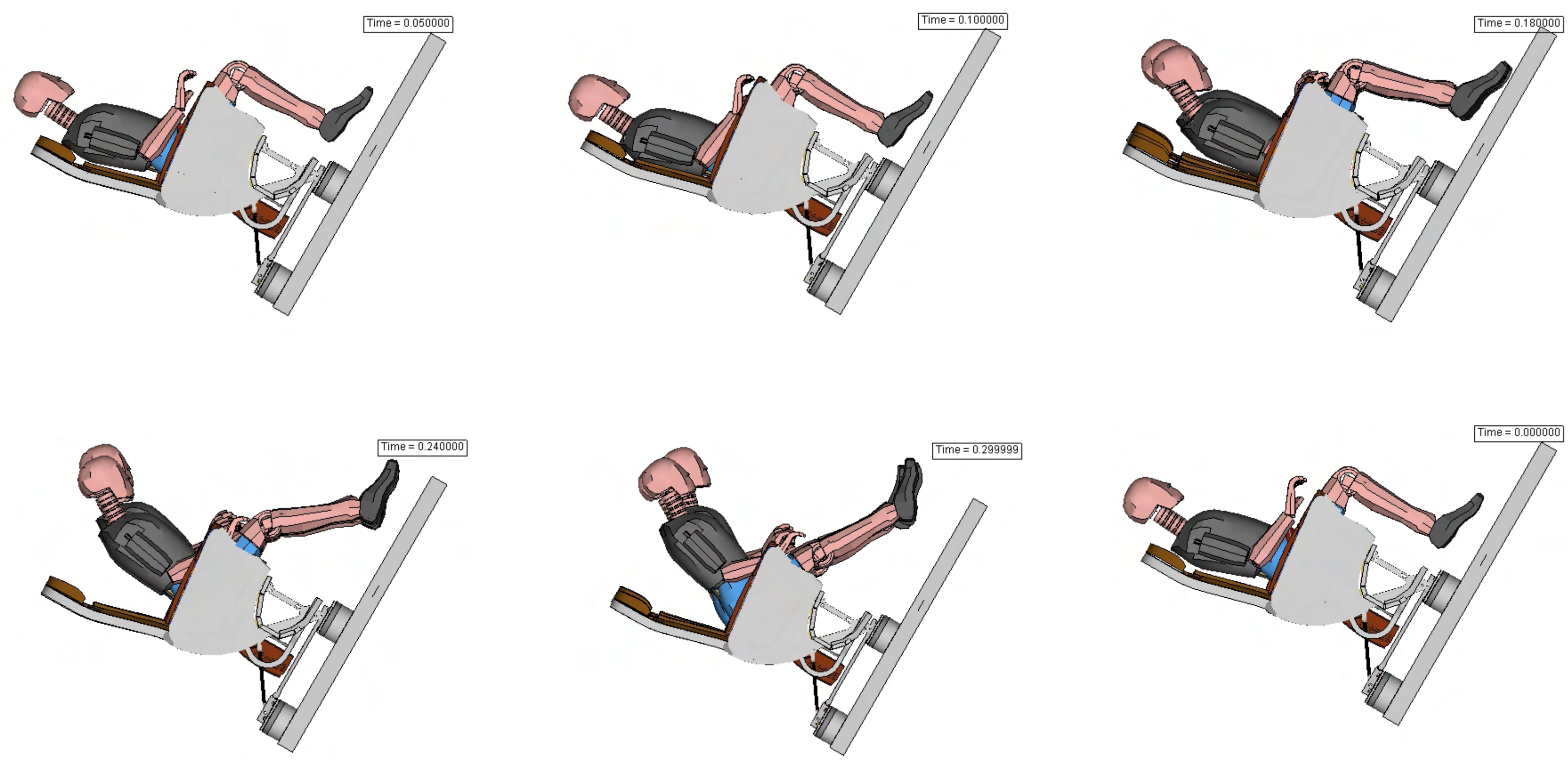
Configuration II: FAR 25.562 Test I





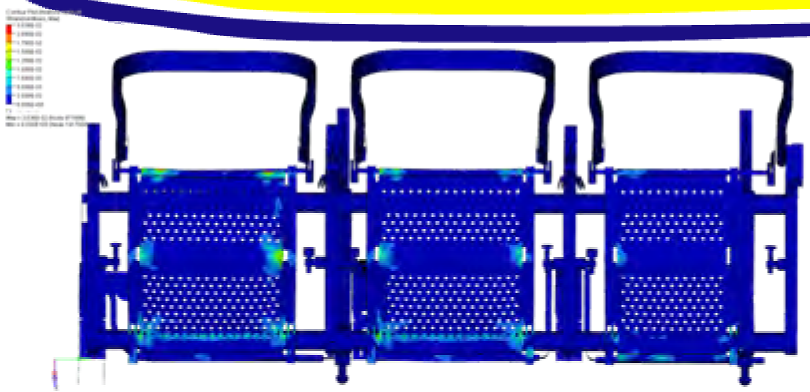


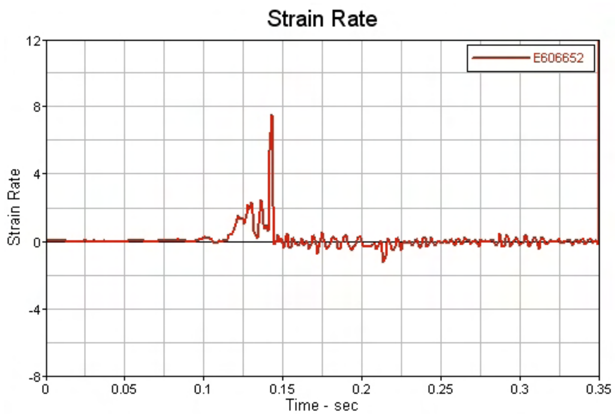
Configuration II: ATD Kinematics



Left Of.

Configuration II: Strain Gauge Locations for Physical Testing



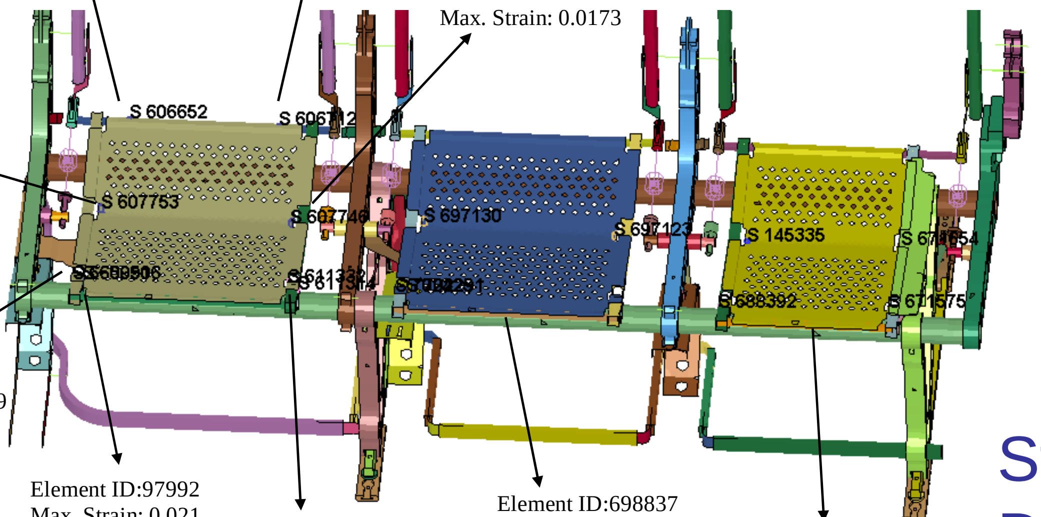


Element ID:606652
Max. Strain: 0.048

Element ID:606712
Max. Strain: 0.061

Element ID:607746
Max. Strain: 0.0173

Element ID:607753
Max. Strain: 0.0248



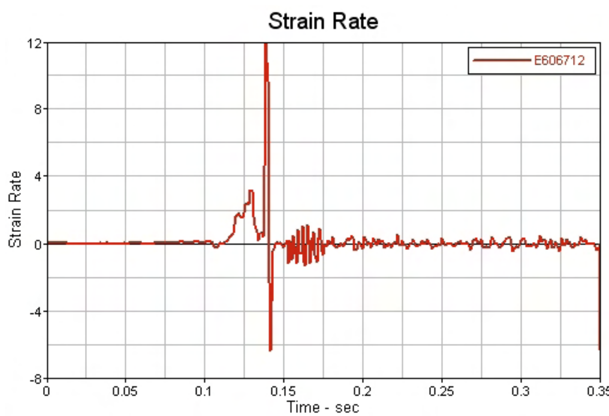
Element ID:25291439
Max. Strain: 0.0125

Element ID:97992
Max. Strain: 0.021

Element ID:97002
Max. Strain: 0.0261

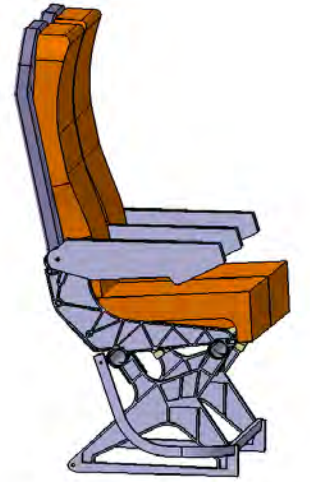
Element ID:698837
Max. Strain: 0.0487

Element ID:677013
Max. Strain: 0.0427

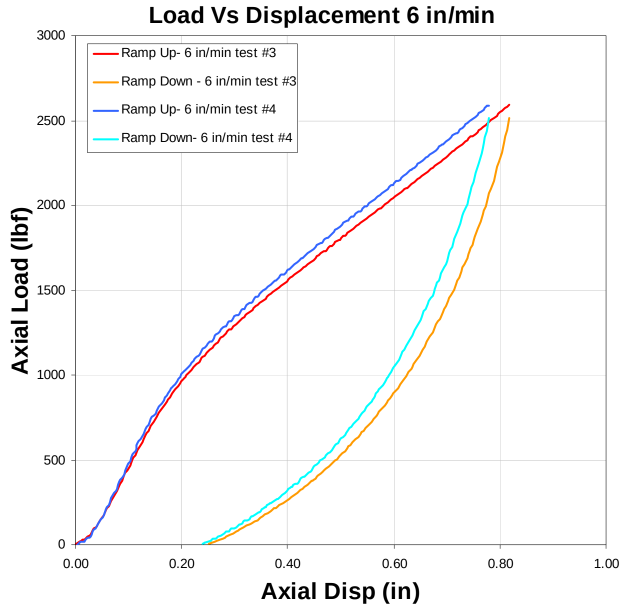


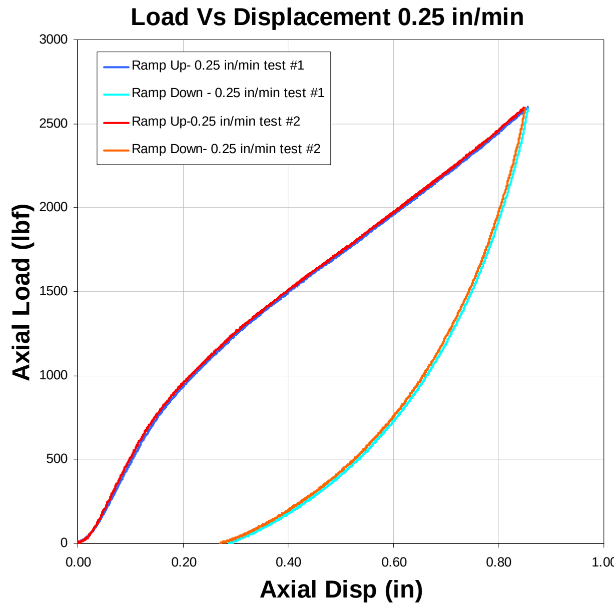
Strain rate bellow 12 /s
Data analysis ongoing

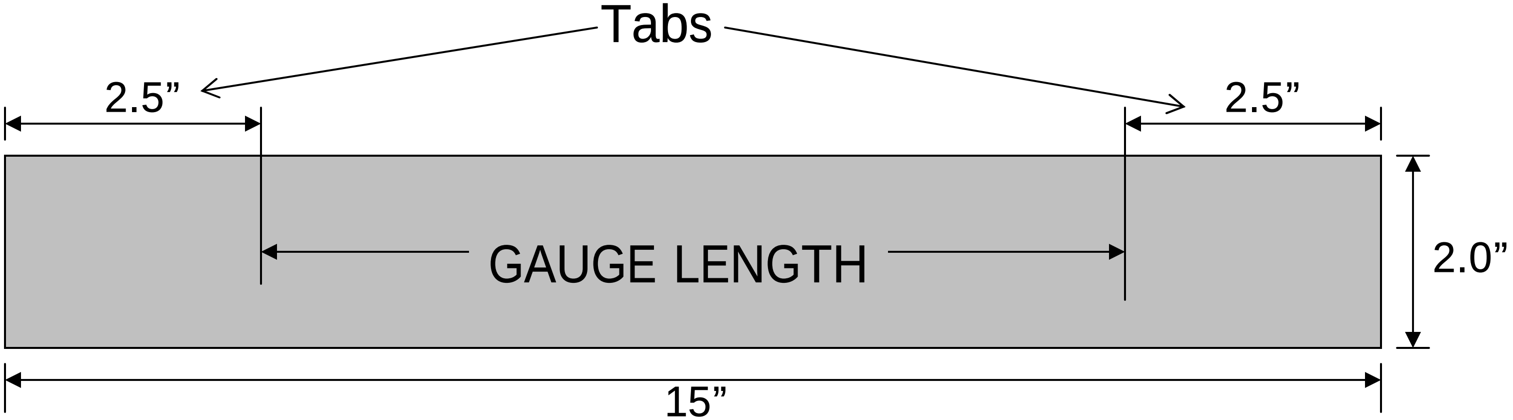
FE Modeling Study Seat Type II



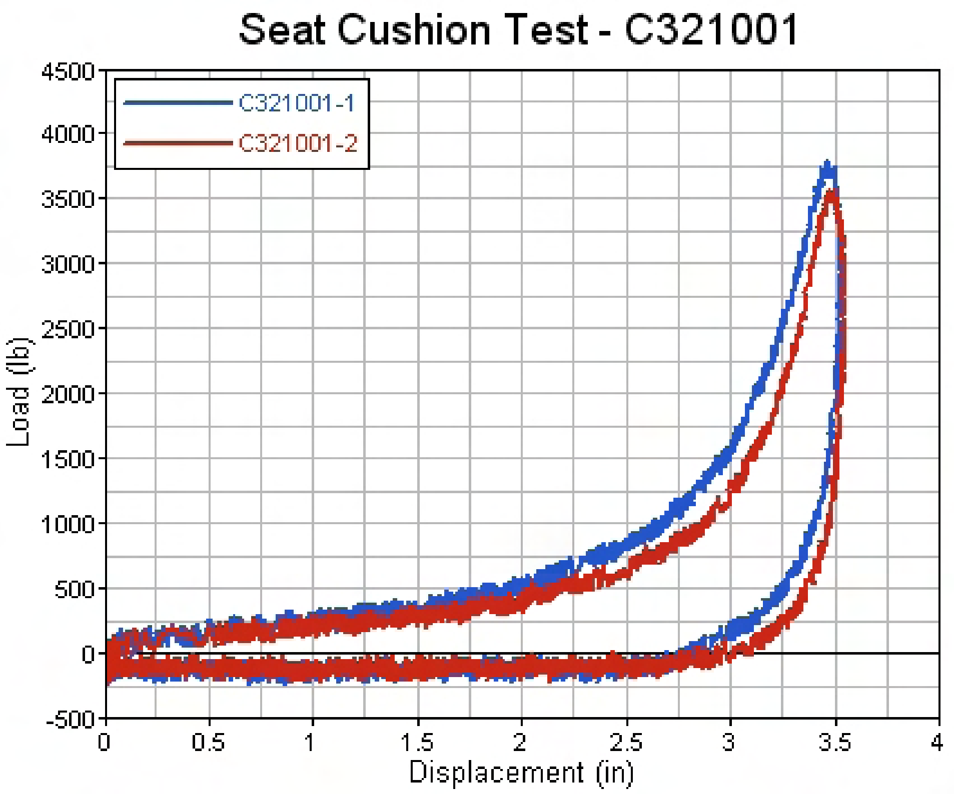
FE Study II: Belt Webbing Testing





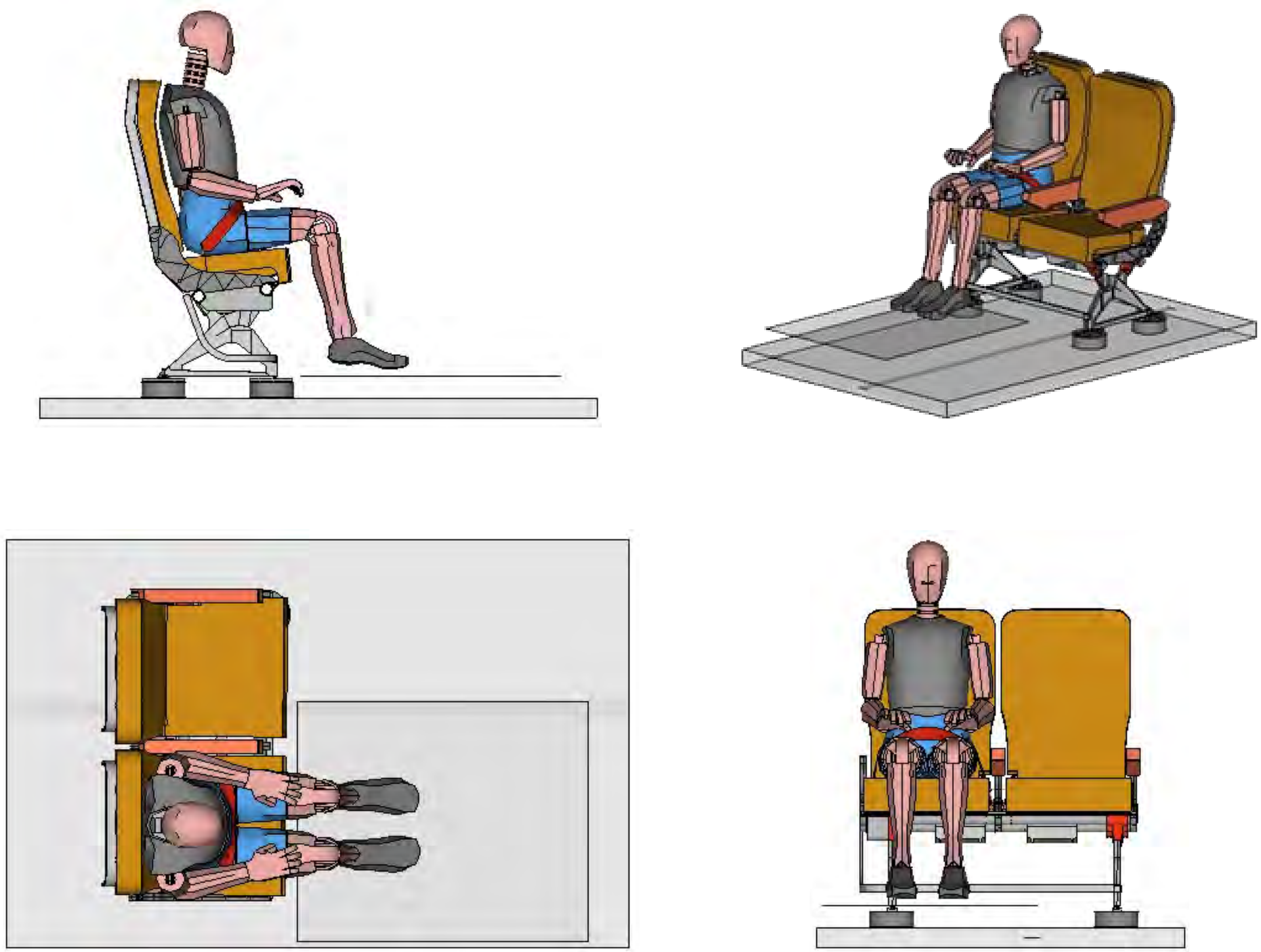


FE Study II: Seat Cushion Testing

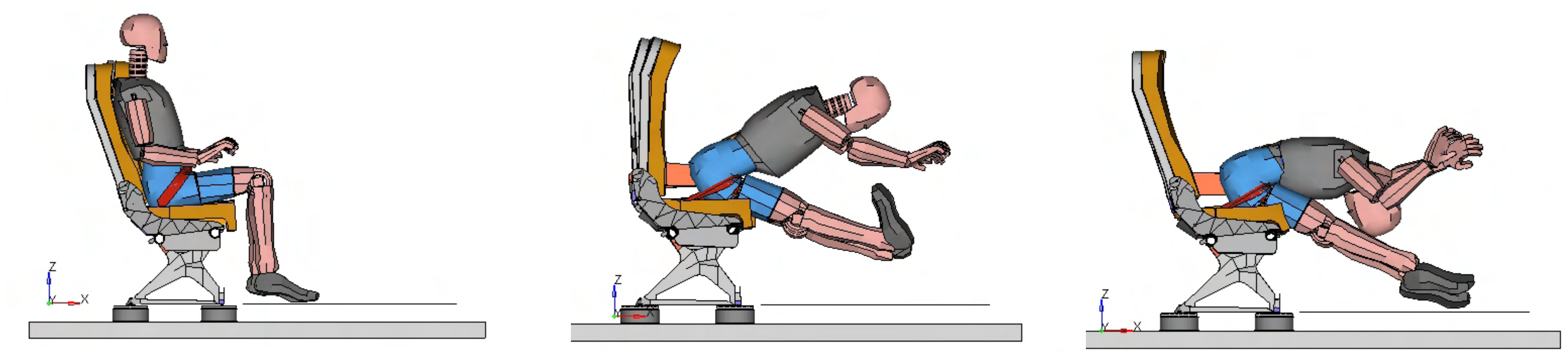


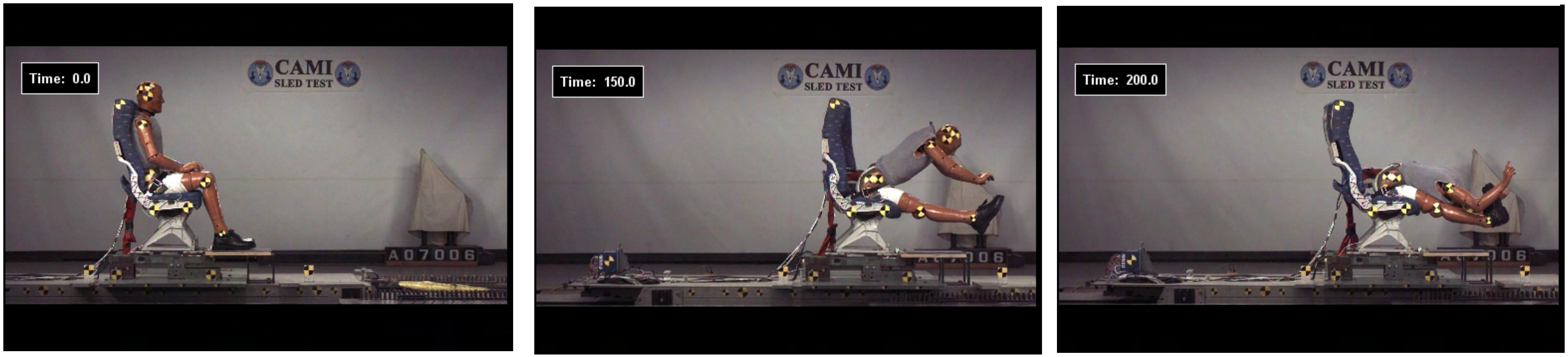
Note: Quasi-static an dynamic (30 in/sec) test procedures as described in Aircraft Seat Cushion Component Testing document DOT/FAA/AR-05/5

FE Study II: FAR 25.562



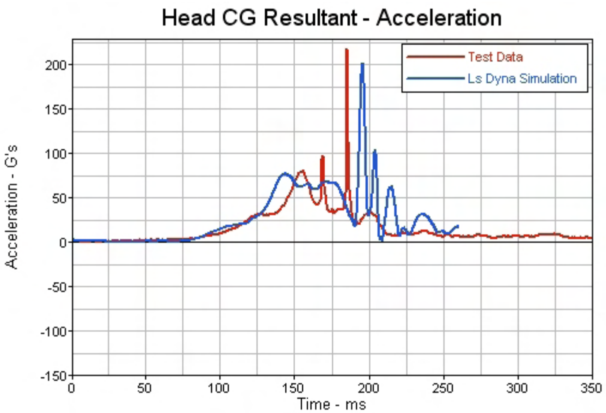
FE Study II: ATD Kinematics

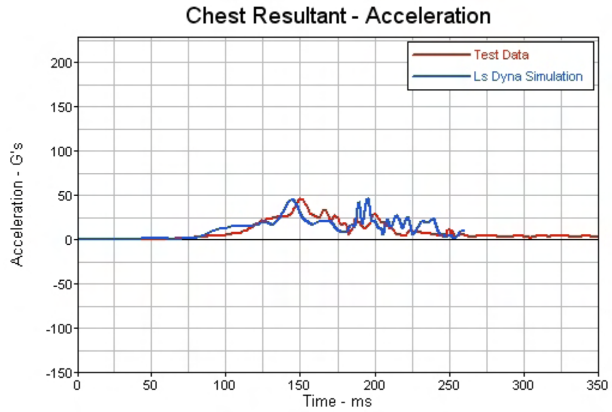


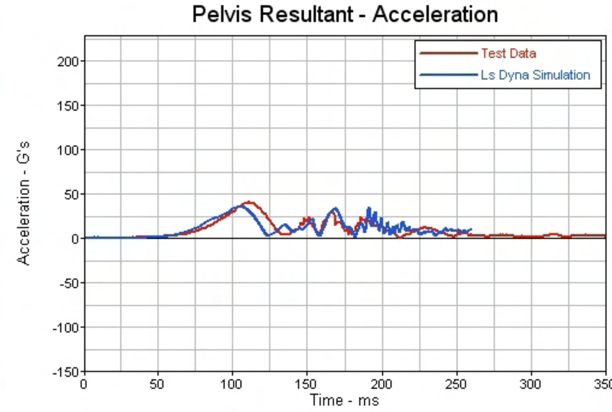


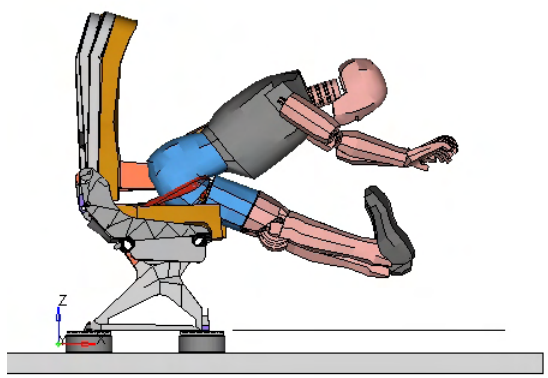
Left Of.

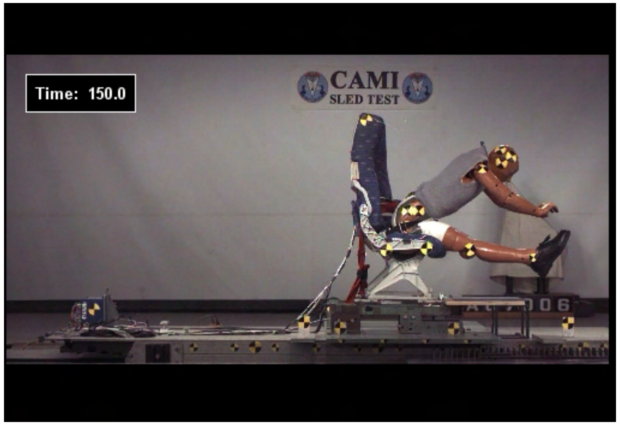
FE Study II: ATD Accelerometer Data



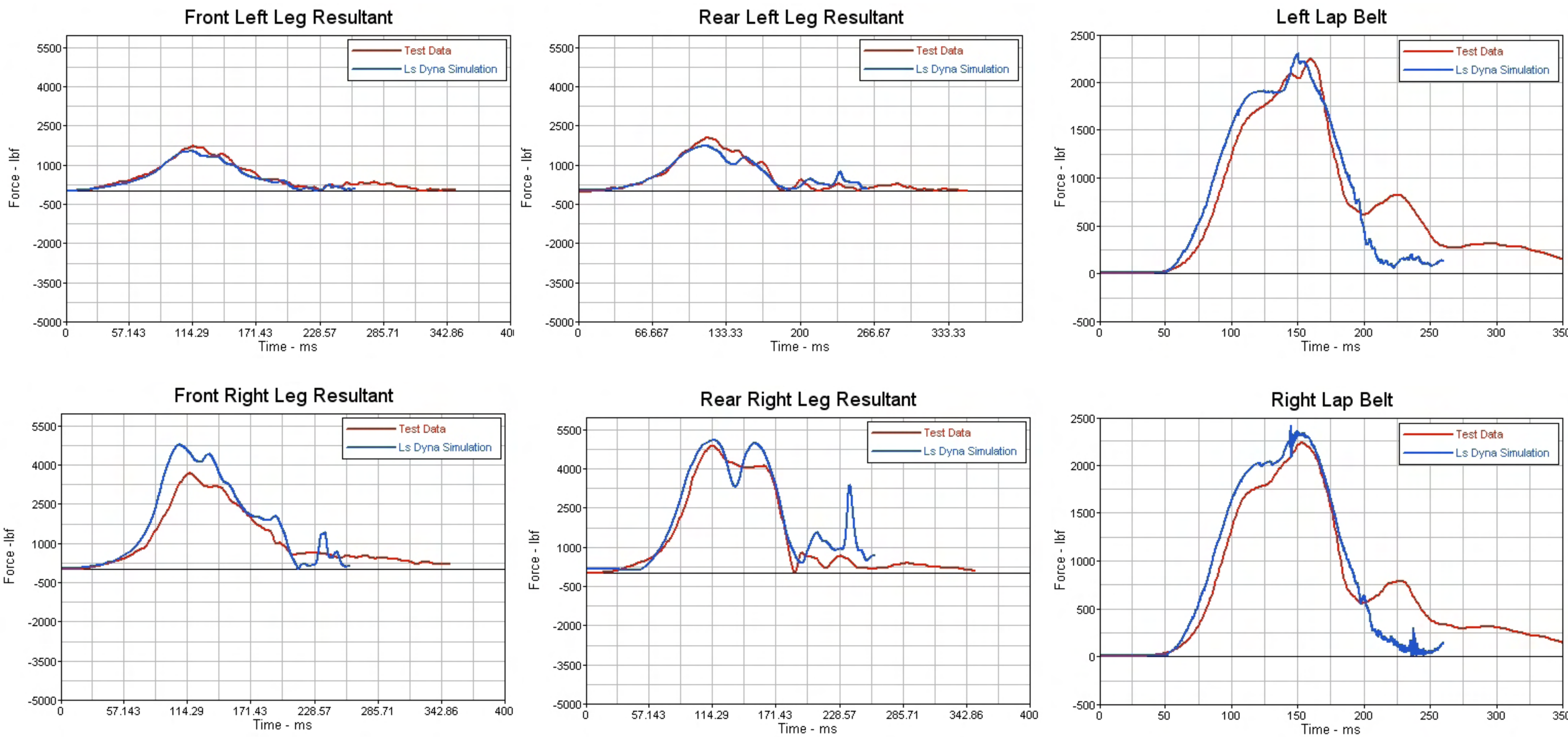








FE Study II: Load Cell Data

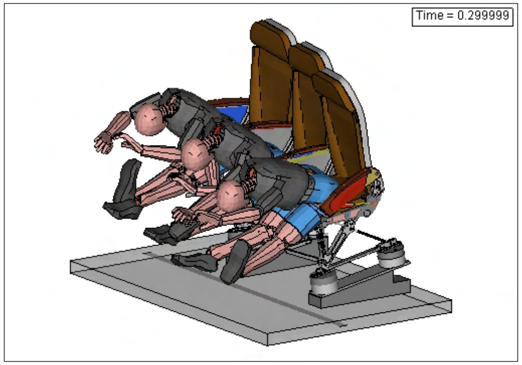


Conclusions CBA Phase II

- Four types of seats (2 an 3 place coach seats, first class seat and a business jet seat) have been analyzed for FAR 25.562 Type II (no pitch roll or yaw) condition:
  - Strain rates do not exceed 1.0 /s [Testing and simulation 3 place coach seat]
  - Further numerical analysis with pitch, roll and yaw is ongoing
- Three types of seats have been analyzed for FAR 25.562 Type I condition:
  - Strain rates do not exceed 12.0 /s [Based on simulation]
  - Physical testing preparation ongoing
- Define recommended testing protocols for:
  - Seat Cushion Testing – quasi static and dynamic testing
  - Metallic component material testing – quasi static and high strain rate testing
  - Seat Belt Webbing Testing
- Test repeatability studies for a typical aircraft seat installation is ongoing. This data may be used to establish correlation levels for AC 20-146 and/or ARP 5765.
- Material list for typical aluminums and steels has been defined. Quasi-static material data parameters required for simulation models are available in MIL HBK 5 for most of these materials.

Future Work

- Joints and fittings modeling techniques
- Modeling fastener pre-loads
- Predictive component failure modeling:
  - Component level
  - Seat assembly level
- Numerical ATD initial positioning methods
- Numerical seat model pitch and roll procedures
- Numerical seat model permanent deformations
- Non-deterministic seat modeling evaluation. Based on component test variability.
- Installation evaluations:
  - Row-to-row configuration
  - Bulkhead configuration
  - Seat cushion replacement
- Prepare CBA Industry workshops



A Look Forward

- **Benefit to Aviation:**
  - Reduce certification costs
  - Reduce development cycles
  - Improve product design (Passenger Safety and Weight Reduction)
  - Provide data for ongoing SAE Aerospace Recommended Practice ARP 5765 on CBA
  - Provide a simulation industry standard
- **Future needs:**
  - Typical joints and fittings modeling guidelines:
    - Component Testing, Failure Models, Modeling Techniques
  - System level computational Stochastic and DOE analyses:
    - Eliminate deterministic models and designs hence improving the “robustness” of the designs
  - Research additional applications such as row-to-row, bulkhead, HUD and OHU installations, and side facing seats
  - Develop Virtual Certification protocols