Certification by Analysis I and II

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July 22nd 2009

A Center of Excellence AMTAS Advanced Materials in Transport Aircraft Structures

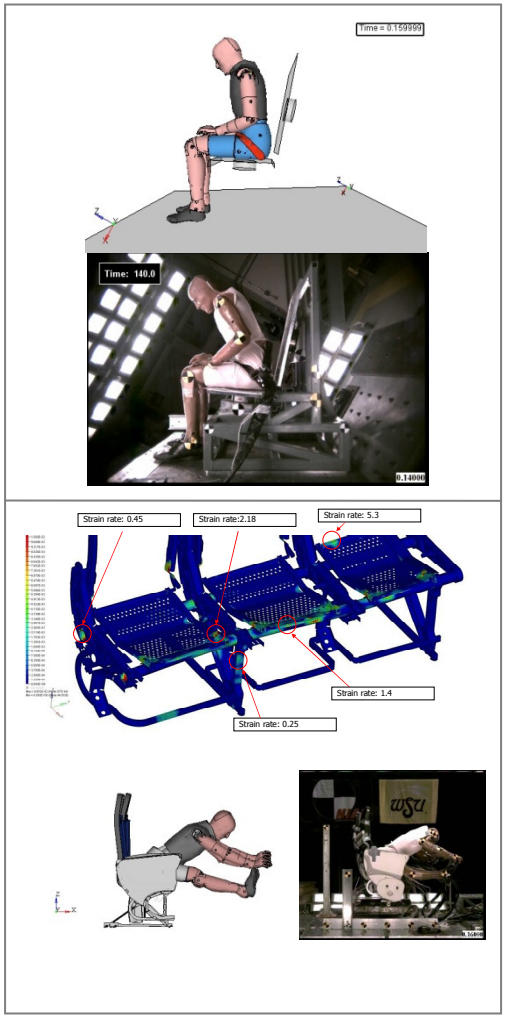
WICHITA STATE UNIVERSITY

CECAM center of excellence for composites and advanced materials

The Joint Advanced Materials and Structures Center of Excellence

CBA Research Program Overview

- **Phase I:** HII and HIII FAA Numerical ATD Validation
  [July 2005 - July 2009]:
  - Test variability HII and HIII FAA ATD with 2,3, and 4-point restraints.
  - Numerical ATD V&V Procedure.
  - Comparison HII and HIII FAA Dynamic Performance.
  - SAE ARP ATD Reference Data.
- **Phase II:** Seat Structural Modeling Techniques
  [September 2006 - September 2009]:
  - Seat Structure: Material models, joint definitions, and Modeling techniques FE and MB.
  - Component Level Tests Protocols.
  - Pitch and Roll Modeling Procedures.



FAA Sponsored Project Information

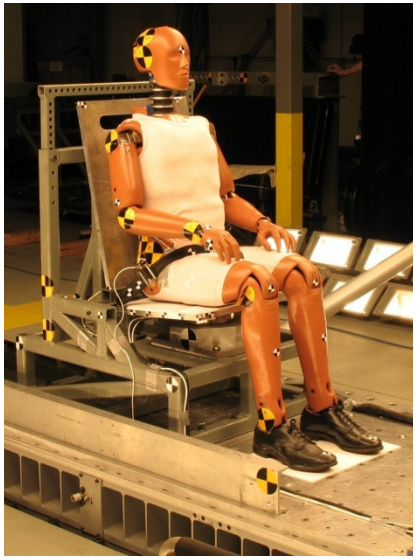
- Principal Investigators & Researchers
  - G.Olivares PhD, PI.
  - S. Keshavanarayana PhD (High Strain Rate Testing)
  - V. Yadav, Students: O. Oliva, M. Nagrecha, N. Dhole.
- FAA Technical Monitor
  - Allan Abramowitz.
- Other FAA Personnel Involved
  - Rick Dewesse (CAMI).
  - David Moorcroft (CAMI).
- Industry Participation
  - Weber Aircraft, Contour Seating ,B/E Aerospace, SICMA, IPECO, Recaro, Schroth Safety Products, AMSAFE, TASS/TNO-MADYMO, Altair-Radioss, FTSS, ESI-Pamcrash, MSC, Cessna, Airbus NA, Hawker/Beechcraft, Gulfstream, 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.

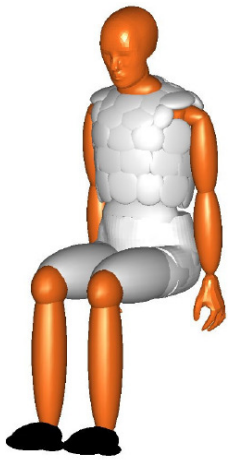
Certification by Analysis I

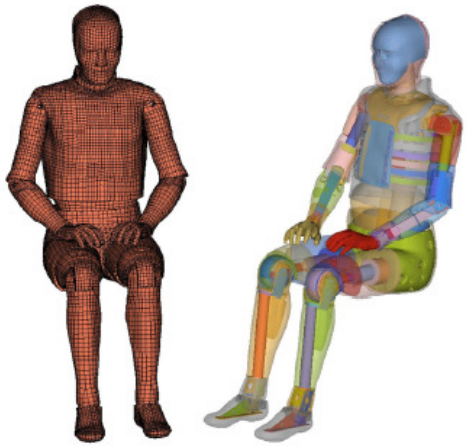
- **Phase I: Numerical Anthropometric Test Dummies:**
  - Literature review and numerical tools survey.
  - Sled testing – Rigid Seat (Series I [23 Sled Test] and II [30 Sled Tests]).
    - Test variability studies – Establish corridors for validation criteria.
    - ATD Validation reference database.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



Conclusions CBA Phase I

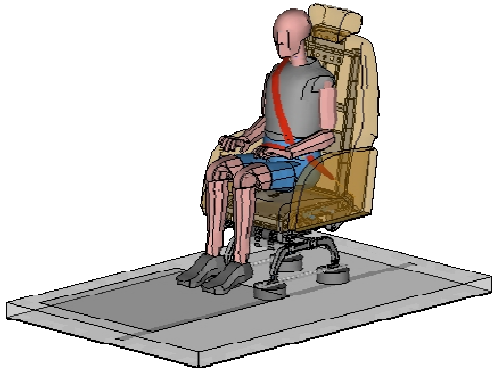
- Reference Sled Tests completed, submitted to numerical ATD developers and SAE ARP 5765 working group. ✓
- Develop testing protocols and data requirements to validate computer models. ✓
- HII and HIII FAA test repeatability studies completed ([2, 3 and 4 point restraints] [0 and 60 deg Test Conditions] [Dynamic conditions FAR 23.562 and 25.562]). ✓
- CBA Phase I final reports volume one and two under review. ✓
- Comparison study of HII and HIII FAA performance for typical aerospace applications.[2, 3 and 4 point restraints] [0 and 60 deg Test Conditions] [Dynamic conditions FAR 23.562 and 25.562]. ✓
- Ongoing report: Comparison Study of the HII and HIII FAA ATDs under FAR 23.562 and 25.562 Dynamic Test Conditions.
- Technology Transfer:
  - Participation SAE Seat Committee.
  - Validation metrics, criteria, and test database submitted to SAE ARP 5765 WG. ✓
  - Support development and validation efforts of numerical models. ✓
  - HII and/or HIII FAA ATD Finite Element and Multibody numerical models are available from FTSS, MADYMO, Pamcrash, and Radioss. ✓
  - Three technical reports (Volume I and II ATD Reference Test and Validation Methodology) (Volume III Comparison Study of the HII and HIII FAA ATDs under FAR 23.562 and 25.562 Dynamic Test Conditions. (Ongoing)

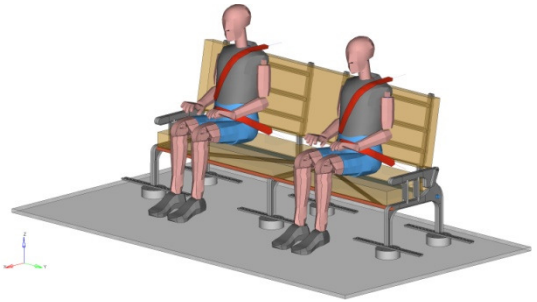


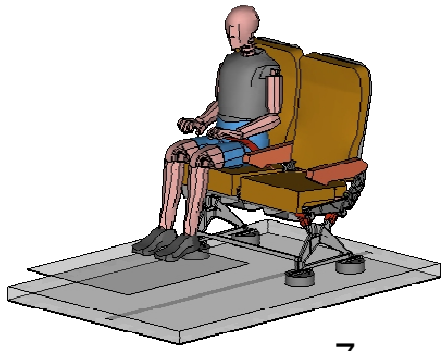


Certification by Analysis II

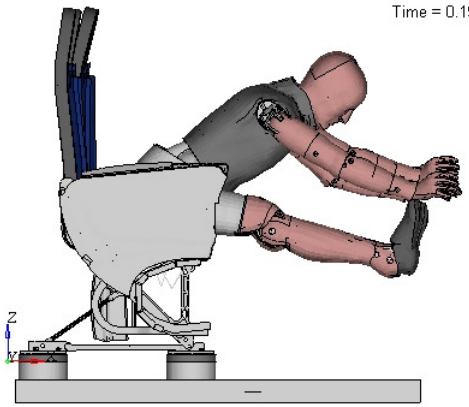
- **Phase II: Aerospace Seat Material Modeling Requirements and Component Testing Protocols:**
  - Literature review: Material data, testing protocols.
  - Survey of materials used in aerospace seating applications.
  - Review of material data required for numerical analysis:
    - Material Models: Structural components, cushions, and webbing.
    - Strain rate definition for typical structural components.
  - Analytical FE Studies for various aerospace seat configurations:
    - Two and three passenger coach class seats (Part 25).
    - One first class seat (Part 25).
    - Two business jet seats (Part 23 and 25).
    - One side facing seat (Part 25).
  - Experimental Studies for various aerospace seat configurations.
    - Strain and Strain rate measurements.
    - Comparison studies with analytical solutions.
  - Component Testing Protocols: Metallic components, seat cushions, and belt webbing.

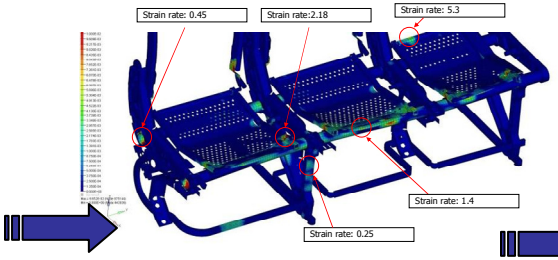


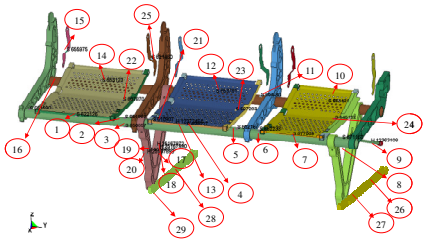


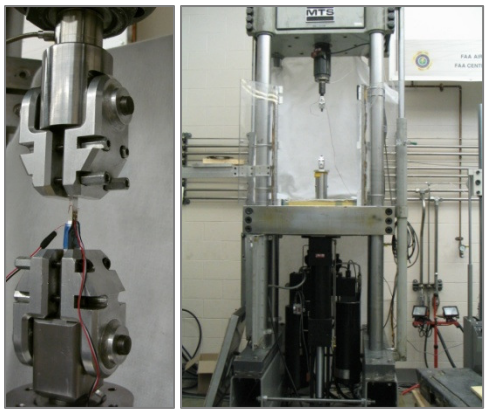


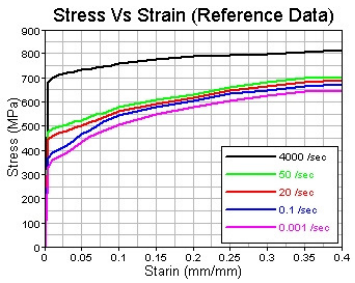
Strain Rate Requirements - Development Process







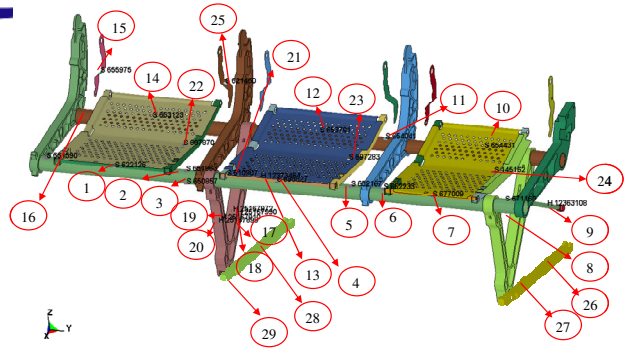


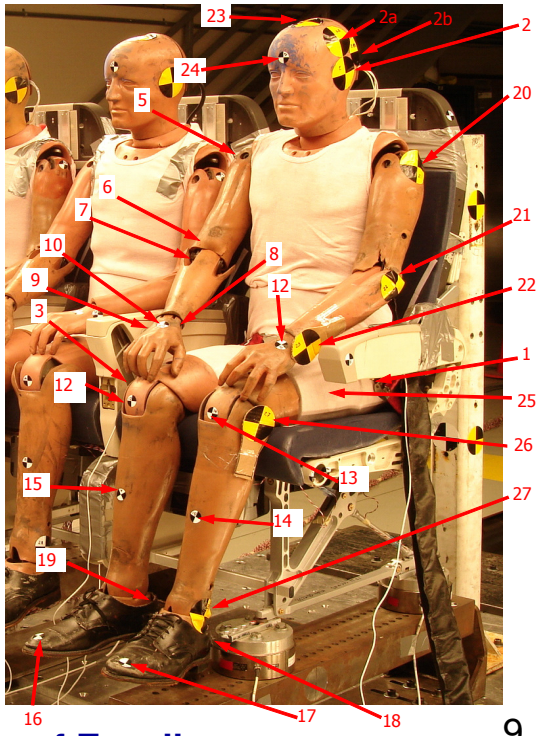


Material Database

Reference Sled Tests Data Channels

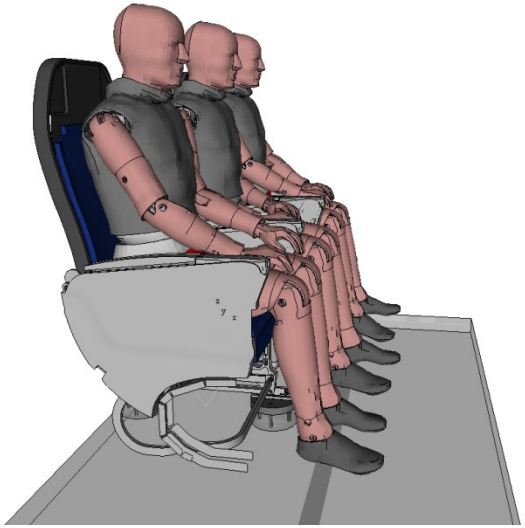
# Channels	Channel Description	Channel Units
1	Sled acceleration	G's vs Sec
3	Head X acceleration	G's vs Sec
3	Head Y acceleration	G's vs Sec
3	Head Z acceleration	G's vs Sec
3	Torso X acceleration	G's vs Sec
3	Torso Y acceleration	G's vs Sec
3	Torso Z acceleration	G's vs Sec
3	Lumbar load X direction	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

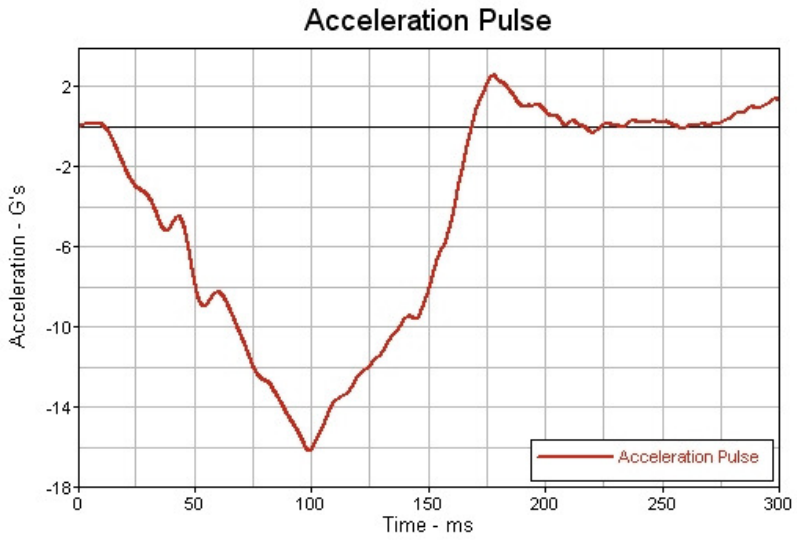




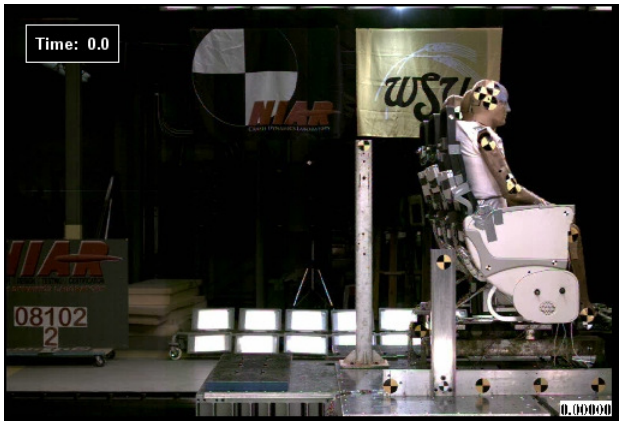
Reference Test Condition I

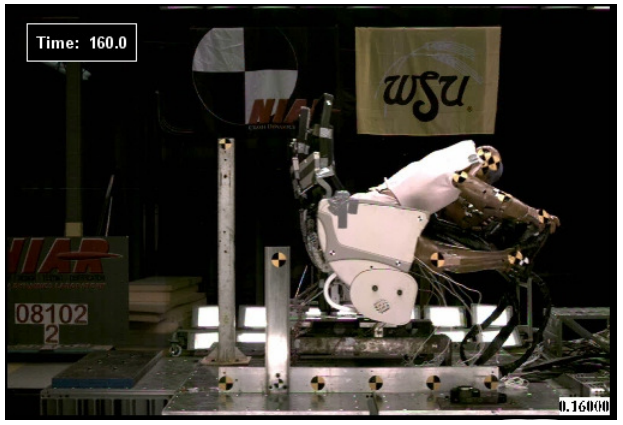
Test No.	08102-2
Pulse	PART 25, Horizontal
Floor Deformation	No
Yaw	No
Type of Dummy	Hybrid II 50%
Type of Belt	2 pt

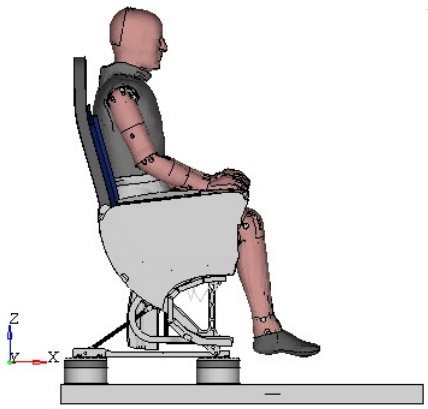


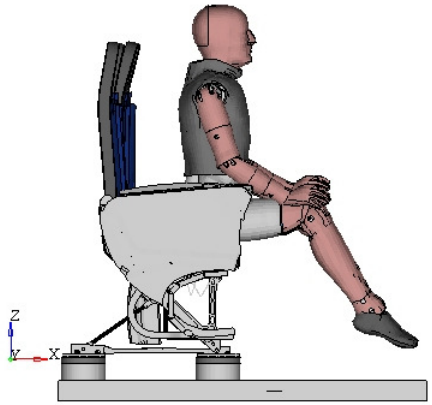


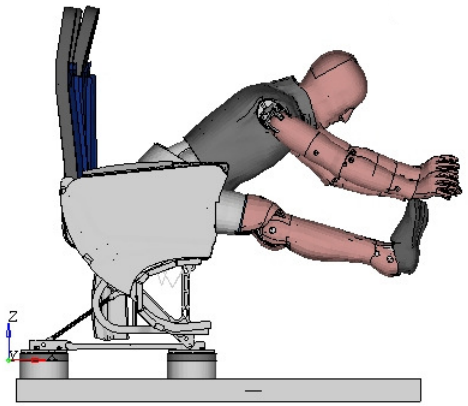
Reference Test Condition I - Kinematics





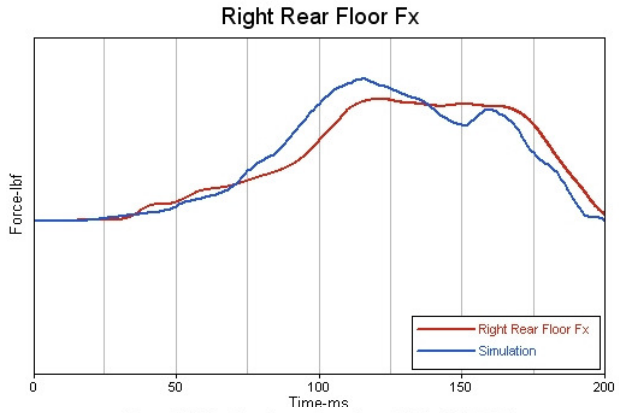


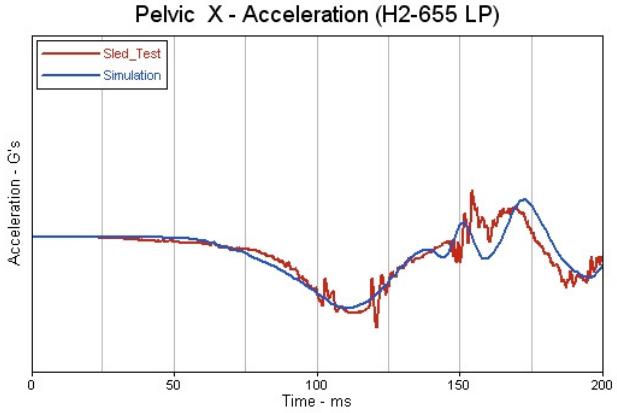


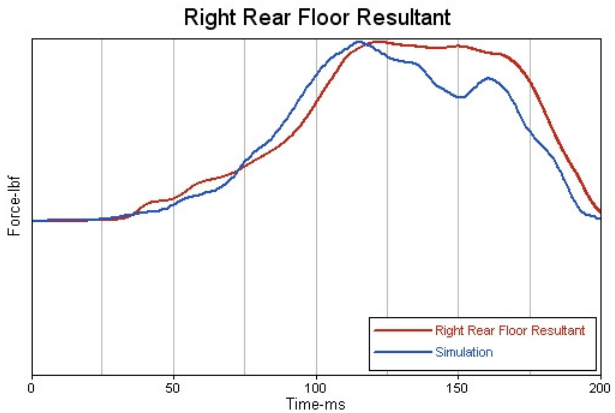


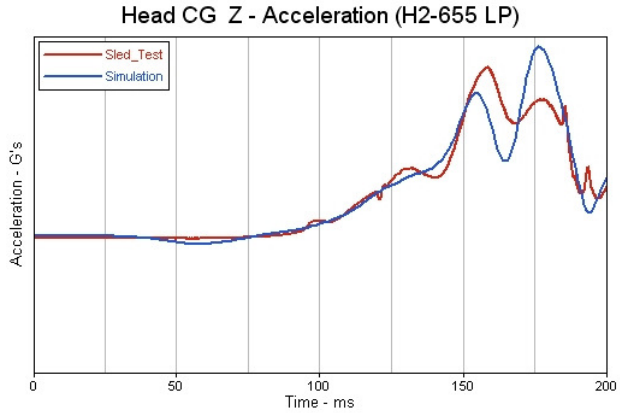
Side

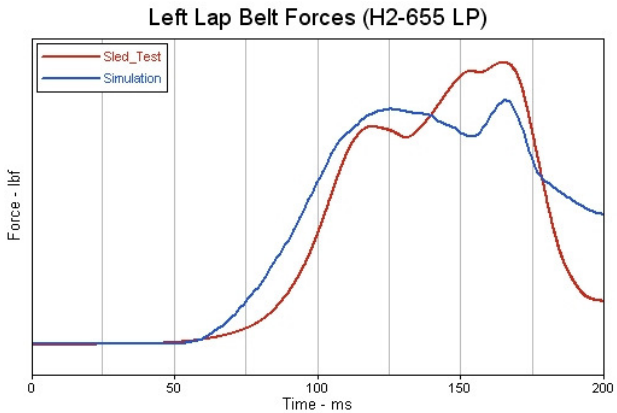
Reference Test Condition I – Sample Data Channels

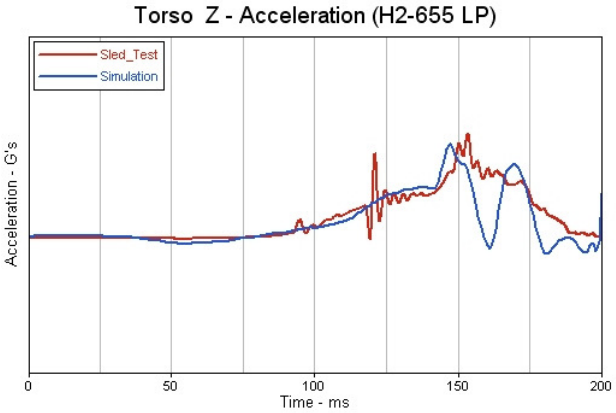




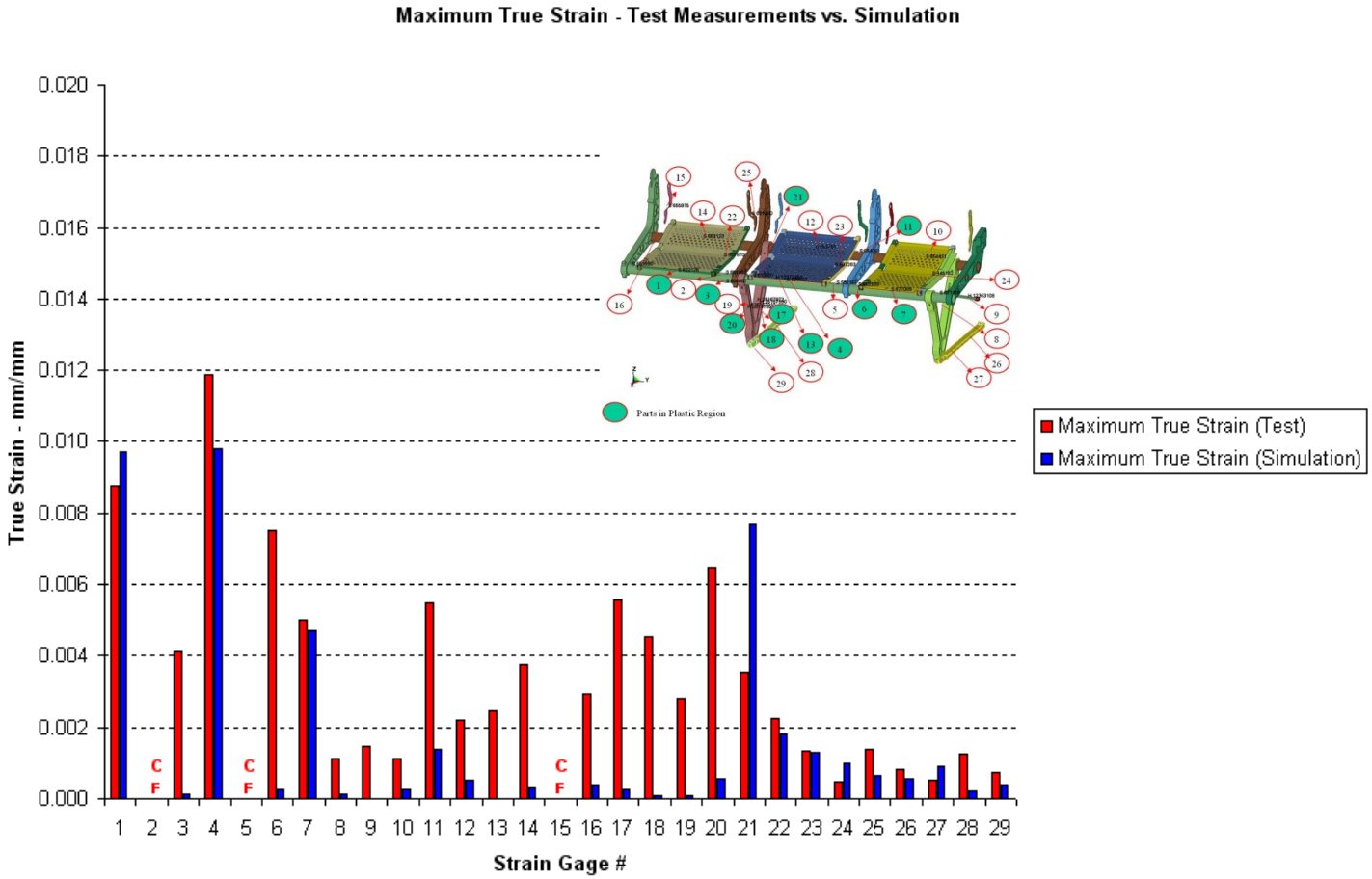








Reference Test Condition I - Maximum True Strain



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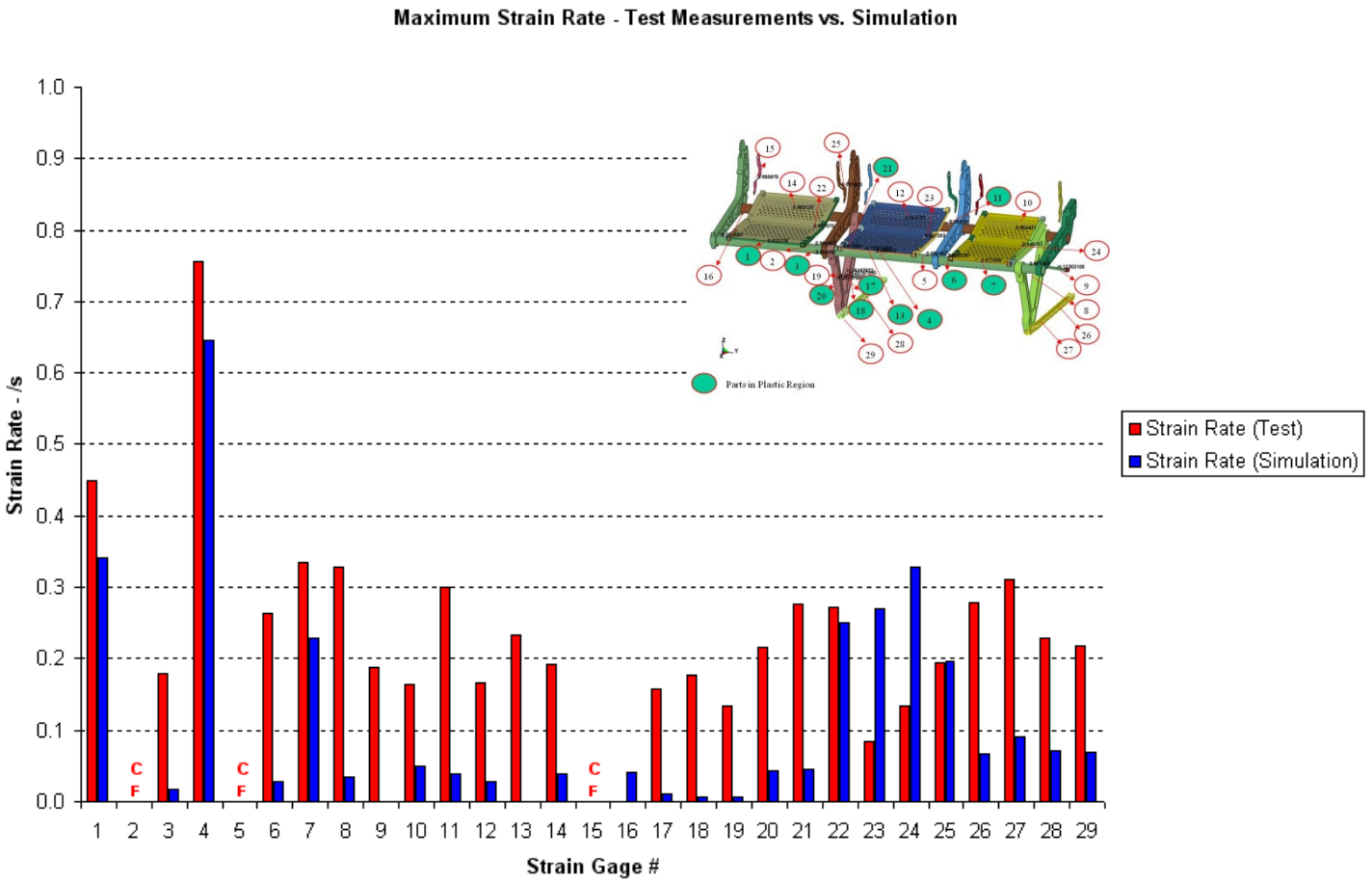
Reference Test Condition I - Maximum Strain Rate



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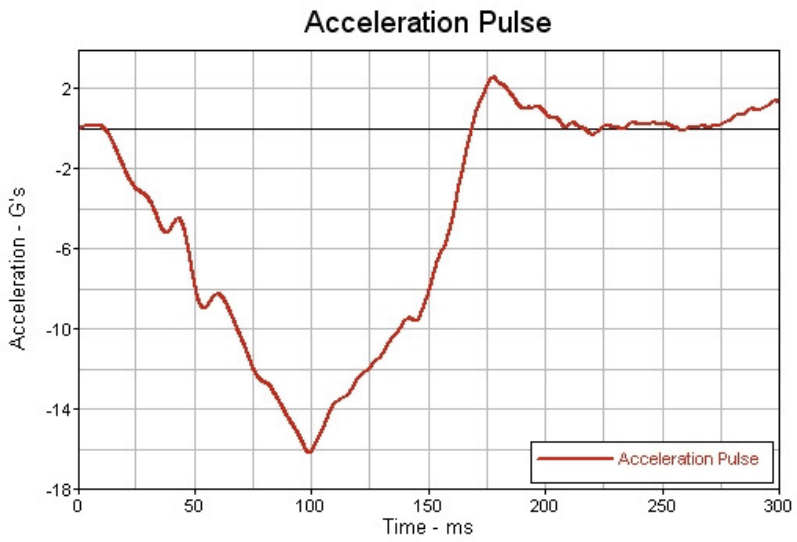
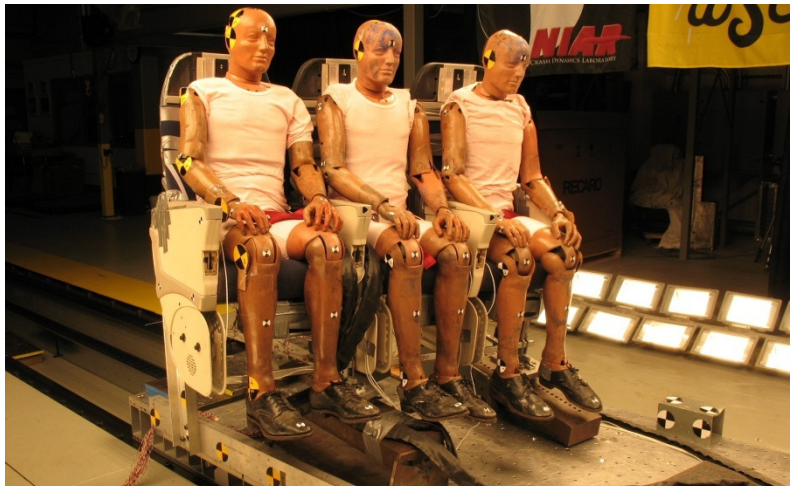
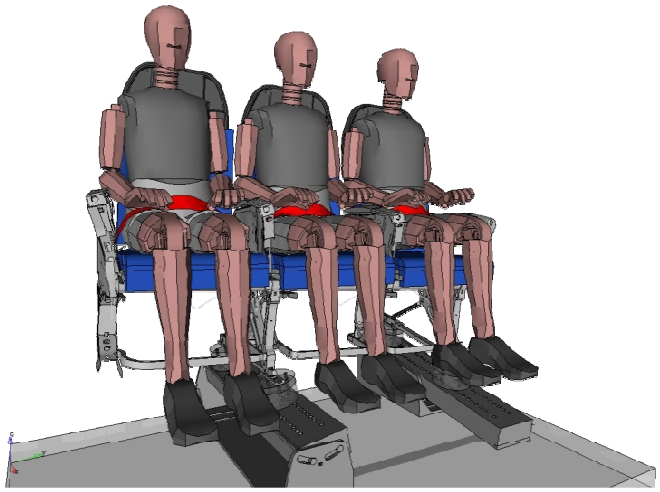
Reference Test Condition II

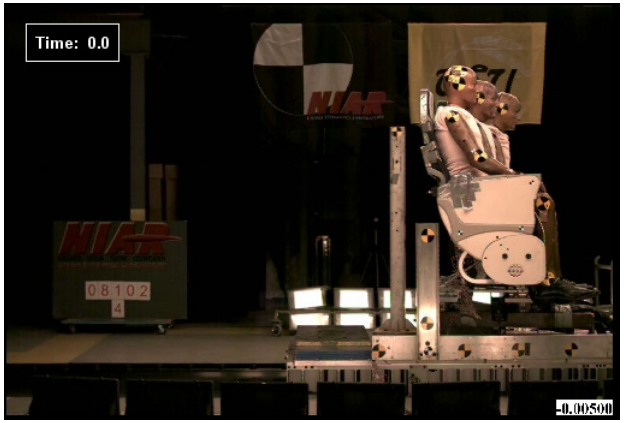
Test No.	08102-4
Pulse	PART 25, Horizontal
Floor Deformation	Roll - 10deg, Pitch - 10deg
Yaw	10deg
Type of Dummy	Hybrid II 50%
Type of Belt	2 pt

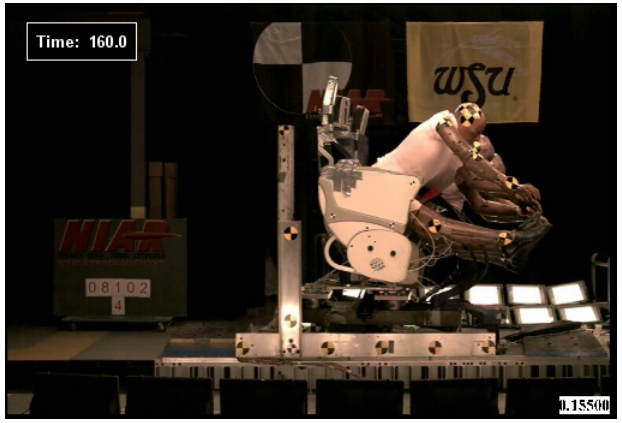


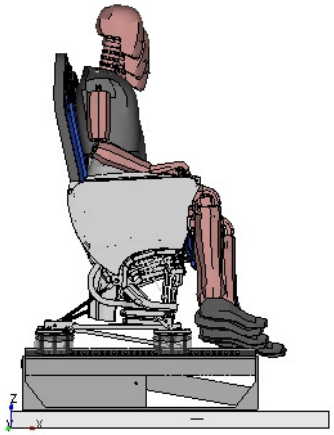


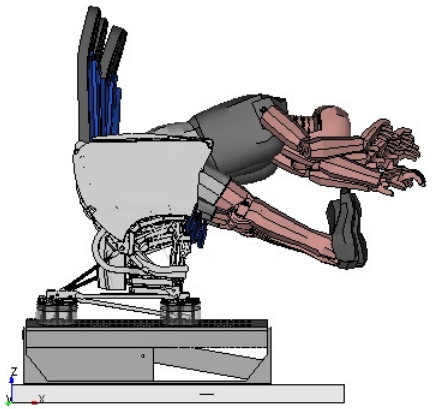


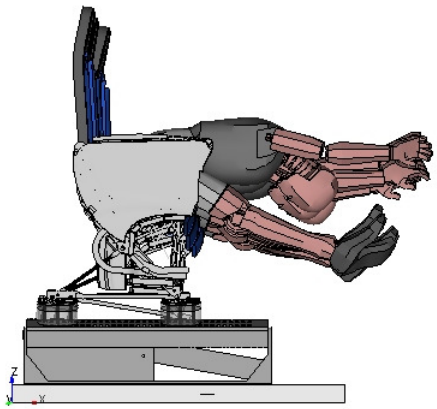
Reference Test Condition II - Kinematics



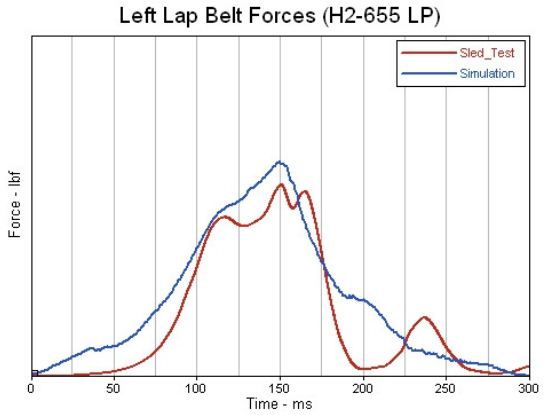


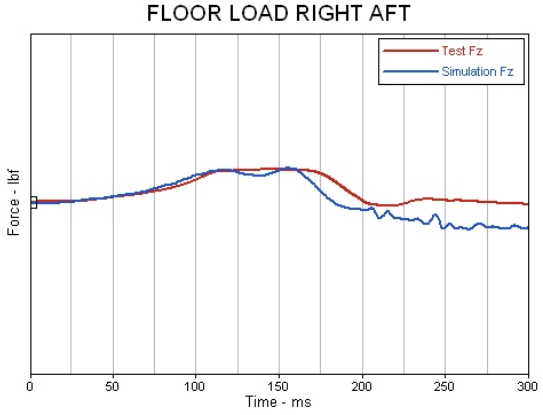


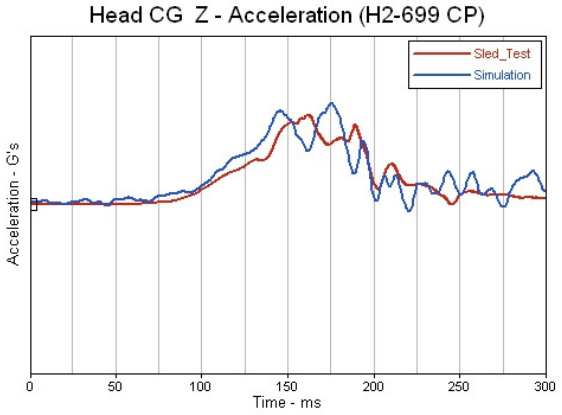


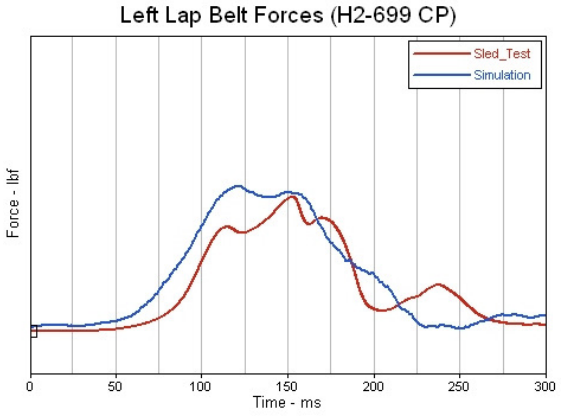


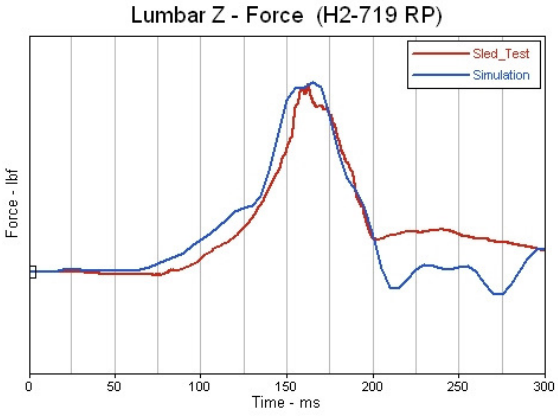
Reference Test Condition II – Sample Data Channels

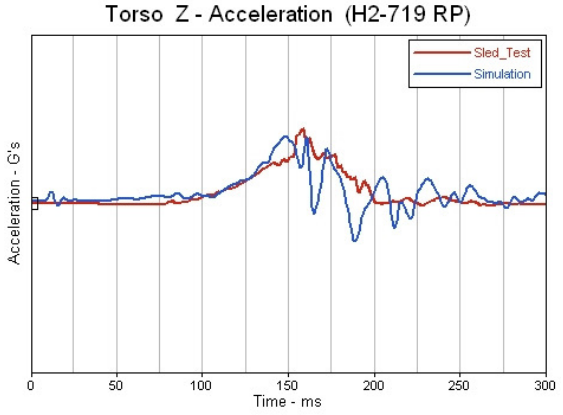






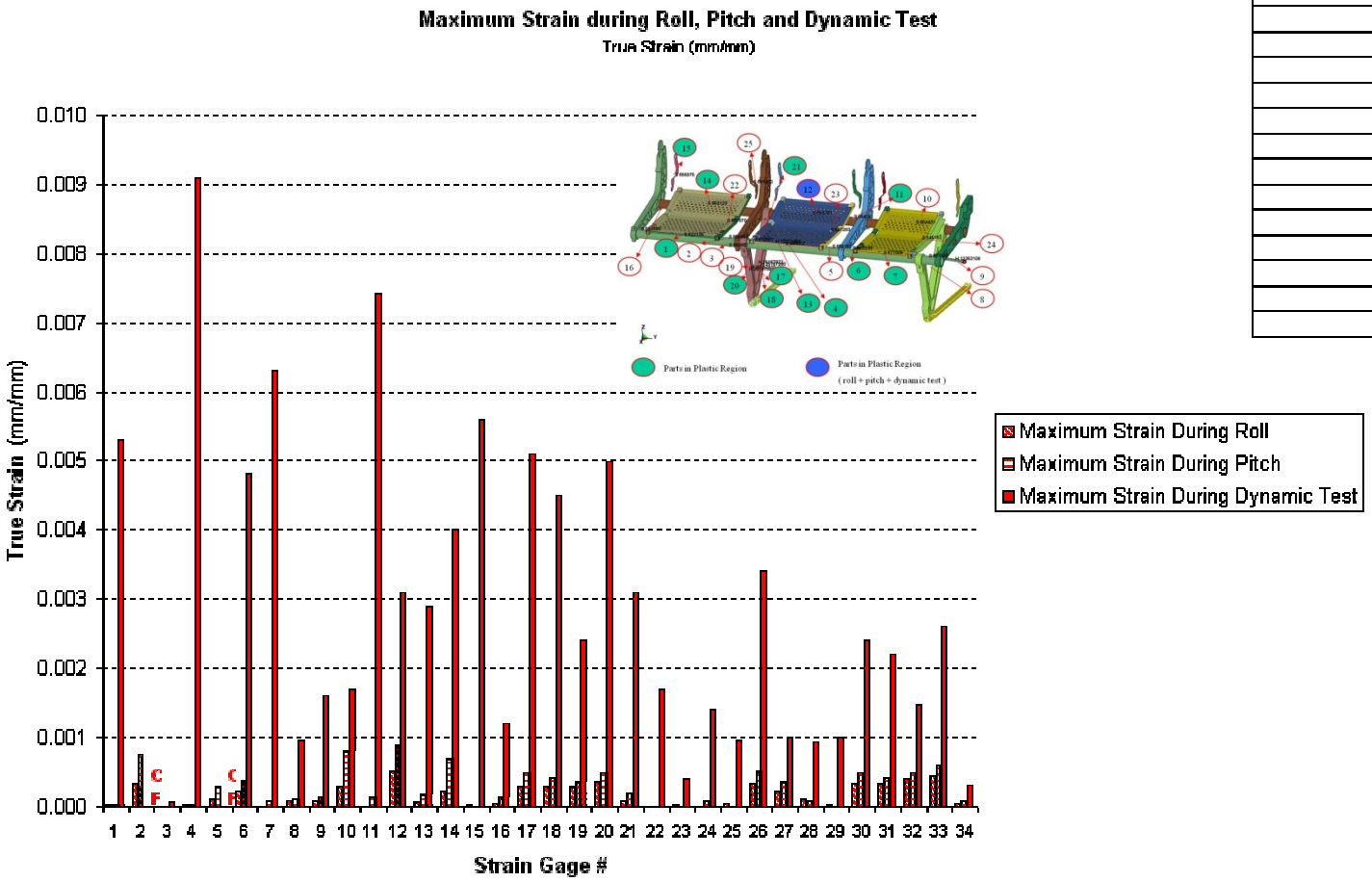






Reference Test Condition II - Maximum True Strain

Gage No. In Plastic Region
1
4
6
7
11
12
13
14
15
17
18
20
21
26



Reference Test Condition II - Maximum Strain Rate

Gage No. in Plastic Region
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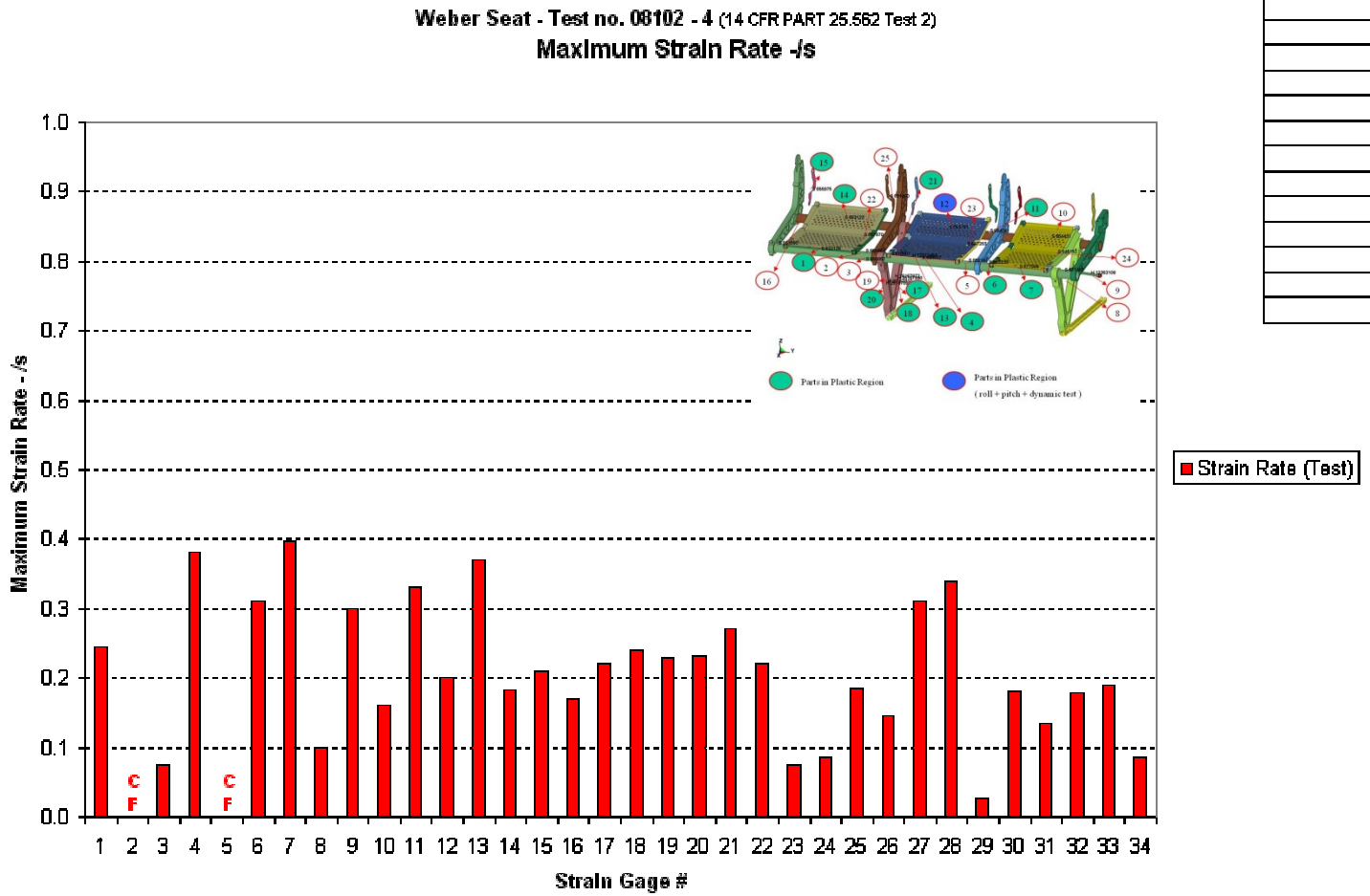
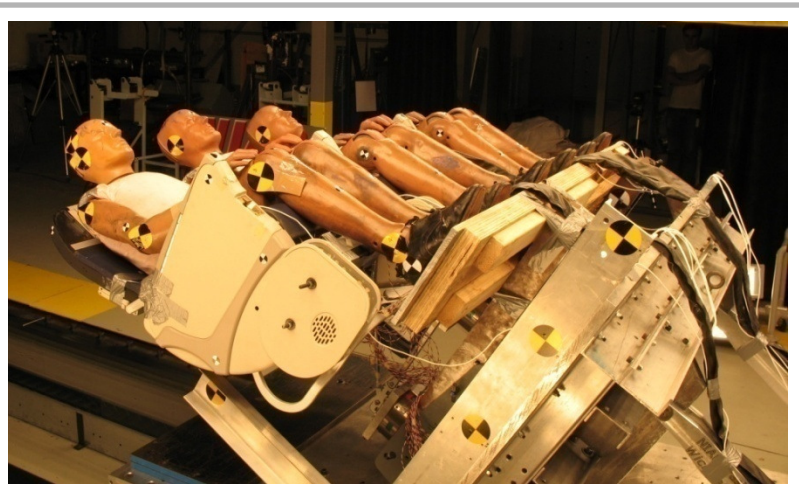
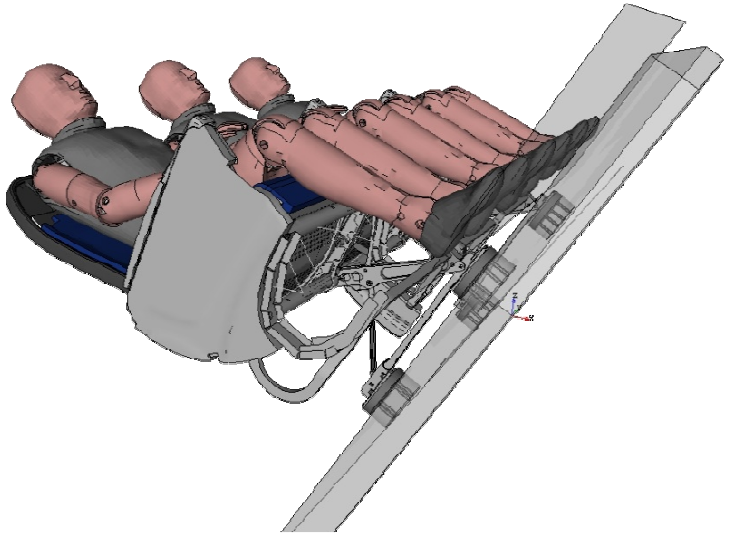
4
6
7
11
12
13
14
15
17
18
20
21
26

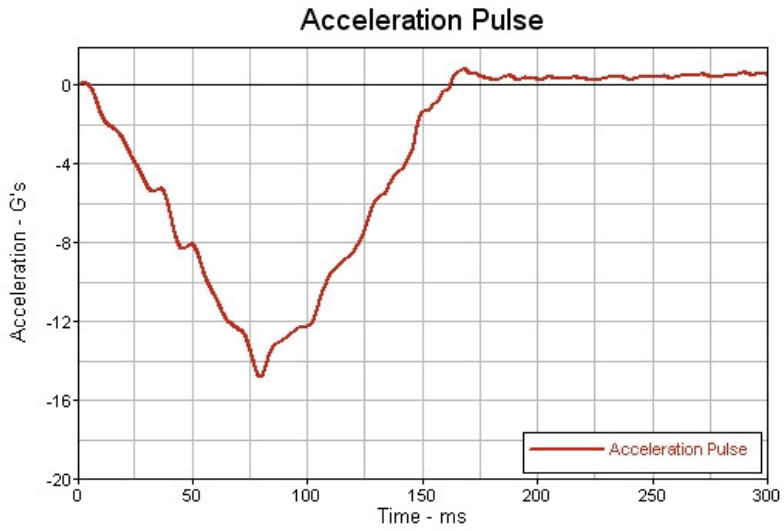


Reference Test Condition III

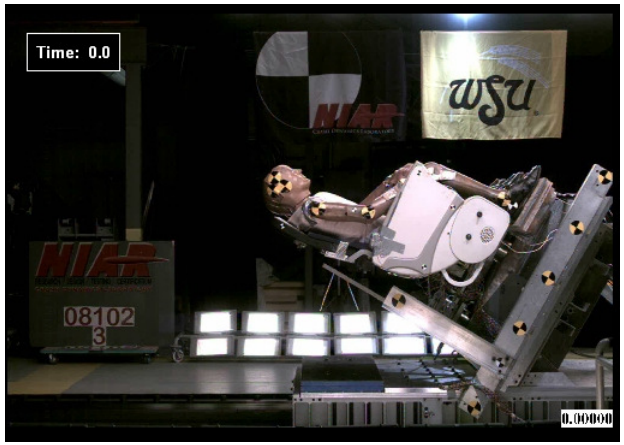
Test No.	08102-3
Pulse	PART 25, Vertical
Floor Deformation	No
Yaw	No
Type of Dummy	Hybrid II 50%
Type of Belt	2 pt

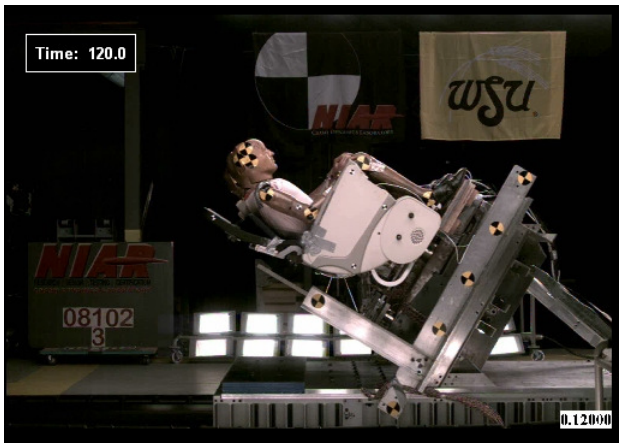


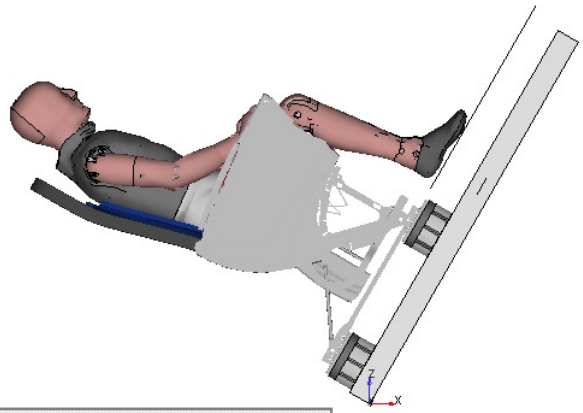


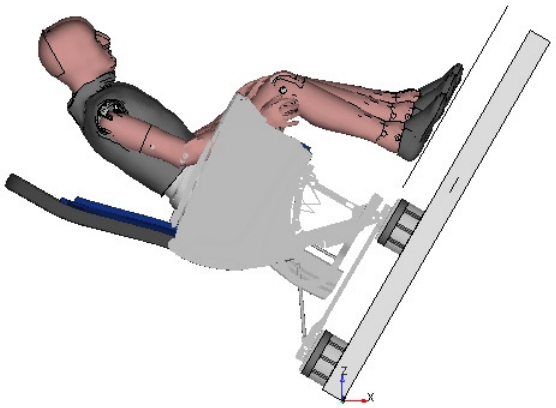


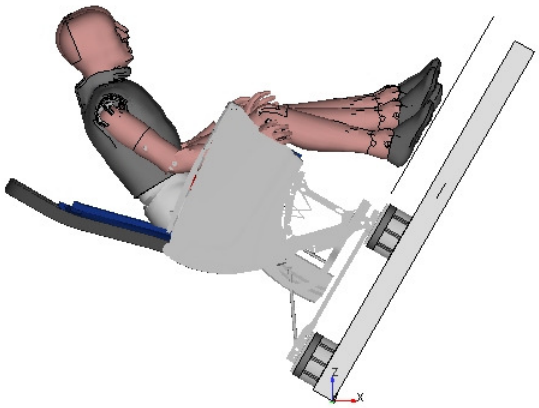
Reference Test Condition III - Kinematics





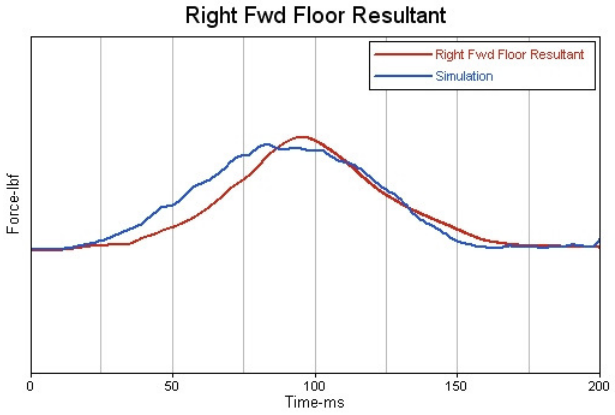


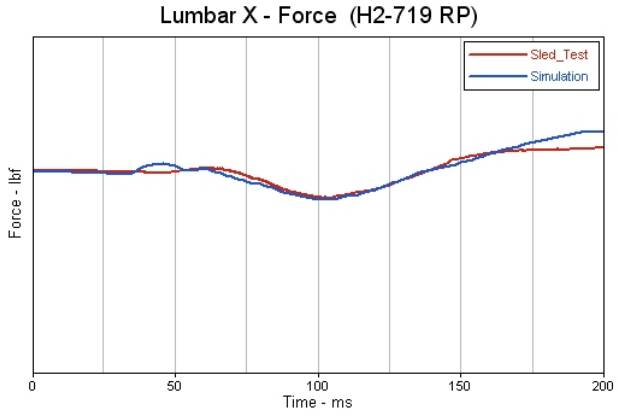


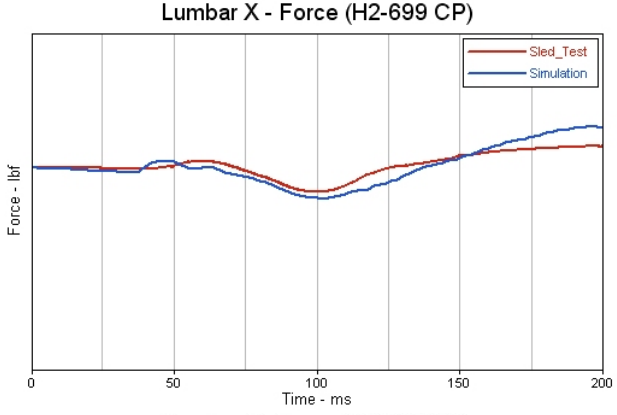


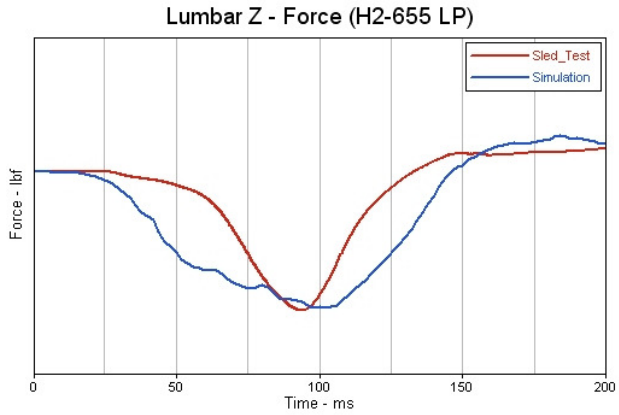
Side

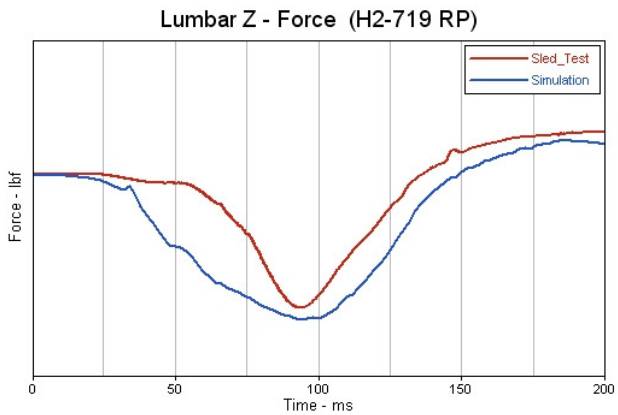
Reference Test Condition III – Sample Data Channels

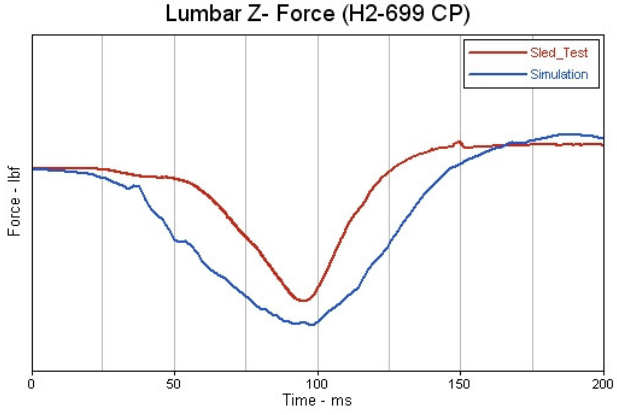




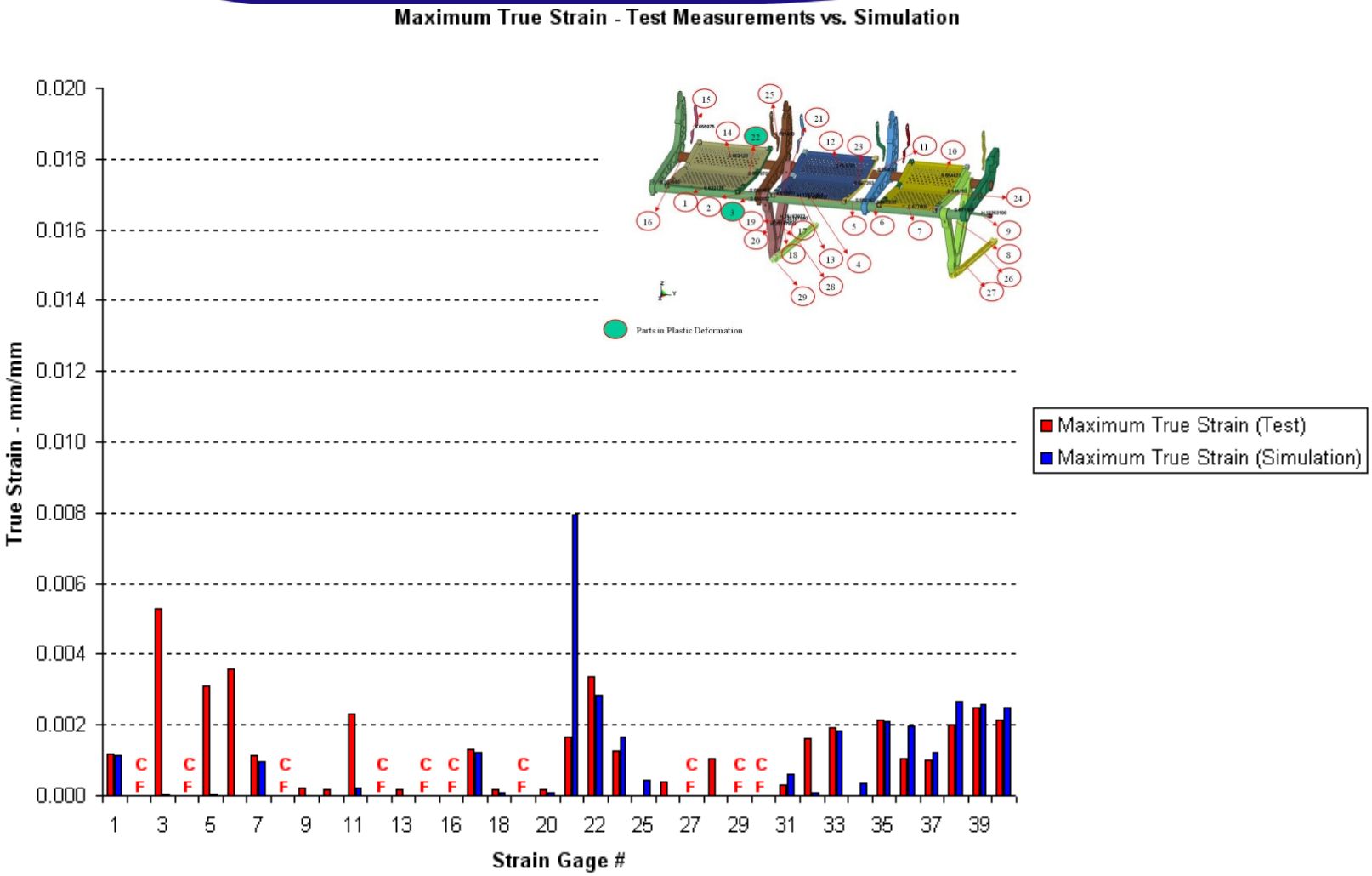




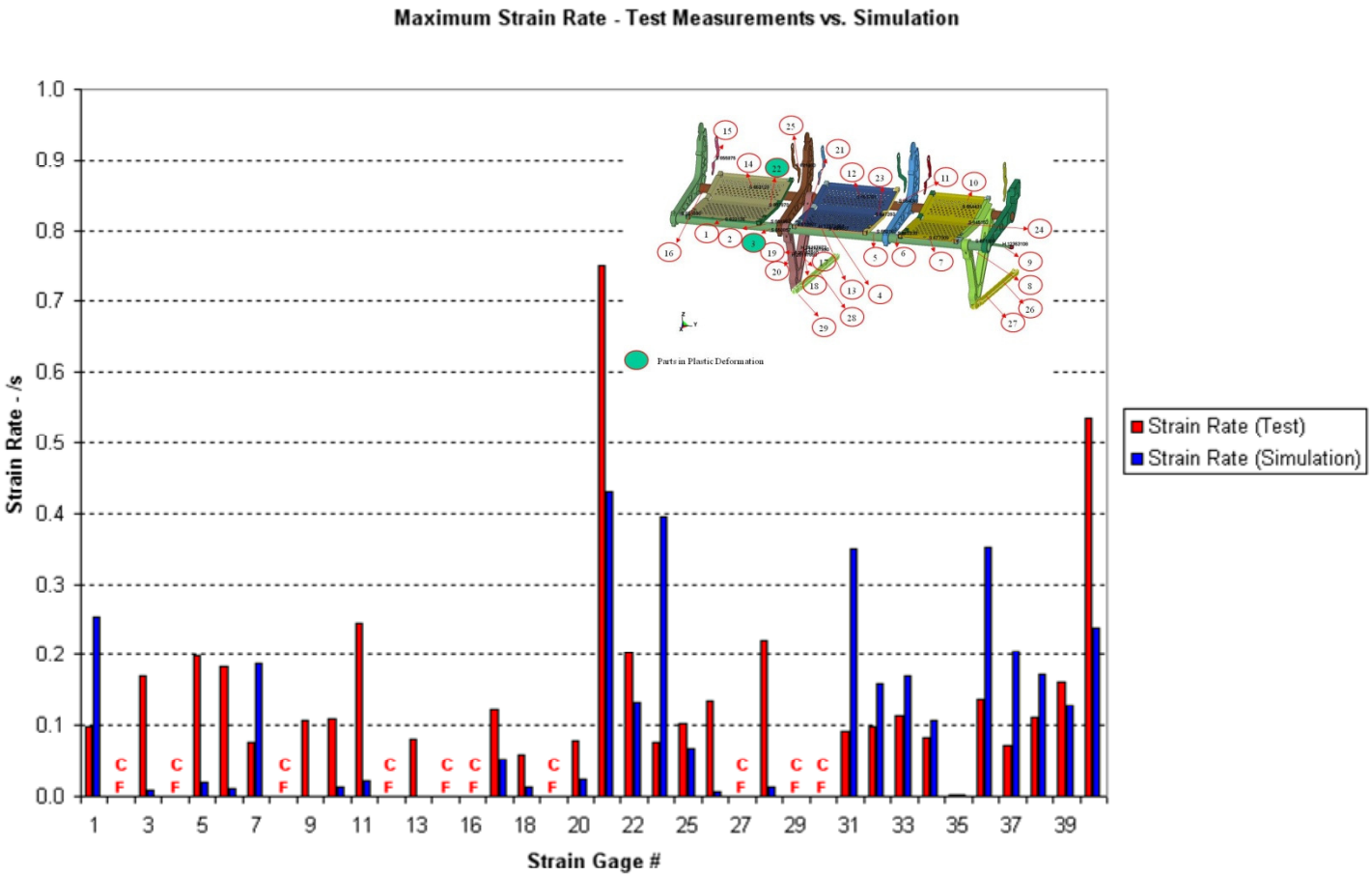




Reference Test Condition III - Maximum True Strain

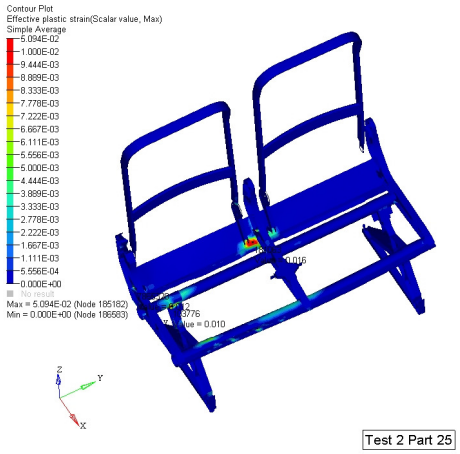


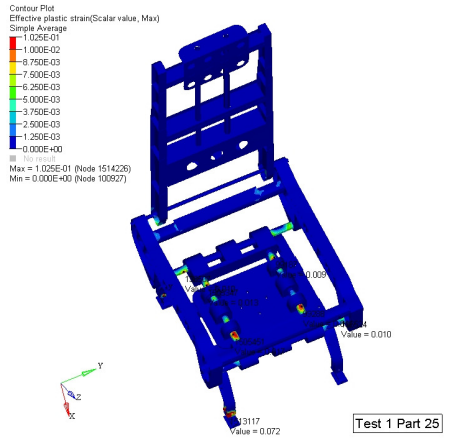
Reference Test Condition III - Maximum Strain Rate



Summary Peak Strain Rate for Various Seat FE Models

- Coach Type Seats (FAR 25.562): For both type I and II test configurations the strain rate is bellow 0.75 /s (Experimental and numerical data).
- Business Jet Type Seat (FAR 23.452): For type II test configurations strain rates up to 7 /s (numerical data).
- Business Jet Type Seat (FAR 25.452): For type II test configurations strain rates up to 1.5 /s (numerical data).
- First Class Type Seat (FAR 25.562): For both type I and II test configurations the strain rate is bellow 12 /s (numerical data).
- For typical coach type seats, part 25.562 testing applications quasi-static material data can provide acceptable results. For heavier seat structures (first class and business jet seats under FAR 25.562 or 23.562 test conditions) certain structural components may have to be defined with strain rate dependent data.





Component Level: Structural Components

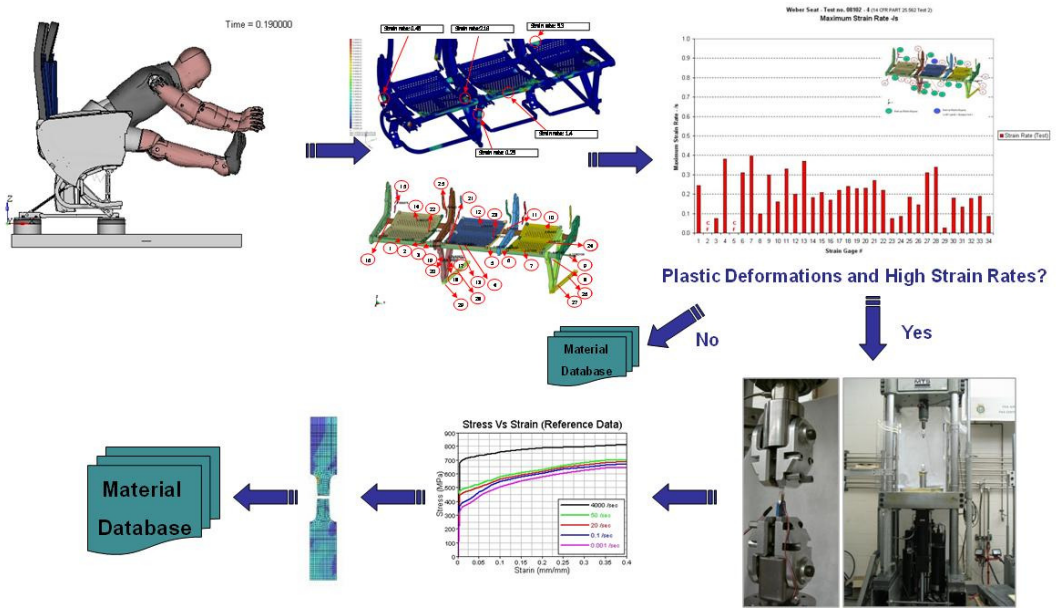
Recommended Procedure:

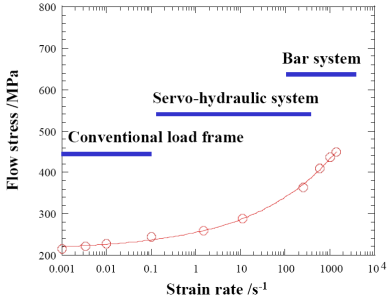
- Conduct a simulation with quasi-static data to identify areas with plastic deformation, and the magnitude of the strain rate for these components.

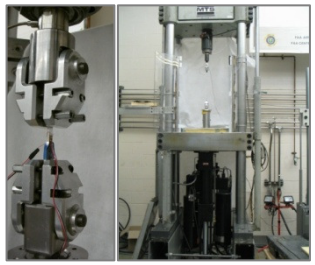
- For most seat structural members, quasi-static data from MMPDS-01 (or MIL HBK 5) may be used to define material properties.

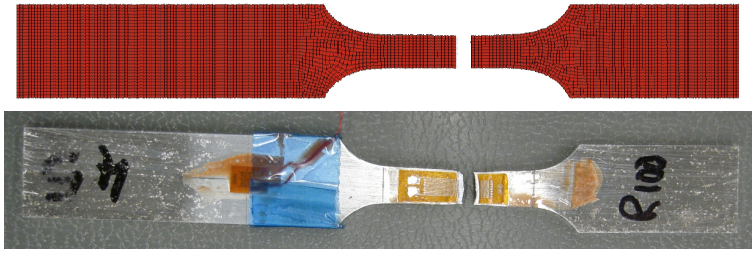
-There are three types of testing equipment that can be used to obtain material properties:

  - Mechanical or Servo-Hydraulic: Quasi-static condition and strain rates bellow 0.1/s.
  - Servo-Hydraulic: Strain rate range 0.1 to 500/s.
  - Bar System: Strain rate range 100 to 1000/s, and higher.

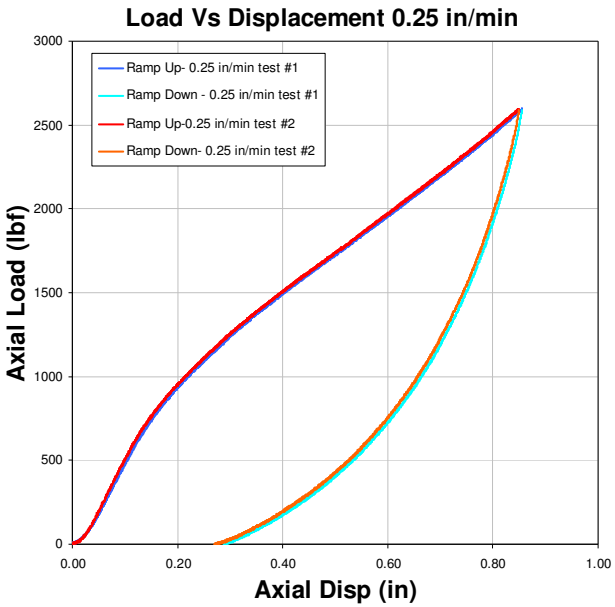






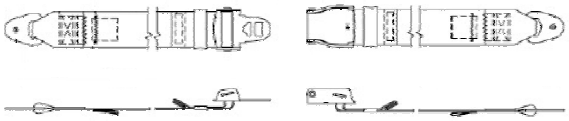


Component Level: Belt Webbing

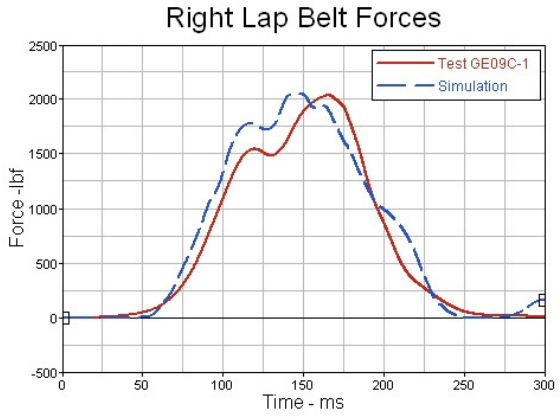


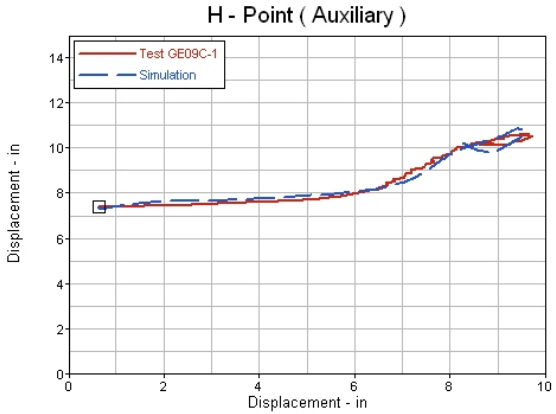
Recommended Procedure:

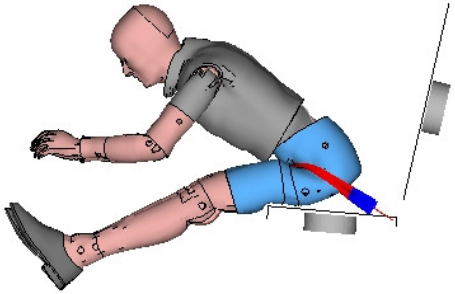
- Quasi-Static Testing.
- Tension Load up to 2600 lbf Unload to 0 lbf.
- Simulation Inputs:
  - Load /Deflection.
  - Stress/Strain.
- Component Level Numerical Model Validation.
- Apply material model to define the Restraint System.

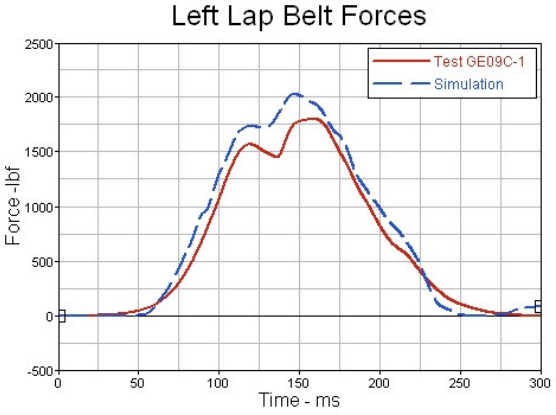


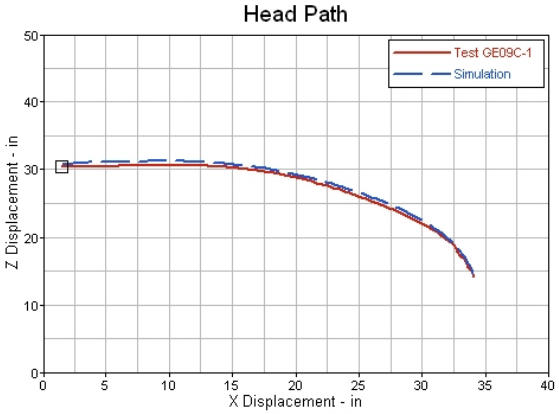
Component Level: Belt Webbing Validation

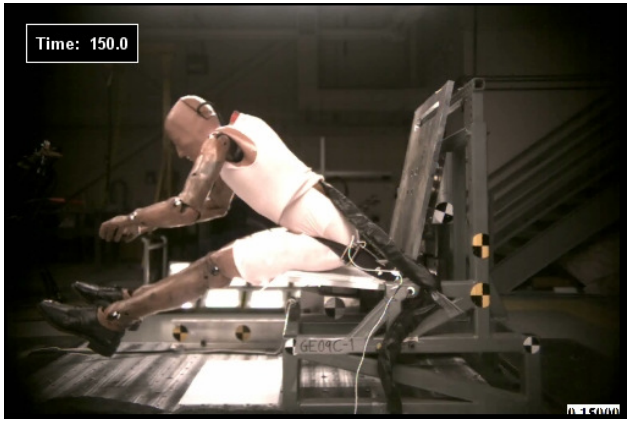




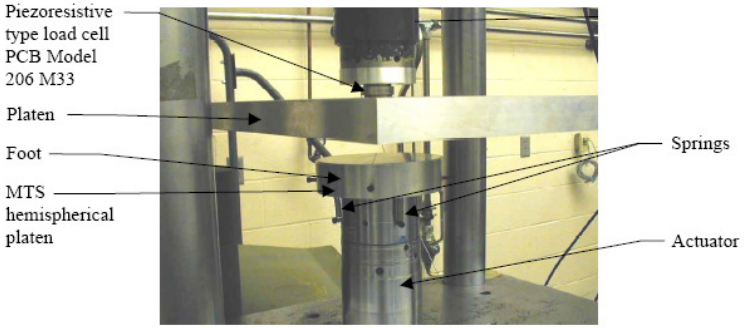


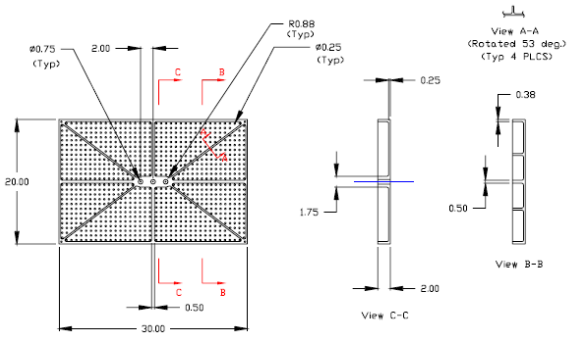


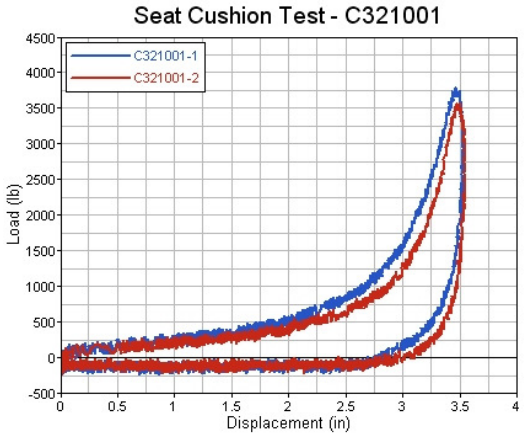




Component Level: Seat Cushion*







Current Procedure under Evaluation:

- Test protocol defined in DOT/FAA/AR-05/5 *Development and Validation of an Aircraft Seat Cushion Component Test.*
- The specimen shall consist of a 7 1/2-in. diameter cylinder. The upper and lower surfaces of the specimens are required to be parallel. The unloaded specimen thickness shall represent the unloaded cushion thickness at the position of the anthropomorphic test dummy (ATD) ischial tuberosity (BRP) when the dummy is placed in the seat.
- The specimen shall be loaded in compression, under displacement control, at a loading rate of approximately 27-33 in/sec to a maximum deflection corresponding to a ΔL/L of 0.9 (or the maximum value achievable without risking damage to the test stand and instrumentation).
- Validate material model and lumbar load predictions with dynamic tests.

*** Note: ongoing work**

Conclusions CBA Phase II

- Six types of seats (two and three place coach seats, one first class seat, two business jet seats and one side facing seat) have been modeled and analyzed for FAR 25.562 or 23.562 dynamic test conditions:
  - For typical coach type seats, part 25.562 testing applications quasi-static material data provides acceptable results. Strain rates less than 0.7 /s for both experimental and numerical models.
  - For heavier seat structures (first class and business jet seats under FAR 25.562 or 23.562 test conditions), certain structural components may have to be defined with strain rate dependent data. The strain rate for the numerical models analyzed did not exceed 12 /s.
- Definition of recommended component testing protocols for:
  - Seat Cushion Testing – quasi static and dynamic testing. (ongoing)
  - Metallic Component Material Testing – quasi static and high strain rate testing.
  - Seat Belt Webbing Testing.
- Material list for typical aluminums and steels has been defined. Quasi-static material data parameters required for simulation models are available in MMPDS-01 (or MIL HBK 5) for most of these materials.
- Technology Transfer:
  - Participation SAE Seat Committee.
  - Strain rate study results presented and submitted to SAE ARP 5765 WG.
  - Support development and validation efforts of numerical models for seat and aircraft manufacturers.
  - Technical Report. (ongoing)
  - Seat modeling workshops. (ongoing – September/October 2009)
  - SAE ARP 5765 WG meetings hosted at NIAR.

Future Work

- Training seminars on seat modeling techniques (industry/academia)
- Numerical modeling procedures:
  - Numerical seat model pitch and roll procedures.
  - Numerical seat model permanent deformations.
- Installation evaluations:
  - HUD installations.
  - Row-to-row configurations.
  - Bulkhead configurations.
  - Seat cushion replacement.