Certification by Analysis

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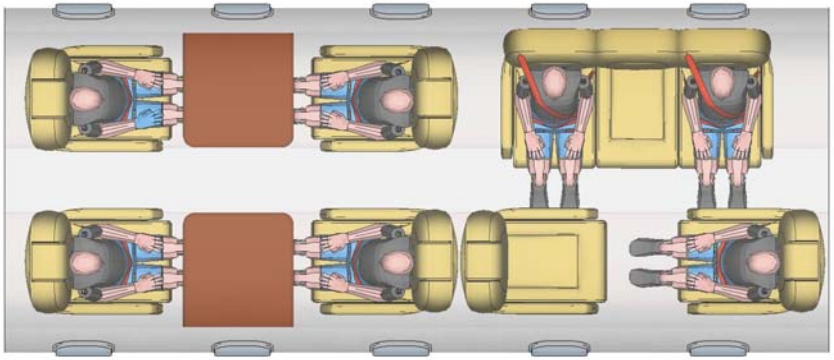
The Joint Advanced Materials and Structures Center of Excellence

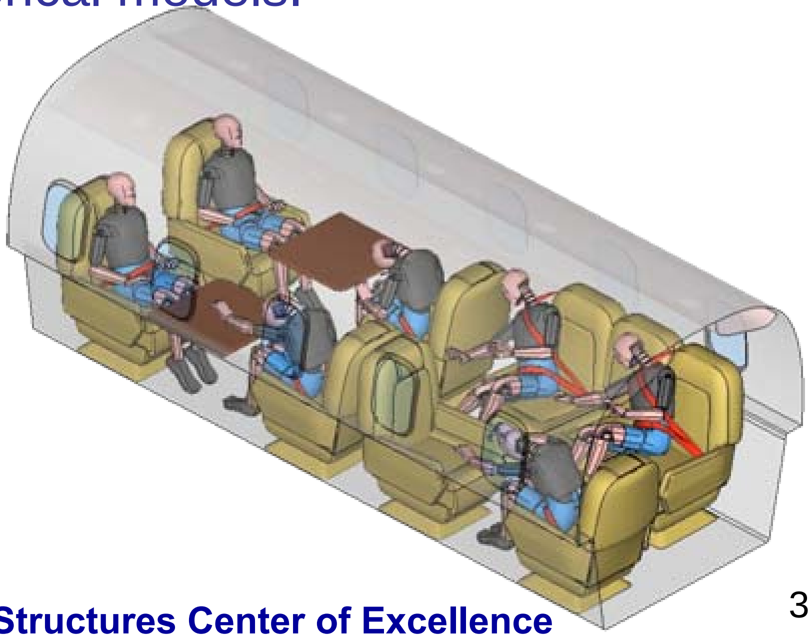
Certification by Analysis

- Motivation and Key Issues
  - Aircraft manufacturers are under strong pressure to reduce costs and development cycles in a highly competitive market. The development of aircraft interiors is driven by individualized customer demands, increasingly complex products and ever shorter innovation cycles. To cope with these challenges, a company must be able to deliver in a timely manner high quality customized interiors that meet their customers specifications and the applicable certification requirements. 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.

Certification by Analysis

- Objective
  - Provide an overview of best practices so that Industry and FAA personnel can gain an understanding of the fundamental modeling methods, a feeling for the comparative usefulness of different numerical approaches, develop an appreciation of the modeling problem areas, and limitations of current numerical models.





Certification by Analysis

- Approach
  - Phase I: Numerical Anthropometric Test Dummies:
    - Literature review and numerical tools survey
    - Sled testing – Rigid Seat:
      - Test variability studies – Establish corridors for validation criteria
      - Comparison performance HII and HIII FAA ATDs
    - Simulation studies:
      - Survey numerical ATD database availability
      - Preliminary evaluation of numerical ATDs with sled test data for part 25.562 pulses
      - Stochastic and/or DOE numerical model evaluation
    - Validation criteria:
      - Validation metrics methods: review and evaluation
      - Identify data channels required, and tolerance levels for model validation
  - Phase II: Aerospace Seat 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
    - Material Database:
      - Physical testing
      - Validation material models: Physical Testing vs. Simulation

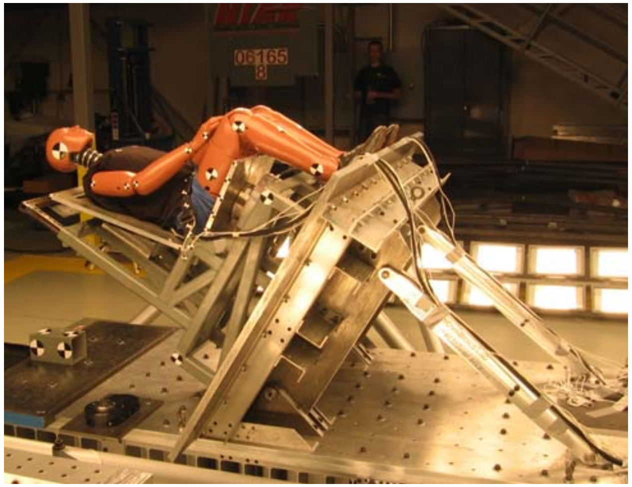
FAA Sponsored Project Information

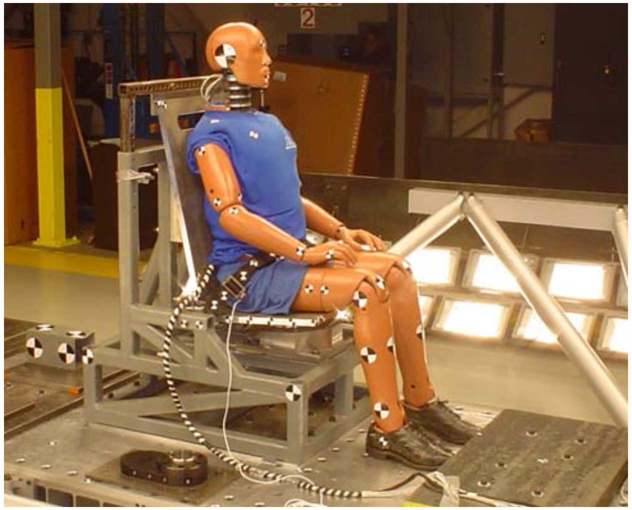
- Principal Investigators & Researchers
  - G.Olivares PhD, PI
  - K. S. Raju PhD, (High Strain Rate Material Testing)
  - J. Guarddon, S. Patrick
- FAA Technical Monitor
  - Allan Abramowitz
- Other FAA Personnel Involved
  - Rick Dewesse (CAMI)
  - David Moorcroft (CAMI)
- Industry Participation
 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

FAR §§ **.562: Emergency Landing Conditions

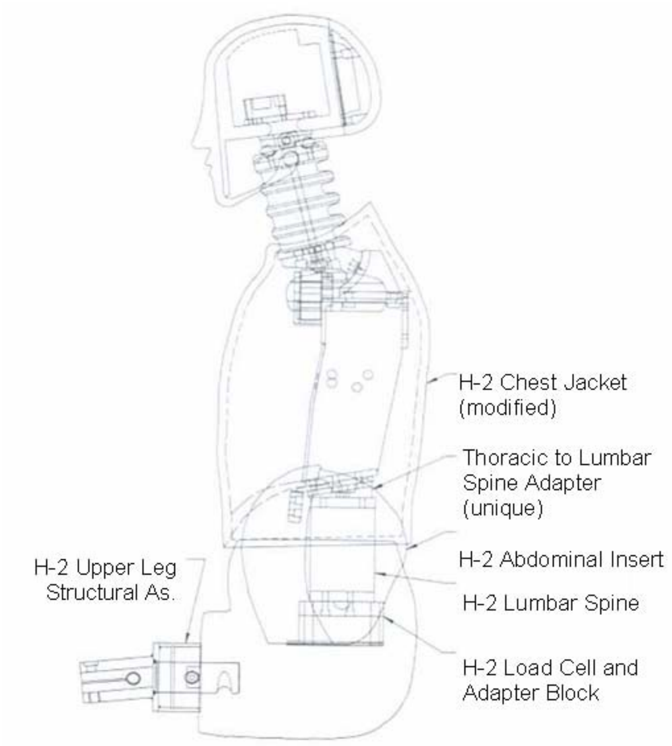


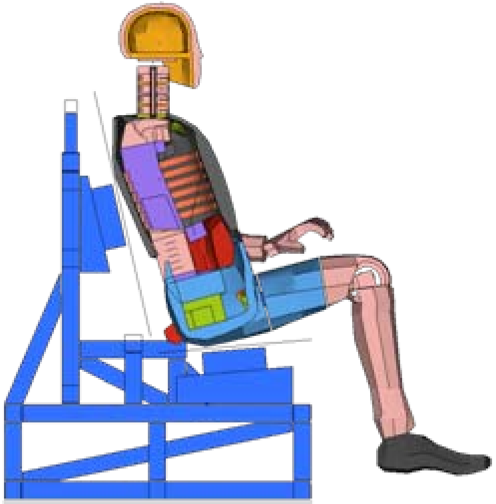


DYNAMIC TEST REQUIREMENTS	PART 23	PART 25	PART 27
TEST 1			
Test Velocity - ft/sec	31 (9.5 m/sec)	35 (10.7 m/sec)	30 (9.2 m/sec)
Seat Pitch Angle - Degrees	60	60	60
Seat Yaw Angle - Degrees	0	0	0
Peak Deceleration - G's	19/15	14	30
Time To Peak - sec	0.05/0.06	0.08	0.031
Floor Deformation - Degrees	None	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

HII and HIII FAA 50th Percentile Anthropometric Test Dummies





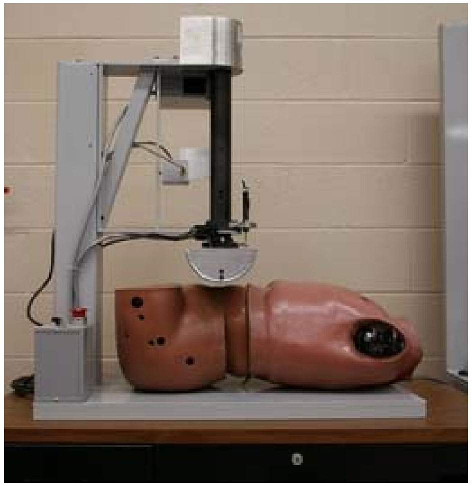
For additional information refer to SAE Document 1999-01-1609

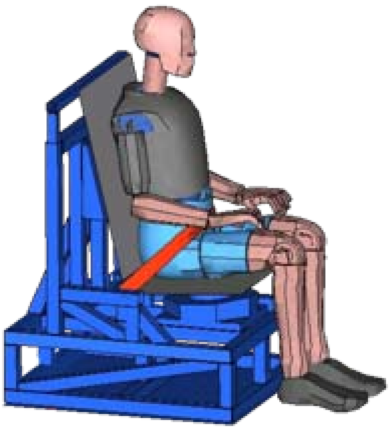
Numerical ATD Validation Process

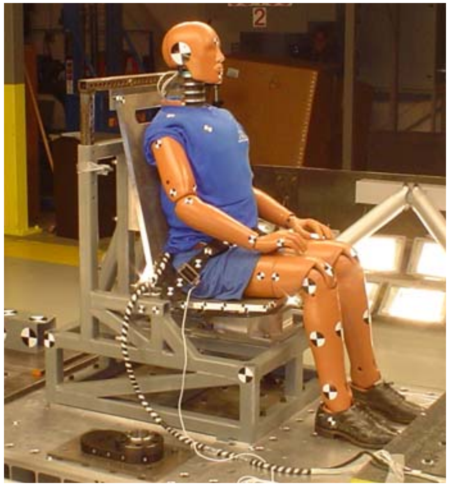
Numerical ATD Certification

ATD Calibration Testing Validation - Component

ATD Application Testing Validation







Component Level Validation

Numerical ATD Calibration

Virtual ATD Calibration Testing

Physical ATD Calibration Testing

Component Numerical Calibration

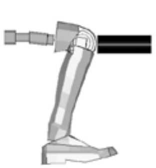
Component Calibration Testing

Head Drop, Knee Impact…

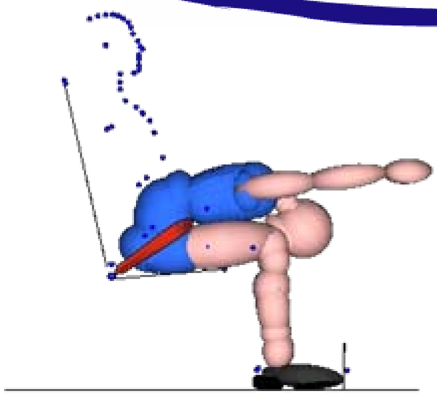
Define Additional Component Tests: Abdomen Stiffness

Numerical Model Calibration Report

Physical Model Calibration Report



ATD Application Level Validation Approach



ATD Application Testing Validation

0 deg – 2, 3 and 4 Point Restraint – Rigid Seat

60 deg – 2 Point Restraint – Rigid Seat without Cushion

60 deg – 2 Point Restraint – Rigid Seat with Cushion

Head Path
Head Acceleration
Belt Forces
Seat Transfer Forces

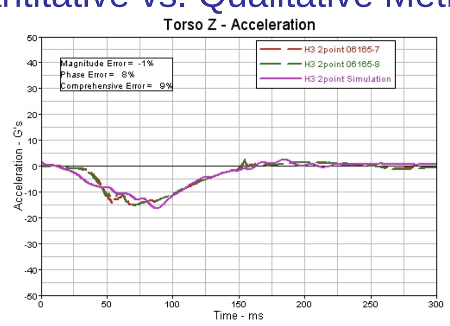
Lumbar Load
Seat Transfer Forces

Lumbar Load
Seat Transfer Forces

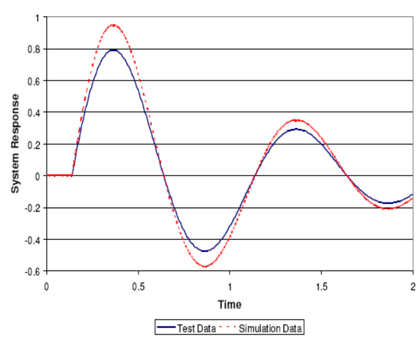
Validation Metrics

- 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)

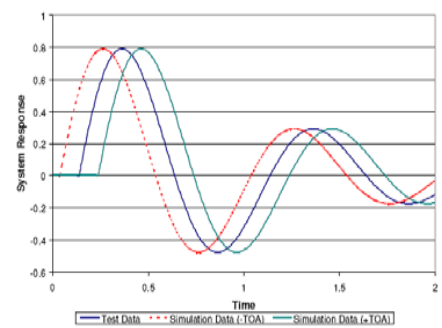
Quantitative vs. Qualitative Methods



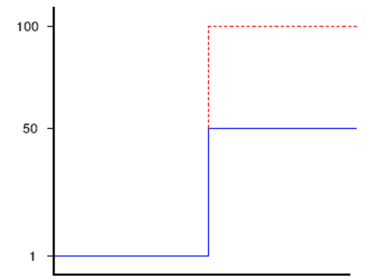
Magnitude Error



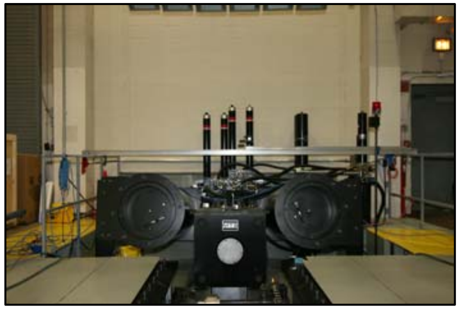
Phase Error



Area Under Curve Error

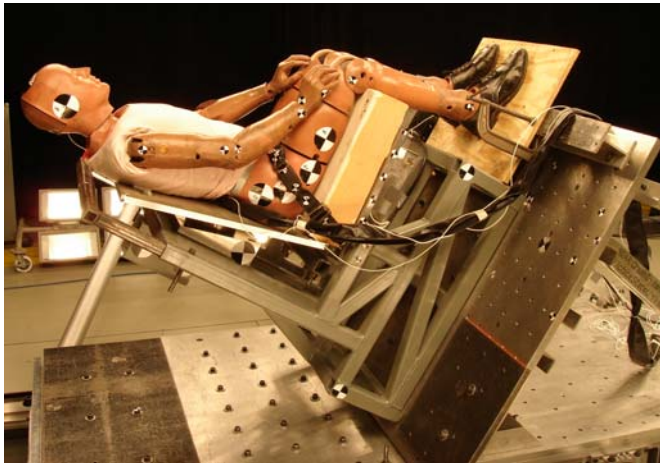
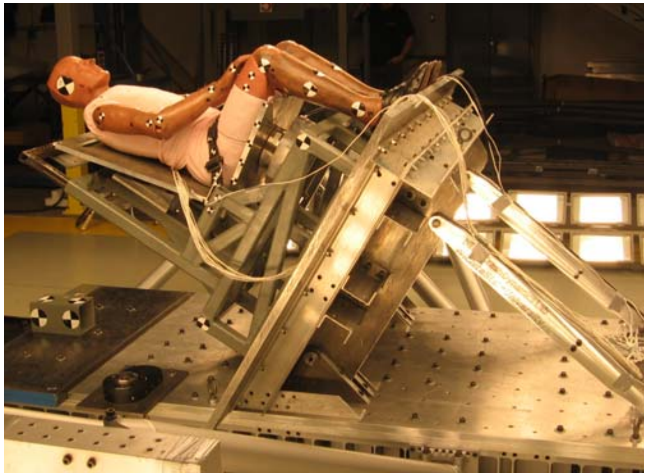


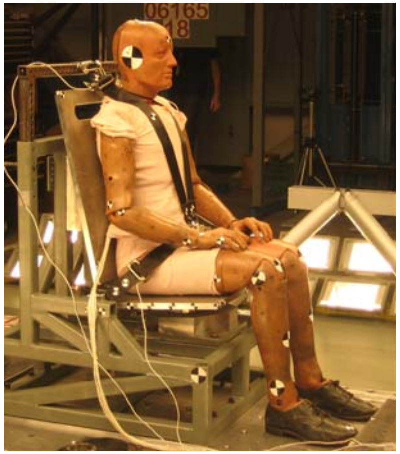
Sled Test Matrix



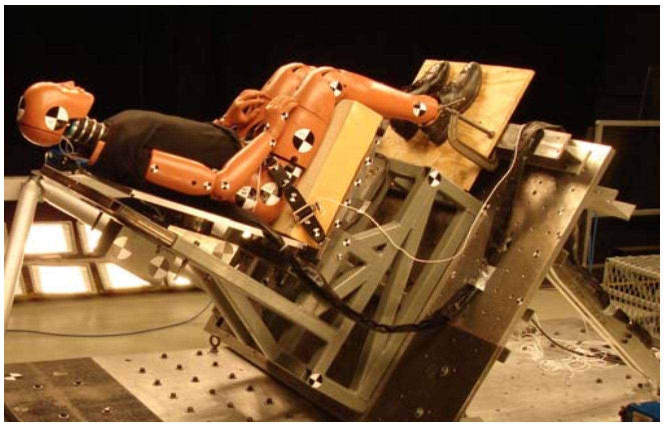
TEST NUMBER	ATD Serial#	BELT TYPE	TEST ANGLE (deg)	LOADING	SEAT TYPE	BELT MATERIAL	CRASH PULSE
06165-1	FAA HYB III 290	2	0	16g	Rigid	100% Polyester	25.562
06165-2	FAA HYB III 290	2	0	16g	Rigid	100% Polyester	25.562
06165-3	HYB II 698	2	0	16g	Rigid	100% Polyester	25.562
06165-4	HYB II 698	2	0	16g	Rigid	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

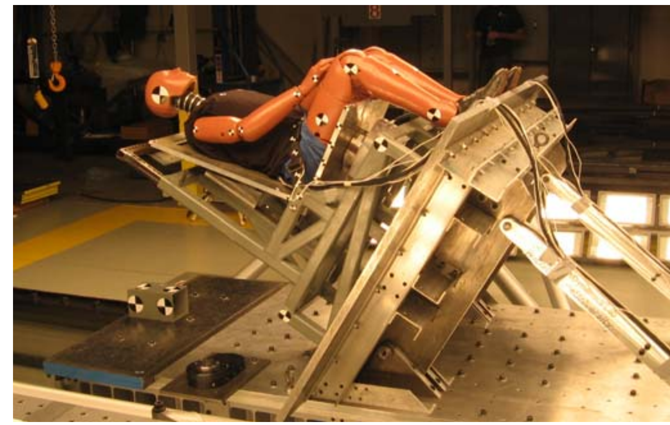
Overview Test Configurations HII 50th percentile ATD

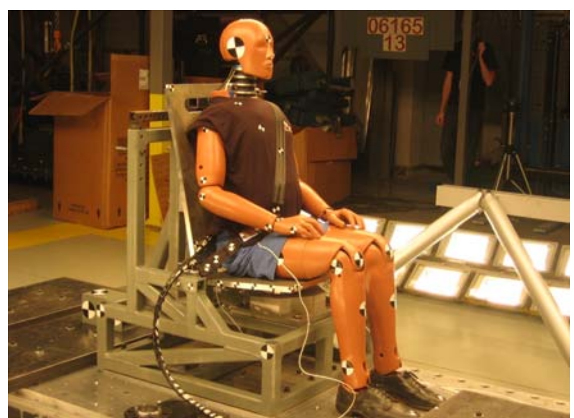



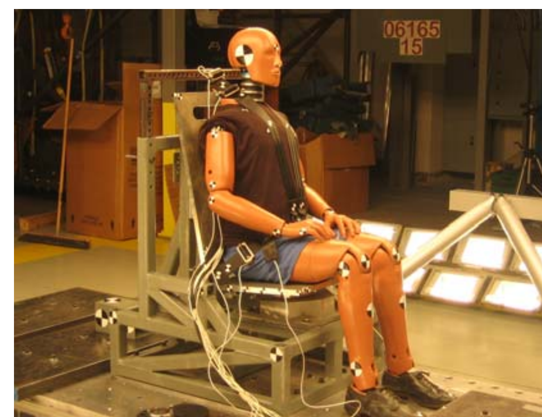



Overview Test Configurations HIII FAA 50th percentile ATD



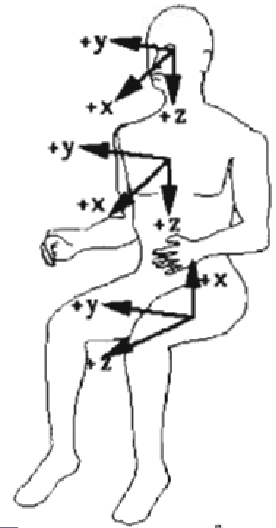


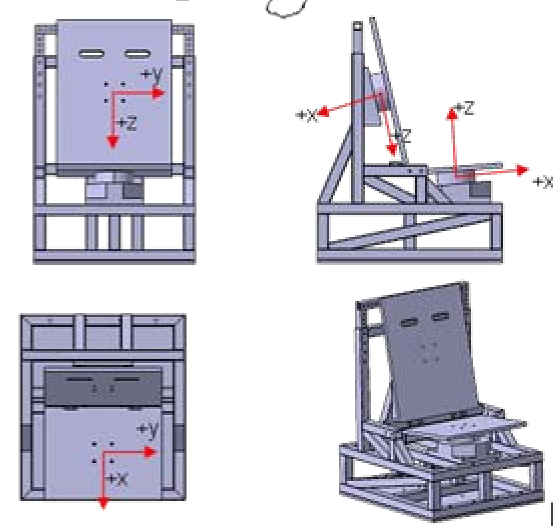




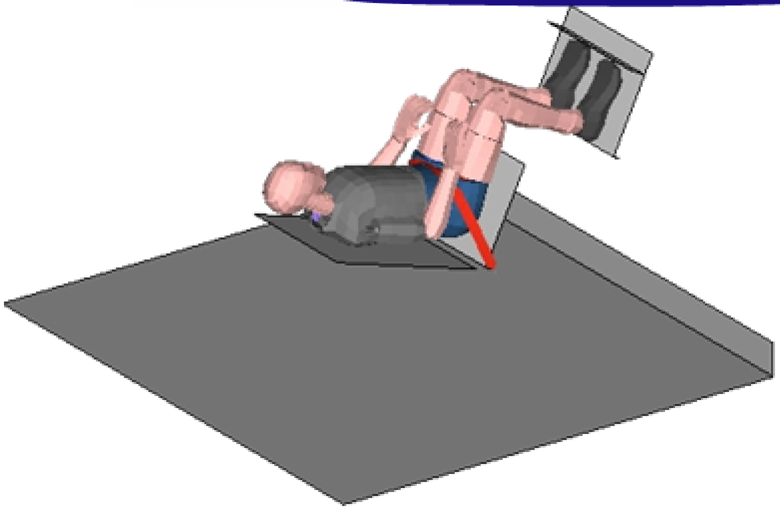
Test Data Channels and Polarities Overview (per SAE J211-1)

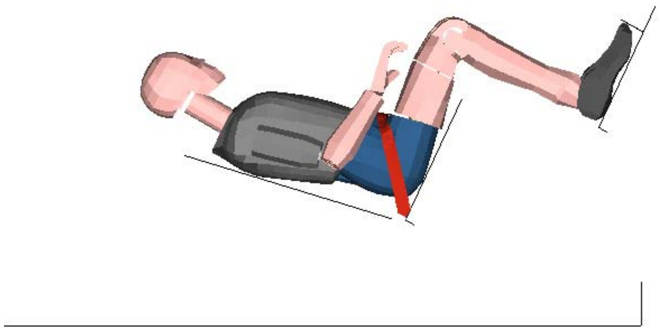
Channel Description	Channel Units	Hybrid II	Hybrid III
Sled acceleration	G's vs Sec	√	√
Head X acceleration	G's vs Sec	√	√
Head Y acceleration	G's vs Sec	√	√
Head Z acceleration	G's vs Sec	√	√
Upper neck force X direction	Lbf vs Sec		√
Upper neck force Y direction	Lbf vs Sec		√
Upper neck force Z direction	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	√	√

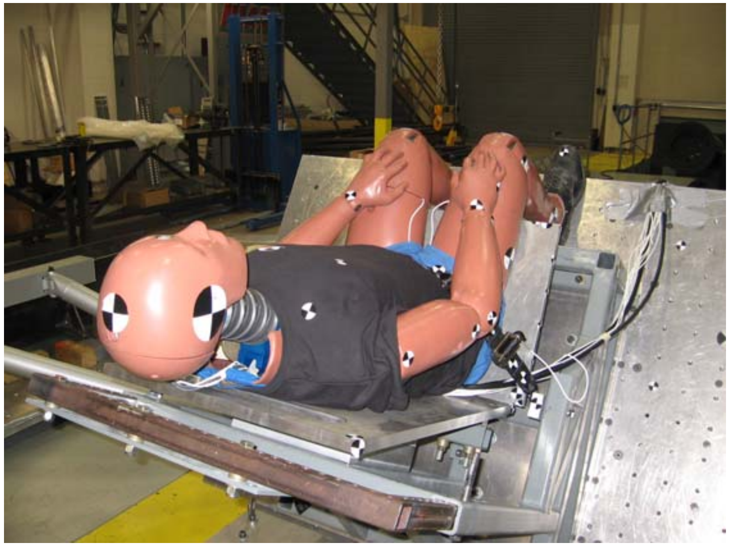


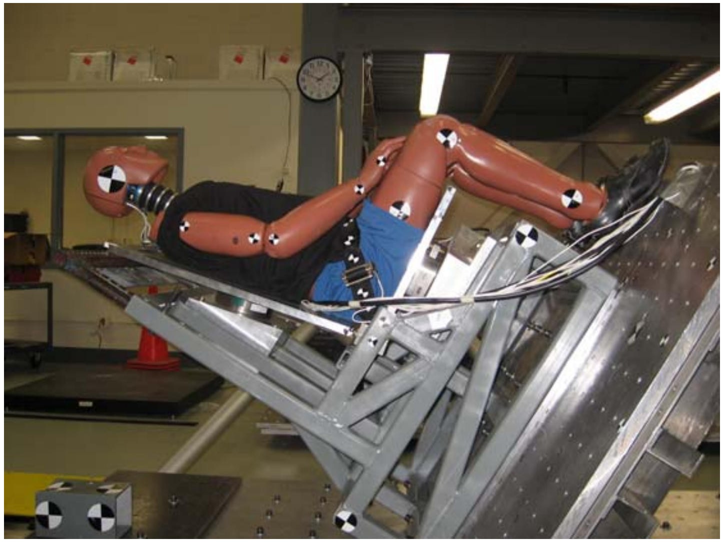


Validation Example: HIII FAA Test Type 1 FAR 25.562

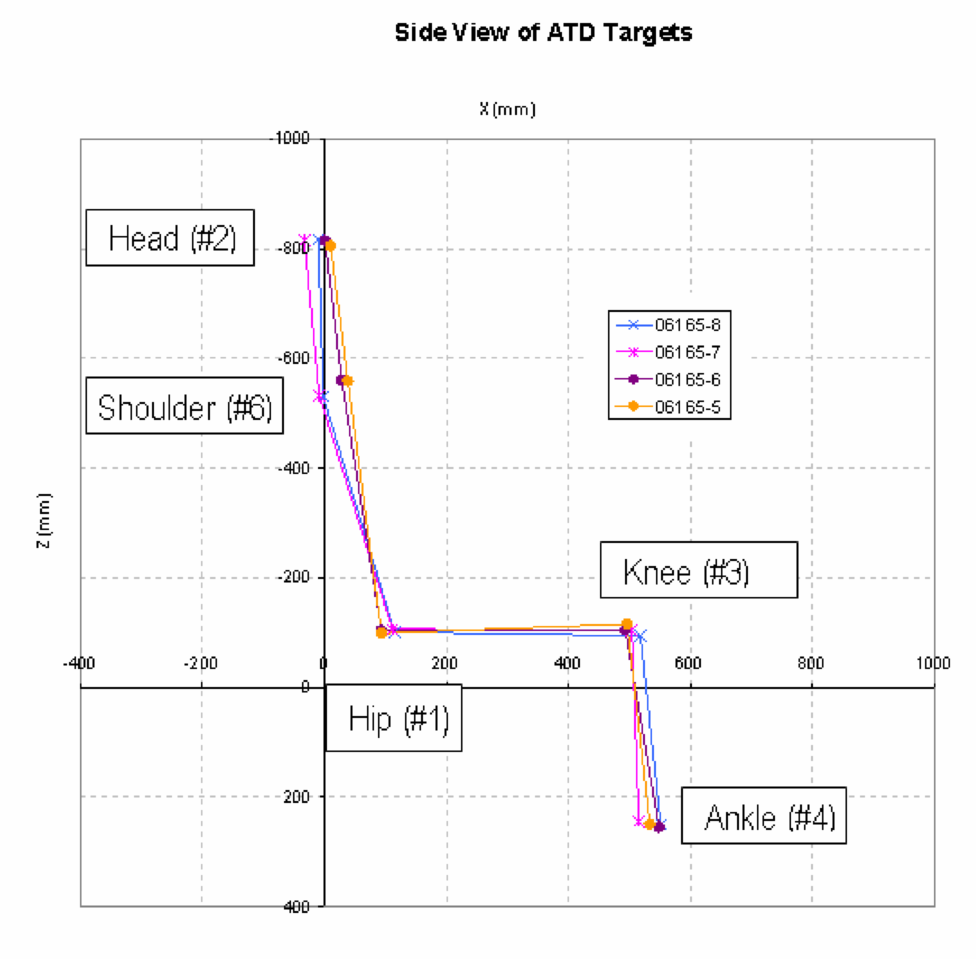


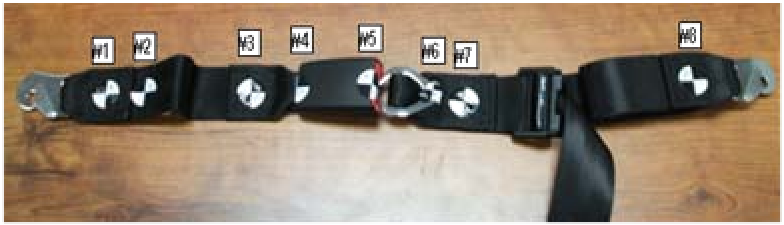


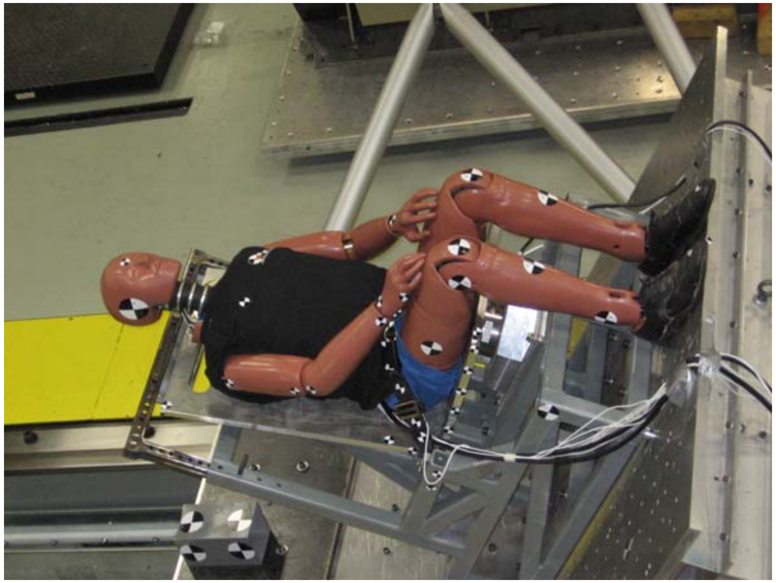




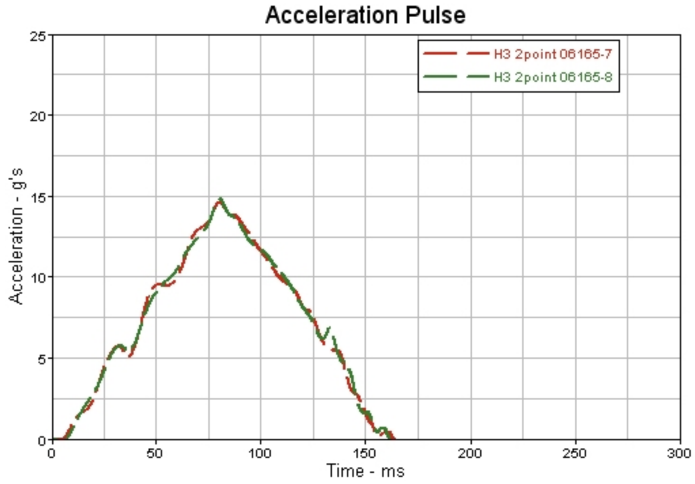
Validation Example: Pre-Test Measurements

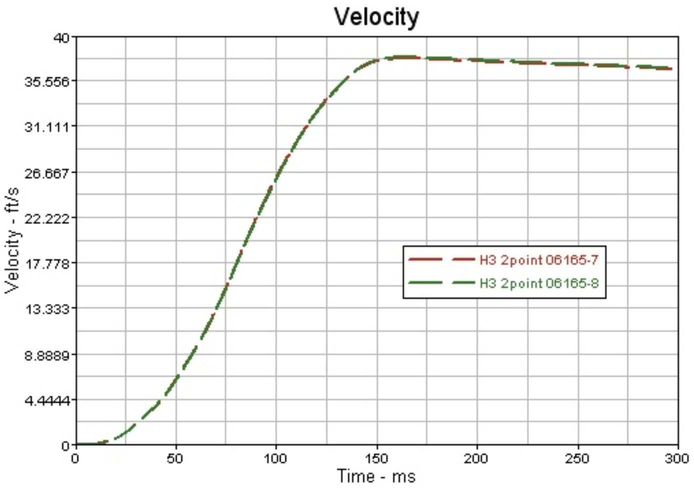


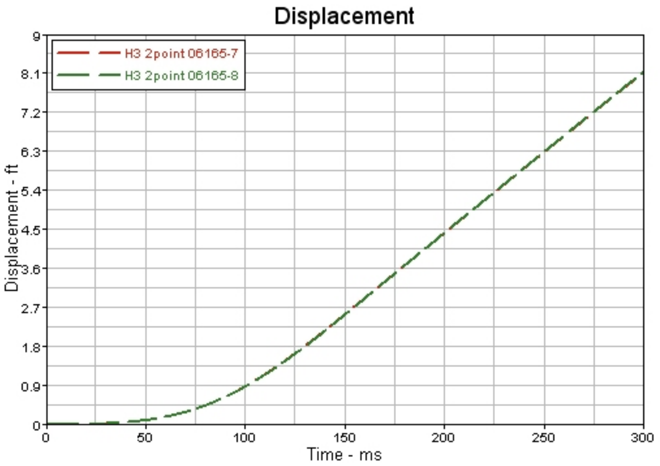




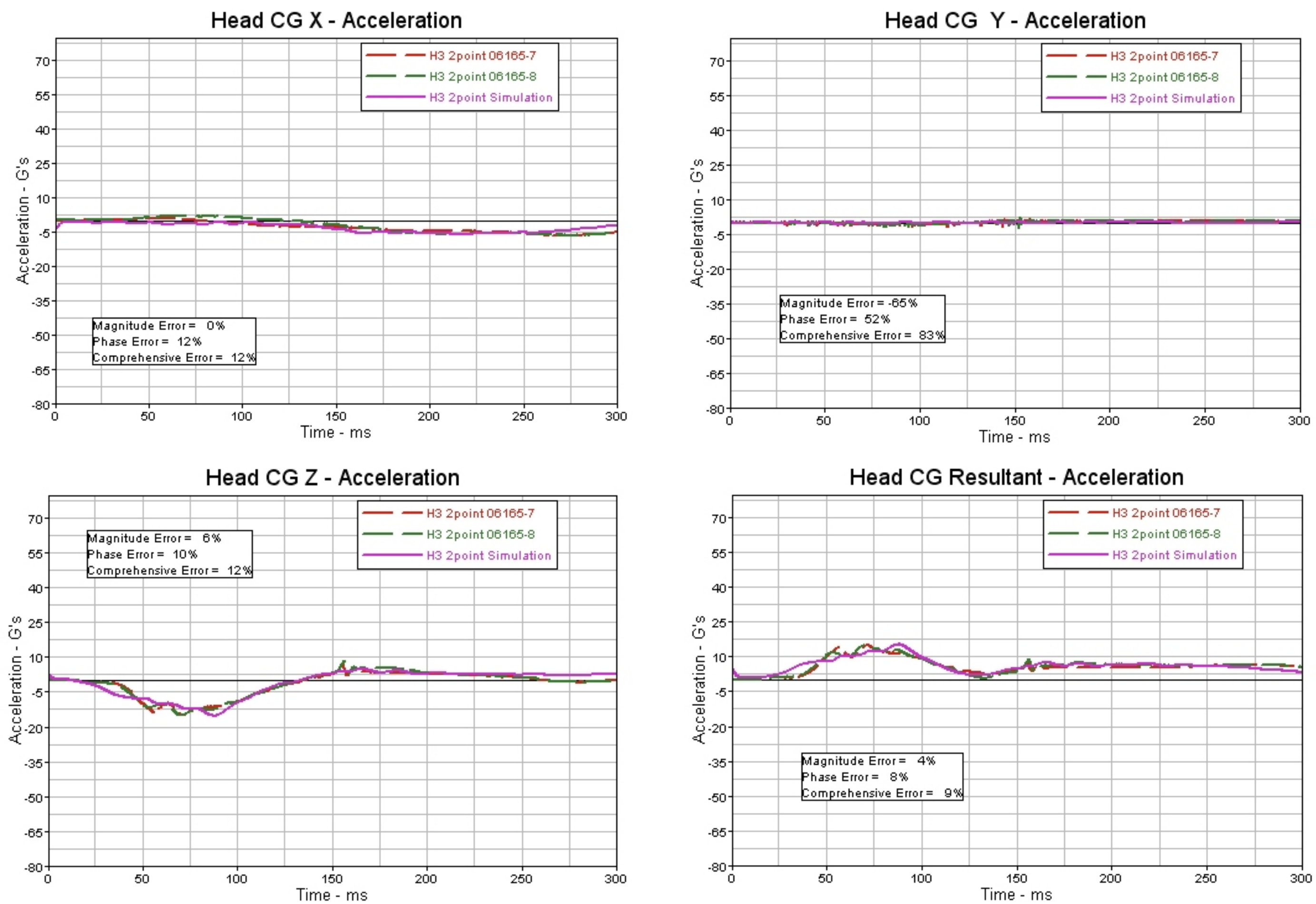
Validation Example: Sled Pulse Repeatability



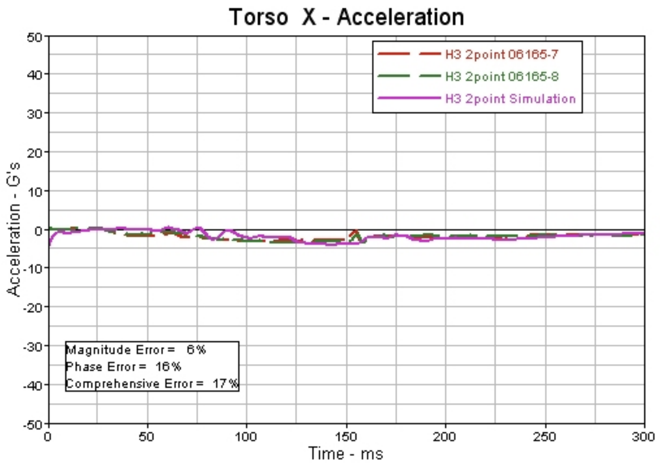


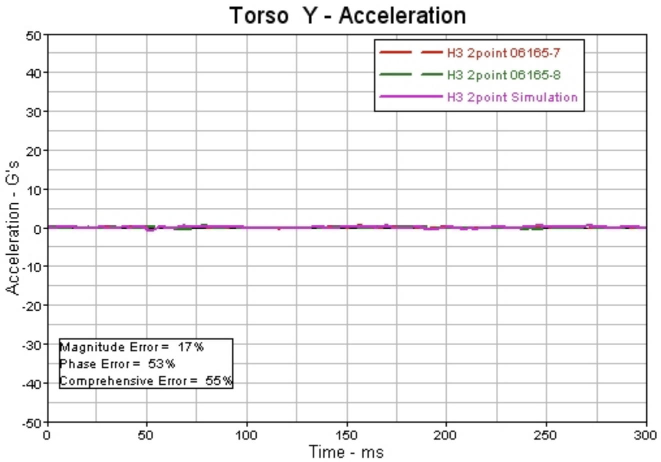


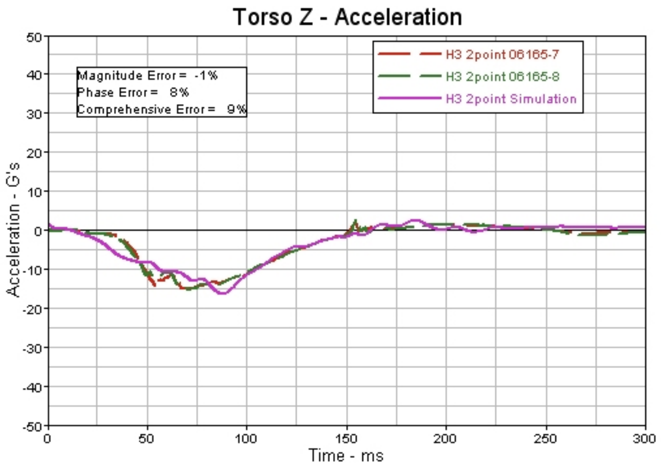
Validation Example: Head Acceleration

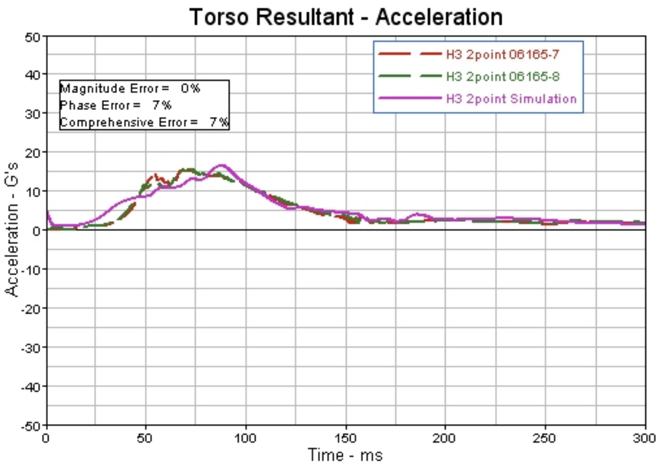


Validation Example: Torso Acceleration

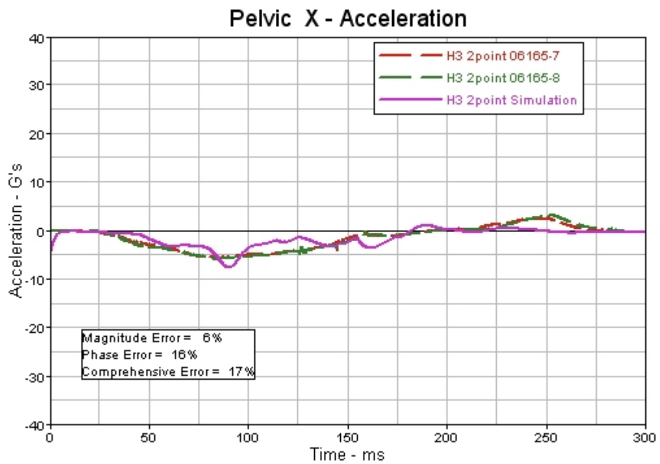


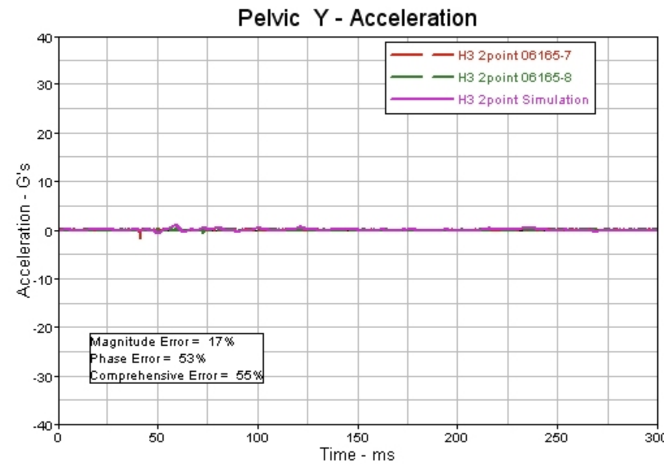


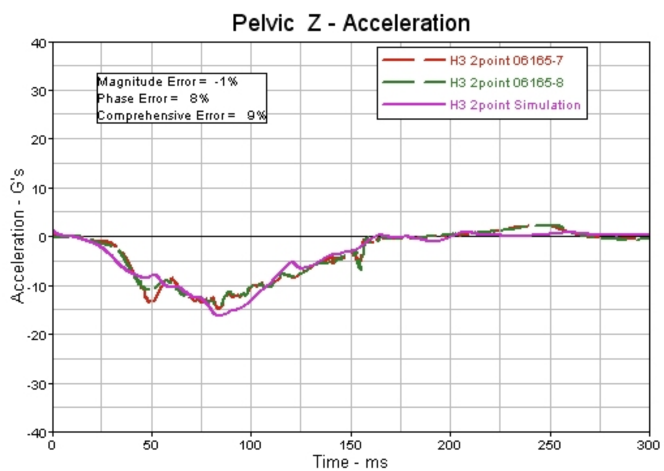


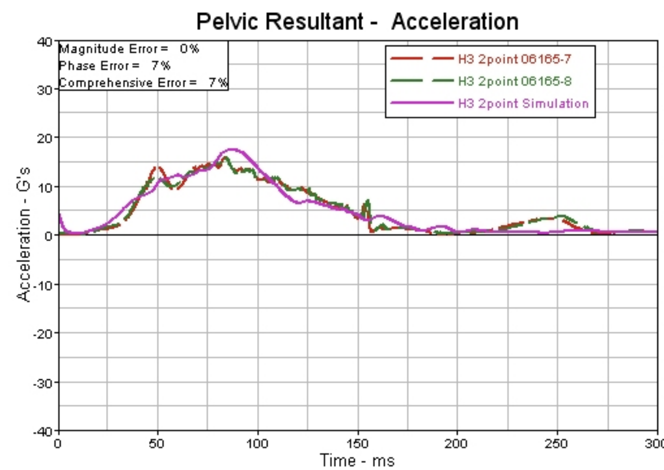


Validation Example: Pelvis Acceleration

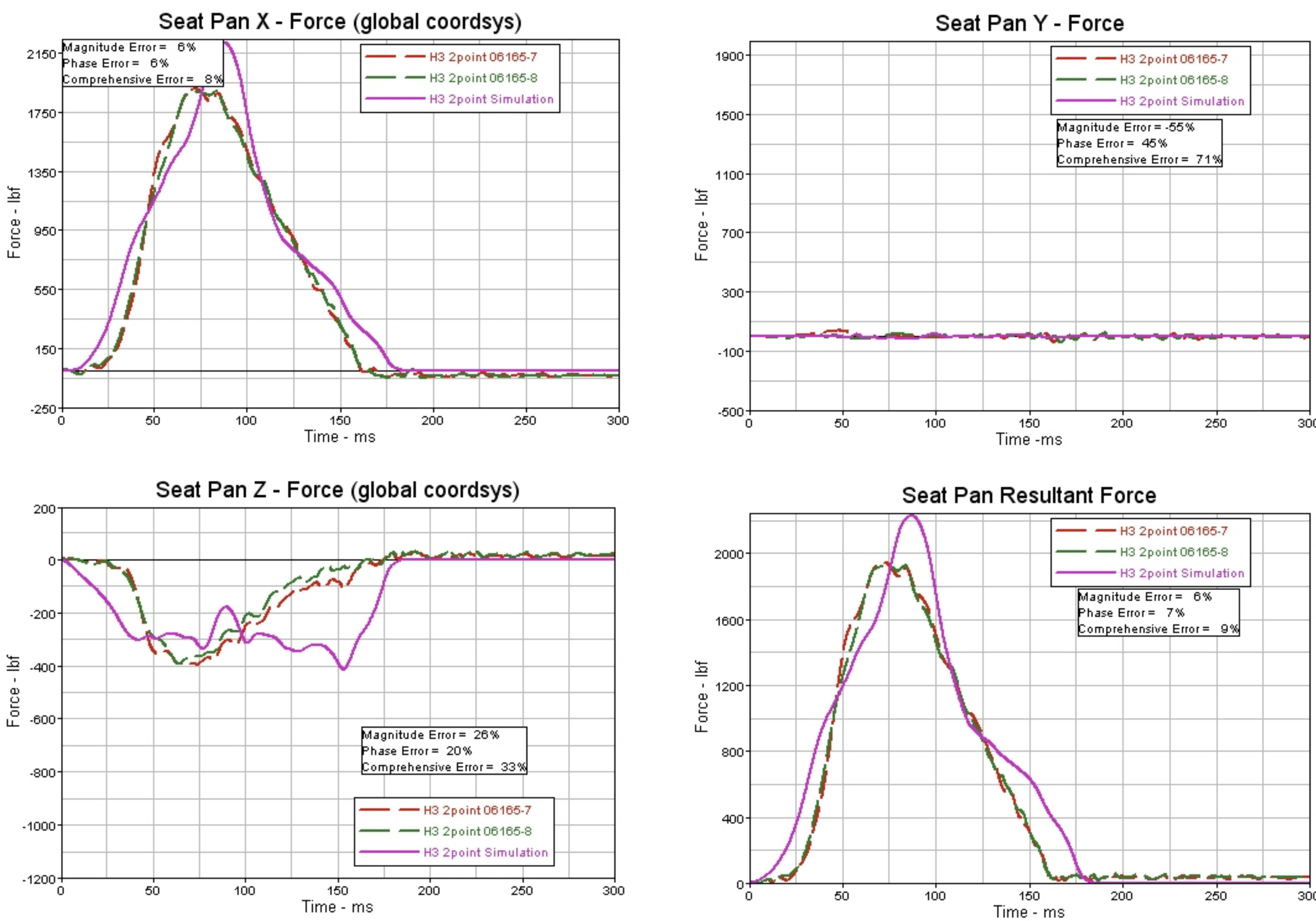




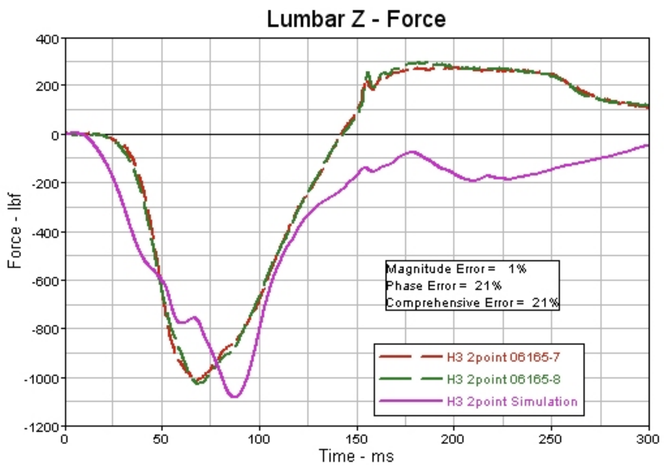


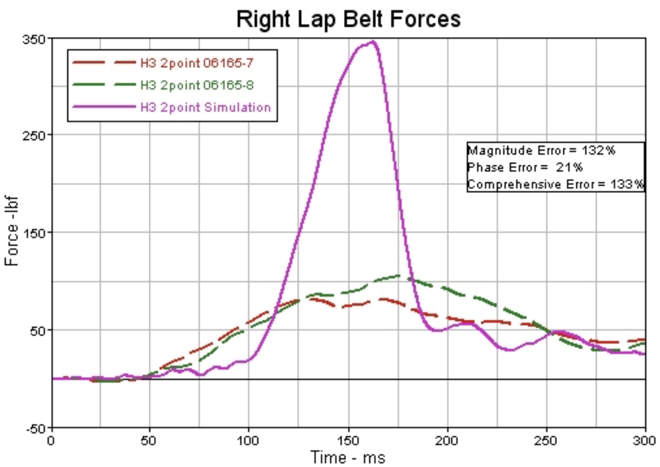


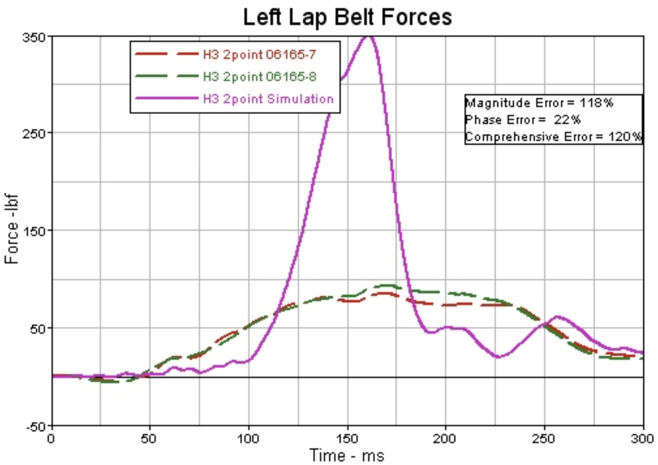
Validation Example: Seat-pan Reaction Forces



Validation Example: Lumbar and Lap Belt Forces



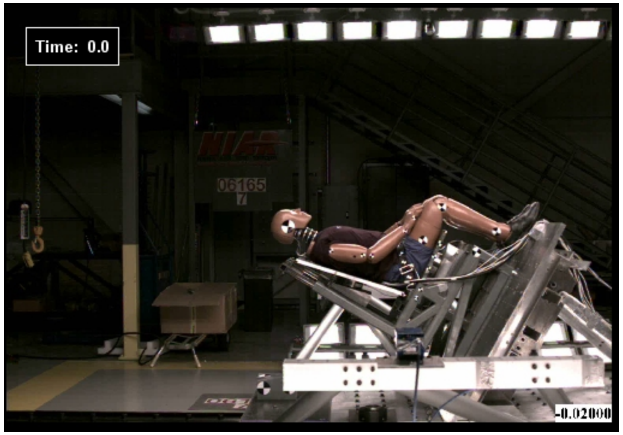


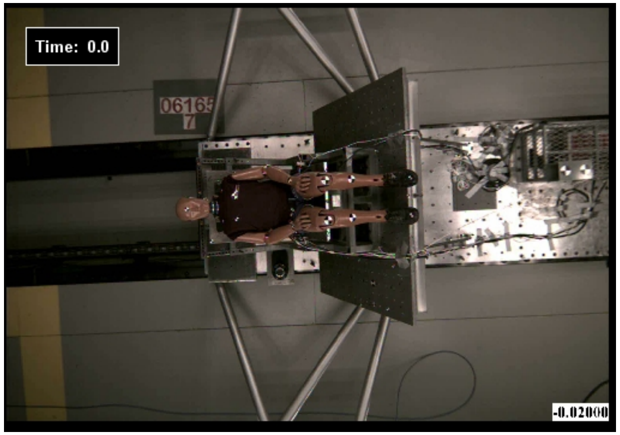


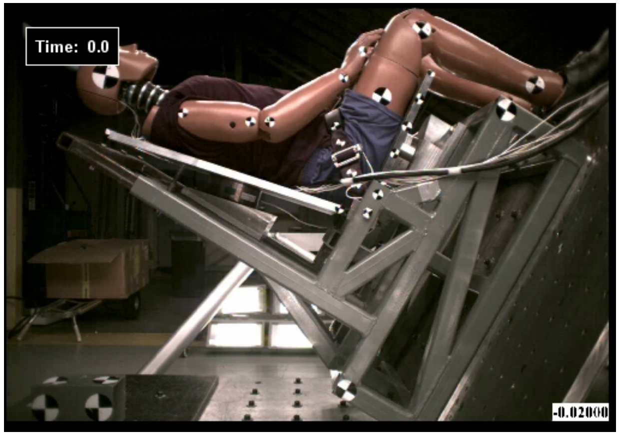
Validation Example: Validation Metric (Sprague and Geers)

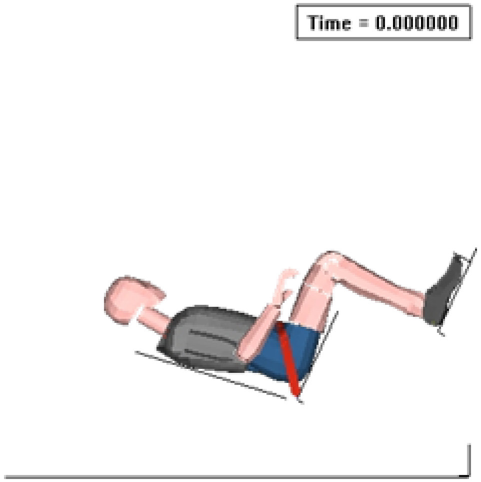
CHANNEL	TEST CONDITION		MAGNITUDE ERROR	PHASE ERROR	COMBINED
HEAD RESULTANT ACCELERATION	TEST vs. TEST	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 60° (06165-8)	5%	4%	6%
	TEST vs. Simulation	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 0° (SIMULATION)	4%	8%	9%
SEAT PAN REACTION FORCE X	TEST vs. TEST	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 60° (06165-8)	5%	2%	5%
	TEST vs. Simulation	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 0° (SIMULATION)	6%	6%	8%
SEAT PAN REACTION FORCE Y	TEST vs. TEST	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 60° (06165-8)	-5%	22%	22%
	TEST vs. Simulation	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 0° (SIMULATION)	-55%	45%	71%
SEAT PAN REACTION FORCE Z	TEST vs. TEST	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 60° (06165-8)	-1.35%	1.01%	1.69%
	TEST vs. Simulation	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 0° (SIMULATION)	26%	20%	33%
SEAT PAN REACTION FORCE RESULTANT	TEST vs. TEST	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 60° (06165-8)	-0.90%	1.00%	1.34%
	TEST vs. Simulation	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 0° (SIMULATION)	6%	7%	9%
LAP BELT REACTION FORCE LEFT	TEST vs. TEST	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 60° (06165-8)	5%	2%	6%
	TEST vs. Simulation	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 0° (SIMULATION)	118%	22%	120%
LUMBAR LOAD	TEST vs. TEST	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 60° (06165-8)	0.55%	1.27%	1.38%
	TEST vs. Simulation	2 POINT BELT, 60° (06165-7) 2 POINT BELT, 0° (SIMULATION)	1%	21%	21%

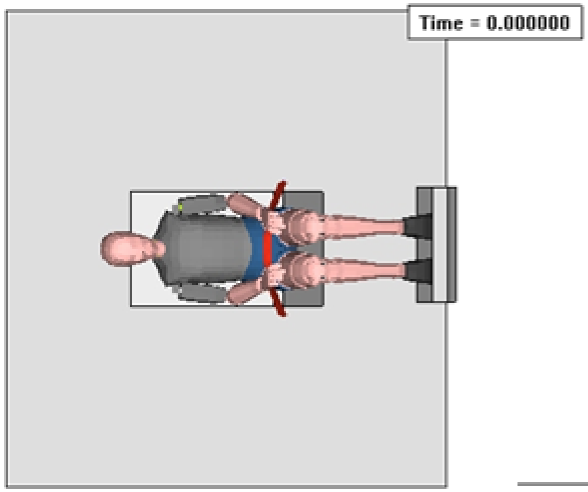
Validation Example: Occupant Kinematics

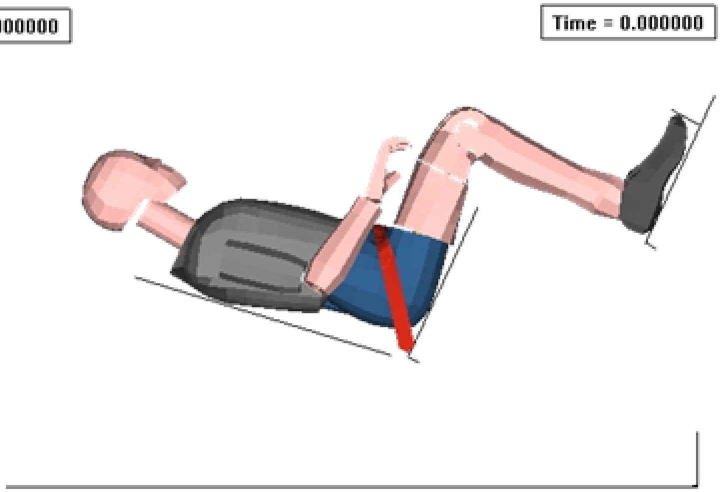




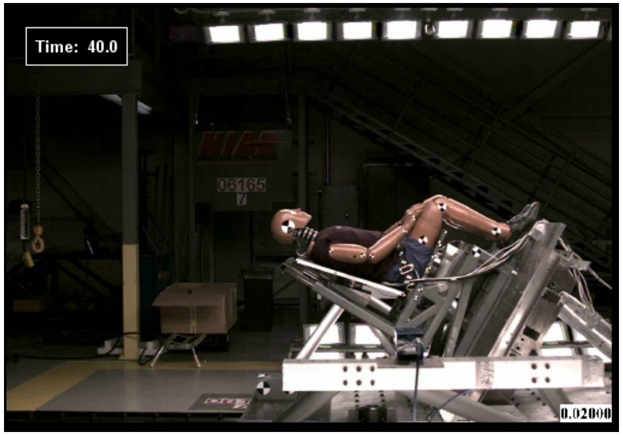


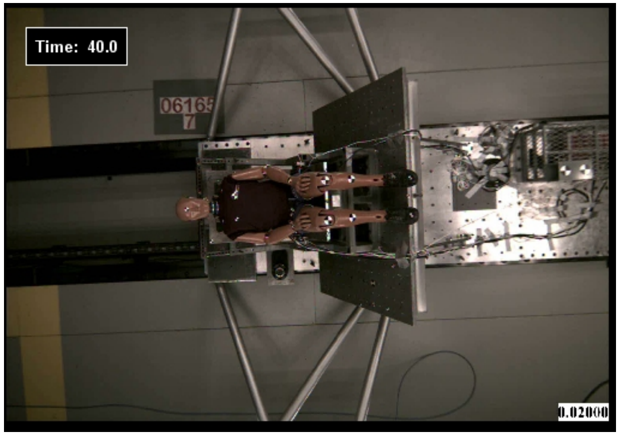


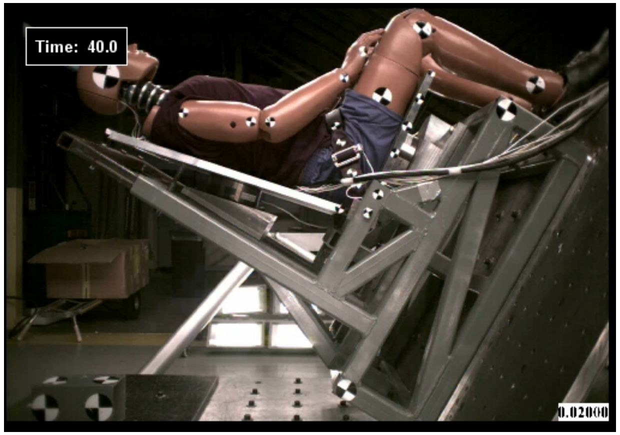


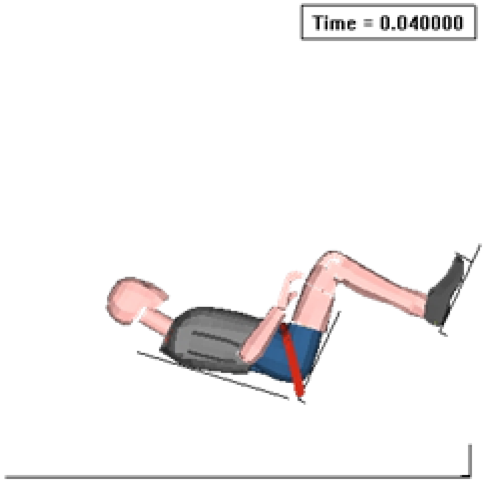


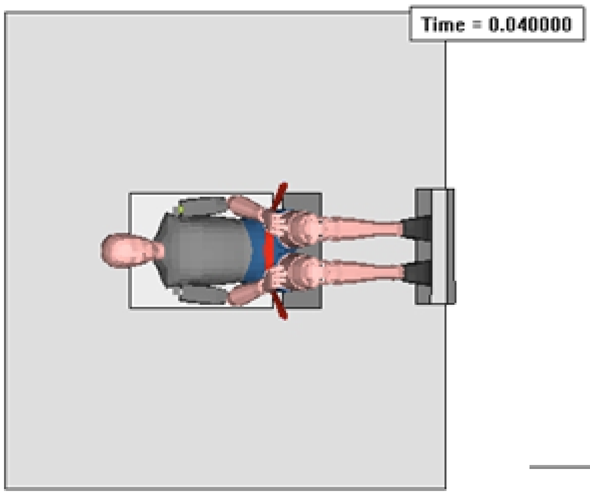
Validation Example: Occupant Kinematics

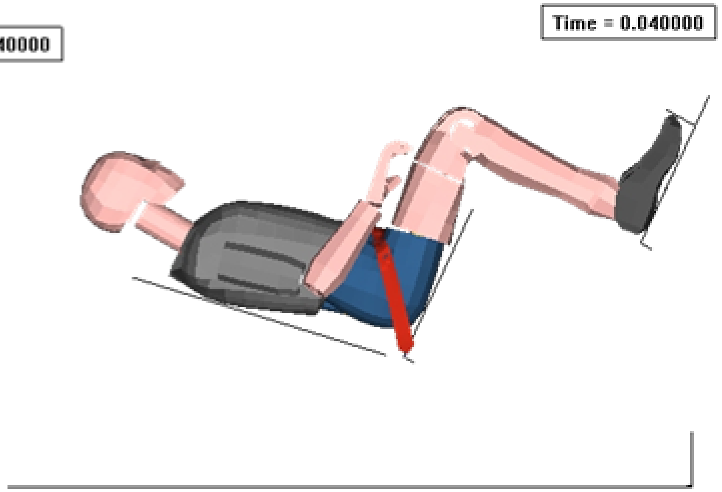




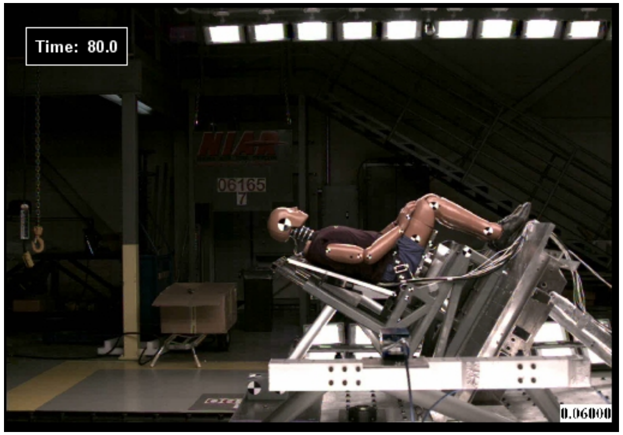


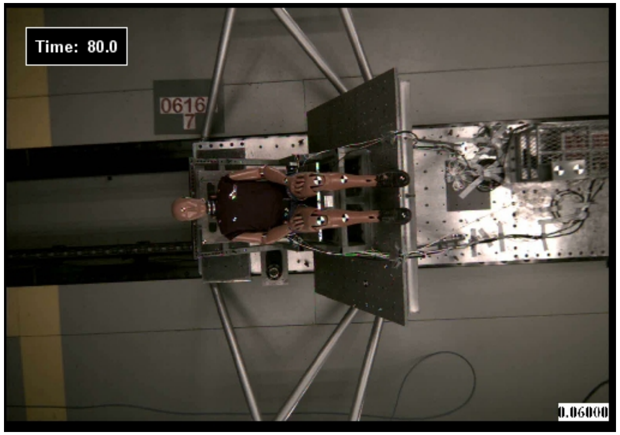


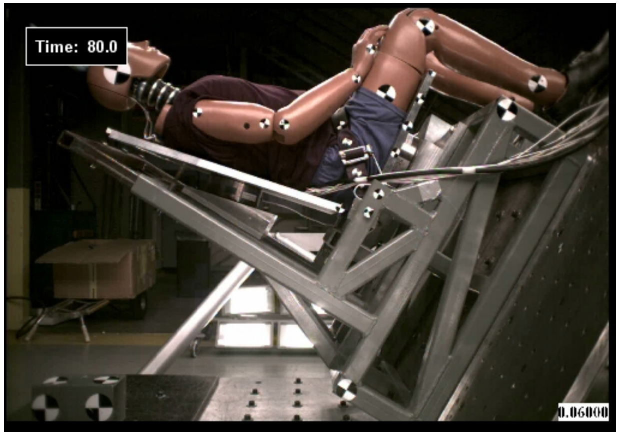


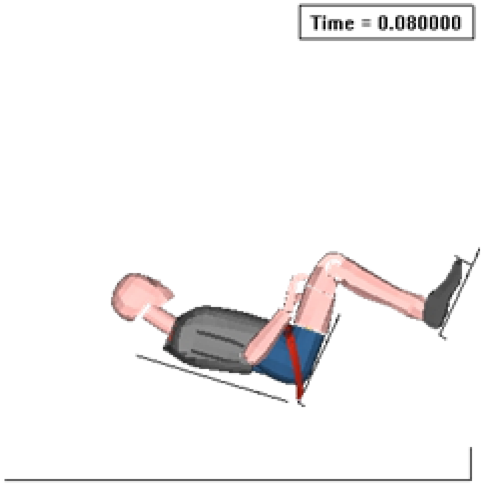


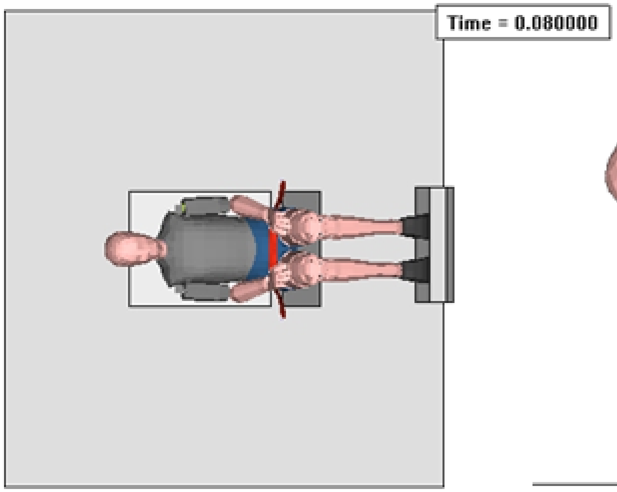
Validation Example: Occupant Kinematics

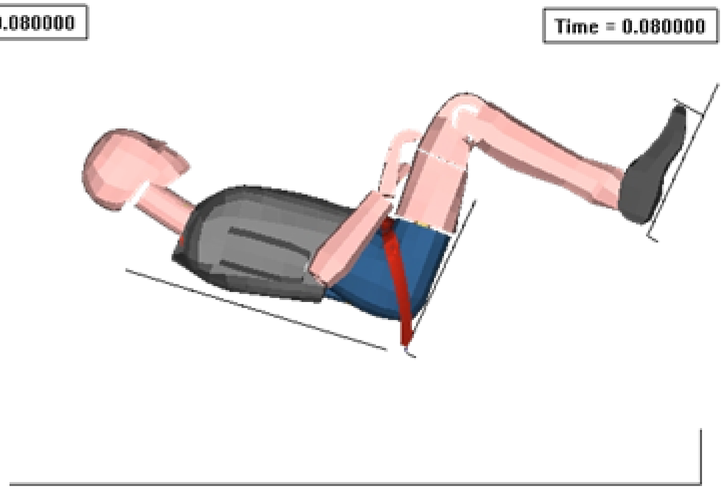




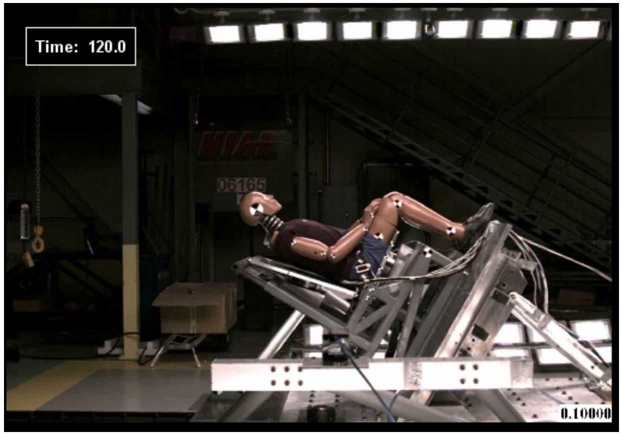


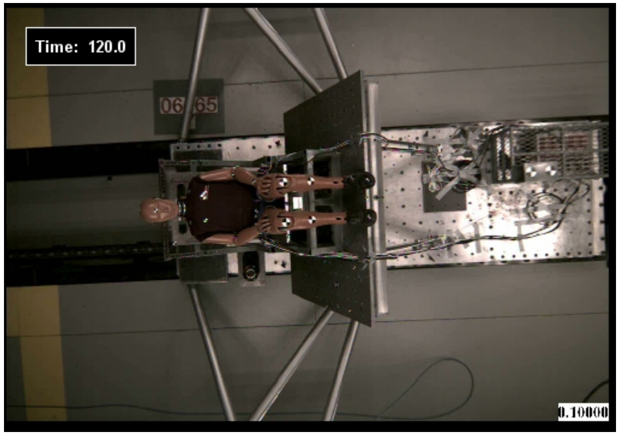


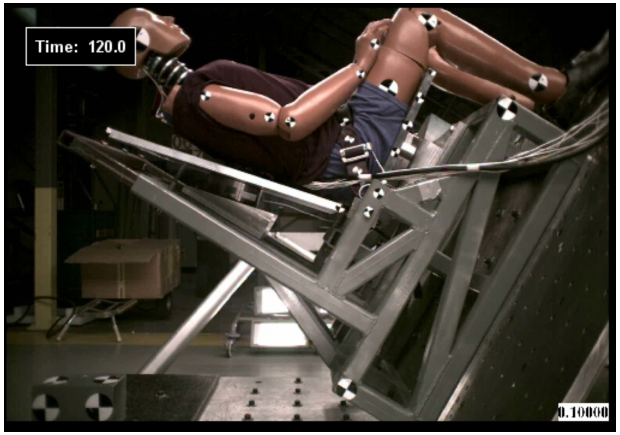


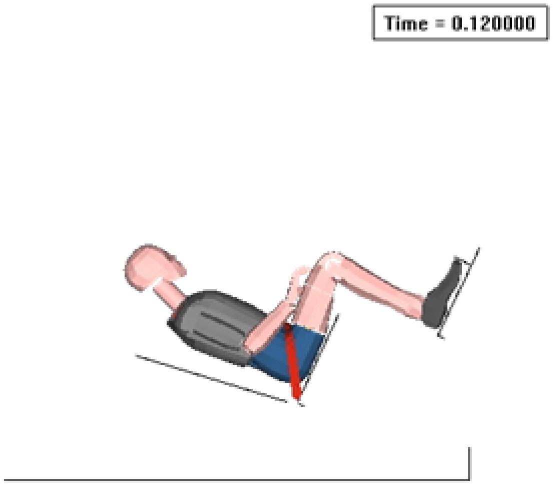


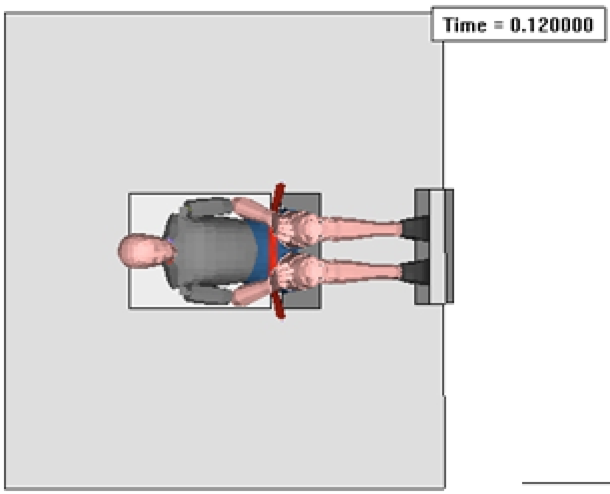
Validation Example: Occupant Kinematics

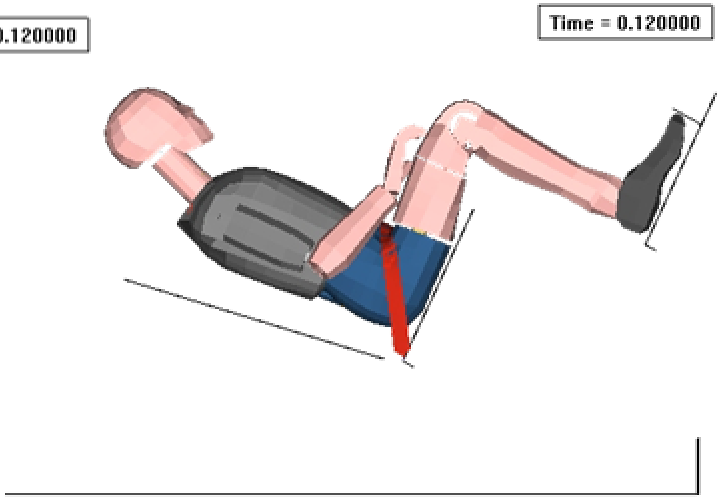




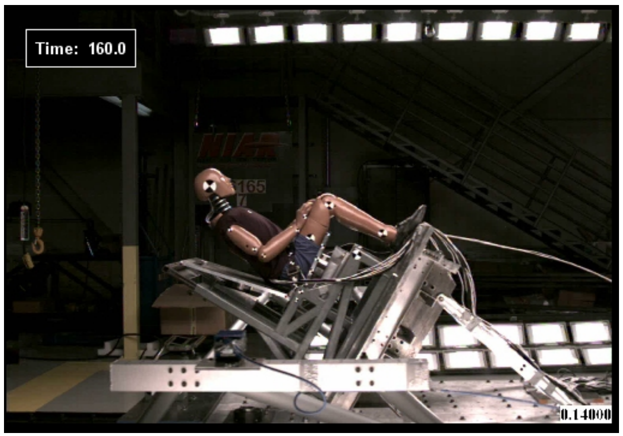


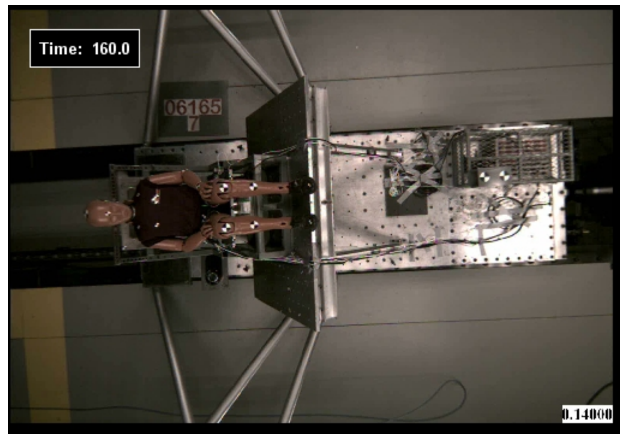


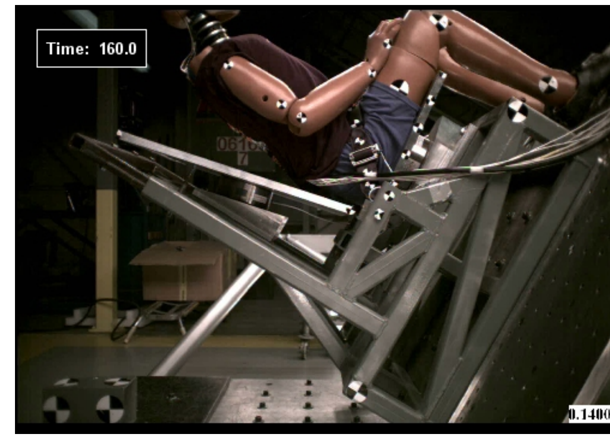


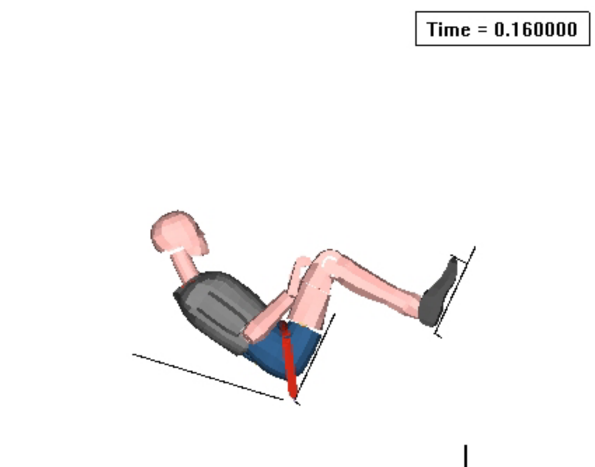


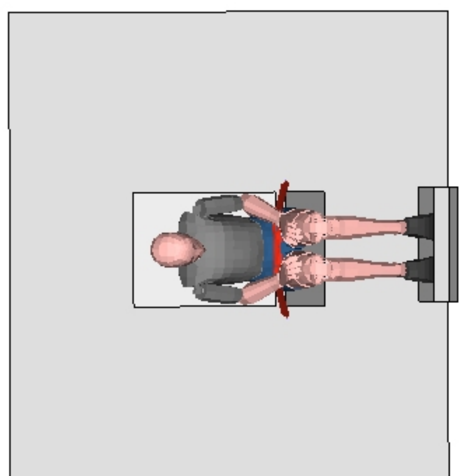
Validation Example: Occupant Kinematics

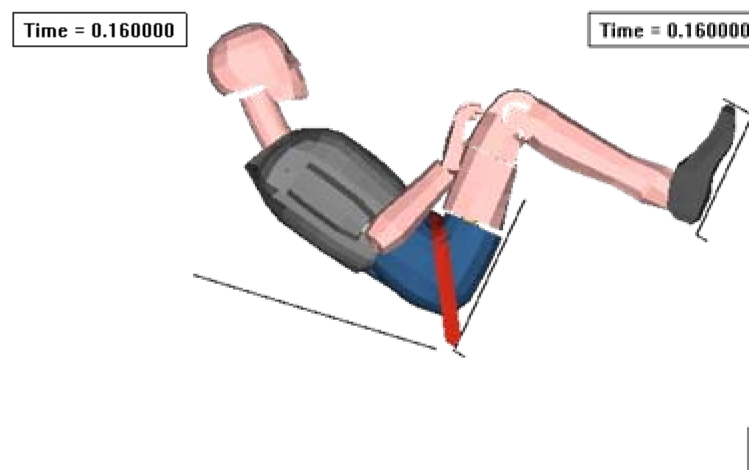




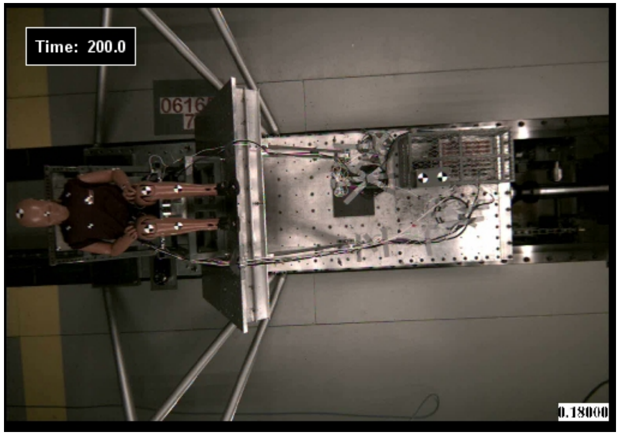


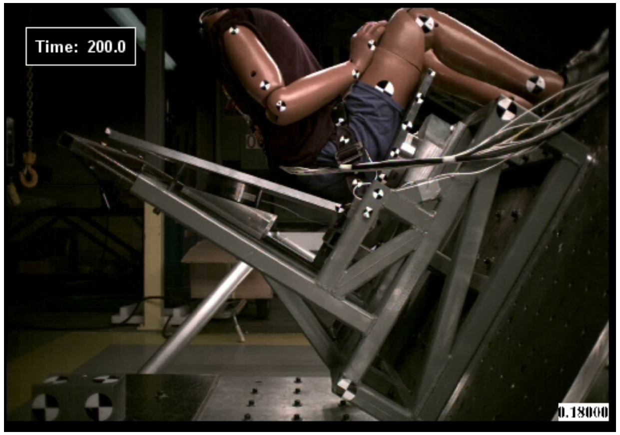


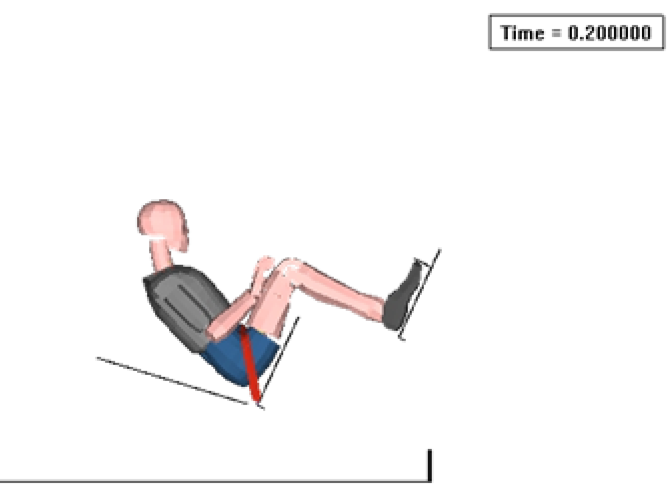


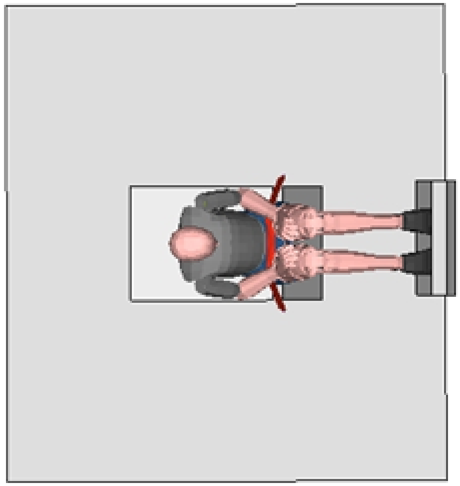


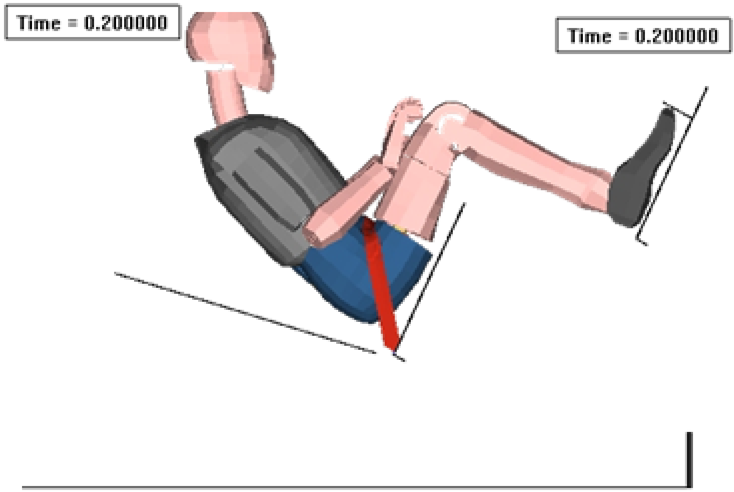
Validation Example: Occupant Kinematics











Testing Variability Summary: 2 - Point Belt – Type 1 FAR25.562

CHANNEL	TEST CONDITION		MAGNITUDE ERROR	PHASE ERROR	RESULTANT
HEAD RESULTANT ACCELERATION	HYBRID 2	2 POINT BELT, 60° (06165-5)	6%	8%	10%
		2 POINT BELT, 60° (06165-6)			
	HYBRID 3	2 POINT BELT, 60° (06165-7)	5%	4%	6%
		2 POINT BELT, 60° (06165-8)			
LAP BELT REACTION FORCE LEFT	HYBRID 2	2 POINT BELT, 60° (06165-5)	-16%	6%	17%
		2 POINT BELT, 60° (06165-6)			
	HYBRID 3	2 POINT BELT, 60° (06165-7)	5%	2%	6%
		2 POINT BELT, 60° (06165-8)			
SEAT PAN REACTION FORCE X	HYBRID 2	2 POINT BELT, 60° (06165-5)	-1%	2%	2%
		2 POINT BELT, 60° (06165-6)			
	HYBRID 3	2 POINT BELT, 60° (06165-7)	5%	2%	5%
		2 POINT BELT, 60° (06165-8)			
SEAT PAN REACTION FORCE Y	HYBRID 2	2 POINT BELT, 60° (06165-5)	-5%	22%	22%
		2 POINT BELT, 60° (06165-6)			
	HYBRID 3	2 POINT BELT, 60° (06165-7)	-22%	44%	49%
		2 POINT BELT, 60° (06165-8)			
SEAT PAN REACTION FORCE Z	HYBRID 2	2 POINT BELT, 60° (06165-5)	5%	2%	5%
		2 POINT BELT, 60° (06165-6)			
	HYBRID 3	2 POINT BELT, 60° (06165-7)	-1%	1%	2%
		2 POINT BELT, 60° (06165-8)			
SEAT PAN REACTION FORCE RESULTANT	HYBRID 2	2 POINT BELT, 60° (06165-5)	4%	2%	5%
		2 POINT BELT, 60° (06165-6)			
	HYBRID 3	2 POINT BELT, 60° (06165-7)	-1%	1%	1%
		2 POINT BELT, 60° (06165-8)			
LUMBAR LOAD	HYBRID 2	2 POINT BELT, 60° (06165-5)	8%	4%	8%
		2 POINT BELT, 60° (06165-6)			
	HYBRID 3	2 POINT BELT, 60° (06165-7)	1%	1%	1%
		2 POINT BELT, 60° (06165-8)			

Testing Variability Summary: 2-Point Belt – Type 2 FAR25.562

CHANNEL	TEST CONDITION		MAGNITUDE ERROR	PHASE ERROR	RESULTANT
HEAD RESULTANT ACCELERATION	HYBRID 2	2 POINT BELT, 0° (06165-3) 2 POINT BELT, 0° (06165-4)	10%	6%	12%
	HYBRID 3	2 POINT BELT, 0° (06165-1) 2 POINT BELT, 0° (06165-2)	-2%	4%	4%
LAP BELT REACTION FORCE LEFT	HYBRID 2	2 POINT BELT, 0° (06165-3) 2 POINT BELT, 0° (06165-4)	1%	4%	4%
	HYBRID 3	2 POINT BELT, 0° (06165-1) 2 POINT BELT, 0° (06165-2)	1%	2%	2%
SEAT PAN REACTION FORCE X	HYBRID 2	2 POINT BELT, 0° (06165-3) 2 POINT BELT, 0° (06165-4)	-10%	14%	18%
	HYBRID 3	2 POINT BELT, 0° (06165-1) 2 POINT BELT, 0° (06165-2)	3%	8%	9%
SEAT PAN REACTION FORCE Y	HYBRID 2	2 POINT BELT, 0° (06165-3) 2 POINT BELT, 0° (06165-4)	60%	19%	63%
	HYBRID 3	2 POINT BELT, 0° (06165-1) 2 POINT BELT, 0° (06165-2)	-28%	20%	35%
SEAT PAN REACTION FORCE Z	HYBRID 2	2 POINT BELT, 0° (06165-3) 2 POINT BELT, 0° (06165-4)	-16%	11%	19%
	HYBRID 3	2 POINT BELT, 0° (06165-1) 2 POINT BELT, 0° (06165-2)	18%	6%	19%
SEAT PAN REACTION FORCE RESULTANT	HYBRID 2	2 POINT BELT, 0° (06165-3) 2 POINT BELT, 0° (06165-4)	-14%	11%	17%
	HYBRID 3	2 POINT BELT, 0° (06165-1) 2 POINT BELT, 0° (06165-2)	11%	6%	13%
LUMBAR LOAD	HYBRID 2	2 POINT BELT, 0° (06165-3) 2 POINT BELT, 0° (06165-4)	8%	5%	10%
	HYBRID 3	2 POINT BELT, 0° (06165-1) 2 POINT BELT, 0° (06165-2)	-1%	2%	2%

Testing Variability Summary: 3 - Point Belt – Type 2 FAR25.562

CHANNEL	TEST CONDITION		MAGNITUDE ERROR	PHASE ERROR	RESULTANT
HEAD RESULTANT ACCELERATION	HYBRID 2	3 POINT BELT, 0° (06165-10) 3 POINT BELT, 0° (06165-11)	-37%	17%	41%
	HYBRID 3	3 POINT BELT, 0° (06165-12) 3 POINT BELT, 0° (06165-13)	4%	2%	5%
LAP BELT REACTION FORCE LEFT	HYBRID 2	3 POINT BELT, 0° (06165-10) 3 POINT BELT, 0° (06165-11)	6%	1%	6%
	HYBRID 3	3 POINT BELT, 0° (06165-12) 3 POINT BELT, 0° (06165-13)	0%	2%	2%
SHOULDER STRAP FORCE RIGHT	HYBRID 2	3 POINT BELT, 0° (06165-10) 3 POINT BELT, 0° (06165-11)	2%	2%	3%
	HYBRID 3	3 POINT BELT, 0° (06165-12) 3 POINT BELT, 0° (06165-13)	0%	1%	1%
SEAT PAN REACTION FORCE X	HYBRID 2	3 POINT BELT, 0° (06165-10) 3 POINT BELT, 0° (06165-11)	0%	7%	7%
	HYBRID 3	3 POINT BELT, 0° (06165-12) 3 POINT BELT, 0° (06165-13)	1%	2%	3%
SEAT PAN REACTION FORCE Y	HYBRID 2	3 POINT BELT, 0° (06165-10) 3 POINT BELT, 0° (06165-11)	-6%	16%	17%
	HYBRID 3	3 POINT BELT, 0° (06165-12) 3 POINT BELT, 0° (06165-13)	-6%	11%	13%
SEAT PAN REACTION FORCE Z	HYBRID 2	3 POINT BELT, 0° (06165-10) 3 POINT BELT, 0° (06165-11)	-12%	10%	16%
	HYBRID 3	3 POINT BELT, 0° (06165-12) 3 POINT BELT, 0° (06165-13)	-1%	4%	5%
SEAT PAN REACTION FORCE RESULTANT	HYBRID 2	3 POINT BELT, 0° (06165-10) 3 POINT BELT, 0° (06165-11)	-27%	24%	36%
	HYBRID 3	3 POINT BELT, 0° (06165-12) 3 POINT BELT, 0° (06165-13)	0%	3%	3%
LUMBAR LOAD	HYBRID 2	3 POINT BELT, 0° (06165-10) 3 POINT BELT, 0° (06165-11)	-3%	16%	16%
	HYBRID 3	3 POINT BELT, 0° (06165-12) 3 POINT BELT, 0° (06165-13)	15%	6%	16%

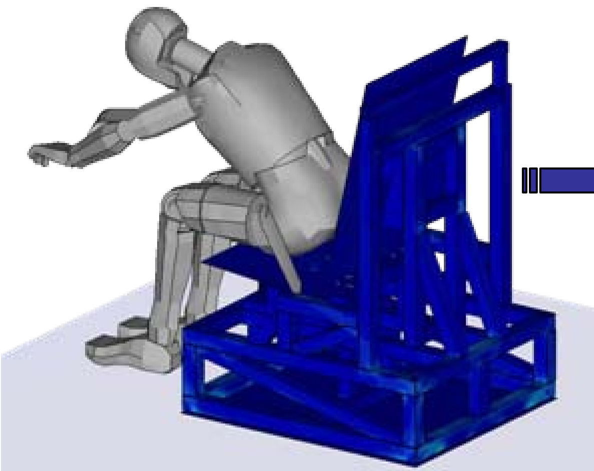
Testing Variability Summary: 4 - Point Belt – Type 2 FAR25.562

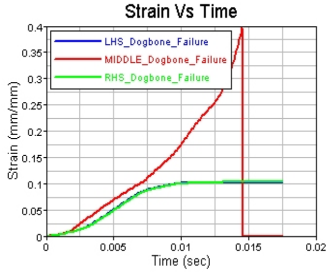
CHANNEL	TEST CONDITION		MAGNITUDE ERROR	PHASE ERROR	RESULTANT
HEAD RESULTANT ACCELERATION	HYBRID 2	4 POINT BELT, 0° (06165-17) 4 POINT BELT, 0° (06165-18)	2%	7%	7%
	HYBRID 3	4 POINT BELT, 0° (06165-14) 4 POINT BELT, 0° (06165-15)	5%	2%	5%
LAP BELT REACTION FORCE LEFT	HYBRID 2	4 POINT BELT, 0° (06165-17) 4 POINT BELT, 0° (06165-18)	1%	5%	5%
	HYBRID 3	4 POINT BELT, 0° (06165-14) 4 POINT BELT, 0° (06165-15)	-2%	1%	3%
SHOULDERS STRAP FORCE	HYBRID 2	4 POINT BELT, 0° (06165-17) 4 POINT BELT, 0° (06165-18)	0%	4%	4%
	HYBRID 3	4 POINT BELT, 0° (06165-14) 4 POINT BELT, 0° (06165-15)	-2%	3%	3%
SEAT PAN REACTION FORCE X	HYBRID 2	4 POINT BELT, 0° (06165-17) 4 POINT BELT, 0° (06165-18)	-1%	5%	5%
	HYBRID 3	4 POINT BELT, 0° (06165-14) 4 POINT BELT, 0° (06165-15)	1%	2%	2%
SEAT PAN REACTION FORCE Y	HYBRID 2	4 POINT BELT, 0° (06165-17) 4 POINT BELT, 0° (06165-18)	-30%	56%	64%
	HYBRID 3	4 POINT BELT, 0° (06165-14) 4 POINT BELT, 0° (06165-15)	102%	31%	107%
SEAT PAN REACTION FORCE Z	HYBRID 2	4 POINT BELT, 0° (06165-17) 4 POINT BELT, 0° (06165-18)	-5%	8%	10%
	HYBRID 3	4 POINT BELT, 0° (06165-14) 4 POINT BELT, 0° (06165-15)	5%	5%	7%
SEAT PAN REACTION FORCE RESULTANT	HYBRID 2	4 POINT BELT, 0° (06165-17) 4 POINT BELT, 0° (06165-18)	-3%	6%	7%
	HYBRID 3	4 POINT BELT, 0° (06165-14) 4 POINT BELT, 0° (06165-15)	3%	3%	5%
LUMBAR LOAD	HYBRID 2	4 POINT BELT, 0° (06165-17) 4 POINT BELT, 0° (06165-18)	-2%	14%	14%
	HYBRID 3	4 POINT BELT, 0° (06165-14) 4 POINT BELT, 0° (06165-15)	-7%	11%	13%

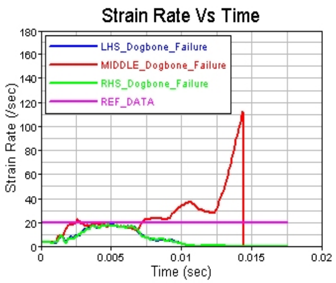
Testing Variability Summary: 2 - Point Belt- Cushion – Type 1 FAR25.562

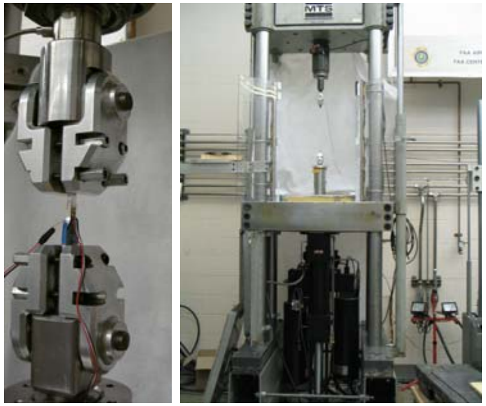
CHANNEL	TEST CONDITION		MAGNITUDE ERROR	PHASE ERROR	RESULTANT
HEAD RESULTANT ACCELERATION	HYBRID 2	2 PT, 60°, CUSHIONED (06165-19A) 2 PT, 60°, CUSHIONED (06165-20)	1%	6%	6%
	HYBRID 3	2 PT, 60°, CUSHIONED (06165-21) 2 PT, 60°, CUSHIONED (06165-22)	4%	4%	6%
LAP BELT REACTION FORCE LEFT	HYBRID 2	2 PT, 60°, CUSHIONED (06165-19A) 2 PT, 60°, CUSHIONED (06165-20)	-23%	3%	23%
	HYBRID 3	2 PT, 60°, CUSHIONED (06165-21) 2 PT, 60°, CUSHIONED (06165-22)	-2%	3%	3%
SEAT PAN REACTION FORCE X	HYBRID 2	2 PT, 60°, CUSHIONED (06165-19A) 2 PT, 60°, CUSHIONED (06165-20)	C.F.	C.F.	C.F.
	HYBRID 3	2 PT, 60°, CUSHIONED (06165-21) 2 PT, 60°, CUSHIONED (06165-22)	7%	4%	8%
SEAT PAN REACTION FORCE Y	HYBRID 2	2 PT, 60°, CUSHIONED (06165-19A) 2 PT, 60°, CUSHIONED (06165-20)	41%	27%	49%
	HYBRID 3	2 PT, 60°, CUSHIONED (06165-21) 2 PT, 60°, CUSHIONED (06165-22)	-12%	59%	60%
SEAT PAN REACTION FORCE Z	HYBRID 2	2 PT, 60°, CUSHIONED (06165-19A) 2 PT, 60°, CUSHIONED (06165-20)	-1%	2%	3%
	HYBRID 3	2 PT, 60°, CUSHIONED (06165-21) 2 PT, 60°, CUSHIONED (06165-22)	0%	1%	1%
SEAT PAN REACTION FORCE RESULTANT	HYBRID 2	2 PT, 60°, CUSHIONED (06165-19A) 2 PT, 60°, CUSHIONED (06165-20)	5%	3%	6%
	HYBRID 3	2 PT, 60°, CUSHIONED (06165-21) 2 PT, 60°, CUSHIONED (06165-22)	1%	1%	2%
LUMBAR LOAD	HYBRID 2	2 PT, 60°, CUSHIONED (06165-19A) 2 PT, 60°, CUSHIONED (06165-20)	1%	3%	4%
	HYBRID 3	2 PT, 60°, CUSHIONED (06165-21) 2 PT, 60°, CUSHIONED (06165-22)	5%	2%	5%

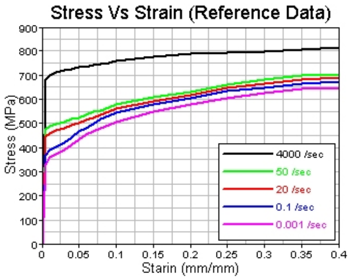
Material Database Development Process







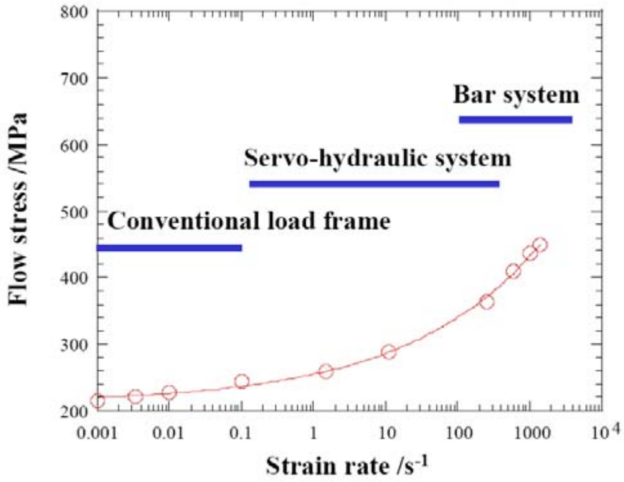




Material Database

Strain Rate Testing

- There are three types of testing systems required for crashworthiness applications:
  - 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
- According to preliminary data analysis strain rates increments 1,10,100 /s are sufficient for describing the material strain rate sensitivity



Strain Rate Testing Materials

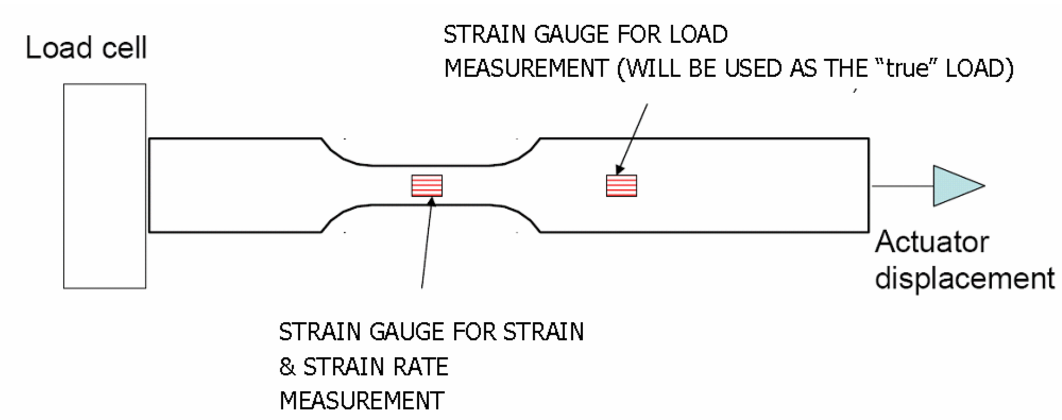
ALUMINUM		
Material Designation	**Material Form**	**Material Specification**
7075 T6	Sheet	AMS-4045 AMS-QQ-A-250/12
	Rolled/Drawn Bar	AMS-QQ-A 225/9
	Extrusion Bar	AMS-QQ-A 200/11
7075 T651	Plate	AMS-4045
2024 T3	Sheet	AMS-4037 AMS-QQ-A-250/4
	Rolled/Drawn Bar	AMS-4086 AMS-QQ-A-225/6
	Extrusion Bar	AMS-QQ-A-200/3
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

Strain Rate Testing Materials

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

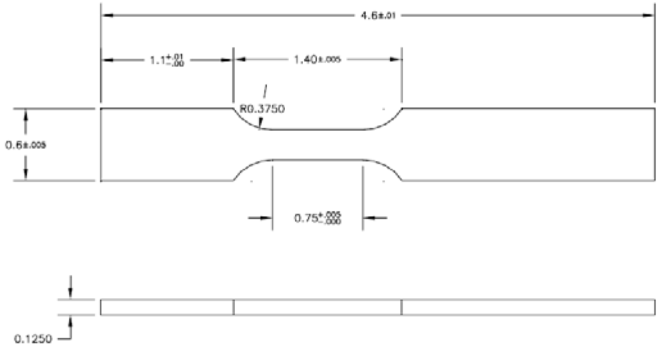
Baseline Testing Objectives

- Generation of medium strain rate data for 7075-T6 Aluminum under tension
- Comparison of load measurement methods
  - Piezoelectric load cell
  - Strain gage based load cell
  - Extended tab gage
- Generation of Transfer functions to correct the load-cell data for modulations

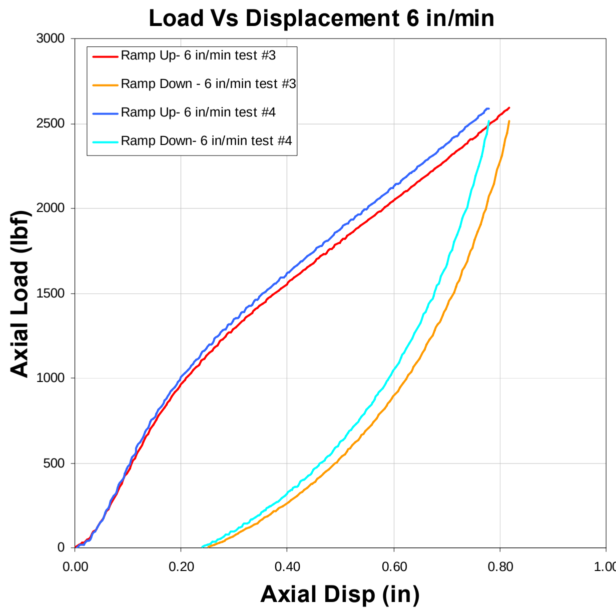


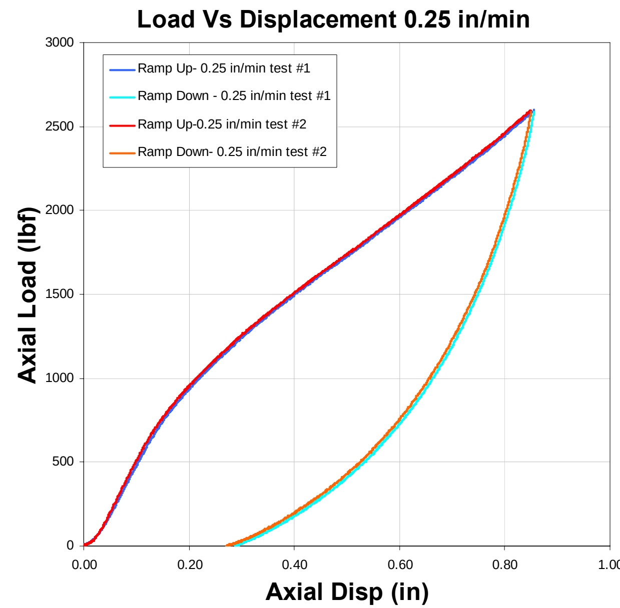
Test Matrix

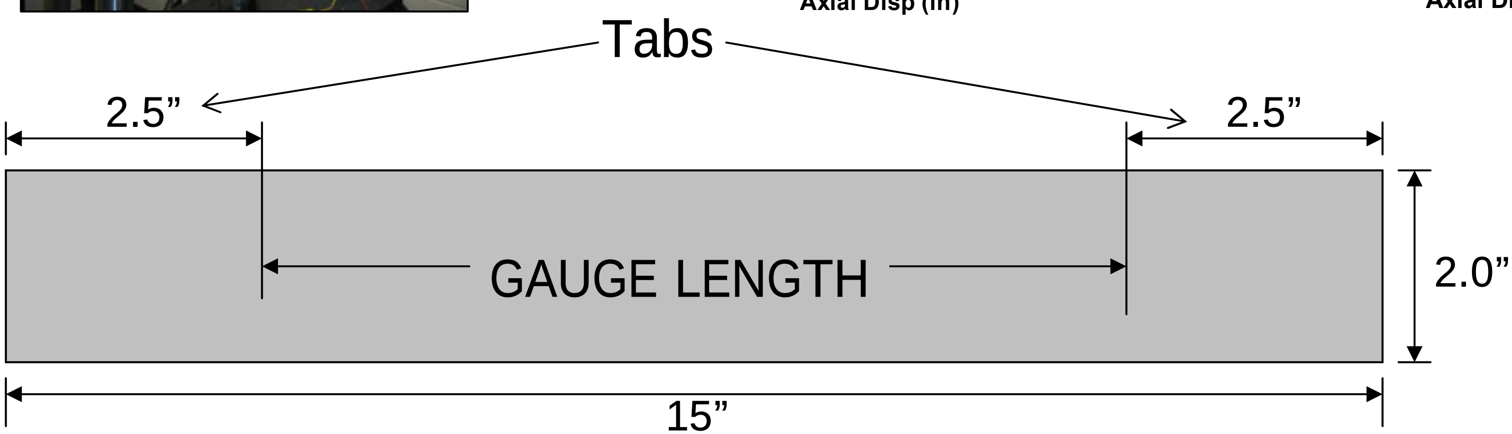
Test speed (in/s)	Load measurement method			
	Piezo load cell	Strain gauge load cell	Tab strain gauge	Strain gauges in gauge region
Quasi-static (0.001)	x3	x3	Used in all tests	Strain gauges used in all tests - to measure strain - to measure strain rate
0.1	x3	x3		
1.0	x3	x3		
10	x3	x3		
50	x3	x3		
100	x3	x3		



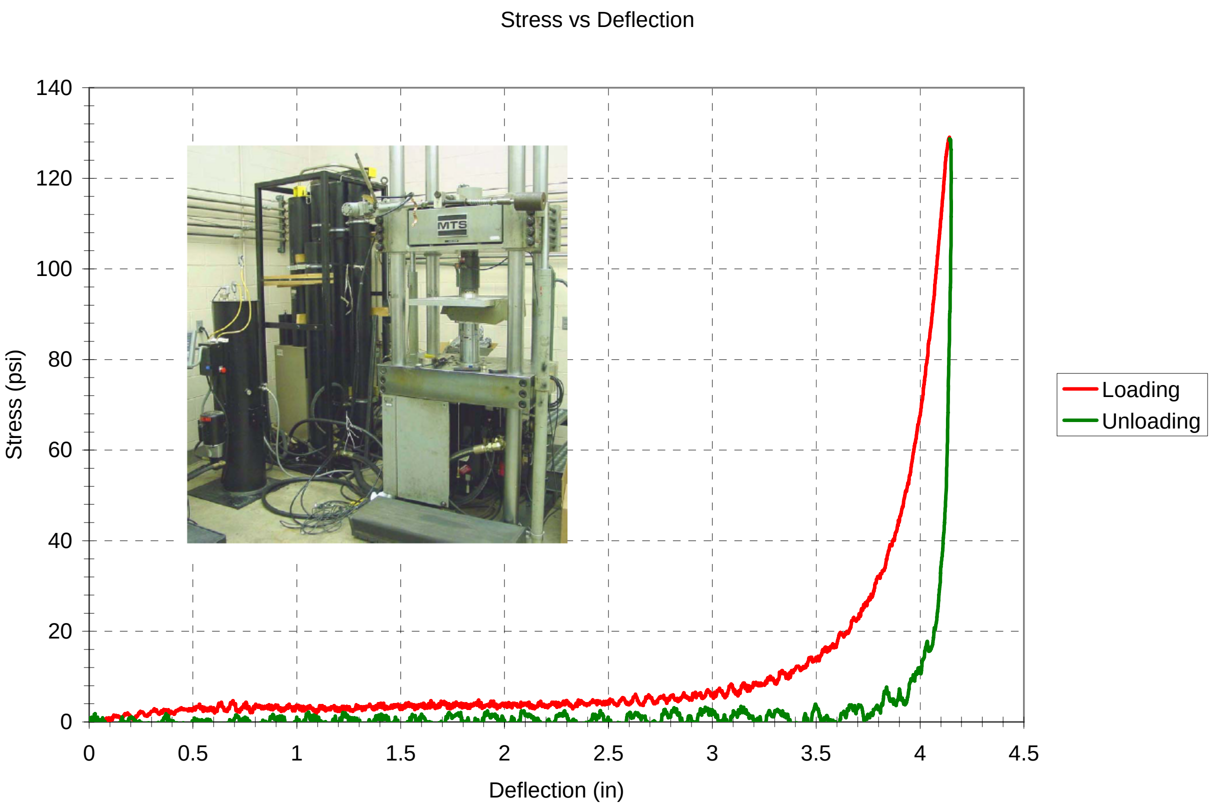
Belt Webbing Testing

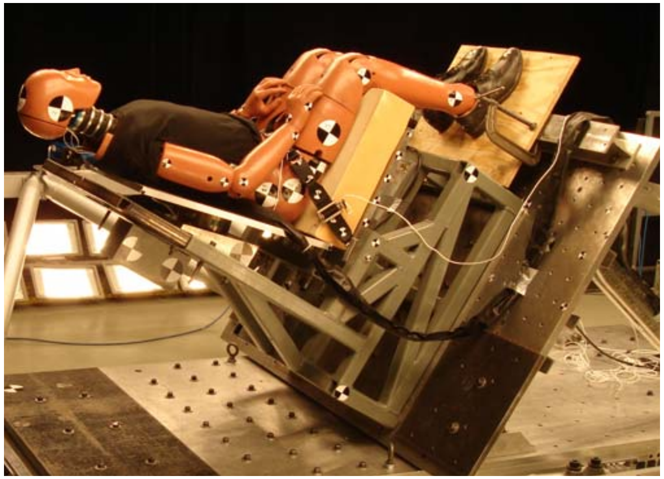


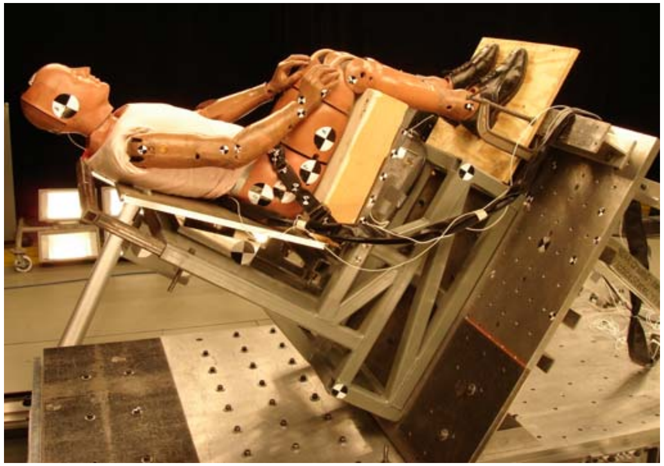




Seat Cushion Testing







Note: For additional information on Aircraft Seat Cushion Component Testing refer to DOT/FAA/AR-05/5

Conclusions and Future Work

- Release report phase I: ATD Validation Data and Procedures – September 2007
- Continue to support numerical ATD developers
- Continue FE seat modeling efforts (strain rate range definition):
  - Continue data analysis and sled validation of available FE models
  - Build FE models of commercial passenger seats to study the strain rates of various components
- Material testing methods and database development
- Continue training graduate students and industry in CBA methods

A Look Forward

- **Benefit to Aviation:**
  - Reduce certification costs
  - Reduce development cycles
  - Improve product design
  - 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

A Look Forward