THE MAKERS OF

madymo

Title: MADYMO HII 50th for aircraft seat design and certification

Date: 10/26/2010

The Sixth Triennial International Fire & Cabin Safety Research Conference

Authors : Mutaz Shkoukani, Robin Van der Made

tass
beyond safe

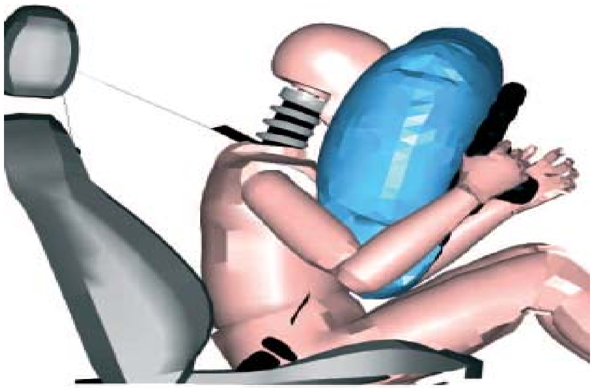
www.tass-safe.com

Content

- TASS and MADYMO introduction
- Dummy models history and update
- Dynamic dummy model validation
- Where/how does it fit in your process?
- Case study
- Conclusion

TASS Introduction

madymo

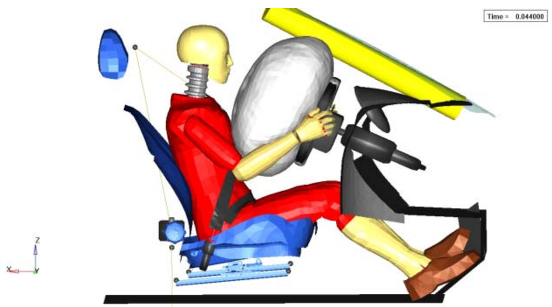


- TASS is a private company, fully owned by TNO
  (independent Dutch R&D organization)
- Headquarters in Rijswijk, the Netherlands
- Our software MADYMO is the world’s leading occupant safety design software
- Building on over 30 years of transport safety experience, our engineers can support you to improve your safety design.
- Industry leader in ATD and Human Model development
- From our headquarters in The Netherlands and offices across the globe, we work closely with top manufacturers and their suppliers to provide dedicated solutions to complex needs

How Do TASS & Our Clients Work Together

tass
beyond safe

- For startup companies, our client is looking at TASS as their partner to help in managing the restraint system development including aircraft seat.



- TASS can take responsibility for all occupant simulations, component testing, sled testing and aircraft seat certification.

- TASS is responsible for pulling together all component suppliers to provide the most efficient way of developing an optimized and robust system.

How Do TASS & Our Clients Work Together

- Our experienced engineering team consults with our client on all the regulations related to developing aircraft safety.

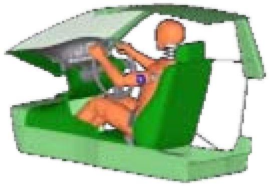
- TTAI: joint venture TÜV Rheinland & TNO is responsible for conducting all full seat certification testing and reporting.

- By working in cooperation with TASS, the efficiencies made possible from the integration of test, simulation and project management all under one roof can be translated into time and cost savings on the project.

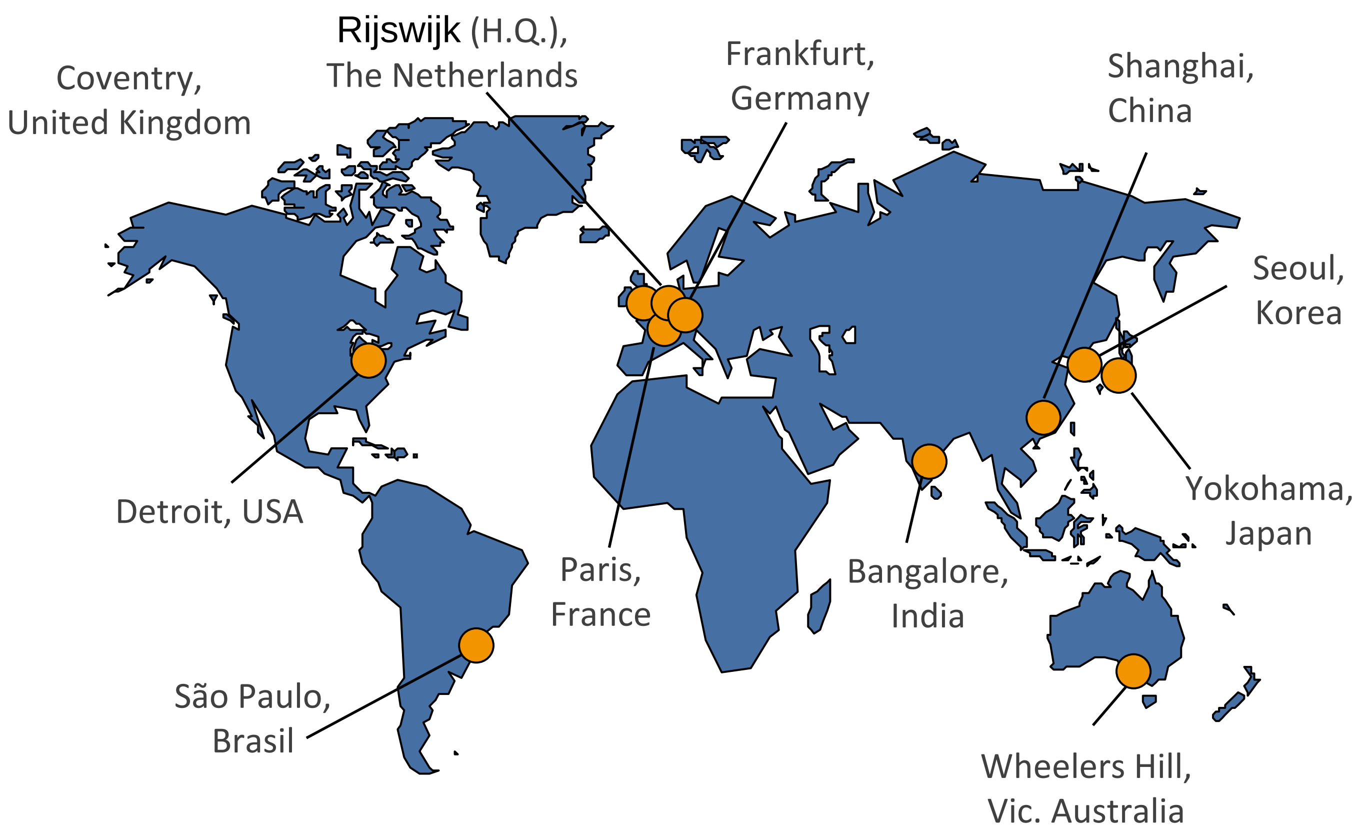
TASS Mission

Mission statement

"to enhance human safety by providing customer-focused solutions and innovative software tools "



TASS global presence



Some of Our Customers Globally

Introduction

- Aircraft seat certification using testing could be very costly and requires multiple phases of development before it can meet the regulations.

- Numerical simulation is less expensive method to be used for the aircraft seat design from concept to production.

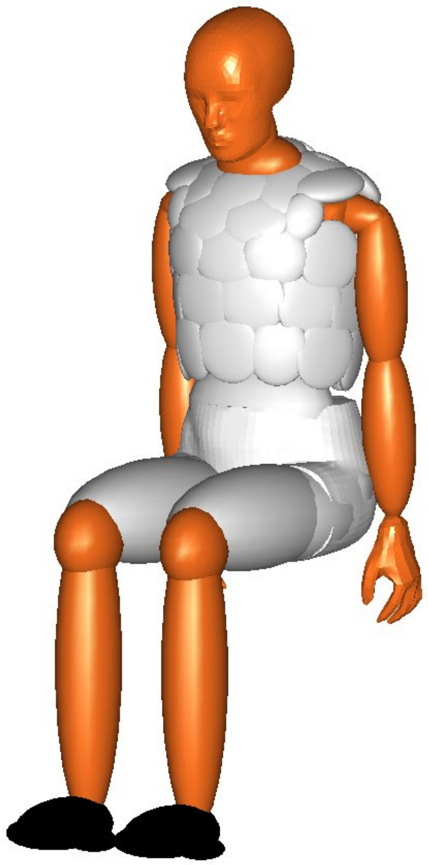
- The test variability always been a challenge in the occupant safety testing for both automotive and aviation, with all the parameters involved in each test, it makes it very difficult to control.

Objective

- This study show that test variability is real and it is hard to control due to multiple parameters.
- Analyze the variability between each repeated test setup and the error matrix was documented.
- Compare the validated model to the test and most of the responses were within the test variability (modeling is still in progress).

Aviation dummy models

- Hybrid-II (50th percentile)
- Hybrid-III FAA (50th percentile)
- Hybrid-III 95th (Research only, no official status)
- Hybrid-III FAA scalable



Model update **_Hybrid-II 50th ell_**

50th Ellipsoid model d_p57250el version 5.0

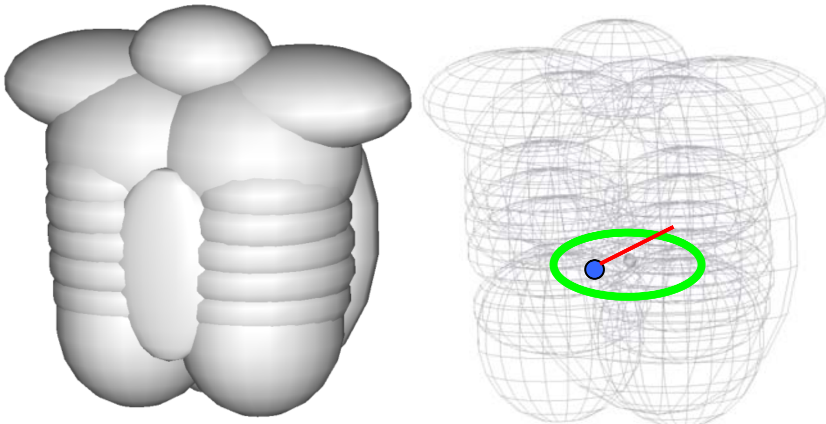
Improvements:

- New thorax model
- New lumbar-spine model
- New pelvis model
- New facet abdomen-pelvis part
- New facet head
- New facet hands

New thorax model

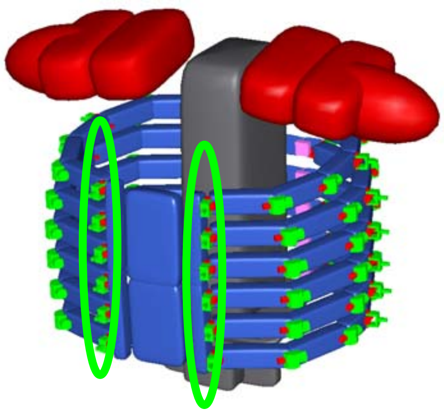
- **RIBCAGE to STERNUM**

LAST MODEL



- Ribcage modeled with 1 cardan and one point restraint
- The ribs are rigidly connected to the sternum

NEW MODEL



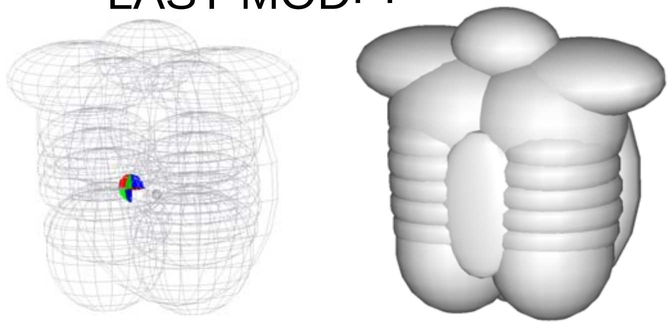
- Ribcage modeled with a chain of bodies and joints
- Ribs connected by means of universal joint

- Advantage: chest deflection more accurate

New thorax model

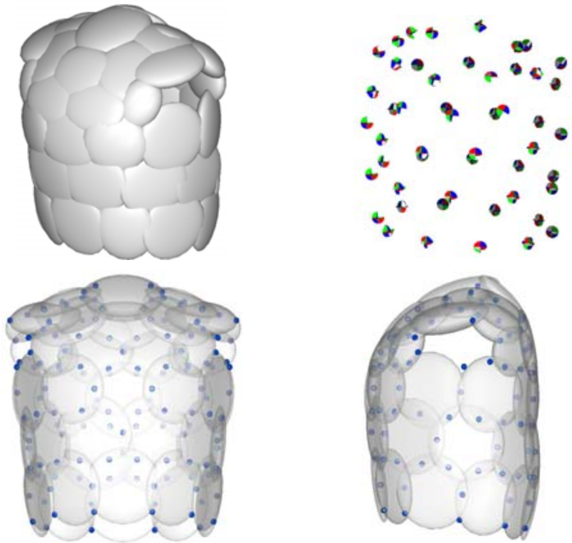
- **JACKET**

LAST MODEL



- Jacket mass concentrated on one body
- Jacket modeled with ellipsoids each rigid connected to the other

NEW MODEL



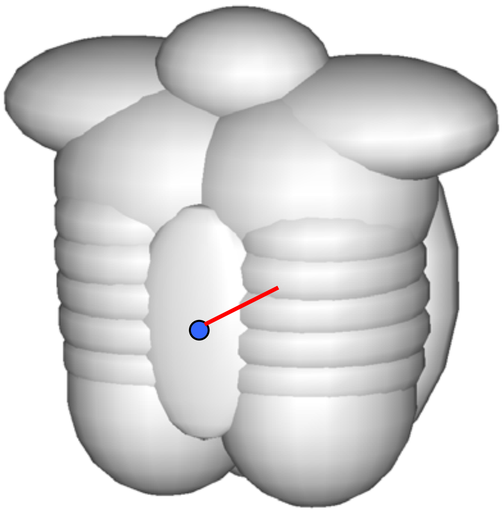
- Jacket mass distributed into 50 bodies
- Jacket modeled with point restraints and cardan restraints

- <u>Advantage</u>: better mass distribution & jacket more representative of real behavior

New thorax model

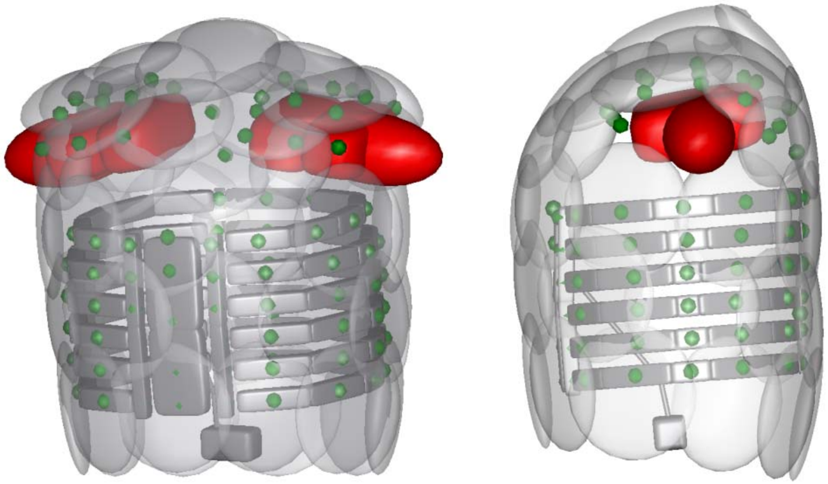
- **JACKET - ribs/clavicles interaction**

- LAST MODEL



- Interaction Jacket-skeleton modeled with 1 point- and 1 cardan restraints and in the contact characteristics

- NEW MODEL



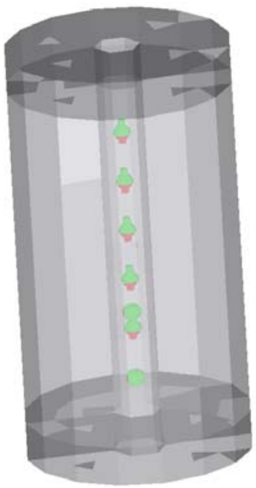
- Interaction Jacket-skeleton modeled by means of point restraints and cardan restraints.

- Advantage: more detailed jacket deformation due to belt loading

New lumbarspine

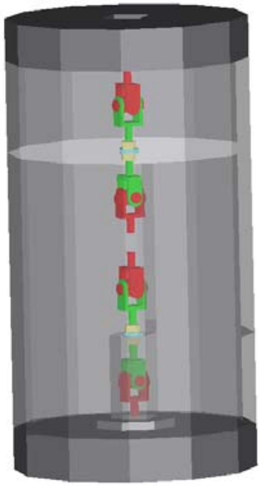
- **LUMBAR SPINE**

LAST MODEL



- Lumbar modeled with 5 free joint. Lumbar cable modeled with 5 spherical joints

NEW MODEL

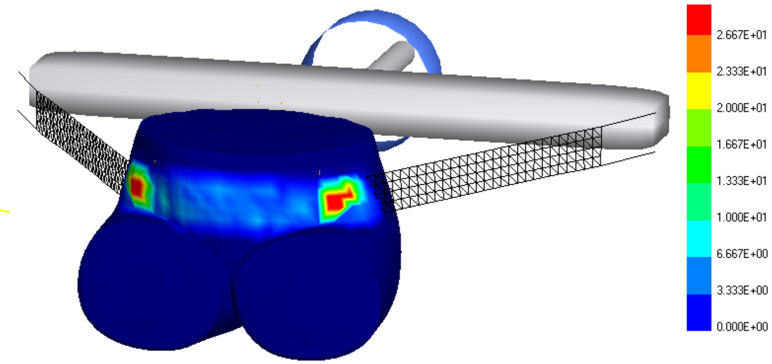


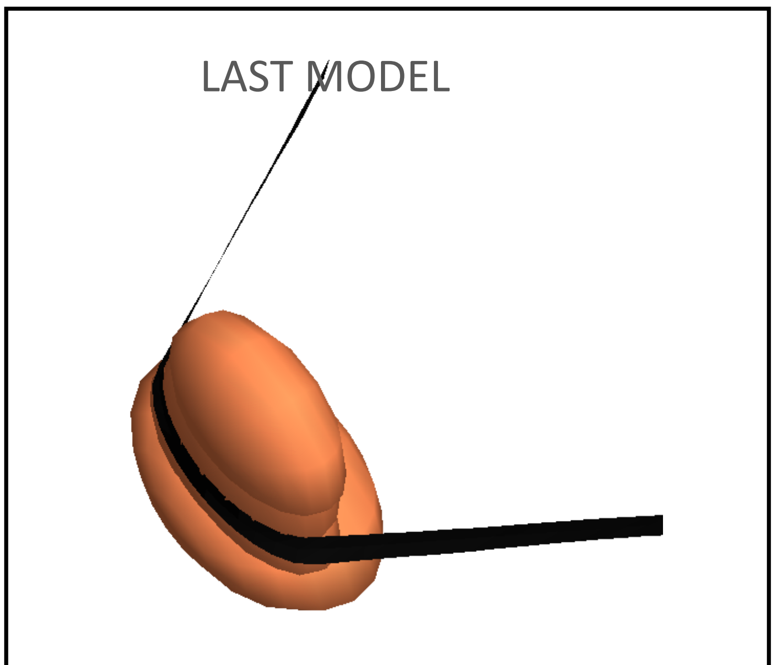
- Lumbar mold modeled with 4 universal and 2 cylindrical joints. Two triple joint restraints are used

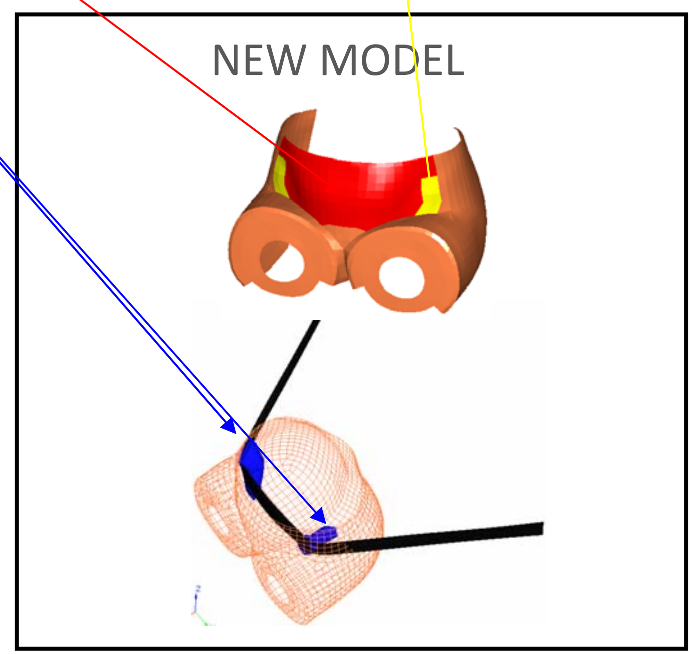
- Advantage: more realistic explicit modelling of the shear and bending

New facet abdomen/pelvis

- New facet abdomen
- New thickness distribution
  - Thin in the front of iliac wings area
  - Thicker at the abdomen area
- Added two iliac wings top
  - Improve the belt pocketing



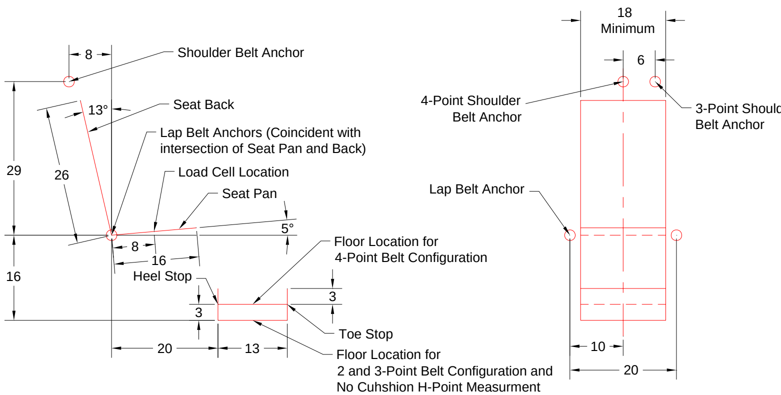




Dynamic dummy model validation

- FAA guidelines

- SAE seat committee is working on a best practice guideline document (ARP 5765)
  - Test descriptions (rigid seat)
    - Frontal impact with 2-point lap belt
    - Vertical impact (60˚) with 2-point belt
    - Frontal impact with 3-point belt
    - Frontal impact with 4-point belt
  - Model guidelines
  - Sprague and Geers method is used for the objective rating of the simulation and test results
  - Validation criteria for kinematics, loads and accelerations are defined based on a subset of channels



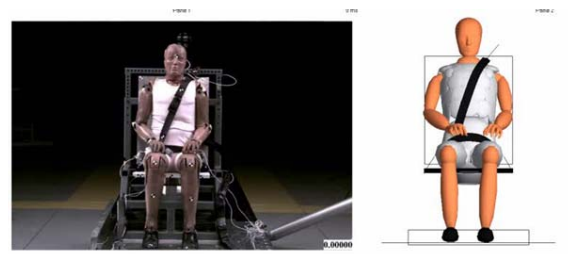
- Tests performed by NIAR and are available to document users

Dynamic dummy model validation

- Simulation results

- All 4 test scenarios have been modeled
- Followed the FAA modeling guidelines
- Modeled the HII as well as the HIII dummy
- Detailed report with all component and full dummy validation (Q-report) is available for HII and HIII dummy models

Frontal impact with 2-point lap belt



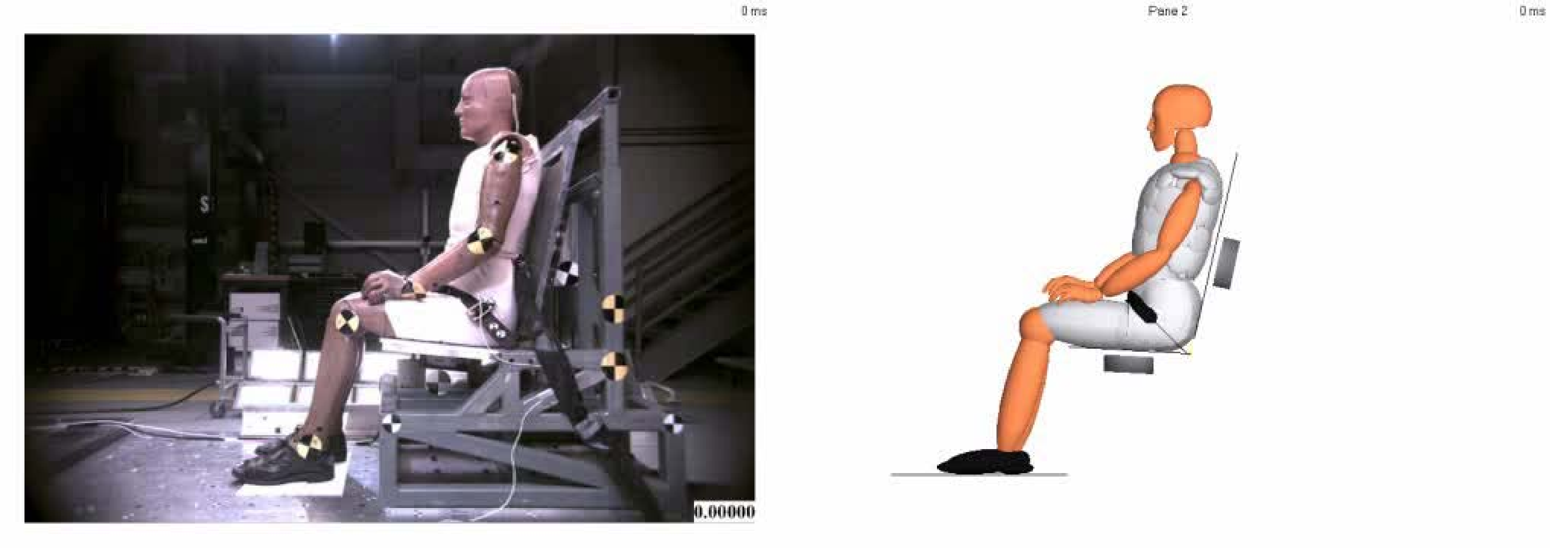
Frontal impact with 3-point lap belt

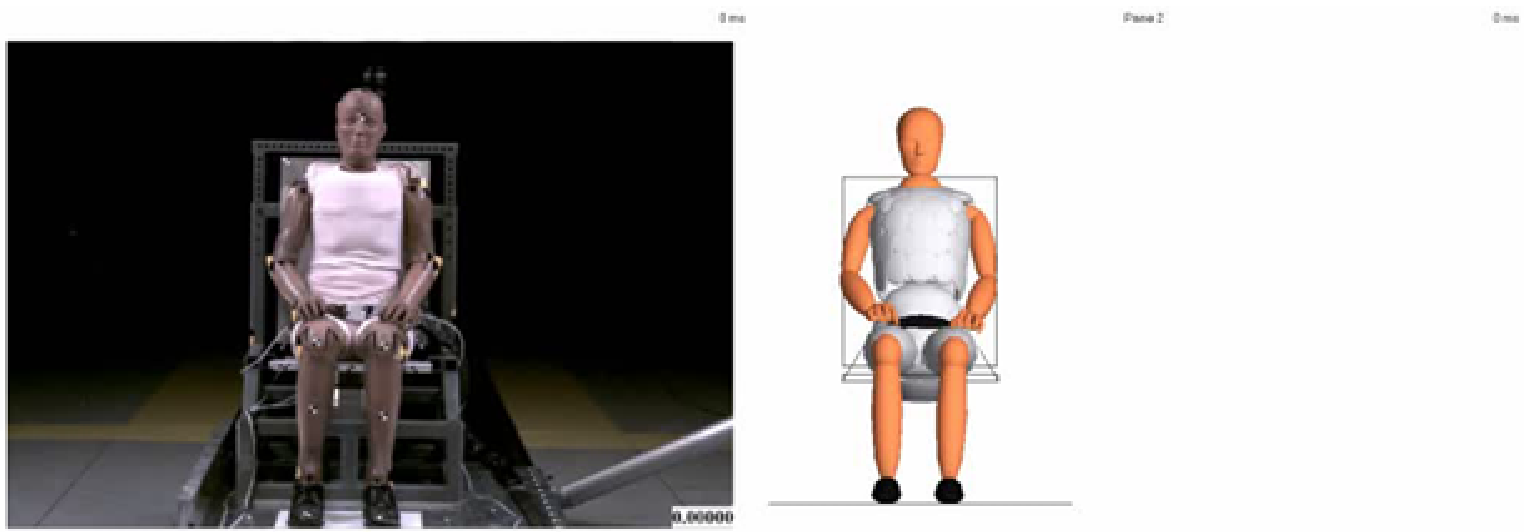
Vertical impact (60 °) with 2-point belt

Frontal impact with 4-point lap belt

Dynamic dummy model validation

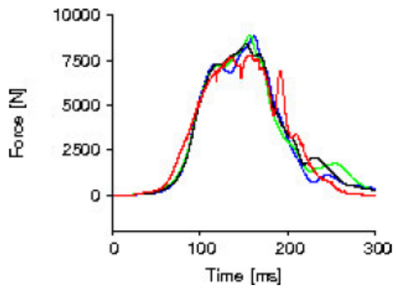
- Frontal impact with 2 point belt



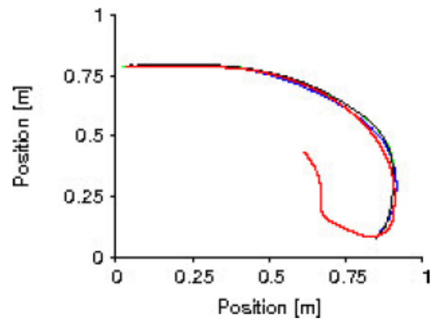


Dynamic dummy model validation

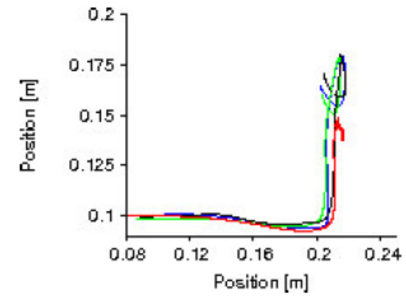
- Frontal impact with 2 point belt



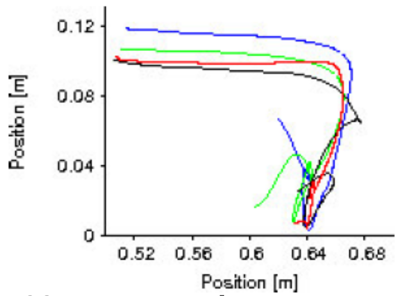
Lap belt load



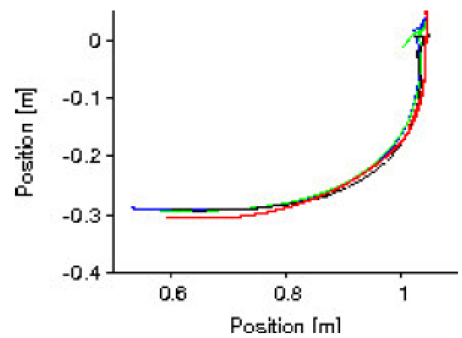
Head path



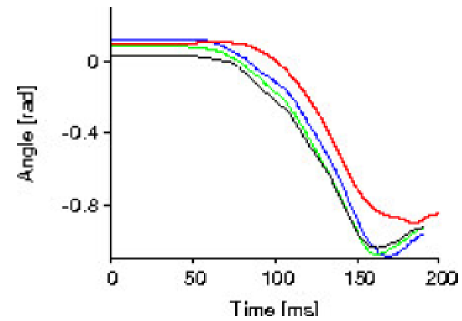
H-point path



Knee path



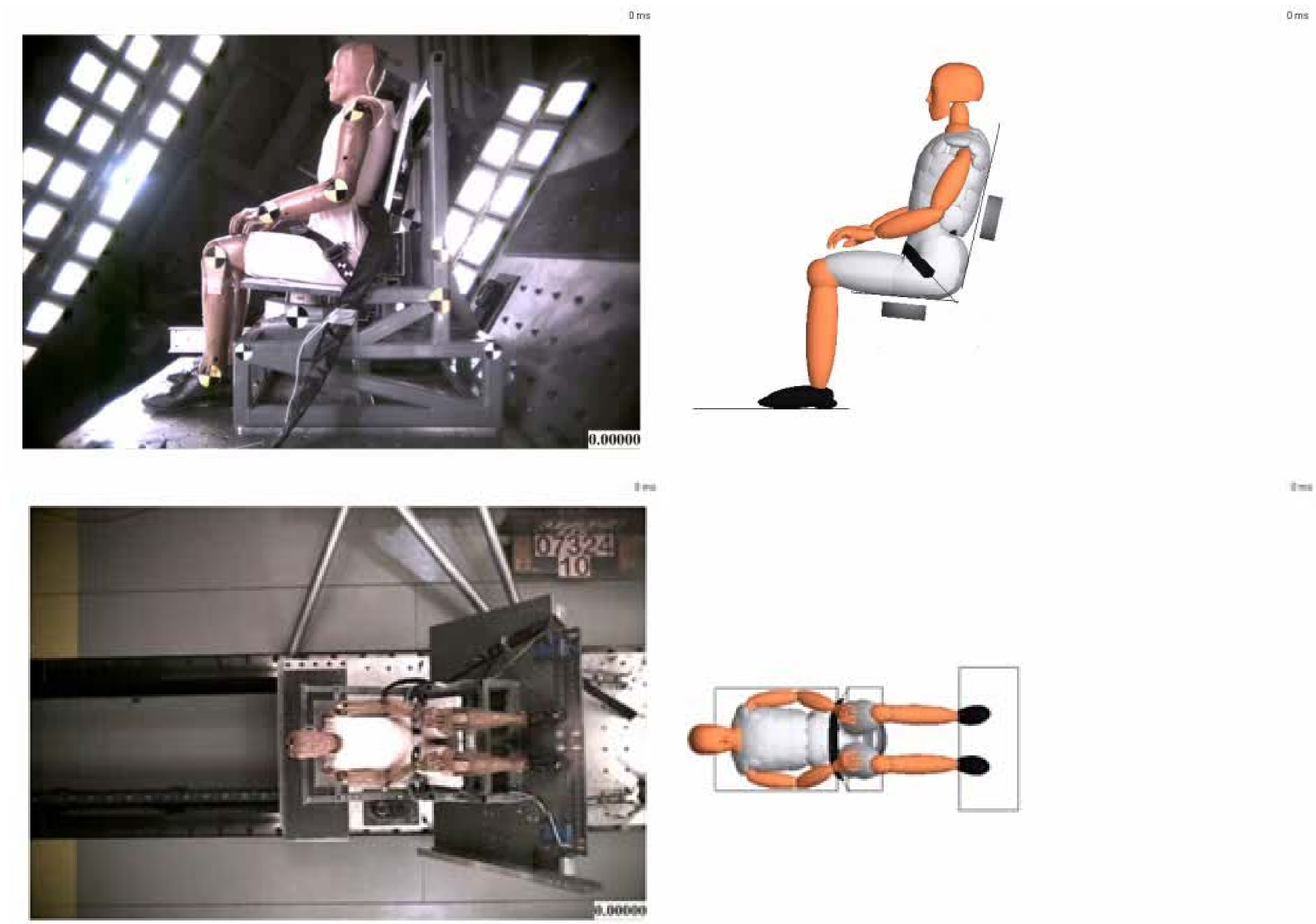
ankle path



Pelvis angle

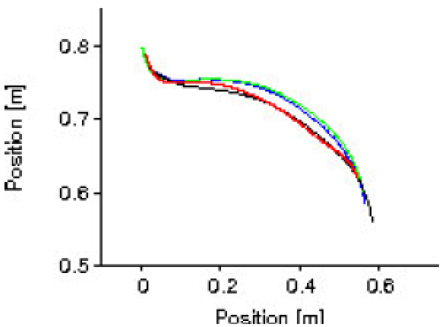
Dynamic dummy model validation

- Vertical impact (60 °) with 2-point belt

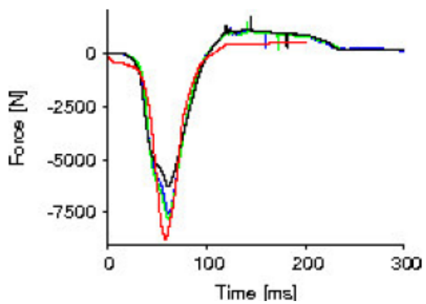


Dynamic dummy model validation

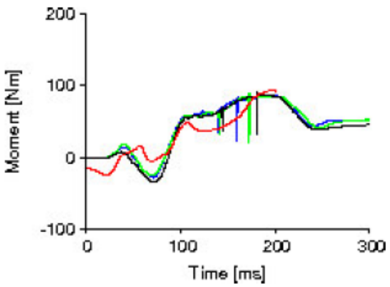
- Vertical impact (60 °) with 2-point belt



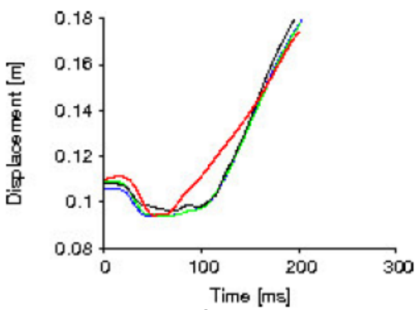
Head path



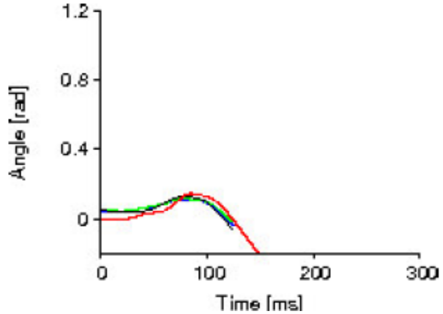
Lumbar compression load



Lumbar bending moment



H-point Z-pos



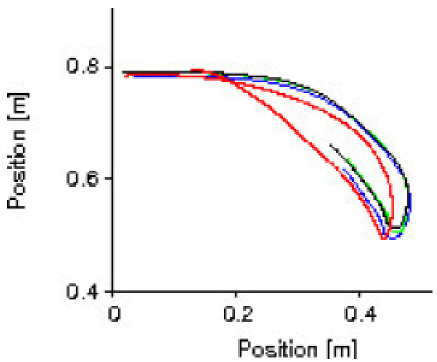
Pelvis angle

Dynamic dummy model validation

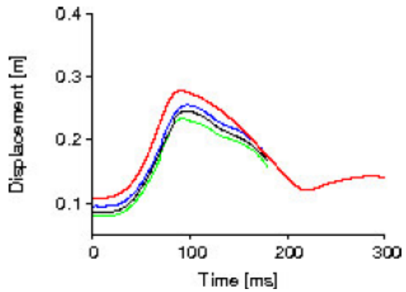
- Frontal impact with 3 point belt

Dynamic dummy model validation

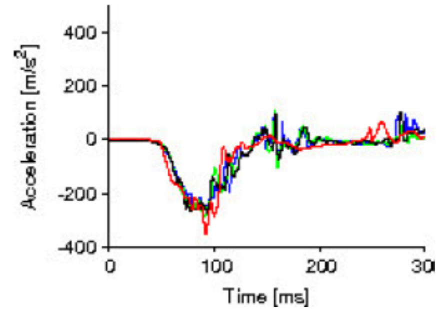
- Frontal impact with 3 point belt



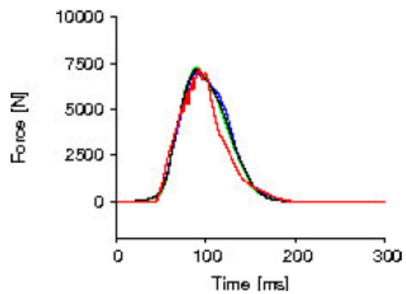
Head path



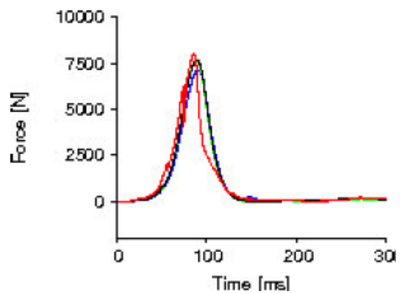
H-point X dis



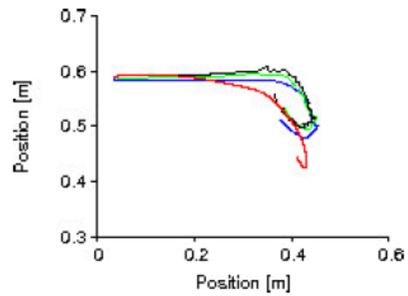
Chest X acc



Shoulder belt load

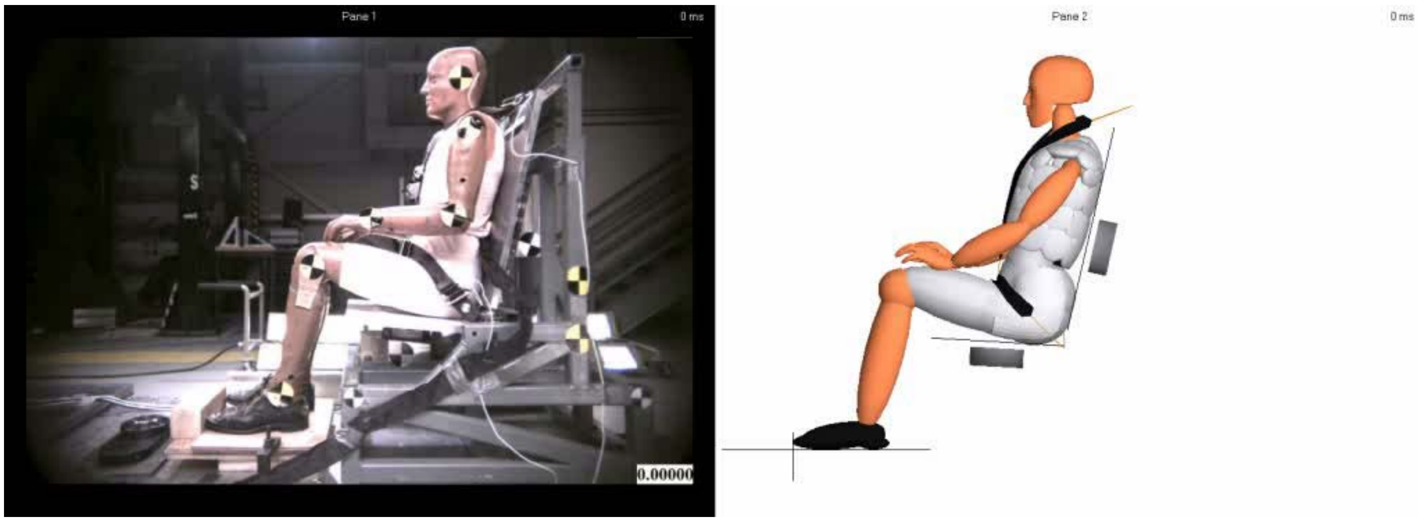


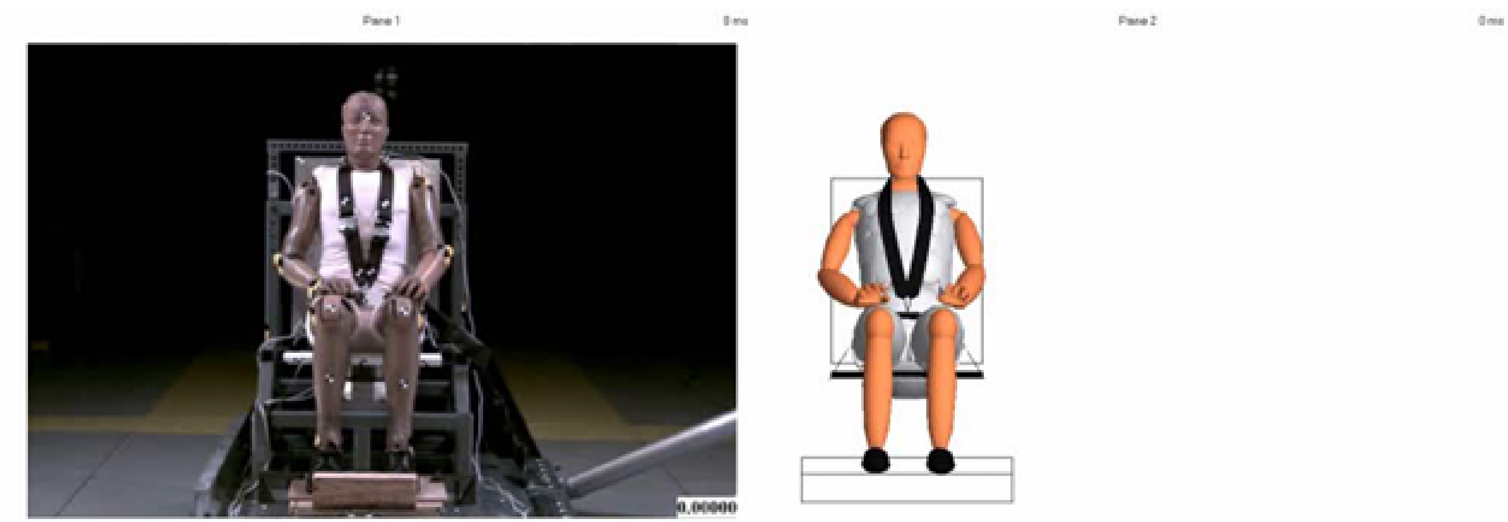
Lap belt load



Right Shoulder path

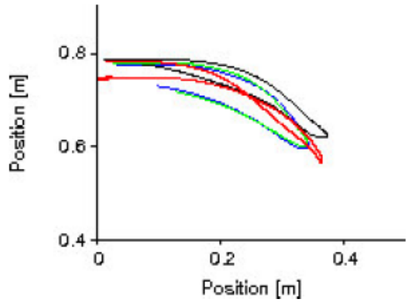
Dynamic dummy model validation
- Frontal impact with 4 point belt



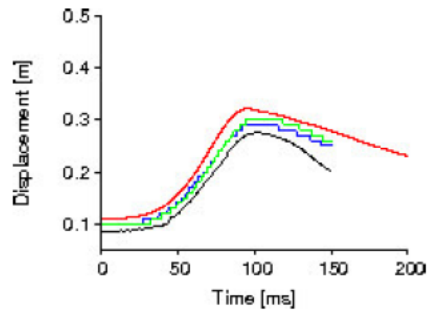


Dynamic dummy model validation

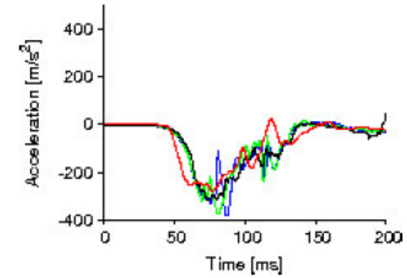
- Frontal impact with 4 point belt



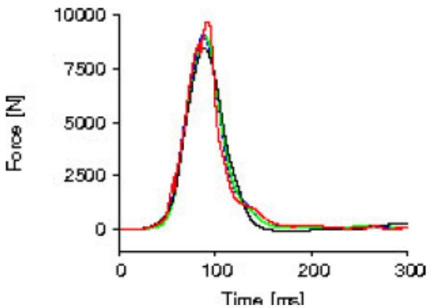
Head path



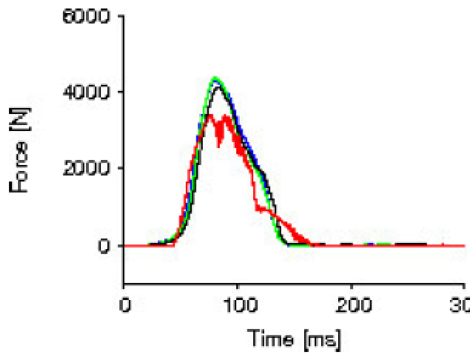
H-point X dis



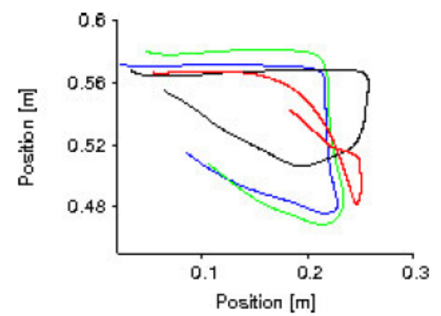
Chest X acc



Lap belt load



Shoulder belt load



Right Shoulder path

Dynamic dummy model validation

tass beyond safe

Validation criteria for kinematics, loads and accelerations are defined based on a subset of channels by the seat committee

	Frontal impact 2-Point belt				Vertical impact 2-Point belt				Frontal impact 3-Point belt				Frontal impact 4-Point belt			
	regulation		sim		regulation		sim		regulation		sim		regulation		sim	
	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape
Chest Ax									10	10			20	15		
Lumbar Fz					30	15										
Lumbar My						25										
Rt Lap Belt load	10	10							10	10			10	10		
Lf Lap Belt load	10	10							10	10			10	10		
Rt Shoulder Belt load													15	15		
Lf Shoulder Belt load									10	10			15	15		
Head CG X position (inch)	0.5	10				10			1.75	10			1.5	10		
Head CG Z position (inch)		10				35				30			1	20		
H-Point X position (inch)	0.25	10							1.25	20			1.25	25		
H-Point Z position (inch)	0.2	10			0.2	25										
Knee X position (inch)	0.25	10											1.25	25		
Knee Z position (inch)		10												60		
Ankle X position (inch)		15														
Ankle Z position (inch)		20														
Right Shoulder X position (inch)									2	15			1.25	20		
Right Shoulder Z position (inch)										40			1	100		
Left Shoulder X position (inch)									0.5	10						
Left Shoulder Z position (inch)										75						
Head Angle (degrees)		10											8	10		
Pelvis Angle (degrees)	7	10			3	40							15	50		

Dynamic dummy model validation

Validation criteria for kinematics, loads and accelerations are defined based on a subset of channels by the seat committee

	Frontal impact 2-Point belt				Vertical impact 2-Point belt				Frontal impact 3-Point belt				Frontal impact 4-Point belt			
	regulation		sim		regulation		sim		regulation		sim		regulation		sim	
	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape
Chest Ax									10	10	23	9	20	15	10	7
Lumbar Fz					30	15	16	14								
Lumbar My						25		133								
Rt Lap Belt load	10	10	13	18					10	10	9.6	8	10	10	30	29
Lf Lap Belt load	10	10	13	17					10	10	20	17	10	10	25	23
Rt Shoulder Belt load													15	15	17	19
Lf Shoulder Belt load									10	10	11	15	15	15	28	32
Head CG X position (inch)	0.5	10	2	1.6		10		7.6	1.75	10	3.4	23	1.5	10	0.7	18
Head CG Z position (inch)		10		5.4		35		1		30		2.8	1	20	4.8	6.7
H-Point X position (inch)	0.25	10	0.15	1					1.25	20	0.8	8.5	1.25	25	3.4	25
H-Point Z position (inch)	0.2	10	2	15	0.2	25	0.2	2.3								
Knee X position (inch)	0.25	10	1.1	2									1.25	25	2.9	13
Knee Z position (inch)		10		12										60		10
Ankle X position (inch)		15		0.4												
Ankle Z position (inch)		20		3												
Right Shoulder X position (inch)									2	15	2.4	14	1.25	20	0.9	9.8
Right Shoulder Z position (inch)										40		5	1	100	3.1	8.2
Left Shoulder X position (inch)									0.5	10	1.2	13				
Left Shoulder Z position (inch)										75		2.8				
Head Angle (degrees)		10		8									8	10	0.85	11
Pelvis Angle (degrees)	7	10	11.4	29	3	40	20	256					15	50	22	51

Dynamic dummy model validation

tass beyond safe

Validation criteria for kinematics, loads and accelerations are defined based on a subset of channels by the seat committee

	Frontal impact 2-Point belt				Vertical impact 2-Point belt				Frontal impact 3-Point belt				Frontal impact 4-Point belt			
	regulation		sim		regulation		sim		regulation		sim		regulation		sim	
	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape	Peak	Shape
Chest Ax									10	10	30	12	20	15	12	14
Lumbar Fz					30	15	39	17								
Lumbar My						25		31								
Rt Lap Belt load	10	10	1.4	10					10	10	0.7	8.7	10	10	16	7
Lf Lap Belt load	10	10	7.4	4.5					10	10	4.2	13	10	10	15	6
Rt Shoulder Belt load													15	15	18	14
Lf Shoulder Belt load									10	10	0.17	10	15	15	22	33
Head CG X position (inch)	0.5	10	0.5	3.5		10		8.5	1.75	10	1	2.7	1.5	10	0.5	1.4
Head CG Z position (inch)		10		2.2		35		1.9		30		1.5	1	20	1.9	3
H-Point X position (inch)	0.25	10	0.17	4.5					1.25	20	0.3	3.7	1.25	25	0.9	11
H-Point Z position (inch)	0.2	10	1.2	9	0.2	25	0.16	3.8								
Knee X position (inch)	0.25	10	0.6	0.4									1.25	25	0.7	3
Knee Z position (inch)		10		3.8										60		25
Ankle X position (inch)		15		1												
Ankle Z position (inch)		20		2												
Right Shoulder X position (inch)									2	15	0.3	2.3	1.25	20	1.1	7.2
Right Shoulder Z position (inch)										40		6	1	100	1	3
Left Shoulder X position (inch)									0.5	10	1.5	18				
Left Shoulder Z position (inch)										75		2.5				
Head Angle (degrees)		10		4									8	10	4.4	1
Pelvis Angle (degrees)	7	10	3.9	14	3	40	4	55					15	50	10	27

Where/how does it fit in your process?

Concept | Design | Virtual-DV | PV | Certification → **SOP**

Concept MB modeling

madymo Preparation
- Model Update
- Model Validation

Design Space Definition
- Max. webbing
- Seat Geometry
- Etc

DoE Optimization
- Matrix
- Load conditions

Efficient Optimization loop across numerous load cases and conditions

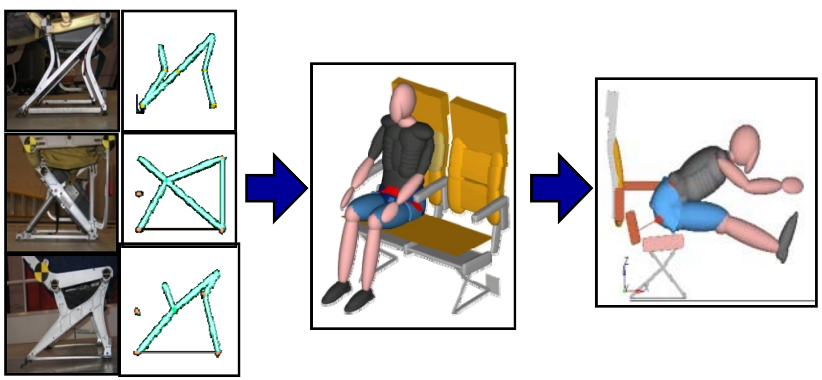
Robustness Analysis
- System Optimum
- DoE Results
- Seat system specifications

System Recommendation
- Belt system specs (Belt webbing, LL, Pretensioning,...)
- Seat Geometry
- Etc

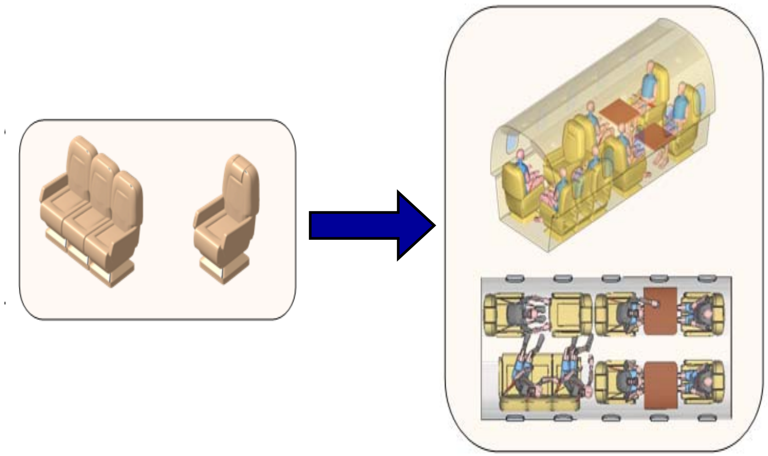
System Confirmation
- Certification tests
- Physical or virtual

Where/how does it fit in your process?

▪Example 1: Conceptual phase for seat structure



Example 2: Design layout & safety studies



Where/how does it fit in your process?

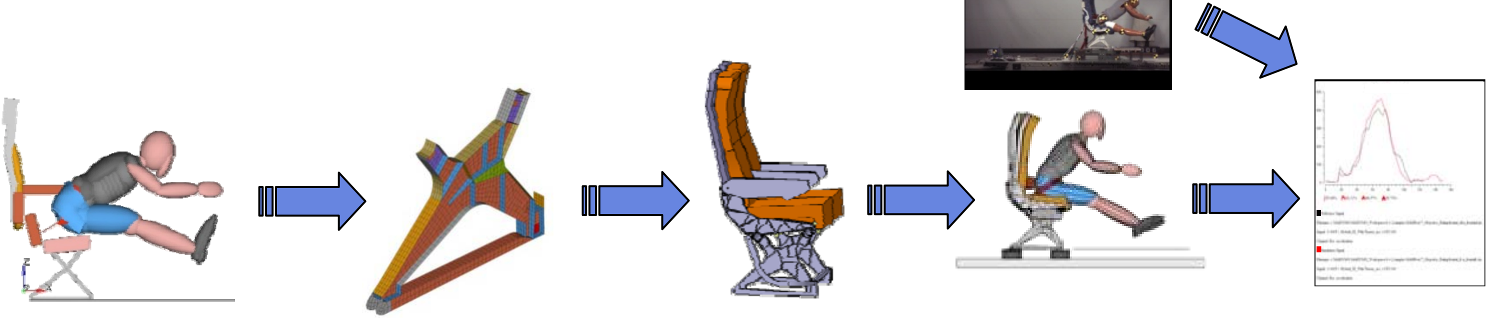
tass beyond safe

Concept | Design | Virtual-DV | PV | Certification → **SOP**

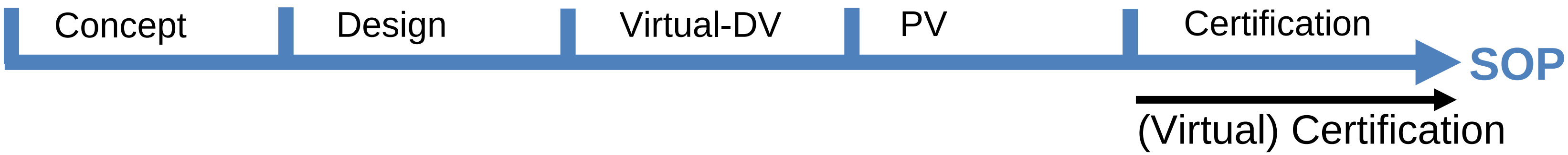
Component MB & FE modeling

Component & sled testing

- Extract Structural Loads from MB Model
  - Design CAD Geometry Components
  - Component level FE Analysis
- Coupling MB dummy with FE seat structure
  - ATD & Seat Structural Analysis
  - Structural design improvements and weight optimization
- Correlation against first series of tests



Where/how does it fit in your process?



- FAR XX.562 allows analysis instead of testing
  - Provided baseline tests has been performed
  - Applicant must prove correlation of simulation with baseline test
  - Documentation must be provided

- SAE Seat committee developed AC 20-146: guidelines for virtual testing
  - Requirements for models
  - Dummy model comparison study

- AC 20-146 applicable for
  - Aircraft manufacturer not using a TSO approved seat
  - Seat manufacturer
  - Aircraft manufacturer installing a TSO approved seat

Where/how does it fit in your process?

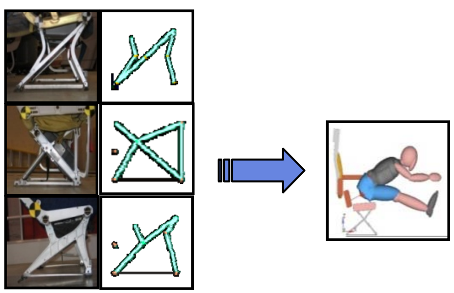
Concept | Design | Virtual-DV | PV | Certification → **SOP**

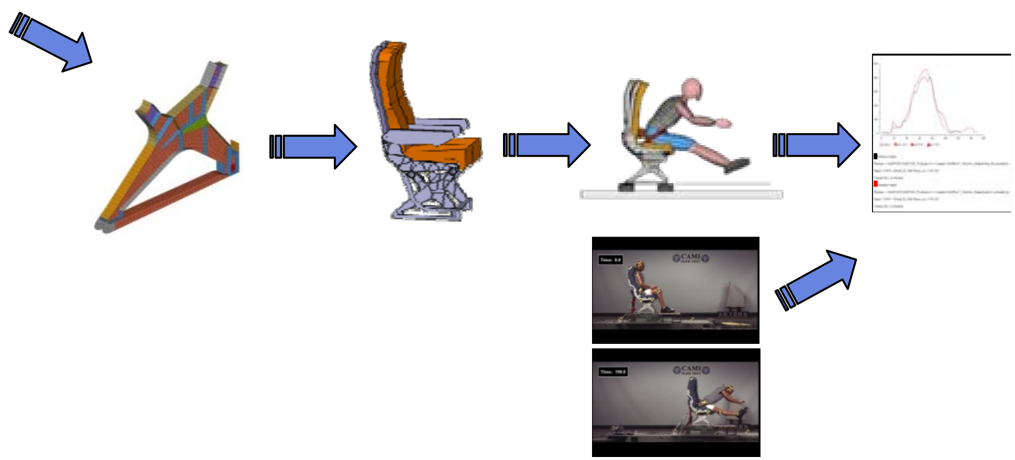
Concept MB modeling

Component MB & FE modeling

Component & sled testing

(Virtual) Certification

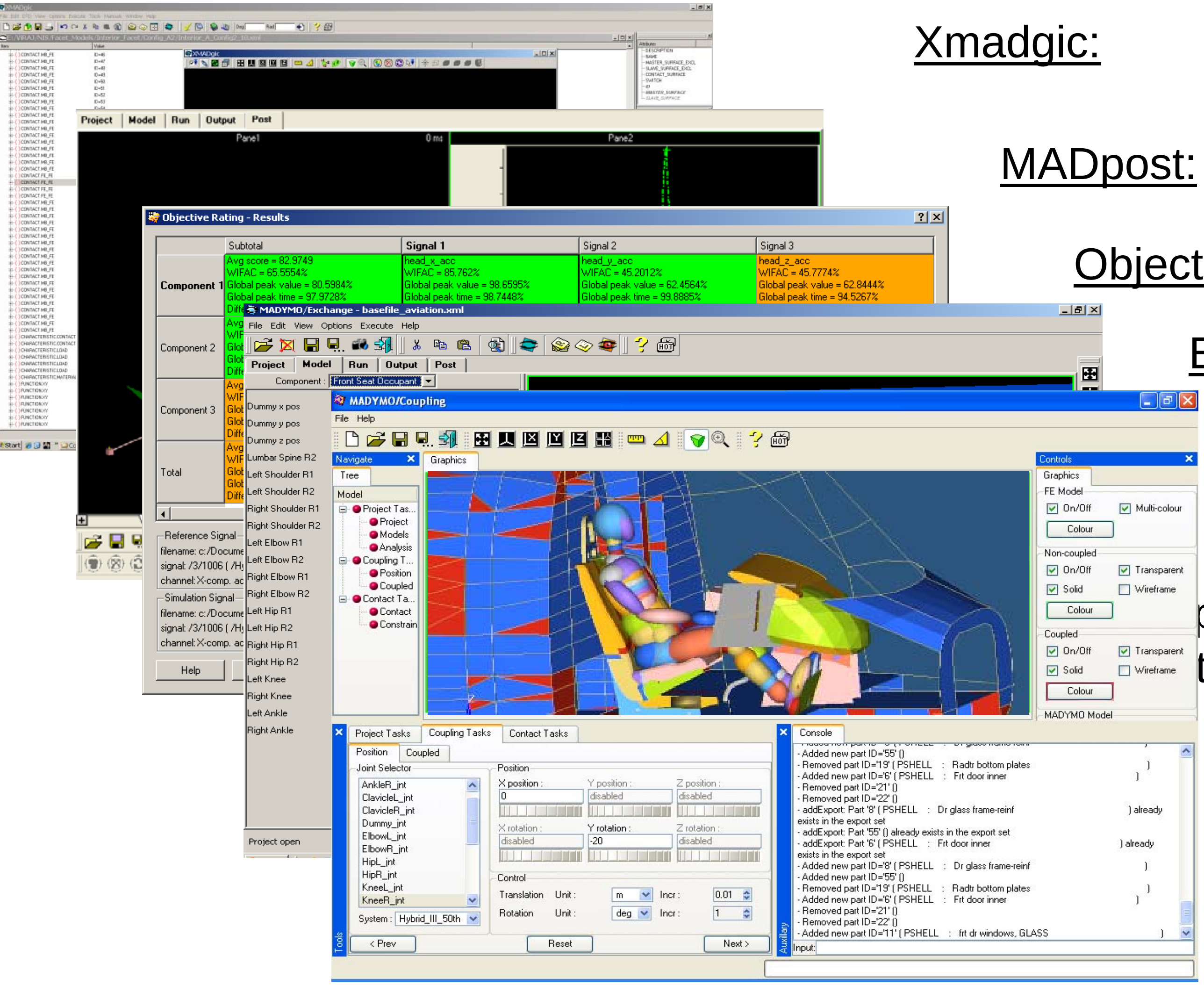




- **From concept to production**

Where/how does it fit in your process?

- MADYMO toolset



Xmadgic:

MADpost:

Objective rating:

Exchange:

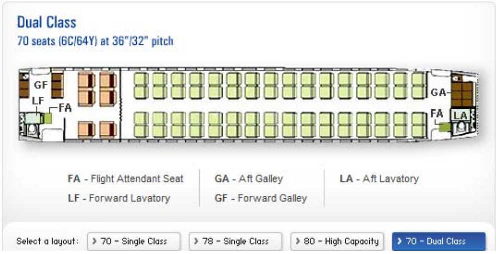
CouplingAssistant:

Preprocessing tool for the
pling of MADYMO with
ther FE code.

Case Study – Aviation: Embraer

Description:

- Seat Layout Certification: each new seat layout requires testing to prove that no head injuries occur.



Solution:

- By using MADYMO Embraer can experiment with various layouts to maximize passenger capacity without the need for costly testing.
- Embraer uses MADYMO in support to Certification and reduced testing.

Financial Benefits:

- Testing HIC for each new seat layout may cost $300,000+, which can often be completely eliminated using Madymo.

Case Study – Aviation: Embraer

Embraer witness:

> ”By using Madymo Embraer not only saves time and costs in developing and certifying new seat layouts for our Regional Jets but also saves time and costs while reducing risks on seat installation for new Programs.”

Sergio Soares

Product Development Team Leader,

Structures/Interiors

Conclusion

- MADYMO is a unique solver that combines a Multi-body and Finite Element approach. This results in a fast, robust design optimization that allows for development time and cost reduction.
- We offer a complete suit of dummy models that are accepted by the FAA for use in virtual certification.
- We provide a complete solution including all required software tools, engineering (methodology) support and critical partnerships.