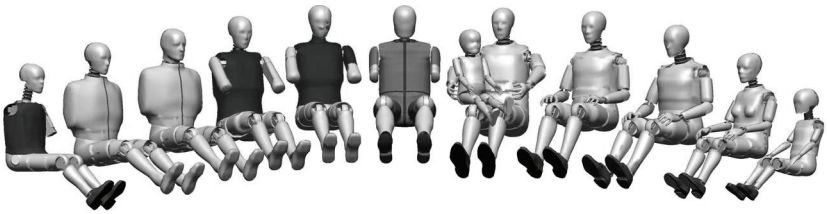
A Full Suite of Hybrid III 50th Dummy Models with the Latest Upgrades

– from Runtime Savor, High Quality Performer, to the More Detailed Model (E)

Z. Zhou, M. Li, J. Rasico, F. Zhu, R. Kant (FTSS, Inc.)



A full suite of Hybrid III 50th dummy models with the latest upgrades

from runtime savor, high quality performer, to the more detailed model

Zaifei Zhou, Michael Li, Jim Rasico, Fuchun Zhu, Robert Kant

First Technology Safety Systems, Inc.

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Contents

- Current model status
- Future development direction driven by customers
- Modular model
- Detailed model

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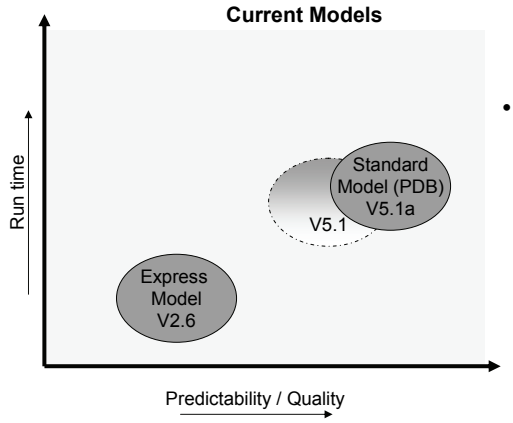
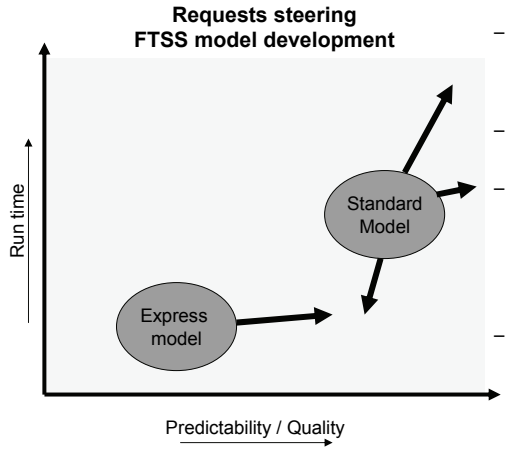
FTSS H3-50th Dummy Models



- The PDB HIII 50th model has become the standard model per October 1, 2007
  - Significantly higher quality and validation level

For more information on the PDB model see also *"Enhancements in Dummy Model Development", LS-DYNA User's Conference Gothenburg 2007*

Customer Feedback



- ***"Models should be more detailed"***

  …A group of OEM's (outside Germany)

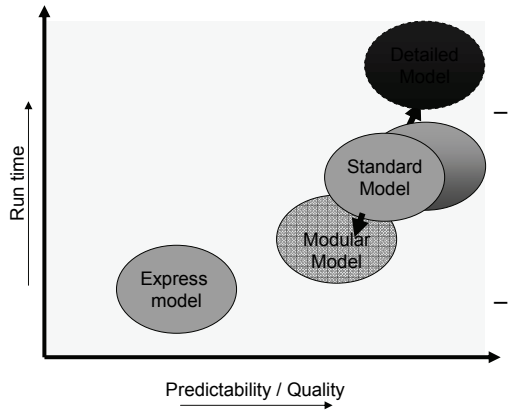
- ***"Standard (PDB) model is "almost ready" and runtime is OK even for restraint development"***
- ***"Further enhancements of the standard model should still be given highest priority"***

  … German OEM's and German restraint suppliers

- ***"We need a fast(er) model but with acceptable quality to optimize restraints"***

  …restraint suppliers (outside Germany)

Three Development Directions



- ***Research and develop detailed models***
  - Time step < 0.8 µs
- ***Continue the standard models***
  - Maintain "1 µs" & order of element count
  - Lessons learned from detailed model are steering the standard model improvement.
  - Refine the mesh when proven to be beneficial
- ***Explore "modular models"***
  - Targeting model speed-up and acceptable quality

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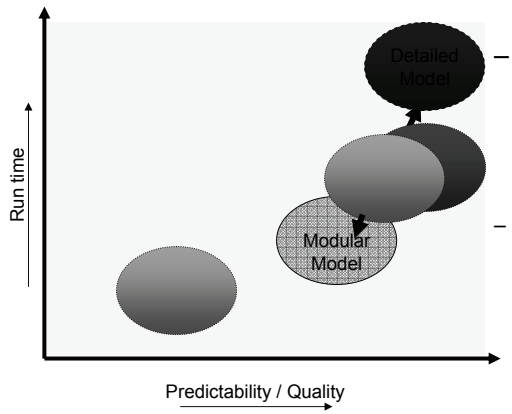
Presentation Focus



- *This presentation includes project information of the detailed and the modular models.*
- *More info of the standard models can be found in the proceedings of the LS-DYNA User's Conference Gothenburg 2007 and a status update is available upon request.*

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Modular
H3-50th Dummy Model

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Modular FEA Model Concept

- FTSS initiated a pilot project to evaluate the benefits of a modular model
  - Combination of pure rigid and/or deformable modules;
  - A user defined selection.
- Development steps:
  - A deformable full dummy model was split into individual component modules according to joint/positioning functions;
  - CoG location and mass inertia properties were calculated for each module;
  - The counterpart rigid module model was created with rigid shells and calculated mass inertia properties;
  - Two full sets of exchangeable modules were created, sharing the same joint and connection definitions;
- Provides users with the ultimate flexibility in choosing a dummy model assembly and balancing model accuracy and run time.
  - Rigid modules for non-contact, not in the loading path components;
  - Deformable modules for injury induced areas.

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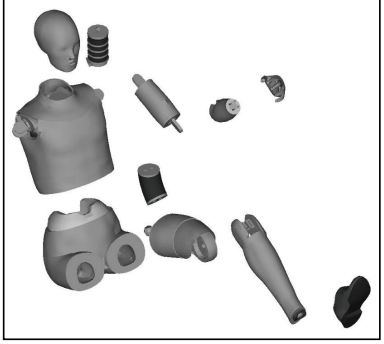
Modular Model

Specification

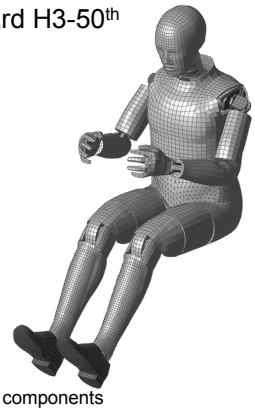
- Modular functionality (*INCLUDE files)
  - Users choose either deformable or rigid module
  - Maintains existing geometry
  - Positioning file and data extraction capabilities preserved
- Optional:
  - Efficient Spring+Rigid Body neck and lumbar spine models with realistic performance
- Minimum time step controlled by deformable components

Modular Options



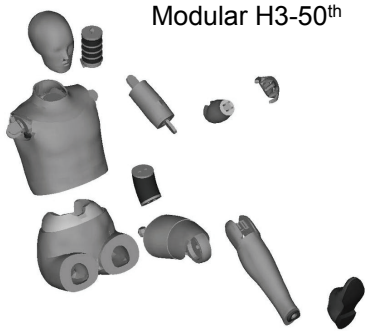
Standard vs. Modular H3-50th

Standard H3-50th



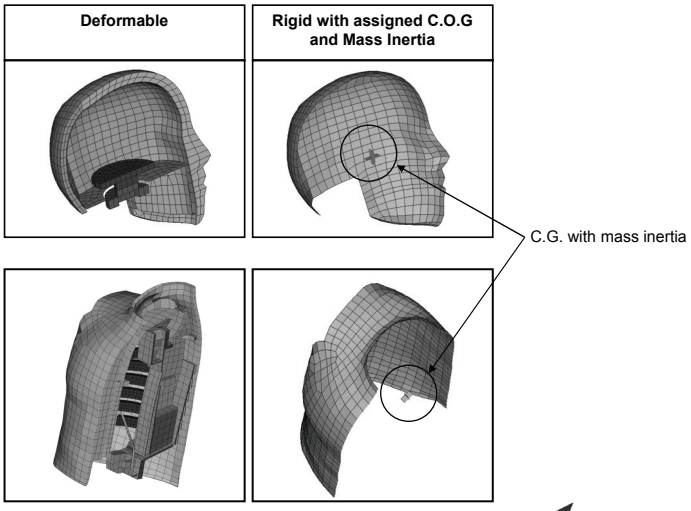
- Deformable components
- Positioning function
- Minimum time step: 1 µs
- Deformable element count: 50K

Modular H3-50th



- Rigid and/or deformable components
- Positioning function
- Minimum time step: 1 µs or higher
- Deformable element count: varies

Module Examples



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Modular Model: Master File Format

- Main file:
  - *KEYWORDS
  - *CONTROL CARDS
  - *DATABASE CARDS
  - *INCLUDE
    - Include individual module file one by one
  - *CONTACT CARDS
  - *DUMMY POSITION TREE

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Modular H3-50th Model

Conclusion

- The modular dummy model can be easily customized by users by selecting the desired combination of rigid and deformable modules;
- The modular model can be highly run-time efficient compared to a fully deformable dummy model.

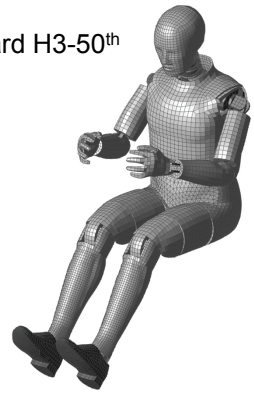
Further work

- Customer beta testing to explore the benefits.
  - Can the model reduce the run-time significantly and still keep the acceptable predictability?

Detailed HIII 50th Model

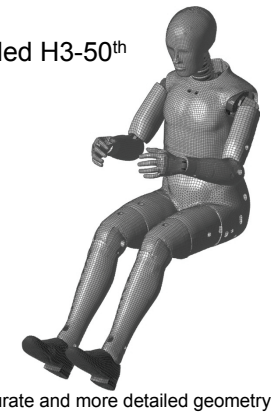
Standard vs. Detailed H3-50th

Standard H3-50th



- Detailed geometry
- Effective material model parameters
- Minimum time step: 1 µs
- Element count: < 100K

Detailed H3-50th

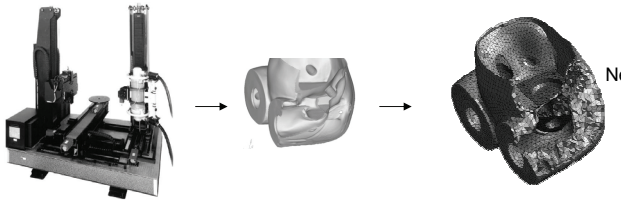


- Most accurate and more detailed geometry
- Vinyl and foam separated, allowing more accurate physical material model parameters to be applied
- Minimum time step: 0.8 µs
- Element count: < 300K

Detailed Geometry

Actual geometry is captured by X-Ray scan and laser scan

- Capture assembled dummy geometry
- Improved accuracy through exact material distribution



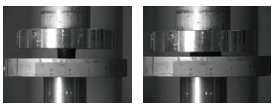
New model

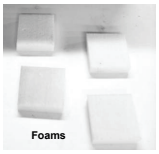
Whole dummy scan data

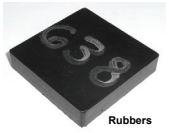
New Material Tests

Multiple strain rate tests for key materials for better material parameters

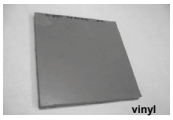
Material	Test Type
Vinyl 2 Grades	Compression (4 strain rates) Volumetric Compression Stress Relaxation
Butyl Rubber 3 Grades	Compression (4 strain rates) Tension Stress Relaxation Volumetric Compression
Foam 3 Grades	Compression (4 strain rates)
Ensolite Foam	Compression (4 strain rates)
Rib Damping Material	Compression (4 strain rates) Stress Relaxation Poison's Ratio

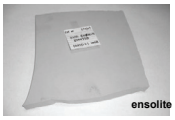






Total: 148 new tests





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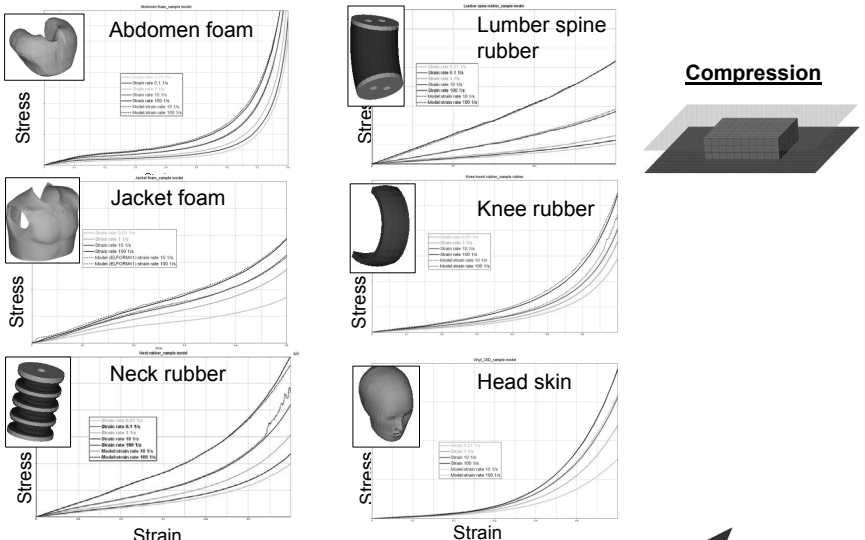
New Validation of Material Models



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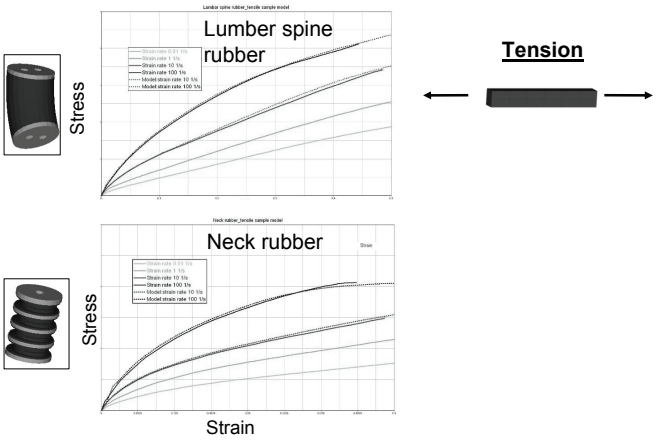
New Validation of Material Models



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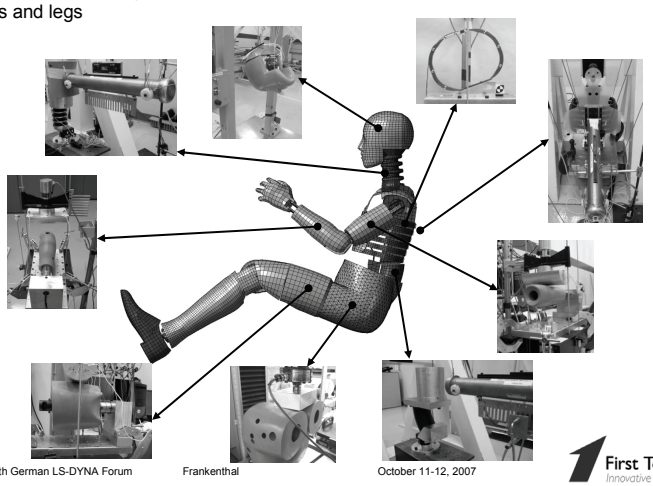
New Component Tests

- New component tests were performed in addition to the extensive PDB component test series
  - More realistic loading conditions for the head, neck, thorax, lumbar spine, rib, pelvis, arms and legs



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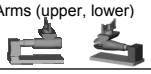
Component Validation Matrix

Component	Test Type	#Tests	Comments
Head 	Drop test - 3 speeds	> 100	Partly new tests
	PDB Prescribed motion impact to forehead and cheek	3	
Neck 	Calibration; flexion and extension 2 speeds	> 100	
	Head replacement direct impact: flexion, extension; straight and oblique	> 40	**New** tests
Arms (upper, lower) 	Multiple speeds dynamic drop - Need bone loadcell, new fixtures	48	**New** tests
Upper leg 	Drop test - loadcell	36	**New** tests
Lower leg 	Euro-foot impact tests on heel and toe	> 100	
	PDB Multiple impacts - Instrumented tibia		
Knee 	Knee slider	> 100	
	Knee impact	> 100	

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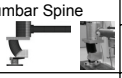
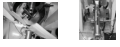
Component Validation Matrix

Component	Test Type	#Tests	Comments
Lumbar Spine 	Pendulum - flexion / Extension	6	
	Straight and Oblique torsion loading, multiple speeds - Seatbelt loading/twisting mode	56	**New** tests
Abdomen insert 	Drop test: 2 speeds	2	
Pelvis 	Range of motion	>100	
	Quasi-static Compression tests	12	**New** tests
Thorax 	Orthogonal drop, multiple speeds	14	**New** tests
Single rib	Oblique drop, multiple speeds	11	**New** tests
	No jacket - round and square drop heads 3 speeds	14	
Thorax 6-rib sub-assembly  	PDB Chest impacts – different impactor shapes, locations and pulses	15	
	Multiple speeds, straight and oblique impact	22	**New** tests

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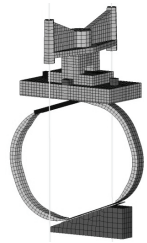
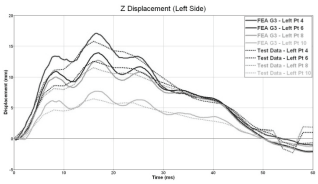
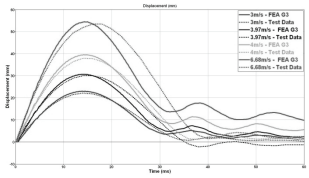
New Rib Validation

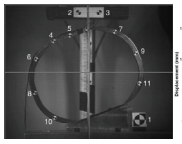
Flat

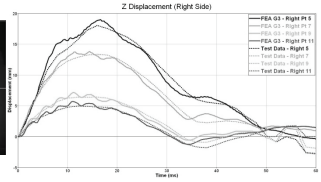
Oblique











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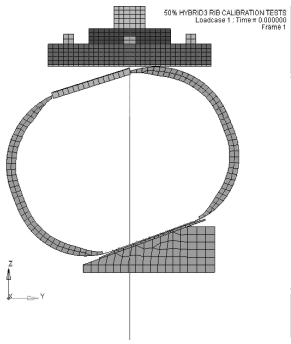
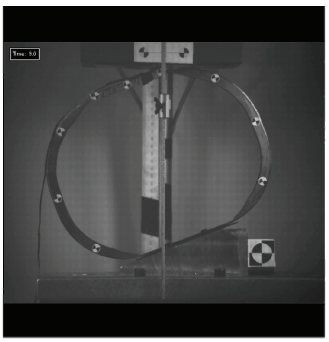
New Rib Validation





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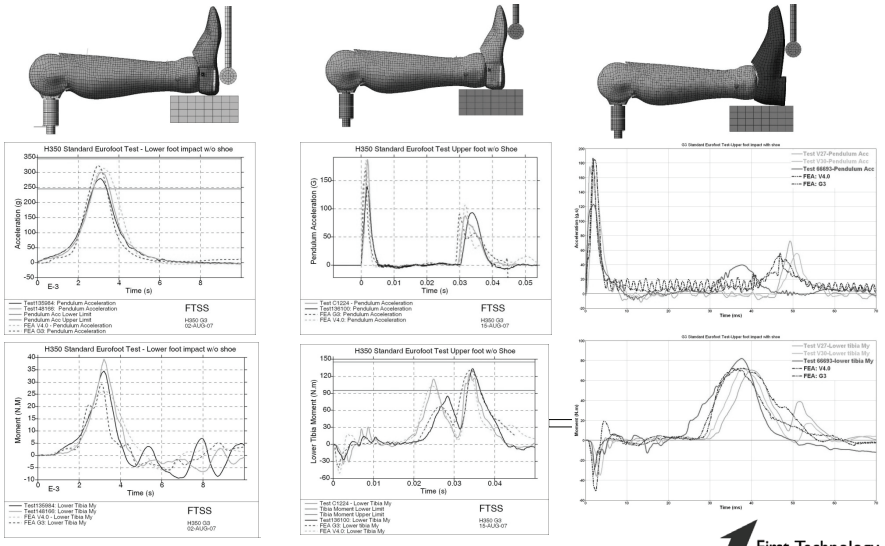
New Lower Leg Validation



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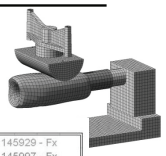
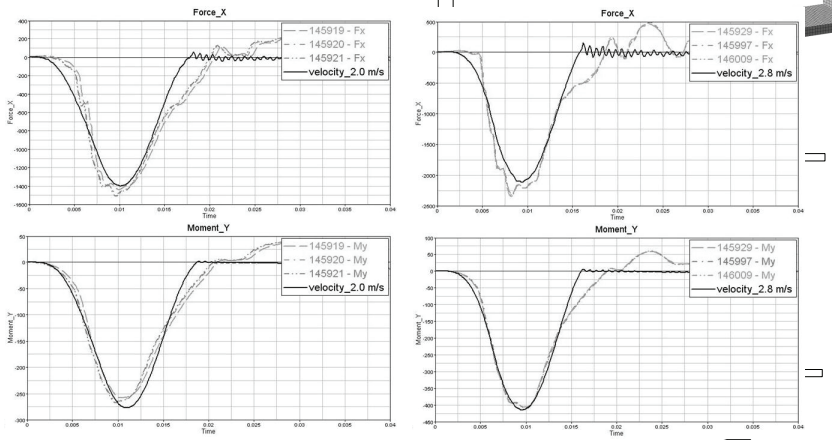
New Upper Arm Validation



2 m/s 2.8 m/s



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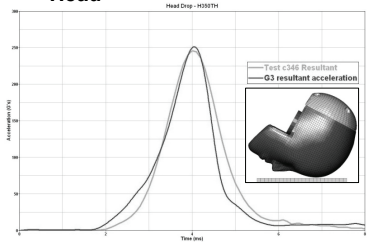
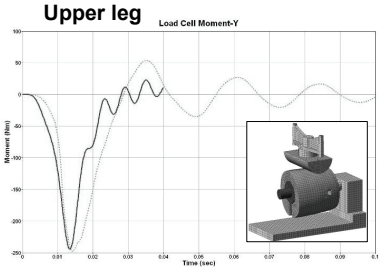
More New Component Validations

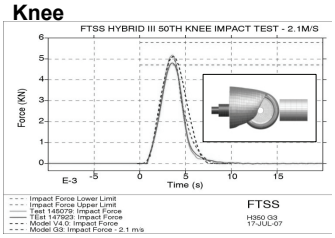
Head



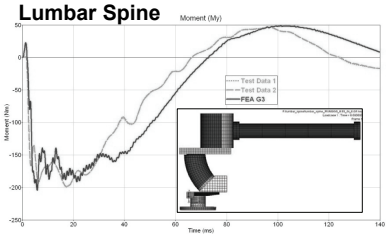
Upper leg



Knee



Lumbar Spine



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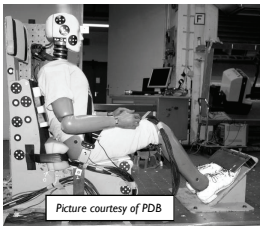
Full Dummy Validation

Test	Pulse (G-km/h)	Belt	AB	Seat	# ATD's	Total # tests including repeats
Sled test serie 1	15-48	X		Rigid		2
1996	15-48		X	Rigid		2
						4
Sled test serie 2						
Planned sept 2007	x-40		X	Rigid	10	12
FMVSS208/NCAP	x-40	X		Rigid	10	12
	x-56	X	X	Rigid	4	4
	x-56	X	X	Deform	2	2
						30
Sled test serie 3						
PDB	18-41	X		Rigid	3	9
Planned oct 2007						



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Detailed H3-50th Model

Conclusion

- The first correlation improvements on component level have been achieved through more detailed geometry meshing and material modeling;
- Further proof is needed to claim the benefit of detailed model at full dummy level.

Future work

- Complete validations on both component and full dummy level;
- Benchmark the standard and detailed model on full dummy level;
  - In-house and customer beta testing.
- Study dummy hardware reproducibility and explore development of a stochastic model to consider effects of physical dummy variations.
  - FTSS history database.

