NHTSA
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

NHTSA THOR Update

October 30, 2012

Dan Parent
Human Injury Research Division

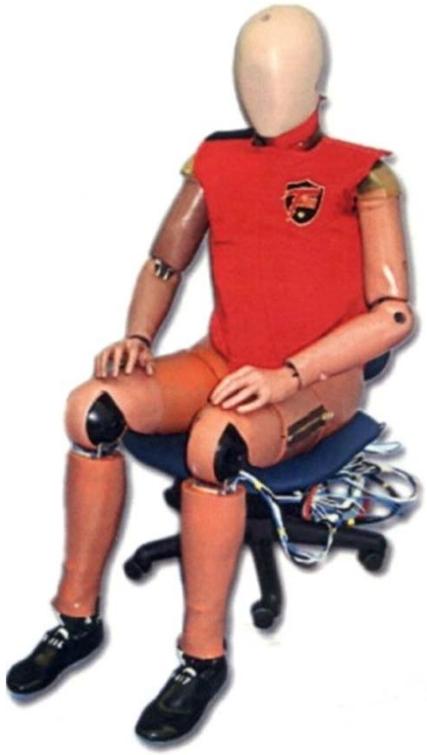
Test Device for Human Occupant Restraint

NHTSA

1992 — **TAD-50M**

2001 — **THOR Alpha**

2005 — **THOR-NT**



Mod Kit Motivation

NHTSA

2005-2009

THOR-NT Field Testing

- **SAE THOR Evaluation Task Group**
- **EEVC WG12**
- **JAMA**

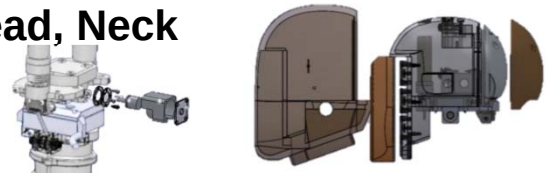
Short Term Enhancements

Long Term Enhancements

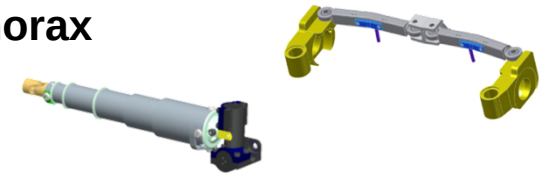
2009-2010

Mod Kit Development

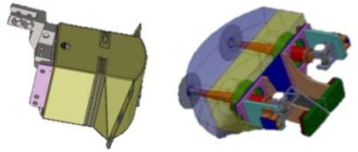
Head, Neck



Thorax



Abdomen



Knee, Thigh, Hip

Mod Kit Hardware History

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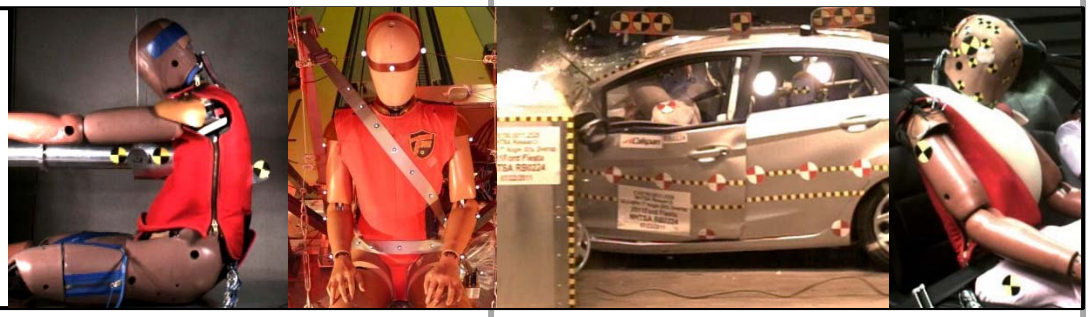
2010 | 2011 | 2012

THOR Mod Kit (n=1)

Evaluation



THOR Mod Kit (n=3) Consolidation and Fabrication

THOR Metric (n=1) Conversion and Fabrication

THOR Research Plan

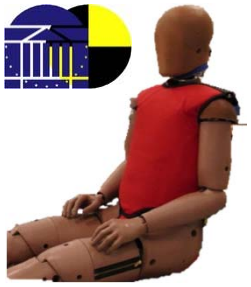
NHTSA

2012 2013

THOR Metric Evaluation

Inspection Cert Testing

Multi-Point Thoracic Injury Criteria Development



Repeatability & Reproducibility

THOR Mod Kit

Finalize Hardware	Finalize Hardware, Release Technical Data Package	Biofidelity Evaluation	Hybrid III Comparison
Finalize Procedures	Certification	Seating	Injury Criteria, IARVs

Parallel NHTSA Agency Needs	Oblique MDB Vehicle Testing	Advanced Adaptive Restraint Program	Rear Seat Advanced Restraints Program

THOR 50th NHTSA Agency Decision

Technical Data Package (TDP)

Mod Kit
Allow users to upgrade THOR-NT

Metric THOR

- Status: Drafts provided by Humanetics, currently under revision
- Drawing package to include:
  - Bill of Materials (BOM)
  - Drawing Index
  - Drawing Specifications
  - 2D Drawings (in DWG and PDF formats)
  - 3D Parametric Database (in Autodesk Inventor and generic formats)
- Associated updates to documentation provided by Humanetics, more updates necessary

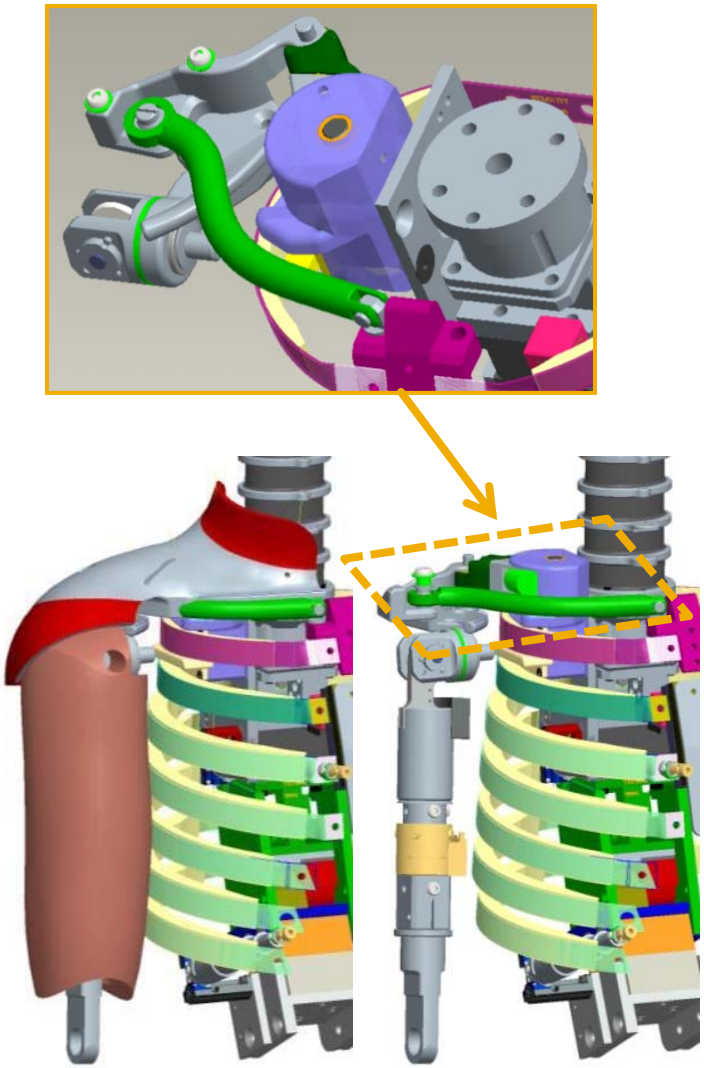
Finalize Hardware

- Include SD3 shoulder?
  - Evaluation (University of Virginia)
    - Decision matrix (following slides)
  - Input from THORAX TAG
    - Durability
    - Biofidelity evaluation
    - Guidance on SD3 certification

- Is thoracic response sufficiently biofidelic?

THORAX Project Coordination: SD3 Shoulder

- Updated “SD3” shoulder evaluated in NHTSA Mod Kit THOR
- U. Virginia Gold Standard
  - Condition 1: 40 km/h, standard belt
  - Condition 2: 30 km/h, load-limited belt
- Evaluate usability
  - More joints → more complexity
- Evaluate durability
  - Good compared to SD1, SD2
  - Comparable to standard THOR shoulder



Finalize Hardware Release Technical Data Package

NHTSA

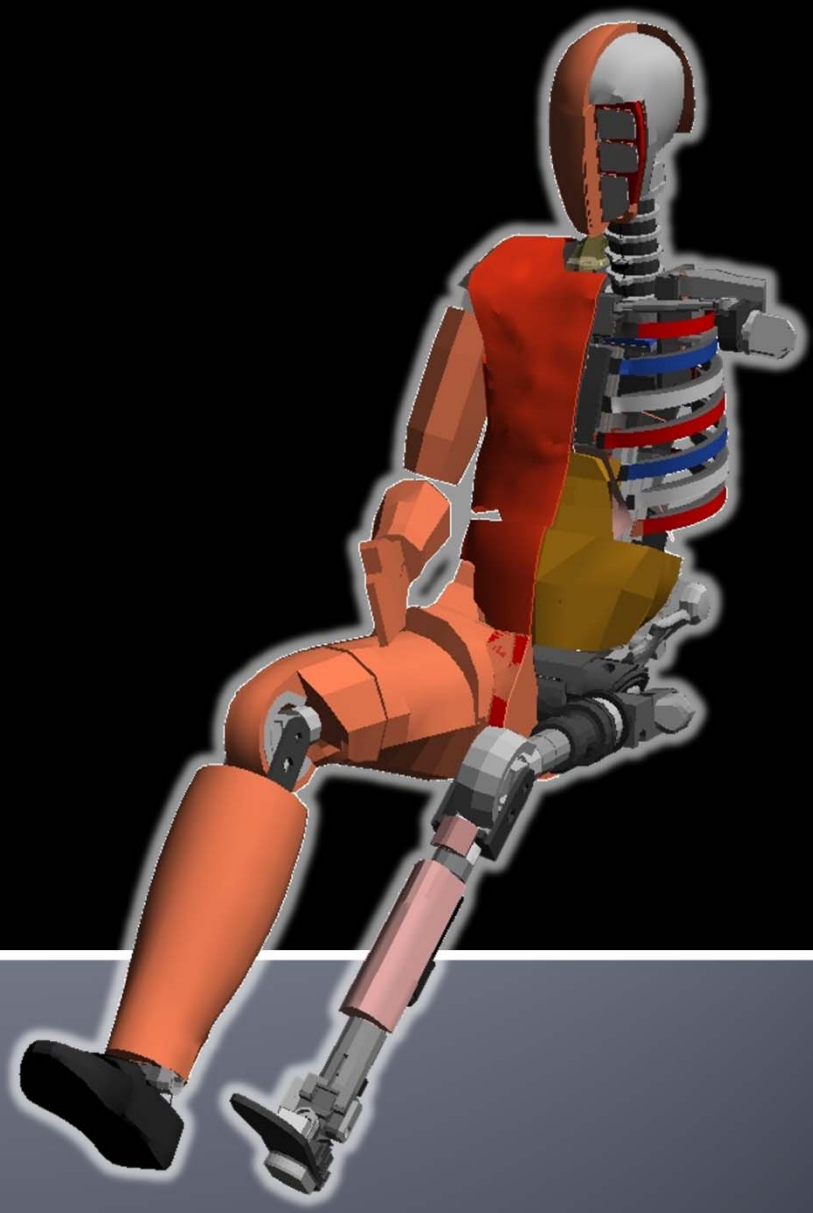
- Include SD3 shoulder?
  - Abstract submitted to 2013 ESV
  - *Shaw et al: Response Comparison of Hybrid III, THOR Mod Kit with the Chalmers SD3 Shoulder, and PMHS in Frontal Sled Tests*
- Is thoracic response sufficiently biofidelic?
  - Abstract submitted to 2013 ESV
  - *Parent et al: Thoracic Biofidelity Assessment of the Mod Kit THOR ATD*

NHTSA Agency Decision

- THOR 50th — Agency Decision in 2013
  - Review, release TDP
  - Fabricate additional Metric THORs?
  - Finalize certification requirements
  - Initiate thorough R&R

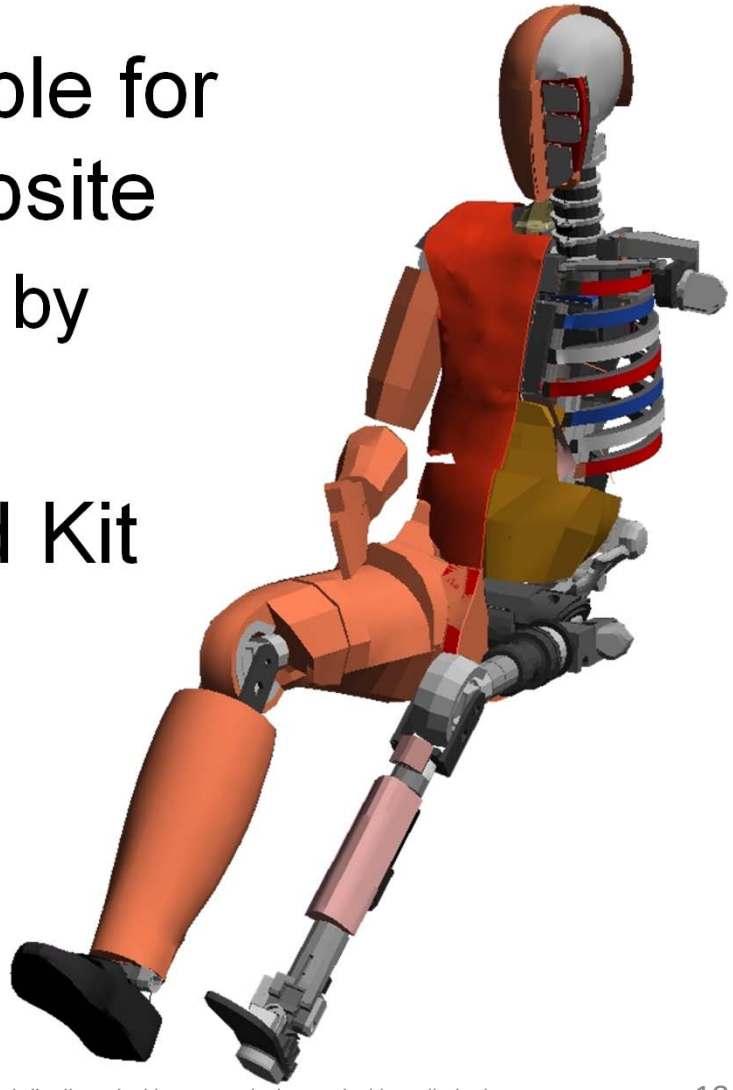
- THOR 5th — Agency Decision in 2014
  - Assess anthropometry (UMTRI)
  - Update biomechanical response requirements
  - Update design with Mod Kit components
  - Fabricate, review, release TDP

THOR 50th Finite Element Model

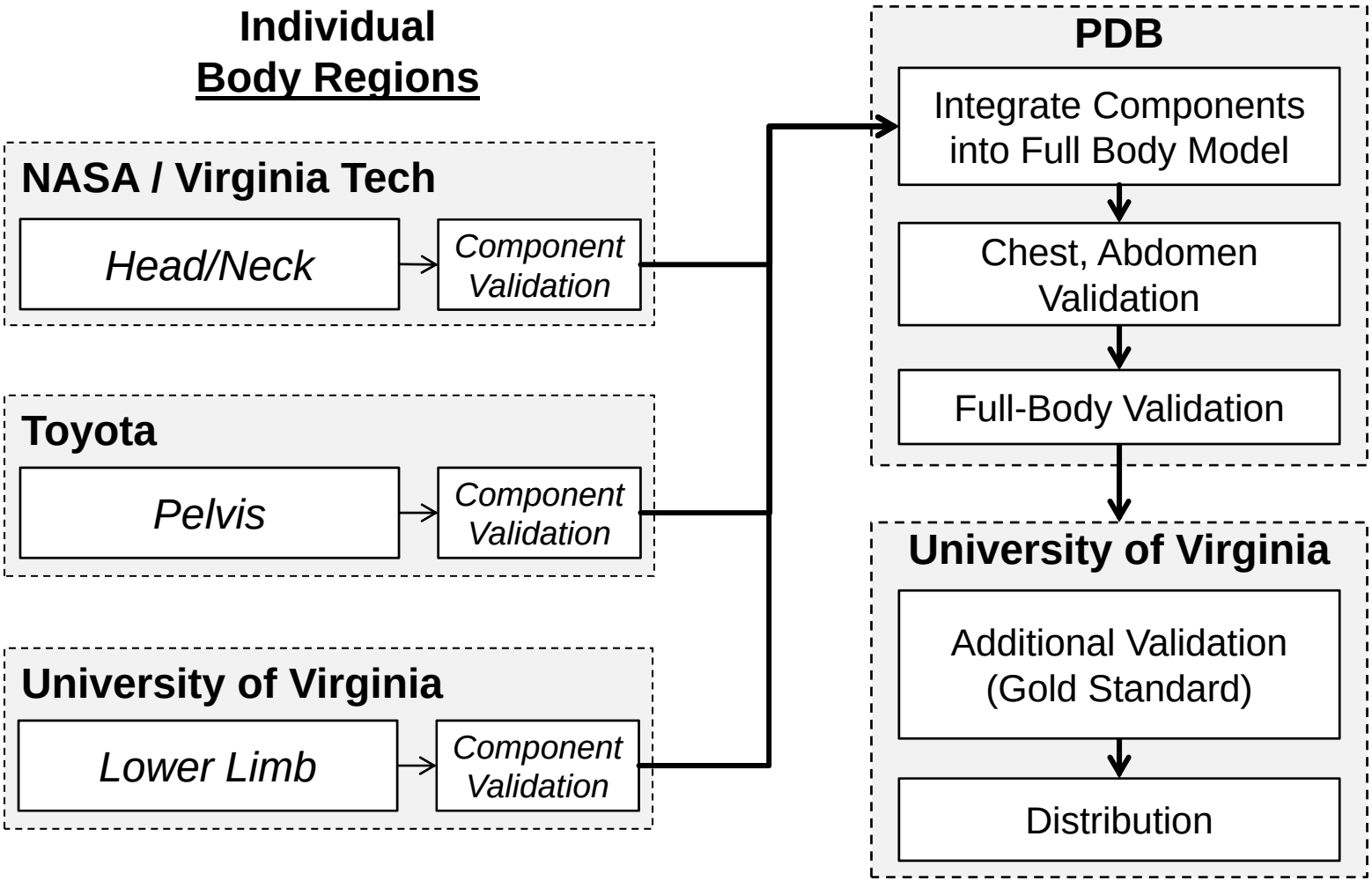


THOR
Finite Element Model

- THOR-NT FE model available for download from “Collab” website
  - Feedback has been provided by industry
- Currently incorporating Mod Kit components into model
  - Collaborative effort
- Still need:
  - SD3 shoulder

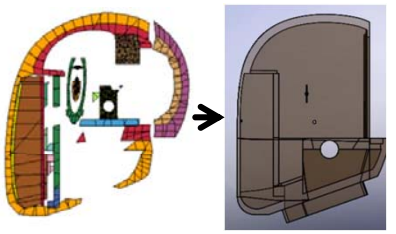


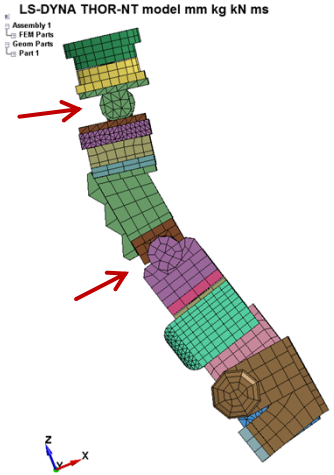
THOR FE Model Collaboration Strategy



NASA / Virginia Tech Head and Neck

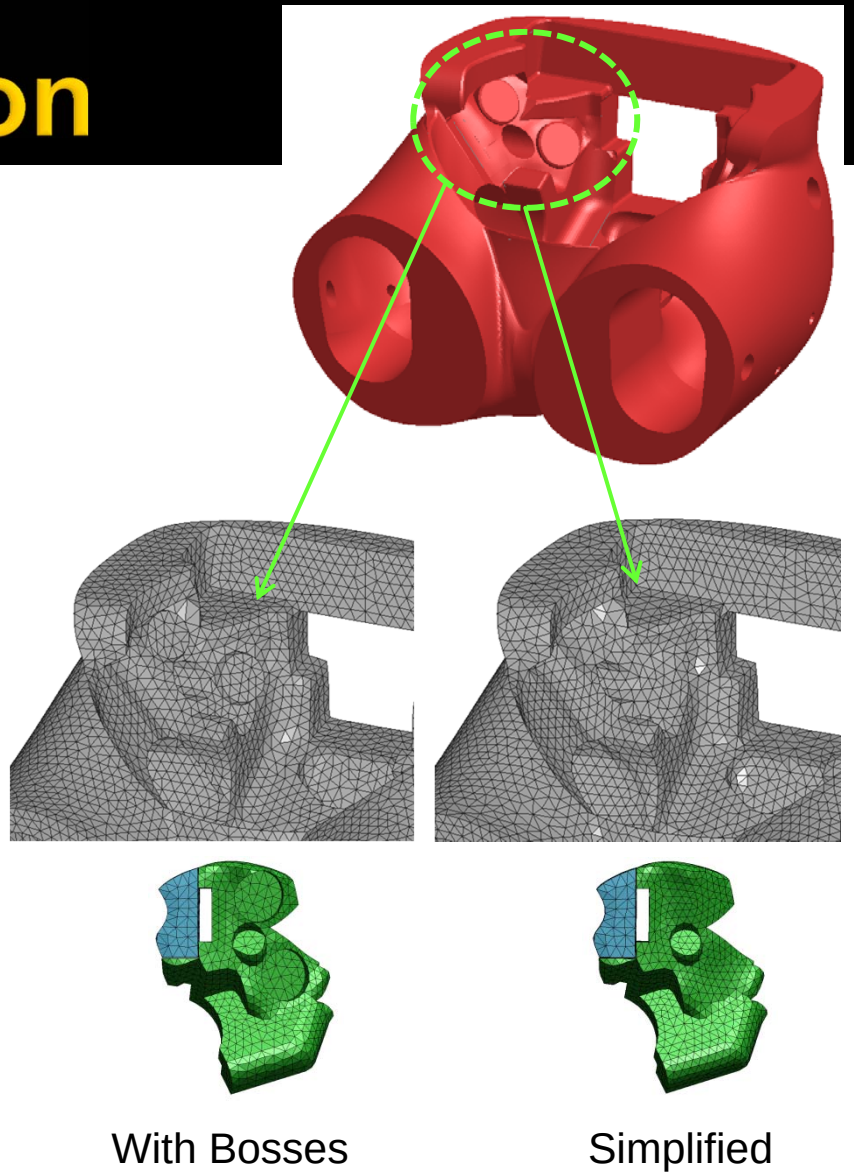
- Contributions to THOR FE Model
  - Update head skin geometry, mesh
  - Simplify OC joint
    - Will evaluate using defined joint properties instead of contact, bump stop deformation
  - Model neoprene spacer in neck safety cable
  - Implemented neck pitch change joint, lumbar spine pitch change joint in positioning tree
- Model Validation Conditions
  - Head impact test
  - Neck flexion/extension/lateral bending pendulum tests
  - Neck flexion NBDL tests once data available





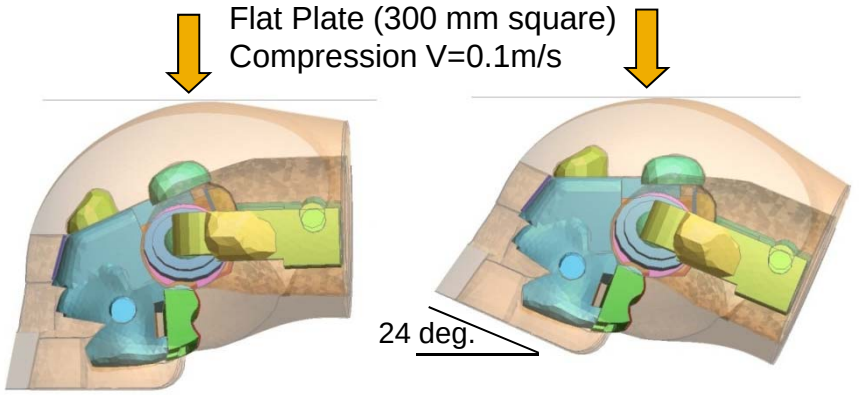
Toyota – Pelvis Model Construction

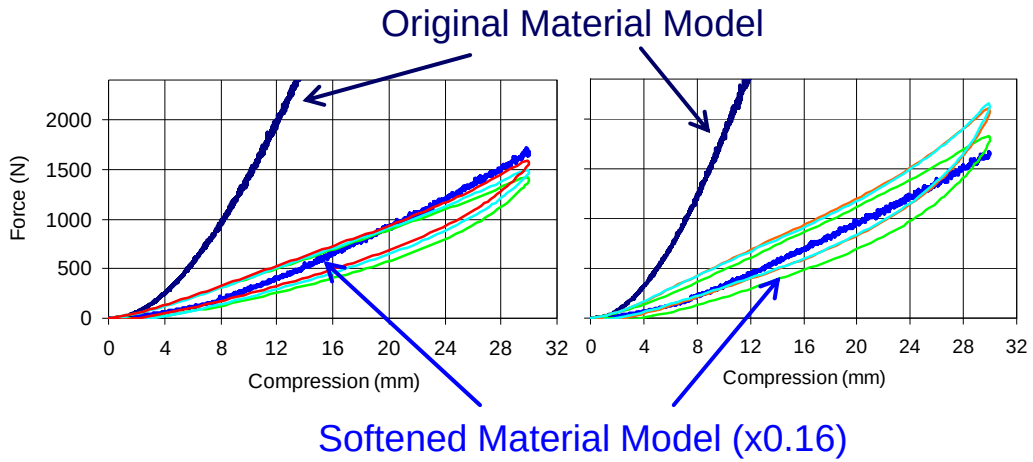
- Created mesh of Mod Kit pelvis flesh and bone
  - Option A – With Bosses*
  - Option B – Without Bosses
    - *bosses = raised geometry intended to reduce pelvis bone motion relative to pelvis flesh
  - Minimum element size
    - With Bosses: 4mm
    - Without Bosses: 5mm



Toyota – Pelvis Model Validation

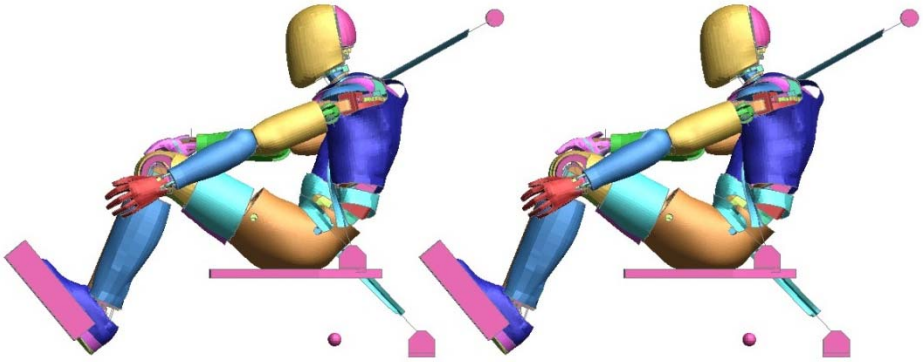
- Component Tests
  - Flat plate compression, bottom of pelvis
  - Flat plate compression, angled pelvis



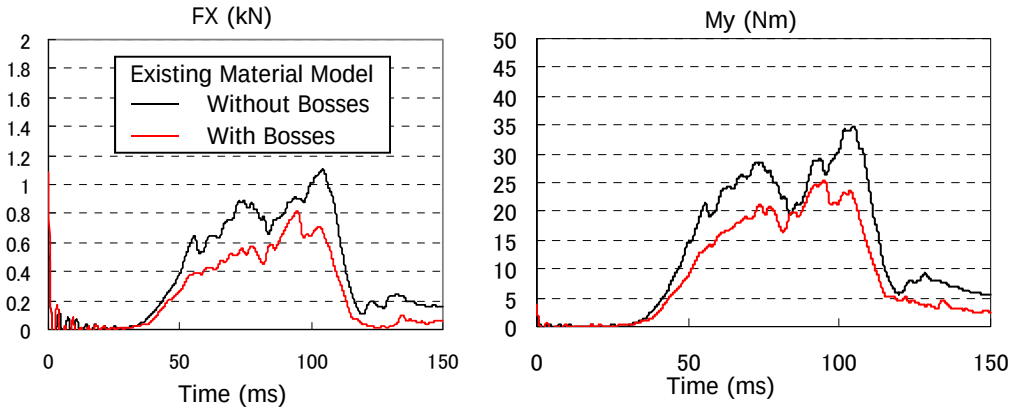


Toyota – Pelvis Model Validation

- Full-body Tests
  - Gold Standard sled test without knee bolster
  - Evaluate difference with and without bosses
- Decision
  - Since there does appear to be a difference, retain bosses in model
  - Also found large difference between existing and “soft” pelvis model
- Validation
  - University of Virginia to run Gold Standard test without knee bolster to validate ASIS, seat reaction loads

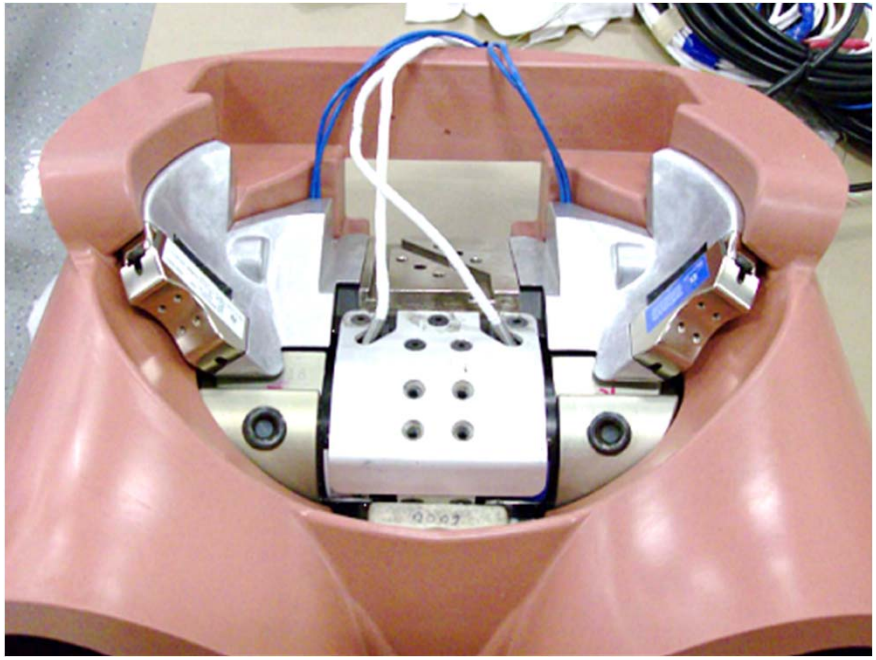


Kinematics similar…

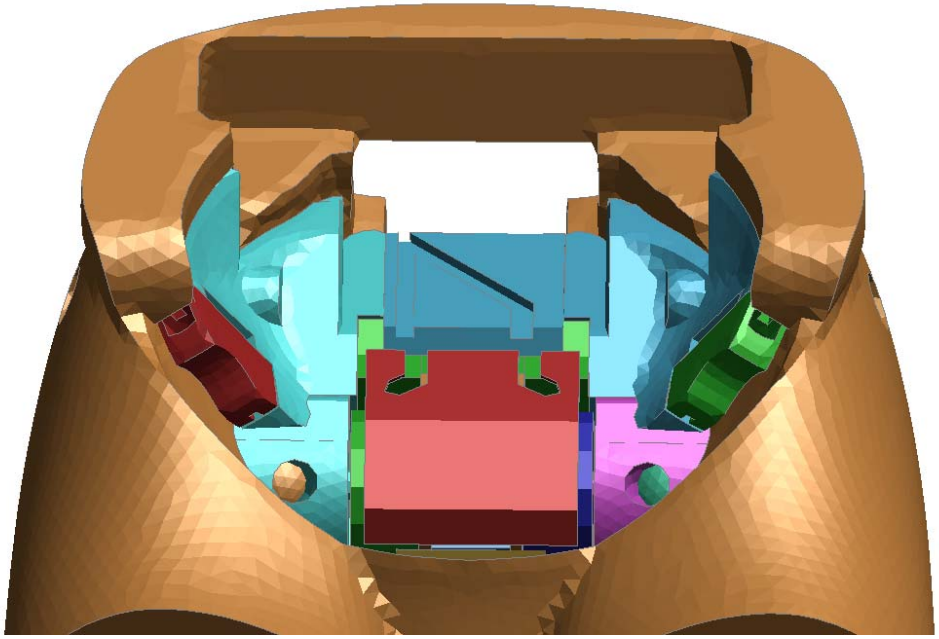


…but local loading to ASIS differed

Toyota – Pelvis Model Construction



Mod Kit THOR Pelvis

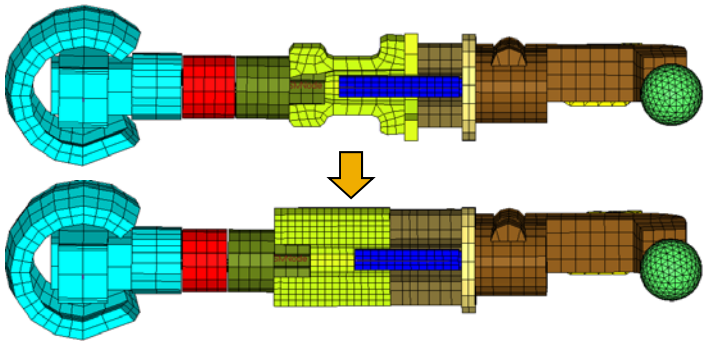


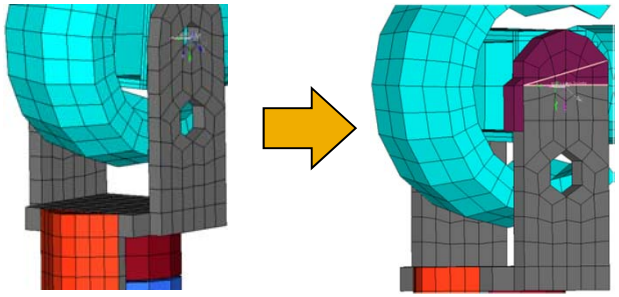
FE Model Pelvis

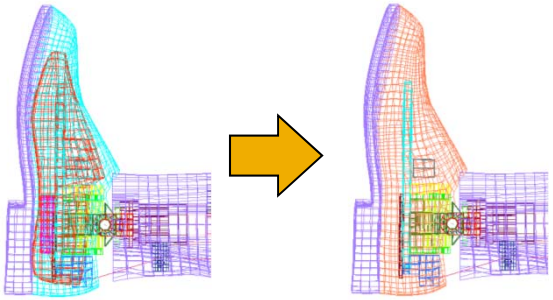
- Mod Kit FE Pelvis Model will be included in next THOR FE Model release

University of Virginia Lower Limb

- Contributions to THOR FE Model
  - Updated femur geometry, response
  - Integrated knee slider joint, restraint
  - Improved load cell definitions
  - Initiated modeling of molded shoe
    - Scanned, meshed
    - On hold due to potential changes from Humanetics
- Model Validation Conditions
  - Dynamic X-version
  - Dynamic Dorsiflexion
  - Heel impact







PDB – Model Integration

- After body region model is complete and response is verified and presented, components will be uploaded to Collab and PDB will integrate into full body model
- Additional model usability updates requested:
  - Body region segmentation
  - Instrumentation consistent with hardware
    - Use locking joints where possible
    - Ideally label output with ISO-MME codes
  - Complete positioning tree (use NASA / VT work)
  - Renumbering
  - Revision control
- Model validation in defined conditions

THOR FE Group
Overall Guidance

NHTSA

- Proposal A – Body Region Segmentation
- Proposal B – Renumbering
- Proposal C – Validation Conditions
- Proposal D – Model Acceptance

Model Validation Requirements

	Verify response in:	After modifications to:
Bio/Certification Tests *See THOR Cert and Bio Manuals for details*	Head impact (forehead)	pelvis and above
	Neck pendulum	head or neck
	Upper ribcage 4.3m/s impact	pelvis and above
	Lower ribcage oblique impact	pelvis and above
	Upper abdomen impact	pelvis and above
	Lower abdomen impact	pelvis and above
	Seated knee impact	LX/KTH
	X-version, BOF/Heel Impact	LX
	NBDL neck	head or neck
Other Component Tests	Pelvis compression tests	pelvis
	Fixed femur dynamic compression	femur
	Knee slider dynamic	knee slider
Sled Tests	Gold Standard 1	everything but LX
	Gold Standard 2	everything but LX

Model Validation Acceptance Criteria

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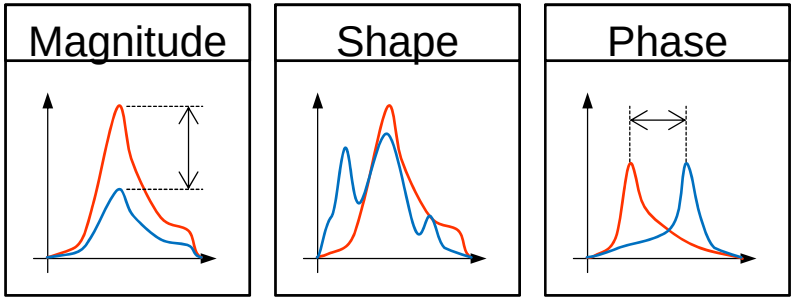
Similarity Analysis

Compare time-histories
CORA 3.6 Software
Gehre, 2011 ESV
Provides overall rating
1.000 = Perfect Agreement



- Minimum Correlation Method rating = 0.900
- Relevant measurements for given test
  - For certification tests, compare signals included in certification requirement
  - For other tests, propose relevant signals
    - Example: for Gold Standard sled tests, compare belt loads, head and chest accelerations, multi-point chest deflection