VTTI Center for Injury Biomechanics

PARTNERS
Virginia-Maryland College of Veterinary Medicine
Institute for Critical Technology and Applied Science
Virginia Tech-Carilion Research Institute
Virginia Bioinformatics Institute
Virginia College of Osteopathic Medicine
Wake Forest University


Duma


Gabler


Hardy


Kemper


Rowson


Untaroiu


VandeVord

Biomechanics and Injury Prevention

- Mechanism (multiple scales):
  - Mechanical response,
  - Injury response.
- Tolerance:
  - Injury metric/function to be evaluated (HIC, ADFS),
  - Injury Assessment Reference Values (IARVs).
- Mitigation:
  - Tools for design/evaluation of environments and equipment,
    - Physical and numerical models.
- Treatment:
  - Understanding mechanism can lead to improved diagnosis,
  - Can provide foundation for new treatment regimes.

CIB Research Areas

	Application			
Body Region	Automobile Safety	Military	Sports	*Other*
Head/Brain	FMVSS 208	Blast	Football	Treatment
Eye/face	Airbag/Particle	IED/Shrapnel	Softball	Products
Neck	Nij	Head Mass	Football	Stents
Thorax	Belt Loading	Restraints	Shoulder Pad	Treatment
Upper limb	Airbag Loading	Airbags	Brace Design	Surgery
Pregnant	Restraints	Work/time	Eligibility	Violence
Pelvis	Side Impact	Vehicle	Football	Pregnancy
Lower limb	Knee Bolster	Paratrooper	Brace Design	Prosthetics

CIB Activities

1. **Empirical Biomechanics**
   - Impact and injury response characterization
     - Transportation
     - Recreation
     - Military
   - Multiscale, multimodal, multirate investigation
   - Mechanism determination
   - Material property description
   - Tolerance quantification
   - Injury risk formulation
   - Surrogate implementation
   - Protective system evaluation
   - Mitigation strategy realization

2. **Computational Biomechanics (Dr. Costin Untaroiu)**
   - Rigid body modeling
   - Finite element modeling

3. **Test Subjects**
   - Cadavers (PMHS)
   - Animals (rats, pigs)
   - Dummies (ATDs)
   - Human volunteers

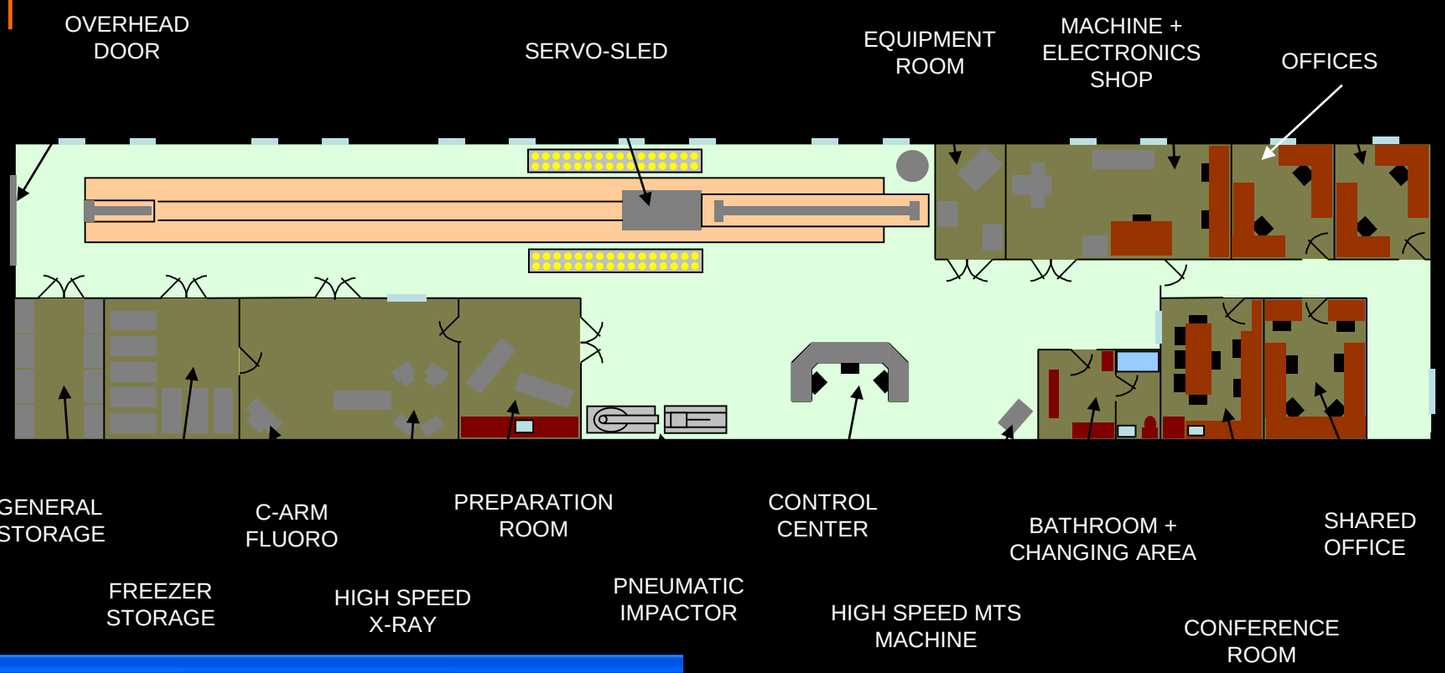
CIB Personnel and Funding

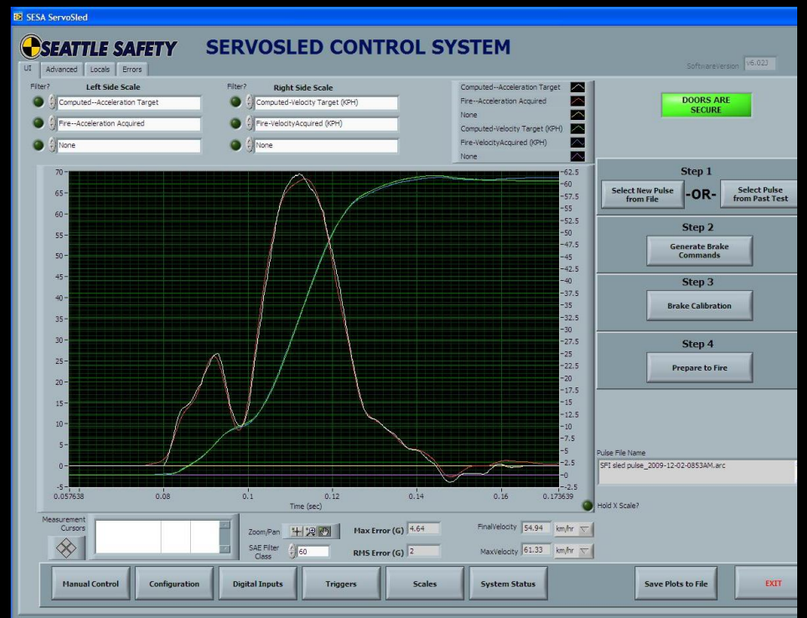
1. **Personnel**
   - Seven Principal Investigators
   - Four staff
   - Four post-doctoral fellows
   - Twenty-six graduate students

2. **Funding**
   - Historically maintain > $30m open research

3. **Historical Funding Sources**
   - Department of Defense
   - National Highway Traffic Safety Administration
   - Centers for Disease Control
   - NIH
   - NSF
   - NASA
   - OEM Automobile Manufacturers
   - Tier-One Suppliers

Crash Sled and Impact Laboratory

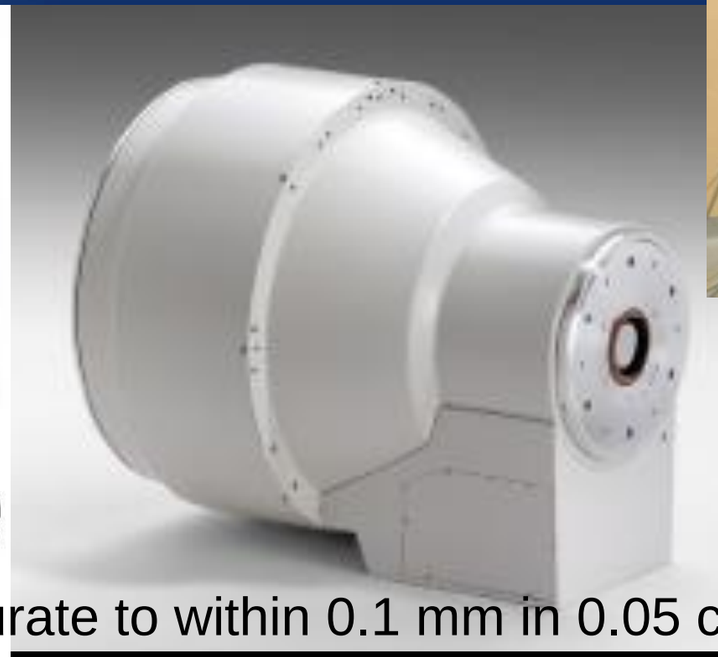




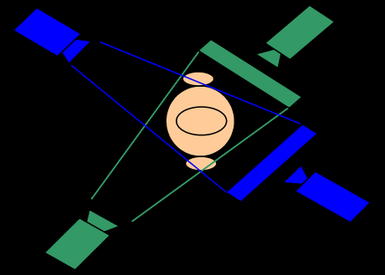
- 1.4 MN
- 475,000 N-m
- 90 kph and 93 g (20 g/ms)
- 57 kph and 37 g
- 2500-kg payload
- High-frequency (500 Hz)
- 2-m driving stroke

High-Speed Biplane X-Ray

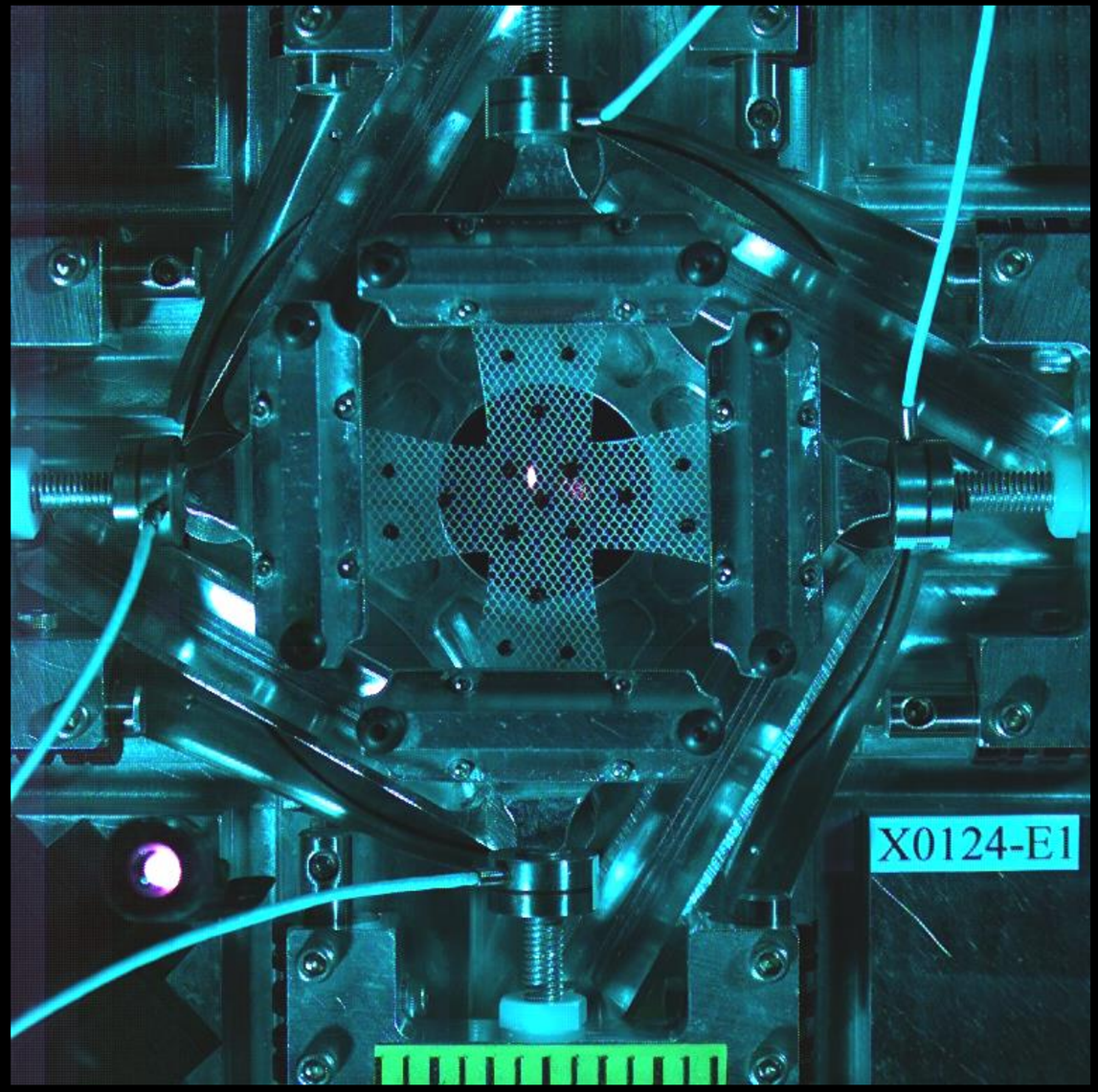
A high-frequency
Dual-axis x-ray generator
80 kW: 150 kV or 1,000 mA



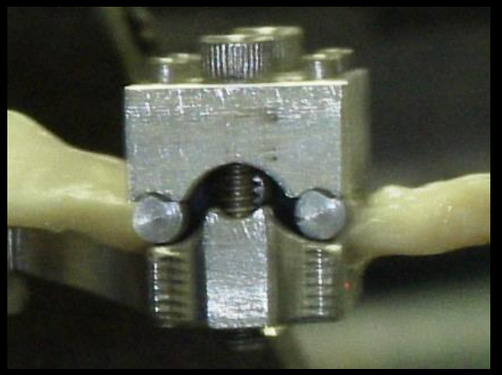
Accurate to within 0.1 mm in 0.05 cubic meter

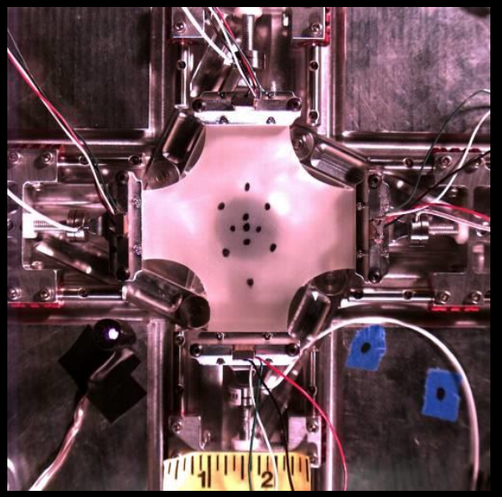


Tissue Testing

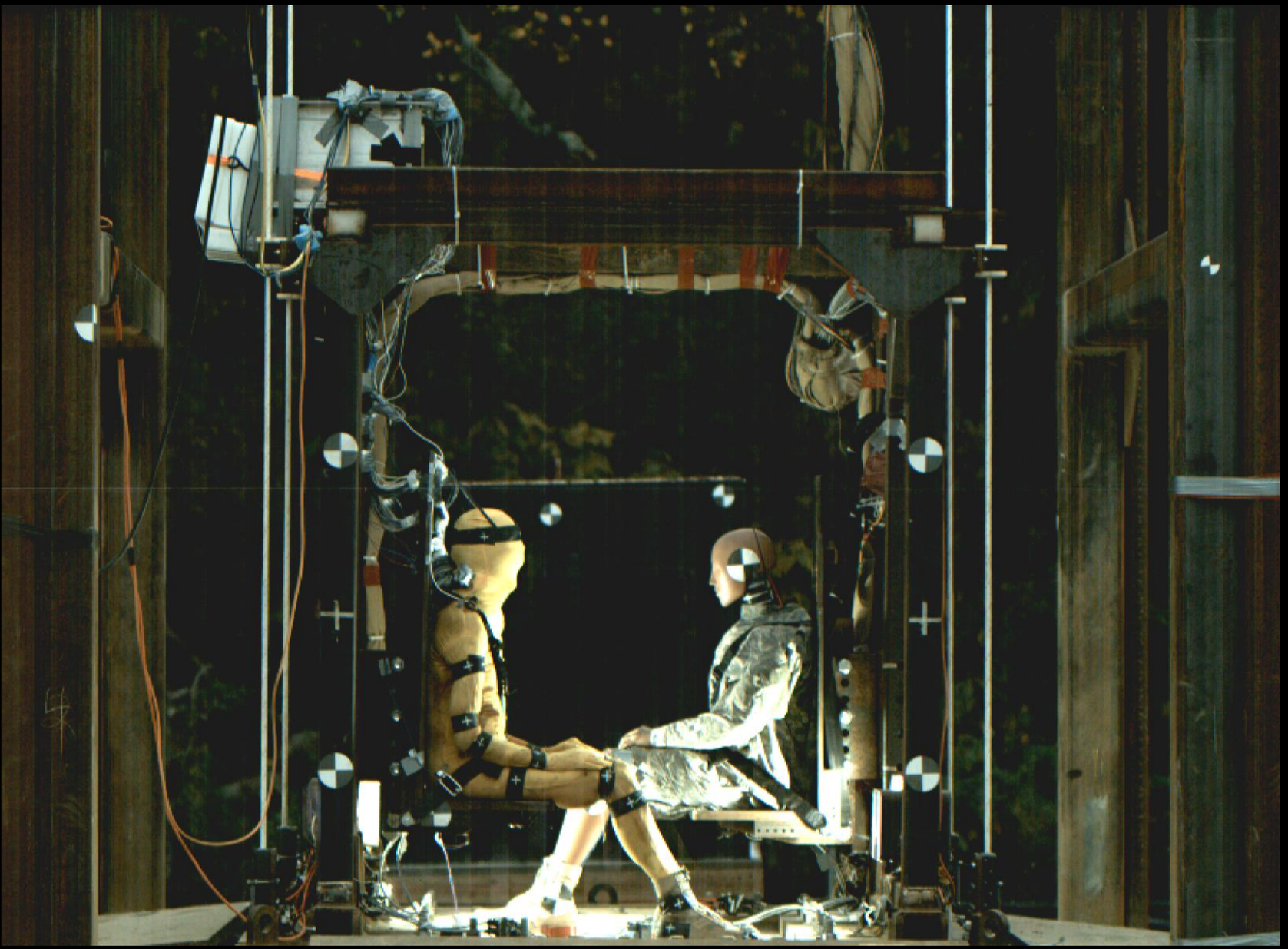


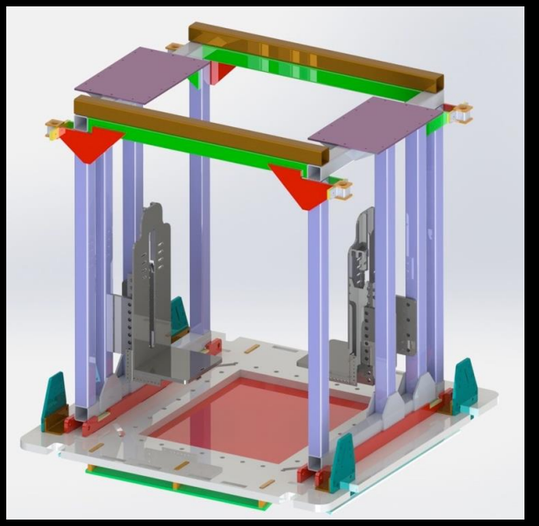
Biaxial Tissue Testing



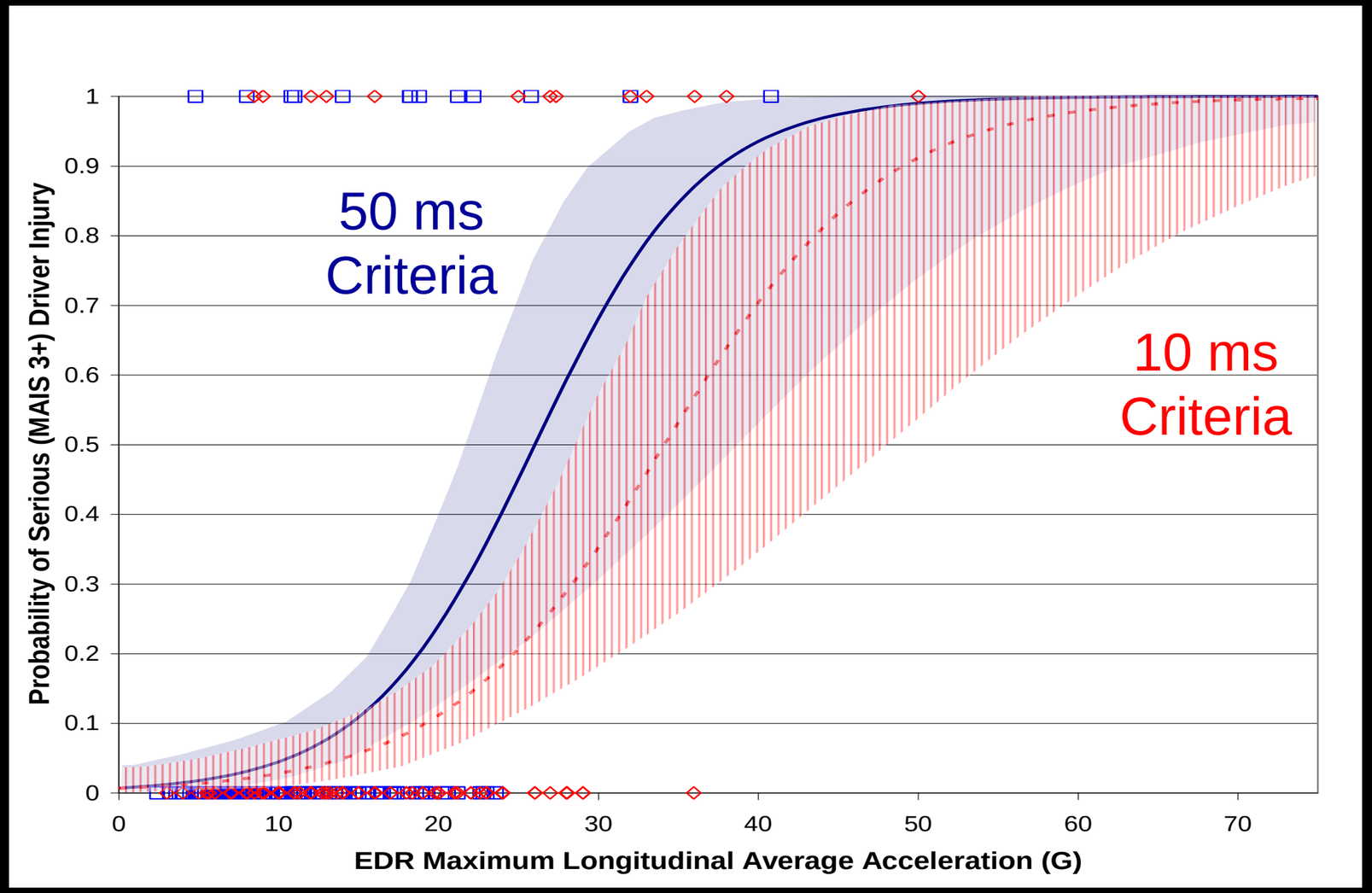


Military Applications

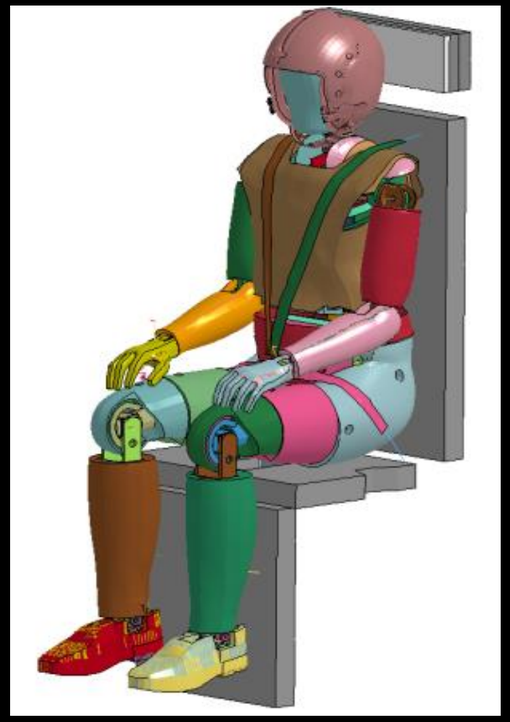


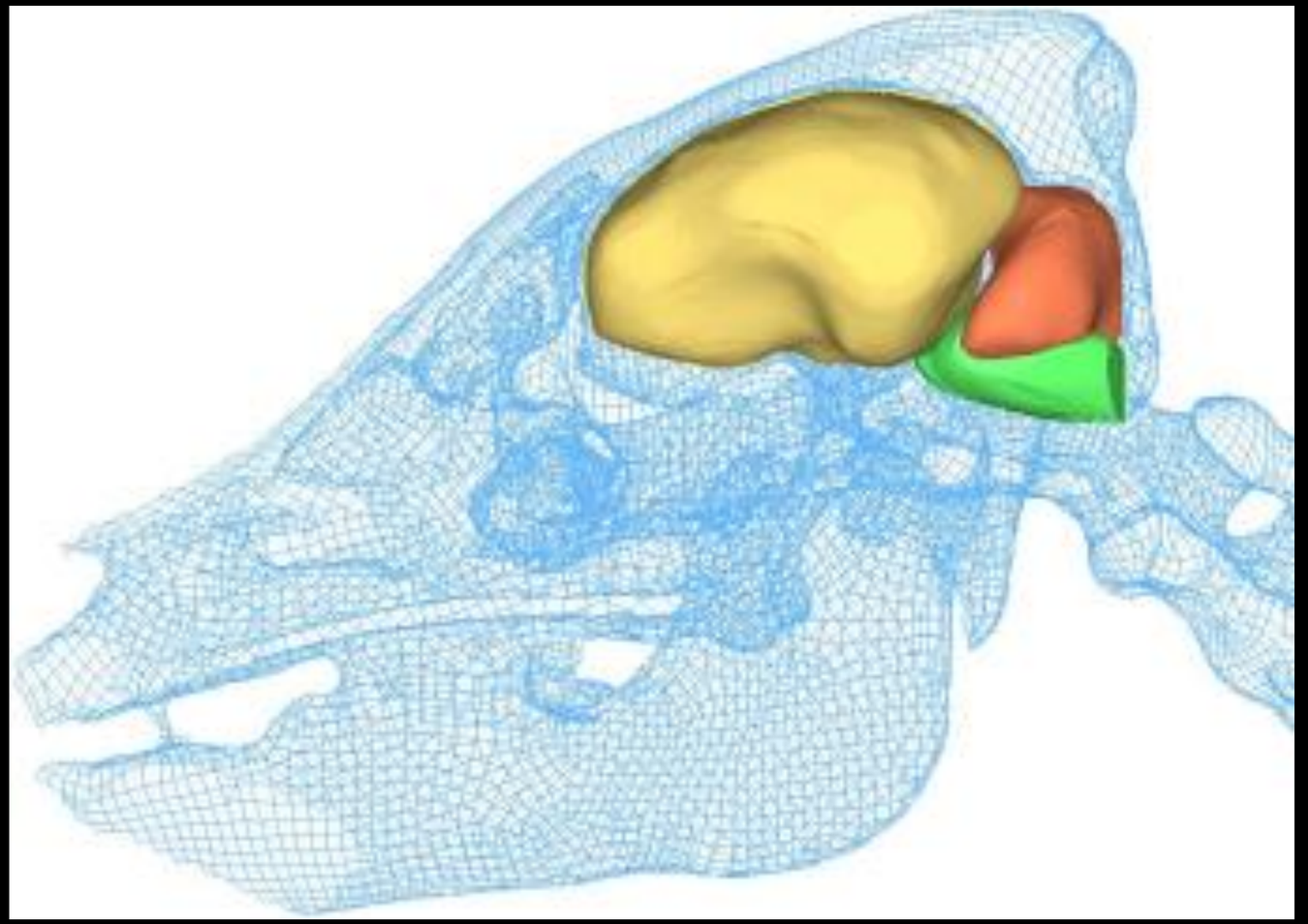


Accident Investigation, Simulation, Statistics

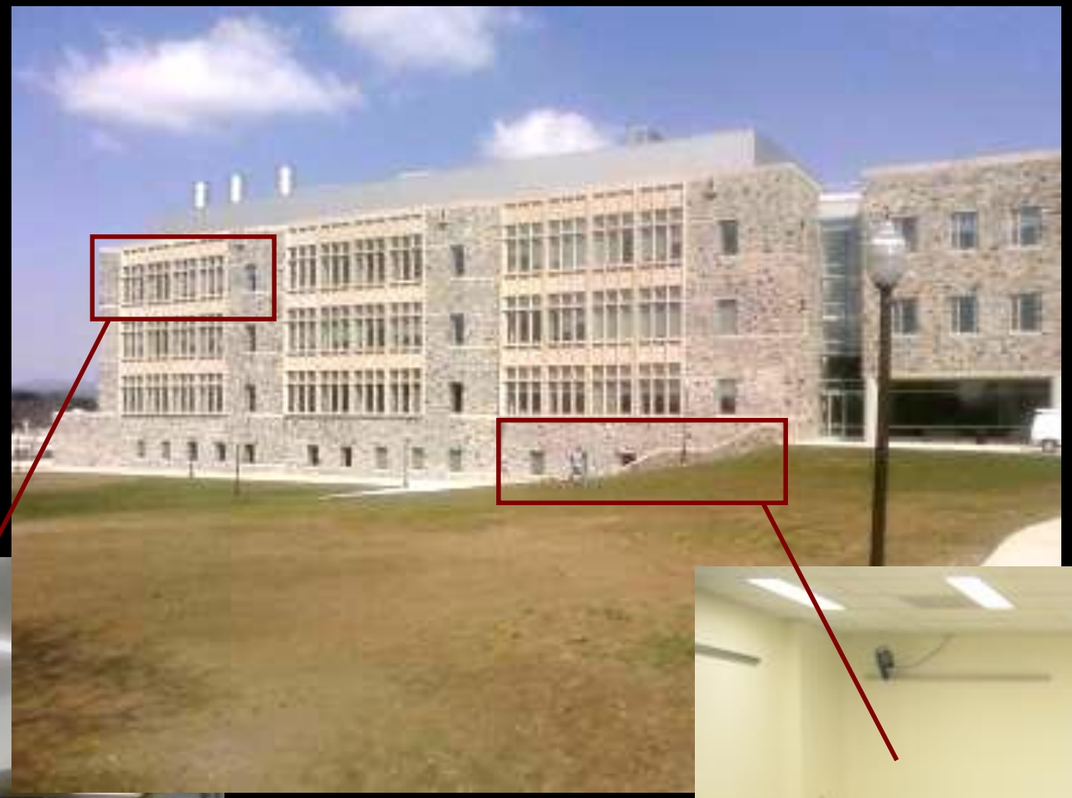


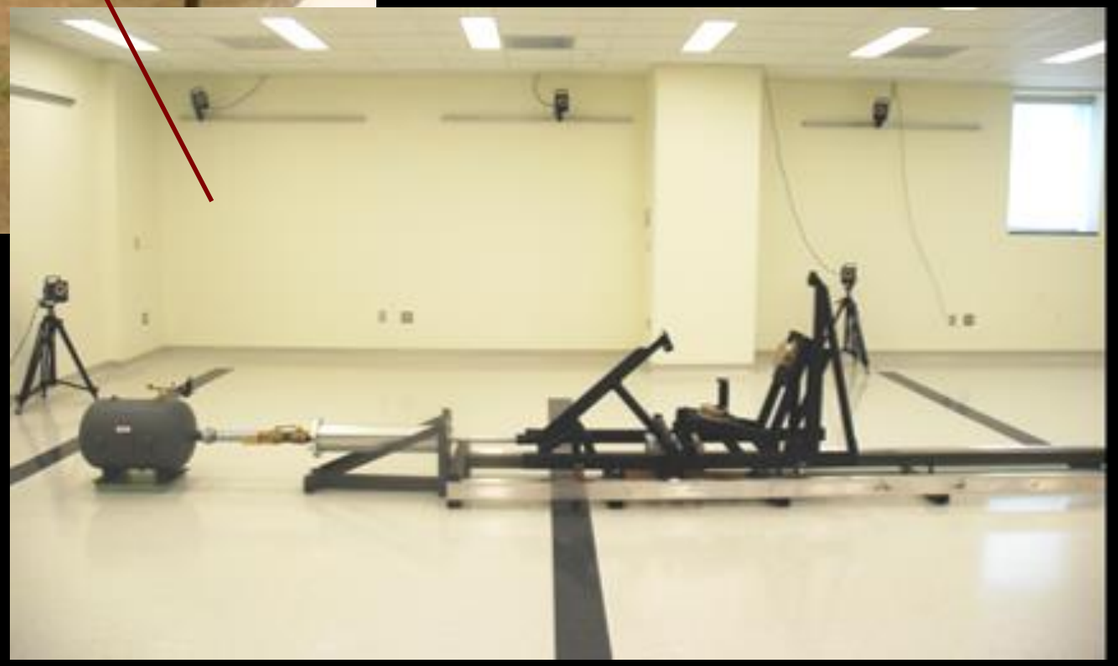
Finite Element Modeling





Kelly Hall Building (Biomedical Laboratories)



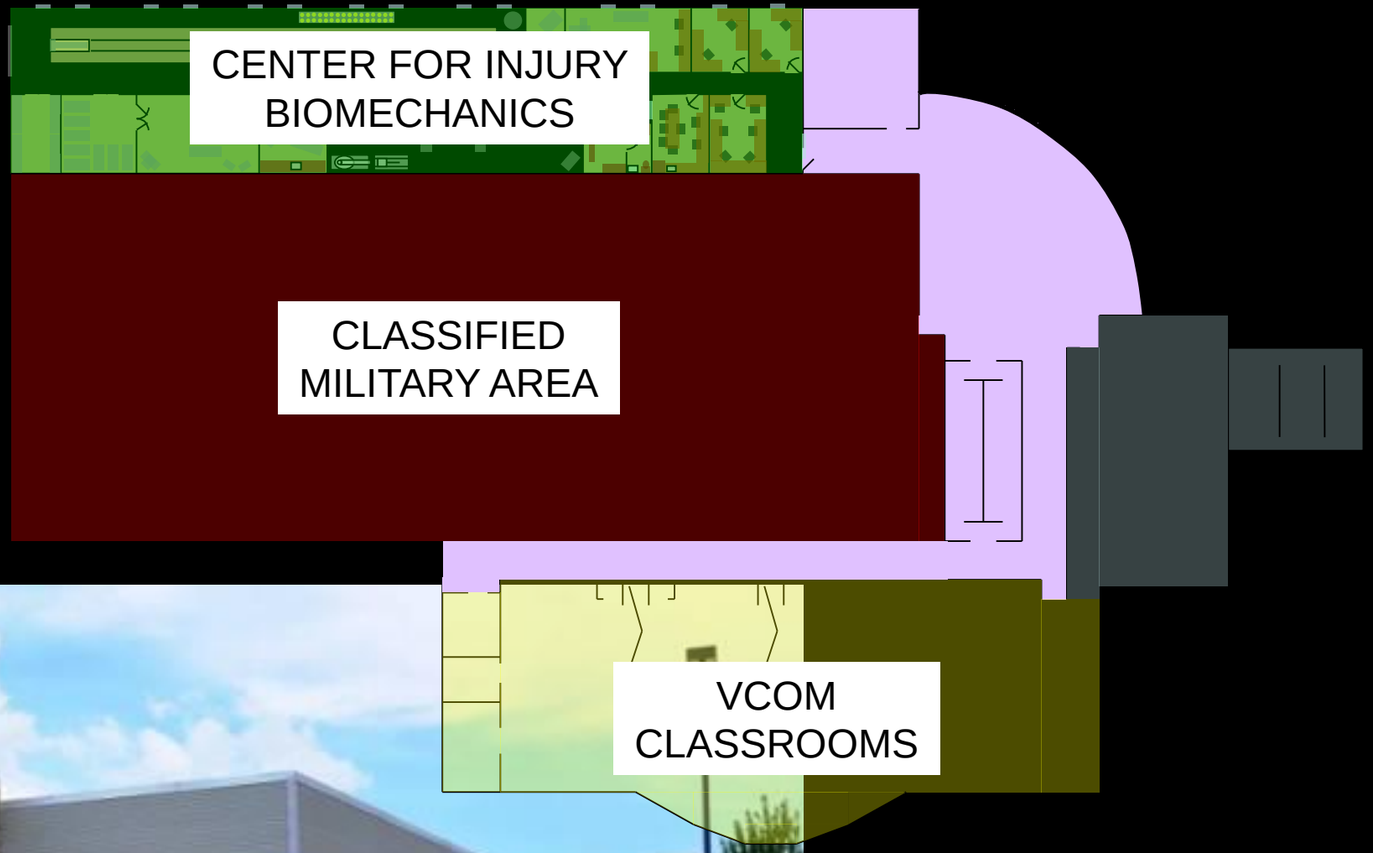


Mini-sled

Vicon Motion Capture System

-18 MX-T20 cameras (2 megapixel)
-Max Resolution = 1600 x 1280
-Max Sampling = 2000 fps

VCOM II Building



Computational Biomechanics (current/recent projects)

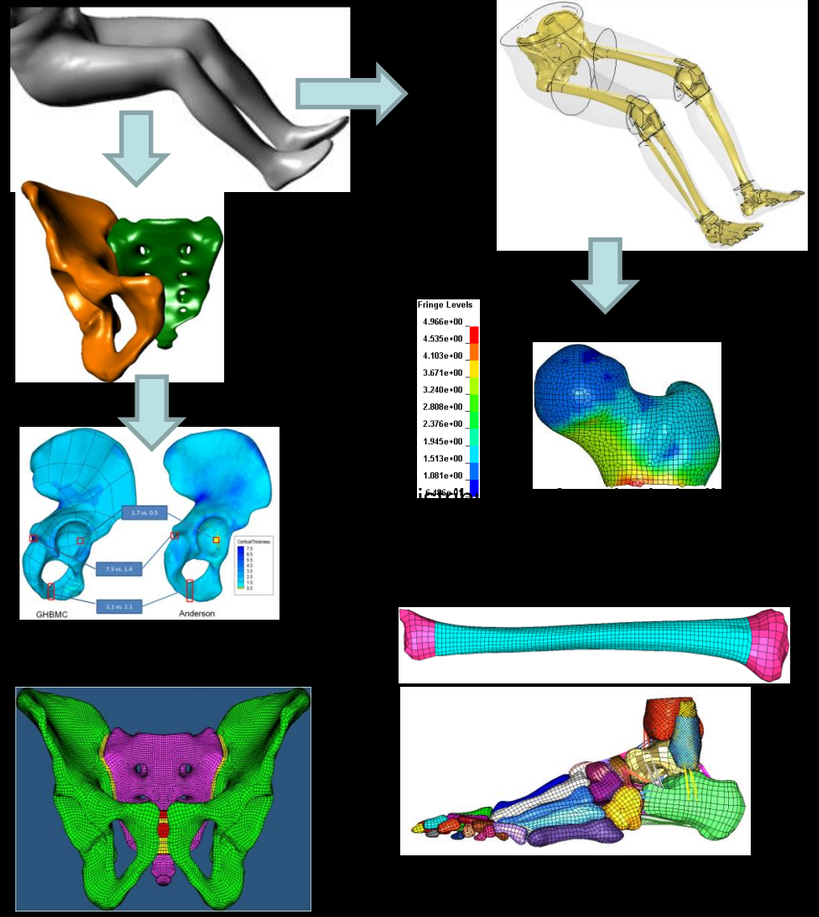
1. Development and validation of occupant/pedestrian human FE Models (e.g. GHBMC, THUMS, etc,)
2. Testing and material identification of biological tissues (e.g. liver, spleen, ribs etc.)
3. Statistical shape analysis of human organs
4. Development and validation of ATD FE models (e.g. THOR - automotive, WIAMAN –military)
5. Adaptive restraint systems

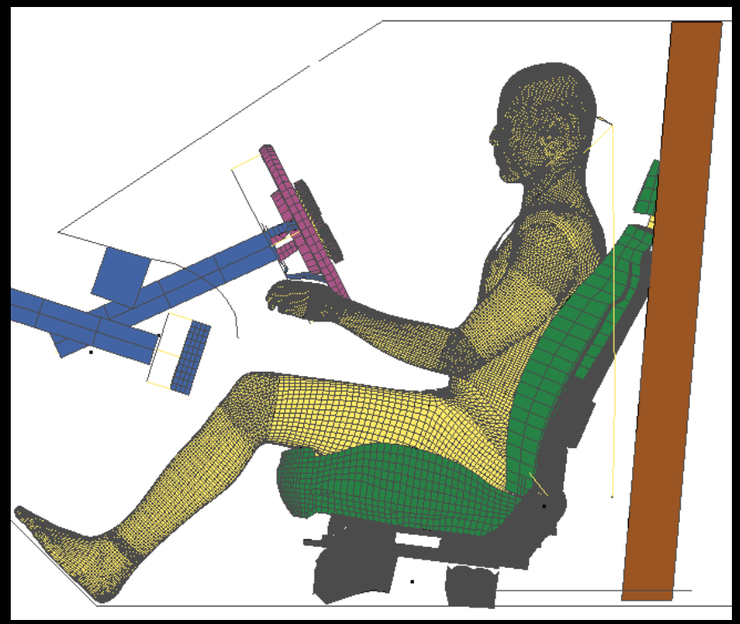
GHBMC occupant FE Model

GHBMC Pelvis and Lower Extremity Finite Element

- **Geometry**
  - Reconstructed geometry of 50th male volunteer
  - Additional data from literature for defining the cortical bone shells with thin thickness (e.g. in pelvis and epiphysis regions) and foot/hip ligaments
- **Meshing**
  - Almost 625k elements and 322k nodes included in 285 distinct components (parts)
  - More than 73% solid elements (93% hexa)
  - All elements fulfill GHBMC mesh quality criteria (Jacobian solid/shell>0.3/0.4; Tet collapse>0.2, etc.)
  - Model stable with 0.3/0.6 µs time steps (0.4/6% mass scaling)
- **FE Model Validation**
  - 19 Component / sub-system validations
  - 4 Robustness/Stability simulations
- **Biomechanical Database**
  - Develop a biomechanical database which includes all validation data (loading curves, test setups etc.) corresponding to component validations
  - Develop test data corridors

* This database obtained from published references /databases can be used in developments of further GHBMC FE models (e.g. 5th female)



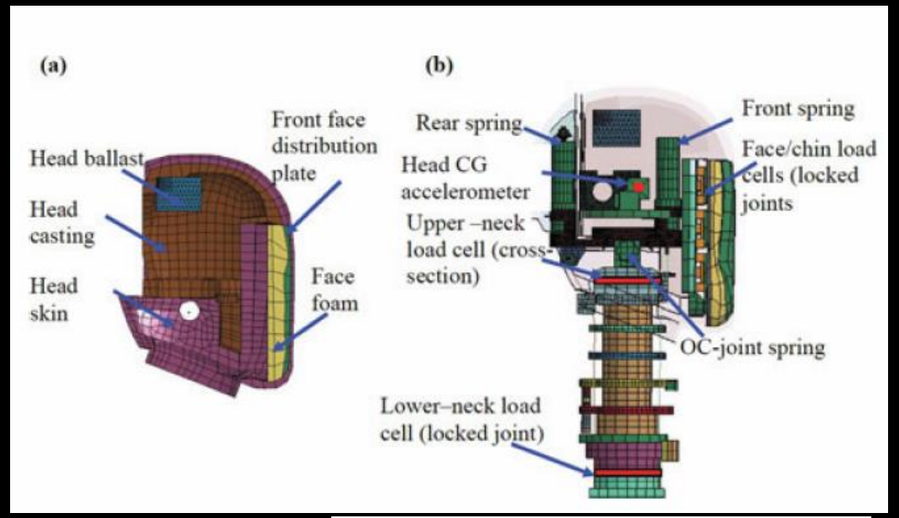


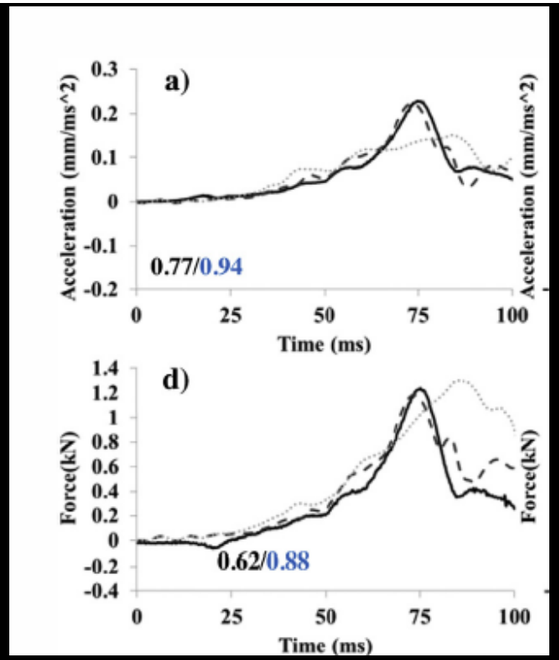
Dr. Jaeho Shin
Neng Yue

Reference: Untaroiu et al. 2012- PLEX User 's Manual

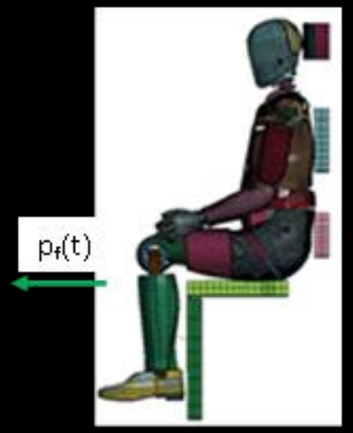
Development and validation of THOR-k FE Model

Development of head neck

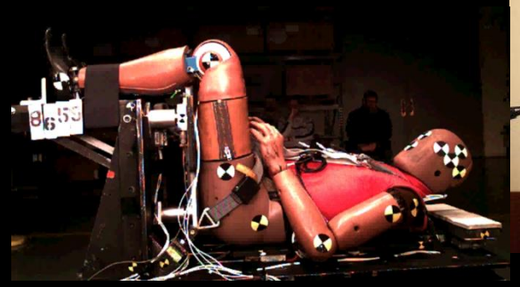




Frontal loading

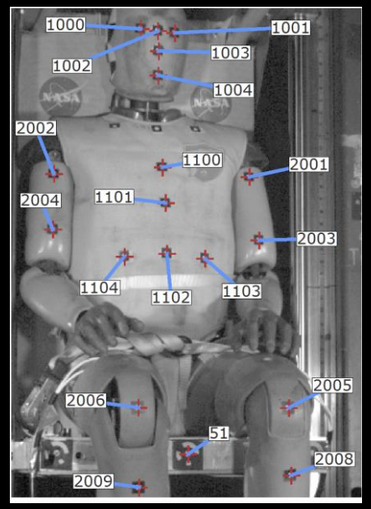


Vertical loading

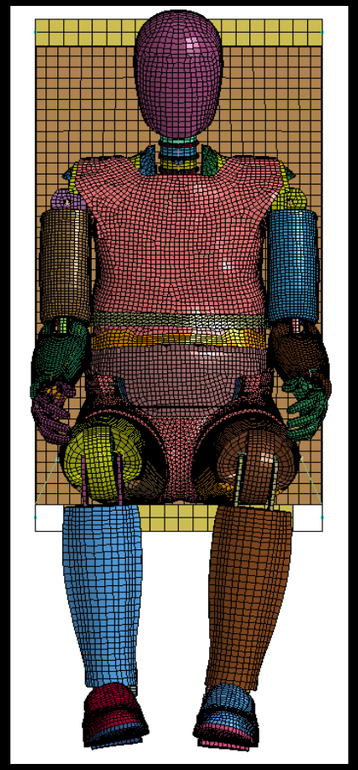


Jacob Putnam (NASA, former VT MSc student)

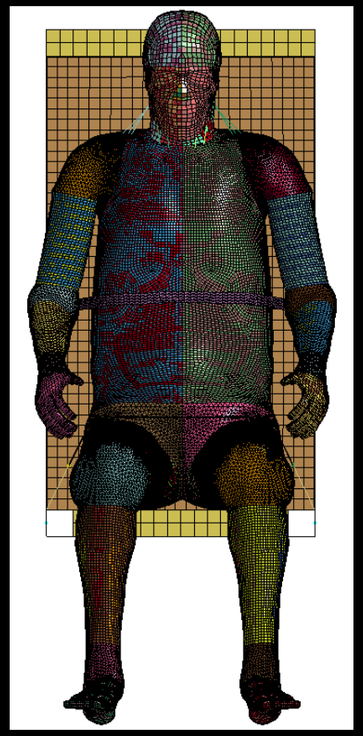
ATD vs. Human under vertical loading



Photogrammetric Imaging
* 18 Markers
* Localized to chair



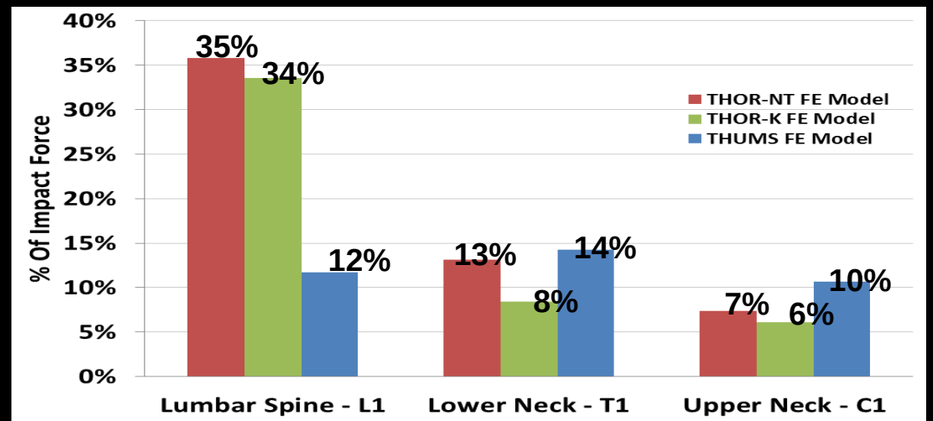
THOR



THUMS

T=0 ms **T=75 ms** **T=150 ms**

% Force Distributed Through Model



Material modeling of abdominal organs

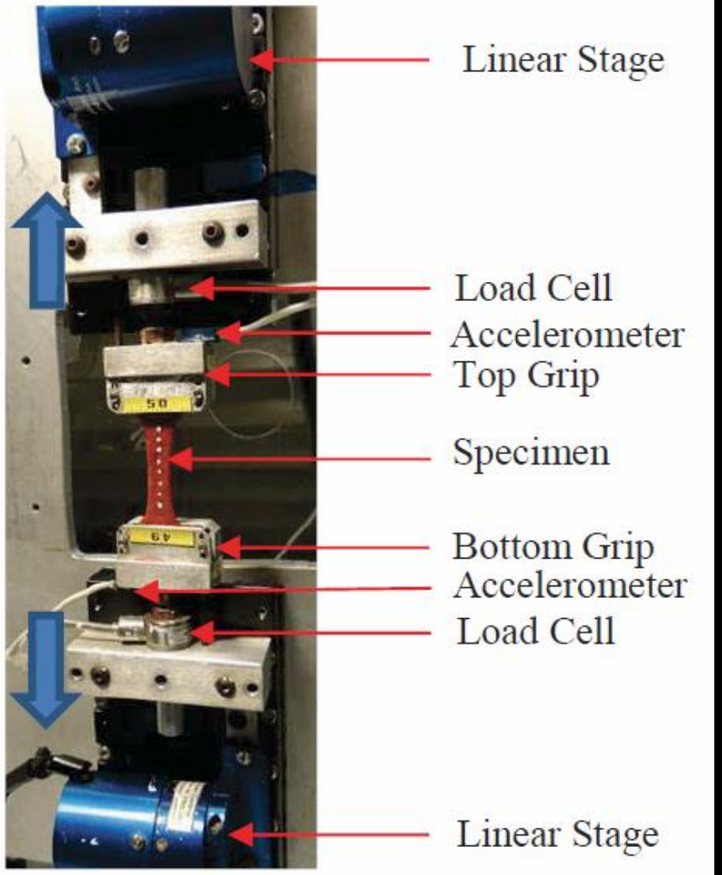


Figure 3. Experimental setup.

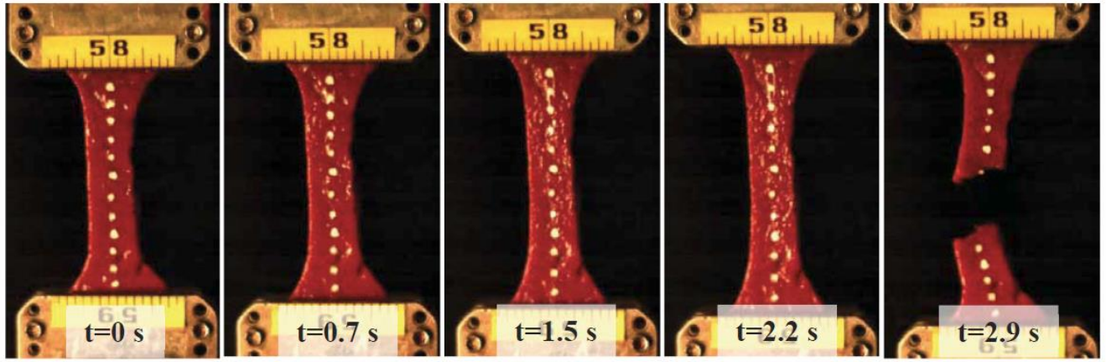
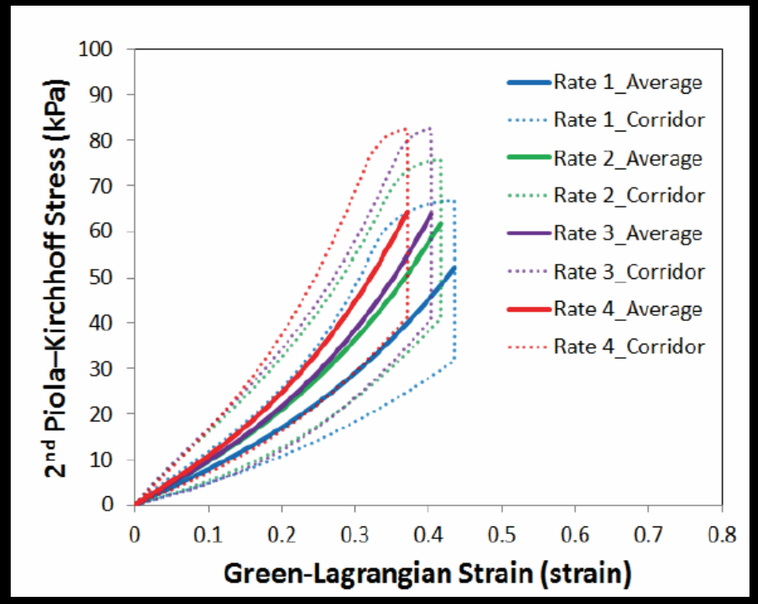


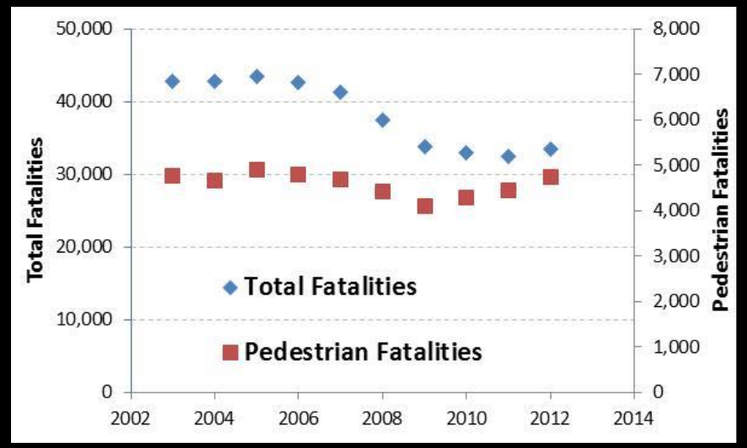
Figure 8. High-speed video stills of a typical uniaxial tensile test (Rate 2: 0.1 s^{-1}).

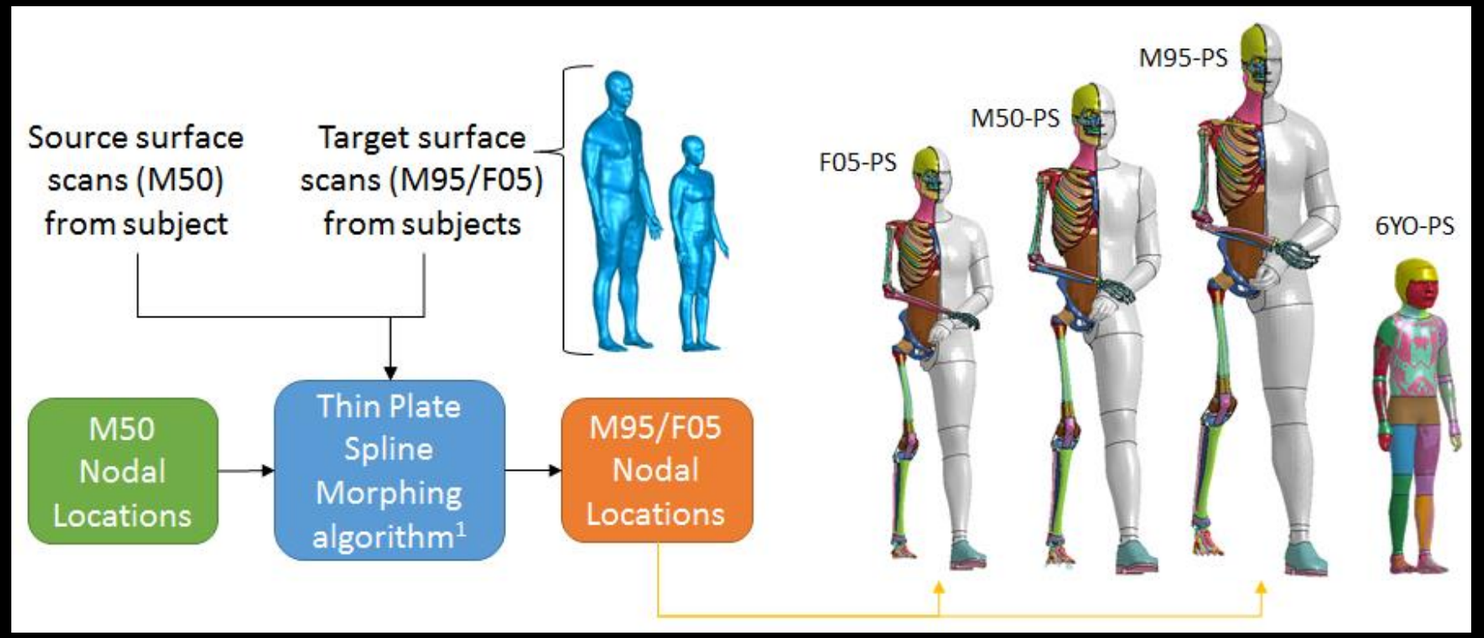


Dr. Yuan-Chiao Lu (Uniformed Services University of the Health Sciences, former VT PhD student)

GHBMC adult pedestrian FE Models

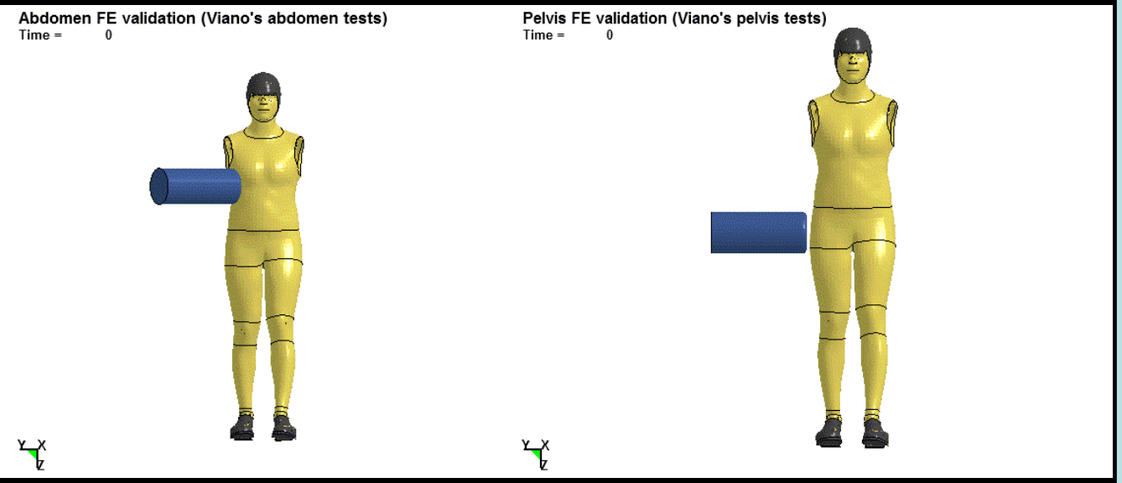
US (2012) 4,743 pedestrians killed & 76,000 pedestrians injured (NHTSA 2014)

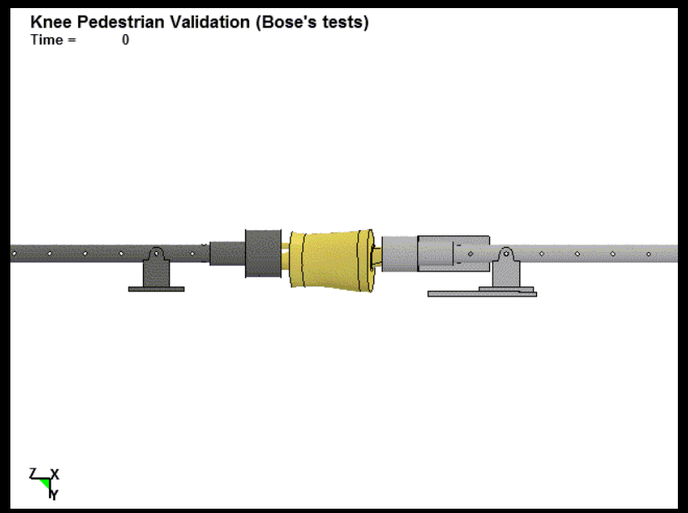




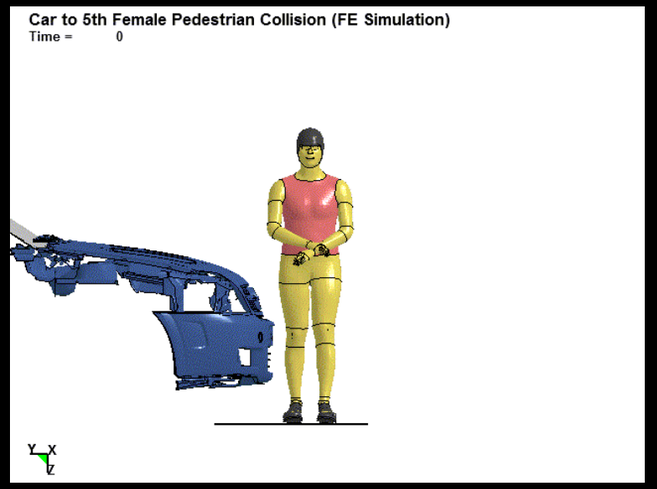
GHBMC adult pedestrian FE Models

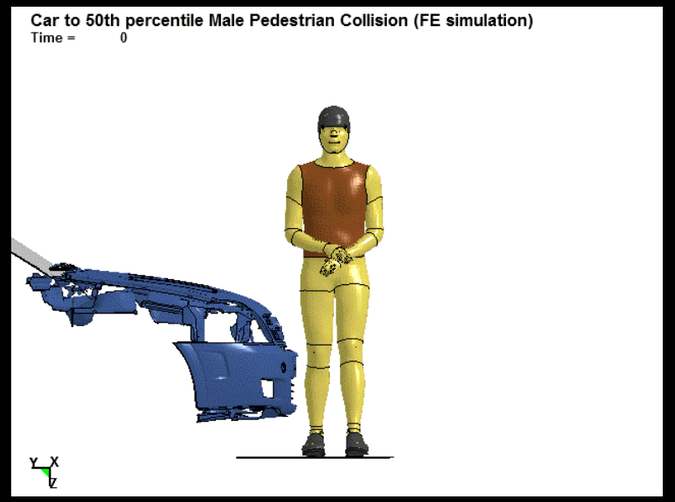
Component validation





Vehicle-to-pedestrian validation

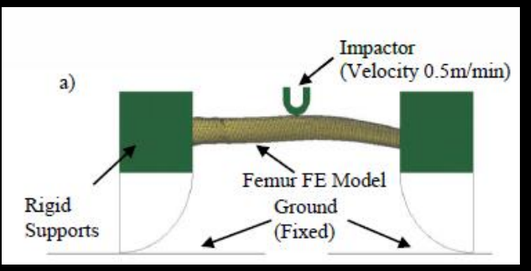


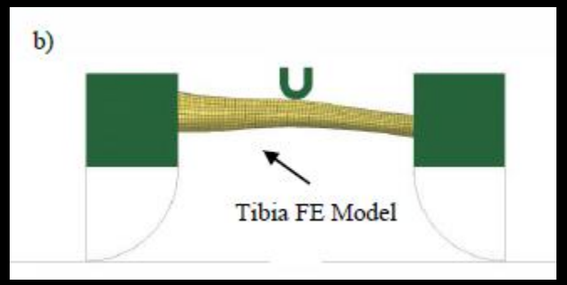


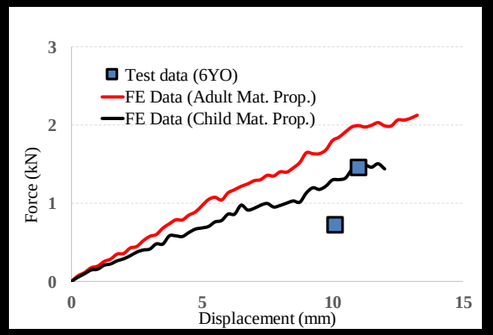
Wansoo Pak (VT PhD student)
(wspak@vt.edu)

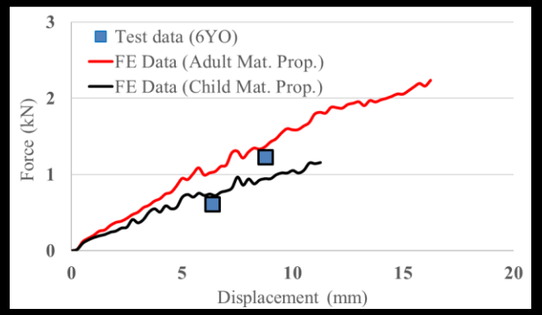
GHBMC child pedestrian FE Models

Component validation

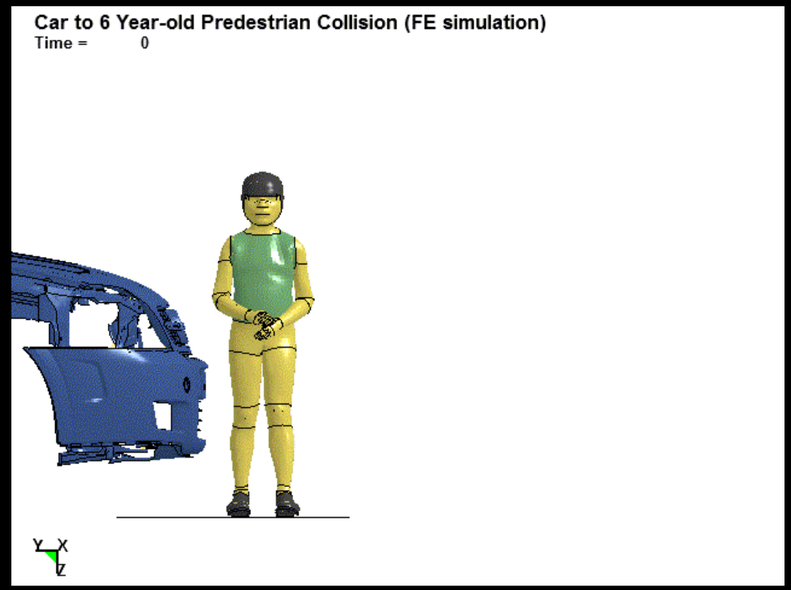


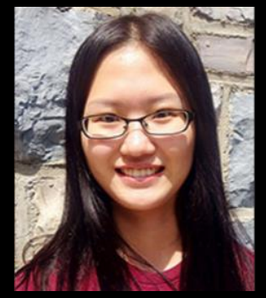






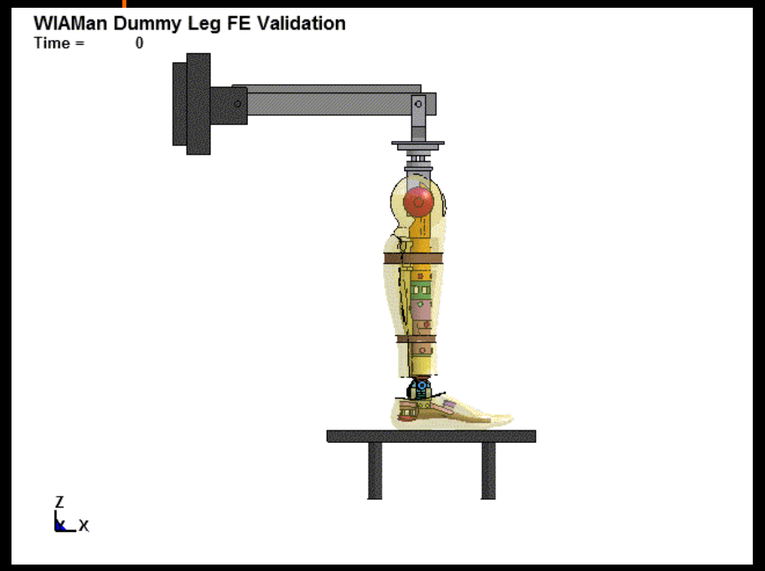
Vehicle-to-pedestrian validation

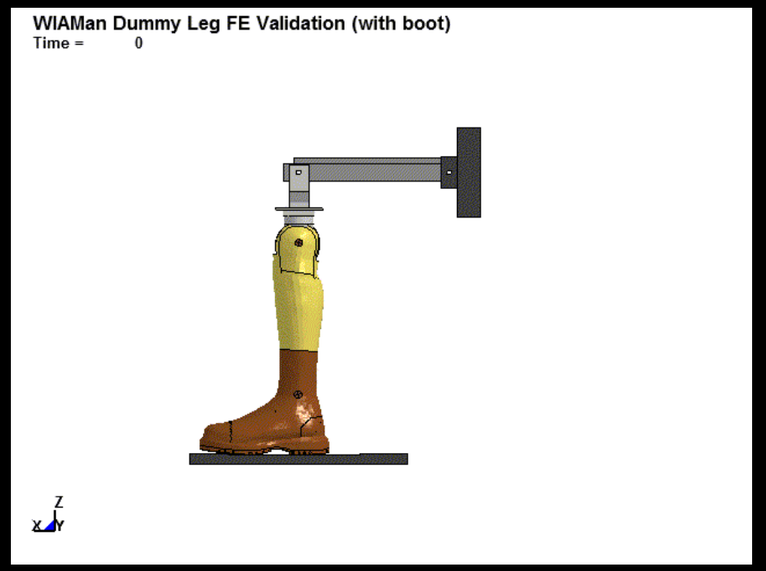




Yunzhu Meng (VT MSc student)
(mengyz@vt.edu)

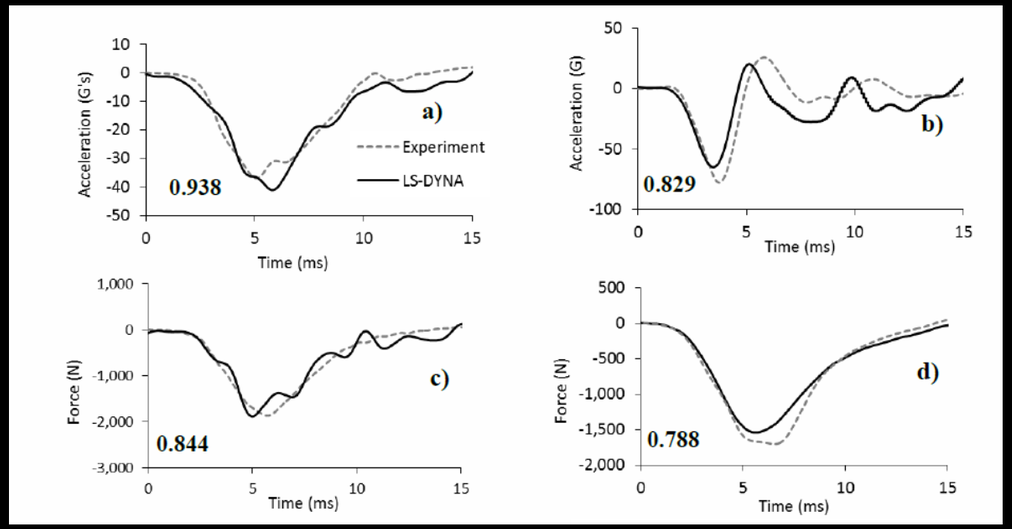
Development and validation WIAMAN leg FE model

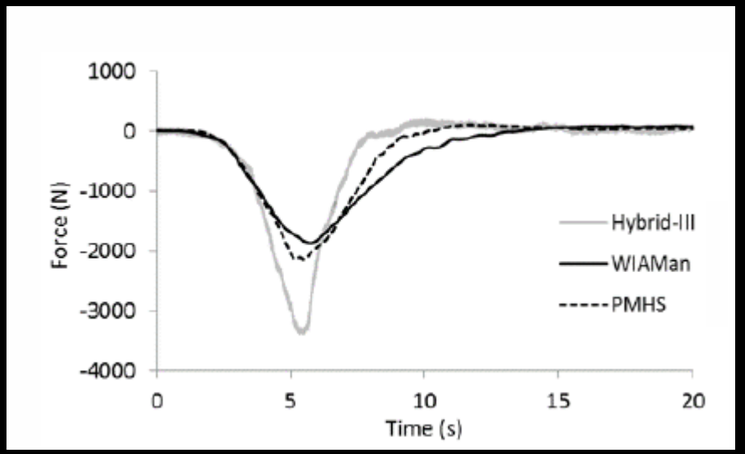




Wade Baker – VT
MSc student
(wadeb6@vt.edu)

Validation of WIAMAN FE Model

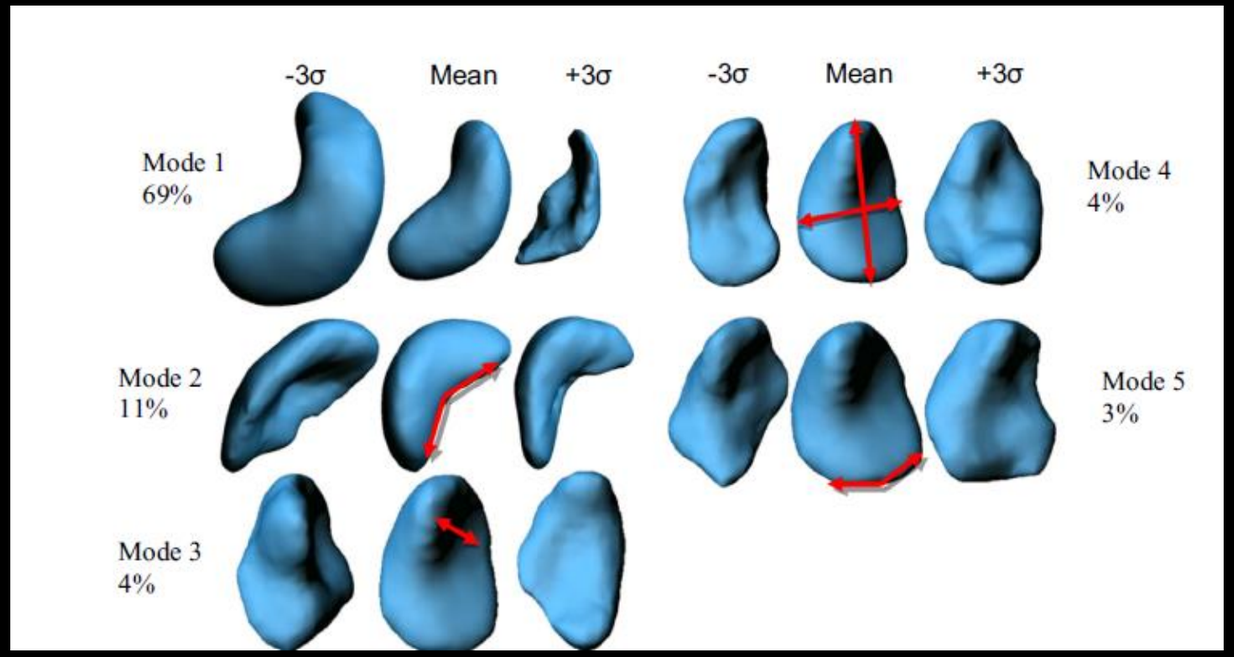




WIAMAN better biofidelity than HIII !

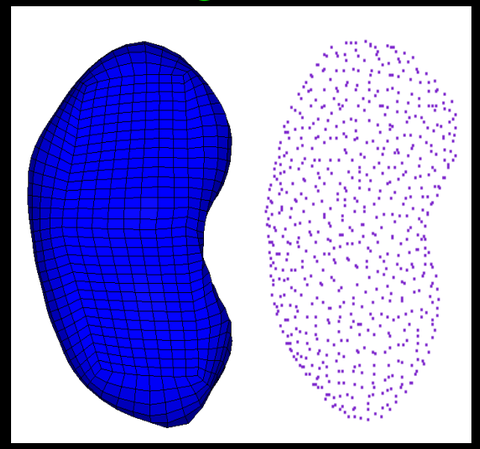
Statistical Shape Analysis & Mesh Morphing

Keegan Yates – VT
PhD student
(kmyates@vt.edu)

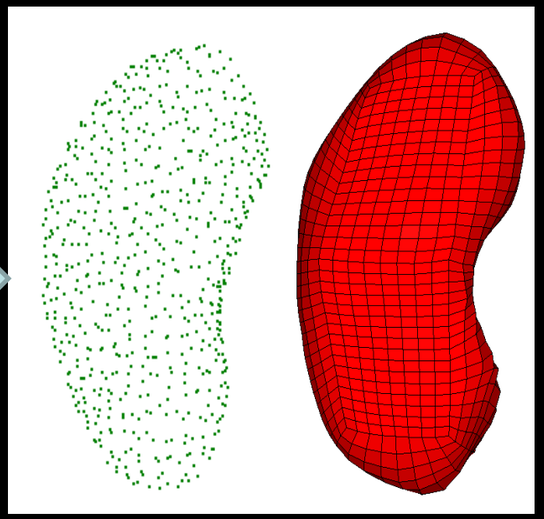


(Yates et al. 2016)

Original mesh

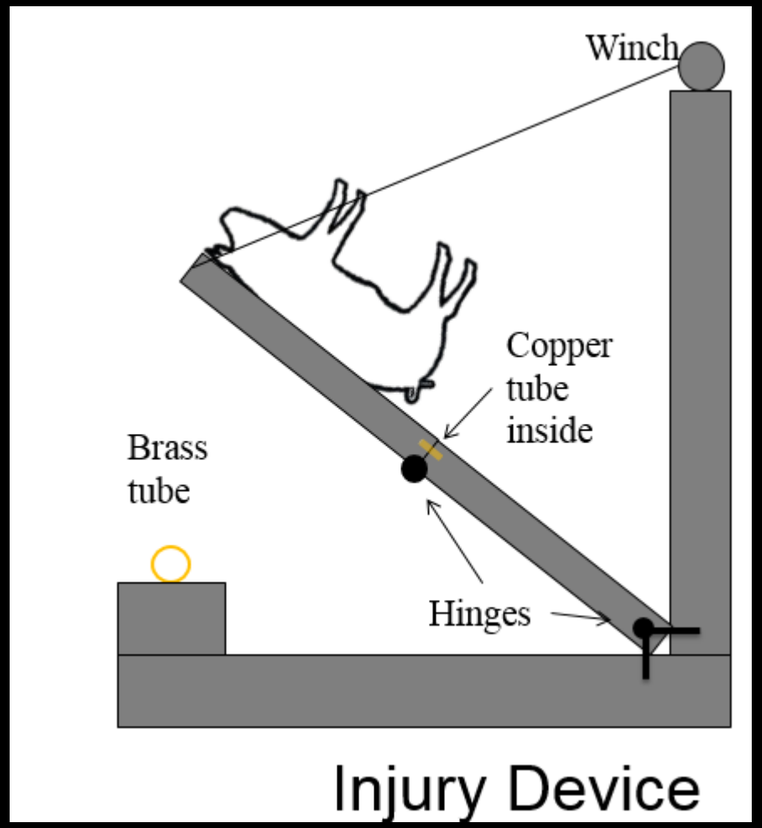


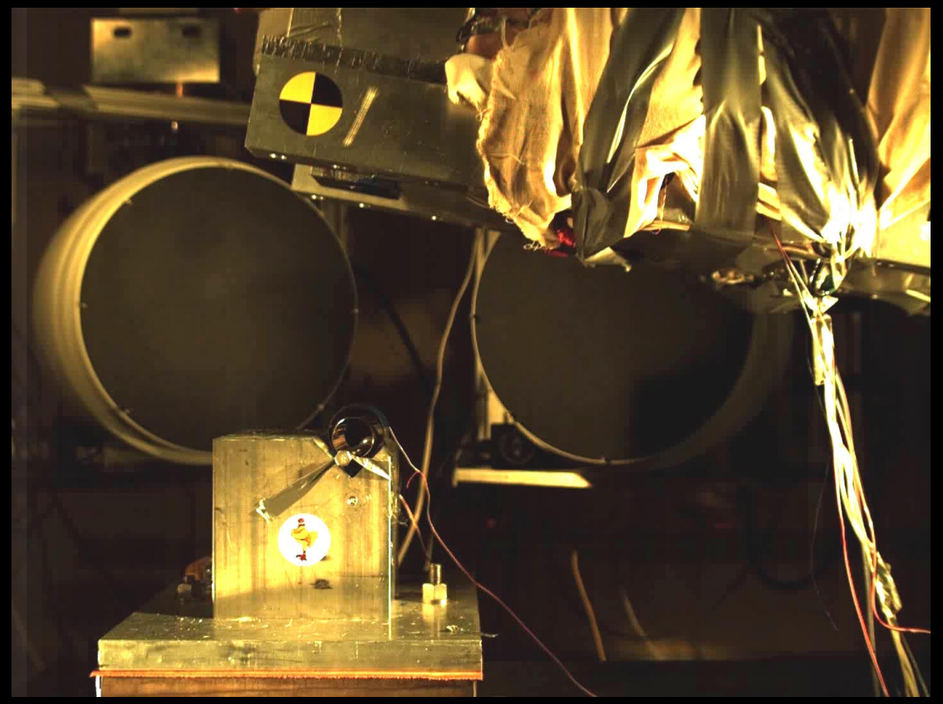
Morphed mesh



Identifying TBI thresholds using animal and human FE models

Göttingen mini-pigs





Identifying TBI thresholds using animal and human FE models

Animal testing

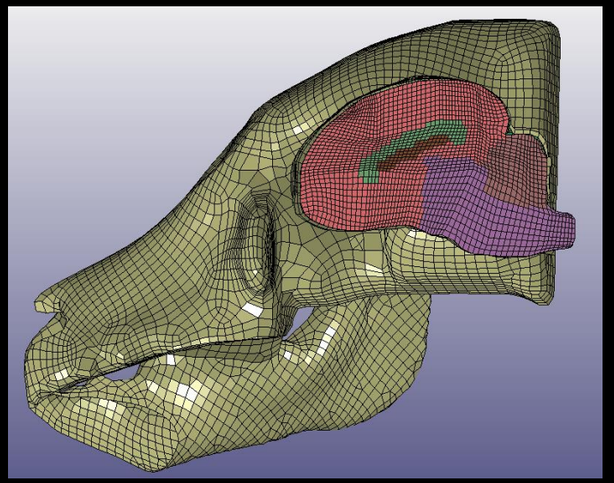
Animal finite element (FE) model

Human FE model

PMHS testing

Simulate Injury

Develop specific transfer function



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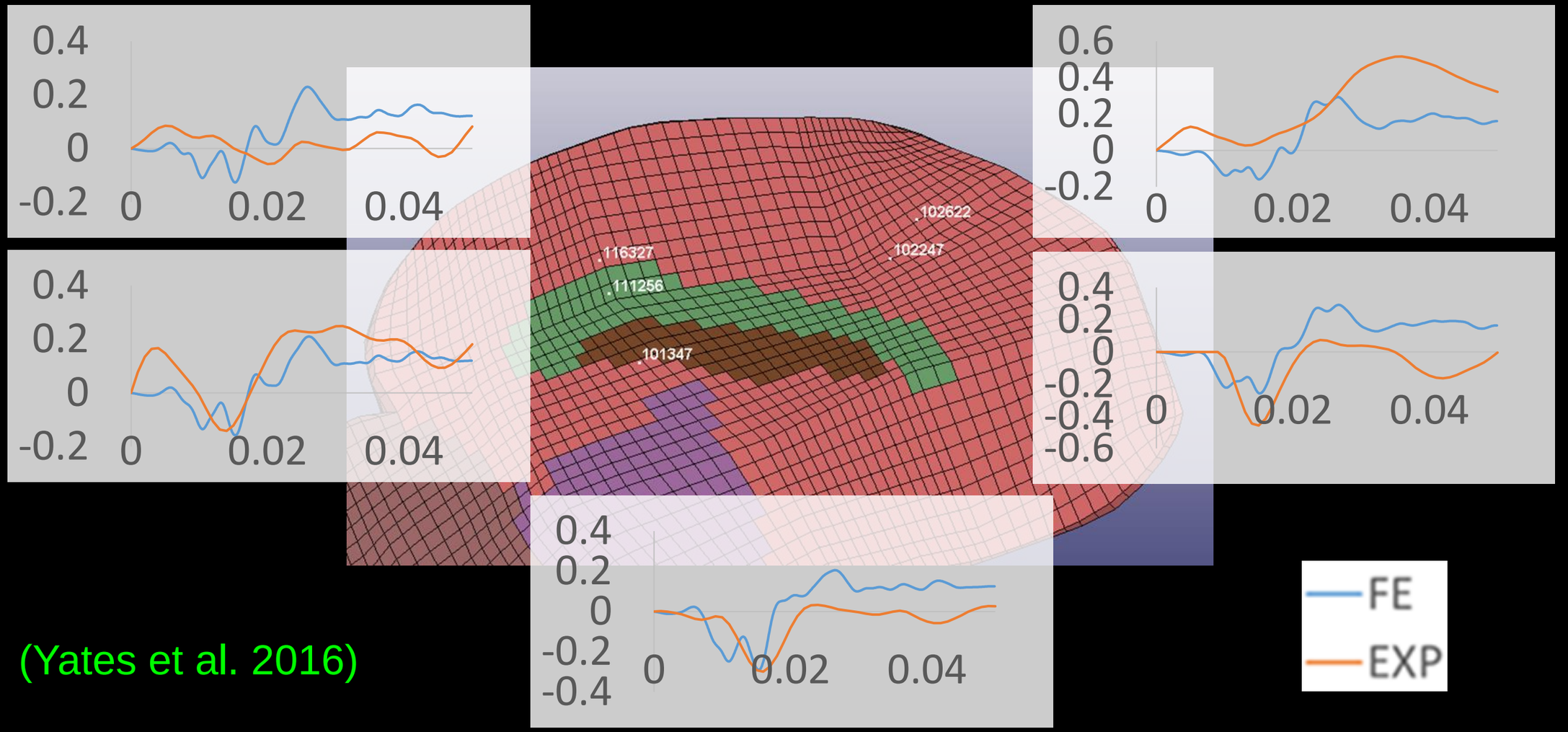
Results – Horizontal Displacement (mm) Time (s) Histories

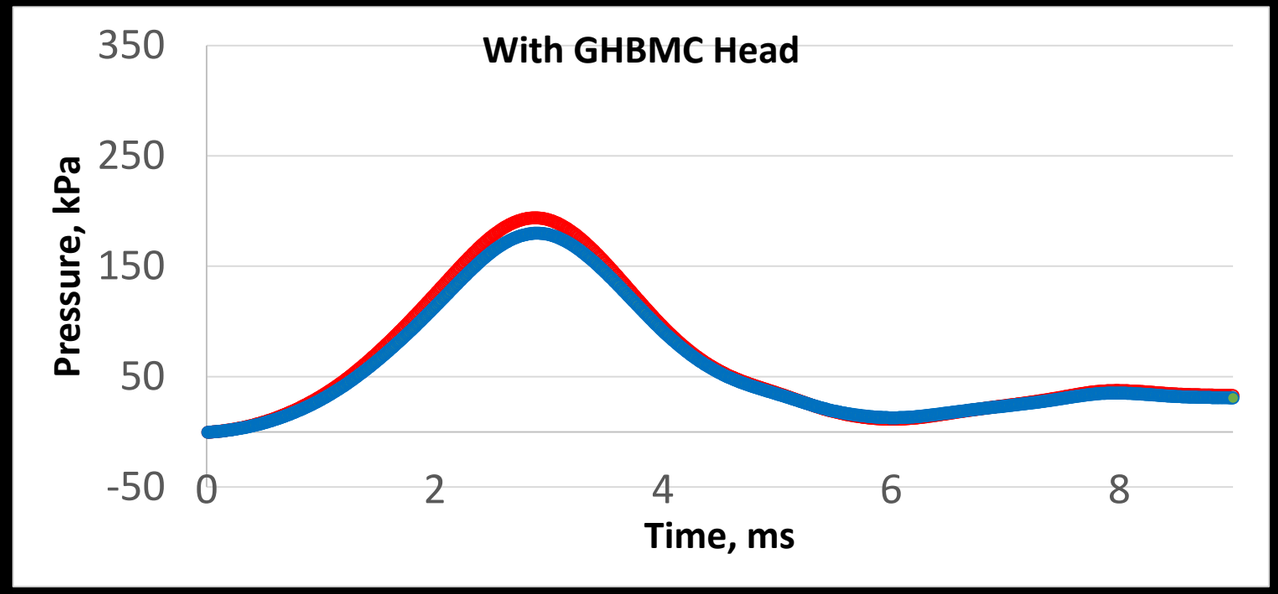


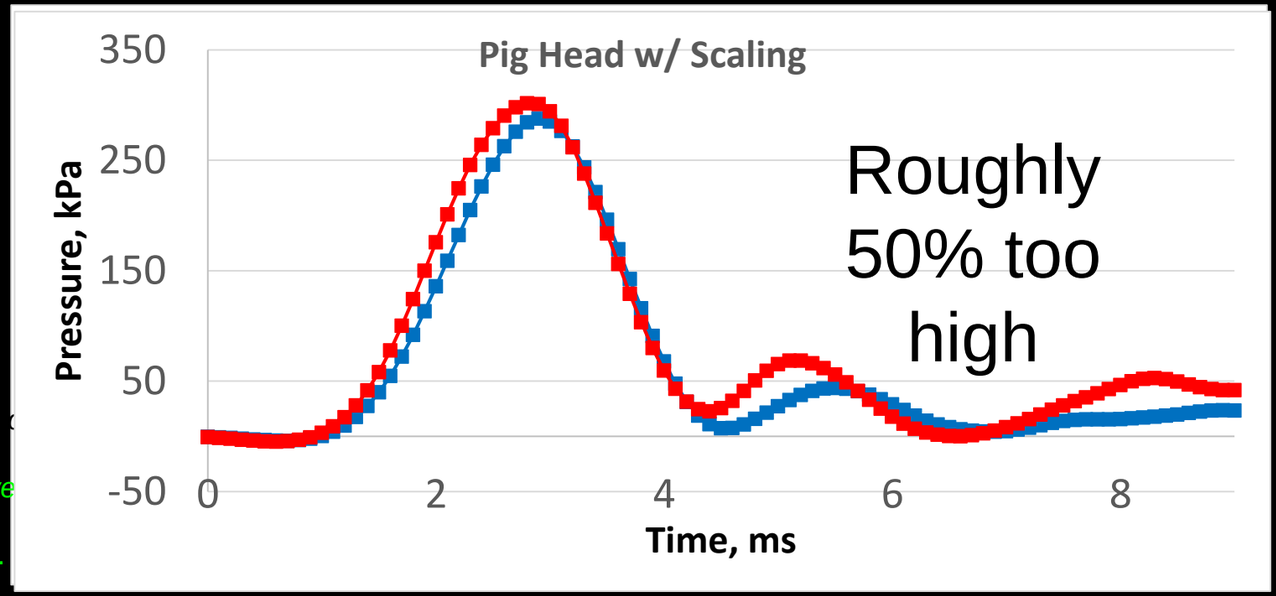
(Yates et al. 2016)

Identifying TBI thresholds using animal and human FE models

- Simulations can be run applying similar loadcases to human models
  - Allows investigation of scaling methods
  - Better scaling can be developed

(Yates et al. 2016)





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