

ARC Farside Meeting Update Task 3: Carotid Artery

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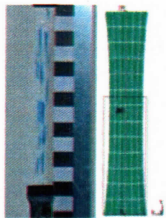
Center for Injury Biomechanics



Carotid artery modeling goals

- Computational model of the carotid artery for the prediction of injury
- What's been done:
 - Develop a robust material model and mesh of the artery (Gayzik et al. *RMBS*, 2005)
 - Organ level validation of the material model (Gayzik et al. *AAAM* 2006, Gayzik et al. *ASB* 2006)
- Currently:
 - Regional level neck model

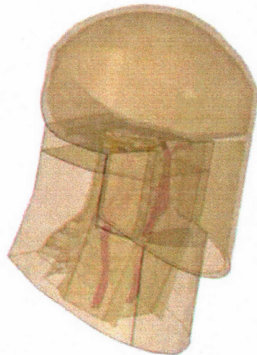
FE model development strategy



1. Tissue Level



2. Organ Level



3. Update: Regional Level

Review: Regional neck model

Materials:

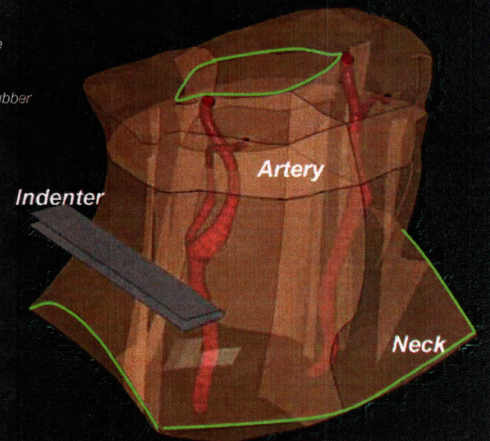
- Neck fascia & musculature
 - *Mat_Viscoelastic
- Carotid
 - *Mat_Simplified_rubber
- Indenter
 - *Mat_Rigid

Contact:

- Neck to carotid
 - Auto surf to surf
- Neck to neck
 - Tied

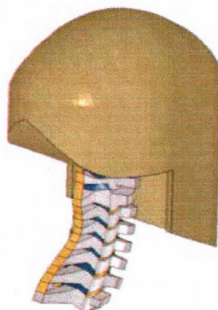
Boundary:

- Locked nodes on indenter
- Clara and medial vertebral body space



Update: Regional Model Integration with NHTSA Neck

- Integration of NHTSA model of the head and cervical spine
- Kleinberger, Stapp, 1993 "Application of Finite Element Techniques to the Study of Cervical Spine Mechanics"
- Application of MCW crash pulse on integrated model



Update: NHTSA neck model

Materials:

- Vertebral Bodies, Head
 - *Mat_Rigid
- Ligaments, Disks
 - *Mat_Elastic

Boundary Conditions:

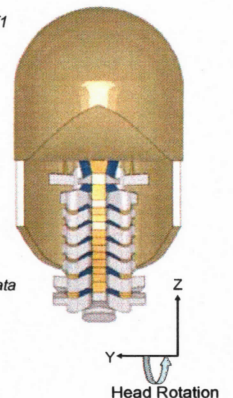
- Prescribed motion applied to T1 vertebral body

Contact:

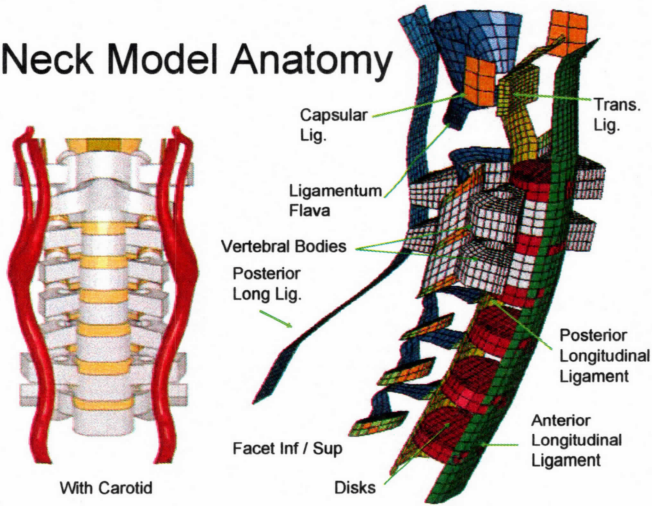
- Posterior ligament to posterior aspect of the head
 - nodes to surface
- Head Rotation about an anterior/posterior axis
 - constrained joint revolute

Validation:

- Axial Compression: Good agreement with experimental data (Pintar et al. Stapp, 1989) (Myers et al. Stapp 1991)
- Frontal Flexion: Not favorable agreement (Wismans, STAPP, 1984) (Wismans, STAPP, 1987)
- Lateral Flexion: No validation performed?**



Neck Model Anatomy



Regional model simulation matrix

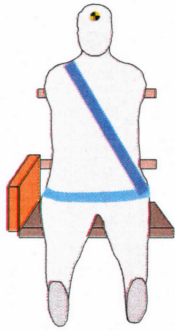
- Proposed Methods:**
- Apply T1 acceleration boundary condition
 - Validate with belt force data

Test matrix:

| PMHS Test No. | Carotid Injury | Belt Position | ΔV |
|---------------|----------------|---------------|------------|
| 134 | No | Low | Low |
| 135 | Yes | Low | High |
| 140 | Yes | High | Low |
| 141 | Yes | High | High |

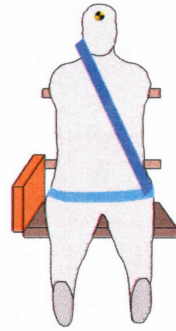
PMHS Belt Placement

Low Belt Configuration



D-Ring posterior to shoulder, Belt contacts shoulder

High Belt Configuration



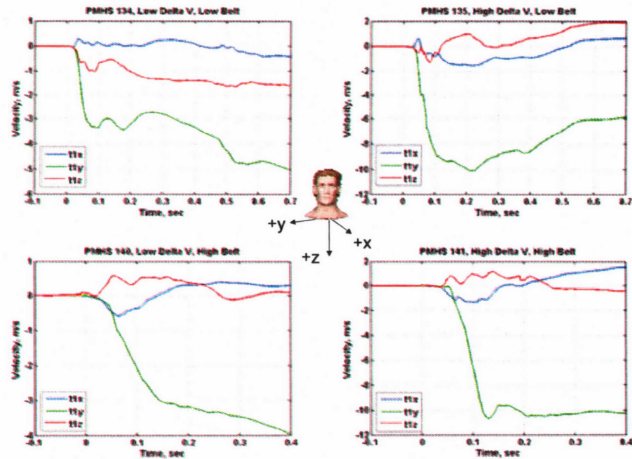
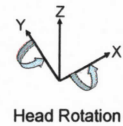
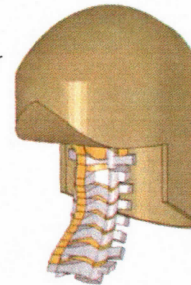
D-Ring superior and posterior to shoulder, Belt contacts neck

Update: Combined neck model; MCW Load Curves

- Materials:**
- Vertebral Bodies, Head
 - *Mat_Rigid
 - Ligaments, Disks
 - *Mat_Elastic
 - Neck fascia & musculature
 - *Mat_Elastic
 - Carotid
 - *Mat_Simplified_rubber

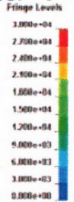
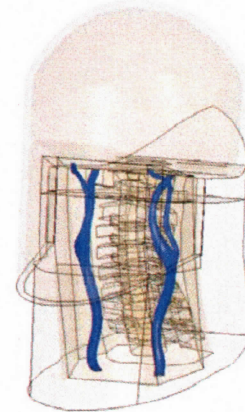
- Boundary:**
- Prescribed motion from PMHS tests applied to T1 vertebral body

- Contact:**
- Preserve NHTSA neck contacts
 - Top nodes of regional model to constrained to the head
 - Constrained extra nodes set
 - Neck to carotid
 - Tied surf to surf
 - Neck vertebral bodies to neck fascia
 - Auto surf to surf



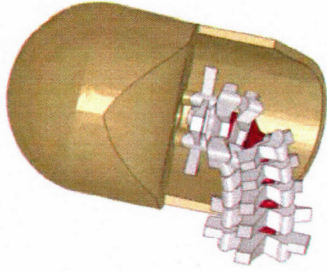
Combined Neck Model, Low Delta-V

Temp = 0
 Contents of Maximum Principal Stress
 max 981.5442
 min -0, at elem# 4022005
 max=30000, at elem# 6022005



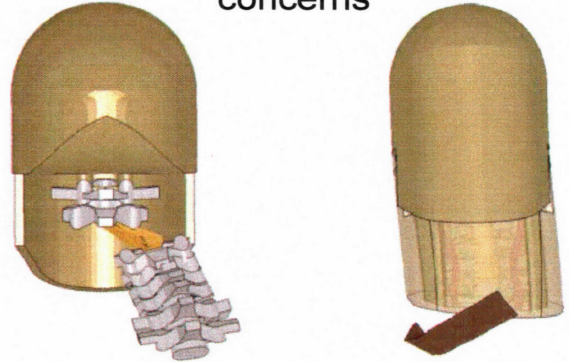
NHTSA Neck, High Delta-V Pulse

- Concerns:
 - Vertebral body nodal penetration
 - No contacts defined here
 - Facet nodal penetration
 - No contacts between facets
 - Negative volumes
 - Intervertebral Disks



Attempt to resolve by applying both T1 and Head CG as acceleration B.C.

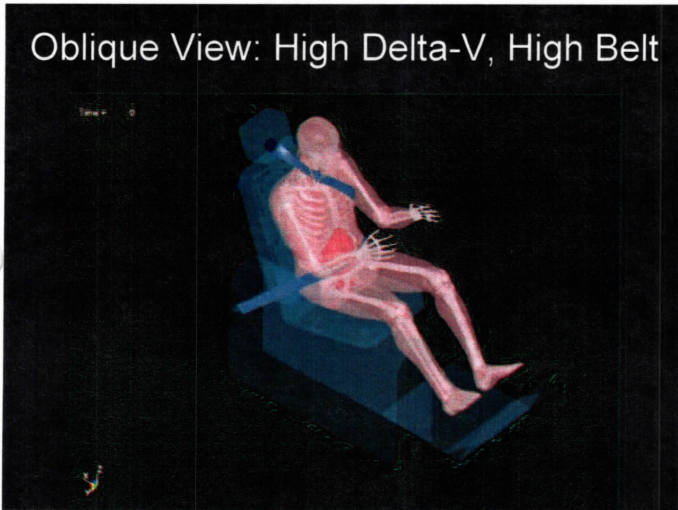
NHTSA Neck, Other modeling concerns



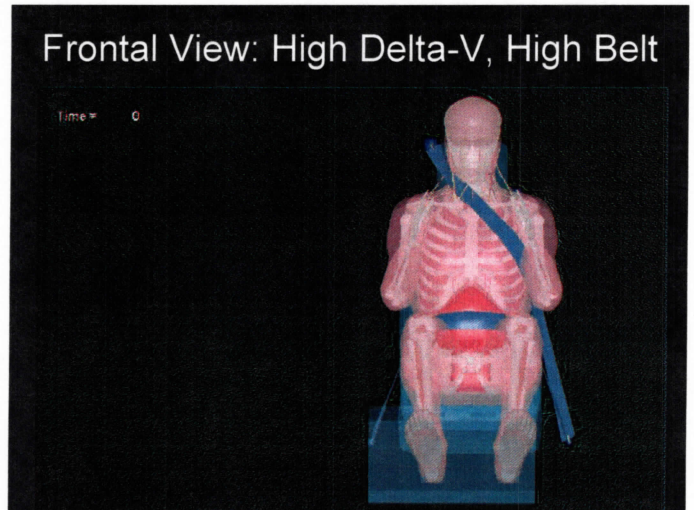
Application of Head CG and T1:
Resolve through THUMS Modeling

Low belt does not interact with neck:
Resolve by adding a shoulder form

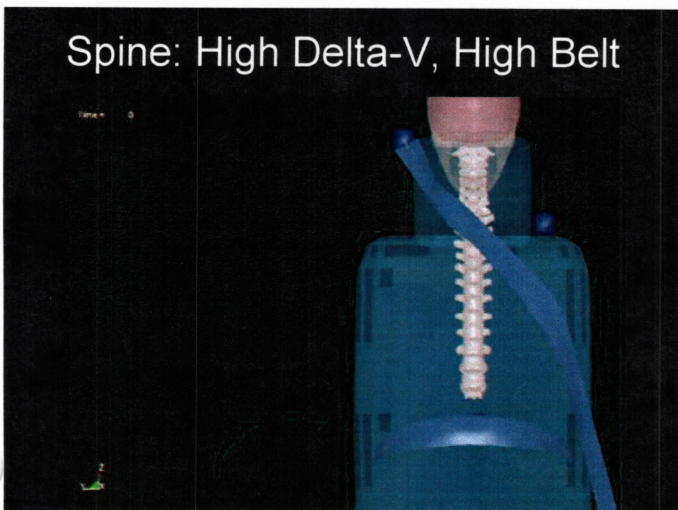
Oblique View: High Delta-V, High Belt



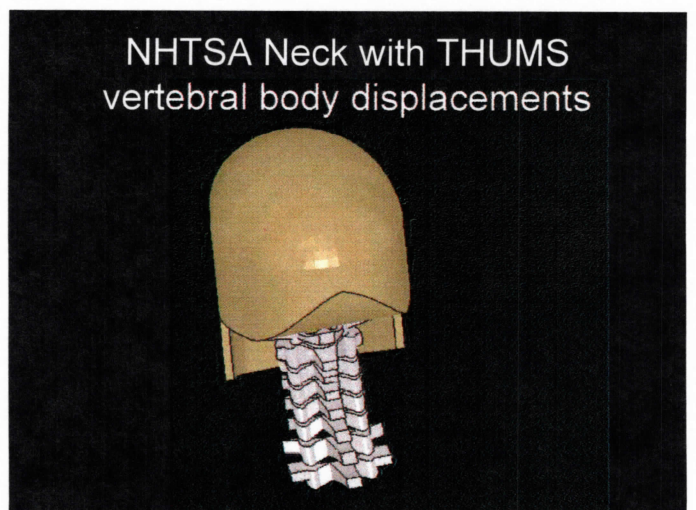
Frontal View: High Delta-V, High Belt



Spine: High Delta-V, High Belt



NHTSA Neck with THUMS vertebral body displacements

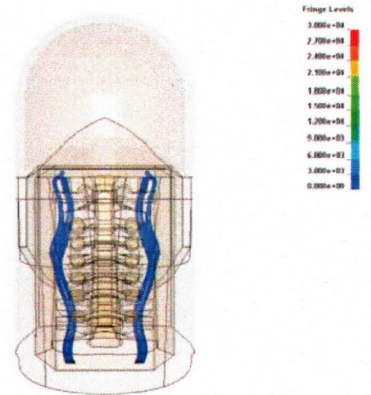


Summary of Update:

- Current modeling issues and tasks:
 - Regional neck model with embedded carotid artery
 - NHTSA neck in lateral flexion
 - Contacts, negative volumes, kinematics
 - Belt interaction with the neck fascia
 - Belt slips off of neck given a low belt

Current Focus

- Integrate THUMs results into full neck model
- Add shoulder interaction structure for the low belt case
- Assess strain in the carotid



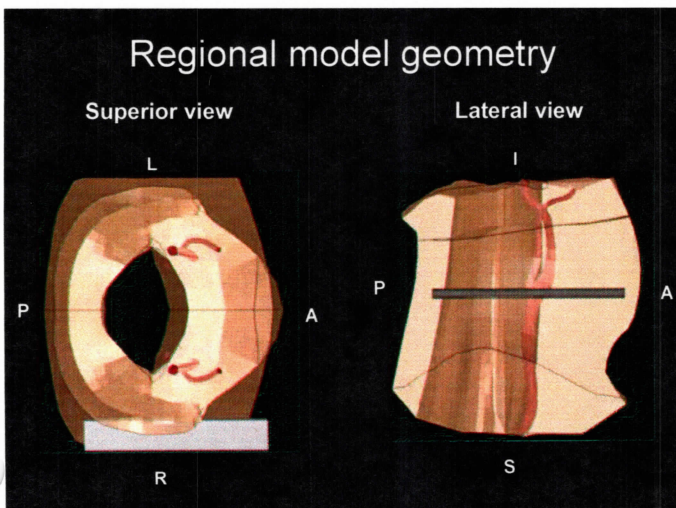
Acknowledgments

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 - Far Side Group
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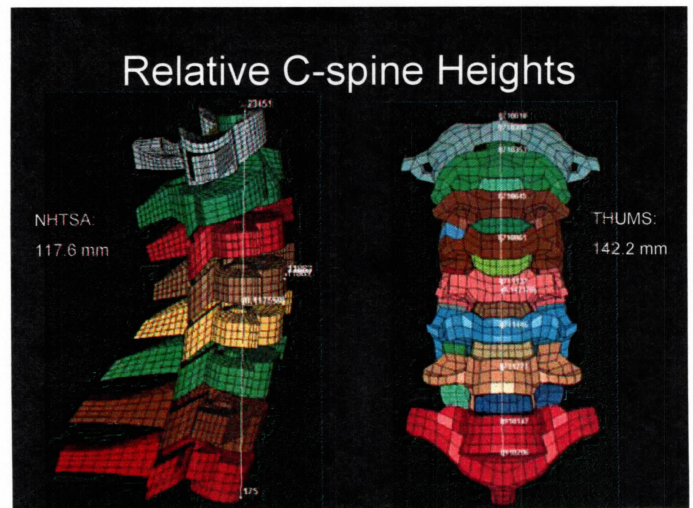
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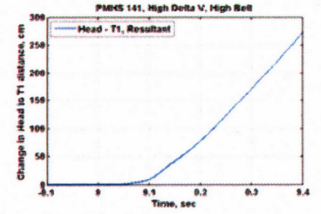
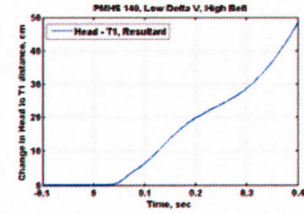
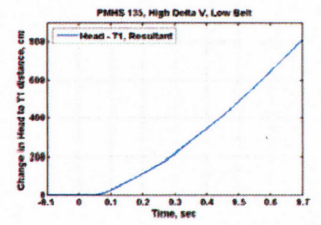
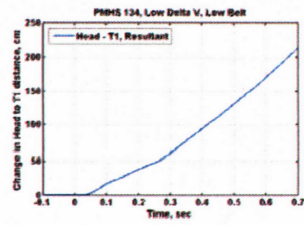
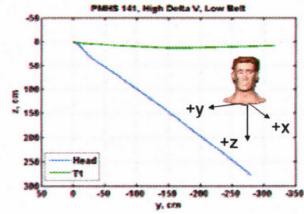
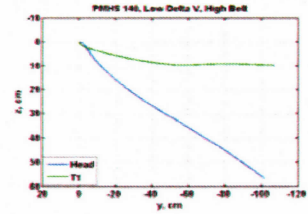
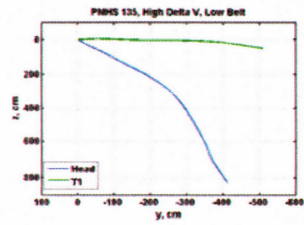
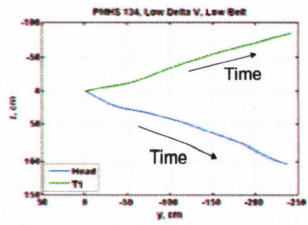
Supplemental Slides

Regional model geometry



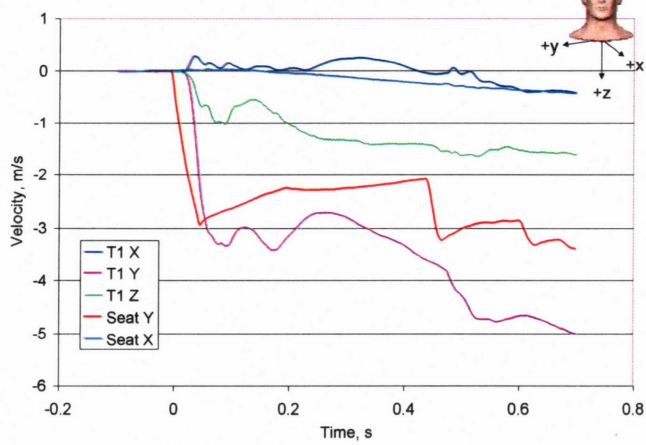
Relative C-spine Heights





$$\text{Resultant displacement} = (\Delta x^2 + \Delta y^2 + \Delta z^2)^{0.5}$$

Input data: PMHS 134, Low Delta-V, Low Belt



Input data: PMHS 135, High Delta-V, Low Belt

