THOR Update
GRSP Informal Working Group on Frontal Impact
April 18, 2012

Dan Parent
Human Injury Research Division
Test Device for Human Occupant Restraint

1992
- TAD-50M

2001
- THOR Alpha

2005
- THOR-NT

2009-2010
- Mod Kit

2011-2013
- Mod Kit THOR Evaluation
# THOR Schedule

## NHTSA Priority Plan

**2012 Plan**
- Update NHTSA-owned THOR ATDs
- THORAX chest, shoulder evaluation
  - Release Technical Data Package (TDP)
- Usability testing
- Biofidelity evaluation
- Injury criteria development
- Update THOR FE model

**2013 Plan**
- R&R testing to finalize:
  - Certification corridors
  - Seating procedure
  - Data processing procedures

## Agency Decision in 2013
Update NHTSA-owned THOR ATDs

- Two (2) Mod Kit THORs Under Evaluation
  - One Fabricated by Denton, FTSS, GESAC
    - Status: sled testing, vehicle testing
  - One Fabricated by Humanetics
    - Status: certification testing
    - Next: THORAX shoulder evaluation

- One (1) additional Mod Kit THOR Under Construction
  - Due April 2012

- One (1) Fully-Metric Mod Kit THOR Under Construction
  - Due June 2012
Update NHTSA-owned THOR ATDs

- Mod Kit components fabricated, installed by Humanetics
- Preliminary data show agreement with certification requirements

New Skull Casting Fabricated

Clavicle Load Cells, IR-TRACCs Installed

ASIS Load Cells, Attachment Point for Lifting Apparatus
THORAX Project Coordination: Chest Response

Objective

- Incorporate results of EU THORAX research
- Design includes chest, shoulder, and upper arm

Chest

- NHTSA, THORAX have similar impact response target in 4.3 m/s blunt impact
- Rib damping material thickness reduced compared to THOR-NT
  - Ribs 2, 3, 4 shaved to ~9mm
THORAX Project Coordination: SD3 Shoulder

- Updated “SD3” shoulder to be installed on 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, durability
- Evaluate biofidelity vs. PMHS response
  - Chest deflection
  - Shoulder belt loads
  - Head, shoulder trajectories

→ Decide on shoulder design
Standard vs. SD3

→ Finalize Mod Kit Technical Data Package (TDP)
Usability Testing: Small Overlap/Oblique Vehicle Tests

- Support NHTSA crashworthiness research in small overlap/oblique crash modes
- 15 vehicle tests completed
  - 8 Small Overlap
  - 7 Oblique
- Full results presented at SAE World Congress (Saunders et. al, 2012)

→ Refinements to Documentation
  - Polarity test checklist
  - Inspection guidelines
  - Data processing scripts
**Test: Head Contact Locations**

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Airbag</th>
<th>Side Curtain</th>
<th>Roof Rail</th>
<th>Door Panel</th>
<th>IP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC1</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC2</td>
<td>X</td>
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</tr>
<tr>
<td>PC3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>PC4</td>
<td>X</td>
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<tr>
<td>PC5</td>
<td>X</td>
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<td>PC6</td>
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</tr>
<tr>
<td>PU1</td>
<td>X</td>
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</tr>
</tbody>
</table>

Field Injury Source: 4% IAV / IARV, 28% IAV / IARV, 12% IAV / IARV (Rudd, 2011)

Br/15

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

IAV / IARV

PC1 PC2 PC3 PC4 PC5 PC6 SUV1 PU1

BR/15

0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

HIC15

PC1 PC2 PC3 PC4 PC5 PC6 SUV1 PU1

**SOI: Head Response**

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**SOI: Chest Deflections**

- **NASS/CIREN SOI: Chest injury sources**
  - Belt: 38%
  - Steering wheel: 16%

- **SOI Tests: Chest deflection sources**
  - Primarily belt interaction
  - Evidence of steering wheel interaction in smaller vehicles (e.g. PC2)
4 tests exceeded acetabulum IARV
2 tests exceeded femur IARV

2 tests that exceeded acetabulum IARV did not exceed femur IARV

Rudd (2011) showed that over half of acetabulum injuries occurred in absence of femur injury
# Biofidelity Evaluation

<table>
<thead>
<tr>
<th>Body Region</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Head</strong></td>
<td>Forehead Impact</td>
</tr>
<tr>
<td></td>
<td>Head Drop</td>
</tr>
<tr>
<td><strong>Neck</strong></td>
<td>NBDL Applied T1 Acceleration</td>
</tr>
<tr>
<td></td>
<td>Neck Pendulum Flexion/Extension Lateral Bending</td>
</tr>
<tr>
<td><strong>Thorax</strong></td>
<td>Upper Thorax Blunt Impact</td>
</tr>
<tr>
<td></td>
<td>Lower Thorax Oblique Blunt Impact</td>
</tr>
<tr>
<td></td>
<td>Gold Standard Sled Test</td>
</tr>
<tr>
<td><strong>Abdomen</strong></td>
<td>Upper Abdomen Steering Rim Impact</td>
</tr>
<tr>
<td></td>
<td>Lower Abdomen Rigid Bar Impact</td>
</tr>
<tr>
<td></td>
<td>Lower Abdomen Belt Loading</td>
</tr>
<tr>
<td><strong>Knee/thigh/hip</strong></td>
<td>Knee Slider Impact</td>
</tr>
<tr>
<td></td>
<td>Full-body Knee Impact</td>
</tr>
<tr>
<td></td>
<td>Dynamic Femur Compression</td>
</tr>
<tr>
<td><strong>Lower Extremity</strong></td>
<td>Inversion Eversion</td>
</tr>
<tr>
<td></td>
<td>Toe Impact</td>
</tr>
<tr>
<td></td>
<td>Heel Impact</td>
</tr>
</tbody>
</table>
Injury Criteria Development

- **Head**
  - Rotational brain injury criterion (BRIC)
  - See Saunders et. al 2012 SAE World Congress paper

- **Neck**
  - Combined criterion

- **Thorax**
  - Multi-point thoracic deflection

- **Abdomen**
  - Bi-lateral deflection

- **Knee-thigh-hip**
  - Femur and acetabulum loads

- **Lower extremity**
  - Revised Tibia Index, ankle rotation
THOR Finite Element Model (U. Virginia)

- THOR-NT FE model available for download from “Collab” website

- Currently incorporating Mod Kit components into model
  - Knee, thigh, hip
    - Knee slider ✓
    - Femur compression element ✓
    - Pelvis flesh
    - ASIS load cells
  - Lower Extremity
    - Ankle response
    - Molded shoe

- Future collaboration
  - SD3 model
  - Head, neck, thorax
THOR Tentative Schedule

- **Fabrication:**
  - Mod Kit THOR #1 (Upgrade)
  - Mod Kit THOR #2 (Upgrade)
  - Metric Mod Kit THOR (New)
  - Mod Kit THOR #3 (Upgrade)
  - Mod Kit THOR #4 (Upgrade)

- **Evaluation:**
  - Usability Evaluation (Vehicle, Sled Testing)
  - Biofidelity Evaluation
  - Thoracic Injury Criteria Development

- **Cert & Shoulder Install:**

- **Milestone:**
  - NHTSA Agency Decision

- **Testing:**
  - Round-Robin Testing
  - Evaluation and Documentation: Durability, Usability, Biofidelity
  - Finalization of Procedures: Certification, Seating, Data Processing

**KEY:**
- Completed
- In Progress
- Planned

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