APPLICATIONS OF THE THOR ATD IN NHTSA RESEARCH

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OUTLINE

• **THOR 50\textsuperscript{TH} MALE**
  ▫ Biomechanics
    • Biofidelity Evaluation
    • Injury Criteria Development
    • Repeatability and Reproducibility (R&R)
  ▫ Crashworthiness
    • Oblique Moving Deformable Barrier Test
    • Advanced Adaptive Restraints Program
    • Rear Seat Advanced Restraints
    • Rear Seat Restraints
    • Pre-impact Braking

• **THOR 5\textsuperscript{TH} FEMALE**
  ▫ Development
THOR TERMINOLOGY

THOR = Test Device for Human Occupant Restraint

THOR-NT
MFG: GESAC
Drawing Package Released on NHTSA Website in 2005

Modification Kit
MFG: FTSS/Denton/GESAC
Design work and manufacturing carried out in 2009-2010 under NHTSA contracts

THOR Mod Kit
MFG: Humanetics
Quantity = 4
Drawing Package to be Released by NHTSA

THOR Metric
MFG: Humanetics
Quantity = 3
Drawing Package to be Released by NHTSA

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See Ridella and Parent, 2011 ESV
BIOFIDELITY EVALUATION

• NHTSA VRTC, TRC

• OBJECTIVE
  ▫ Evaluate THOR response against biomechanical response corridors
  ▫ Head, neck, thorax, abdomen, knee/thigh/hip, lower extremity

• METHODOLOGY
  ▫ Impactor, sled testing
  ▫ Biofidelity Ranking System (BRS)

• FINDINGS TO DATE
  ▫ Thoracic biofidelity (2013 ESV)
    • THOR Mod Kit, Metric indistinguishable from human subject in biofidelity corridor
    • THOR achieved better BRS score than Hybrid III
INJURY CRITERIA DEVELOPMENT

• OBJECTIVE
  ▫ Develop injury risk functions applicable to THOR
  ▫ Adapt/apply existing human injury risk functions

• METHODOLOGY
  A: Paired testing with post-mortem human surrogates (PMHS)
  B: Computational extrapolation
  C: Development of transfer functions between THOR response and human response

• EXAMPLES
  A: 4-Point Thoracic Injury Criteria for THOR (UVa; previous presentation)
  B: BrIC (Takhounts, 2013 Stapp)
  C: Neck, knee/thigh/hip, lower extremity
REPEATABILITY AND REPRODUCIBILITY

• NHTSA VRTC, TRC, HUMANETICS

• OBJECTIVE
  ▫ Ensure within-ATD repeatability, ATD-to-ATD reproducibility, and lab-to-lab reproducibility are within acceptable thresholds.

• METHODOLOGY
  ▫ Certification/biofidelity impactor tests
  ▫ Testing using three THOR ATDs in at least two laboratories

• FINDINGS TO DATE
  ▫ Within ATD repeatability “excellent” or “good” in certification test conditions (THOR Mod Kit)
  ▫ THOR Metric ATD-to-ATD reproducibility “excellent” or “good” in nearly all certification test conditions (Humanetics)

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**CV Repeatability Assessment**

<table>
<thead>
<tr>
<th>CV %</th>
<th>Assessment</th>
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<tbody>
<tr>
<td>0 – 5%</td>
<td>Excellent</td>
</tr>
<tr>
<td>&gt;5 – 8%</td>
<td>Good</td>
</tr>
<tr>
<td>&gt;8 – 10%</td>
<td>Acceptable</td>
</tr>
<tr>
<td>&gt;10%</td>
<td>Unacceptable</td>
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SID-II's Final Rule; Docket No. NHTSA 25442

**Correlation Analysis Assessment**

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Phase</th>
<th>Shape</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
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OBLIQUE MOVING DEFORMABLE BARRIER TEST PROCEDURE

• CALSPAN

• OBJECTIVE
  ▫ Evaluate performance of vehicles in an impact condition suggested to be a high source of injury and fatality despite advanced restraint systems

• METHODOLOGY
  ▫ Impact with high-mass moving deformable barrier at 15° angle with 35% overlap

• FINDINGS TO DATE
  ▫ Despite good performance in IIHS small overlap test, some vehicles show high risk of head, chest, and knee/thigh/hip injury in oblique impact condition (Saunders, 2014 SAE-GIM)
  ▫ Response of far-side occupants not addressed by current restraint systems, resulting in a high risk of rotation-related brain injury
ADVANCED ADAPTIVE RERAINTS PROGRAM

• TAKATA

• OBJECTIVE
  ▫ Demonstrate the capability of an adaptive advanced restraint system to protect a wide range of occupants in the current and future fleet of vehicles

• METHODOLOGY
  A: Baseline sled tests using soft and stiff pulses, different ATDs (5\textsuperscript{th}, 50\textsuperscript{th} THOR, 95\textsuperscript{th}), and both full-frontal and oblique angles
  B: Optimization using finite element analysis refined using baseline tests
  C: Development, fabrication, and validation in subsequent sled tests

• FINDINGS TO DATE
  ▫ THOR FE model was implemented successfully
UNIVERSITY OF MICHIGAN TRANSPORTATION RESEARCH INSTITUTE, TRW

OBJECTIVE
- Demonstrate the potential for reduction in injury risk to rear-seat occupants using current and future restraint system technologies

METHODOLOGY
A: Baseline sled tests using soft and stiff pulses, different ATDs (5th, 50th THOR, 95th), and both full-frontal and oblique angles
B: Optimization using multi-body lumped-mass computational analysis refined using baseline tests
C: Development, fabrication, and validation in subsequent sled tests
REAR SEAT RESTRAINTS

- **NHTSA VRTC, TRC**
- **OBJECTIVE**
  - Evaluate effectiveness of production restraint systems when installed in a rear-seat environment
- **METHODOLOGY**
  - Sled tests with a simulated average NCAP pulse

EFFECT OF PRE-IMPACT BRAKING ON REAR SEAT OCCUPANT KINEMATICS

- **NHTSA VRTC, TRC**
- **OBJECTIVE**
  - Measure the response of a rear-seat occupant during pre-impact braking using human volunteers and human surrogates
- **METHODOLOGY**
  - Position occupants in the rear seat of a moving vehicle and apply brake; record occupant response on video
- **FINDINGS TO DATE**
  - See Prasad - Effects of Pre-impact Braking on Rear Seat Occupant Kinematics (G104)
OTHER STUDIES

• LOW-SPEED SENSITIVITY
  ▫ VRTC / TRC (Rhule, 2011 ESV)
  ▫ THOR exhibits sufficient sensitivity to be used in low-speed impacts

• ABDOMEN BIOFIDELITY EVALUATION
  ▫ Toyota / IFSTTAR / VRTC
  ▫ Assessment of the existing and prototype abdomen in rigid bar impact and belt loading conditions

• ROLLOVER
  ▫ University of Virginia CAB
  ▫ Response of THOR in a controlled laboratory vehicle rollover event

• COMPUTATIONAL ANALYSIS
  ▫ George Washington University NCAC, National Center for Manufacturing Sciences
  ▫ Simulation of THOR FE Model in Oblique RMDB test mode

• NASA (not NHTSA-funded)
  ▫ Newby, 2013 Stapp
  ▫ Evaluated THOR in X-, Y-, and Z-axis surrogate for orbital lander environment
THOR 5TH FEMALE ATD

• **OBJECTIVE**
  ▫ Apply advances in biofidelity, durability, repeatability, and usability from THOR 50th Mod Kit and Metric ATDs to THOR 5th design

• **METHODOLOGY**
  ▫ Update existing THOR 5th drawing package to Mod Kit design level using either scaled versions of THOR 50th parts or redesign as necessary

• **FINDINGS TO DATE**
  ▫ Anthropometry assessment complete (UMTRI, 2013)
    ▪ Overall anthropometry of existing THOR 5th design is representative of current 5th female population
    ▪ Some local adjustments are necessary, such as increasing upper arm length, updating pelvis flesh design to match THOR 50th mod kit design level, and improvement to thorax design to improve belt fit.
  ▫ Proof-of-concept using head design completed in 2013; remainder of ATD underway