

APPLICATIONS OF THE THOR ATD IN NHTSA RESEARCH

Dan Parent

Human Injury Research Division

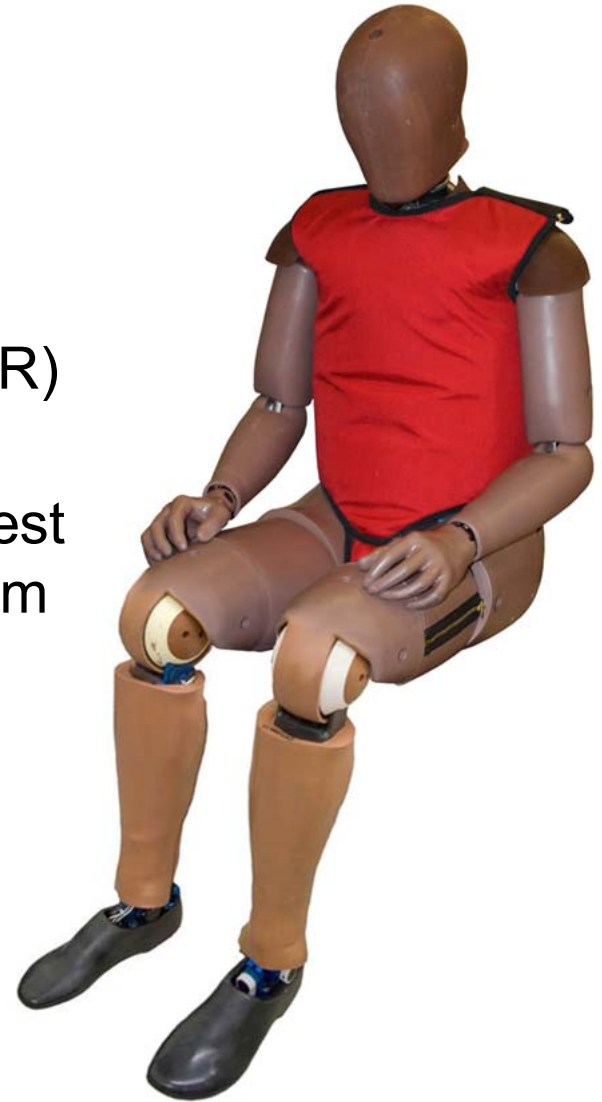
National Highway Traffic Safety Administration



THIS IS A U.S. GOVERNMENT WORK NOT SUBJECT TO COPYRIGHT PROTECTION IN THE U.S.
IT MAY BE COPIED AND DISTRIBUTED WITHOUT PERMISSION AND WITHOUT LIMITATION.

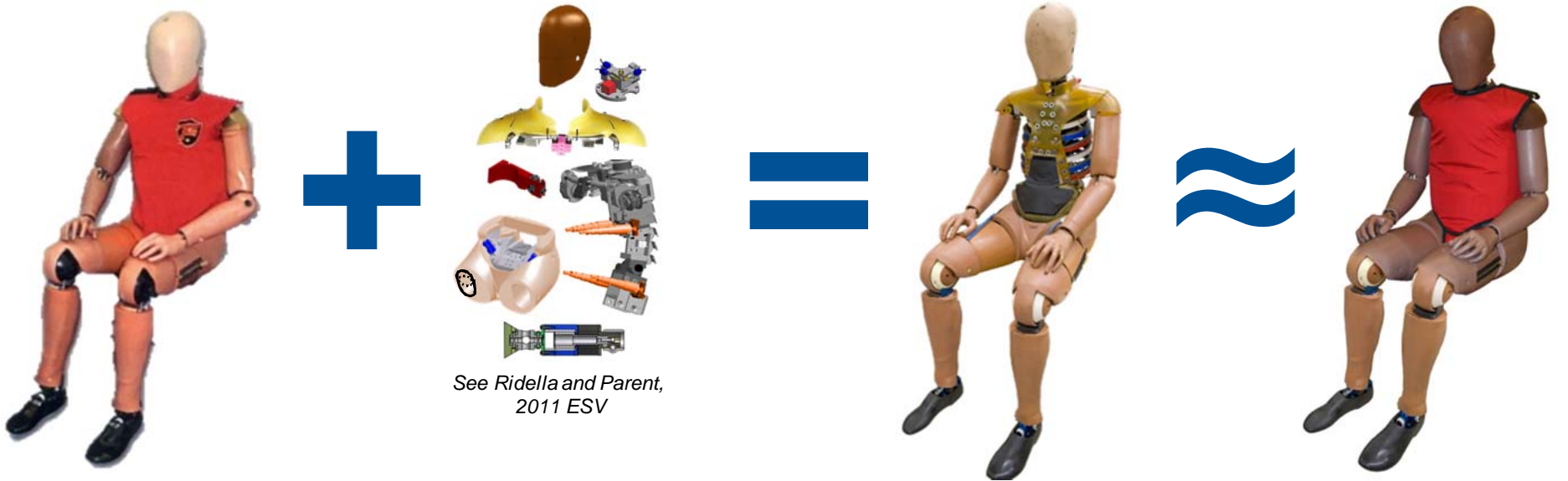
OUTLINE

- **THOR 50TH 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 5TH FEMALE**
 - Development



THOR TERMINOLOGY

THOR = Test Device for Human Occupant Restraint



See Ridella and Parent,
2011 ESV

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

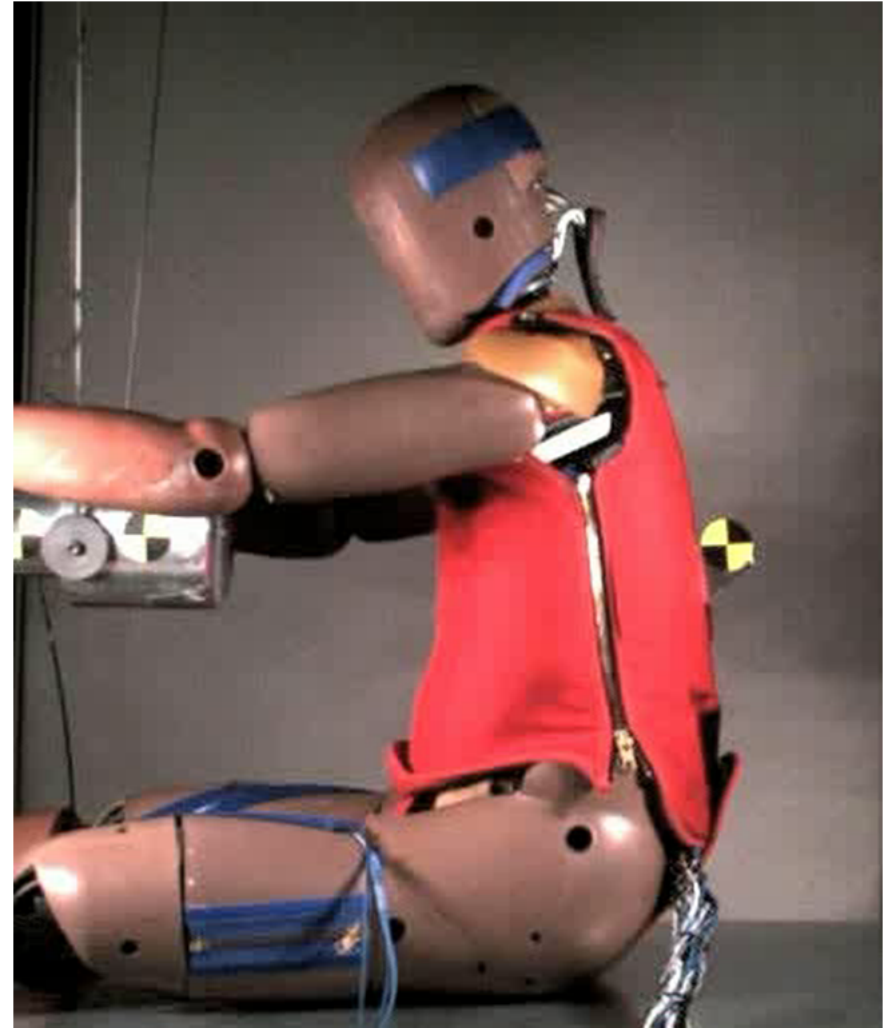
THOR Metric

MFG: Humanetics
Quantity = 3

Drawing Package to be
Released by NHTSA

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

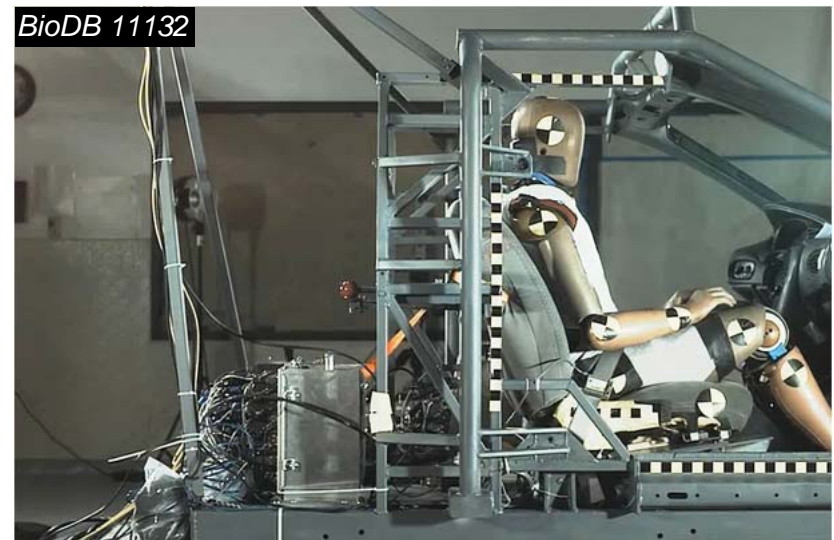
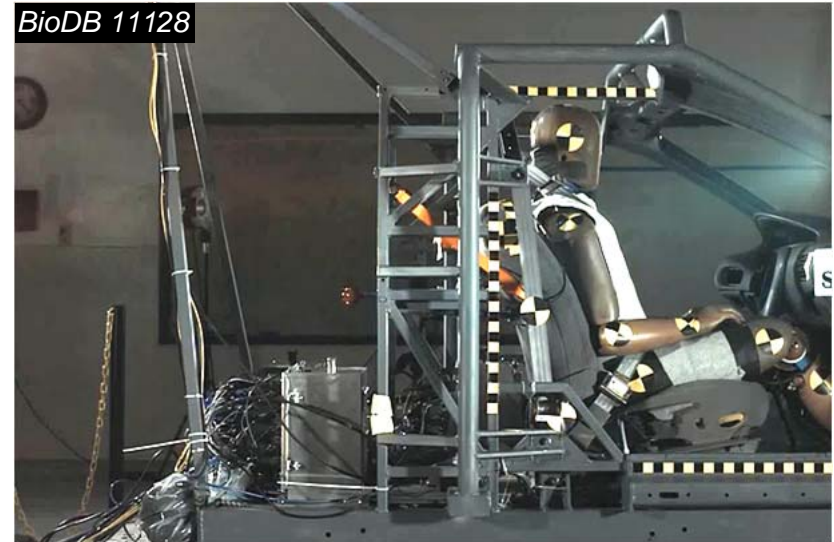
C: Development of transfer functions between THOR response and human response

- **EXAMPLES**

A: 4-Point Thoracic Injury Criteria for THOR (UVa; previous presentation)

B: BrIC (Takhounts, 2013 Stapp)

C: Neck, knee/thigh/hip, lower extremity

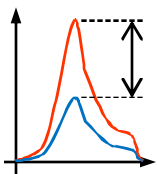
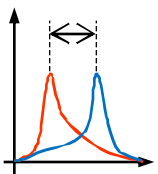
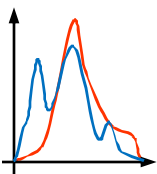


REPEATABILITY AND REPRODUCIBILITY

- **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)

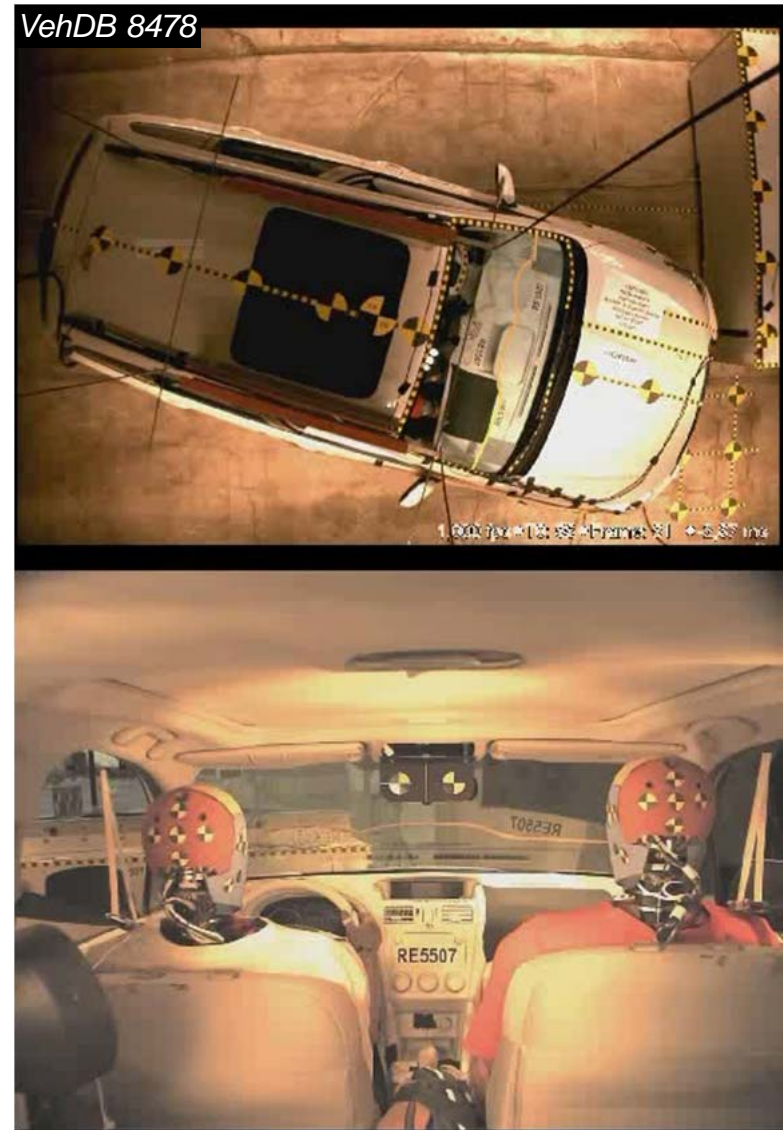
CV Repeatability Assessment	
0 – 5%	Excellent
>5 – 8%	Good
>8 – 10%	Acceptable
>10%	Unacceptable

SID-IIs Final Rule; Docket No. NHTSA 25442

Correlation Analysis Assessment		
Magnitude	Phase	Shape
		

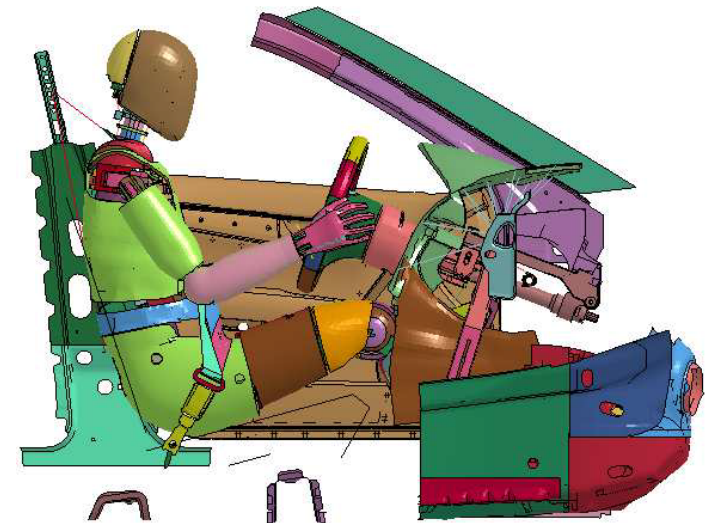
OBLIQUE MOVING DEFORMABLE BARRIER TEST PROCEDURE

- **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

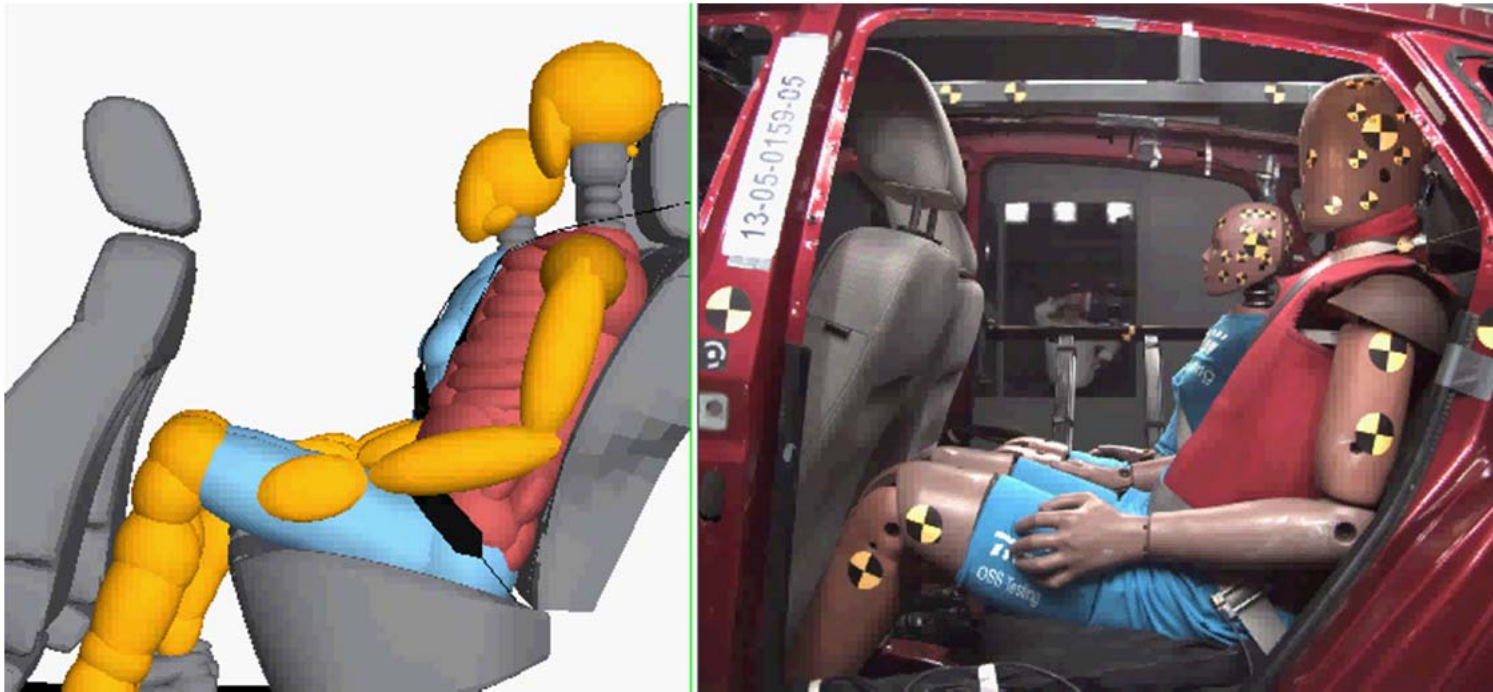


ADVANCED ADAPTIVE RESTRAINTS PROGRAM

- **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 (5th, 50th THOR, 95th), 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



REAR SEAT ADVANCED RESTRAINTS



- **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



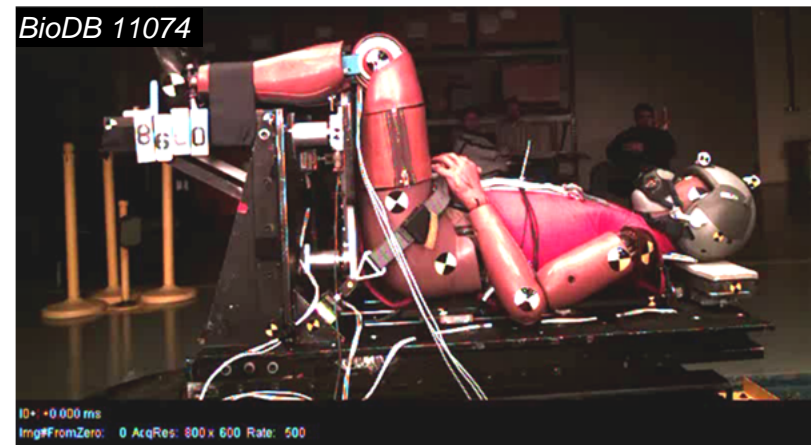
EFFECT OF PRE-IMPACT BRAKING ON REAR SEAT OCCUPANT KINEMATICS

- **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