



Biofidelity Assessment of THOR-50M and H3 50th ATDs in Rear-Facing Rigid Seat Tests

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Overview & Goals

- Evaluate and compare ATD responses to PMHS
 - Biofidelity
 - Injury assessment
 - Effect of seat recline angle
- Match PMHS as closely as possible
 - Instrumentation
 - Positioning
- Identify areas in need of improvement
 - Improve biofidelity
 - Flexible positioning in various recline angles
 - Added instrumentation in areas where injuries occur
 - Protect sensors from damage



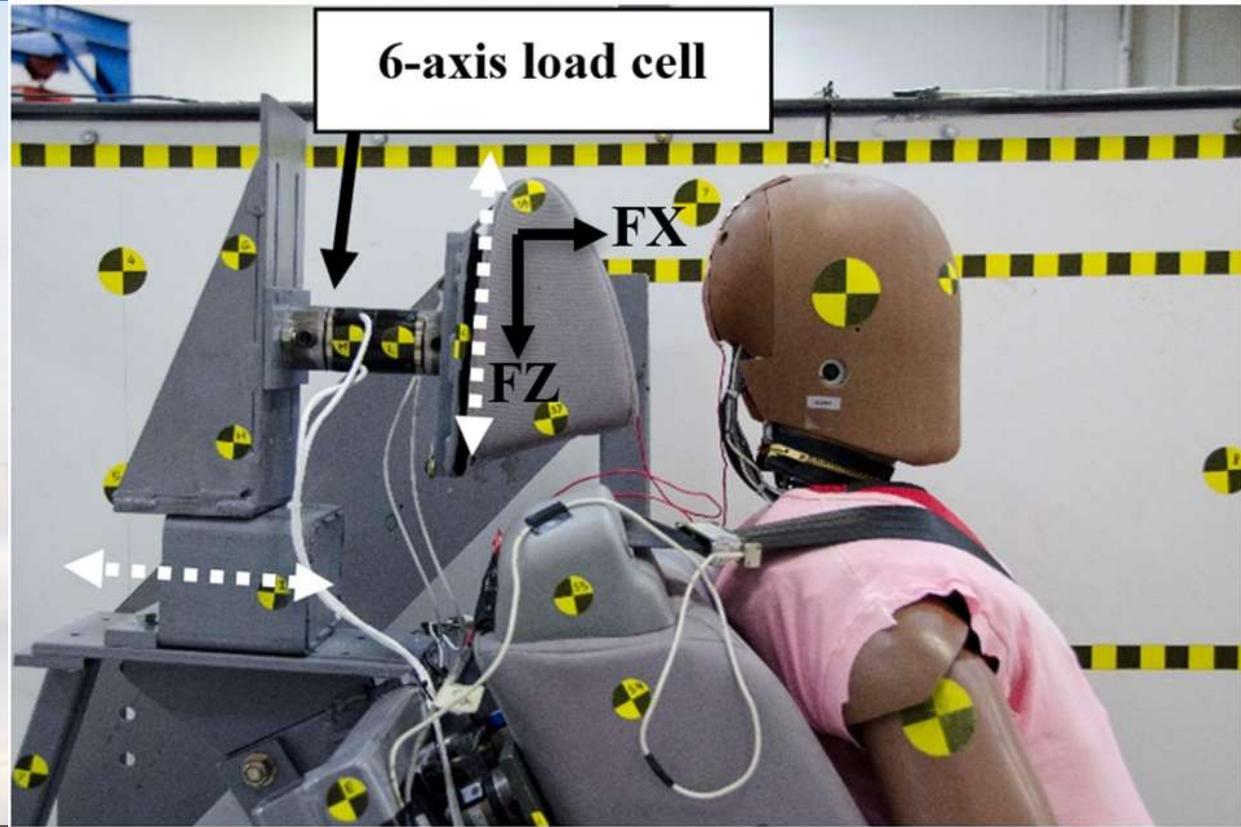
Hybrid III 50th



THOR 50M

Methods: Sled Buck Design

- Adjustable HR
 - forward
 - aft
 - up
 - down
- 6-axis load cell behind HR
- Accels on HR plate



Methods: Sled Buck Design

- Adjustable seatback recline
 - 25° and 45° used in these tests
- Three load plates behind seatback:
 - top, mid, bottom
 - 6-axis load cells on left and right sides of each plate
 - accel on each plate



Methods: Seats Tested

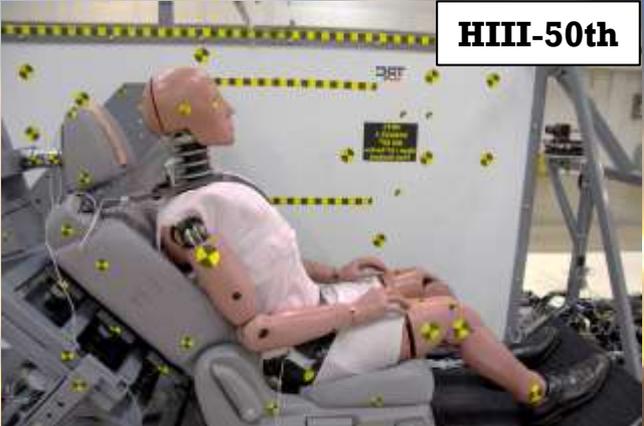
- 2018 Honda Odyssey second row ABTS(all belts to seat)



- 2018 Honda Accord (manual seat)



Methods: ATDs Tested



Methods: Test Severity

- Pulse – same as PMHS
- “high” speed
 - NCAP 56 kph, 35.9 – 53.7 G
- “low” speed
 - 24 kph, ~10.3 G

Methods: Test Matrix

Occupant		25° Recline	45° Recline	25° Recline	45° Recline
		Odyssey Seat Tests		Accord Seat Tests	
56 kph	THOR-50M	3	3	3	2*
	Hybrid III 50 th	3	3	3	3
	THOR-AV	1	1	1	1
24 kph	THOR-50M	3	3	2	2
	Hybrid III 50 th	3	3	1	0
	THOR-AV	0	0	0	0
	BIORID-II	2	2	0	0

* Head restraint & neck failures

Methods: Test Matrix

Occupant		25° Recline	45° Recline	25° Recline	45° Recline
		Odyssey Seat Tests		Accord Seat Tests	
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	Hybrid III 50 th	3	3	3	3
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	Hybrid III 50 th	3	3	1	0
	THOR-AV	0	0	0	0

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Methods: Test Matrix

Occupant		25° Recline	45° Recline			25° Recline	45° Recline
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	Hybrid III 50 th	3	3			3	3
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	Hybrid III 50 th	3	3			1	0

* Head restraint & neck failures

Methods: Test Matrix

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	Hybrid III 50 th	3	3	3	3

* Head restraint & neck failures

Methods: Test Matrix

Occupant		25° Recline	45° Recline
		Odyssey Seat Tests	
56 kph	THOR-50M	3	3
	Hybrid III 50 th	3	3

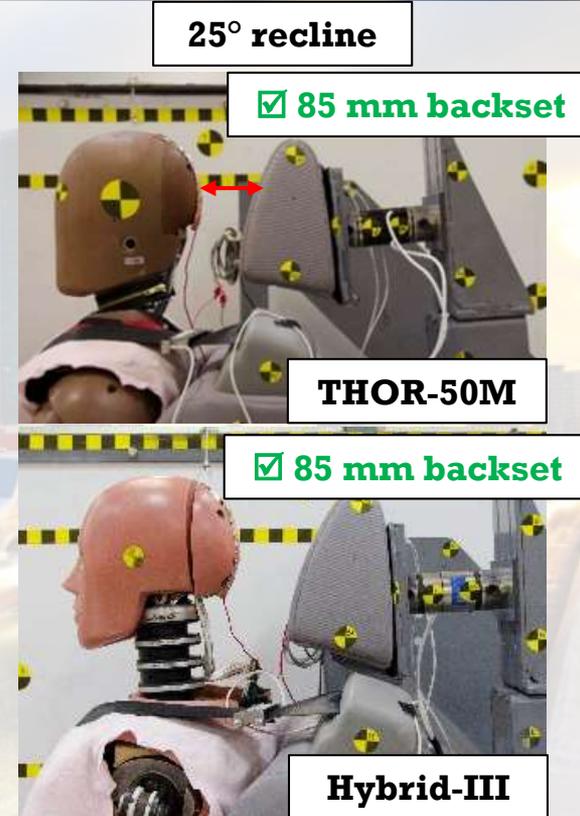
Methods: ATD Positioning

- Match PMHS as closely as possible
- Used UMTRI seating technique

<https://deepblue.lib.umich.edu/handle/2027.42/146263>

Reed, M. and Ebert, S., “Effects of Recline on Passenger Posture and Belt Fit”, UMTRI-2018-2, September 2018.

- At 25° recline:
 - Backset achieved in both ATDs

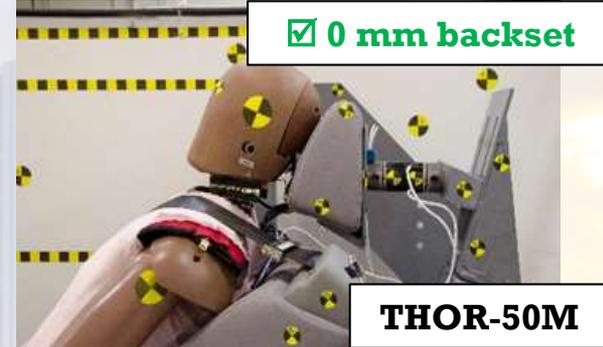


Methods: ATD Positioning

- At 45° recline:
 - THOR-50M
 - Lumbar set “erect”
 - THOR spine more flexible to position compared to H3
 - Achieved contact with HR
 - H3
 - H3 neck angle cannot be adjusted if neck load cell installed
 - Stiff spine
 - Head would NOT contact HR
 - Results in increased head impact forces

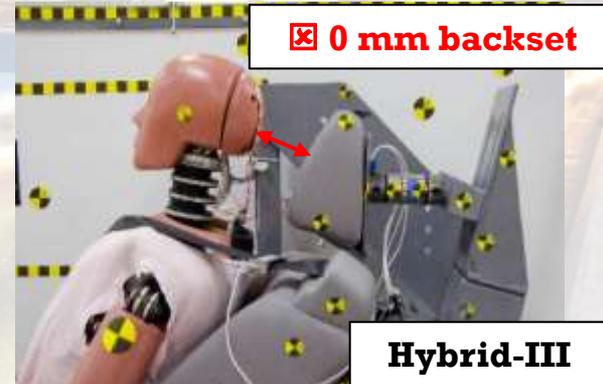
45° recline

0 mm backset



THOR-50M

0 mm backset



Hybrid-III

Methods: Test Matrix

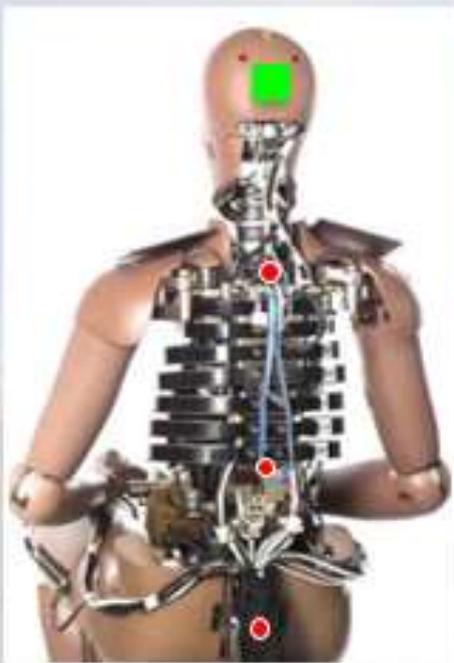
Occupant		25° Recline	45° Recline
		Odyssey Seat Tests	
56 kph	THOR-50M	3	3

Methods: Tests discussed today

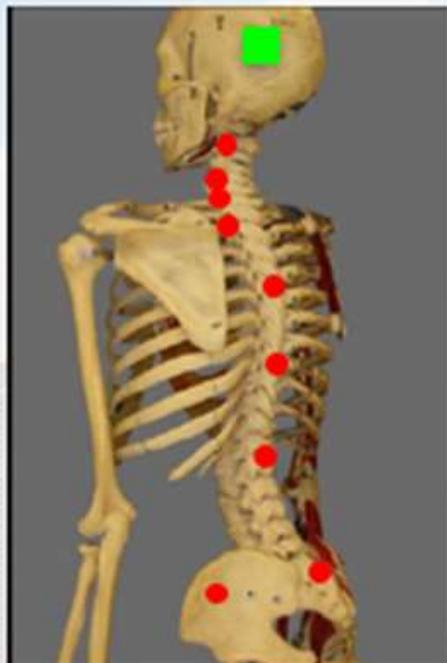
- THOR-50M
- Odyssey seats
- 25° (3 tests) and 45° (3 tests) recline angles
- 56 kph



Methods: THOR vs. PMHS Instrumentation



THOR-50M



PMHS

	THOR-50M	PMHS
Head	■	■
Chest	■	■
C2/4/6	load cell	●
T1	●	●
T4	N/A	●
T6	●	N/A
T8	N/A	●
T12	●	●
Pelvis	load cell ●	● ●
Femur	load cell	● ■
Tibia	load cell	● ■

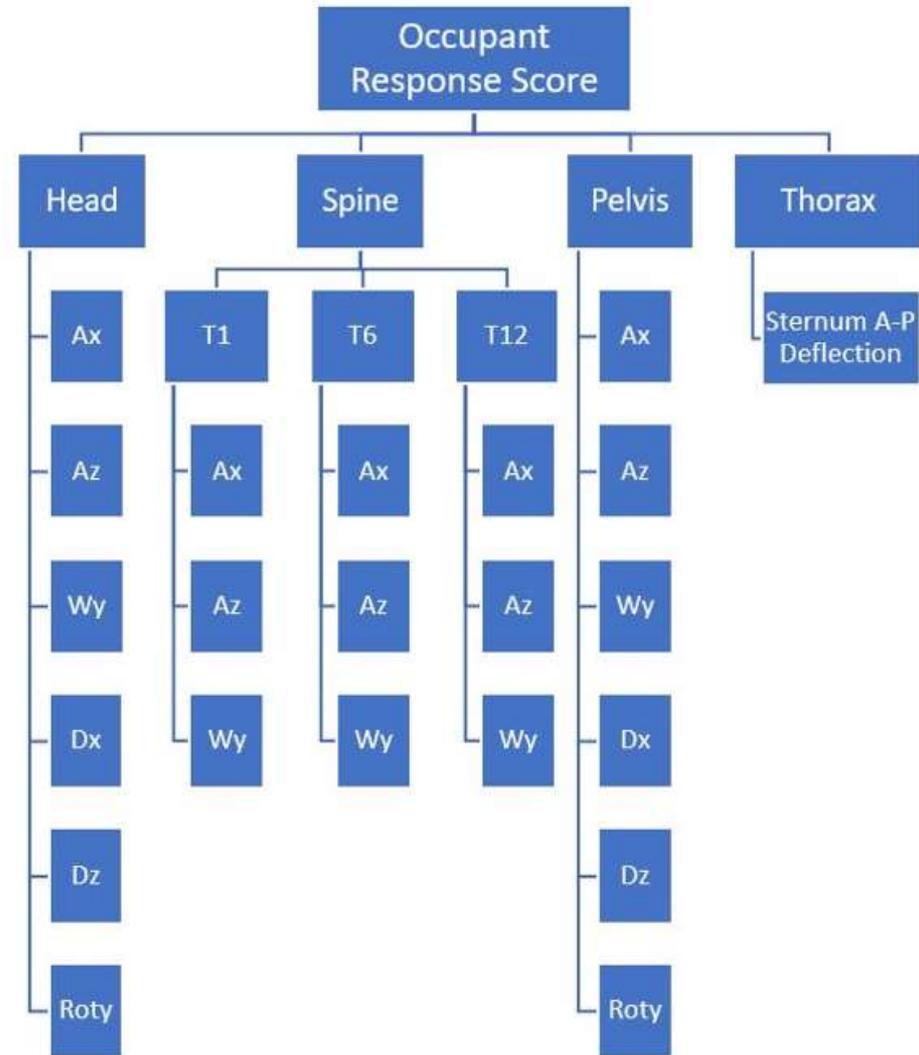
- Coplanar 6a ω
- 3a ω
- Chestband
- Strain Gauges

Methods: Data Processing BRS

- Biofidelity Ranking System (BRS) scores were calculated using *updated* version of BRS (soon to be published) that builds/improves off of Rhule et al. 2018
 - Rhule, H., Stricklin, J., Moorhouse, K., Donnelly, B. 2018. Improvements to NHTSA's Biofidelity Ranking System and Application to the Evaluation of the THOR 5th Female Dummy, IRCOBI Conference, Athens, Greece.
- Updated BRS approach:
 - 1) Align phase between ATD and PMHS
 - 2) Calculate BRS score
 - 3) Report Dummy Phase Shift (along with mean/max PMHS Phase Shift determined when building Biofidelity Corridors)
- Lower Biorank = better biofidelity
 - BRS Score represents multiples of standard deviations from mean PMHS response

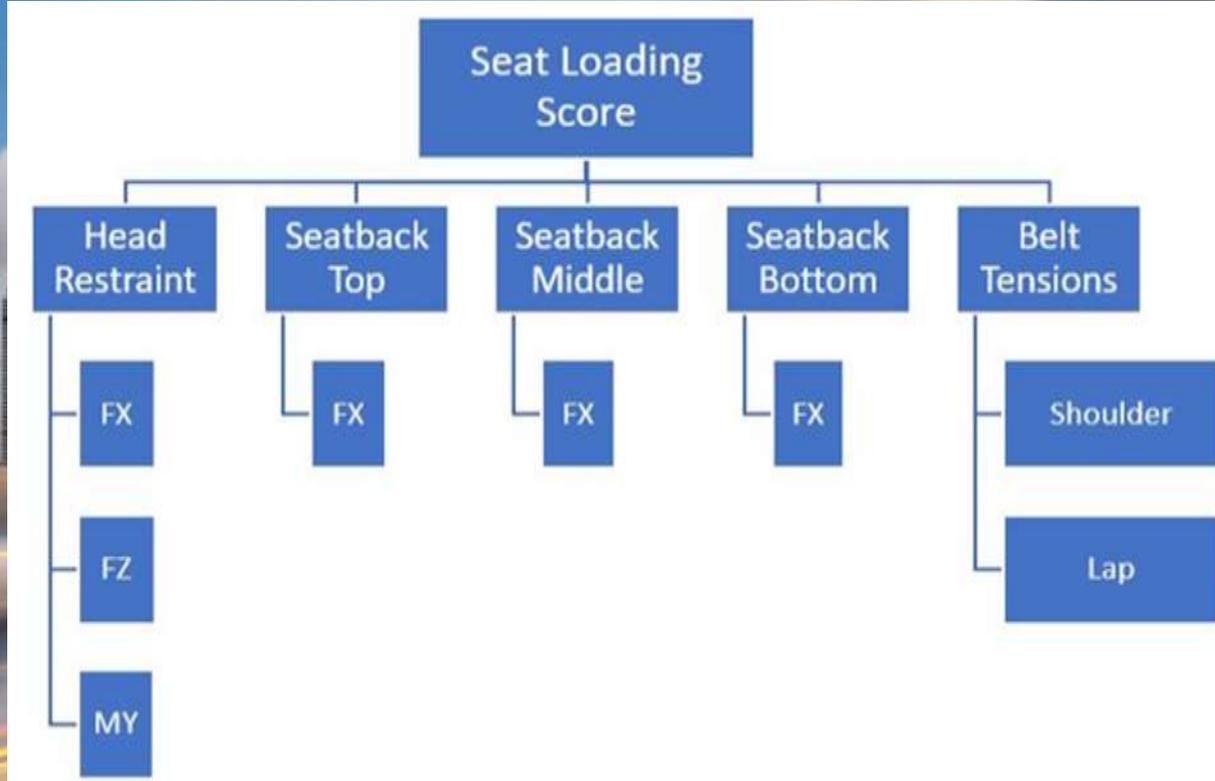
Methods: Occupant BRS

- Occupant scores calculated from
 - Head
 - Spine
 - Pelvis
 - Thorax
- TOTAL occupant response score calculated from average of individual scores

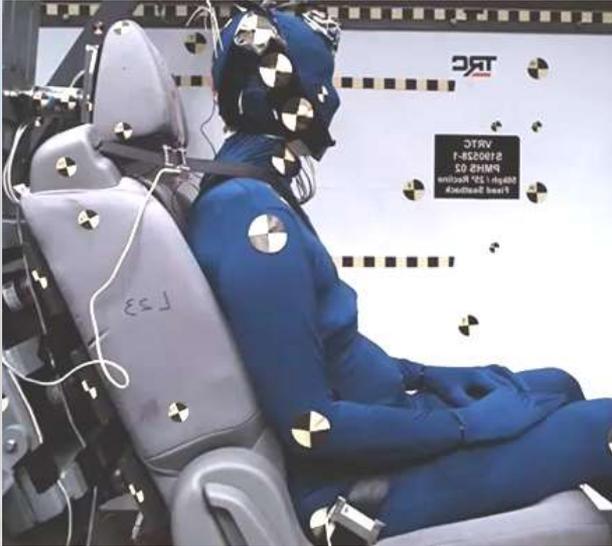


Methods: Seat Loading BRS

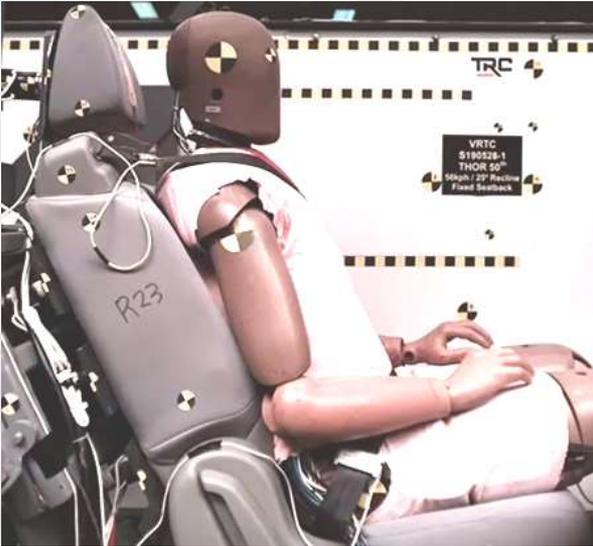
- Seat scores calculated from
 - Head restraint
 - Seatback top
 - Seatback middle
 - Seatback bottom
 - Belt tensions
- TOTAL seat loading score calculated from average of individual scores



Results: High Speed Videos 25° Recline



PMHS



THOR-50M

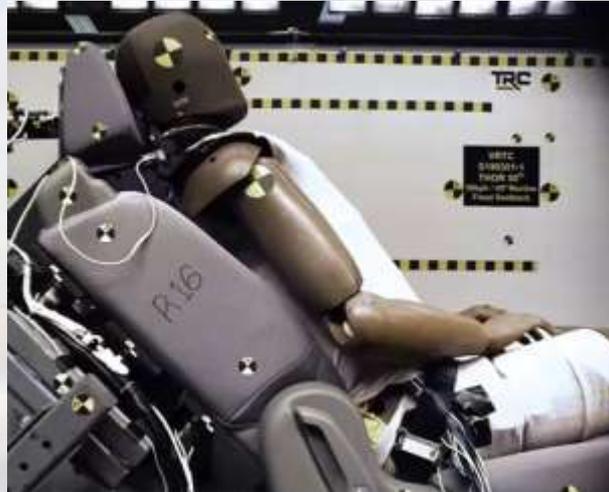


Hybrid III 50th

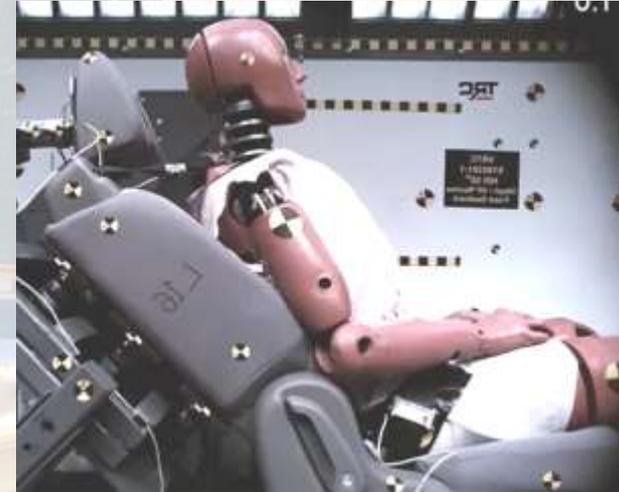
Results: High Speed Videos 45° Recline



PMHS

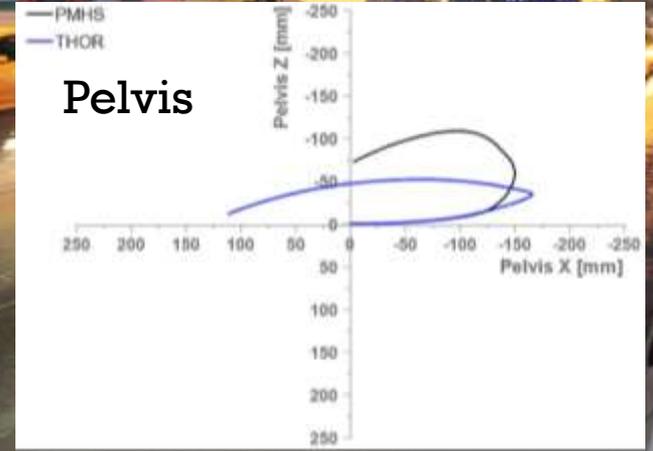
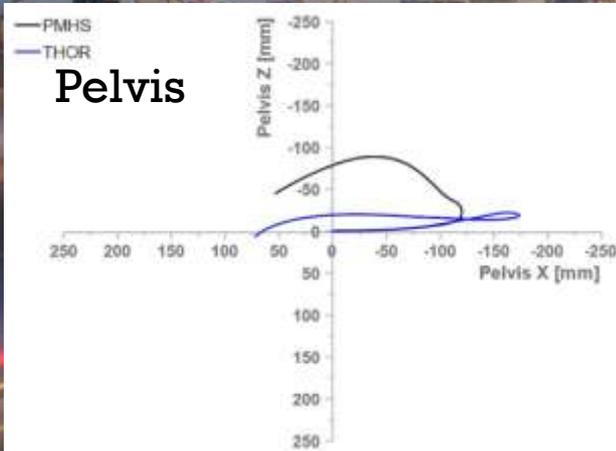
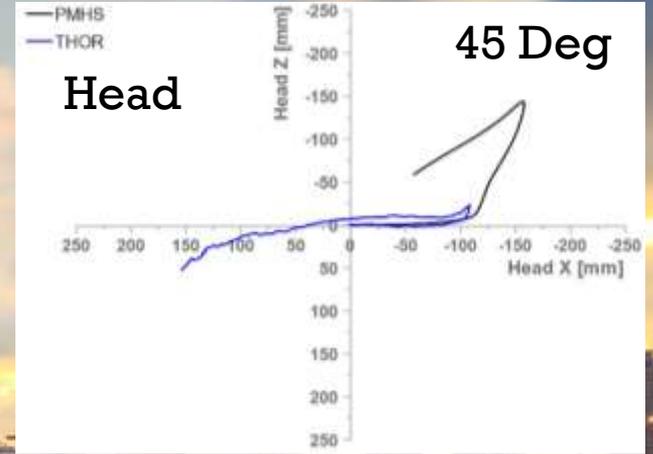
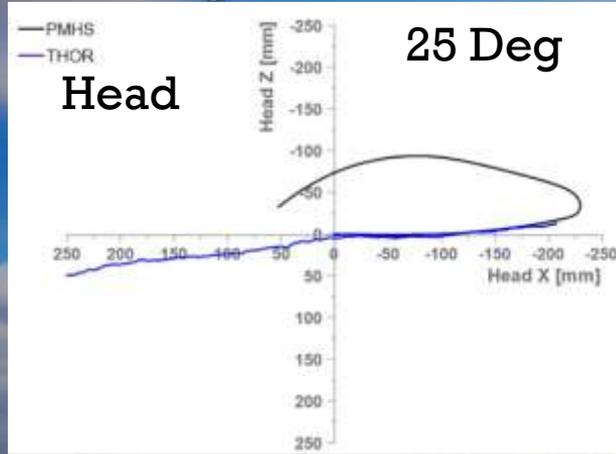


THOR-50M



Hybrid III 50th

Results: Trajectories



Results: BRS Scores

- Any B value over 2 indicates that the THOR response varies from the mean PMHS by more than 2 SD, on average

BRS Score ≤ 1

$1 < \text{BRS Score} \leq 2$

BRS Score > 2

Results: Occupant BRS

BRS Score ≤ 1
1 < BRS Score ≤ 2
BRS Score > 2

- Occupant scores calculated from
 - Head
 - Spine
 - Pelvis
 - Thorax
- TOTAL occupant response score calculated from the AVERAGE of individual scores

Location	25° Recline		45° Recline	
	<i>BRS</i>	<i>DPS</i> (ms)	<i>BRS</i>	<i>DPS</i> (ms)
Head	2.31	2	2.08	2
Spine	1.33	3	1.33	2
Thorax	1.89	2	1.37	0
Pelvis	2.48	2	1.53	3
AVG OCCUPANT RESPONSE	2.00	2	1.58	2

Results: Seat Loading BRS

BRS Score ≤ 1
$1 < \text{BRS Score} \leq 2$
BRS Score > 2

- Seat Loading scores calculated from
 - HR Plate
 - Top Plate
 - Middle Plate
 - Bottom Plate
 - Belt Tensions
- TOTAL seat loading response score calculated from the AVERAGE of individual scores

Location	25° Recline		45° Recline	
	<i>BRS</i>	<i>DPS</i> (ms)	<i>BRS</i>	<i>DPS</i> (ms)
HR Plate	1.56	3	1.98	1
Seat Top Plate	1.94	1	1.71	2
Seat Middle Plate	1.28	2	3.17	3
Seat Bottom Plate	2.53	0	2.70	1
Belt Tensions	1.76	48	2.40	6
AVG SEAT LOADING RESPONSE	1.81	11	2.39	3

Results: Injury Assessment

Measurement	25° Recline (n=3)		45° Recline (n=3)	
	THOR	PMHS	THOR	PMHS
HIC15	3,444 (83% IR)	no skull fx	923 (20% IR)	no skull fx
Upper Neck FX	-900 N	cervical spine laxity	-916 N	cervical spine laxity
Upper Neck FZ	2,076 N		2,035 N	
Upper Neck MY	40.8 Nm		-31.0 Nm	
Chest Res Defl (internal)	62.7 mm (71% IR)	avg. 6 rib fx	49.0 mm (45% IR)	avg. 12 rib fx
Acetabulum Resultant	7,102 N (100% IR)	none	8,424 N (100% IR)	2 of 3 pelvis fx
Lower Tibia FX	-2,268 N	none	-1,036 N	one fibula fx
Upper Tibia FZ	1,055 N (1% IR)		1,423 N (1% IR)	
Lower Tibia FZ	2,254 N (6% IR)		3,046 N (6% IR)	

Craig M, Parent D, Lee E, Rudd R, Takhounts E, Vikas H (2020) "Injury Criteria for the THOR 50th Male ATD", docket# NHTSA-2019-0106-0008 September 2020.

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Results: Injury Assessment

Measurement	25° Recline (n=3)		45° Recline (n=3)	
	Mean	Std. Dev.	THOR	PMHS
HIC15	3,444 (83% IR)	no skull fx	923 (20% IR)	no skull fx
Upper Neck FX	-900 N	cervical spine laxity	-916 N	cervical spine laxity
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Conclusions - Biofidelity

- BRS 25° recline:
 - Good overall biofidelity (BRS score < 2) in occupant responses and seat loading
 - Better seat loading biofidelity than 45° recline
 - Seatback bottom, head, and pelvis all had BRS score > 2
- BRS 45° recline
 - Good overall biofidelity (BRS score < 2) in occupant response but not seat loading
 - Seatback middle, bottom, belt tensions BRS score > 2
 - Better occupant response biofidelity than 25° recline

Conclusions – THOR vs. PMHS Differences

- THOR vs. PMHS differences:
 - THOR spine does not stretch like PMHS
 - Pelvis rotation differences due to spine stretch in PMHS affects ramping and lower body kinematics
 - THOR head rotated forward when interacting with HR but PMHS rotated rearwards
 - More PMHS ramping allowed more neck extension over the head restraint
 - Neck differences led to differences in head behavior
 - THOR and PMHS pelvis interact differently with seatback and belt
 - Large differences in PMHS ramping/kinematics compared to THOR

Conclusions – Injury Assessment

- THOR injury measurements (from frontal IC) compared to PMHS:
 - THOR acetabulum forces exceeded 50% risk injury, so good correlation with PMHS
 - Tibia forces were well below the 50% risk values, correlates with PMHS lower leg (one fibula fracture but no tibia fracture) injuries
 - High HIC values for THOR but no PMHS skull fractures
 - HIC may not be an appropriate predictor of skull fracture in this loading case
 - Internal deflection showed more deformation in the 25° than the 45° recline, even though more rib fractures at 45° recline
 - Possible differences in thoracic injury mechanisms with respect to seatback recline and expansion of chest due to abdomen shifting upwards in PMHS
 - Modify THOR chest instrumentation to identify chest injuries
 - Develop new injury criteria for rear-facing once ATD biofidelity is maximized

Conclusions – THOR Improvement Areas

- Adjust cable routing to avoid damage during test



THOR-50M

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- Neck modifications to aid head kinematics



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THOR-50M

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- Lack of abdomen instrumentation – IR-TRACCs had to be removed to prevent damage



THOR-50M

Conclusions – THOR Improvement Areas

- Adjust cable routing to avoid damage during test
- Neck modifications to aid head kinematics
- Chest instrumentation to better identify chest injuries
- Lack of abdomen instrumentation – IR-TRACCs had to be removed to prevent damage
- Increased flexibility in spine/lumbar region for better recline positioning and simulation of spine stretch



THOR-50M

Conclusions – THOR Improvement Areas

- Adjust cable routing to avoid damage during test
- Neck modifications to aid head kinematics
- Chest instrumentation to better identify chest injuries
- Lack of abdomen instrumentation – IR-TRACCs had to be removed to prevent damage
- Increased flexibility in spine/lumbar region for better recline positioning
- Pelvis/abdomen redesign for reclined posture



THOR-50M

Ongoing & Future Work

- BRS score calculations for other test setups
- Additional PMHS/ATD testing
 - THOR-AV (HIS), THOR with reclined mods (UVA/Cellbond)
 - Accord seat
 - Low-speed tests (24 kph) to encompass range of possible future crash severities
 - Seat belts with pretensioners
- Identify & implement necessary design modifications for THOR
- Data for tests presented today is entered into NHTSA Biomechanics Database (<https://www-nrd.nhtsa.dot.gov/database/VSR/bio/QueryTest.aspx>)

Test numbers 13077 - 13098

Thank you

- QUESTIONS?