



# NHTSA's THOR-05F Development Update

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# THOR-05F Background

- NHTSA developed the THOR-05F ATD to better evaluate injury risk of small female adult occupants.

Year	THOR-05F Recent Activity
2015 - 2018	NHTSA & Humanetics collaborate to build 3 prototype THOR-05Fs.
2018 - 2022	NHTSA evaluated THOR-05F for biofidelity, R&R, and durability.
2022 - 2024	Improved the thorax design & update 3 ATDs.
2024 - 2025	Repeat biofidelity, R&R, and durability assessments.
Nov 2025	Press release & release of documentation*

THOR-05F



Hybrid III-5<sup>th</sup>



\* <https://www.nhtsa.gov/file-downloads?p=nhtsa/downloads/THOR-05F/Drawing-Package/November-2025/>

# THOR-05F Development Objectives

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- Biofidelity – THOR-05F is a good representation of a human occupant.
  - Matched pair tests with PMHS
  - Quantify with NHTSA's Biofidelity Ranking System (BRS)
- R&R – THOR-05F provides reliable (repeatable & reproducible) data.
  - 3 ATDs, 4 labs
  - 19 test modes x 5 tests/mode x 6 series = 570 tests
  - Establishes qualification criteria
- Durability – Minimize damage in severe test environments.
  - Increased energy qualification tests
  - Rear seat sled tests



# THOR-05F Biofidelity Assessment

- Purpose: Ensure ATD is a good representation of a human occupant.
- Result: THOR-05F shows a biofidelity improvement over the HIII 5<sup>th</sup>.
  - Smaller BioRank Score (BRS) = more biofidelic response
- Sled biofidelity testing is currently on-going.
  - Whole-body assessment

Body Region	THOR-05F	HIII-5th
Head	1.05	1.77
Neck	1.11	2.08
Shoulder	0.71	2.14
Thorax	1.50	4.25
Abdomen	1.69	3.36
Lower Extremity	1.22	2.35
<b>Average BRS</b>	<b>1.21</b>	<b>2.66</b>

THOR-05F

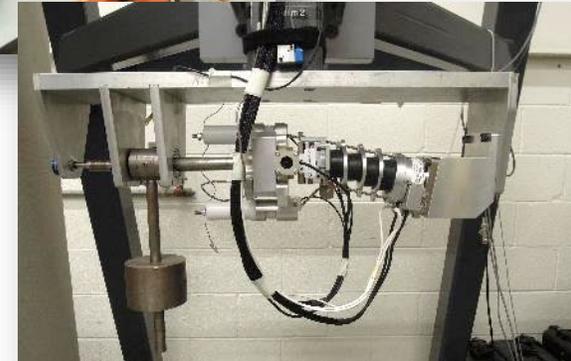
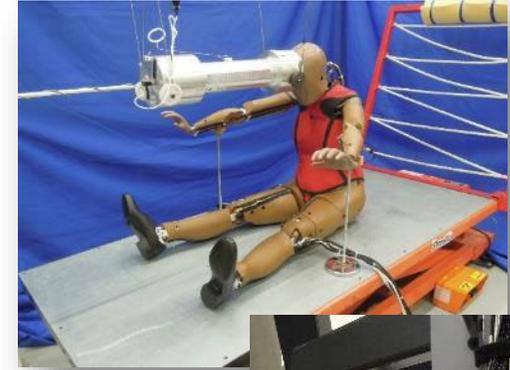


HIII-5<sup>th</sup>



# THOR-05F R&R Assessment

- Purpose: Ensure objectivity in ATD response
  - Support qualification response corridors
  - Establish R&R of the updated THOR-05F response
- Test procedures in THOR-05F Qualification Manual
  - Replicates crash-level loading
  - 19 test modes x 5 tests/mode x 6 series = 570 tests
    - Head
    - Face
    - Neck flexion
    - Neck extension
    - Neck bending (R & L)
    - Neck torsion (R & L)
    - Upper thorax
    - Lower thorax (R & L)
    - Abdomen
    - Upper leg (R & L)
    - Knee
    - Ball of Foot
    - Heel
    - Ankle inversion
    - Ankle eversion
- 19 test modes → 42 responses
  - Peak forces, moments, rotations, deflections, pressures, accelerations, angular rates, etc.
    - Average
    - Standard deviation
    - Coefficient of variation  $\left( CV = \frac{StDev}{Avg} * 100 \right)$
- **Criteria: CV ≤ 10% across all dummies & all labs**

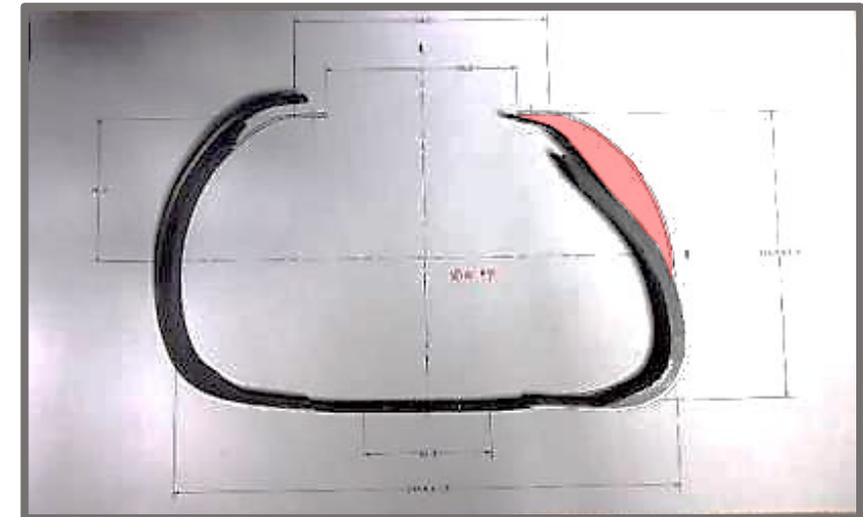


# THOR-05F Durability Assessment

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- Challenge for small female dummies, especially thorax
  - Maintaining biofidelity and durability are often competing priorities
- Purpose: Minimize damage in severe test environments
- Qualification tests at increased energy
  - Baseline, +10%, +20%, +30%, final baseline
  - Initial & final baseline tests must meet qualification criteria.
  - No damage during post-test inspection
- Rear seat sled test
  - 2018 design: Deformed ribs, broken instrumentation, & data loss
  - NCAP pulse: 35 mph  $\Delta V$ , 40 G
  - No load limiter or pretensioner
  - No major damage or data loss

2018 Design: Rib #7 post rear seat sled test



# THOR-05F R&R & Durability Results

## R&R: THOR-05F demonstrated acceptable R&R.

- All CVs < 10%
- R&R data suitable for developing qualification criteria
- Full qualification of THOR-05F for crash testing:
  - 24 required tests
  - 66 response requirements

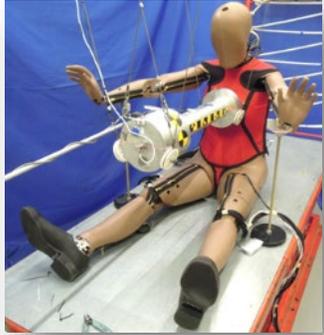
## Durability: THOR-05F demonstrated acceptable durability.

- Increased energy tests:
  - All final baseline met qualification requirements
  - No damage observed during post-test inspection
- Rear seat sled tests:
  - No major damage or data loss



Test Mode	CV Results
Head Impact	2.2 – 3.3%
Face Impact	9.5%
Neck Flexion	1.4 – 3.2%
Neck Extension	2.0 – 9.0%
Neck Bending (R&L)	2.5 – 3.8%
Neck Torsion (R&L)	1.3 – 2.3%
Upper Thorax	3.5 – 5.4%
Lower Thorax (R&L)	5.5 – 7.2%
Abdomen	2.0 – 3.0%
Upper Leg (R&L)	4.4 – 7.5%
Knee	1.0 – 7.6%
Ankle Inversion	1.3 – 4.6%
Ankle Eversion	1.7 – 2.3%
Ball of Foot	7.3 – 9.0%
Heel	2.5 – 5.0%

# THOR-05F Thorax Example



## Upper Thorax (37 tests)

- 14 kg probe at 4.3 m/s
- ATD midline at 3<sup>rd</sup> rib
- Symmetric response left-to-right



## Lower Thorax (74 tests)

- 14 kg probe at 4.3 m/s
- Anterior IR-TRACC attachment (6<sup>th</sup> rib)
- Left & right tested separately

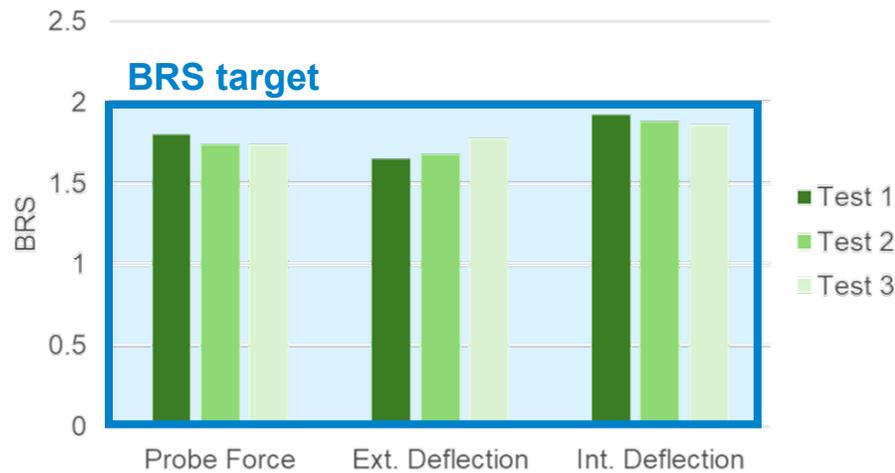


Biofidelity	<ul style="list-style-type: none"> <li>• Probe force</li> <li>• Internal &amp; external deflection (IR-TRACC &amp; HSV)</li> <li>• Small female-specific corridors</li> </ul>	<ul style="list-style-type: none"> <li>• Probe force</li> <li>• External deflection only (chestband)</li> <li>• 15° z-axis rotation to match PMHS</li> <li>• Scaled corridors</li> </ul>	
R&R	<ul style="list-style-type: none"> <li>• Confirms IR-TRACCs, ribs, breast plate, jacket</li> <li>• Probe force</li> <li>• IR-TRACC deflection</li> </ul>		
Durability	Thorax-specific	<ul style="list-style-type: none"> <li>• Increased energy qualification</li> <li>• +10%, 20%, &amp; 30%</li> </ul>	
	Full ATD	<ul style="list-style-type: none"> <li>• Rear seat sled test</li> <li>• 35 mph <math>\Delta V</math>, 40 G</li> </ul>	

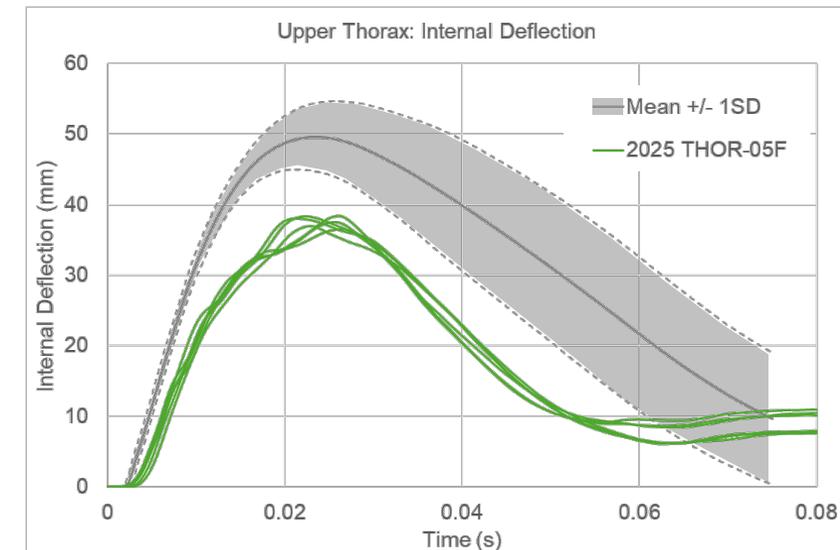
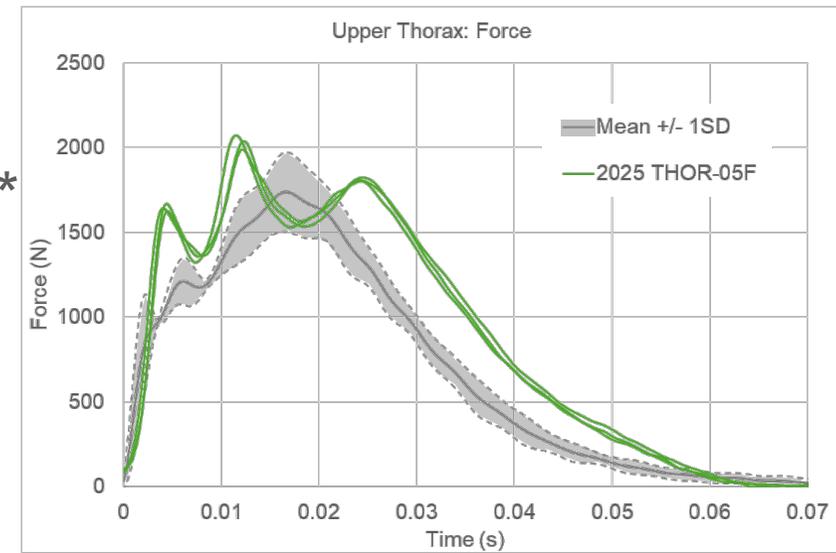
# THOR-05F Upper Thorax Biofidelity

## Upper Thorax Biofidelity

- 3 tests
- Small female-specific PMHS corridors (n=6)\*
- Quantified using BioRank method
  - Smaller BRS = More biofidelic response
  - Target:  $BRS < 2$



**Average BRS: 1.78      1.70      1.89**

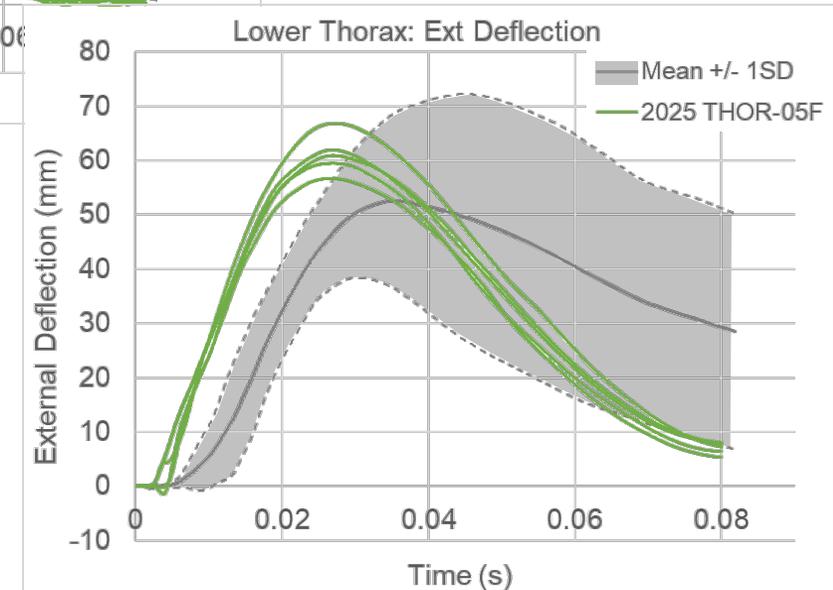
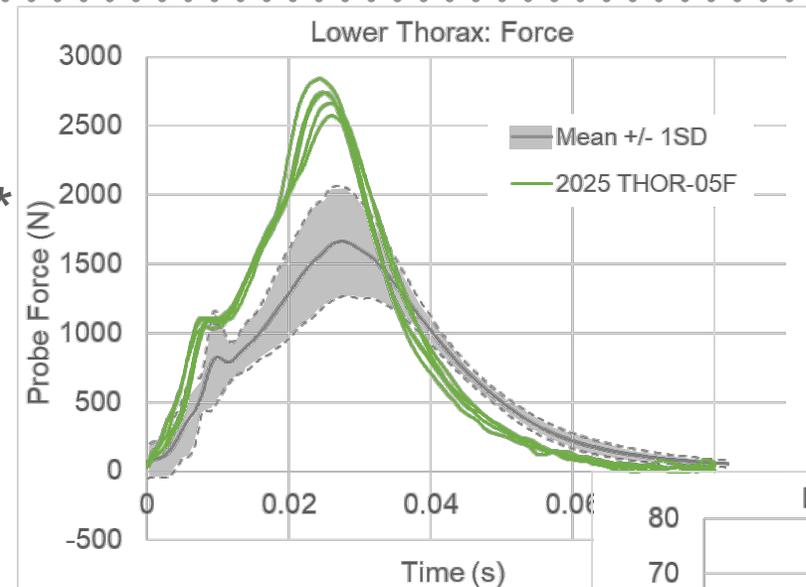
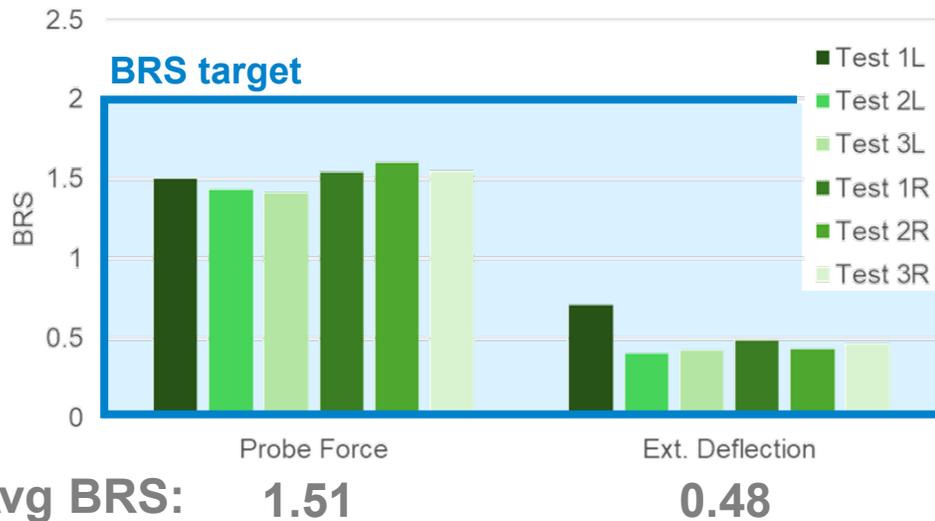


\* Baker GH et al., Female PMHS Thoracic Biomechanical Response Corridors with Preliminary Consideration of the Influence of Breast Tissue in Frontal Impacts, Stapp Car Crash Conference, Nov. 2025.

# THOR-05F Lower Thorax Biofidelity

## Lower Thorax Biofidelity

- 3 tests left & right
- Scaled M50 PMHS corridors (n=7)\*
- Chestband for external deflection



\* Yoganandan, N., Pintar, F., Kumaresan, S., et al. (1997). Impact biomechanics of the human thorax-abdomen complex. International Journal of Crash, 2(2); pp. 219-228.

# THOR-05F Thorax Biofidelity Summary

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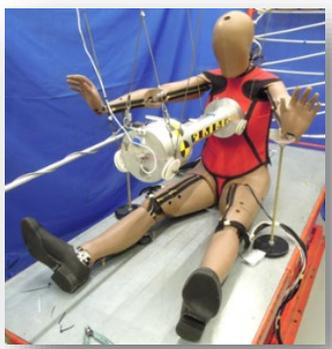
	Measure	BRS
Upper Thorax	Probe Force	1.78
	External Deflection	1.70
	Internal Deflection	1.89
Lower Thorax	Probe Force	1.51
	External Deflection	0.48
<b>Thorax BRS Average</b>		<b>1.50</b>

- All measures: BRS < 2.0
- Significant improvement over Hybrid III 5<sup>th</sup> (BRS = 4.3)

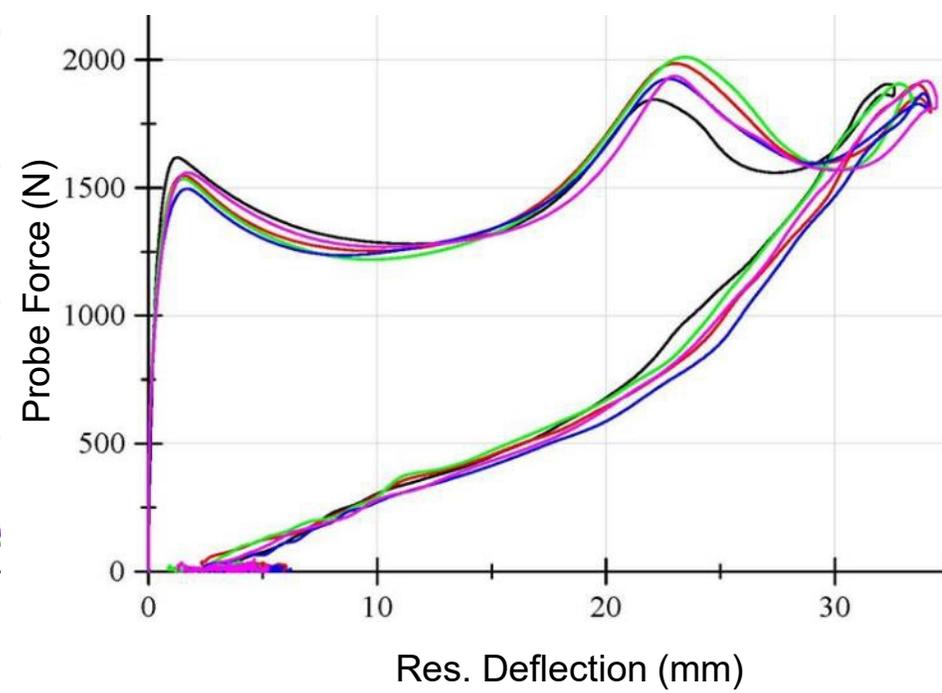
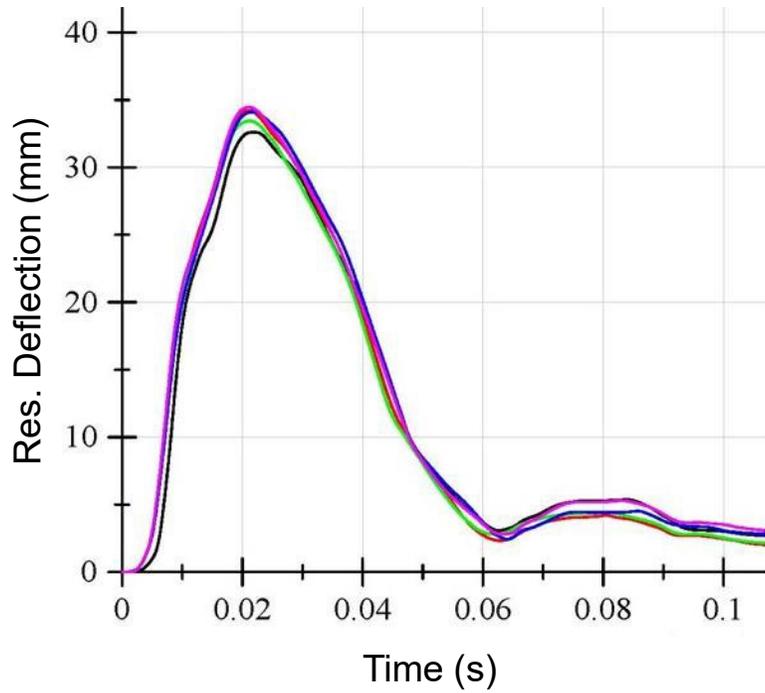
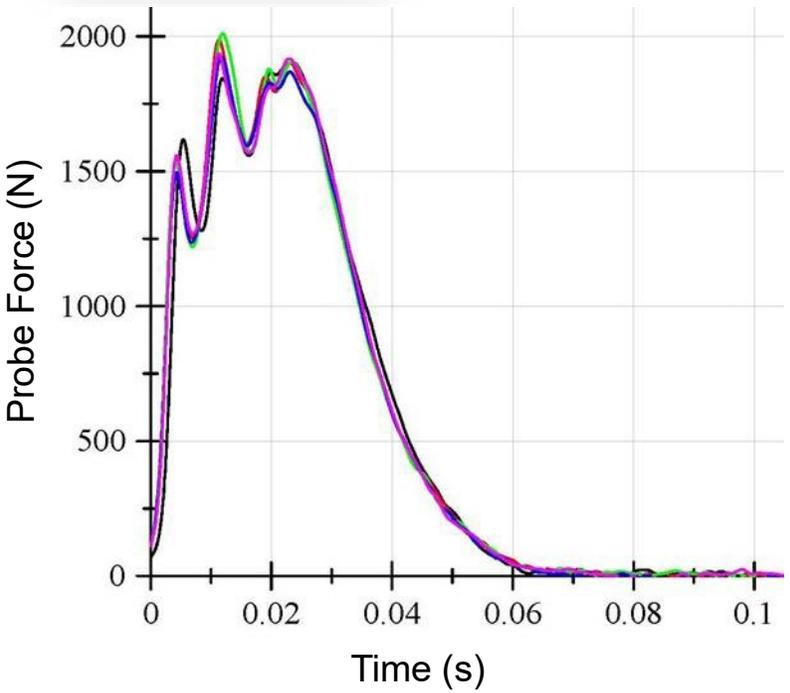


**OK to move on to  
R&R assessment!**

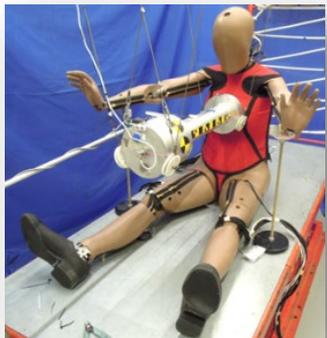
# THOR-05F Upper Thorax R&R



Upper Thorax		Max Probe Force (N)	Max Res. Deflection (mm)	Force @ Max Deflection (N)
All Data (30 tests)	Average	1,995	35.3	1,796
	StDev	89	2.3	70
	CV	4.5%	6.5%	3.9%

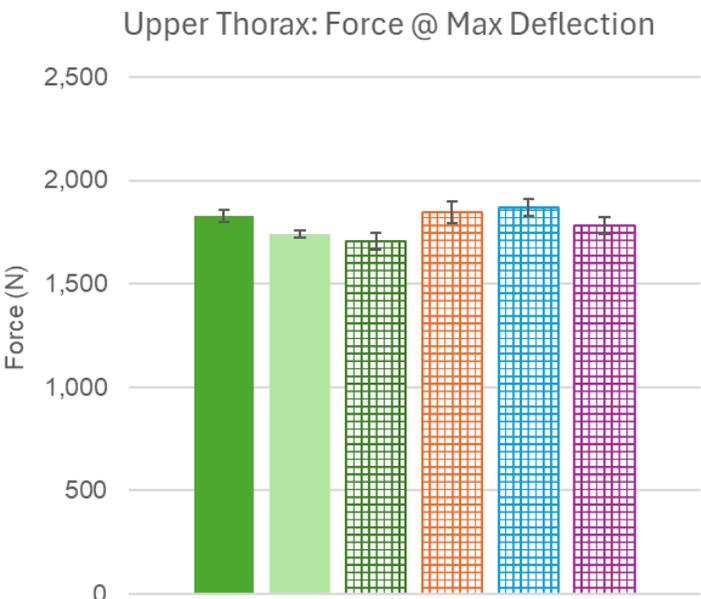
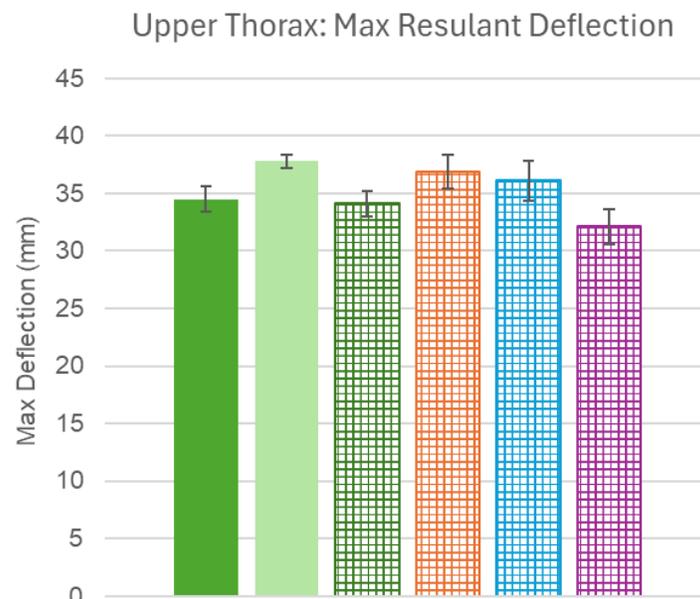
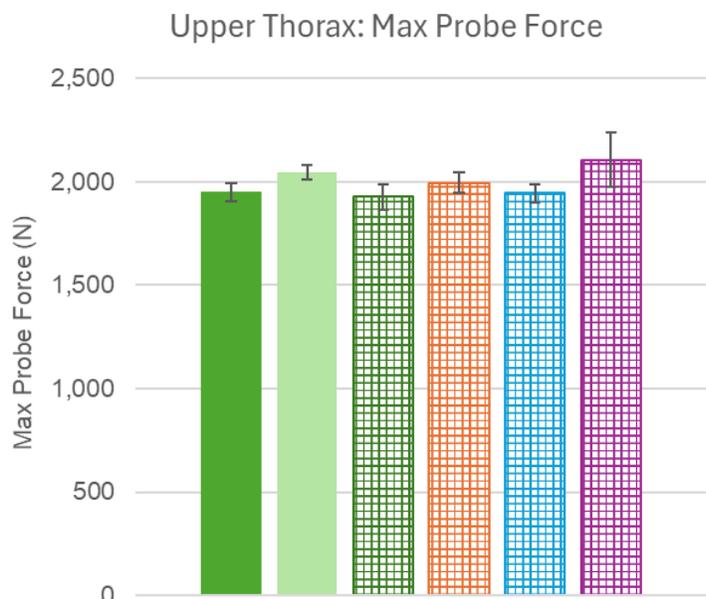


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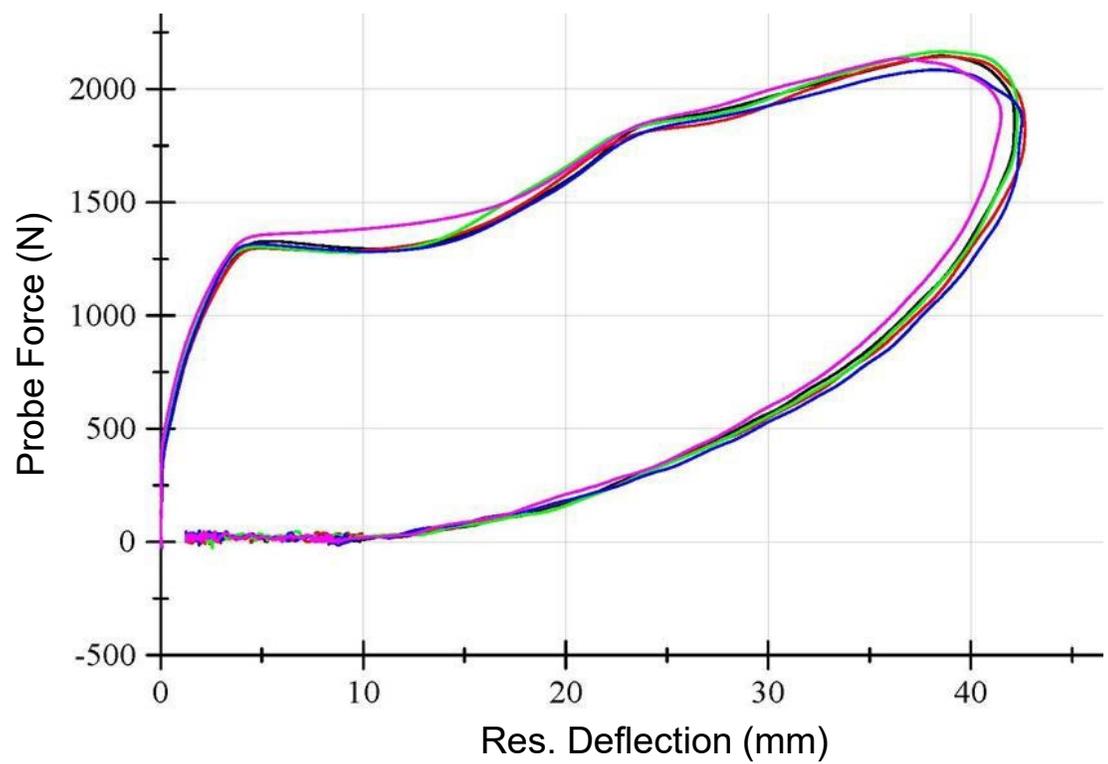
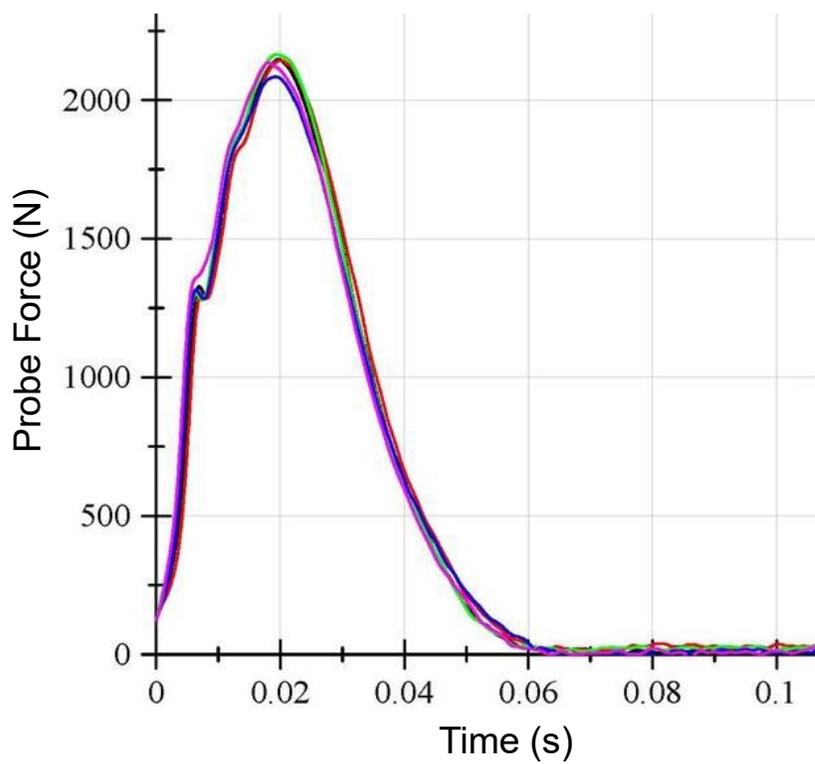
- VRTC ATD #1
- VRTC ATD #2
- VRTC ATD #3
- Humanetic ATD #3
- Calspan ATD #3
- TRC ATD #3



# THOR-05F Lower Thorax R&R



Lower Thorax		Max Probe Force (N)	Res. Deflection @ Max Force (mm)
All Data (60 tests)	Average	2,008	42.7
	StDev	92	3.6
	CV	4.6%	8.5%

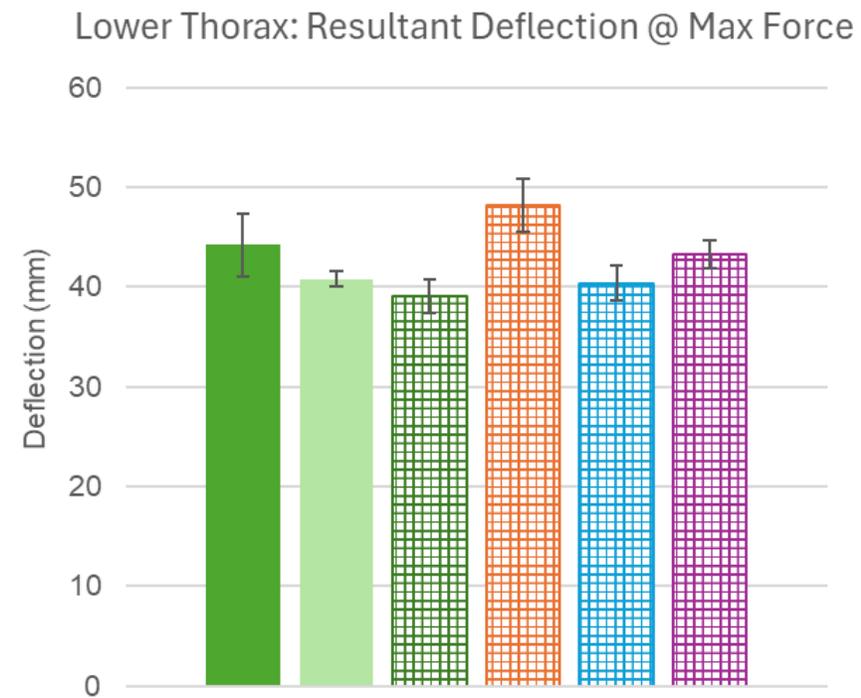


# THOR-05F Lower Thorax R&R



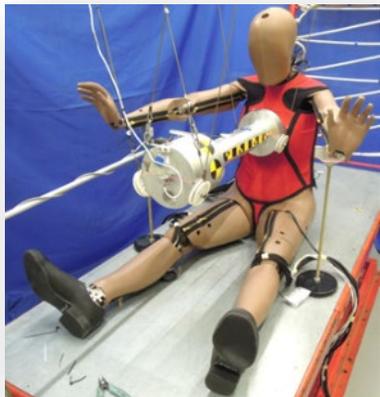
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	StDev	92	3.6
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- VRTC ATD #1
- VRTC ATD #2
- VRTC ATD #3
- Humanetic ATD #3
- Calspan ATD #3
- TRC ATD #3



# THOR-05F Thorax R&R Summary

- CVs < 10% for all measurements → suitable for qualification corridors
- Qualification corridors: average  $\pm 10\%$ 
  - Consistent with THOR-50M
  - Allows for reasonable variation (lab-to-lab, ATD-to-ATD)



Upper Thorax		Max Probe Force (N)	Max Res. Deflection (mm)	Force @ Max Deflection (N)
All Data (30 tests)	Average	1,995	35.3	1796
	StDev	89	2.3	70
	CV	4.5%	6.5%	3.9%
<b><math>\pm 10\%</math> Qualification Corridor</b>		<b>1,796 – 2,195</b>	<b>31.7 – 39.8</b>	<b>1,616 – 1,976</b>

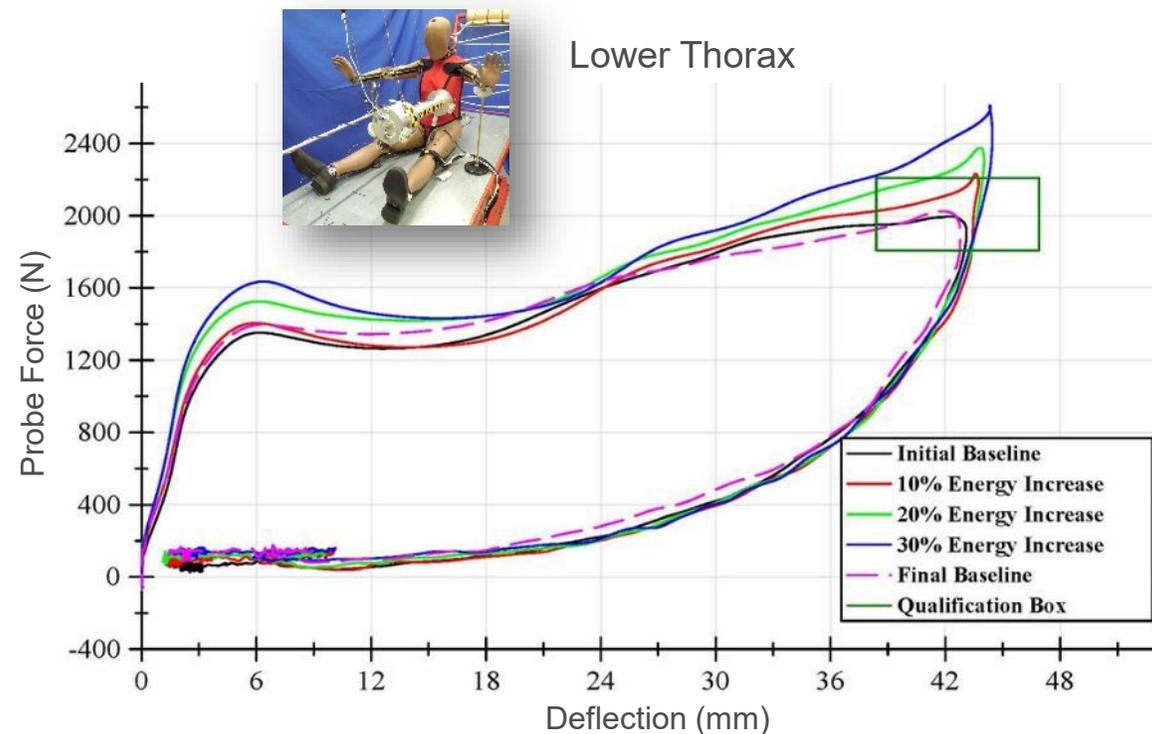
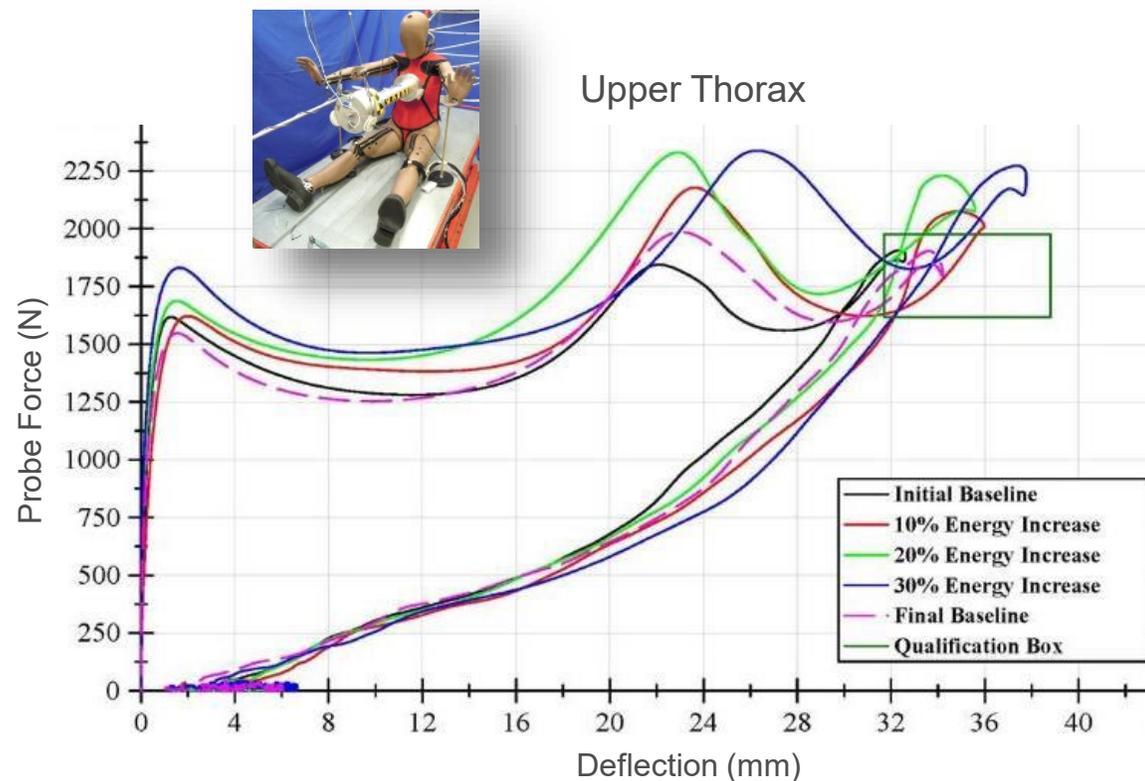


Lower Thorax		Max Probe Force (N)	Res. Deflection @ Max Force (mm)
All Data (60 tests)	Average	2,008	42.7
	StDev	92	3.6
	CV	4.6%	8.5%
<b><math>\pm 10\%</math> Qualification Corridor</b>		<b>1,807 – 2,209</b>	<b>38.4 – 46.9</b>

# THOR-05F Thorax Durability

- Thorax-specific durability done in parallel with R&R.
  - Reduce development time of THOR-05F
  - Qualification tests at increased energy
    - Baseline, +10%, +20%, +30%, final baseline

	Impact Velocity (m/s)
Initial Baseline	4.30
+10% Energy	4.51
+20% Energy	4.71
+30% Energy	4.90
Final Baseline	4.30



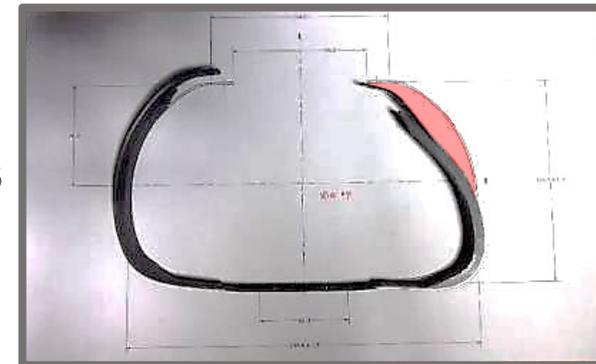
# THOR-05F Thorax Durability

Full body assessment – Rear seat sled testing

- NCAP pulse: 35 mph  $\Delta V$ , 40 G
- No load limiter or pretensioner
- 2018 design – Data loss, IR-TRACC damage, permanently deformed ribs
- Current design – No data loss or significant damage

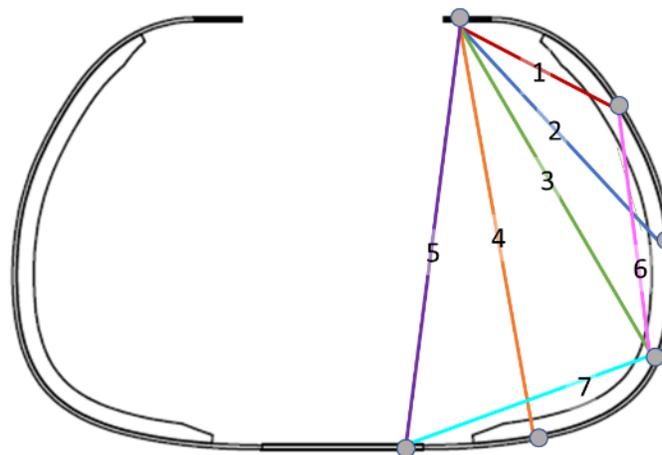


2018 Design: Rib #7 post test



Rib evaluation

- XYZ coordinates of 60 points were measured on ribs pre & post-test
- Distances between the points were calculated (n=69).
- Maximum change < 3mm



Distance	Length (mm)		
	Pre-test	Post-test	Difference (post-pre)
1	105.3	105.1	-0.2
2	137.6	137.9	0.3
3	182.7	180.4	-2.2
4	176.3	176.8	0.5
5	184.1	184.2	0.2
6	78.1	78.6	0.5
7	102.1	101.4	-0.7

# THOR-05F Thorax Durability Summary

- **Durability: THOR-05F demonstrated acceptable thorax durability.**

- Increased energy tests (upper & lower thorax modes):

- All final baseline met qualification requirements
- No damage observed during post-test inspection

- Rear seat sled tests:

- No major damage or data loss

- Biggest challenge for THOR-05F

- Primary reason for the 2023 re-design
- Biofidelity & durability are often competing priorities

ATD	Durability	Thorax BRS Score
Hybrid III 5 <sup>th</sup>	✓	4.3
2018 THOR-05F	✗	1.4
2025 THOR-05F	✓	1.5

# THOR-05F Development Summary

- Evaluations for THOR-05F R&R and durability are complete.
  - Reports for all body regions are publicly available!
  - Across multiple labs and ATDs, the CVs for all measures of interest were  $\leq 10\%$ .
  - 42 qualification response corridors were established.
  - No durability concerns were identified.
- Biofidelity evaluation is on-going
  - Complete by body region
    - Improvement over Hybrid III 5th
  - Full body sled testing is on-going
    - Gold standard & realistic buck test
  - Report will be added to the docket
- Additional on-going work:
  - Injury criteria development
  - In-dummy DAS evaluations
  - OOP
  - Fleet testing



# THOR-05F Documentation

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- November 2025 press release: <https://www.nhtsa.gov/file-downloads?p=nhtsa/downloads/THOR-05F/Drawing-Package/November-2025/>
- **New docket coming soon:** <https://www.regulations.gov/docket/NHTSA-2025-0622>
  - Drawing Package
  - Qualification Procedures and Specifications
  - R&R Report
  - Durability Report
  - PADI
- Original docket: <https://www.regulations.gov/docket/NHTSA-2019-0107>
  - 2019 biofidelity report, drawing package, biomechanical response requirements
  - Copy of new documents will be placed in original docket as well.





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