



NHTSA

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

THOR-05F Neck R&R, Biofidelity, and Durability

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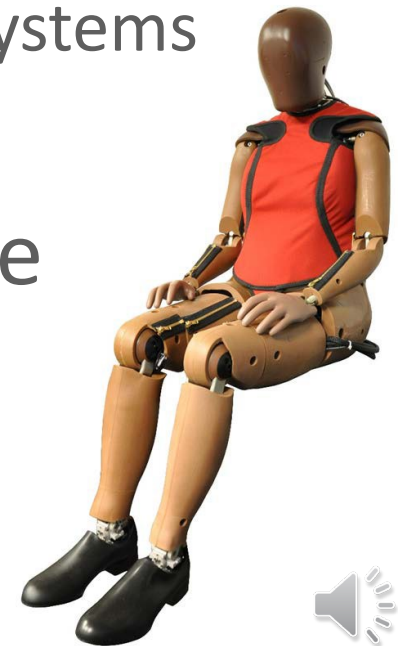


- THOR-05F Neck R&R
- THOR-05F Neck Biofidelity
- THOR-05F Neck Durability



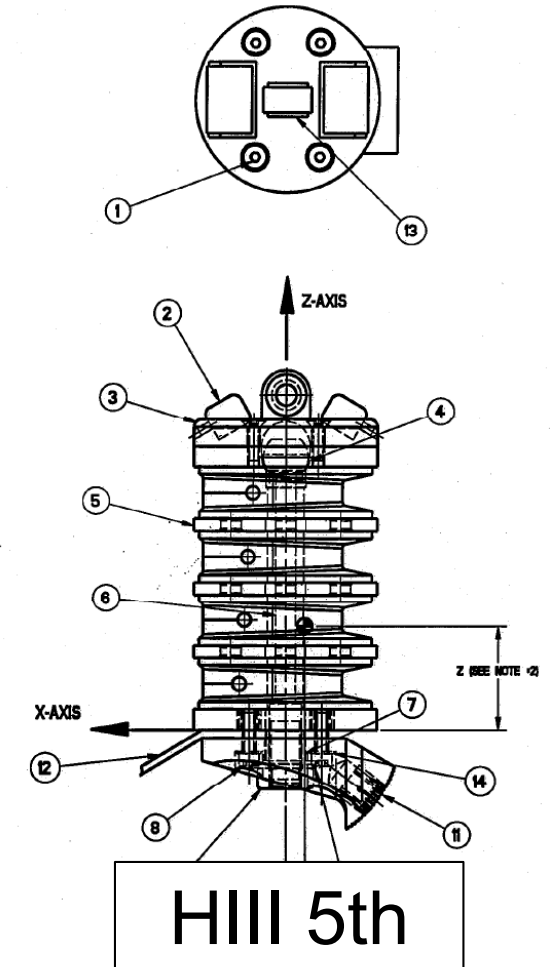
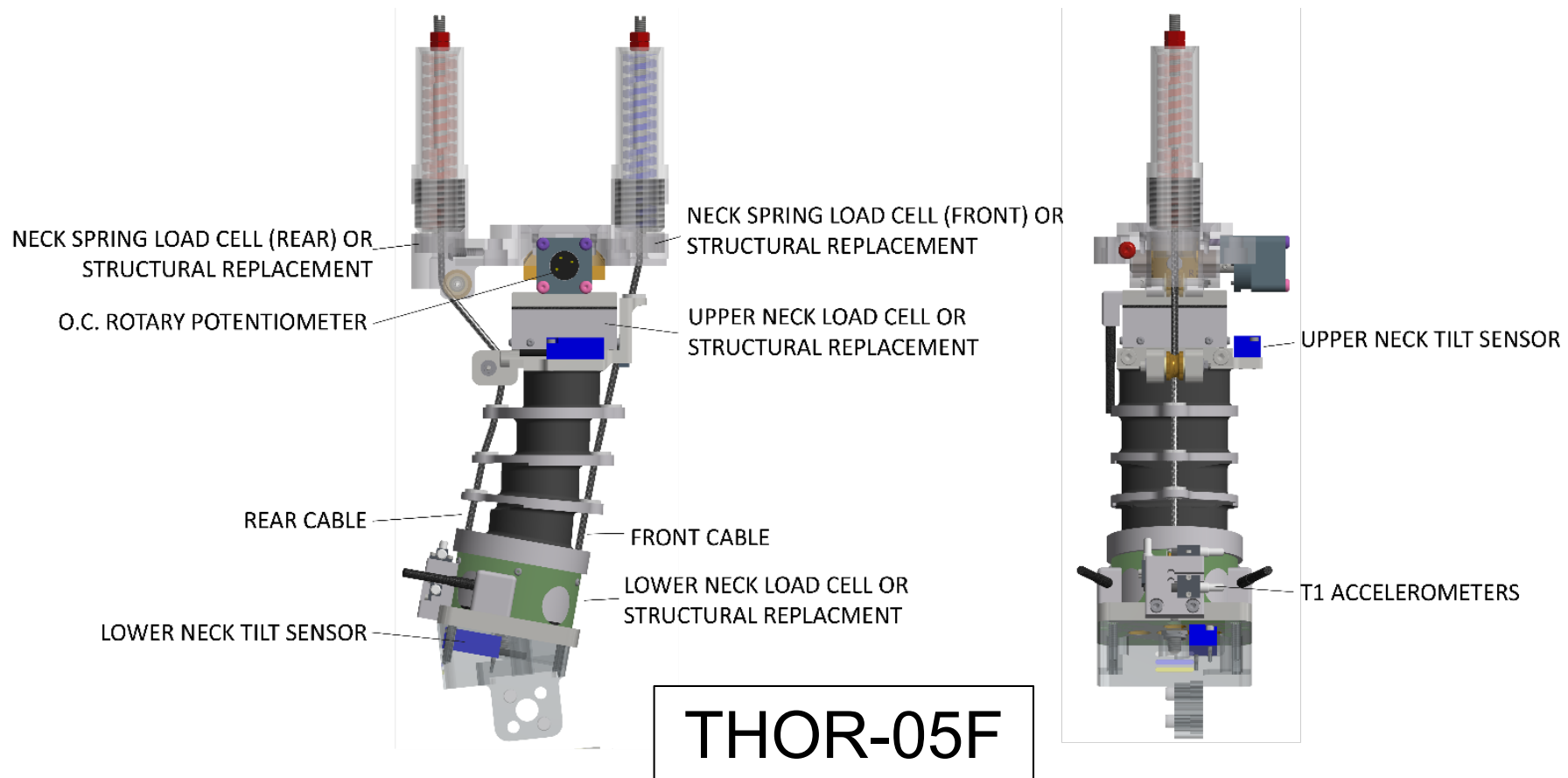
Motivation

- NHTSA developed the THOR-50M ATD to better evaluate injury risk of mid-sized adults
 - Alternative to Hybrid-III in frontal crash tests
 - Improved biofidelity and measurement capability
 - More thoroughly evaluate & improve advanced restraint systems
- Similarly, THOR-05F was developed to evaluate the risks and biomechanics of smaller female adults.



THOR-05F Neck Design

- Goal: Improve biofidelic response and improve measurement capability, while maintaining durability and R&R performance.

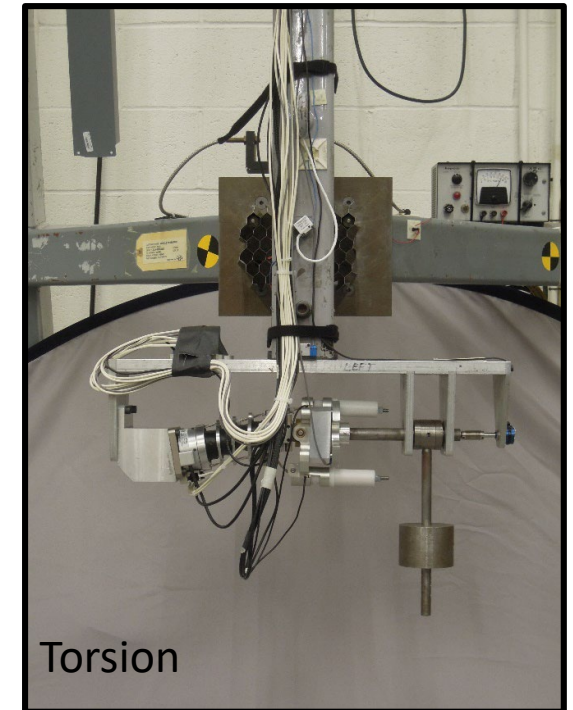
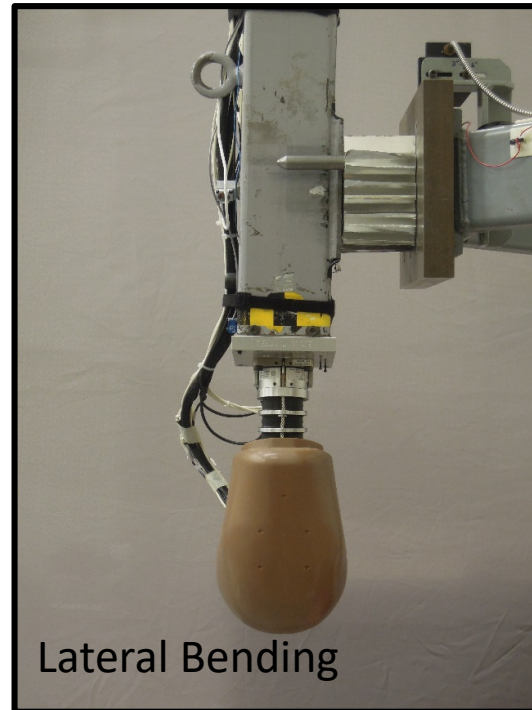
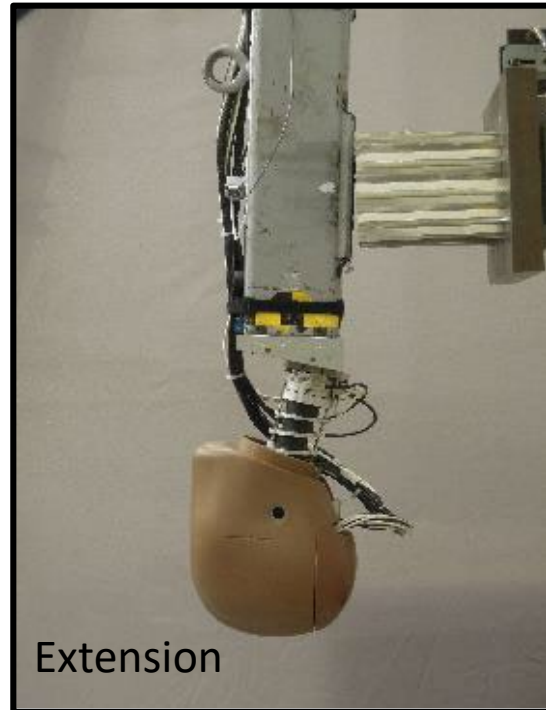
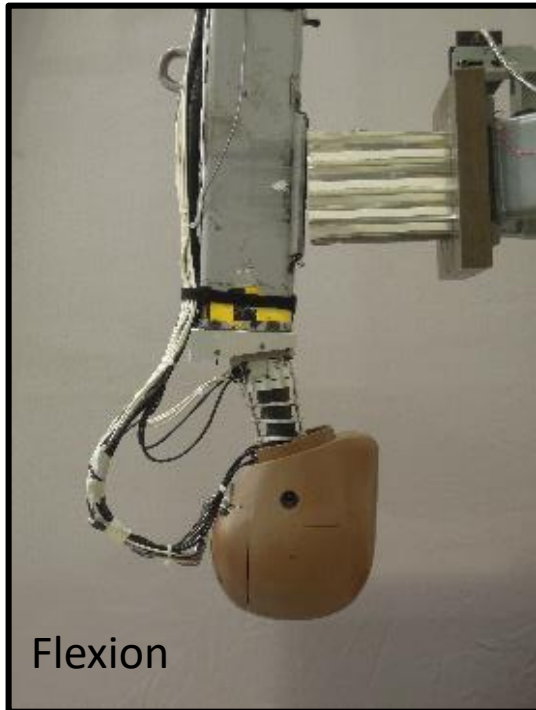


Neck R&R



Neck R&R

- Performed 4 test modes on 3 different ATDs.
 - Pendulum impacts that induce neck flexion, extension, lateral bending, & torsion.
 - Total of 90 neck tests: 5 trials of each test condition on each ATD.
 - $CV < 10\%$ for all measures of interest.



Neck R&R – Frontal Flexion & Extension

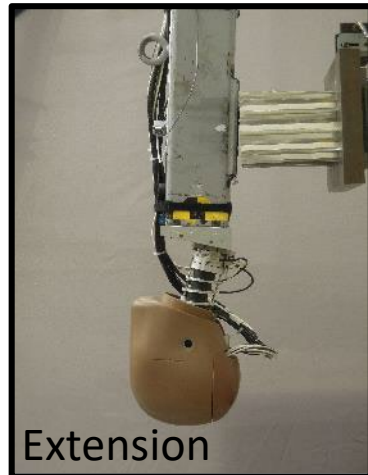
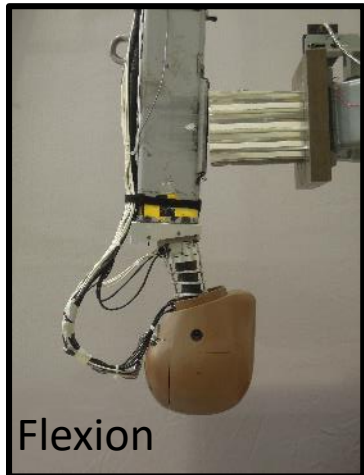
- **Inputs:** Pendulum impact to 6" aluminum honeycomb at 5.0 m/s
- **Outputs:** Peak head Y-rotation
Peak head angular rate about Y-axis
Peak upper neck Z-force
Peak upper neck Y-moment

Frontal Flexion:

Statistic	Rotation (°)	Angular Rate (°/s)	Z-Force (N)	Y-Moment (N·m)
Average	-79.4	-2128	760	16.7
StDev	1.62	41.35	57.34	0.89
CV	2.04%	1.94%	7.54%	5.32%

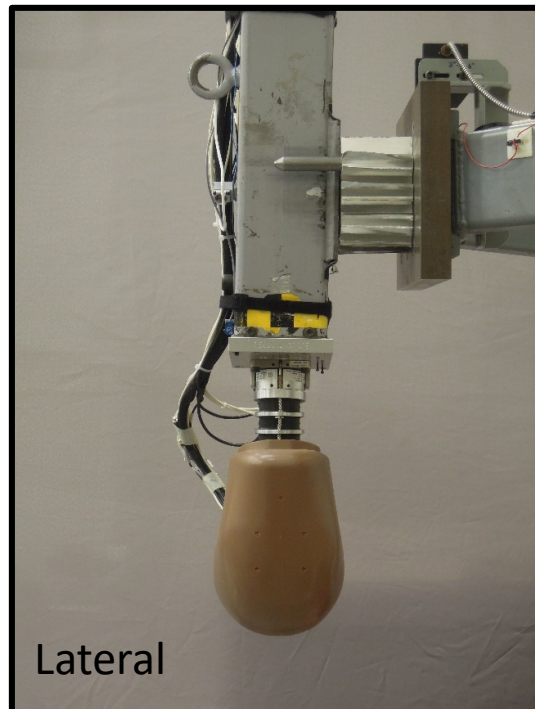
Extension:

Statistic	Rotation (°)	Angular Rate (°/s)	Z-Force (N)	Y-Moment (N·m)
Average	87.6	2419	-1552	-16.9
StDev	1.28	40.50	101.15	0.86
CV	1.46%	1.67%	6.52%	5.08%



Neck R&R – Lateral Bending

- **Inputs:** Pendulum impact to 6" aluminum honeycomb at 3.4 m/s
- **Outputs:** Peak head X-rotation
Peak head angular rate about X-axis
Peak upper neck X-moment

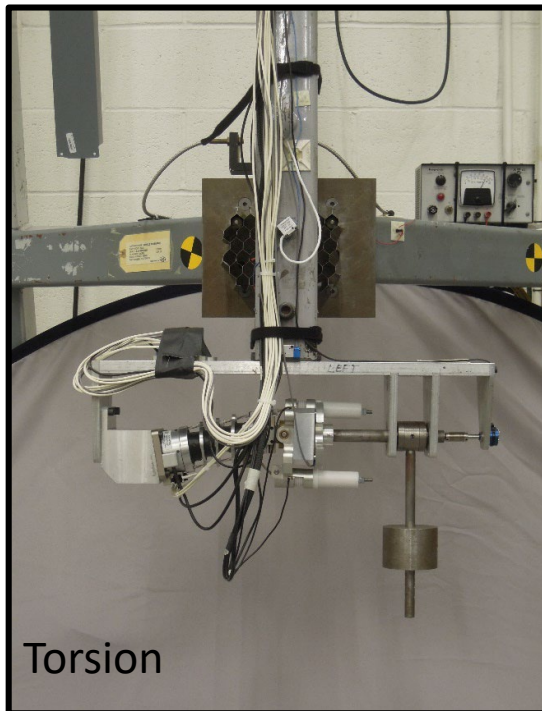


Statistic	Rotation (°)	Angular Rate (°/s)	X-Moment (N·m)
Average	52.9	1347	28.6
StDev	1.11	27.03	0.64
CV	2.10%	2.01%	2.22%



Neck R&R – Torsion

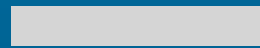
- **Inputs:** Pendulum impact to 6" aluminum honeycomb at 3.4 m/s using the modified THOR-50M torsion fixture
- **Outputs:** Peak head Z-rotation
Peak head angular rate about Z-axis
Peak upper neck Z-moment



Statistic	Rotation (°)	Angular Rate (°/s)	X-Moment (N·m)
Average	52.0	1256	20.2
StDev	1.09	20.53	0.37
CV	2.09%	1.63%	1.83%



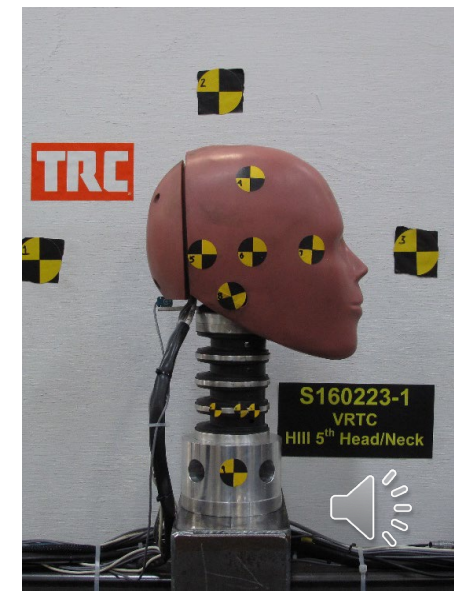
Neck Biofidelity



Neck Biofidelity

- All corridors are scaled to 5th female sizes according to the procedures in the Biomechanical Response Manual for the THOR 5th Dummy¹
- THOR-05F and HIII 5th were BioRanked using updates to the method detailed in Rhule's 2018 IRCOBI paper²

Test	Specifications	Source
Frontal Flexion Pendulum	5.00 ± 0.05 m/s	Mertz and Patrick 1971
Lateral Bending Pendulum	3.40 ± 0.05 m/s	Patrick and Chou 1976
Frontal Flexion Mini-Sled	Neck Flexion T1 Pulse	Thunnissen et al 1995



¹Lee, E., Parent, D. P., Craig, M. J., McFadden, J., & Moorhouse, K. (2019). Biomechanical response requirements manual: THOR 5th percentile female NHTSA advanced frontal dummy, Revision 2. (Report No. DOT HS 812 811). National Highway Traffic Safety Administration

²Rhule H, Stricklin J, Moorhouse K, Donnelly B. Improvements to NHTSA's biofidelity ranking system and application to the evaluation of the THOR 5th female dummy. In: Proceedings of the 2018 International IRCOBI Conference on the Biomechanics of Injury. September 12-14, 2018; Athens, Greece.53-55.

- Phase differences were removed and then the BioRank score (B) was calculated for each response measurement:

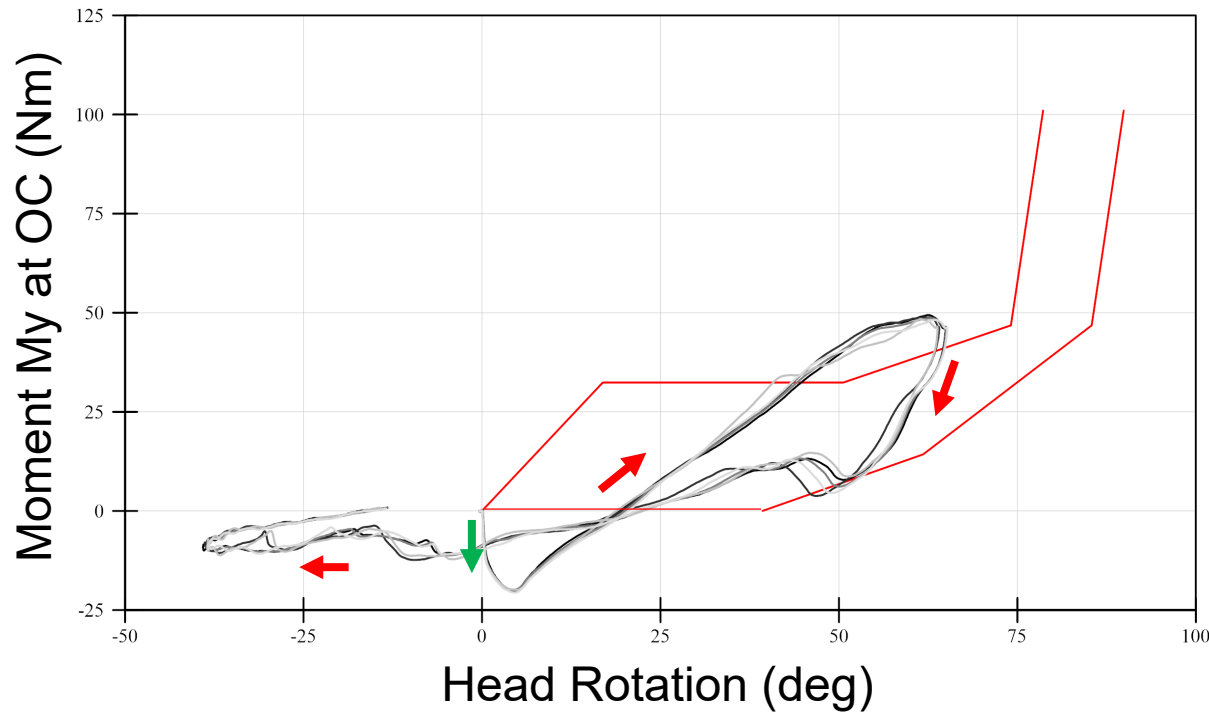
$$B = \frac{DCAD}{CCSD} = \frac{\textit{Dummy Cumulative Absolute Difference}}{\textit{Cadaver Cumulative Standard Deviation}}$$

- For each test condition, the average BioRank score (B_{avg}) from the response measurements was calculated
- The B value represents multiples of standard deviation away from the target response

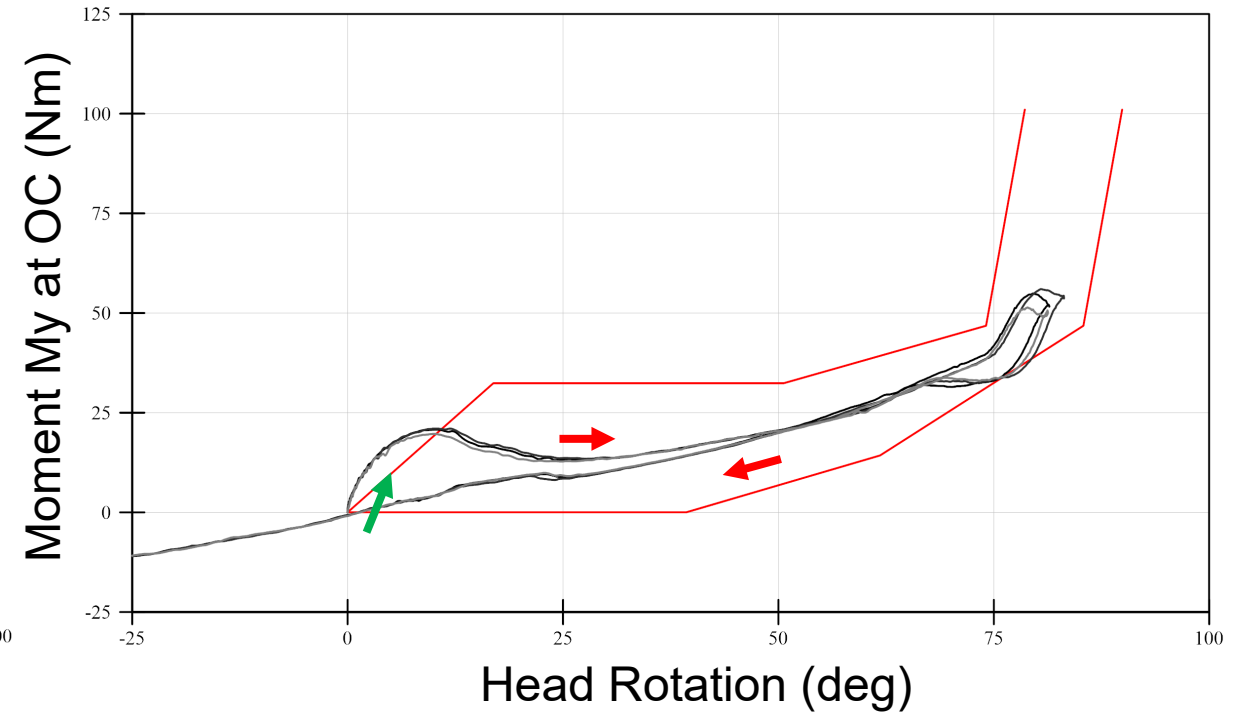


Neck Biofidelity – Frontal Flexion Pendulum

HIII 5th Neck Flexion

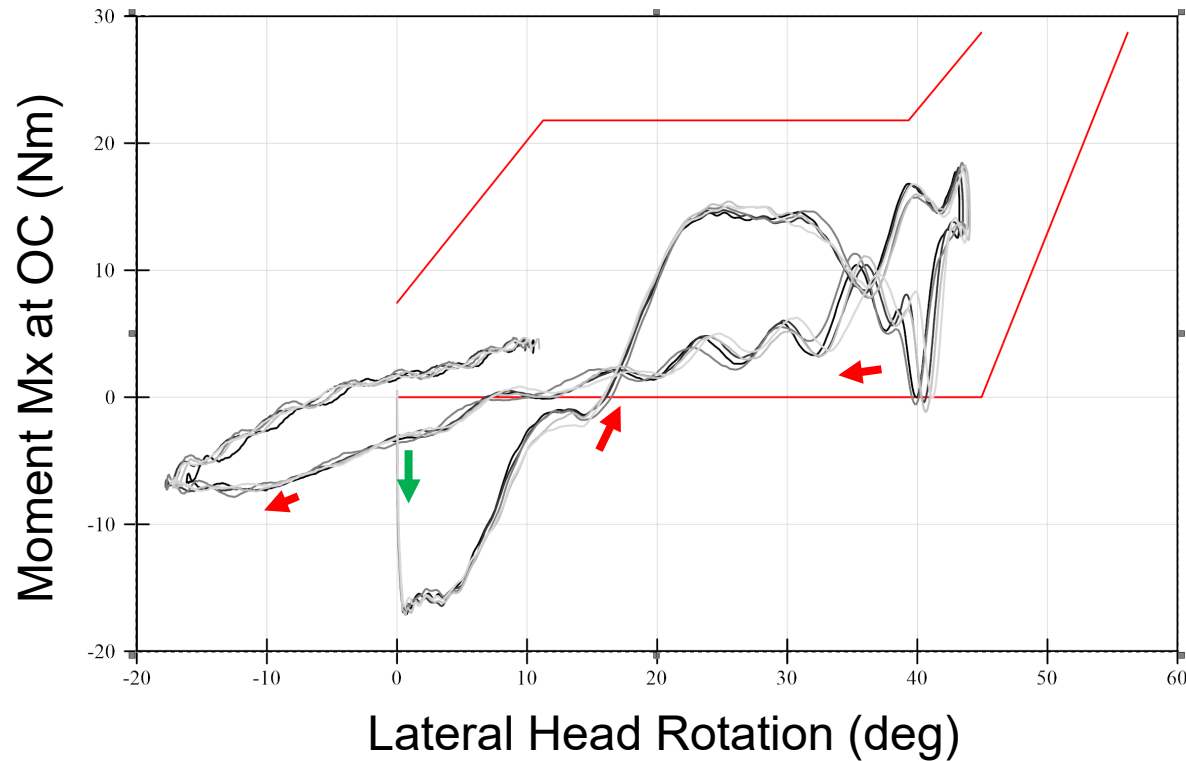


THOR-05F Neck Flexion

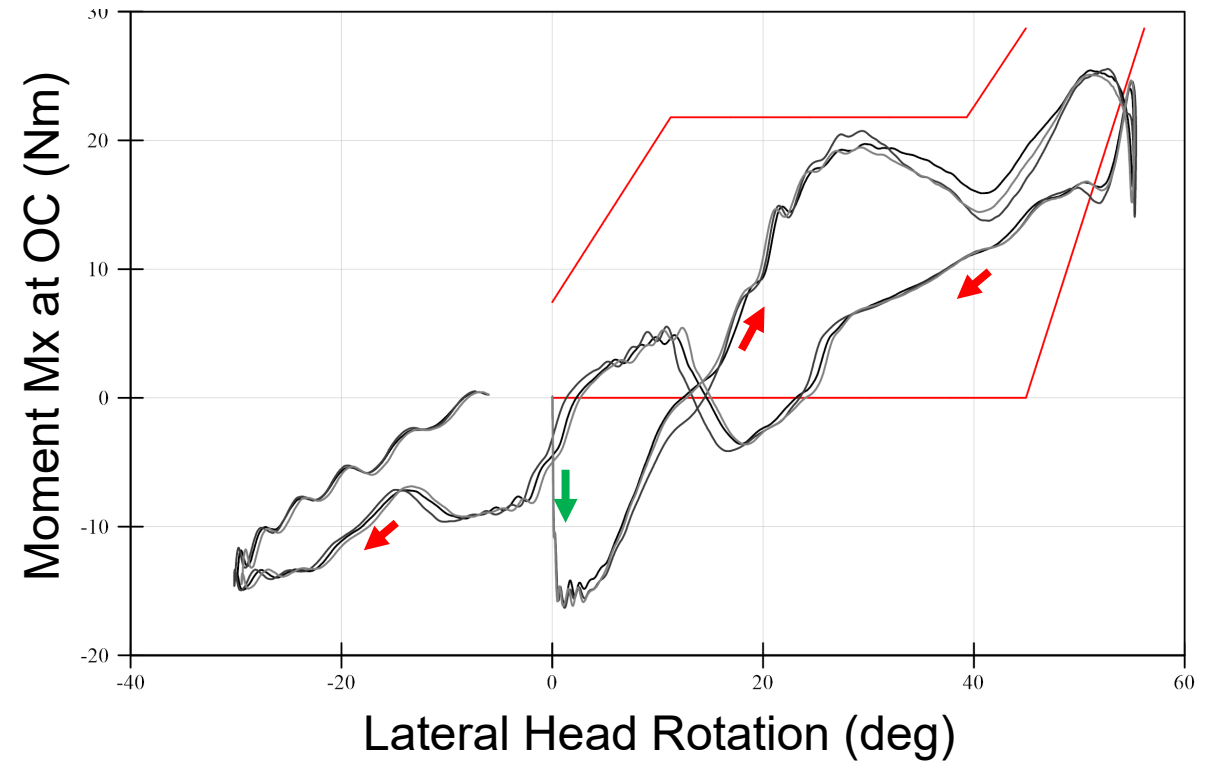


Neck Biofidelity – Lateral Bending Pendulum

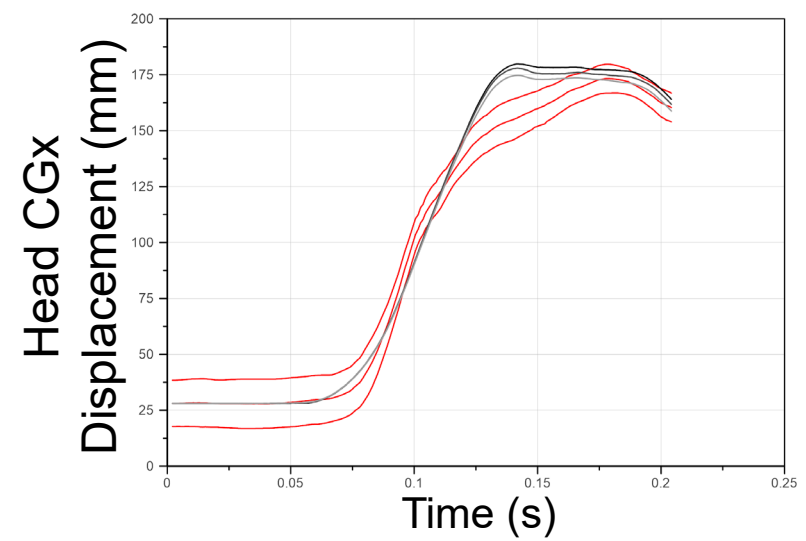
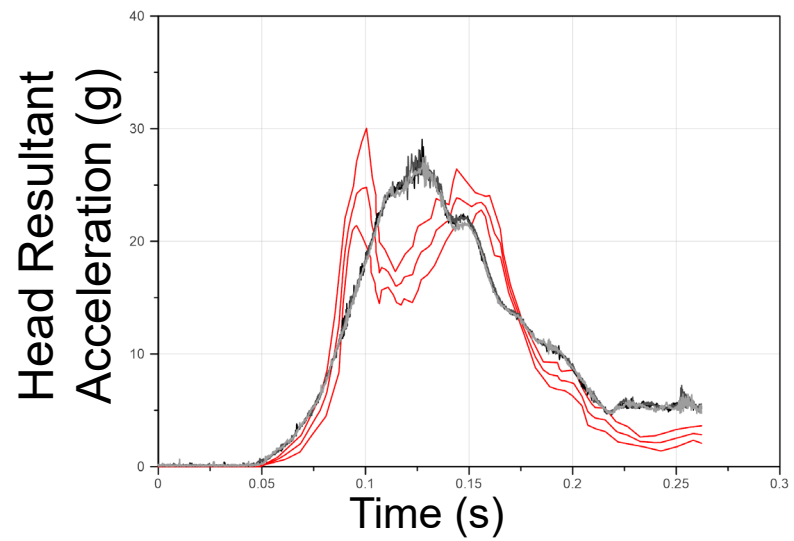
HIII 5th Neck Lateral Bending



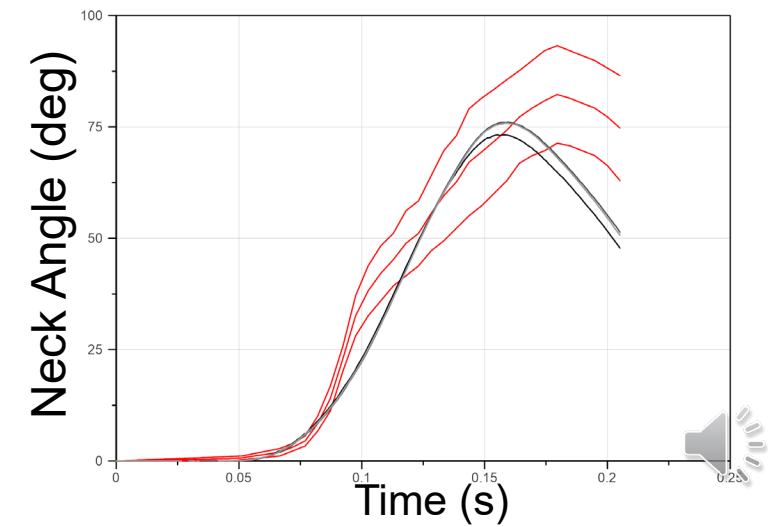
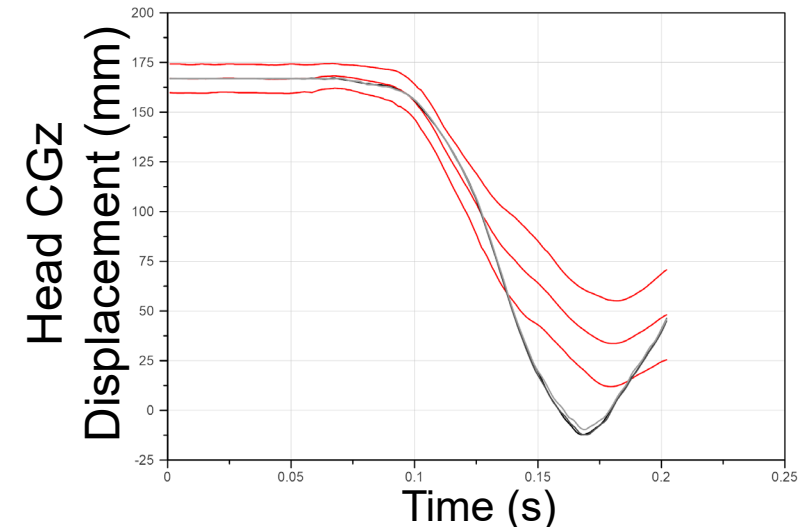
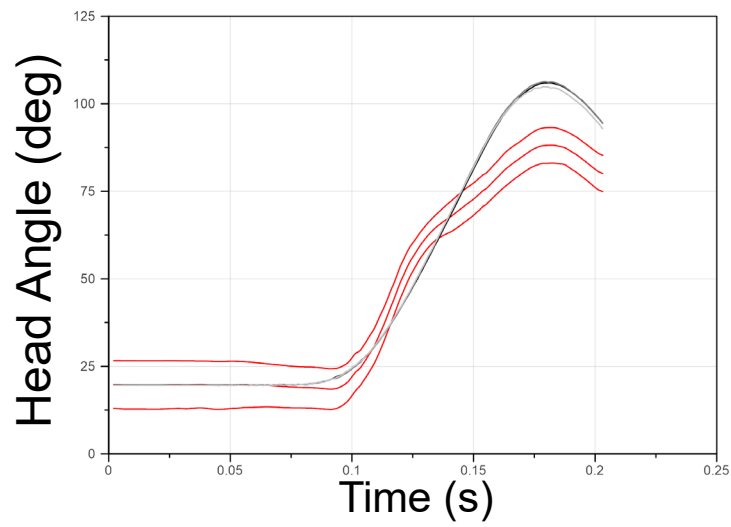
THOR-05F Neck Lateral Bending



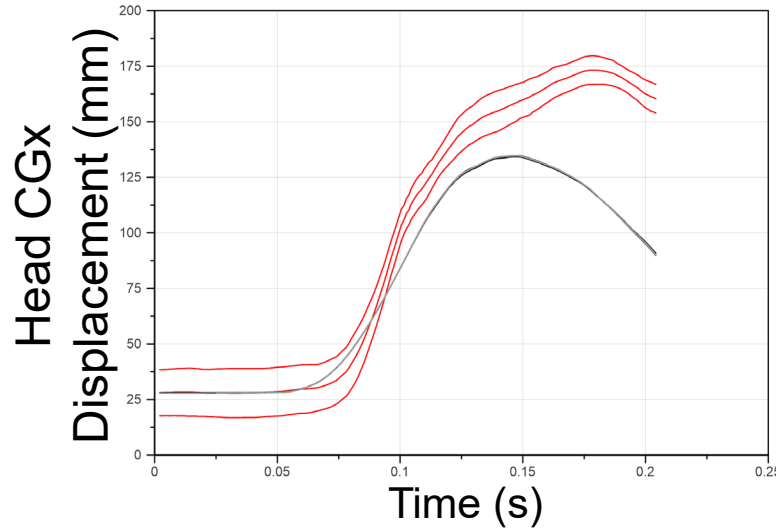
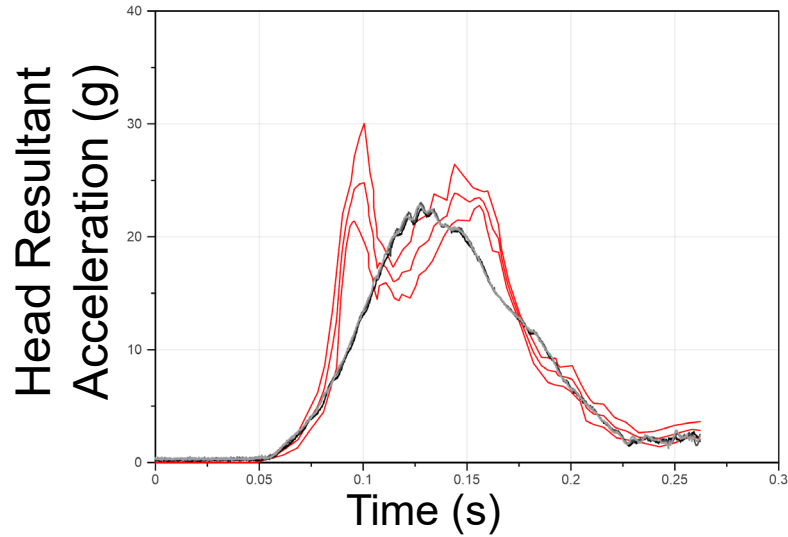
THOR-05F Neck Biofidelity – Flexion Sled



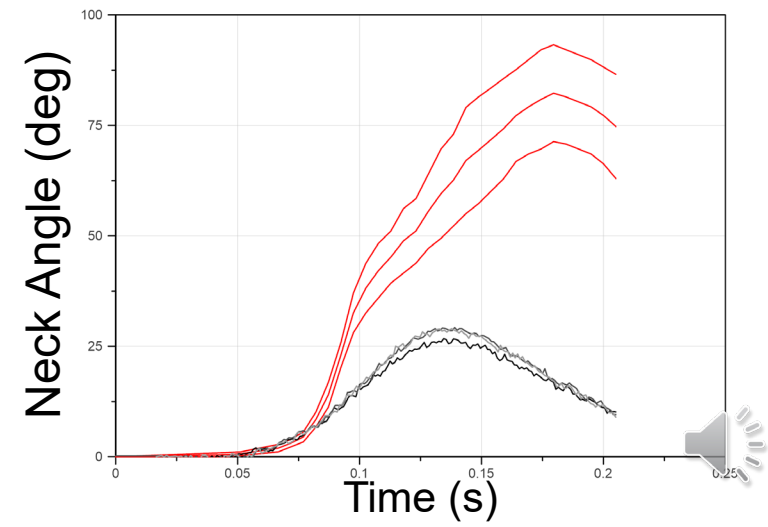
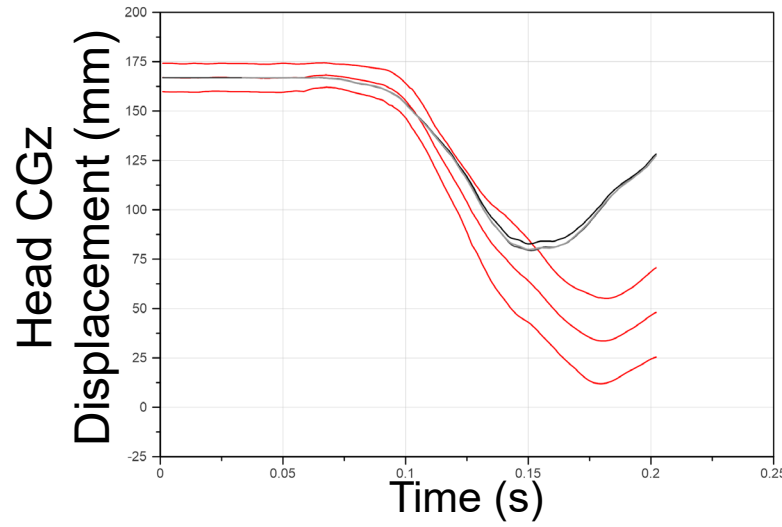
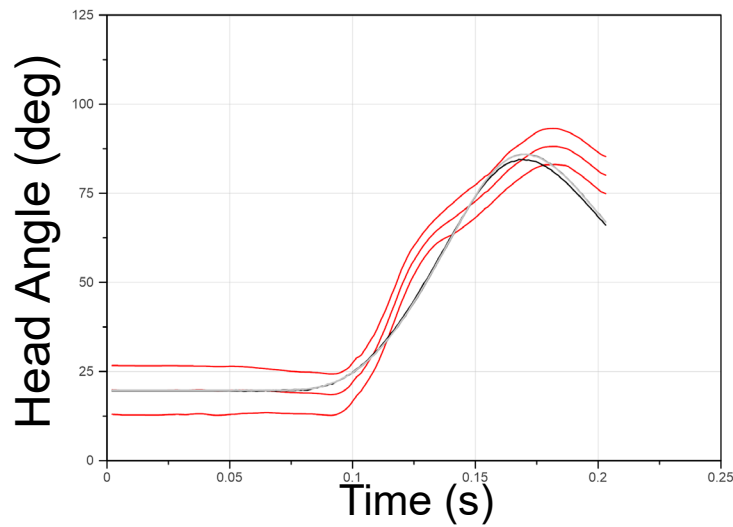
Parameter	B	B _{avg}
Head Resultant Acceleration (g)	2.26	
Head Angle (deg)	1.01	1.17
Head CGx (mm)	0.64	
Head CGz (mm)	0.96	
Neck Angle (deg)	0.97	



HIII 5th Neck Biofidelity – Flexion Sled

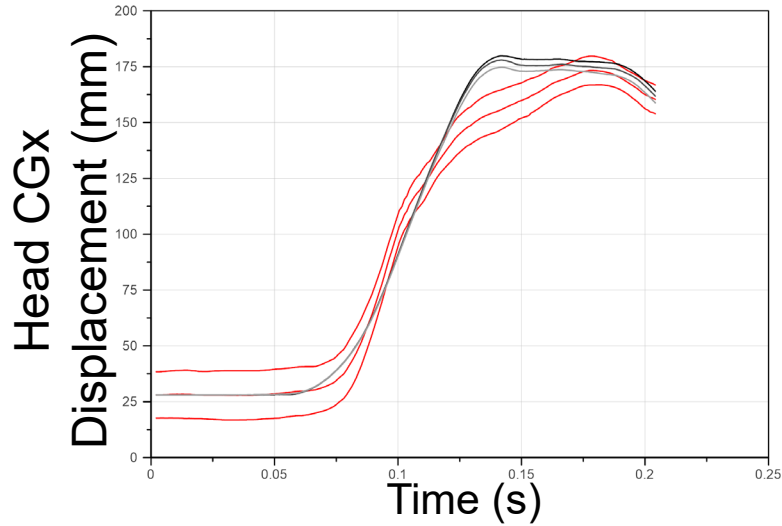


Parameter	B	B _{avg}
Head Resultant Acceleration (g)	1.67	2.05
Head Angle (deg)	0.59	
Head CGx (mm)	2.24	
Head CGz (mm)	1.33	
Neck Angle (deg)	4.43	

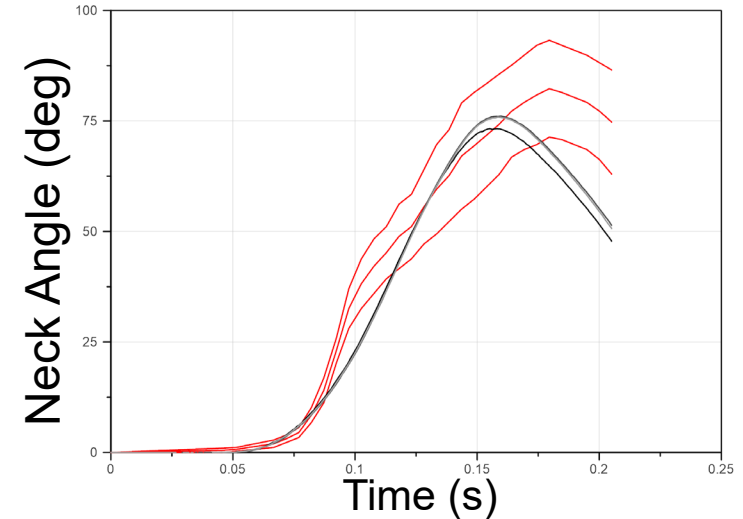


Neck Biofidelity – Flexion Sled

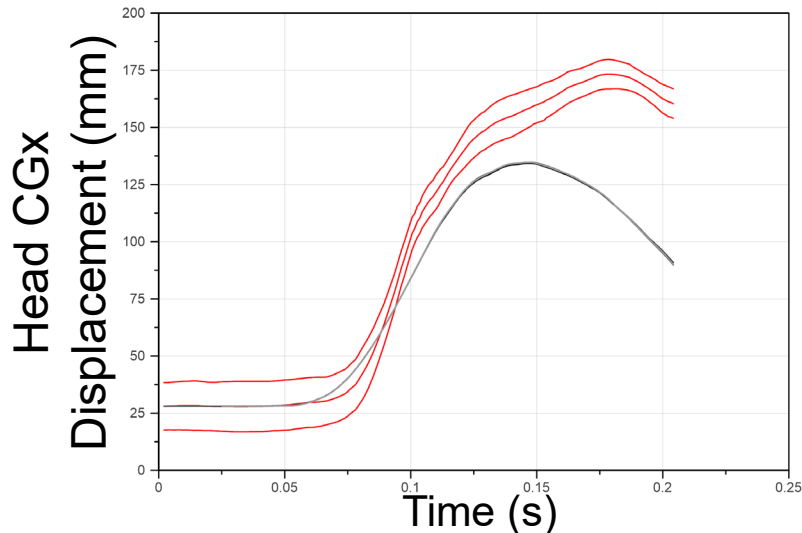
THOR-05F



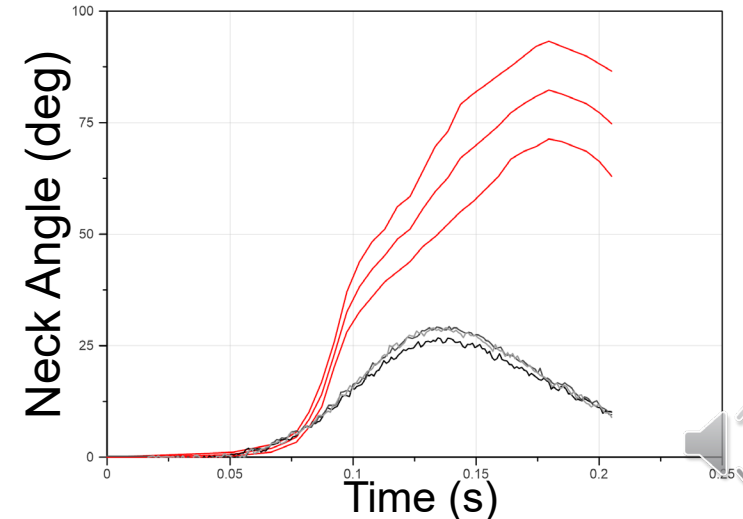
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HIII 5th



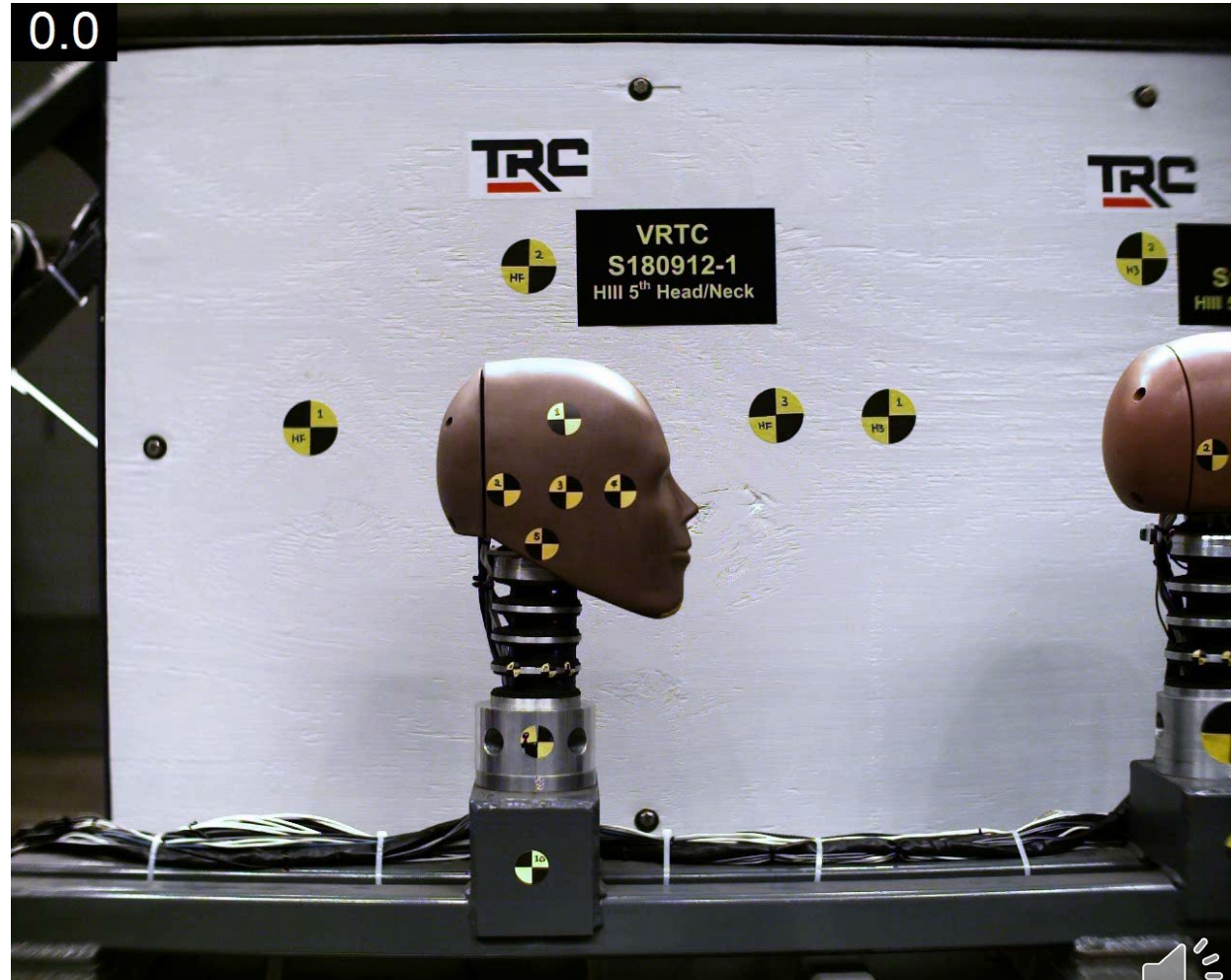
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Neck Angle (deg)	4.43	



Neck Biofidelity – Flexion Sled

THOR-05F

HIII 5th



Neck Durability

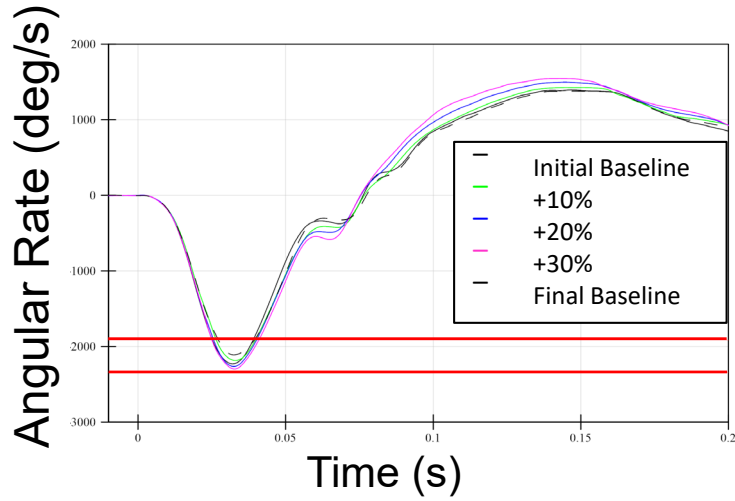


- Neck Durability test matrix
 - Ran the R&R test modes at increasing energy levels

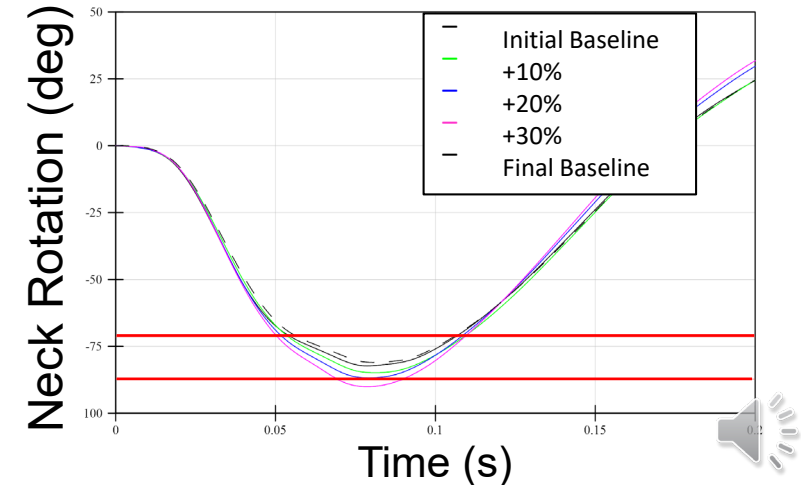
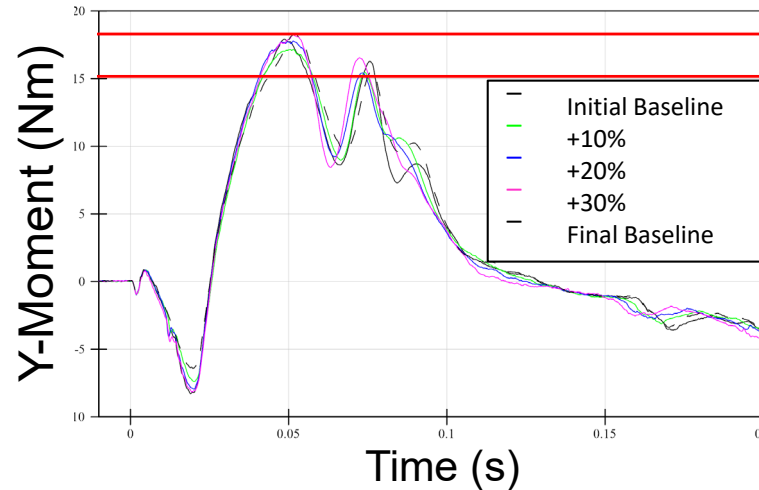
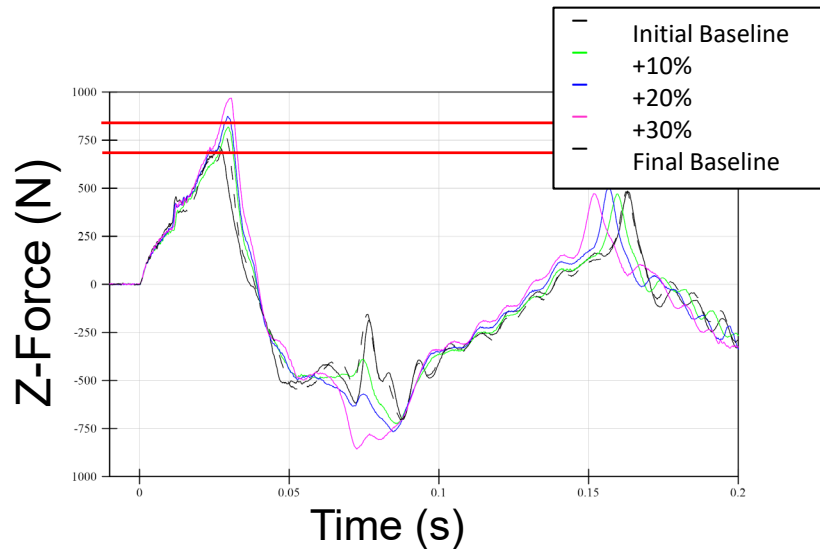
Location	Test	Energy Increase	Impact Velocity (m/s)
Neck	Neck Frontal Flexion	Initial Baseline	5.00
		10% Energy Increase	5.24
		20% Energy Increase	5.48
		30% Energy Increase	5.70
		Final Baseline	5.00
	Neck Lateral Bending	Initial Baseline	3.40
		10% Energy Increase	3.57
		20% Energy Increase	3.72
		30% Energy Increase	3.88
		Final Baseline	3.40
	Neck Torsion	Initial Baseline	3.40
		10% Energy Increase	3.57
		20% Energy Increase	3.72
		30% Energy Increase	3.88
		Final Baseline	3.40
	Neck Extension	Initial Baseline	5.00
		10% Energy Increase	5.24
		20% Energy Increase	5.48
		30% Energy Increase	5.70
		Final Baseline	5.00



Neck Durability – Frontal Flexion

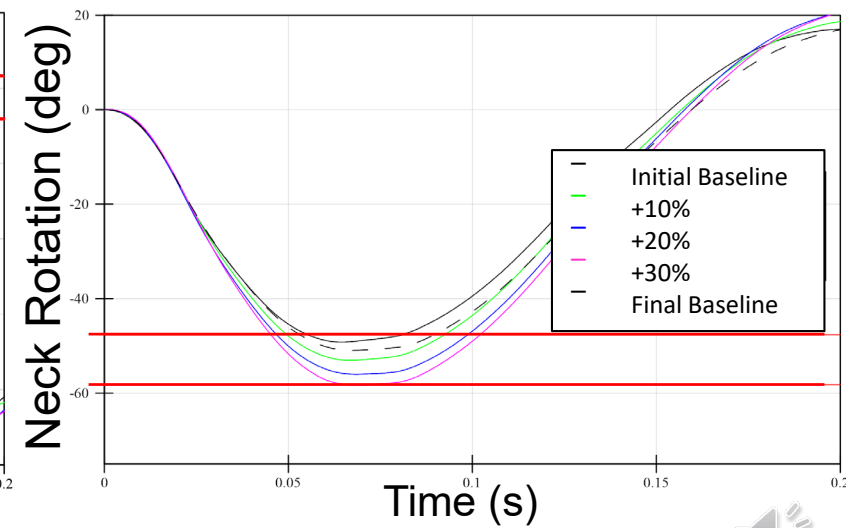
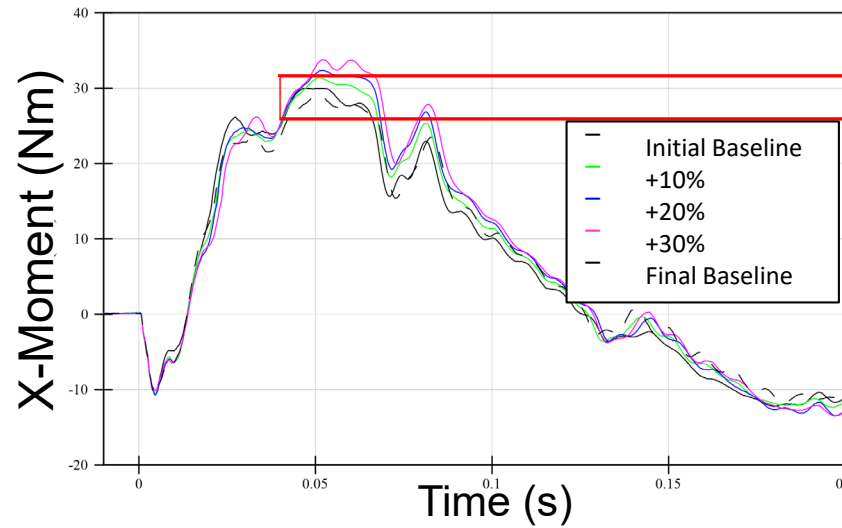
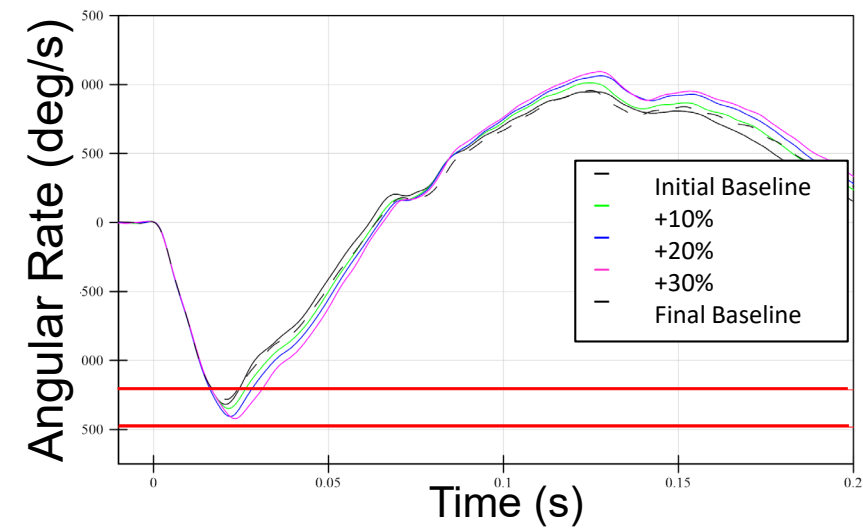


Parameter	Specification Range		Initial Baseline	+10%	+20%	+30%	Final Baseline
Maximum Upper Neck M_y (Nm)	15.05	18.4	17.9	17.2	17.8	18.3	18.3
Maximum Upper Neck F_z prior to 40 ms (N)	684	836	717	818	873	970	764
Minimum Head Angular Velocity ω_y (relative to earth) (deg/s)	-2340	-1915	-2229	-2184	-2264	-2298	-2110
Minimum Head Rotation (relative to pendulum) (deg)	-87.3	-71.5	-82.3	-84.8	-86.8	-90.1	-81.0



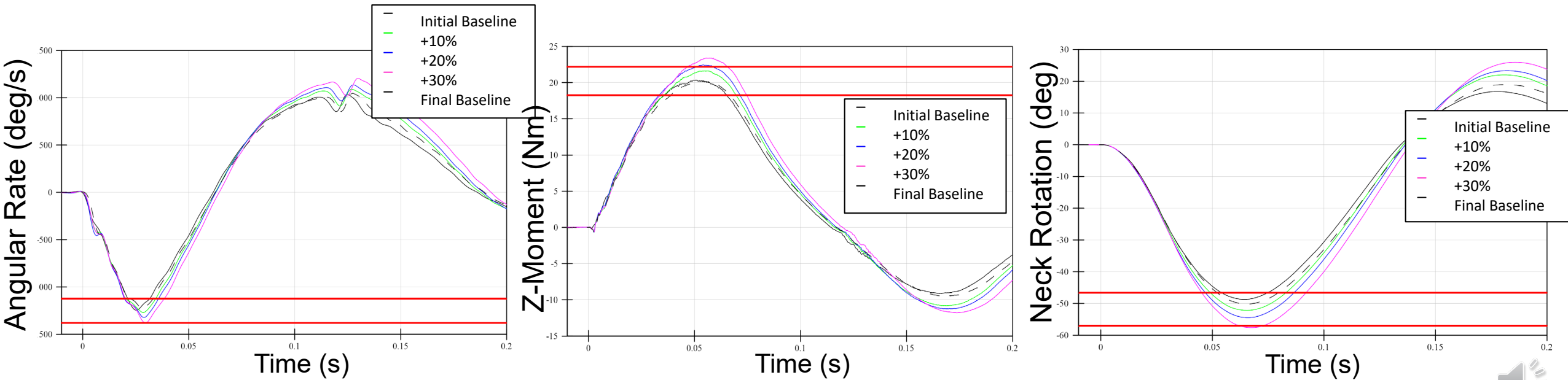
Neck Durability – Left Lateral Bending

Parameter	Specification Range		Initial Baseline	+10%	+20%	+30%	Final Baseline
Maximum Upper Neck M_x after 40.0 ms (Nm)	25.8	31.5	30.0	31.4	32.4	33.8	29.2
Mininum Head Angular Velocity ω_x (relative to earth) (deg/s)	-1482	-1212	-1318	-1348	-1406	-1421	-1281
Minimum Head Rotation (relative to pendulum) (deg)	-58.2	-47.6	-49.2	-53.0	-56.0	-58.4	-51.0

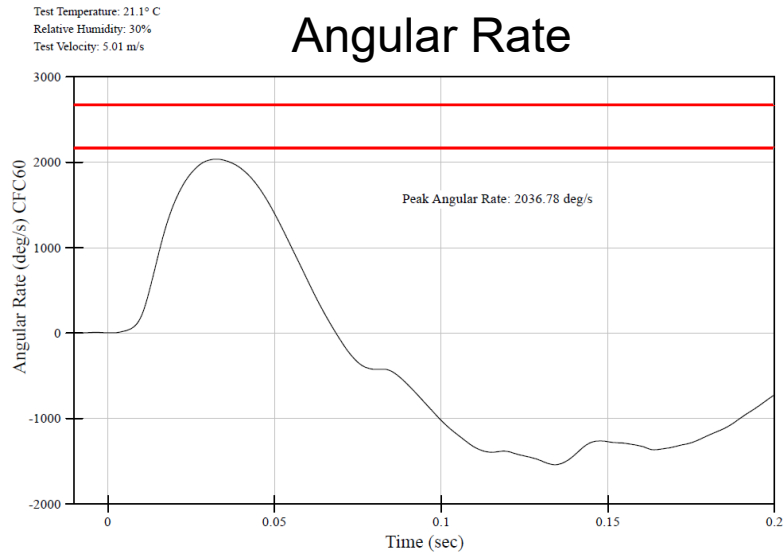


Neck Durability – Left Torsion

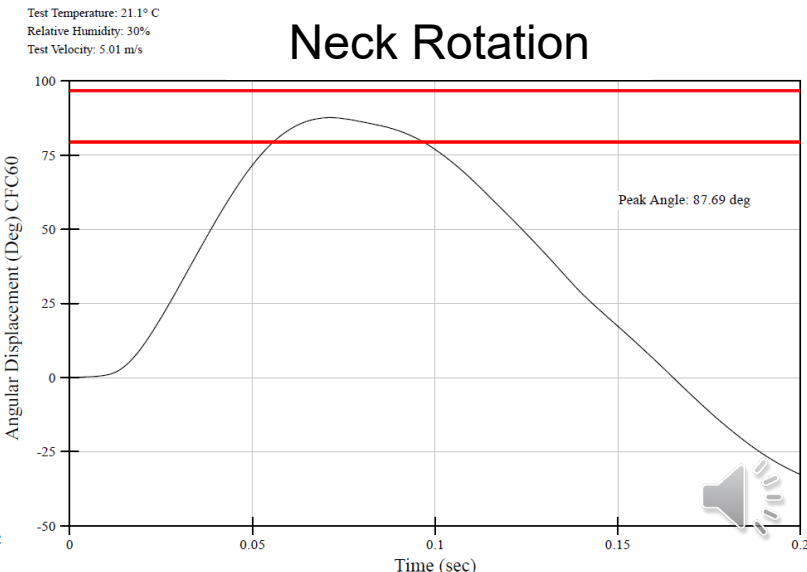
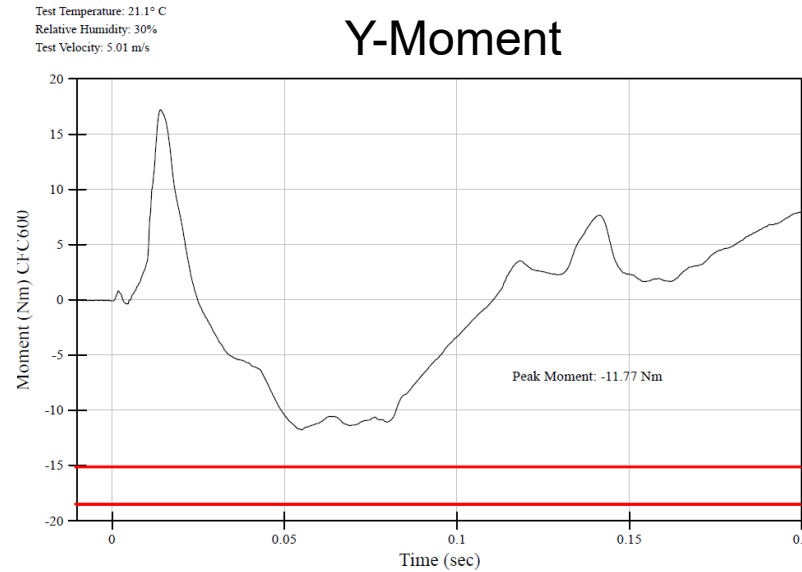
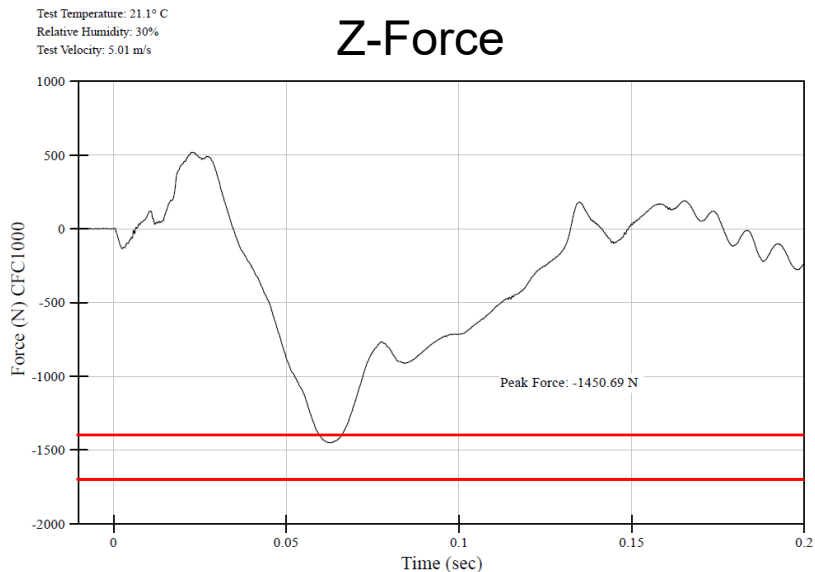
Parameter	Specification Range		Initial Baseline	+10%	+20%	+30%	Final Baseline
Maximum Upper Neck M_z (Nm)	18.2	22.2	20.4	21.6	22.5	23.4	20.3
Minimum Neck Fixture Rotation (deg)	-57.2	-46.8	-48.7	-52.2	-54.5	-57.6	-50.2
Minimum Upper Neck Angular Velocity ω_z (relative to earth) (deg/s)	-1381	-1130	-1245	-1269	-1322	-1379	-1224



Neck Durability - Extension

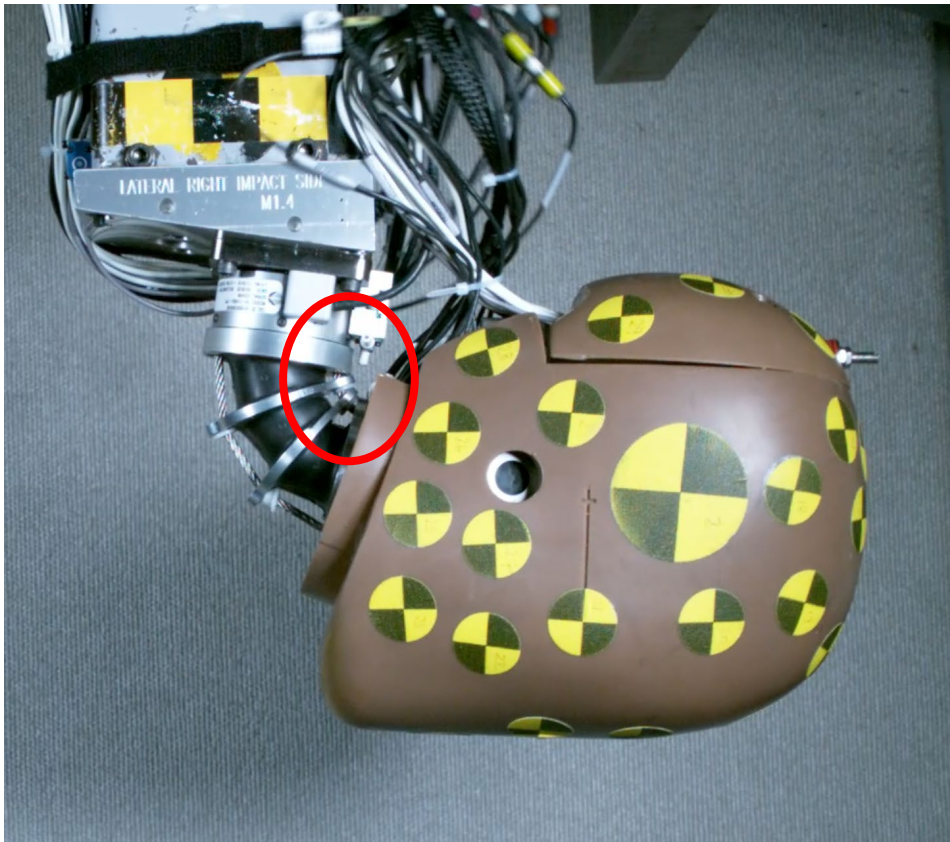


Parameter	Specification Range		Initial Baseline
Minimum Upper Neck My (Nm)	-18.6	-15.2	-11.8
Minimum Upper Neck Fz (N)	-1708	-1397	-1451
Maximum Head Angular Velocity (deg/sec)	2177	2661	2037
Maximum Head Rotation (deg)	78.9	96.4	87.7



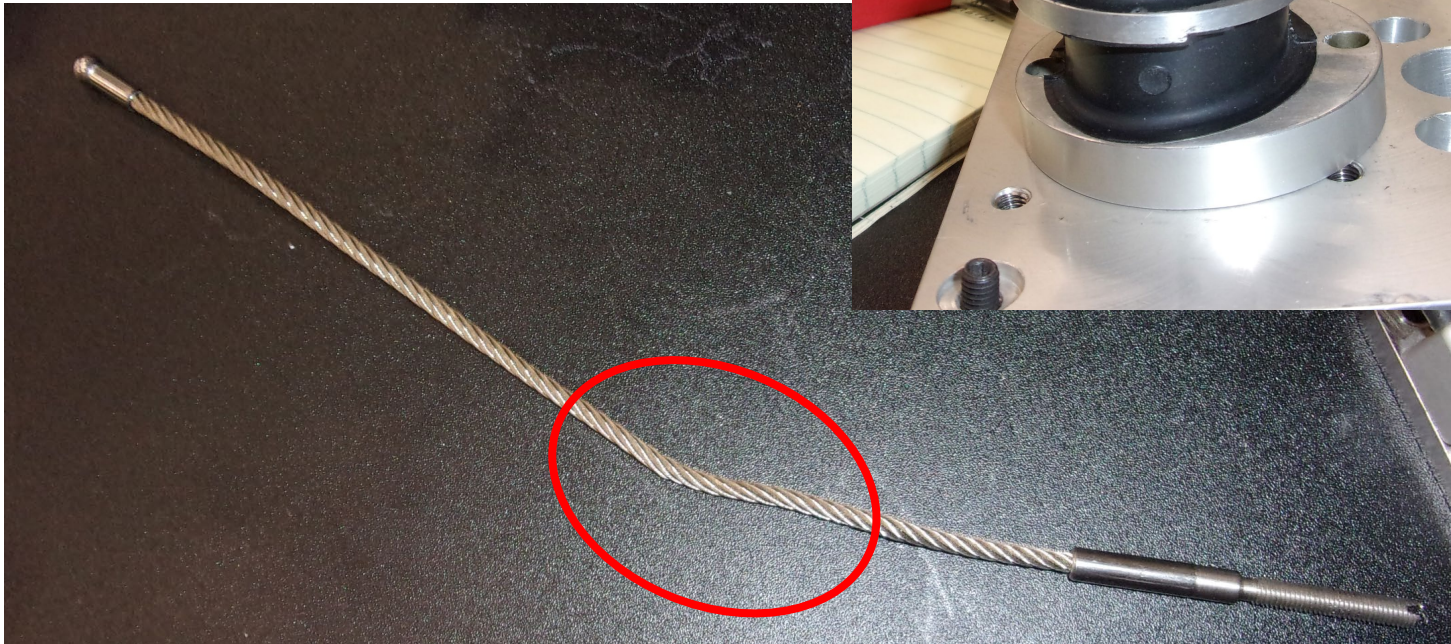
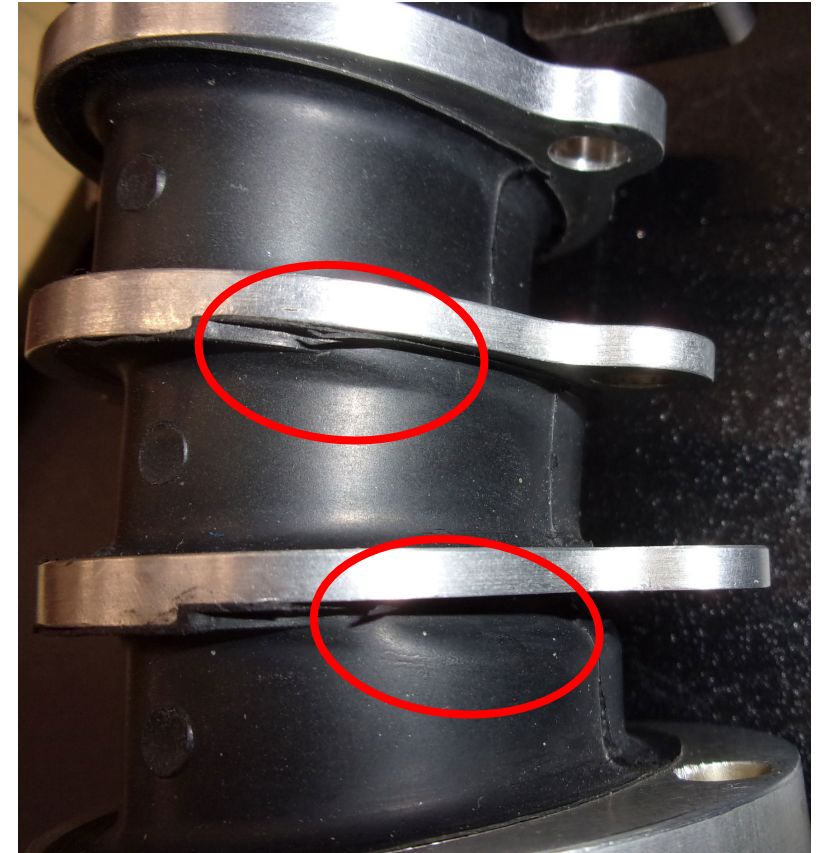
Neck Durability

- Neck Plate contact during initial baseline extension test



Neck Durability

- Post Test Teardown



- THOR-05F neck R&R testing shows good results with CVs < 10%
- Biofidelity
 - Neck Pendulum tests: THOR-05F shows better qualitative biofidelity than HIII 5th
 - Neck Flexion Sled tests: THOR-05F has a better BioRank score than HIII 5th
- THOR-05F neck durability is under further investigation





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NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

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