NHTSA

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Seat Assessment In Standardized Rear Impact Virtual Testing

SAE Government-Industry Meeting

01. 29. 2025

AGENDA

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1. **Background**
2. **Research Question/Approach**
3. **FMVSS 301R Pulse Severity Model Evaluation**
4. **“Strengthened” Seat Model Evaluation**
5. **Summary/Conclusions**

Background

Rear Impact Statistics

Fatality Analysis Reporting System (FARS) and Crash Reporting Sampling System (CRSS) Data (2020)[1]

- Over 2 million rear impacted light vehicles in 2020
- 24.1% of crashed light vehicles are rear impacts
- 21.8% of injured occupants in light vehicle crashes are in rear impacts
- Injury rate in rear impacted light vehicles (30%) is comparable to other crash directions (frontal – 33%, side – 30%)
- 7.2% of light vehicle crash fatalities are in rear impacts
- Fatal injuries are associated with high ΔV crashes

[1]National Center for Statistics and Analysis. (2022, October). Traffic Safety Facts 2020: A compilation of motor vehicle crash data (Report No. DOT HS 813 375). National Highway Traffic Safety Administration.

Current Study

Research Question

Does a seat that is re-designed to lessen deformation and collapse under a FMVSS 301R-style pulse affect seat performance when undergoing the dynamic test for head restraints described in FMVSS No. 202a?

Approach

- Generate FMVSS 301R pulse using the 2014 Honda Accord finite element (FE) model.
- Perform sled FE model FMVSS 301R pulse scaling study to estimate what pulse severity leads to seat collapse.
- “Strengthen” 2014 Honda Accord FE seat model to mitigate seat collapse.
- Evaluate dummy response (HIC15, head-to-torso rotation) in FMVSS 202a with the “Strengthened” seat model.

Seat Finite Element Model

2014 Honda Accord LS-Dyna Model[2]

- Validated versus quasi-static rear pull test and dynamic sled tests
- Model animation showed similar dummy kinematics and seat deformation behavior to dynamic sled test data
- Model predicted similar maximum seat back rotation and dummy response compared to dynamic sled test data
- Plastic deformation patterns were similar as those in tested seats

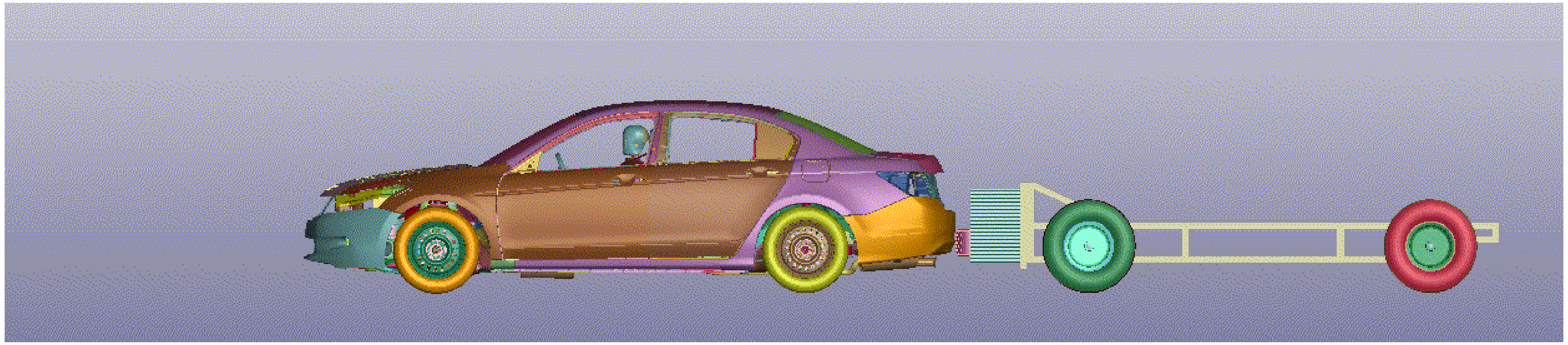
[2]"Front Seat Modeling in Rear Impact Crashes: Development of a Detailed Finite-Element Model for Seat Back Strength Requirements" (2019), https://doi.org/10.21949/1530153

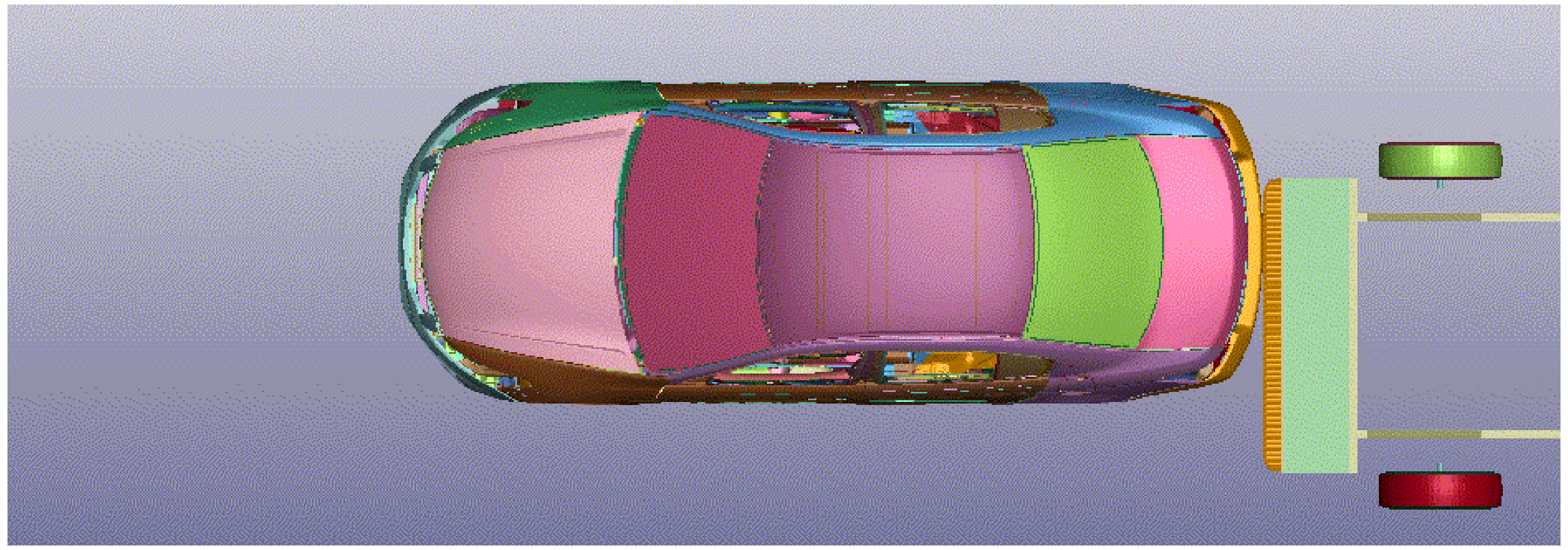
FMVSS 301R Pulse Generation

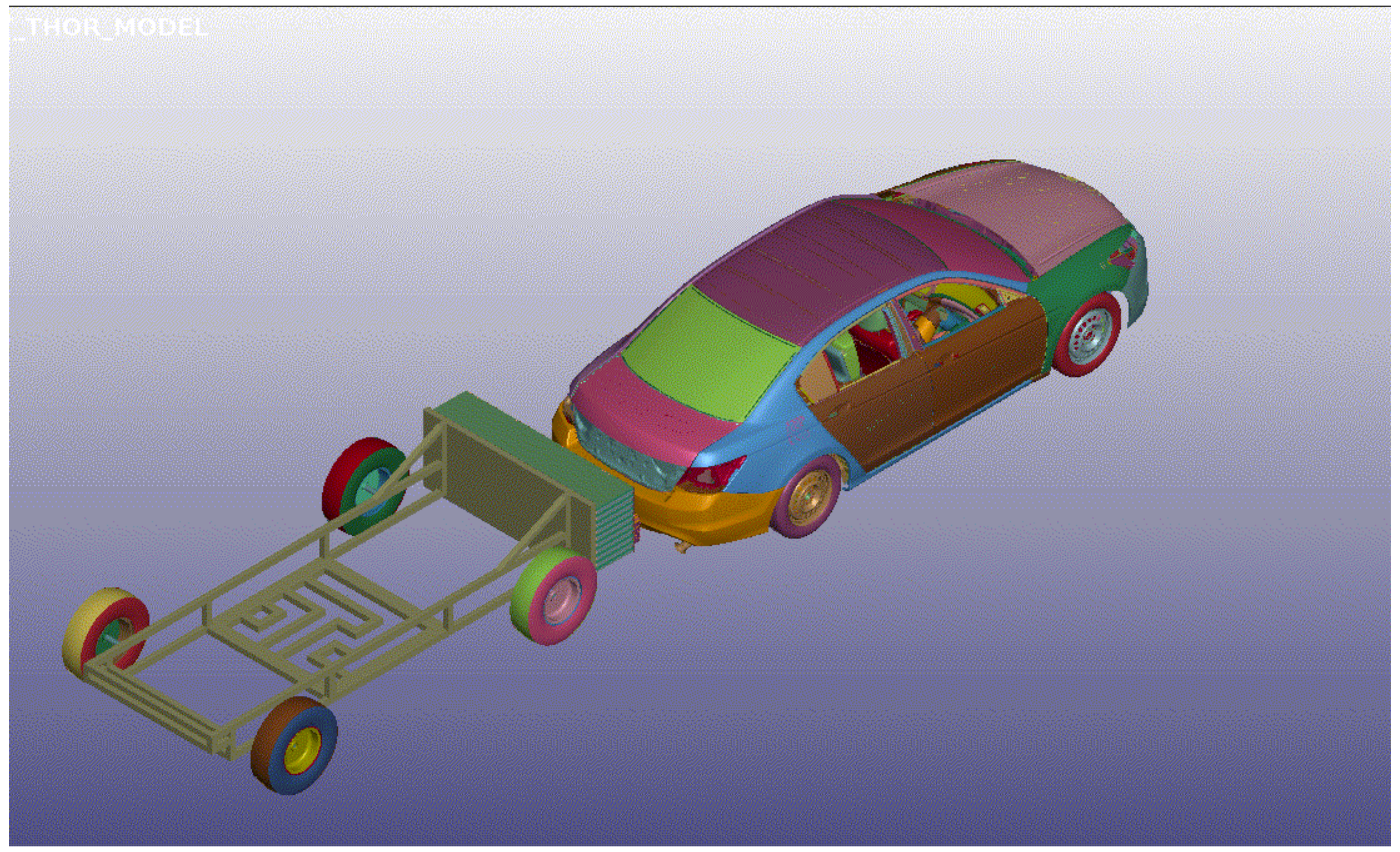
Model Setup

- A 2014 Honda Accord full vehicle FMVSS 301R crash test FE simulation was performed to generate the rear impact acceleration pulse for use in sled the sled models.

- Simulation pulse was extracted from the vehicle B-pillar sill on the driver side.

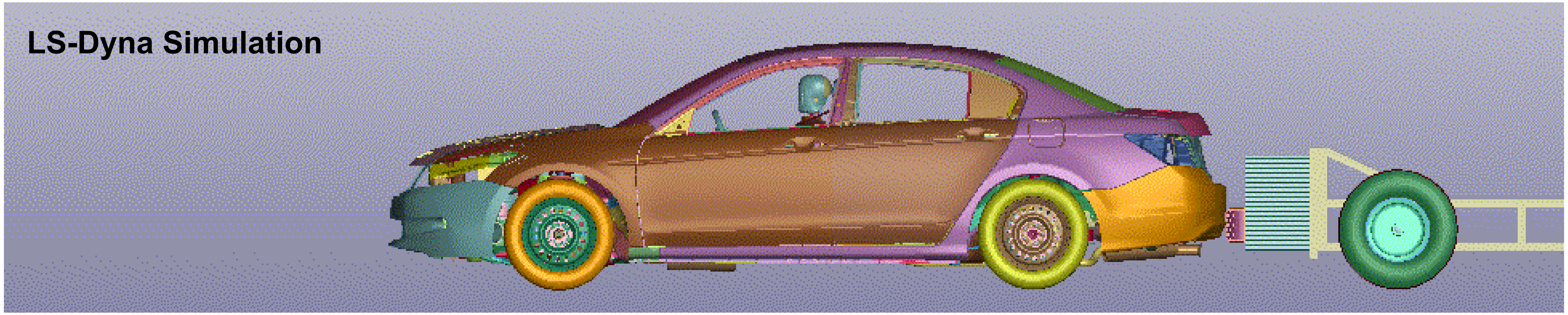






FMVSS 301R Pulse Generation

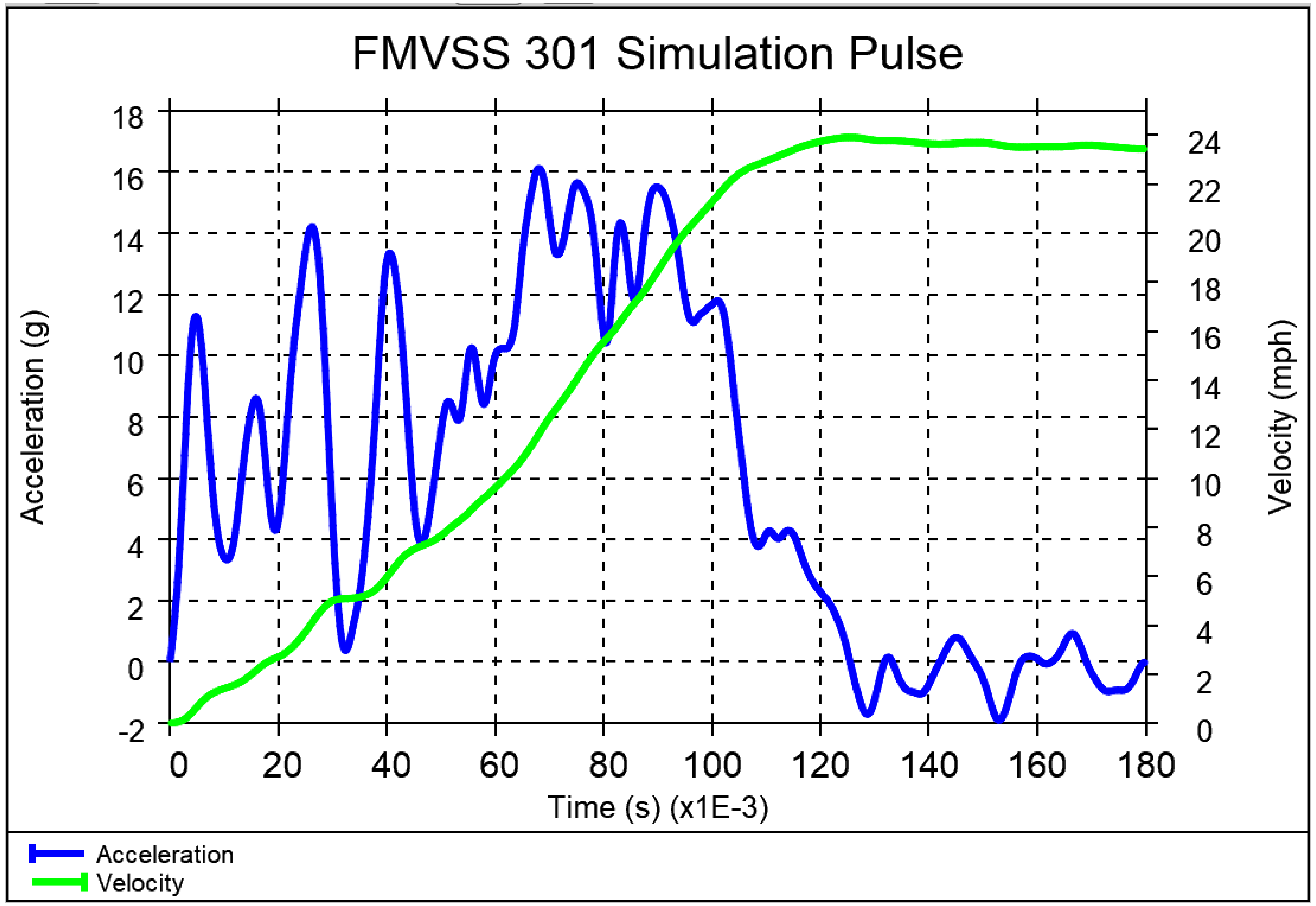
Model Validation



Kinematics in simulation are similar to vehicle crash test

FMVSS 301R Pulse Generation

Pulse Scaling for Simulations

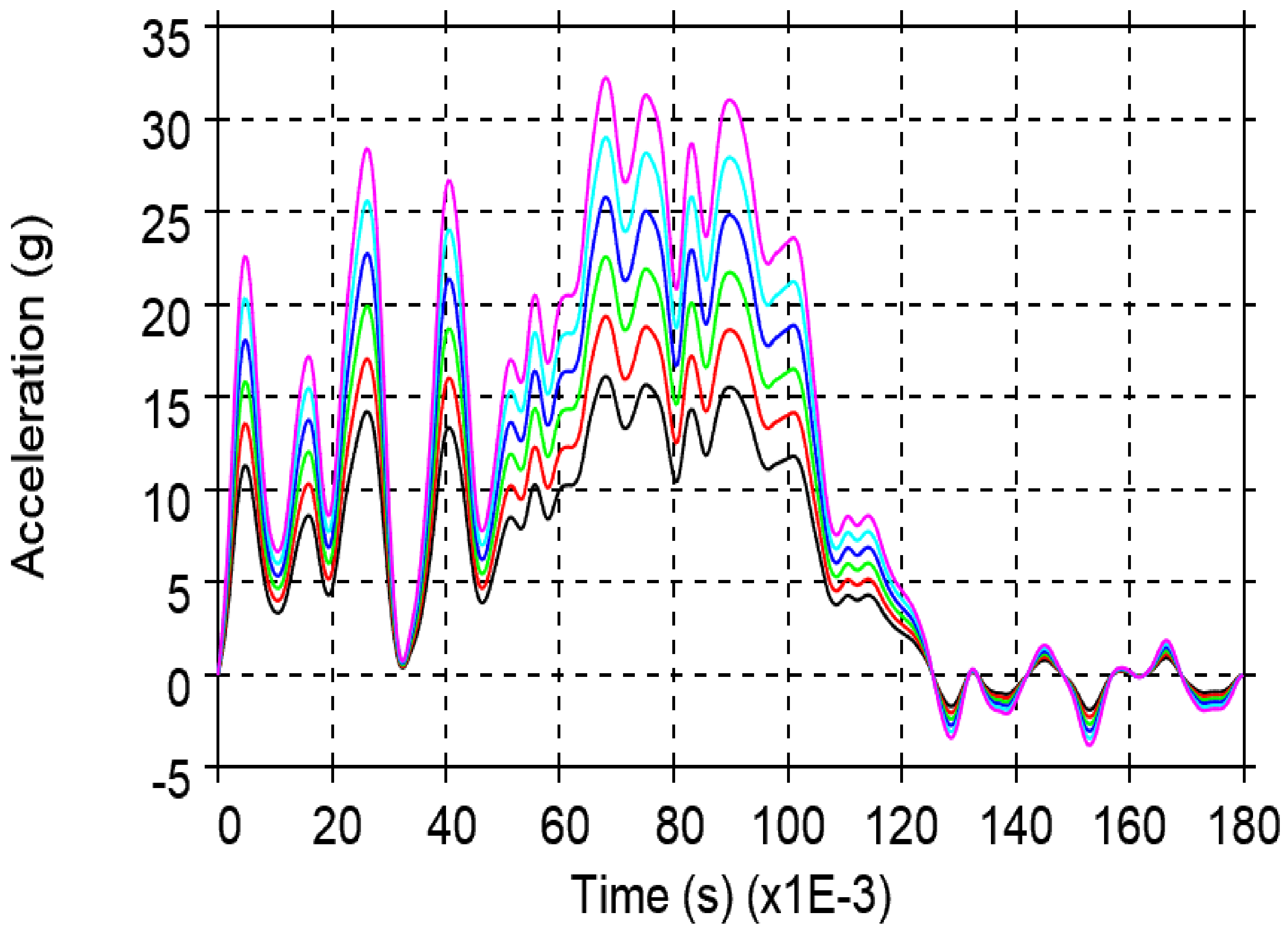


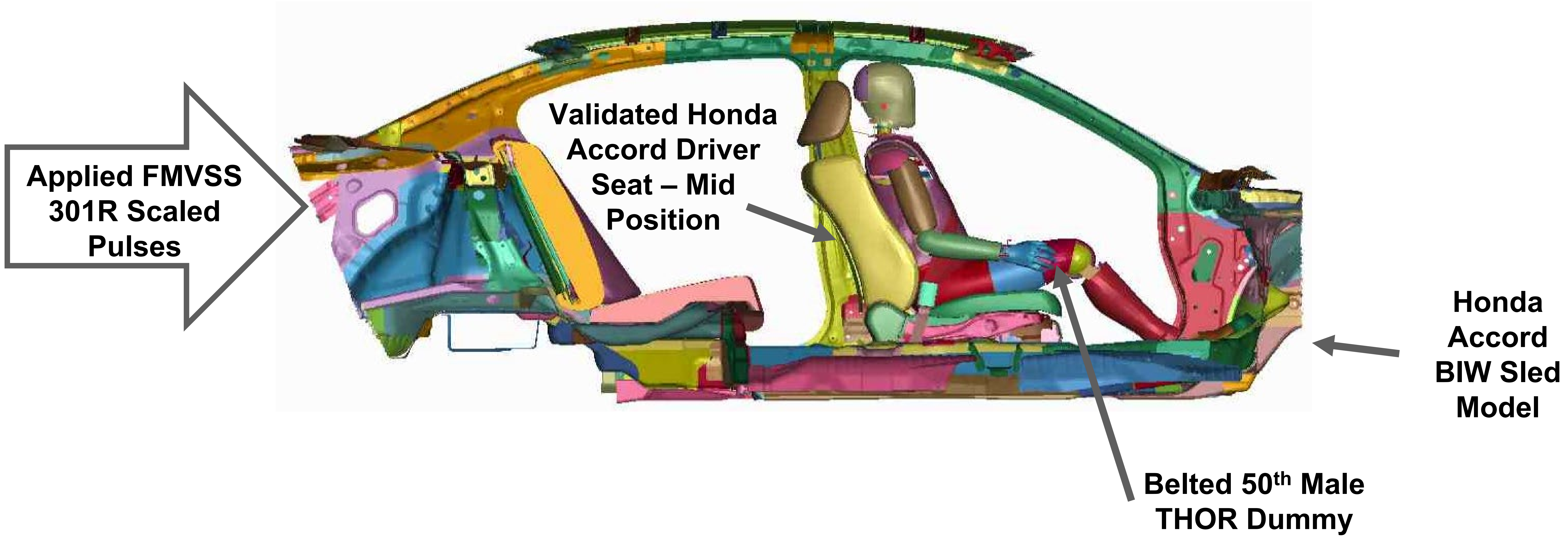
Scaled Pulses for Simulations

Baseline Curve Max Accel (g)	Scale Factor	Max Accel (g)	Velocity (kph)	Velocity (mph)
16	1	16	38.6	24
16	1.2	19.2	46.3	28.8
16	1.4	22.4	54.0	33.6
16	1.6	25.6	61.8	38.3
16	1.8	28.8	69.5	43.1
16	2	32	77.2	47.9

Scaled Pulse Study

Model Setup

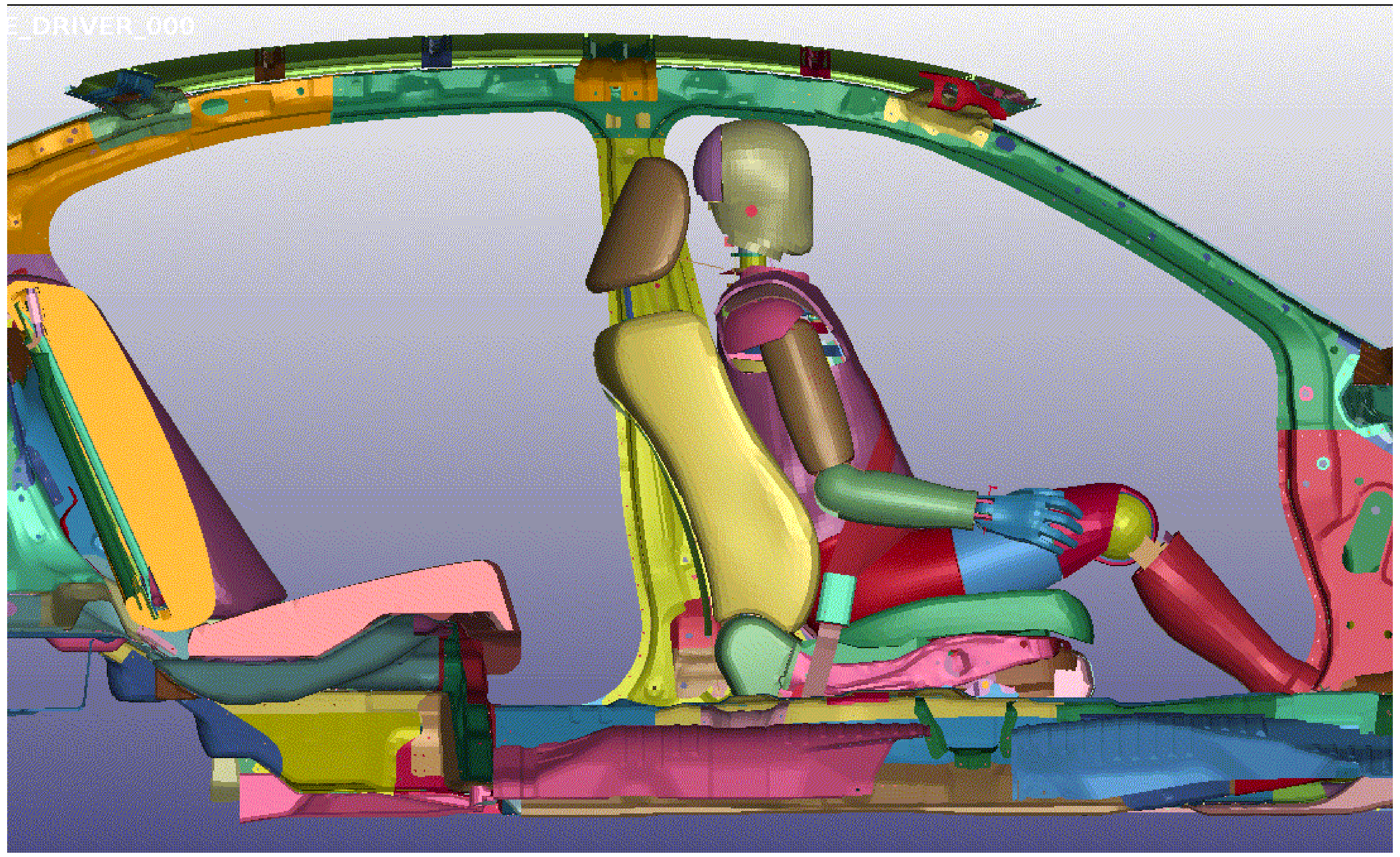




- At what pulse severity does the seat collapse?
- Material failure is not modeled in the seat, evaluated seat collapse subjectively.

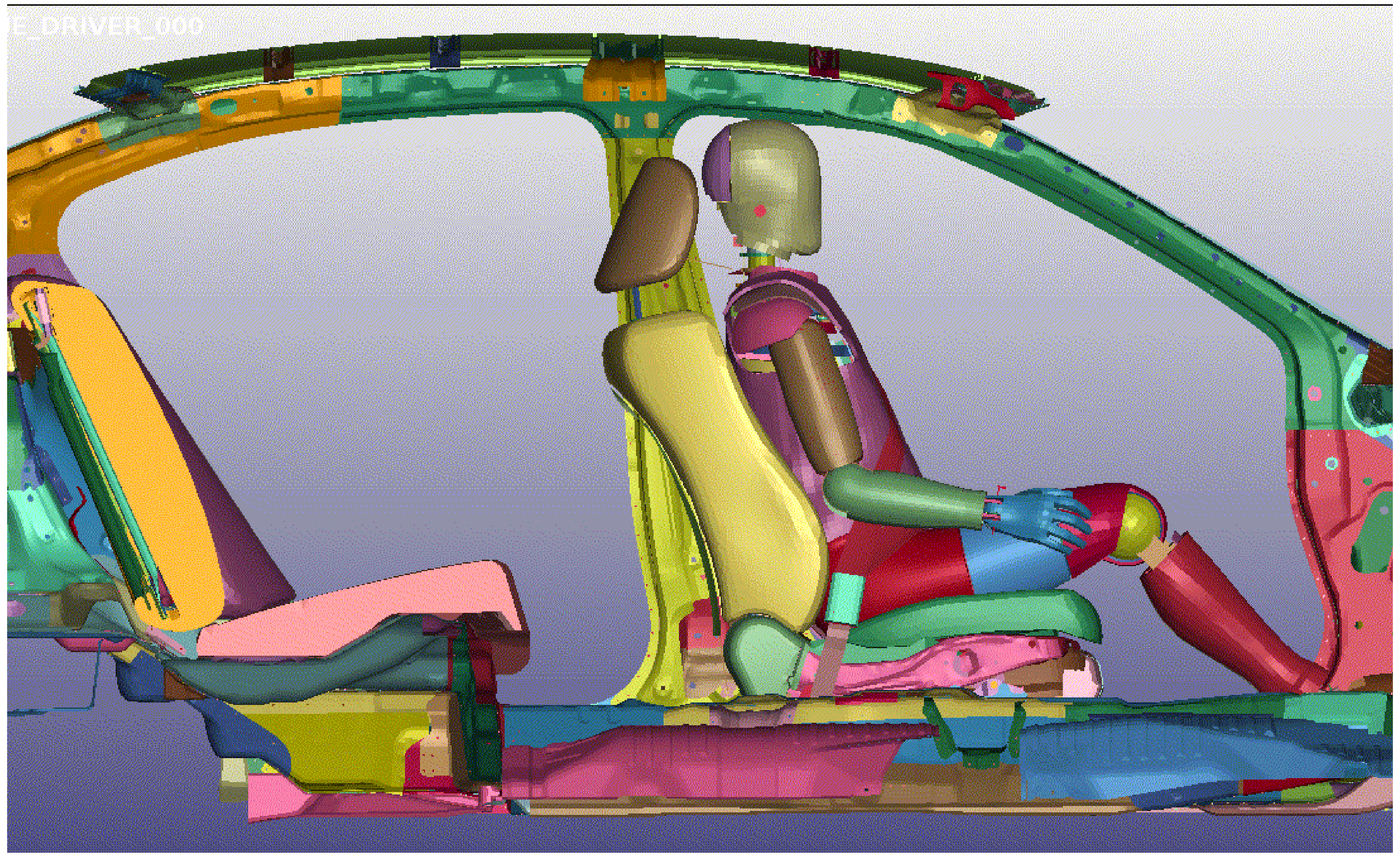
Scaled Pulse Study

Results – Pulse Severity and Seat Collapse



16 g Pulse

29° Seat Back Rotation



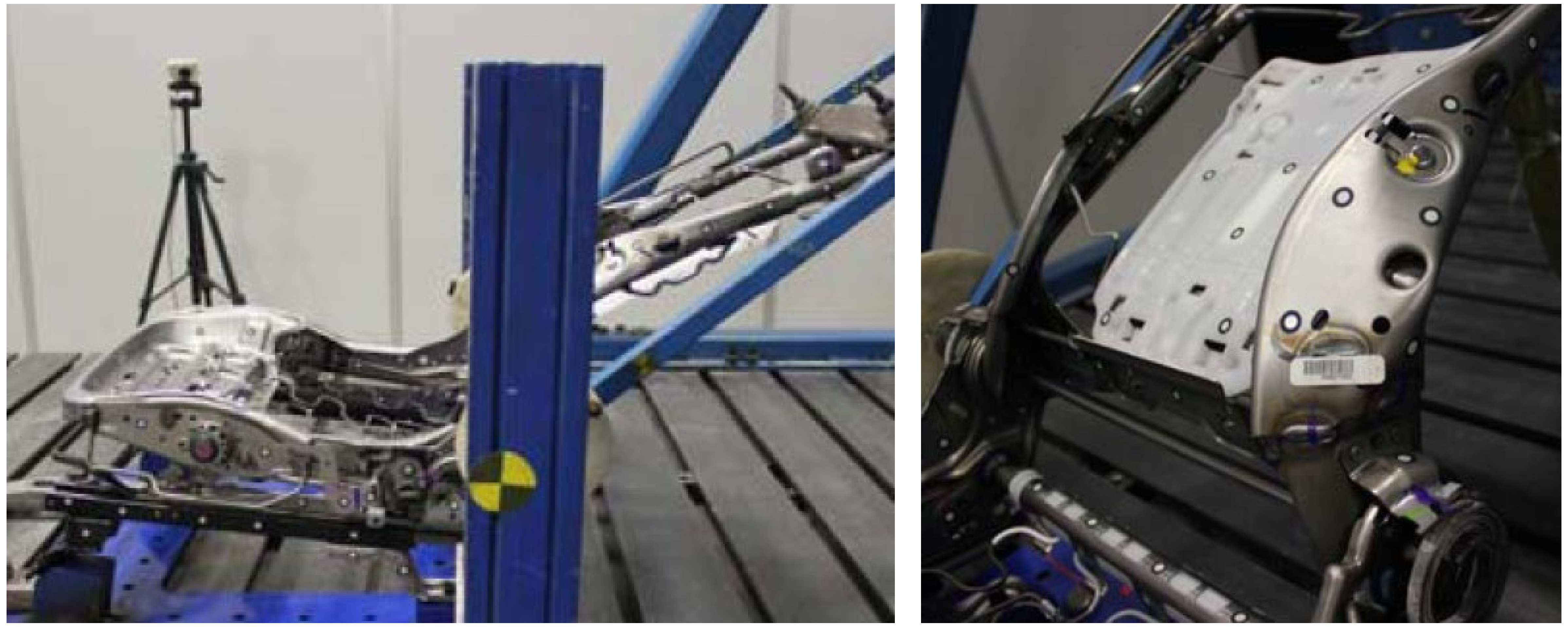
25.6 g Pulse

47.5° Seat Back Rotation

- Lowest severity pulse resulting in what resembled seat “collapse” was 25.6 g (baseline x 1.6).
- Result is increased ramping of 1st row occupant, extreme head and neck kinematics and near head to roof contact during occupant rebound.
- Sled model does not capture likely high amount of rear structure intrusion during a severe crash which could result in a head contact to the rear seat.

Scaled Pulse Study

Results – Seat Deformation and Collapse



EDAG Seat Pull Test[3]

Seat Back Rotation at Collapse = 50°

25.6 g Pulse Simulation

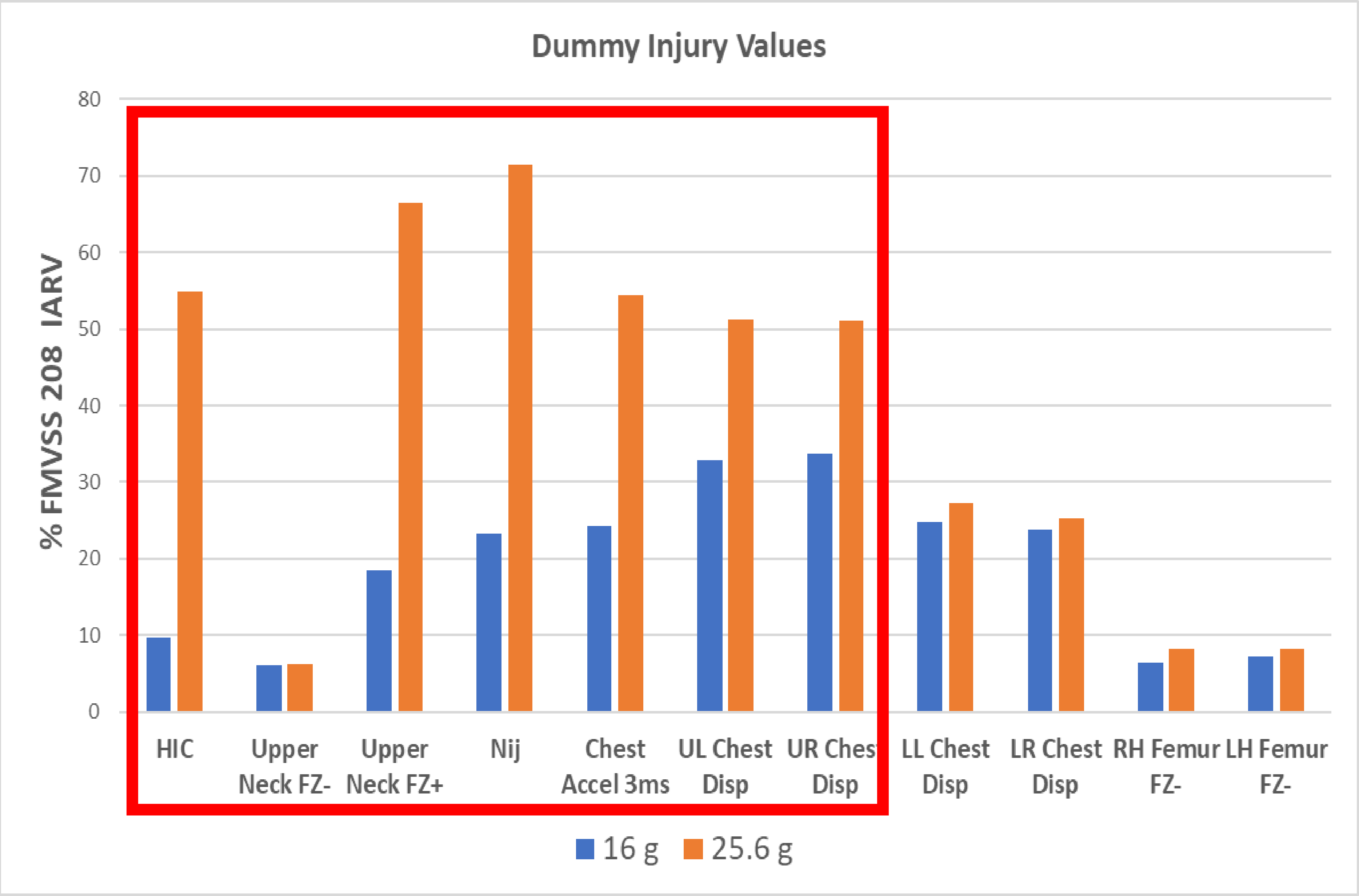
Seat Back Rotation at "Collapse"* = 47.5°

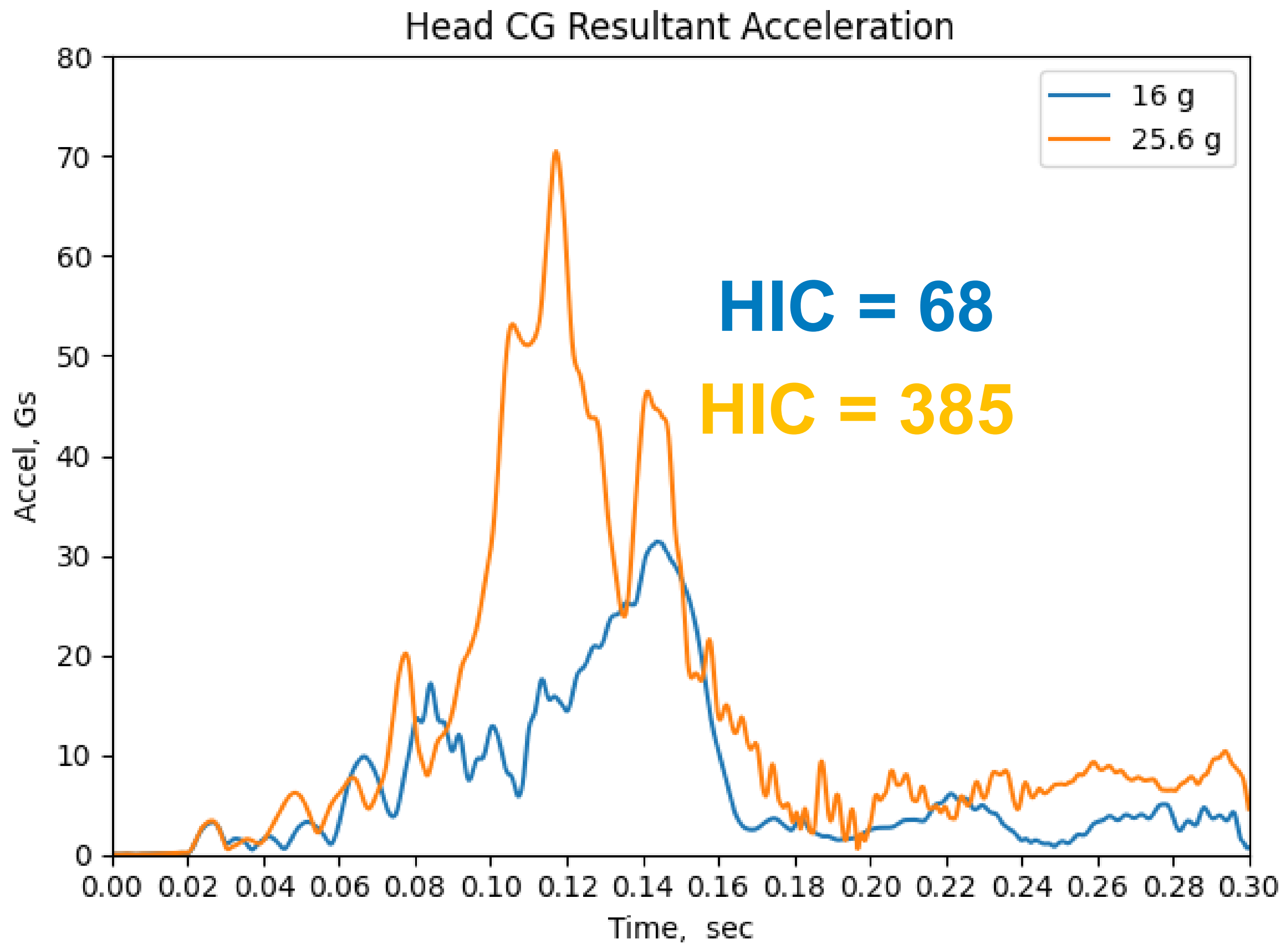
***Seat model does not have material failure built in, so point of "collapse" was estimated characterized by amount of seat rotation and deformation**

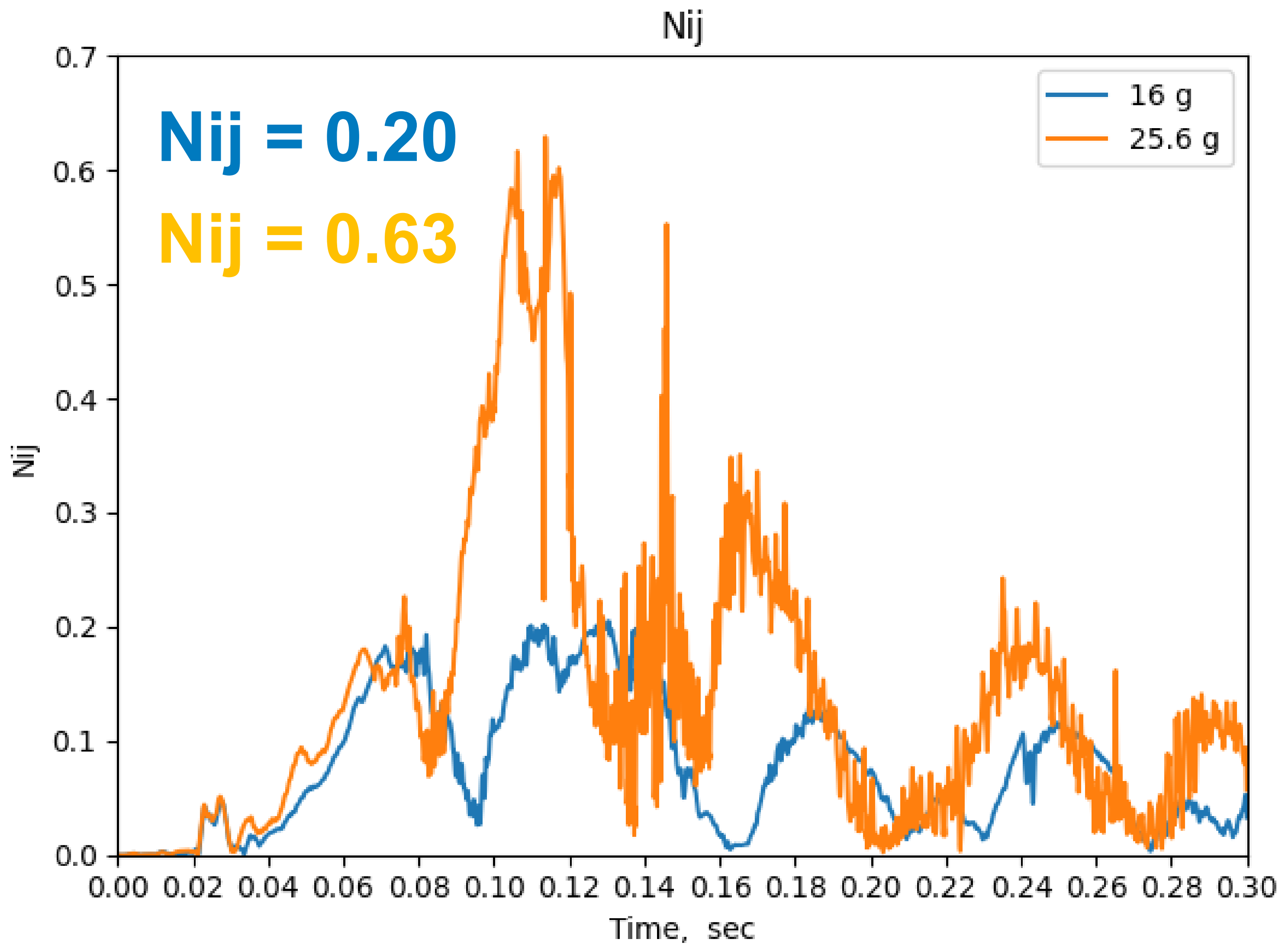
[3]"Front Seat Modeling in Rear Impact Crashes: Development of a Detailed Finite-Element Model for Seat Back Strength Requirements" (2019), https://doi.org/10.21949/1530153

Scaled Pulse Study

Results – 1st Row 50th Male Dummy Responses



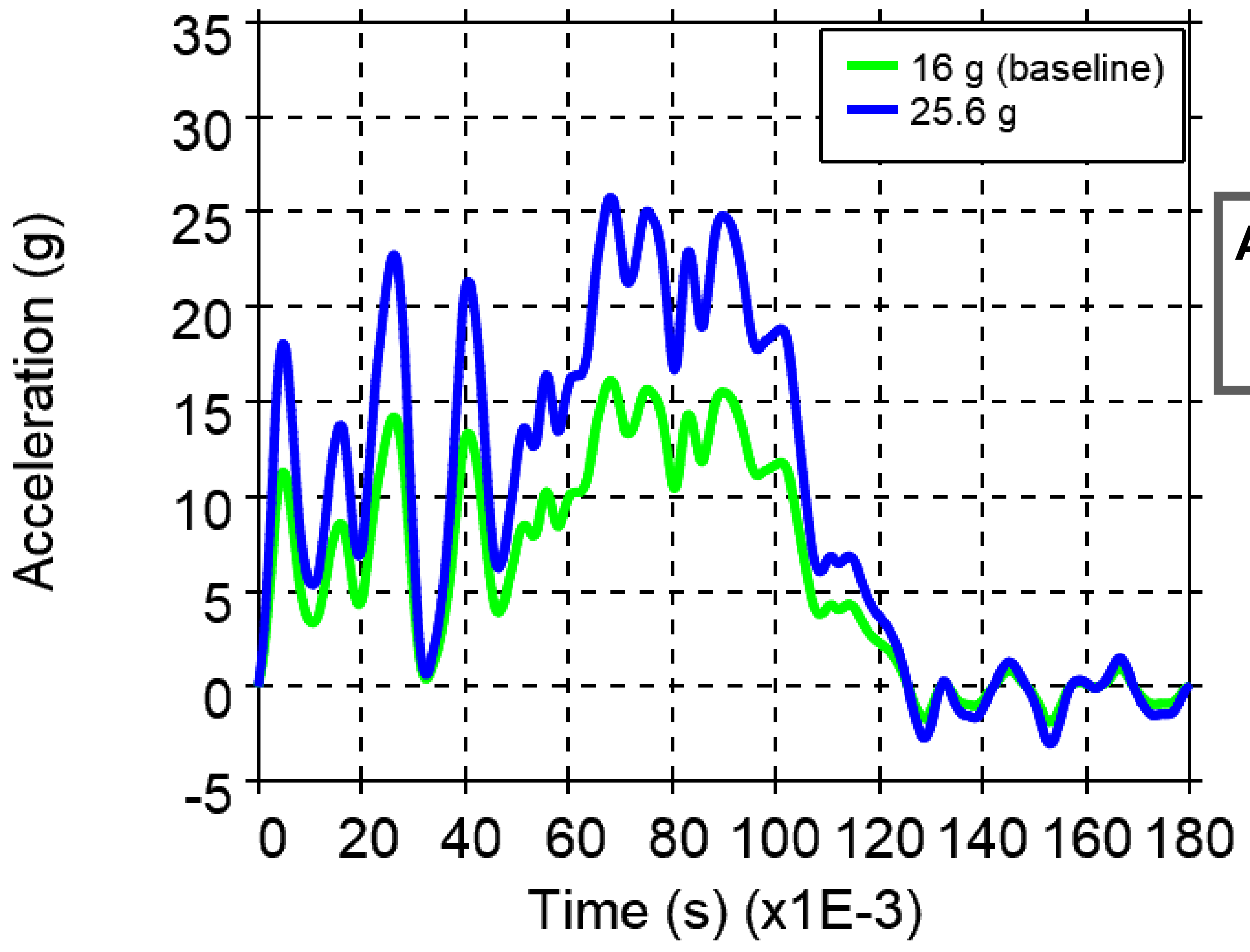


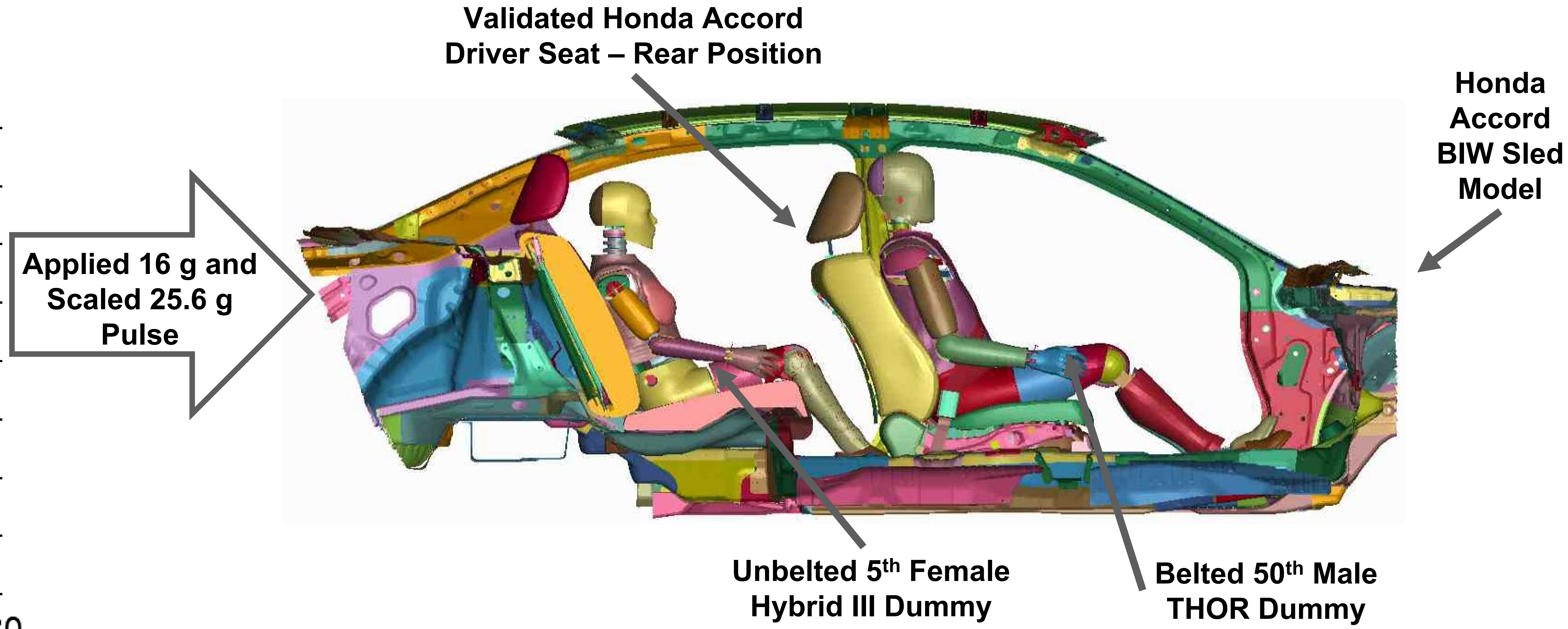


- Higher head and neck injury response from seat collapse due to undesirable head and neck kinematics resulting from extreme ramping.
- Dummy head nearly impacts vehicle roof on rebound.

Seat Collapse Study

Model Setup – 1st and 2nd Row Occupants

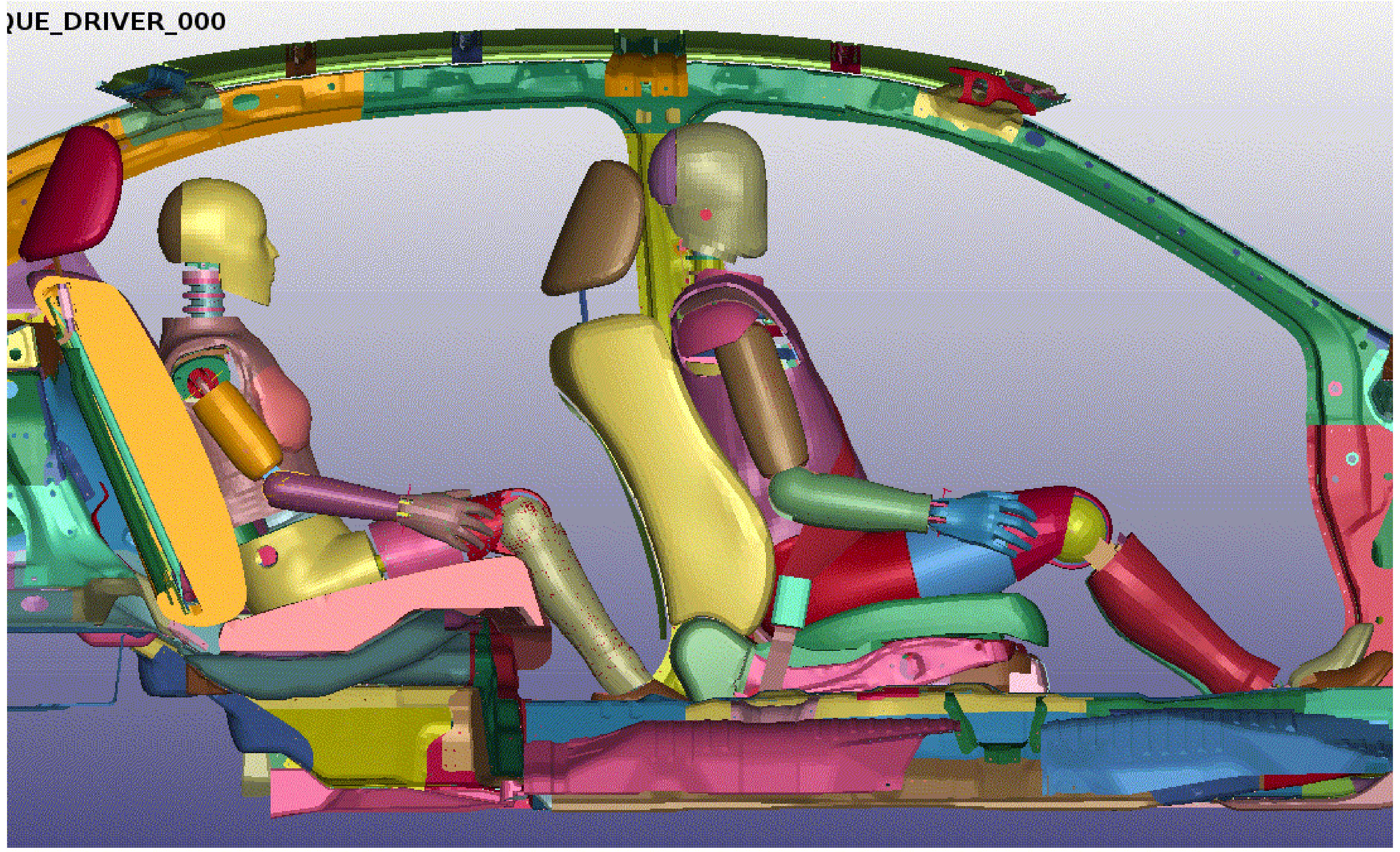




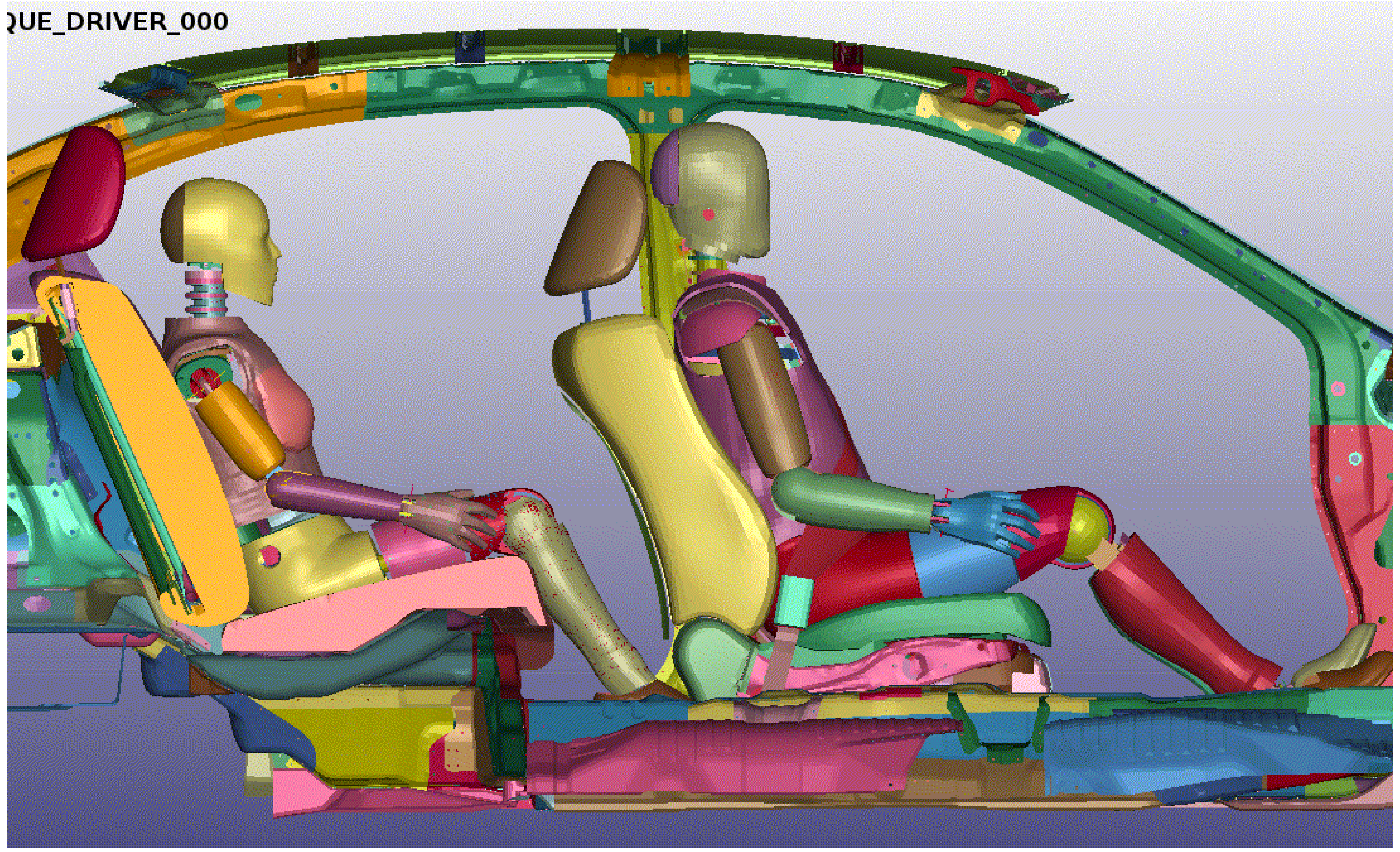
- What injury risk does a collapsing seat pose to first row occupant AND a small second row occupant?

Seat Collapse Study

Results – Pulse Severity and Seat Collapse



16 g Pulse

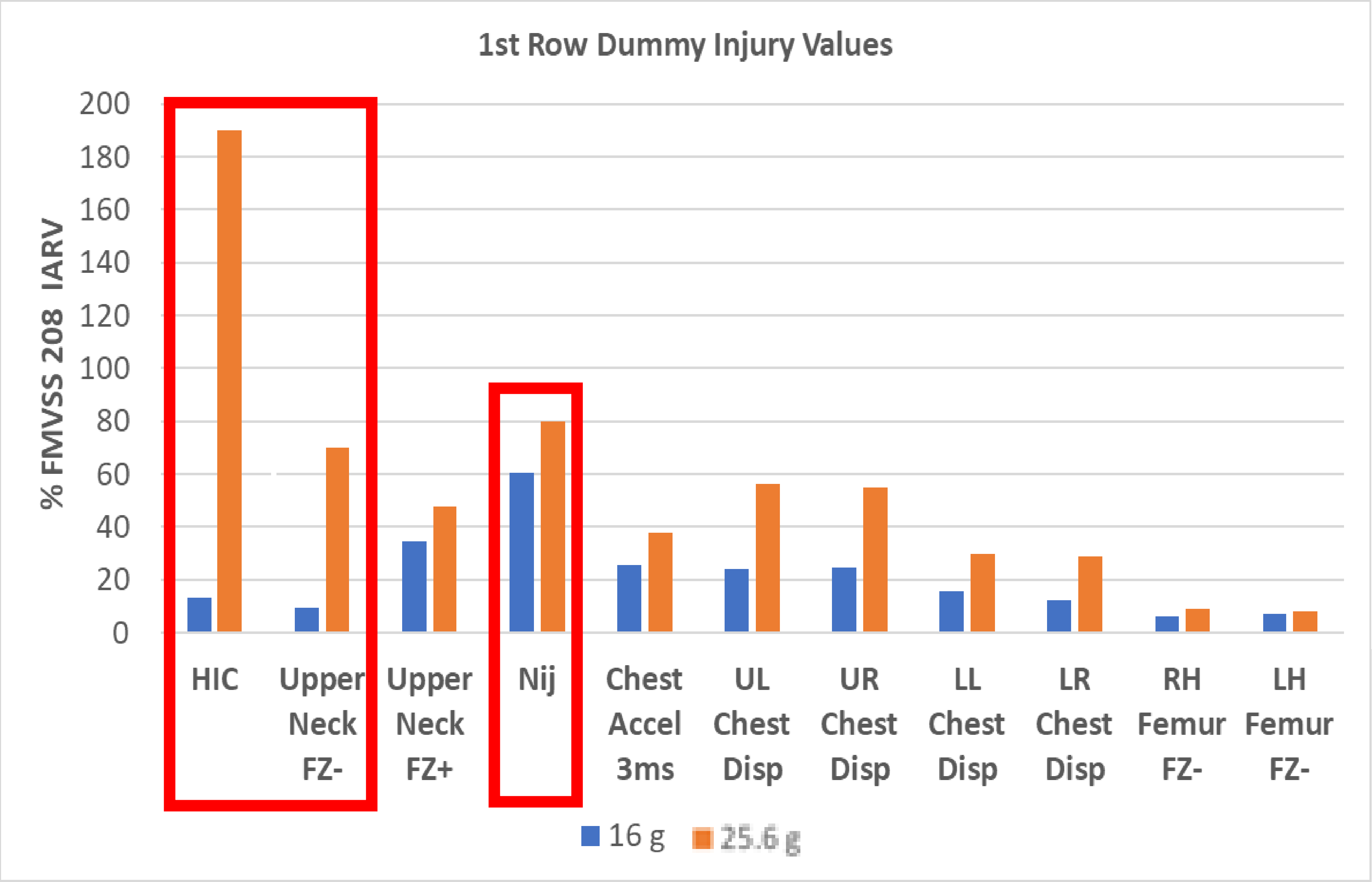


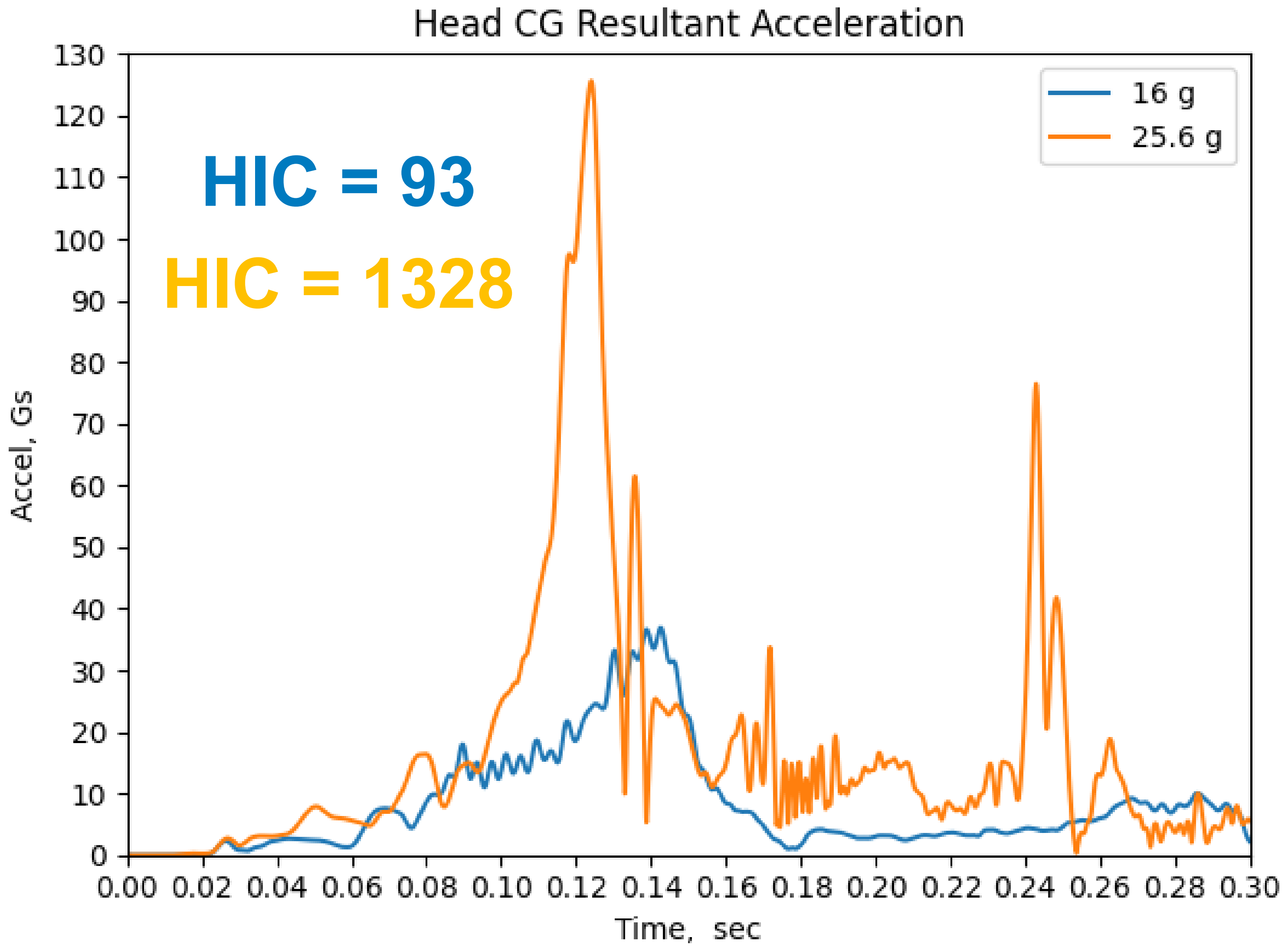
25.6 g Pulse

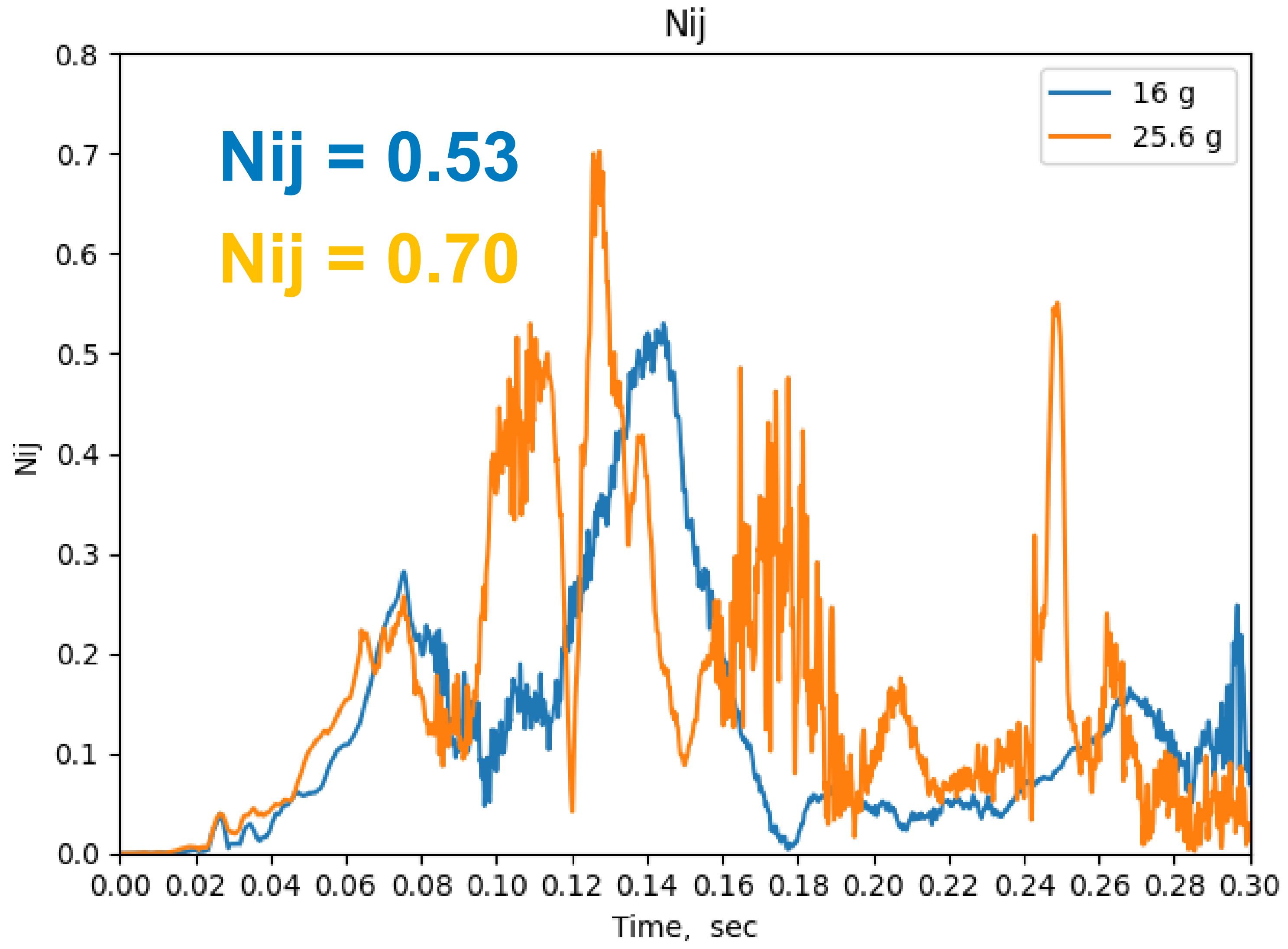
- Increased ramping of 1st row occupant observed in simulation with higher pulse severity/seat collapse.
- The result of increased ramping is a severe contact between 1st row dummy head and 2nd row dummy chest and head/chin, and 1st row dummy head to roof contact on rebound.

Seat Collapse Study

Results – 1st Row 50th Male Dummy Responses



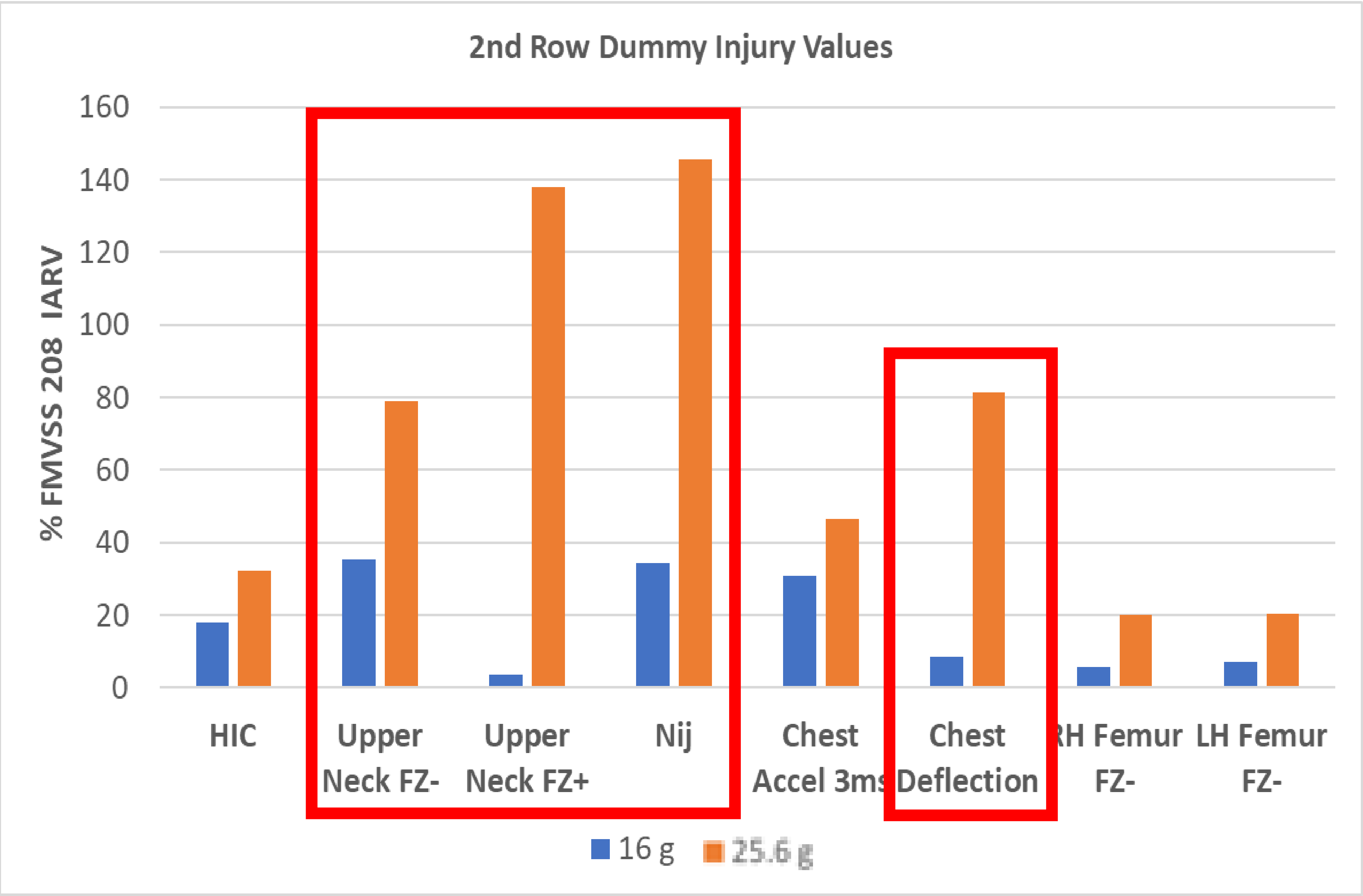


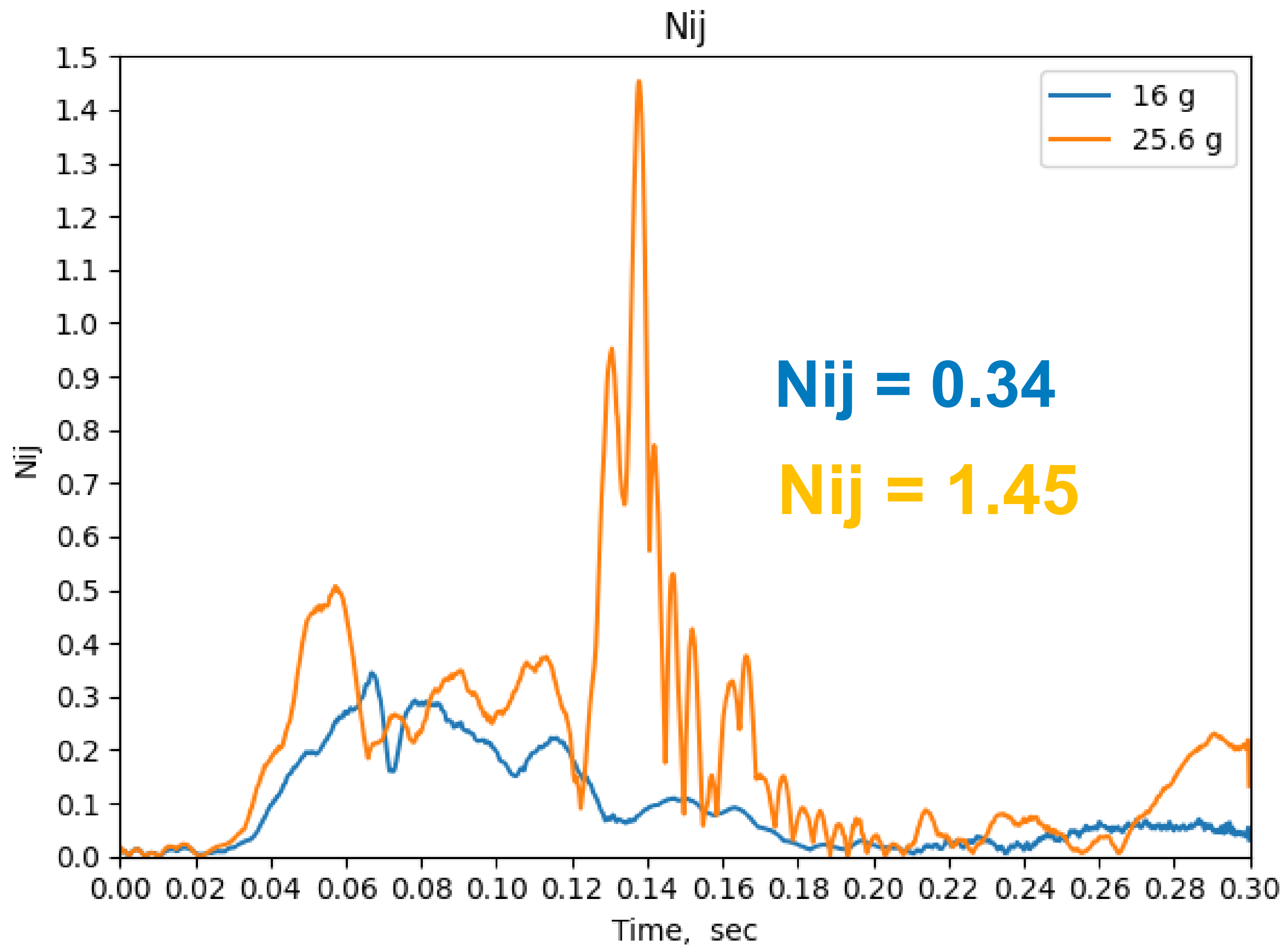


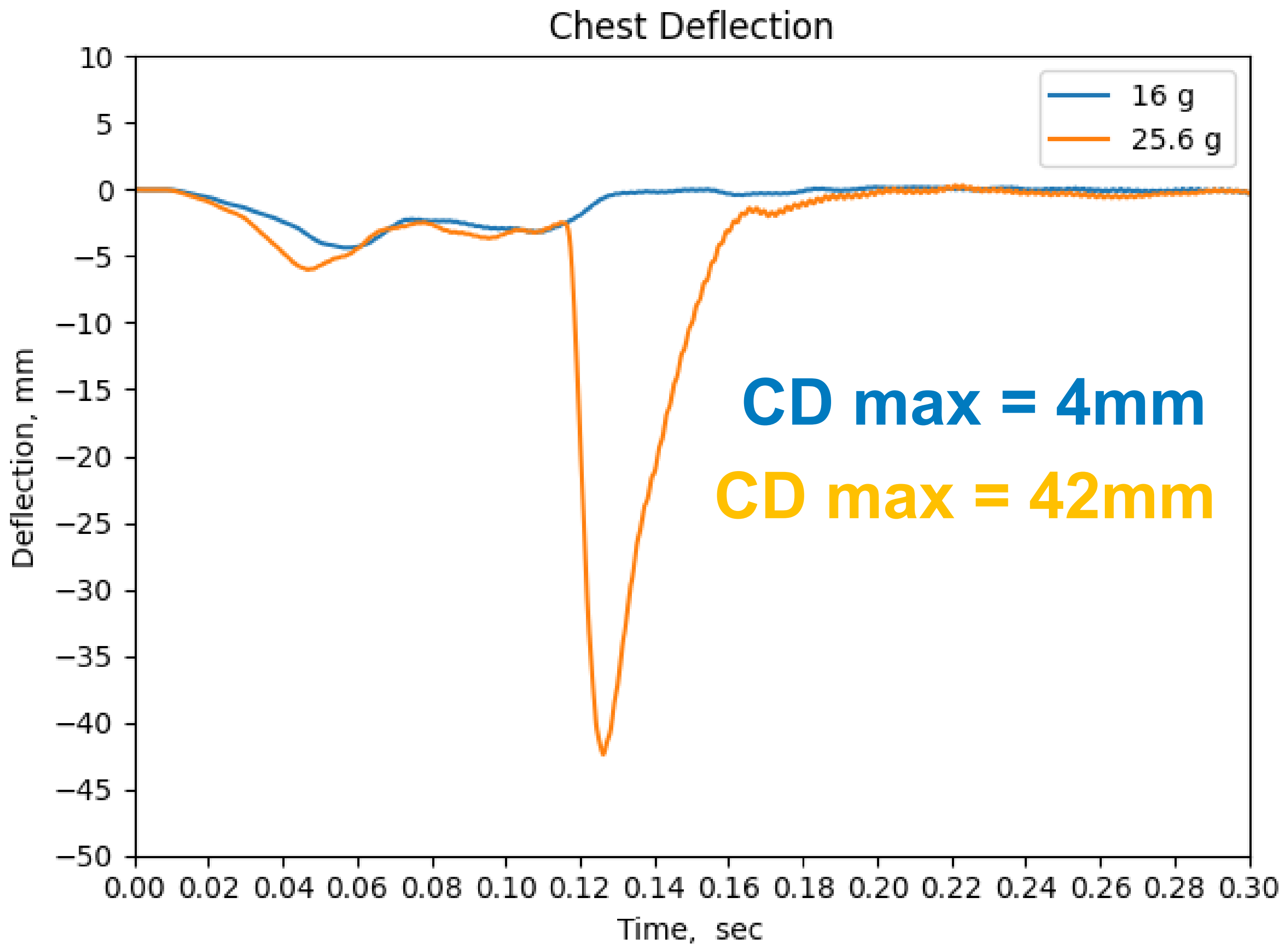
- Simulations predict higher head and neck injury response after seat collapse due to head impact to 2nd row occupant resulting from extreme ramping.
- Dummy head impacts vehicle roof on rebound, resulting in second injury spikes at approximately 240 ms.

Seat Collapse Study

Results – 2nd Row 5th Female Dummy Responses



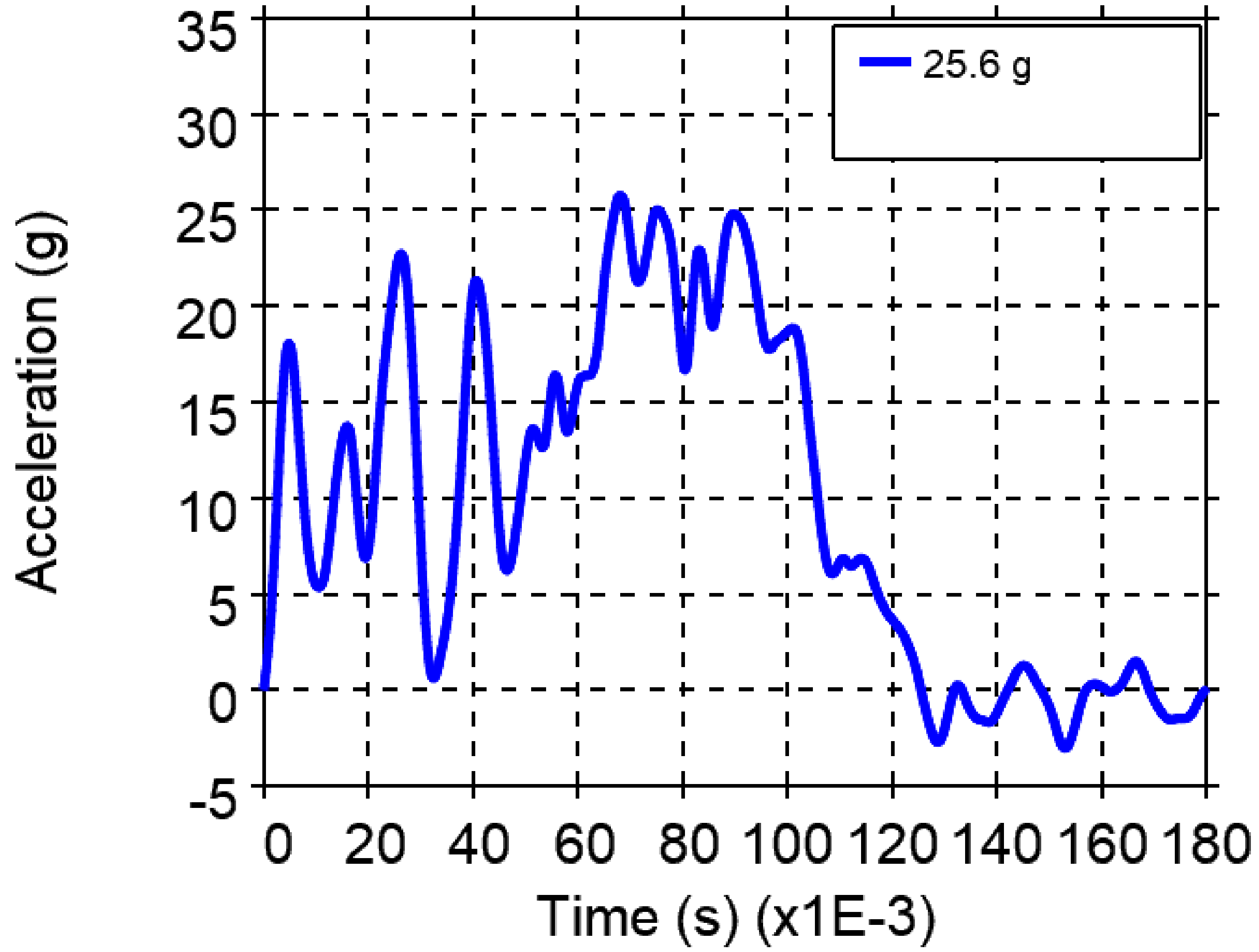




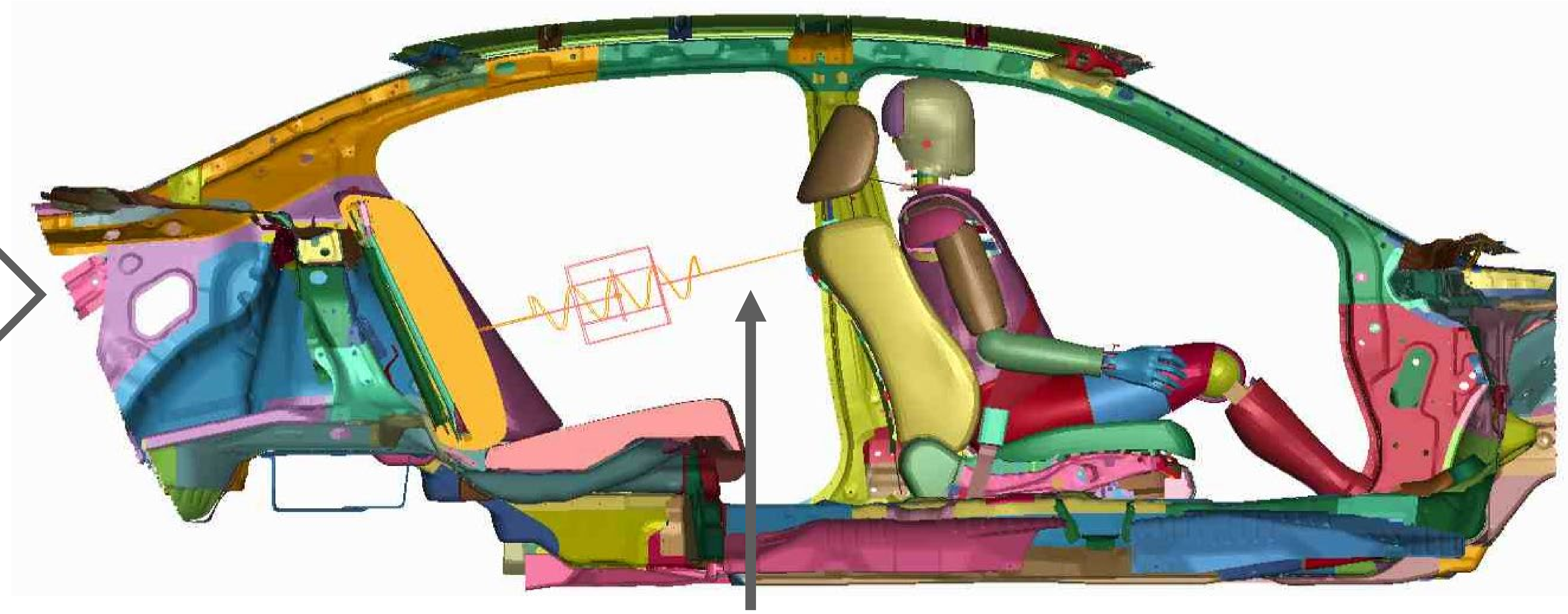
- Simulations predict 2nd row occupant higher neck and chest injury response as a result of seat collapse.
- Similar timing of max neck and chest injury values (120-140ms) indicate both responses are a result of interaction with the ramping 1st row occupant.

“Strengthened” Seat Model

Model Setup

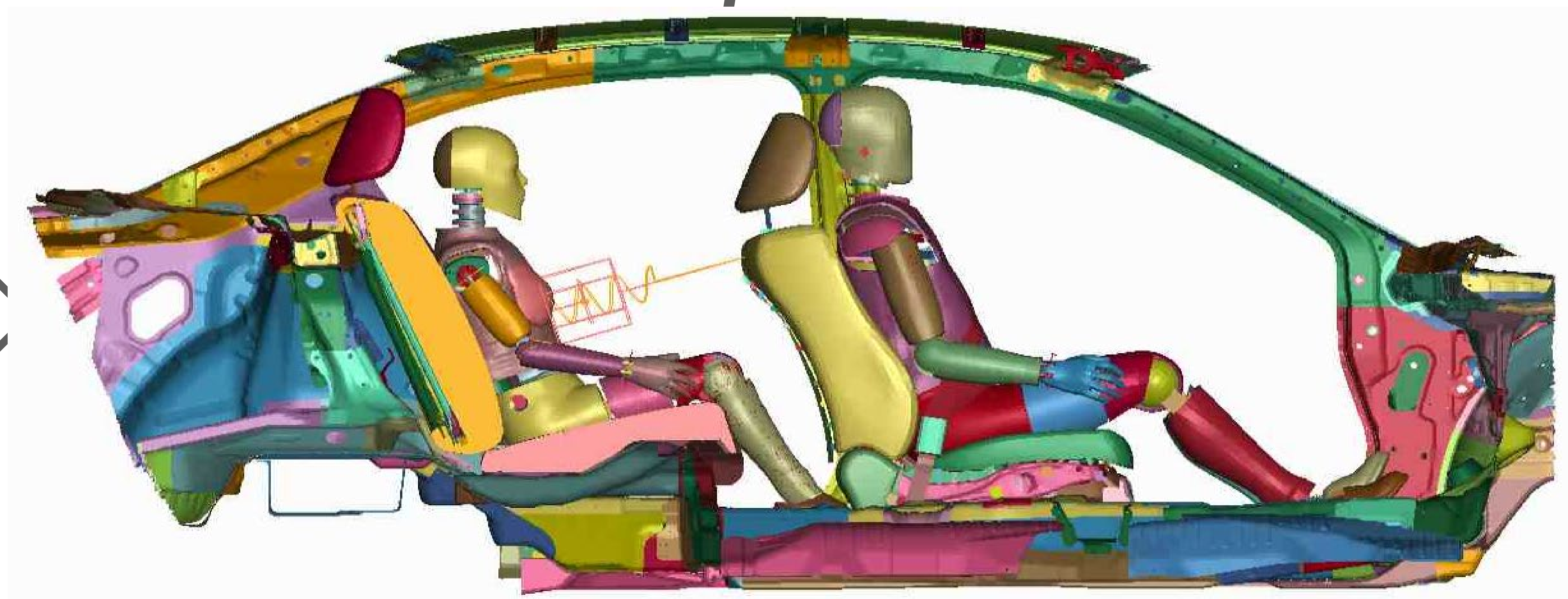


Applied Scaled 25.6 g Pulse



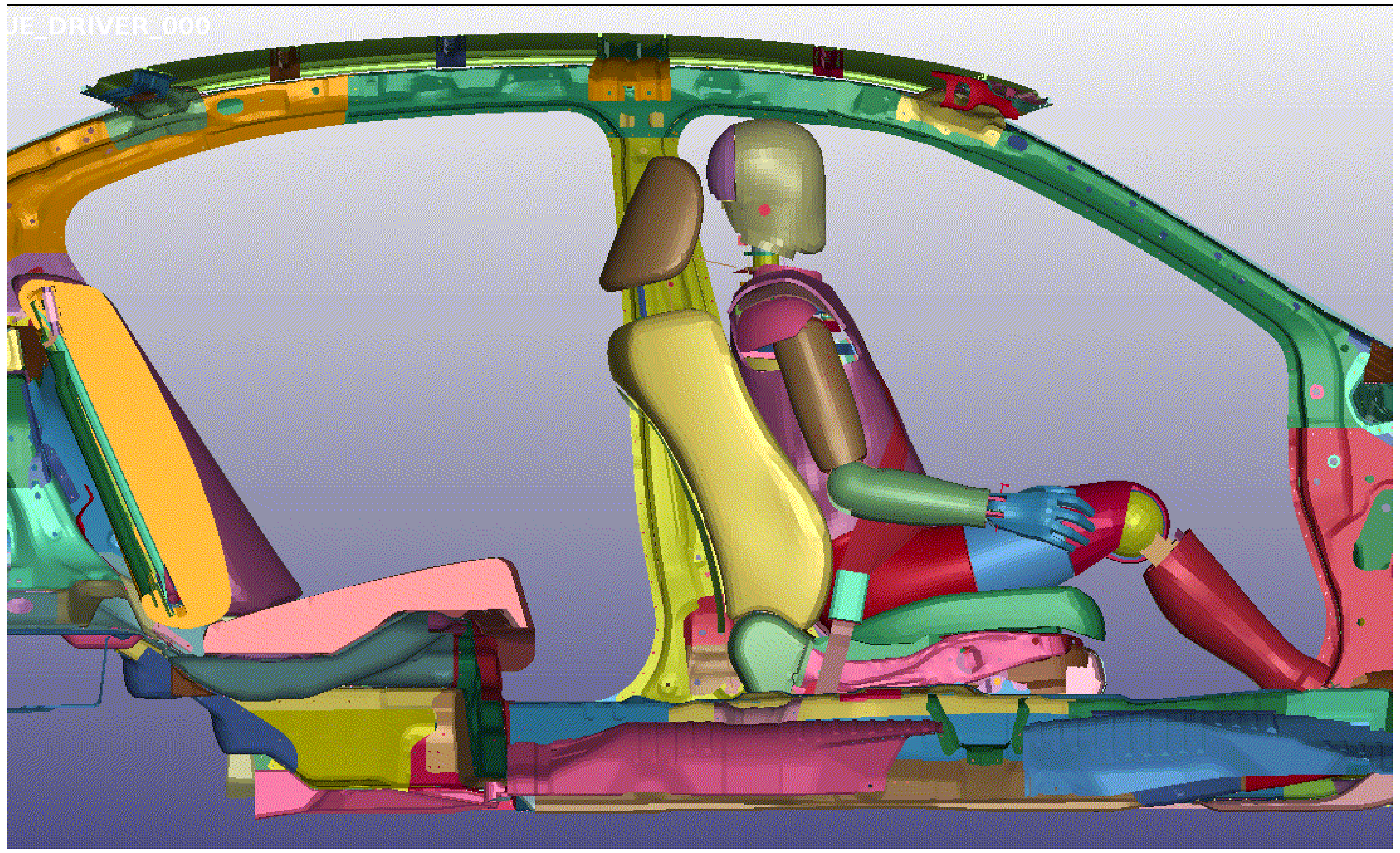
Discrete (spring/damper, k=1/c=2) elements tuned to “strengthen” seat (reduce rotation)

Applied Scaled 25.6 g Pulse



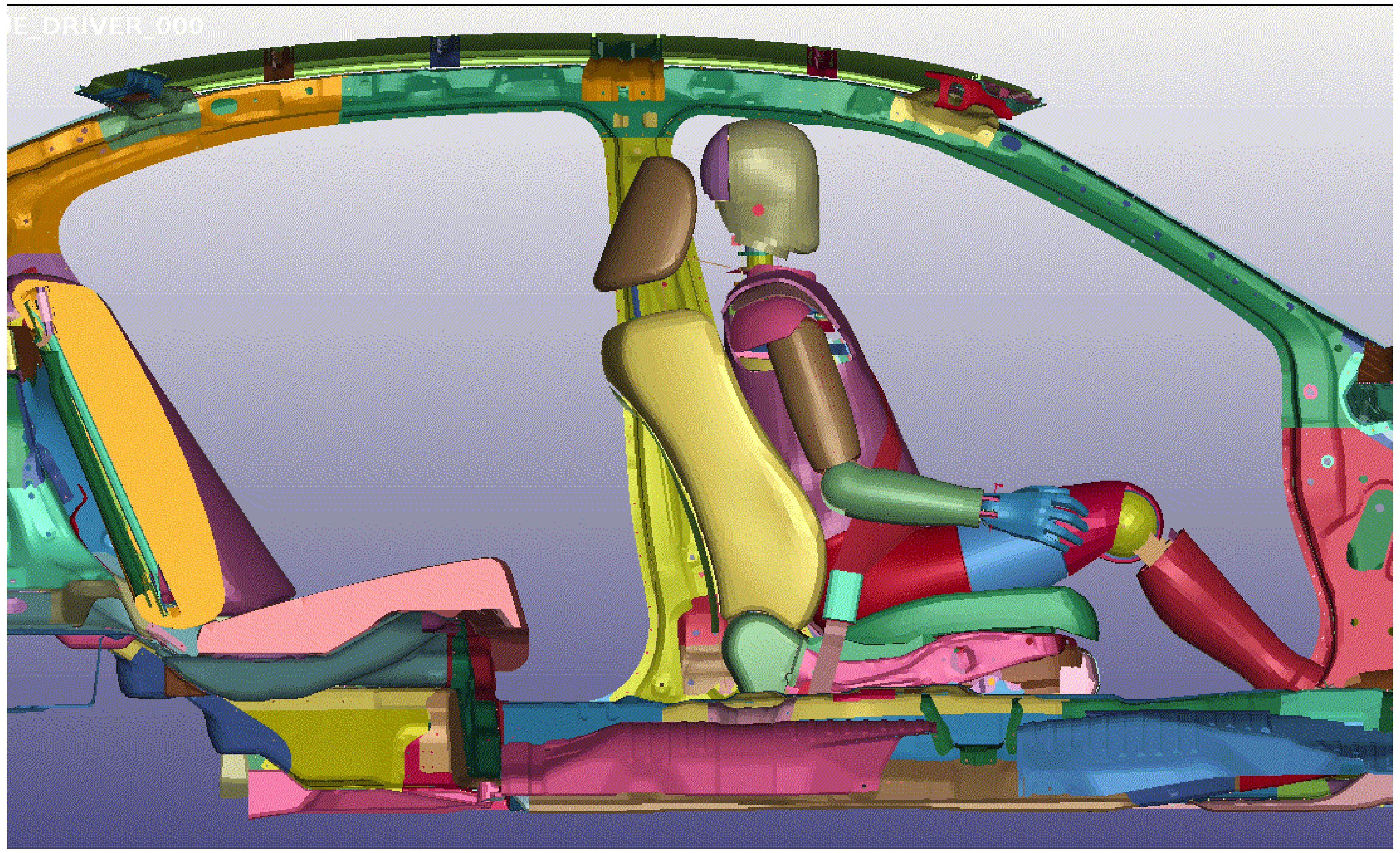
"Strengthened" Seat Model

Results – 1st Row Occupant/25.6 g Pulse



Baseline Seat

47.5° Seat Back Rotation



"Strengthened" Seat

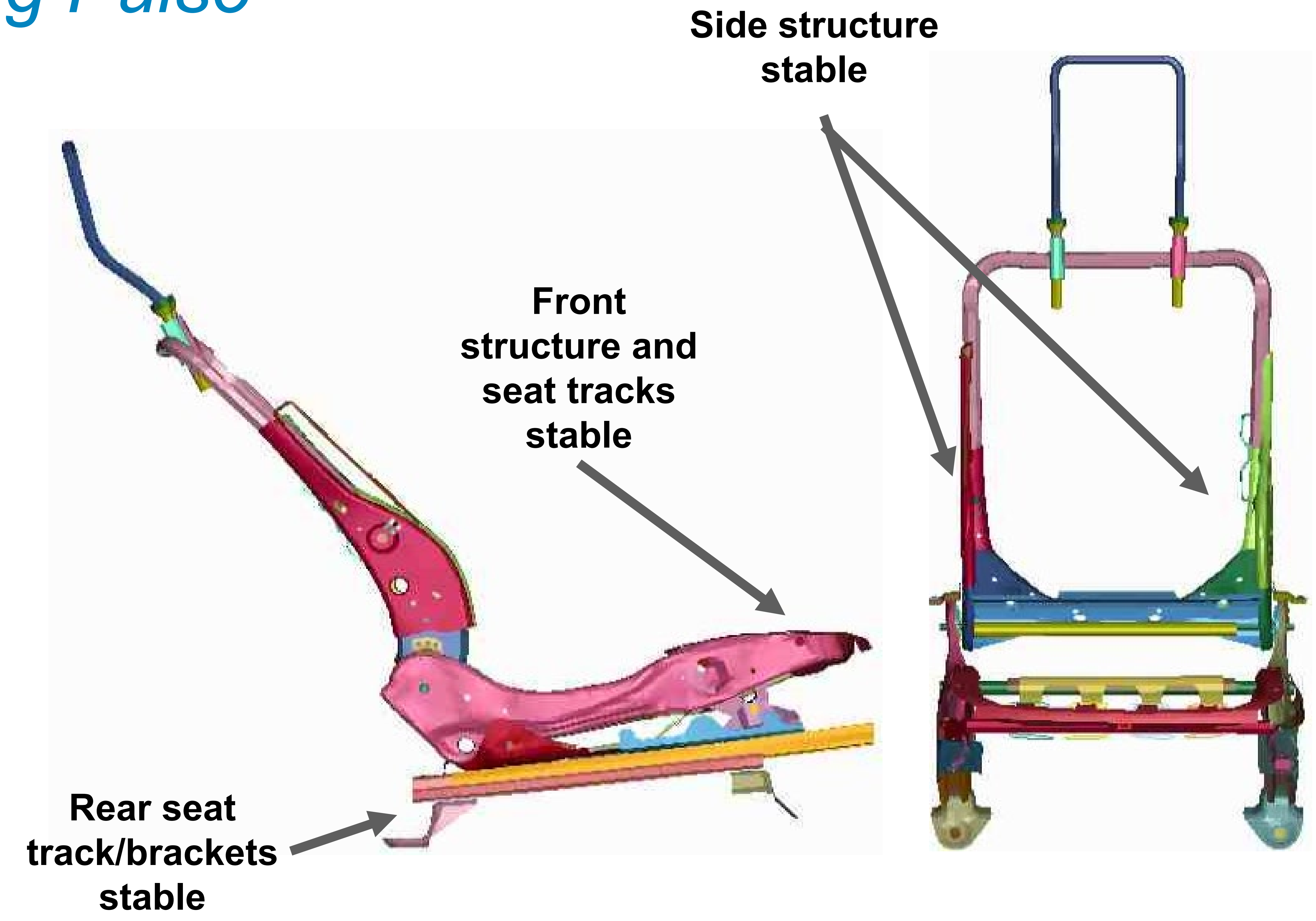
24° Seat Back Rotation

- "Strengthened" seat reduces seat rotation and effectively limits dummy ramping during a high severity rear impact acceleration pulse.
- Reduction in ramping results in more desirable dummy kinematics and more clearance with respect to potential impacts to interior components (rear seat, roof)

"Strengthened" Seat Model

Results – Deformation Comparison/25.6 g Pulse

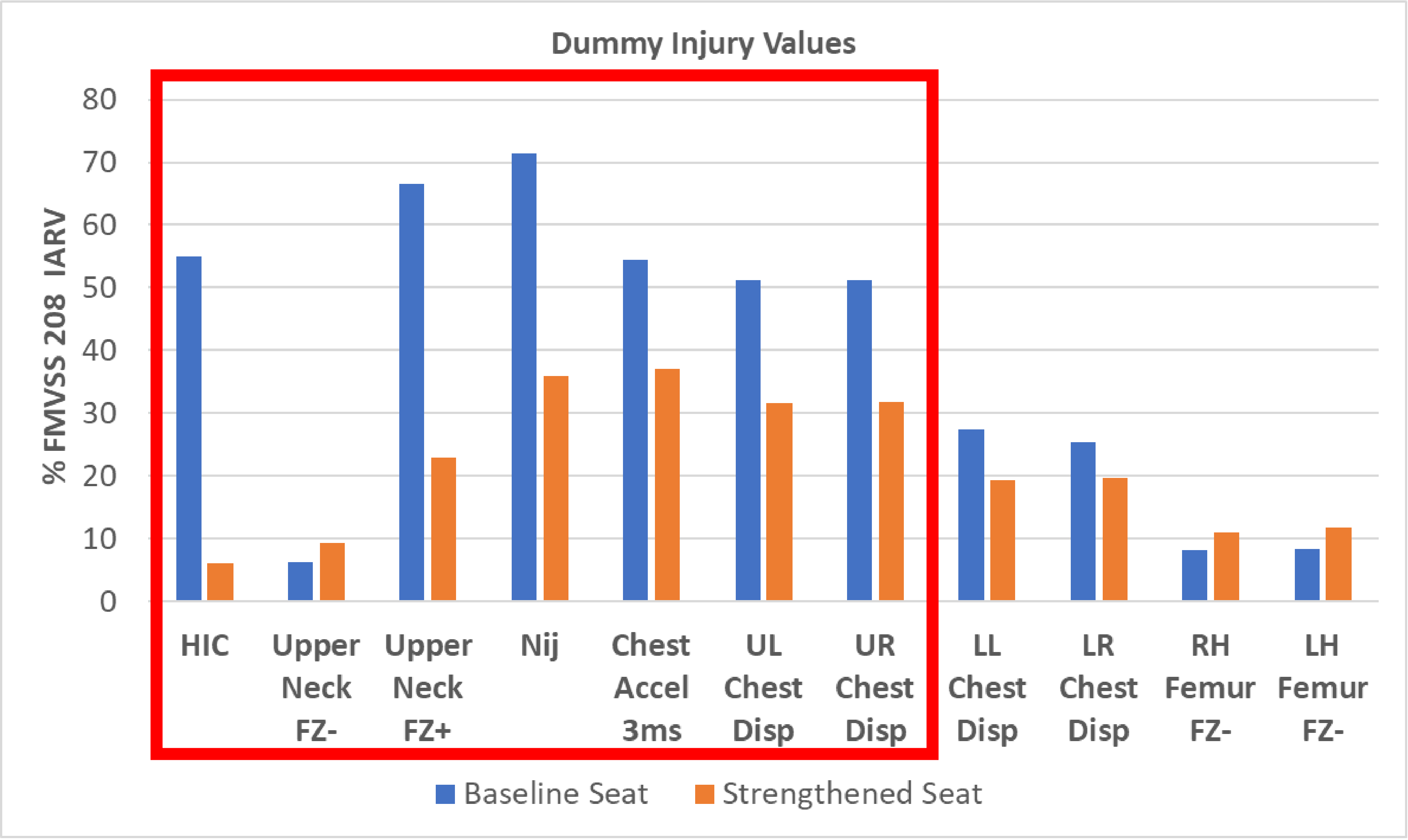
Baseline Seat

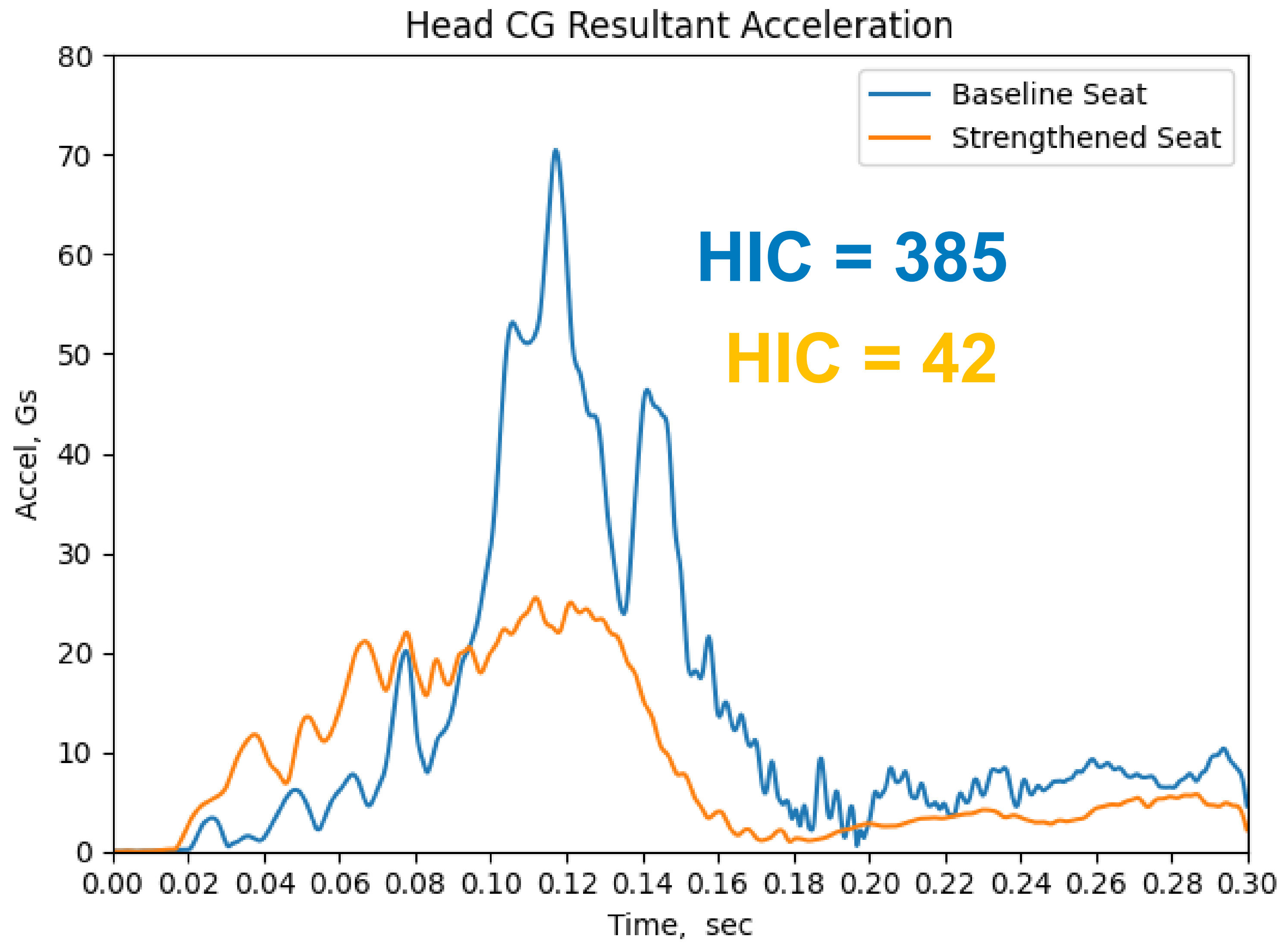


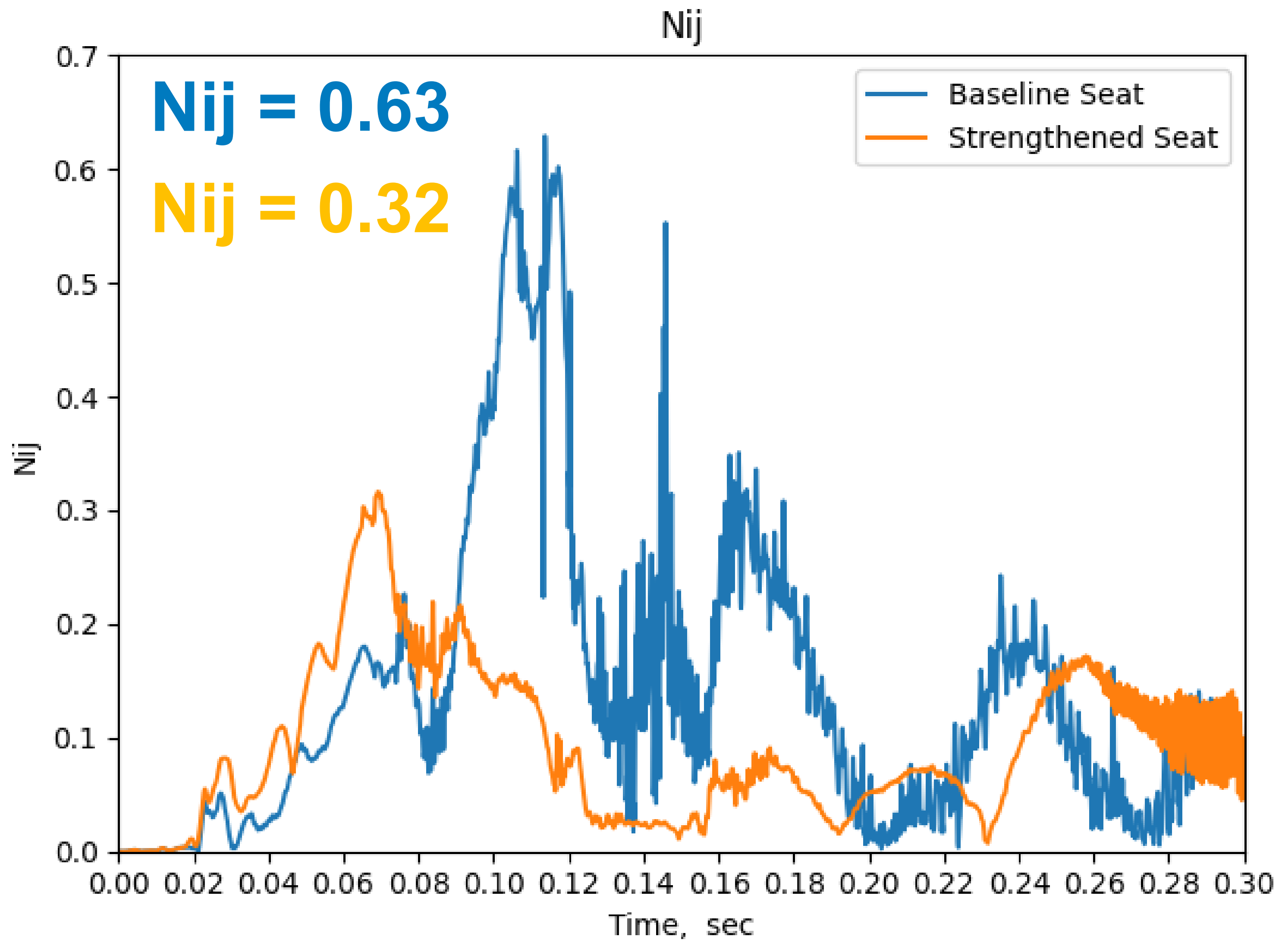
"Strengthened" Seat

“Strengthened” Seat Model

Results – 1st Row 50th Male Dummy Responses/25.6 g Pulse



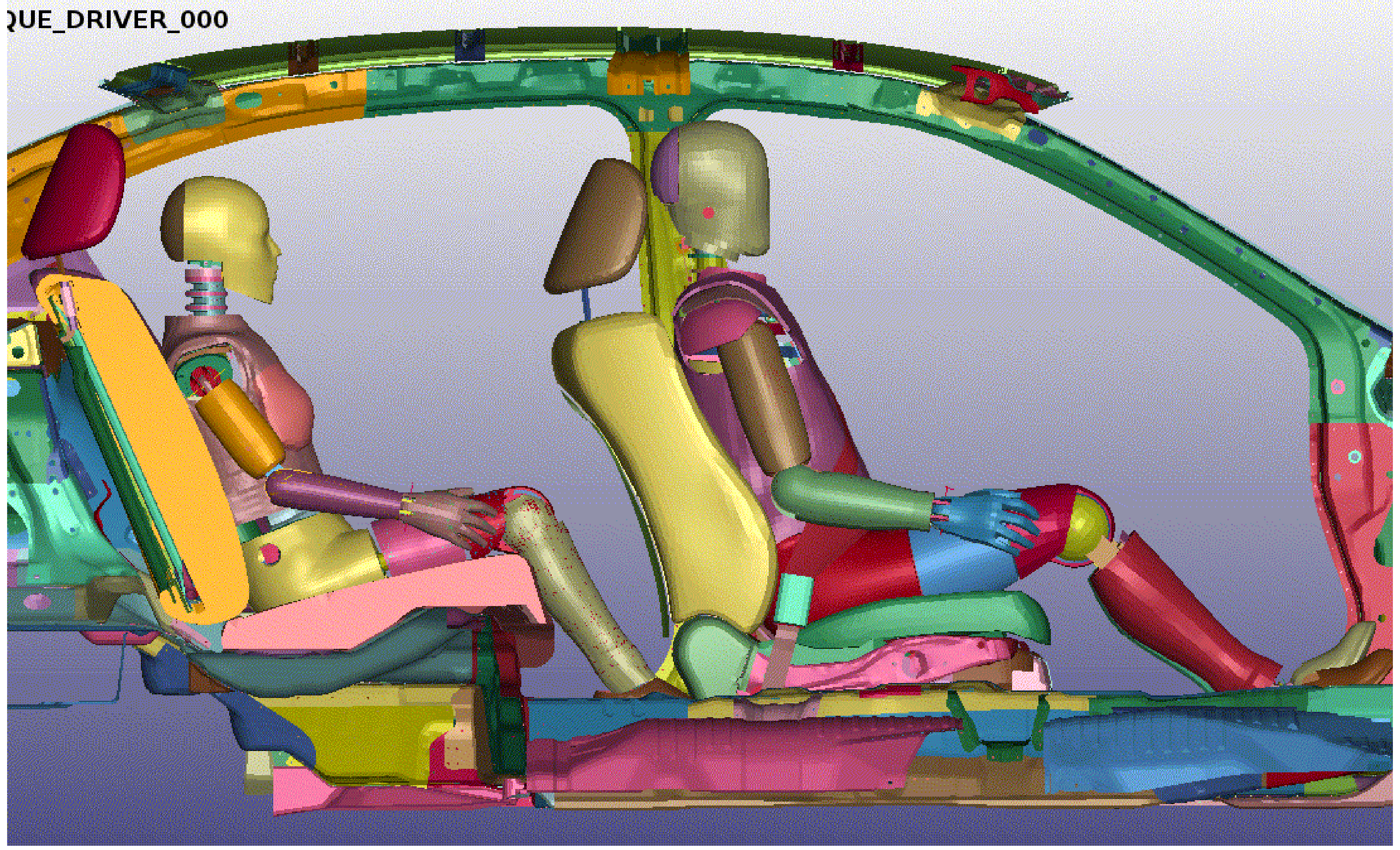




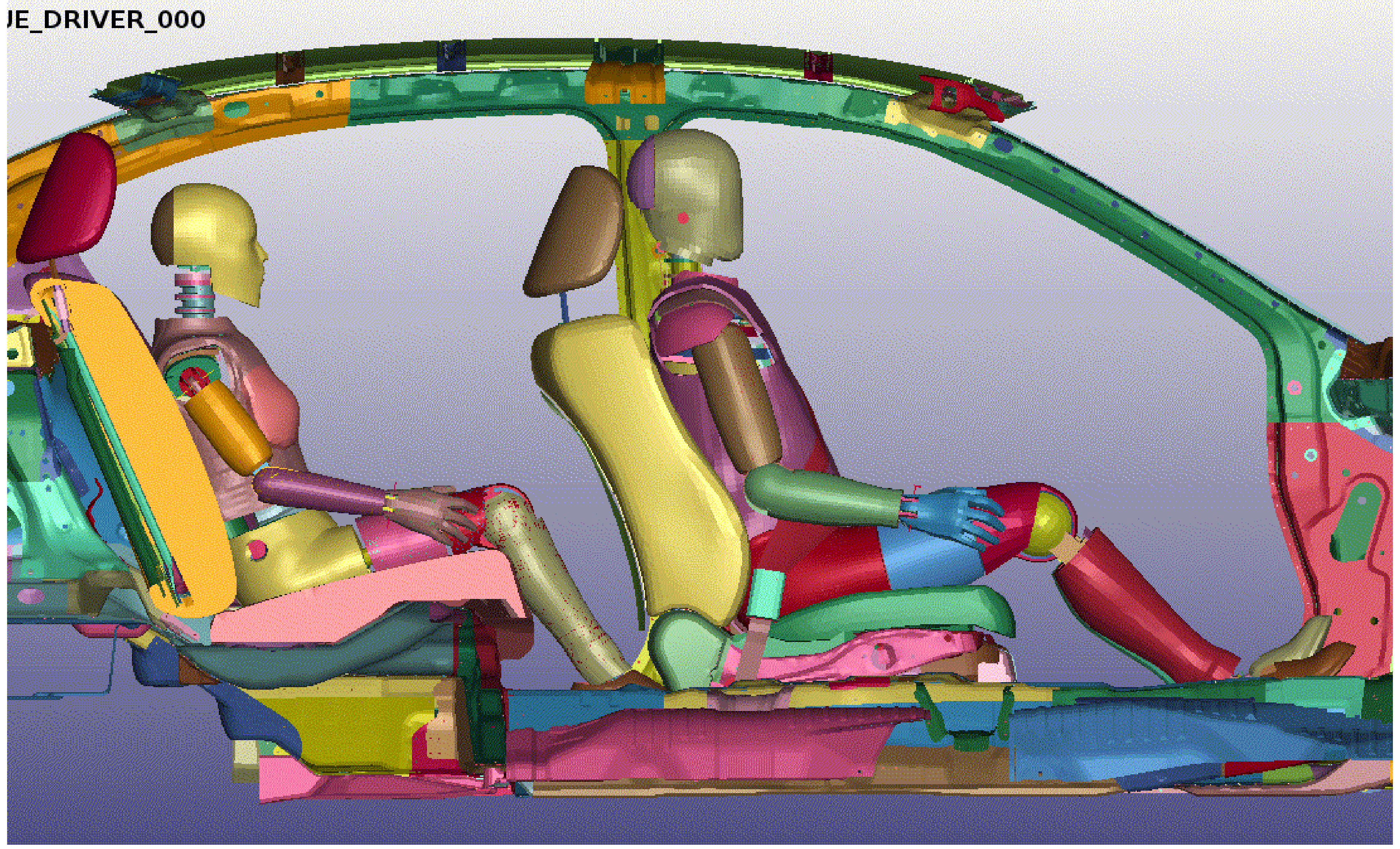
- Simulation predicts reduction in key injury responses (HIC, Nij) with the “strengthened” seat due to the limiting of dummy ramping and improved restraint of the head by the headrest

"Strengthened" Seat Model

Results – 1st and 2nd Row Occupant/25.6 g Pulse



Baseline Seat

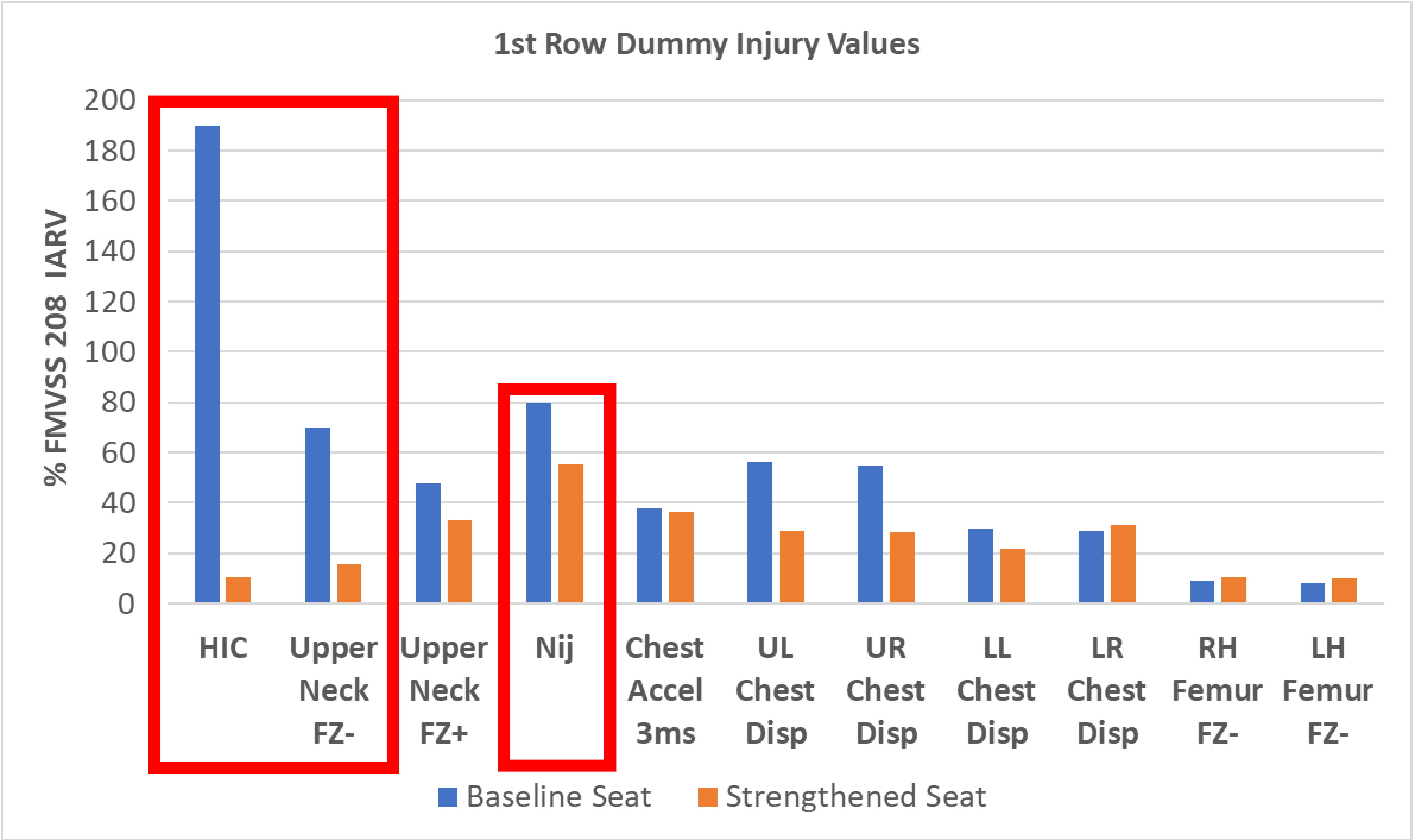


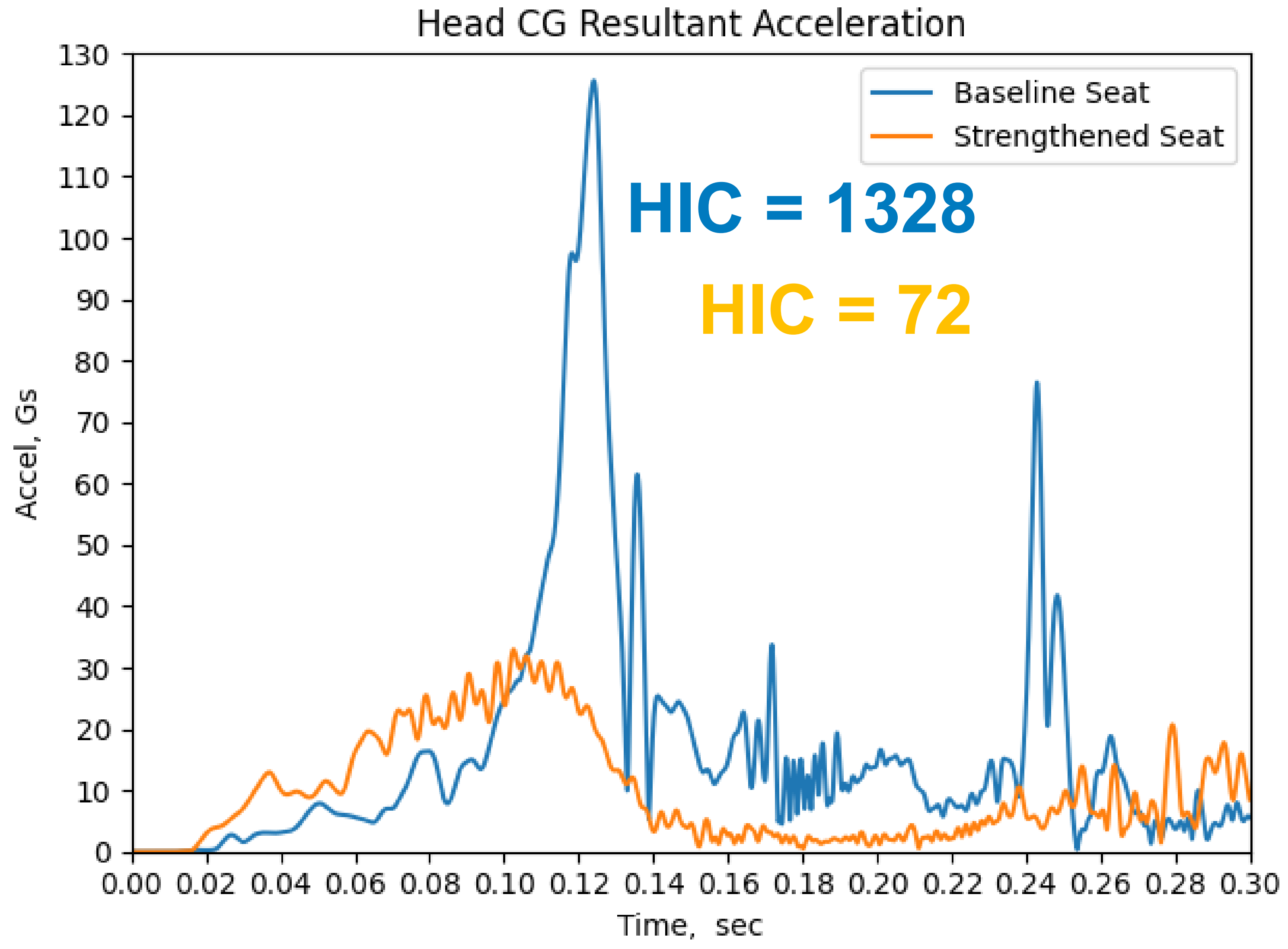
"Strengthened" Seat

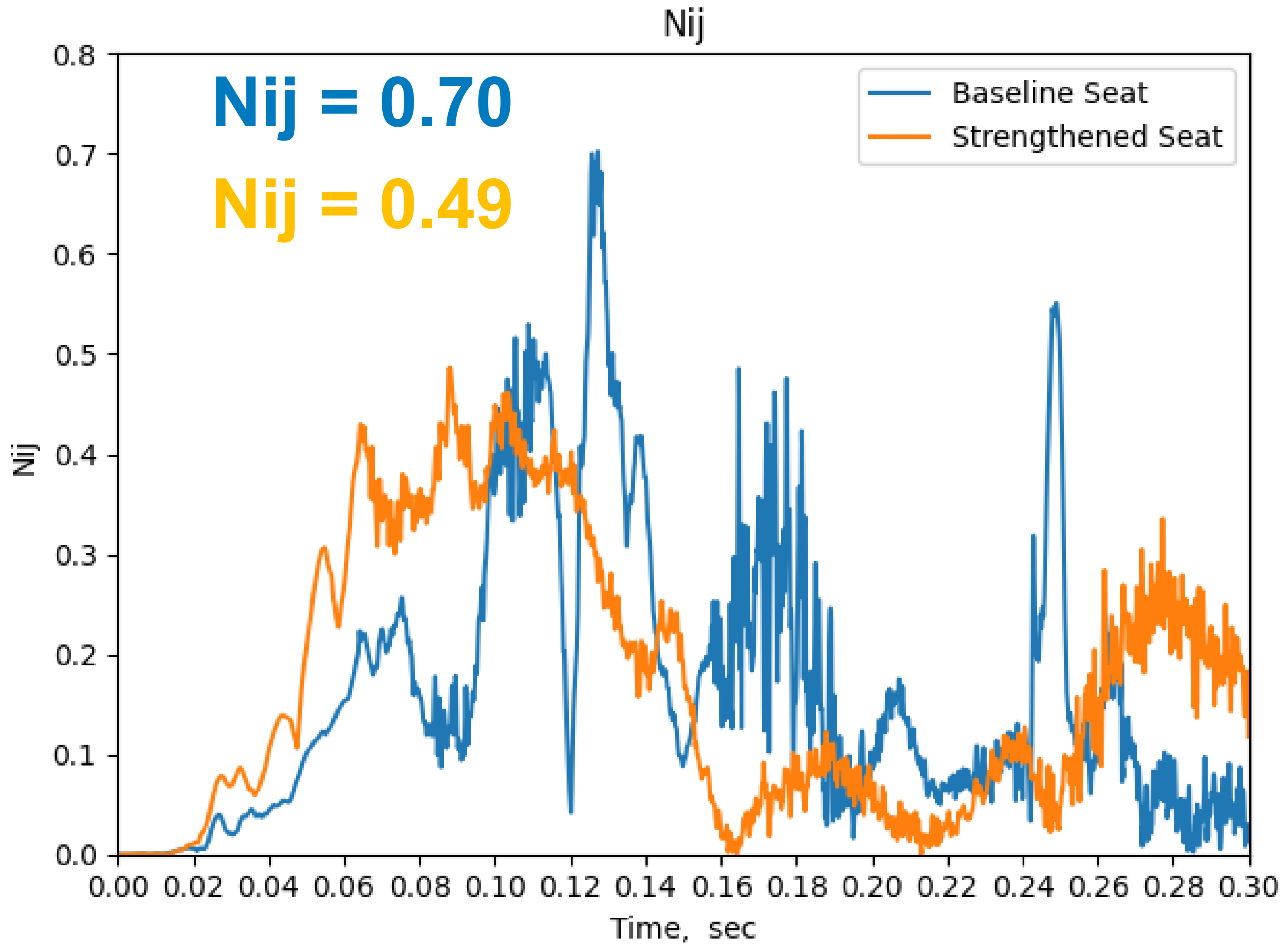
- "Strengthened" seat reduces seat rotation and effectively limits dummy ramping during a high severity rear impact acceleration pulse.
- Reduction in ramping results in more desirable dummy kinematics and large clearance with respect to potential impacts to 2nd row occupant and vehicle roof on rebound.

"Strengthened" Seat Model

Results – 1st Row 50th Male Dummy Responses/25.6 g Pulse



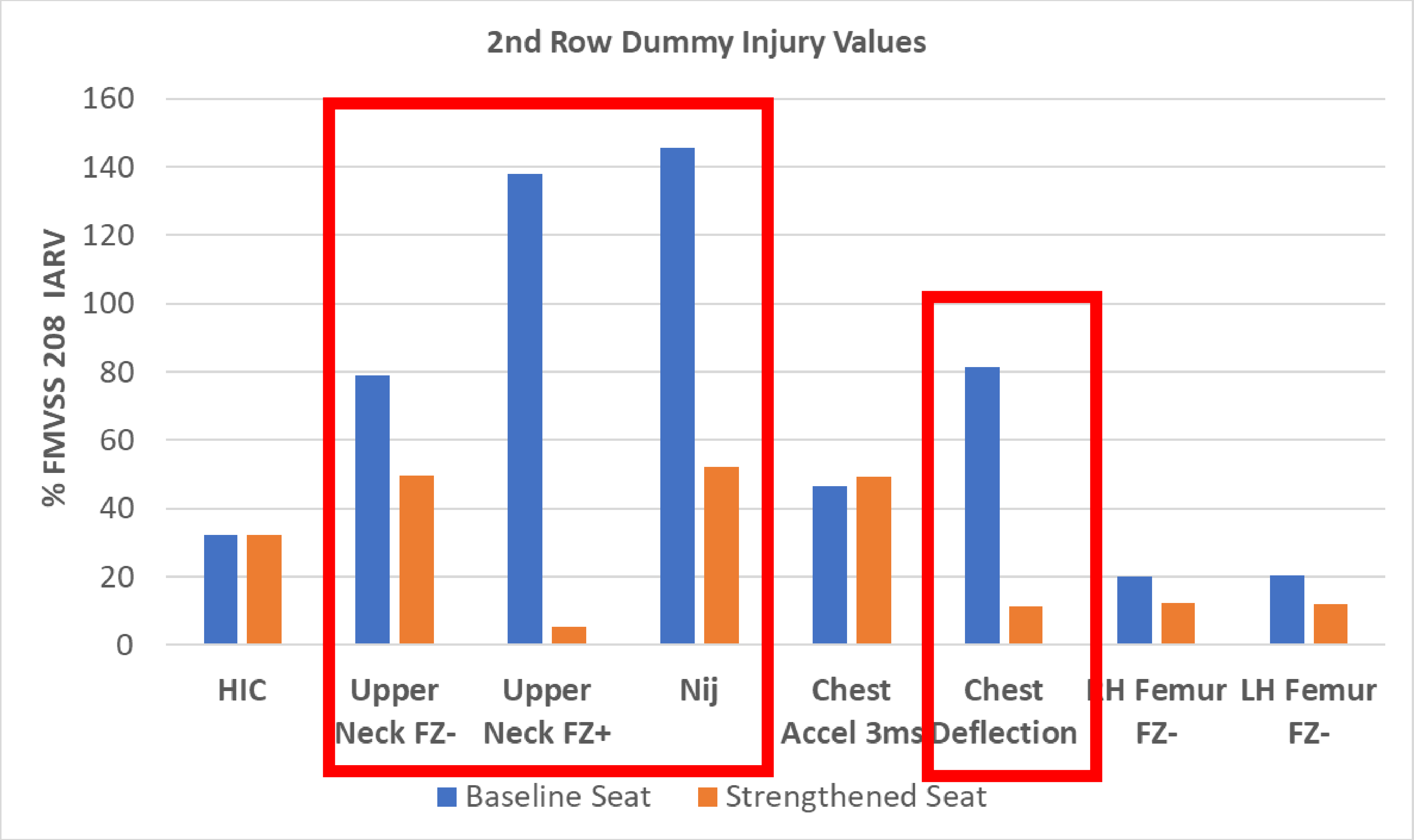


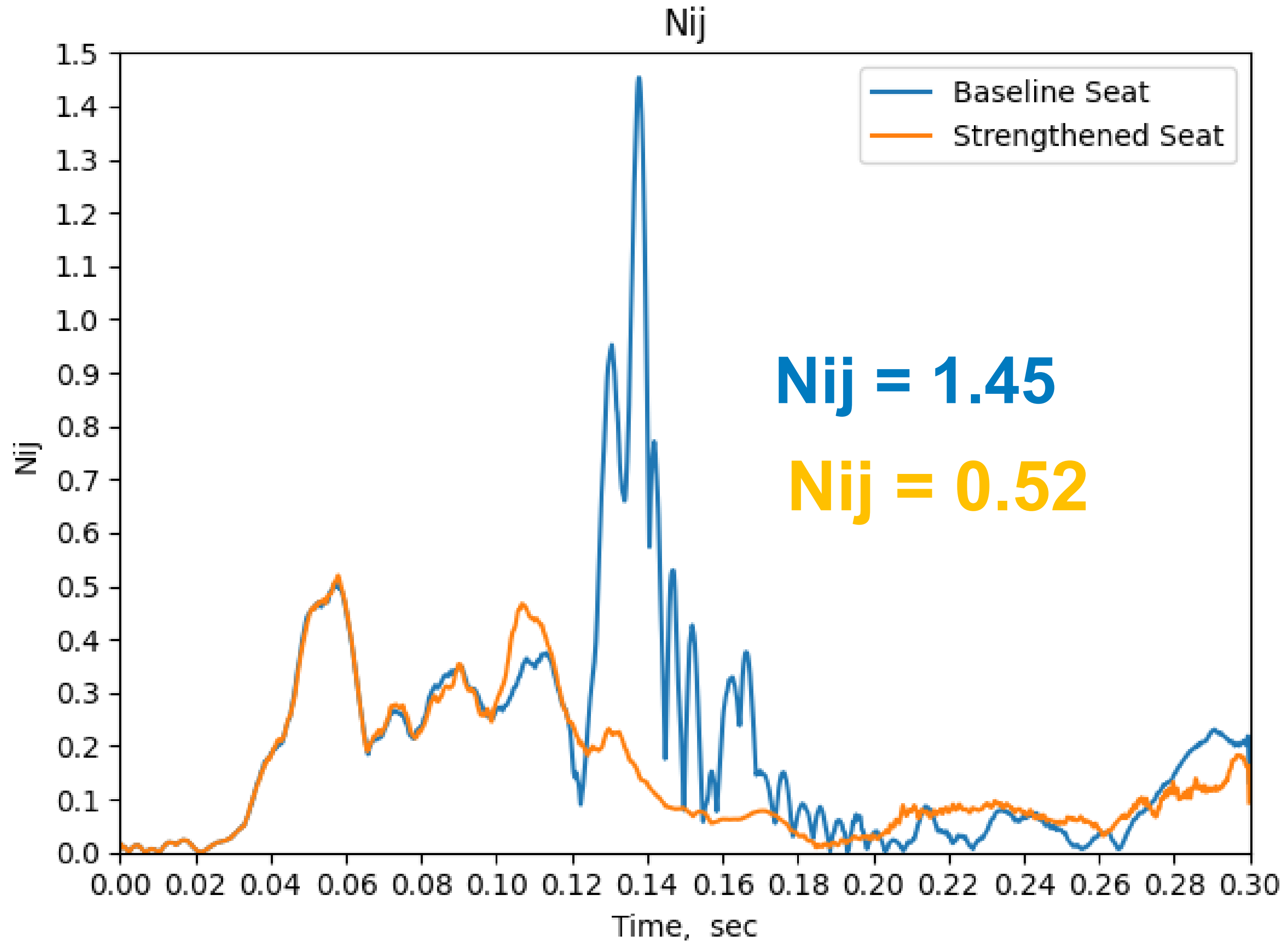


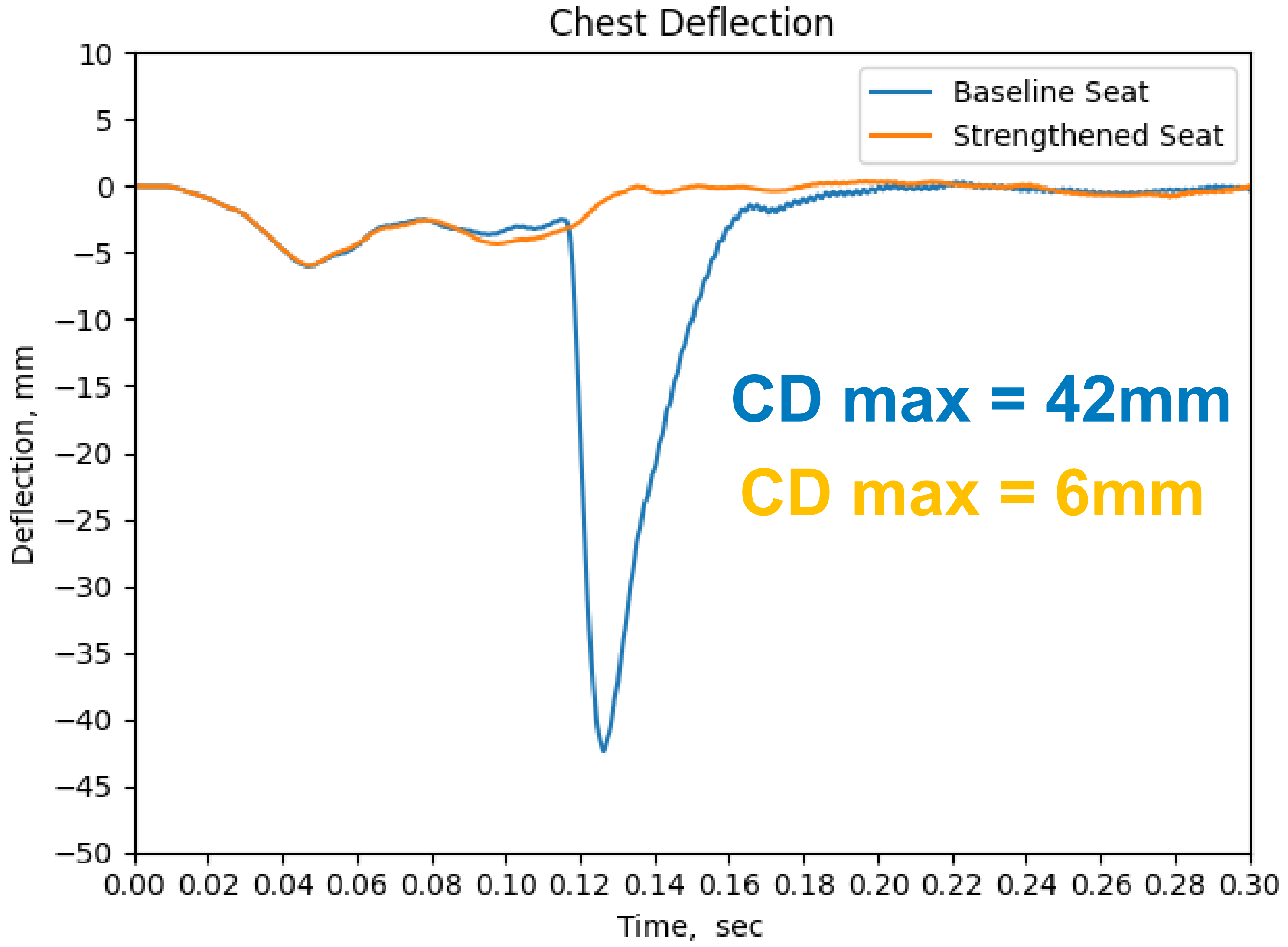
- Simulation predicts reduction in key injury responses (HIC, Nij) with the "strengthened" seat due to the limiting of dummy ramping and improved restraint of the head by the headrest

"Strengthened" Seat Model

Results – 2nd Row 5th Female Dummy Responses/25.6 g Pulse







- Simulation predicts high chest injury response and neck injury response (Nij) is dramatically reduced with a "strengthened" first row seat due to limited 1st row seat rotation and reduced occupant ramping.

FMVSS 202a

Head Restraints – Dynamic Testing

GENERAL REQUIREMENTS

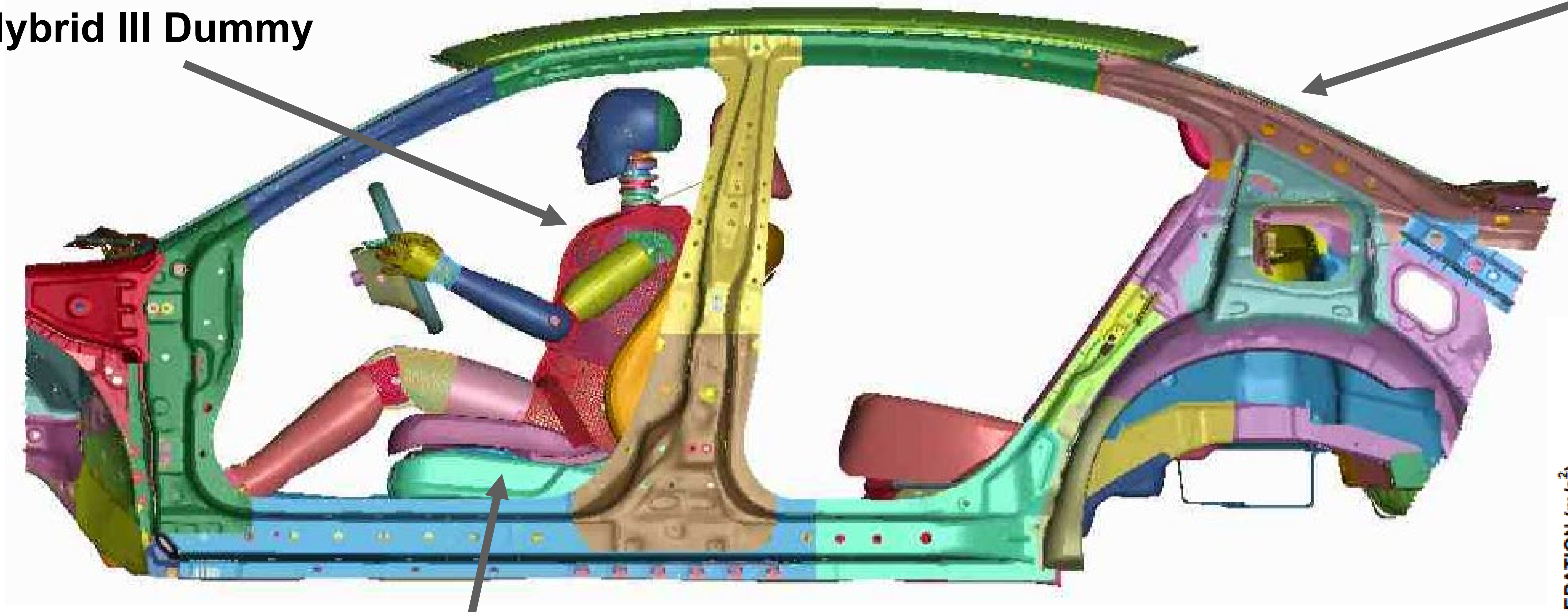
FMVSS 202a, Head Restraints, specifies requirements for head restraints to reduce the frequency and severity of neck injury in rear end and other collisions. The standard applies to each front and rear outboard Designated Seating Position (DSP) with a head restraint, and allows head restraints to be tested either dynamically or statically. Exceptions are made for school buses; refer to the Code of Federal Regulations for the specific exceptions. This test procedure covers the dynamic requirements. The test requirement is that the head restraint must restrict head-to-torso rotation to a maximum of 12 degrees and head injury criteria to a maximum HIC_{15} value of 500.

FMVSS 202a Model

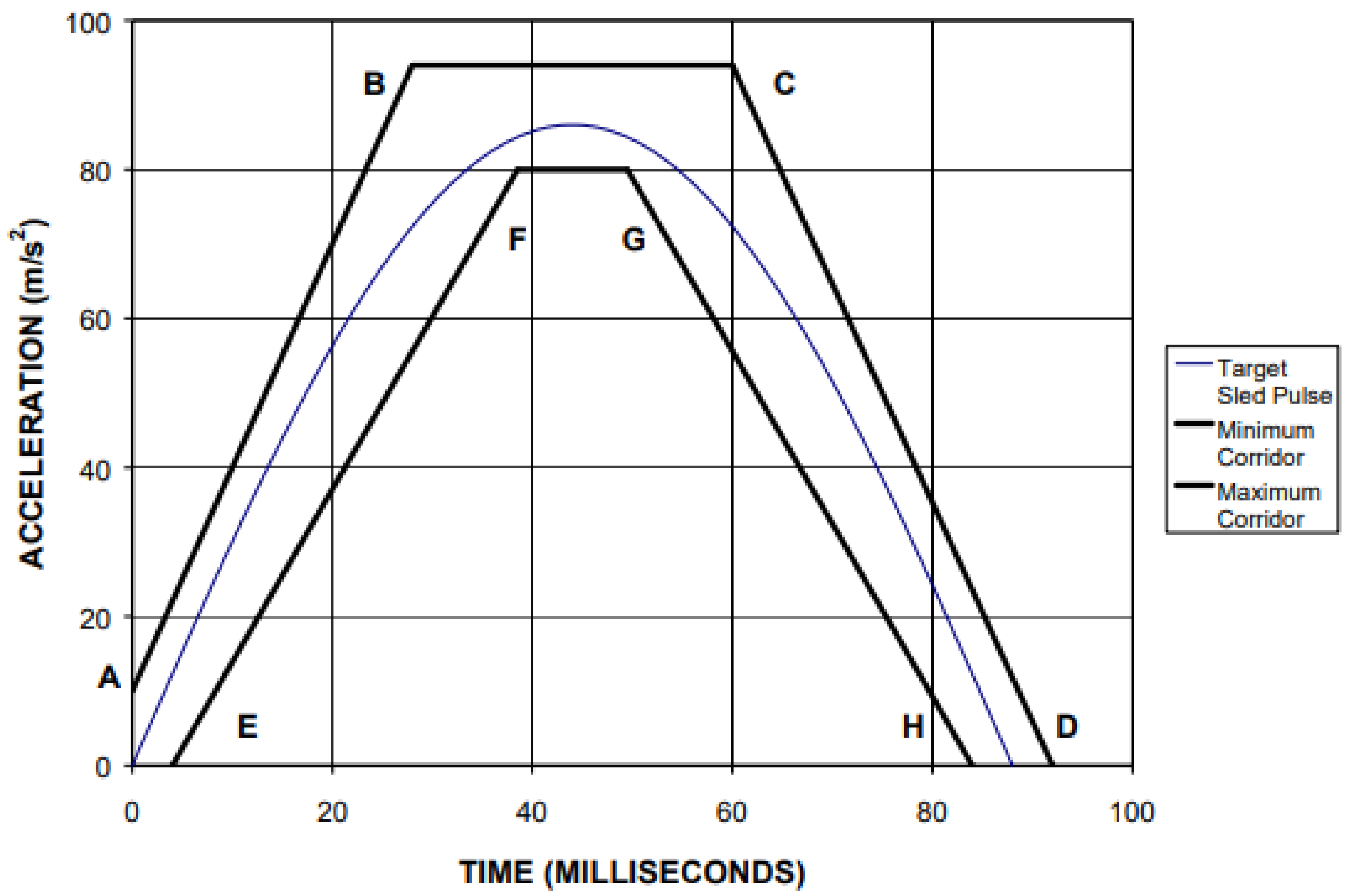
Model Setup

Belted 50th Male Hybrid III Dummy

Honda Accord BIW Sled Model



Applied 202a Test Acceleration Pulse

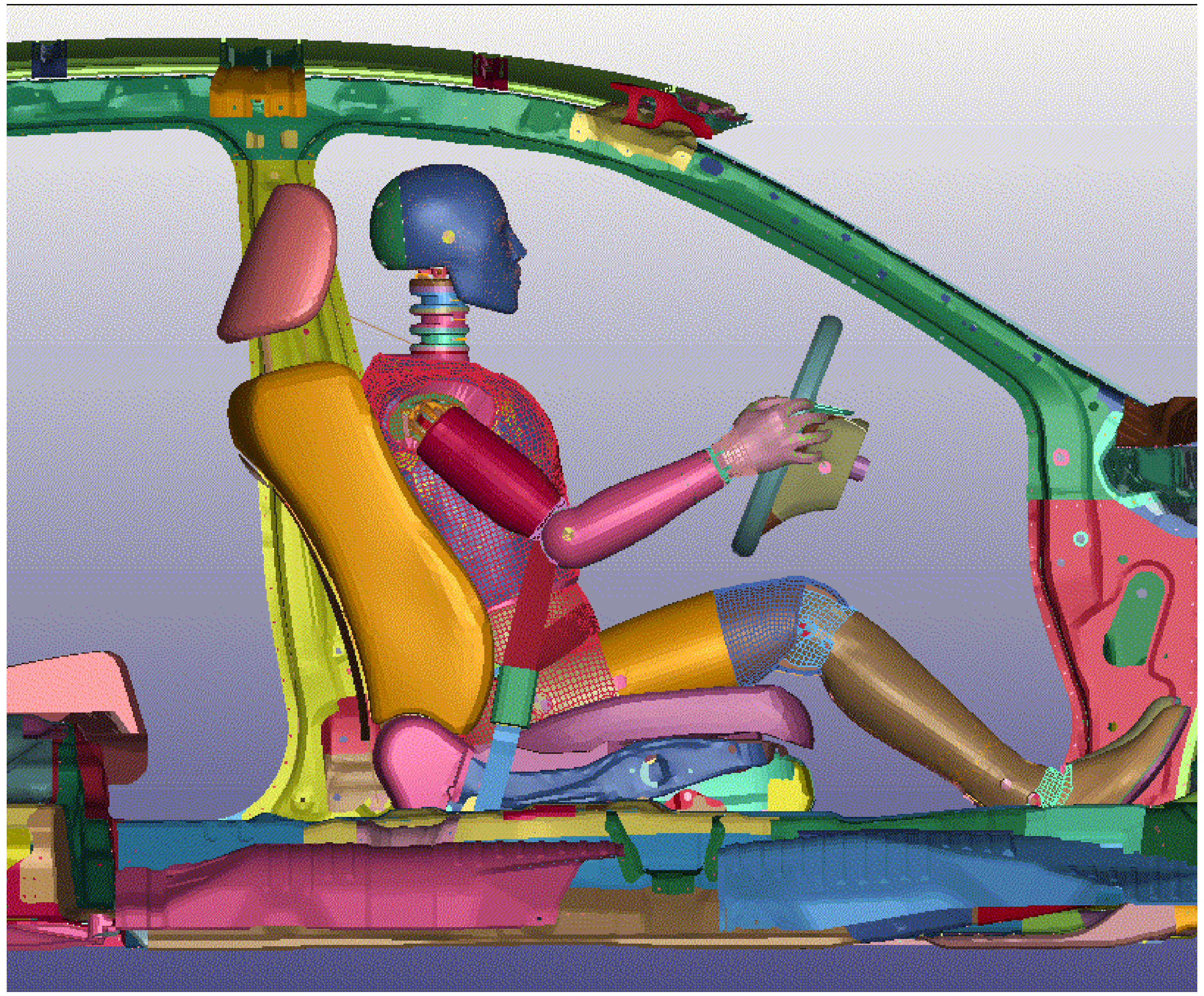


Validated Honda Accord Driver Seat – Mid Position

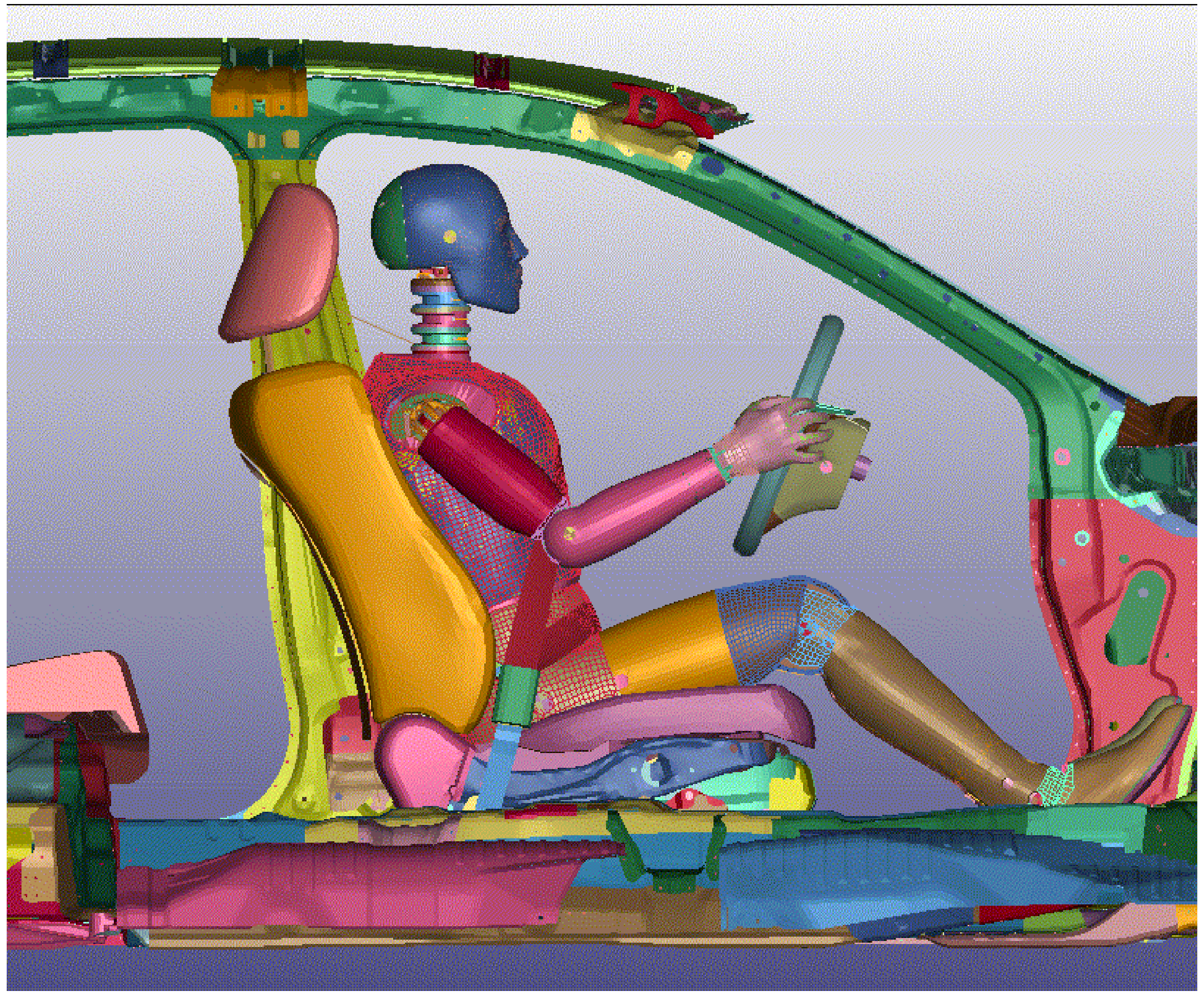
FMVSS 202a Model

Model Comparison - Animation

Baseline Seat



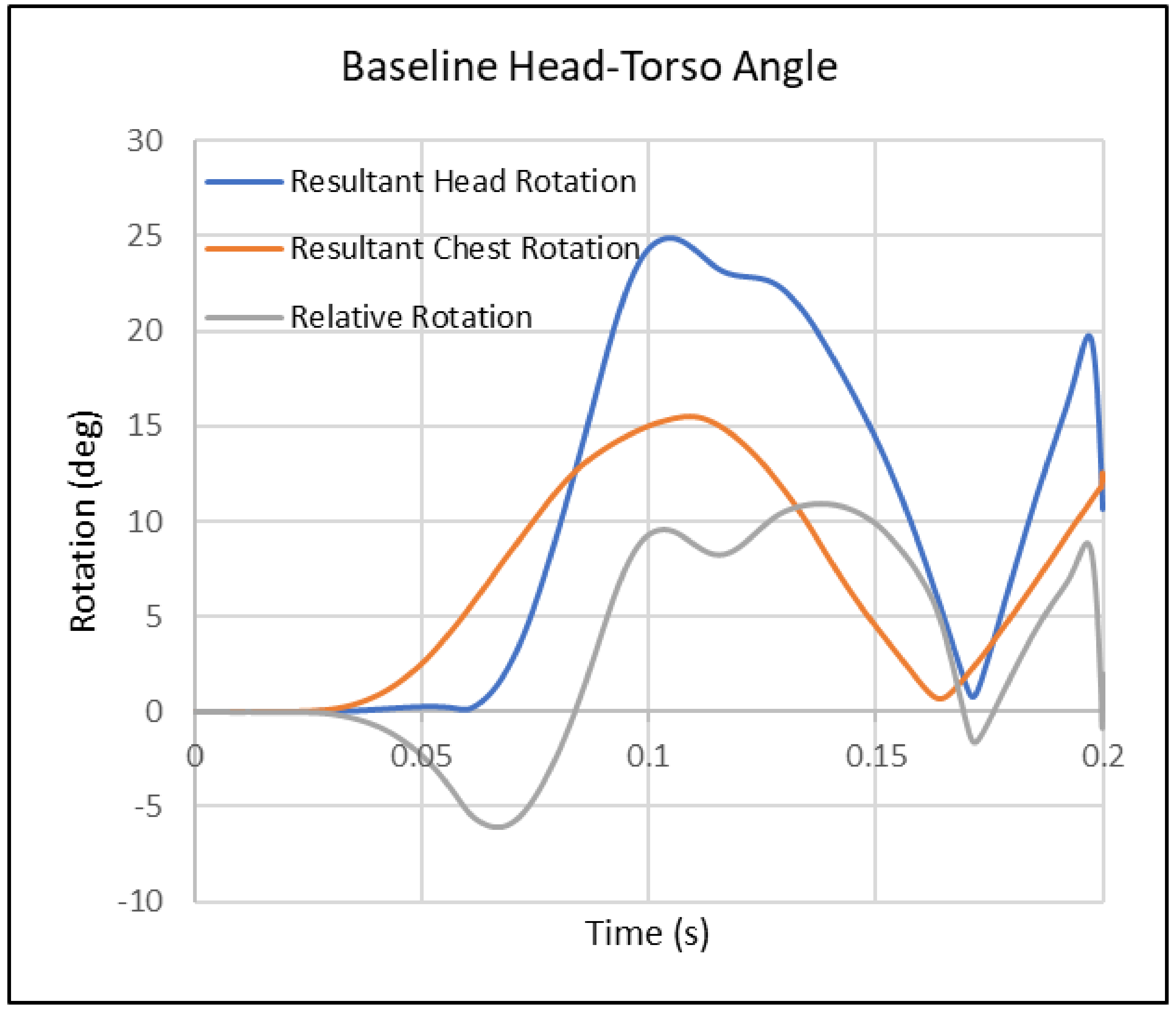
“Strengthened” Seat

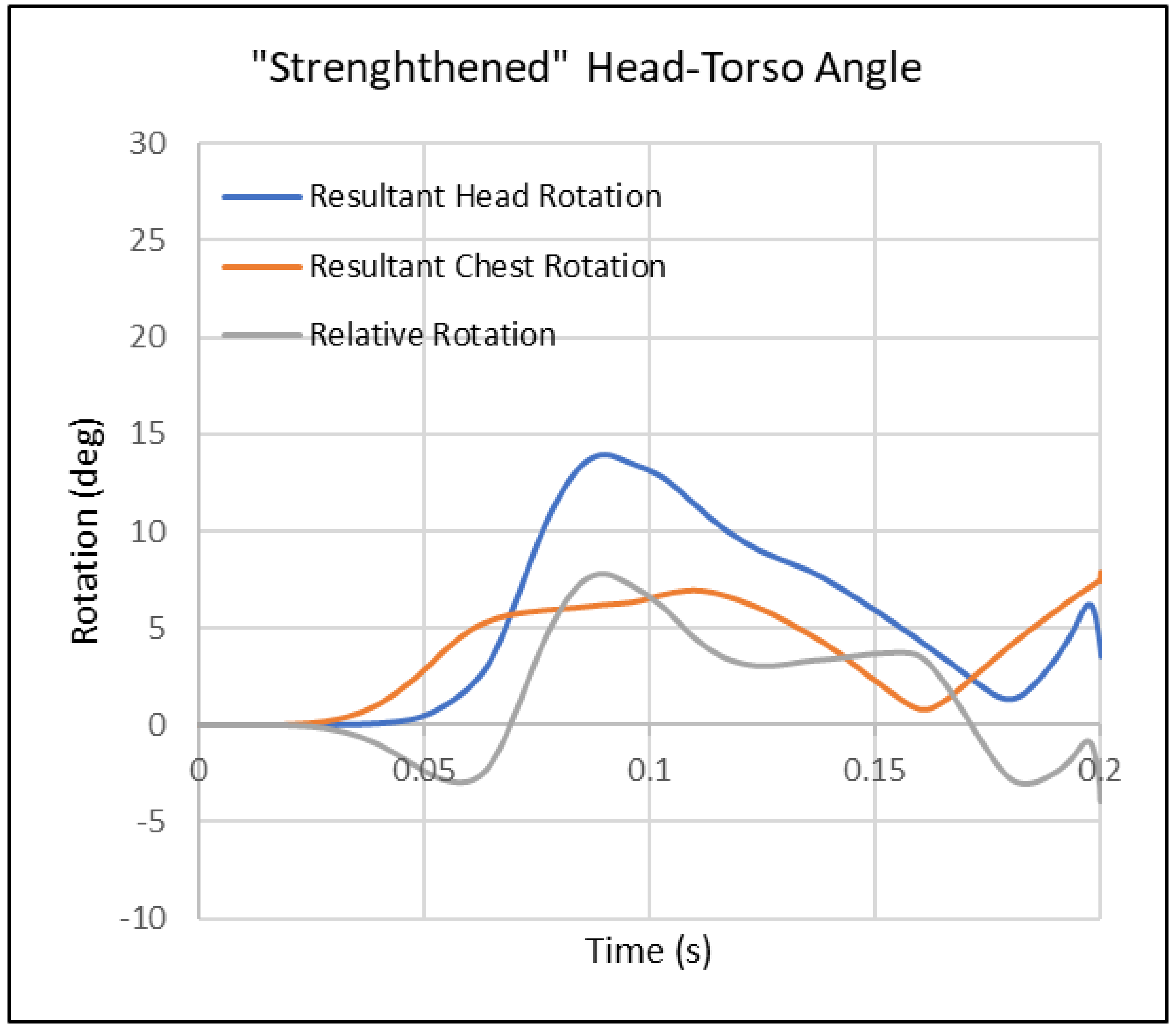


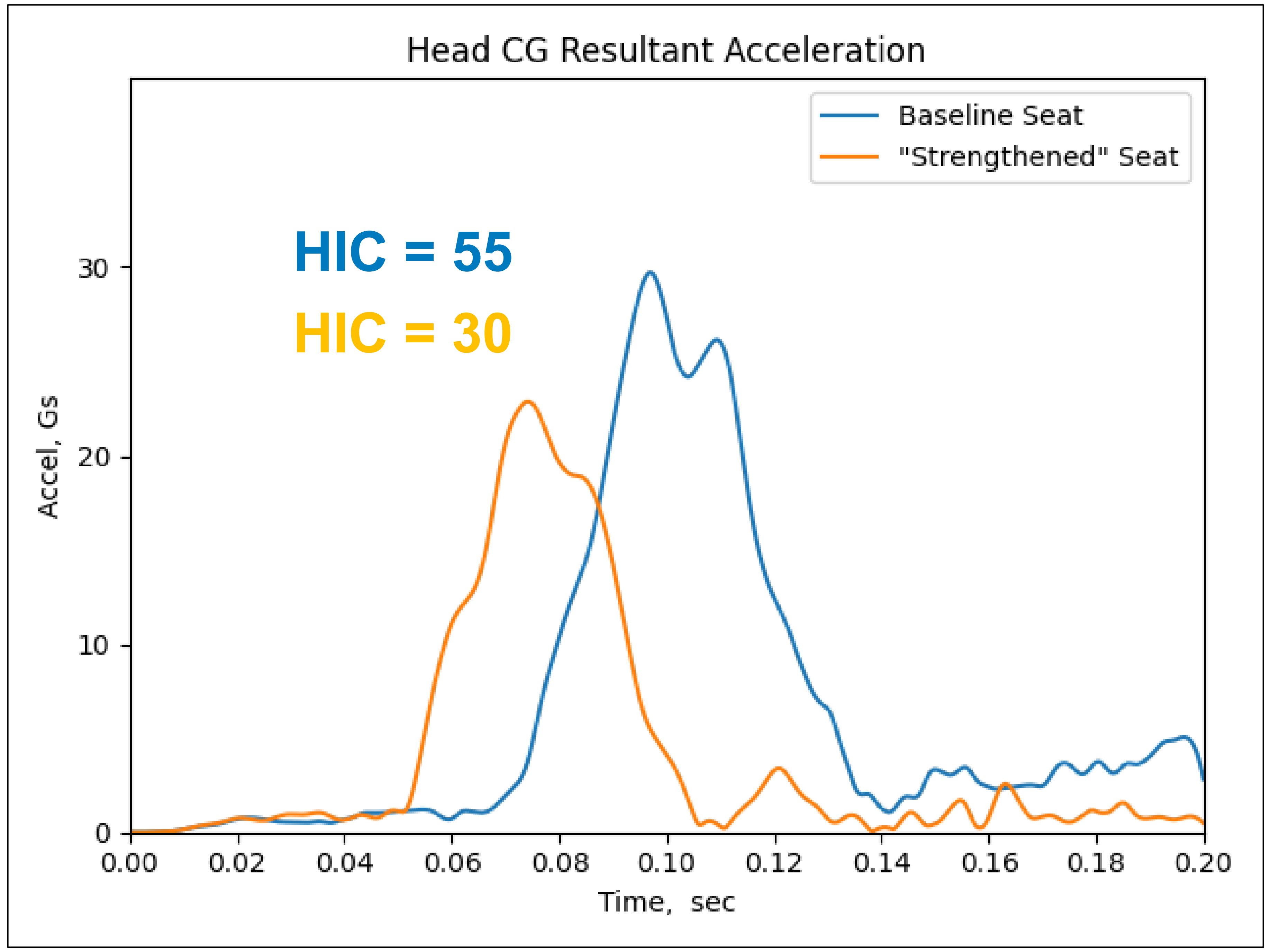
- “Strengthened” seat clearly demonstrates a much stiffer response (less rotation).
- Stiffer response of the “strengthened” seat results in slightly different dummy kinematics.

FMVSS 202a Model

Model Comparison – Hybrid III 50th Dummy Response







- Simulations with baseline and “strengthened” seat both predict compliance with FMVSS 202a for head-to-torso rotation, where the “strengthened” seat (7.8°) performing better than the baseline seat (10.9°)
- Simulations with baseline and “strengthened” seat both predict compliance with FMVSS 202a for HIC (<500) with respective HIC values of 55 and 30

Summary

FMVSS 301R Pulse Scaling Study

- We simulated a FMVSS No. 301R rear impact using a 2014 Honda Accord full vehicle FE model.
- The Honda Accord seat FE model was evaluated in sled simulations by scaling the baseline16 g FMVSS 301R pulse from the full vehicle simulation.
- Kinematics resembling seat back “collapse” was observed in the 25.6 g (1.6 x baseline) pulse simulation.
- Simulations predicted high dummy injury response numbers for both the 1st row 50th male THOR occupant (head, neck) and 2nd row Hybrid III 5th female occupant (neck, chest) for the collapsing seat condition.

Summary

"Strengthened" Seat Study

- The Honda Accord seat model was optimized for reduced seat rotation and potential occupant injury mitigation.
- This "strengthened" seat predicted reduced 1st row occupant ramping, even at high rear impact accelerations (25.6 g) in sled model simulations, and as a result lower occupant injury values.
- The "strengthened" seat model, despite being optimized to lower occupant injury risk for high-severity pulses, predicted compliance in FMVSS 202a simulations.

Future Work

- Perform low-speed impact simulation with IIHS low speed rear impact test protocol (BioRID dummy) with "strengthened" seat model.
- Perform FMVSS 301R pulse severity study with smaller 2nd row occupants (child) comparing baseline model to "strengthened" seat model.

Questions?

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