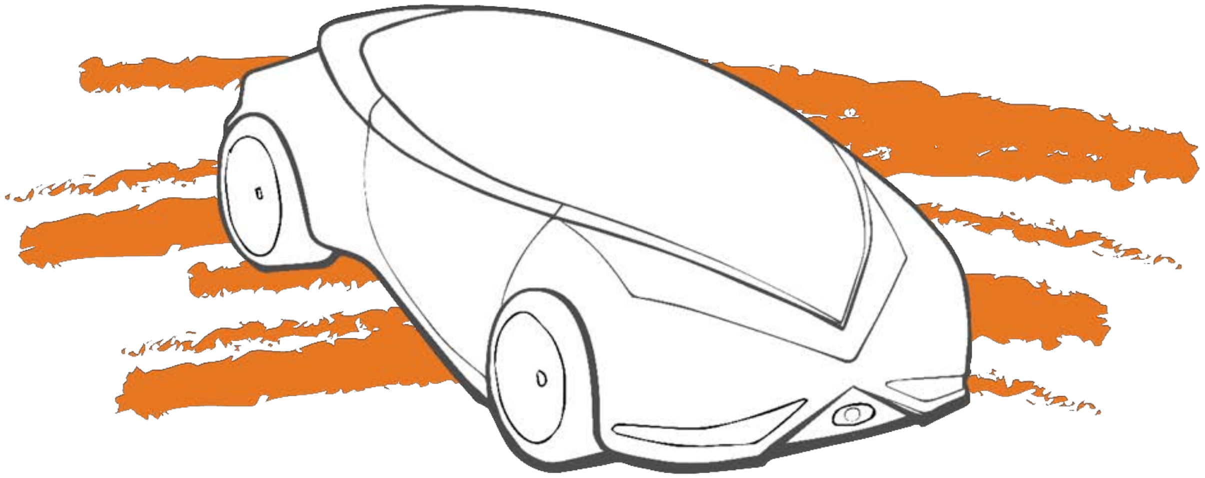
Stakeholder Meeting Day 2: FMVSS Considerations for Automated Driving Systems



WiFi Login Information

Network: **MediaCntr_Net**

Password: **OpenHouse2018**

Opening Remarks

Myra Blanco, Director
Center for Public Policy, Partnerships, and Outreach
VTTI

Crash Avoidance Debrief

Loren Stowe
Michelle Chaka
Kevin Kefauver
Luke Neurauter

Translations Update

Not covered in the April Stakeholder Meeting

- FMVSS Nos. 110 and 126

Updated based on feedback from the April Stakeholder Meeting

- FMVSS Nos. 108 and 111

Crash Avoidance

101 Controls and displays	**110** Tire selection and rims and motor home/recreation vehicle trailer load carrying capacity information	**124** Accelerator control systems
102 Transmission shift position sequence, starter interlock, and transmission braking effect	**111** Rear visibility	**125** Warning devices
103 Windshield defrosting and defogging systems	**113** Hood latch system	**126** Electronic stability control systems for light vehicles
104 Windshield wiping and washing systems	**114** Theft protection and rollaway prevention	**138** Tire pressure monitoring systems
108 Lamps, reflective devices, and associated equipment	**118** Power-operated window, partition, and roof panel systems	**141** Minimum Sound Requirements for Hybrid and Electric Vehicles

Stakeholder Comments: Translation Options

General Comments:

- FMVSS standards respond to basic safety needs for human drivers. ADSs may not have the same concerns. This should be considered when translating the standards for ADS-DVs.
- May want to explore the potential of defining a minimum set of vehicle network parameters that are needed to verify compliance.
- Regulations are typically developed to address a safety need. This is not done until there is a demonstrated need for regulations/actions.

Stakeholder Comments: Translation Options

FMVSS No. 108

- FMVSS No. 108 is not only for the human driver's visibility but is also for other road users. Standard translations should include setting lamp failure ADS actions. This is not just for FMVSS No. 108. Other standards, such as FMVSS No. 111, should consider the appropriate ADS actions relative to the expected human response.
- There are several threads to FMVSS No. 108 that need to be considered in the translations.

Stakeholder Comments: Translation Options

FMVSS No. 111 Translation Strategy:

- Option 1: Standard only applicable to vehicles that can be operated by human drivers
- Option 2: ADS-DVs have comparable 'sensor' coverage

Stakeholder Comments: Translation Options

FMVSS No. 111

- ADS should be able to detect and avoid
    - "Translations don't meet safety needs"
- ADS not direct substitute for human driver
    - No rear camera presented on in-vehicle screen (FOV coverage)
- Why limit to rear visibility?
    - Translation within existing document and safety intent
    - Technically, can document compliance
- ADS-DV – no distinction between looking forward vs. rearward
    - Assumed 360-degree visibility

Stakeholder Comments: Translation Options

FMVSS No. 126

- There may be novel ways of obtaining stability in addition to braking which may need to be considered in developing translation options

Test Methods Being Evaluated

Vehicle-based

- Human control
- Programmed control of the ADS
- ADS normal operation

Non-vehicle-based

- Technical design documentation
- Simulation

Test Procedure Overview

- Identification of common functionalities
- Classification of standards
- Selection of standards for inclusion
- Development of generic test procedures
- Implementation and execution
- Evaluation of test methods
- Iteration of testing and evaluation of results as necessary
- Validation

Stakeholder Comments: Vehicle-Based

General Comments:

- Manufacturer involvement is key in moving forward with vehicle-based test procedures
- Concern expressed regarding cybersecurity issues that may be introduced
  - Human control and programmed methods may provide a path to test the physical vehicle, additional threat vectors could be introduced
  - Allowing an ADS-DV to be operated outside its ODD for compliance verification may provide additional opportunity for unintended operation
  - Stakeholders expressed concern whether the ability to verify compliance on a few vehicles justifies the impact to the entire product offering for its life cycle

Stakeholder Comments: Vehicle-Based

General Comments Cont.:

- Thorough review of standard to identify common functionalities useful in evaluation of test methods
- For the short term the ADS-DVs are based on conventional vehicles
- The different FMVSS have unique requirements and may lend themselves to different test methods
- Standardization of hardware opens the possibility of additional cybersecurity concerns — standardization of parameters in conjunction with OEM involvement could provide path forward

Non-Vehicle-Based Test Methods Overview

- One consideration with using non-vehicle-based test methods is whether they will allow verification of the compliance of actual production vehicles, and not just the theoretical design of a vehicle or system
- The project is evaluating the potential use of
  - Simulation for FMVSS No. 126 and
  - Technical design documentation for FMVSS No. 138

Technical Design Documentation Summary

- The approach taken is to expand upon the Test Specification Forms currently used by Office of Vehicle Safety and Compliance (OVSC)
- Manufacturers complete these forms and submit them to OVSC after a vehicle is selected for potential testing
- The forms vary, but they generally request some, but not all, of the information needed to verify that a vehicle complies with an FMVSS

EXAMPLE ADS-DV TECHNICAL DESIGN DOCUMENTATION METHOD

ADS-DV TECHINCAL DOCUMENTATION
FMVSS No.

Vehicle Model Year and Make: ____________________

Vehicle Model and Body Style: ____________________

1. List the following information for the designated standard and optional OE tires:
   A. Tire Type
   B. Tire Manufacturer
   C. Tire Name
   D. Tire Size
2. State whether the ADS-DV comes with a temporary or full size spare tire. State whether or not the Tire Pressure Monitoring System (TPMS) monitors the spare tire.
3. State whether or not the ADS-DV displays any TPMS information or messages. If so, describe what and where the information can be displayed. If the information is not visible during all trips, then explain the steps required for an occupant to obtain the information.
4. TPMS Information

   NOTE: If more than one level of TPMS is offered for the same vehicle (base vs. luxury), provide information for all TPMSs. If different inflation pressure sensors (direct systems) are used depending on the rim type, provide information for Items 4.B. and 4.C. for each rim offered.

   A. Type:

   B. Tier-one TPMS system supplier: ____________________

   C. Inflation pressure sensor part#/model: ____________________

   D. Provide a systems diagram of all TPMS components including anti-lock braking system (ABS) speed sensors or inflation pressure sensors, antennas, electronic control unit, display interface (module), and any other components or sensors labeled with the applicable part numbers. The diagram must include the part release date and revision date (if any), and it must identify the vehicle make(s), model(s), model year(s), and body style(s) to which it applies.

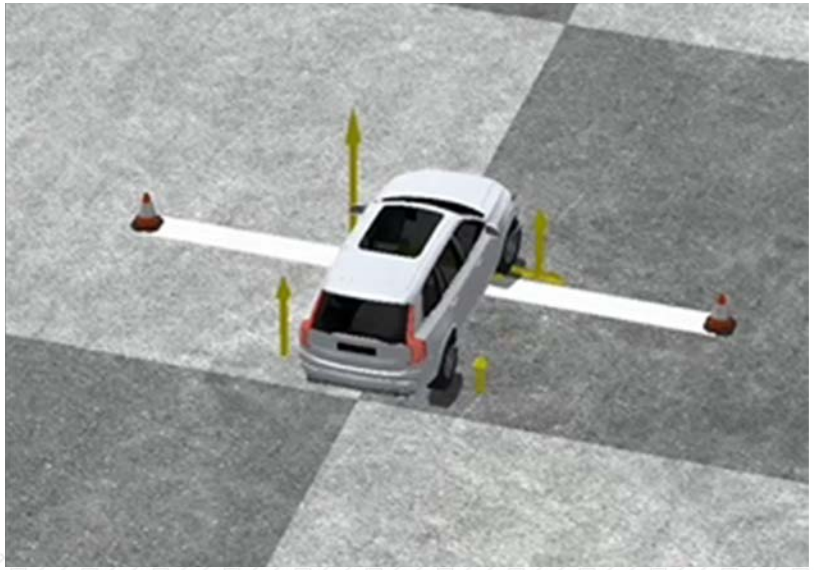
Stakeholder Comments: Non-Vehicle-Based Technical Design Documentation

- The other methods may become complex as you peel back the layers and technical design documentation provides a stop gap measure while other methods are developed
- Regarding trust:
  - The technical design documents shows that a manufacturer went through the process
  - Manufacturers want to keep their customers safe and protect their safety reputation
  - Documentation may include test results that could be difficult to obtain outside the manufacturer performing the tests

Simulation Overview

For simulation to be a viable test method, there must be trust in the model and its simulation output:

- The first step in developing “trust” is to understand the important model parameters directly related the systems being tested. VTTI is conducting a sensitivity study to help identify these parameters.
- Additionally, there must be test processes that include methods for validating the model and the associated simulation
  - Perform actual vehicle measurements that directly relate to the model parameters being verified
  - Compare actual vehicle test output to simulation output



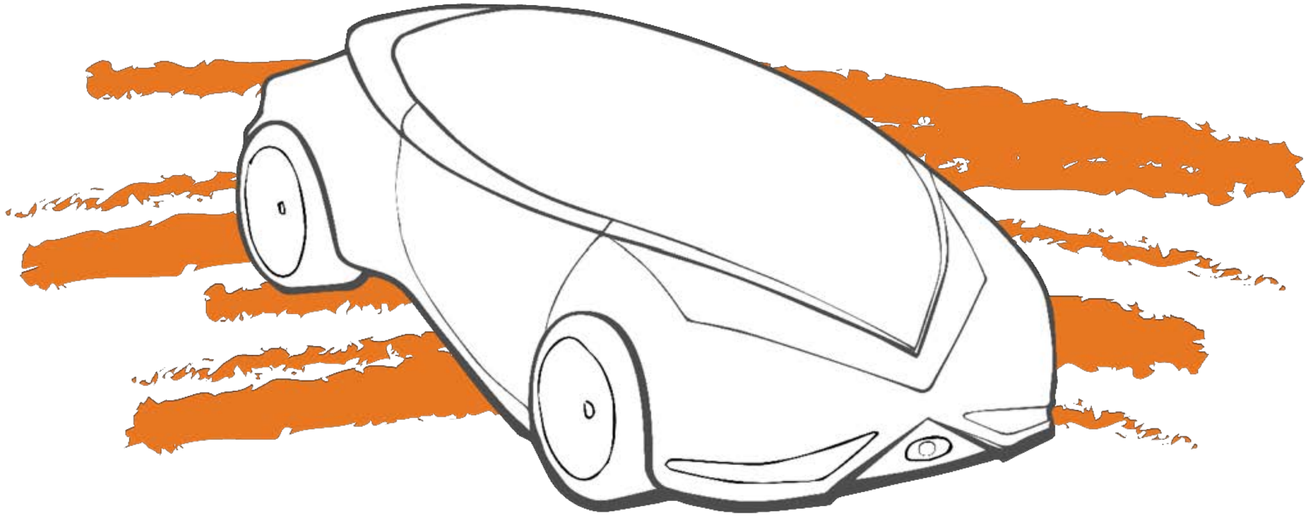
Stakeholder Comments: Non-Vehicle-Based Simulation

- Simulation provides a method for verification that may address concerns of testing a hardened ADS-DV operation outside its ODD
- Simulation is used in the aviation industry
- An anthropomorphic test device (ATD) or crash dummy used today in the crashworthiness regulations is a simulator. It simulates and is able to predict the human response to injury. ADSs also have predictable responses and in an analogous way may be suitable for simulation.
- The manufacturer may need to provide information to NHTSA to support simulation as a test method

Stakeholder Comments: Non-Vehicle-Based Simulation

- Simulation has its place but may be long-term
- Simulation may be suitable for some requirements but needs to be done in conjunction with physical testing
- The auto industry uses simulation for development and more research may be needed for simulation to be used for verification
- Although hardware-in-the-loop provides a method for physical testing in combination with simulation, the interfaces are complex and may require manufacturer cooperation or involvement
- Manufacturer involvement may be critical for simulation to be a viable test method

Thank You



Crash Avoidance Debrief

Crash Worthiness and Occupant Protection Debrief

Warren N. Hardy
Andrew R. Kemper
Costin D. Untaroiu

Crashworthiness and Occupant Protection Rear-Seat Testing and Seating Location Selection

<u>FMVSS 208 Rear Seat Testing and Modeling Overview</u>

Presented by Andrew R. Kemper and Costin D. Untaroiu

1.3 Select Late-Model Vehicles Spanning a Range of Potential Rear-Seat Safety Performance (from 23)

2018	Chevrolet	Equinox
2018	Audi	Q5
2018	Jeep	Compass
2018	Mercedes	GLC-Class
2018	Nissan	Rogue Sport
2018	Nissan	Maxima
2018	Subaru	Legacy
2018	BMW	X1
2018	Chevrolet	Bolt
2018	Honda	Accord Sedan
2018	Hyundai	Santa Fe
2018	Toyota	Camry

2017	Buick	Envision
2018	Cadillac	Cadillac XT5
2017	Chrysler	Pacifica
2018	Honda	Honda Odyssey
2017	Hyundai	Elantra
~~2017~~	~~Kia~~	~~Kia Niro~~
2018	Lincoln	Continental
2017	Mazda	CX-3
2018	Subaru	Impreza
2017	Toyota	Prius
~~2018~~	~~Chevrolet~~	~~Traverse~~

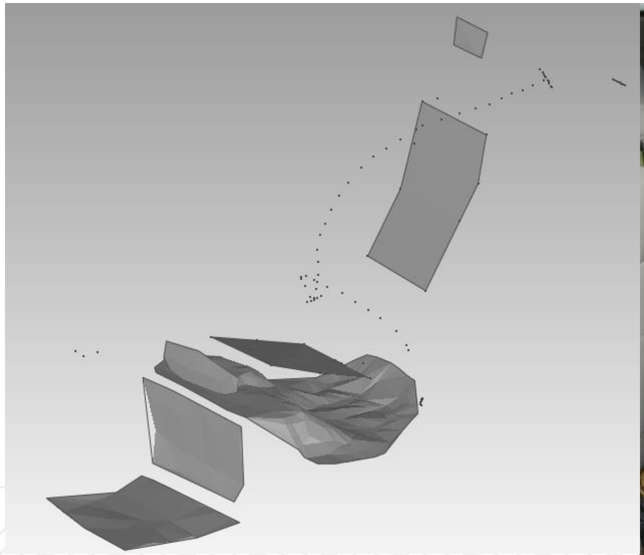
Test Lab
TRC
Karco
MGA
208/MGA
Calspan

1.3 Select Late-Model Vehicles Spanning a Range of Potential Rear-Seat Safety Performance

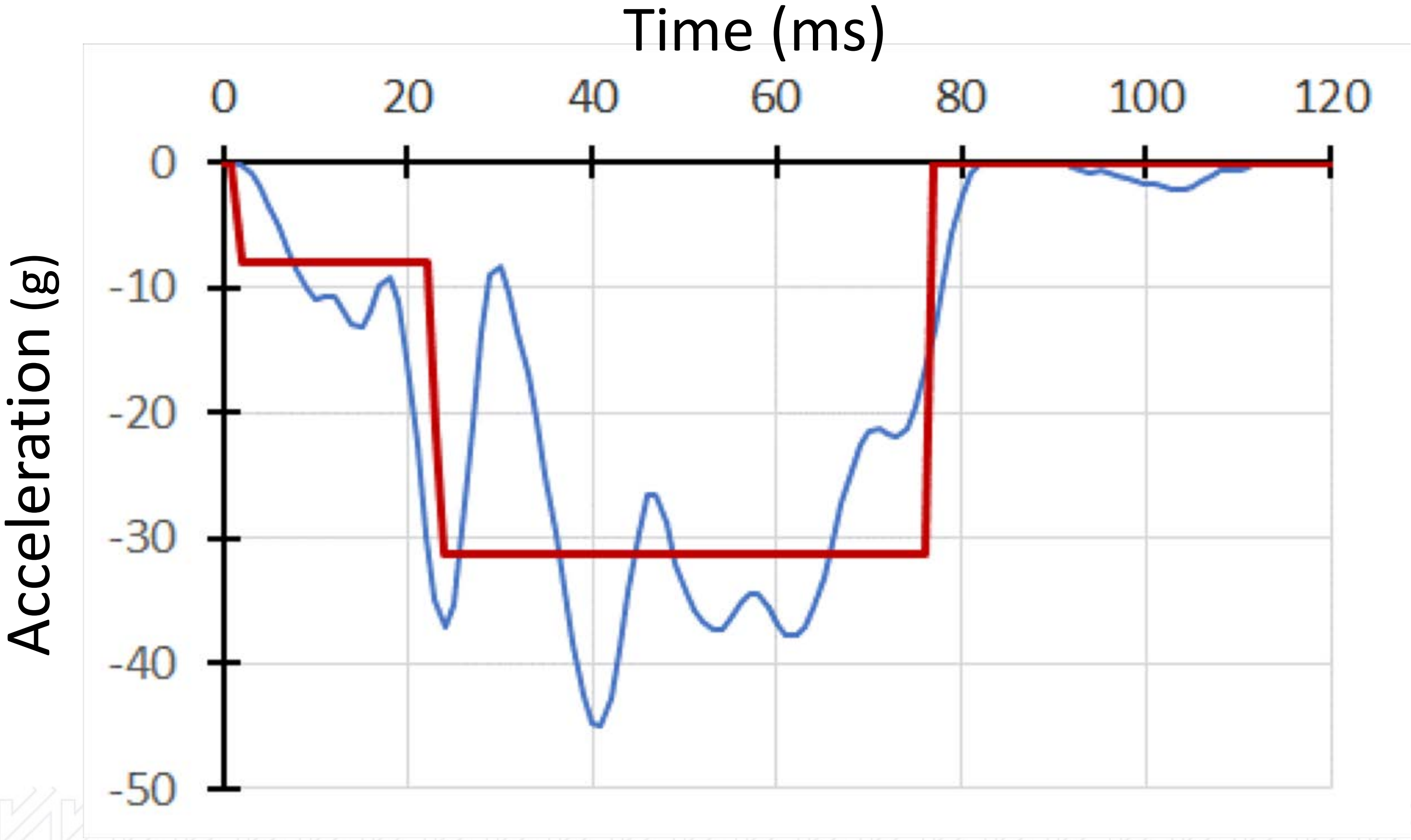
1.3.3 Examine vehicles' package characteristics, restraint geometry, and seat belt routing

Restraint Characteristics
- Belt anchor point locations, including D-rings and retractors
- Presence of load limiters, pretensioners, or inflatable seat belts
- Seat belt routing

Seat Characteristics
- Seat back angle
- Seat bottom angle/length
- Seat pan geometry
- Seat cushion stiffness
- Relative headrest position



Vehicle 16 (V_16) Crash pulse shape/magnitude



Two-step Fit	
t (s)	A (g)
0	0
0.001	0
0.0015	-8.00
0.022899	-8.00
0.023075	-31.25
0.076931	-31.25
0.076931	0
0.12	0

Down-selection to approximately ~10 vehicles for FE modeling

Crash Performance Parameters

- Shoulder Belt Location on Clavicle
- Retractor (P/T, CFR + P/T)
- Seat Pan Ramp, Sub Bar, Box at Ramp End
- Box at end of Ramp
- Drop off at end of Ramp
- Lap Belt Angles
- Seat Foam Stiffness
- Sub Bar
- Foam Stiffness + Sub bar
- NCAP Crash Pulse (shape/magnitude)

Crash Performance

Neck Loads
Chest Deflection
Lumbar Loads
Pelvis Acceleration
Overall

Score: 0 to 200
(larger = better)

Down-selection to approximately ~10 vehicles for FE modeling

Submarining Parameters

- Seat or Floor Pan Ramp Angle
- Anti-Submarining Bar
- Seat A-Surface Pocket
- Seat Surface to Floor Height
- Seat Foam Stiffness, Structure Interaction
- Shoulder Belt Retractor (P/T, CFR, Combo)
- Lap Belt Angle
- Lap Belt P/T
- Lap/ Shoulder Belt Junction

Submarining Performance

Score: 6 to 100
(larger = better)

Worst → Best

Vehicle ID	Sub + Crash (Score 6 to 300)	Crash (Score 0 to 200)	Submarining (Score 6 to 100)
V_1	92	55	37
V_13	120	59	61
V_4	132	85	47
. .	. .	. .	. .
V_8	166	124	42
V_20	166	114	52
V_10	167	129	38
. .	. .	. .	. .
V_6	186	135	51
V_2	190	135	55
V_14	221	140	81

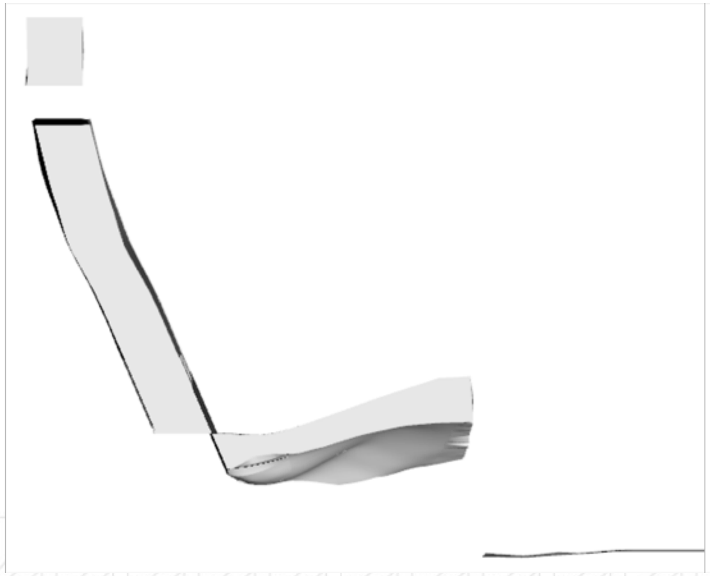
≤ Mean -1 SD

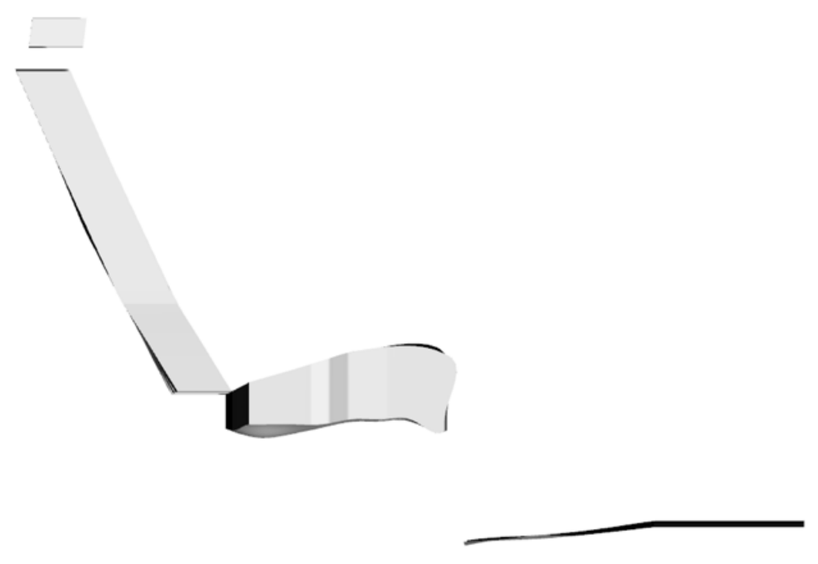
≥ Mean -1 SD & ≤ Mean +1 SD

≥ Mean + 1 SD

Cars Modeled

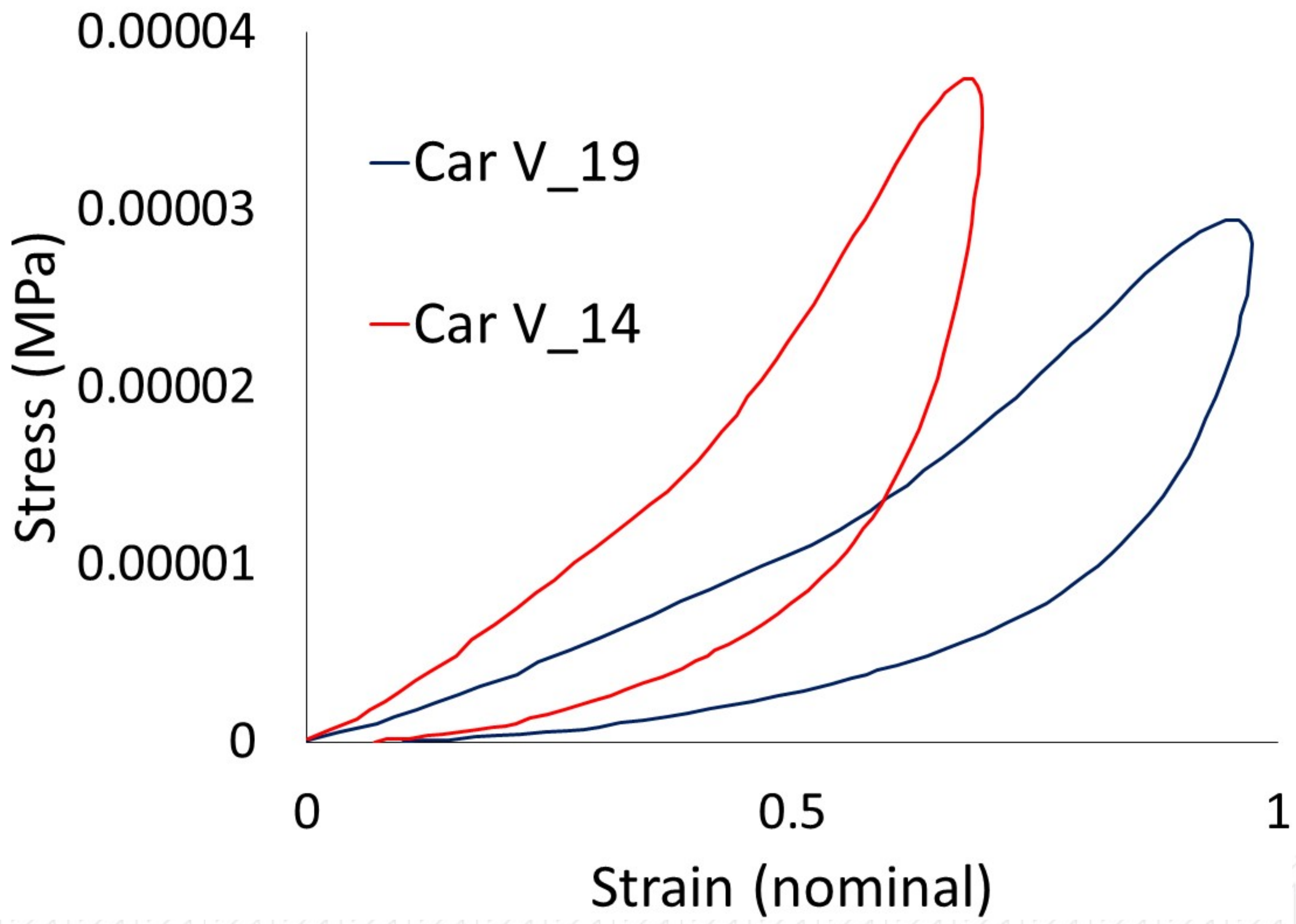
	Car V_19	Car V_14
Seat Angle (deg)	12.6	18.8
Stiffness (N/mm)	9.8	12.2
Pretensioner	No	Yes





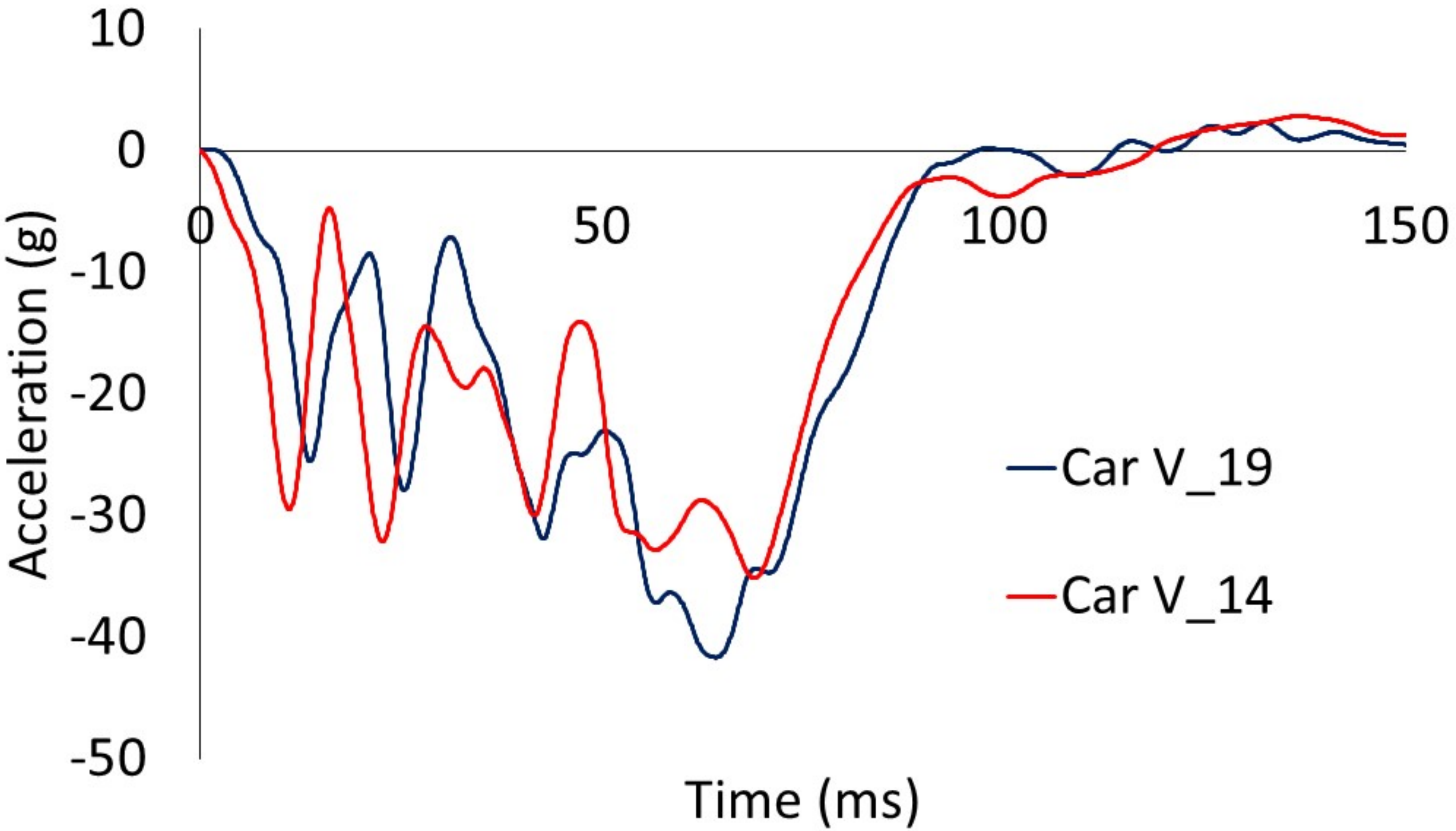
Material Properties: Seat Cushion

- Properties measured by quasi-static test for each seat
- Data fit to load curve of an average seat
- Stress-strain curve approximated with average seat thickness



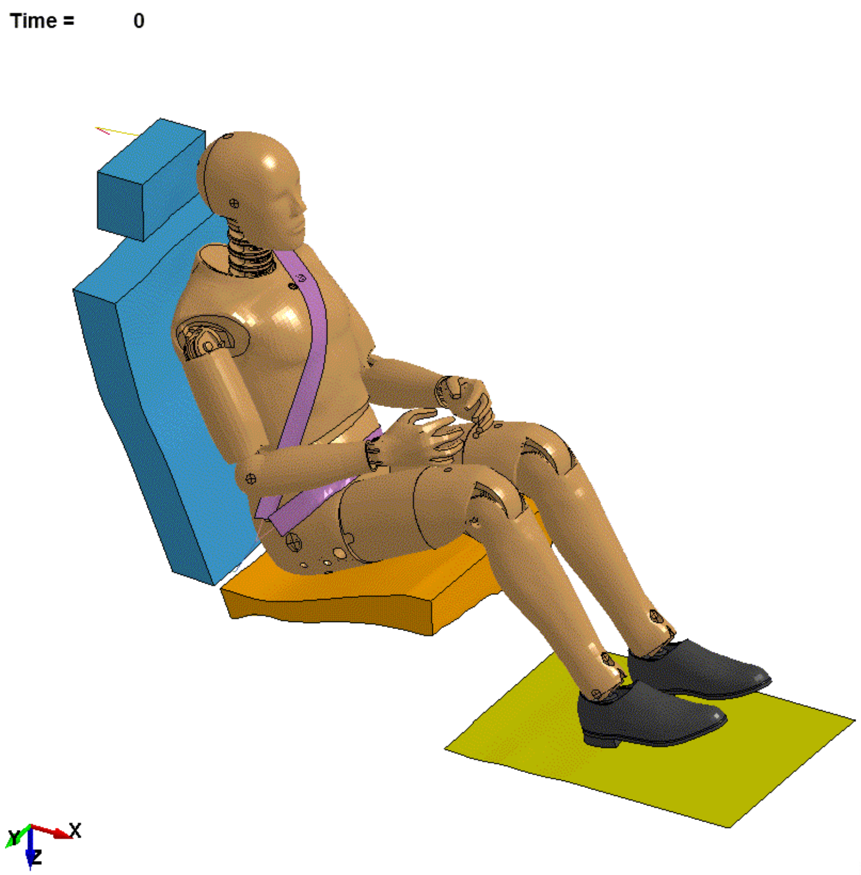
Boundary Conditions: Vehicle Crash Pulses

- Seat pan, seat back, belt anchors, and floor modeled as rigid and coupled
- NCAP full crash pulses applied as well as scaled down to V_0=30mph

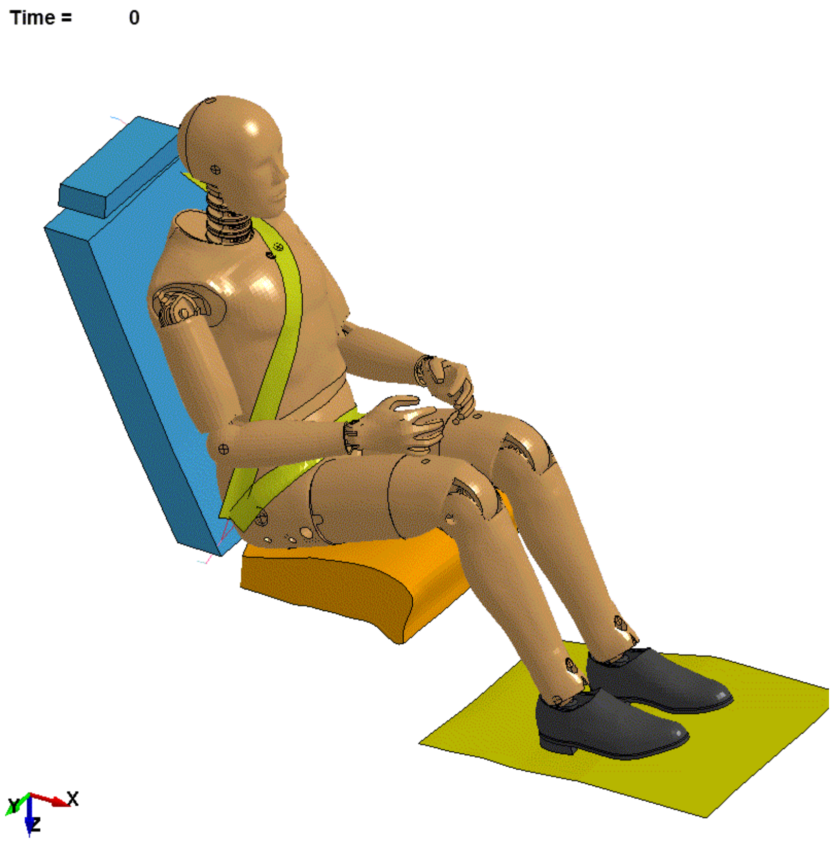


Car-to-Car Variation

Car V_19



Car V_14

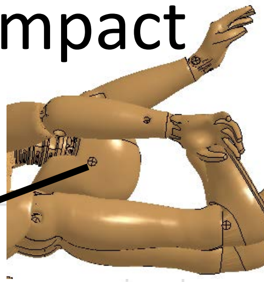


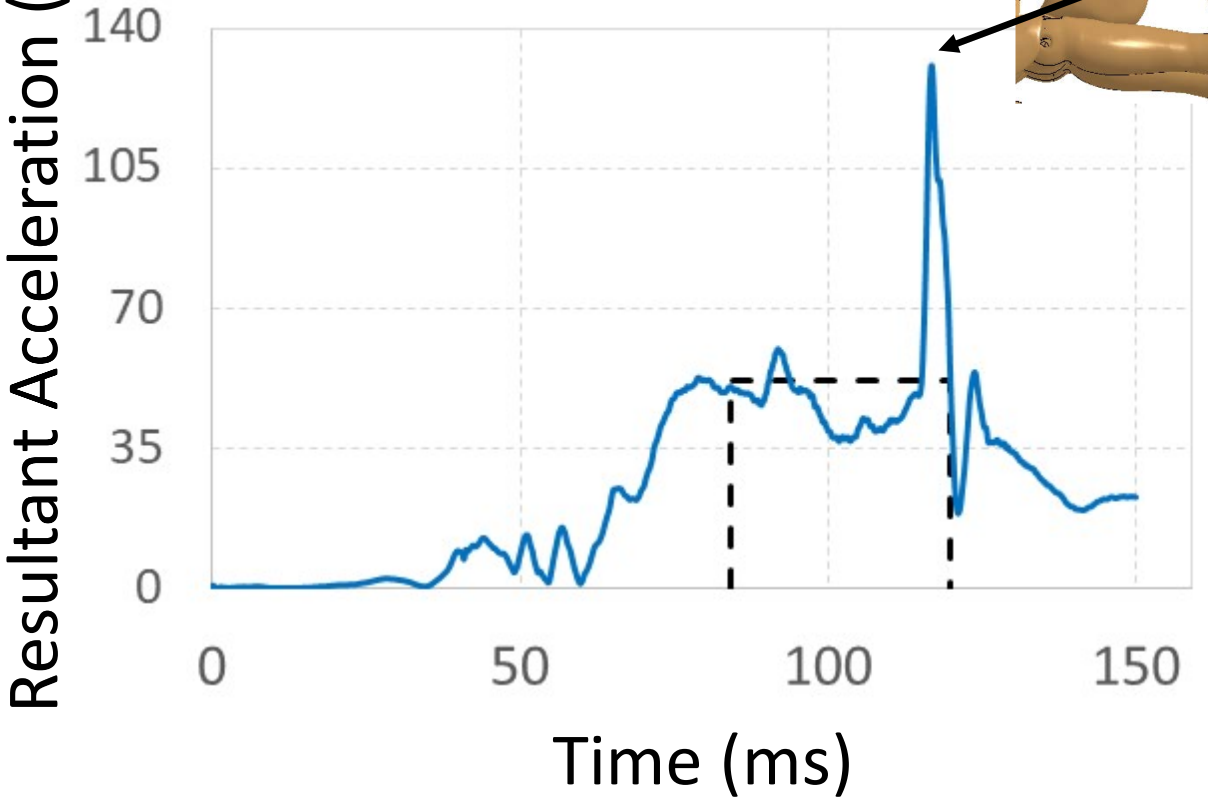
HIC – HIII Predictions

$$HIC = \max\left[\left(\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a(t)\,dt\right)^{2.5}(t_2 - t_1)\right]$$

Car V_19 NCAP Head/leg impact

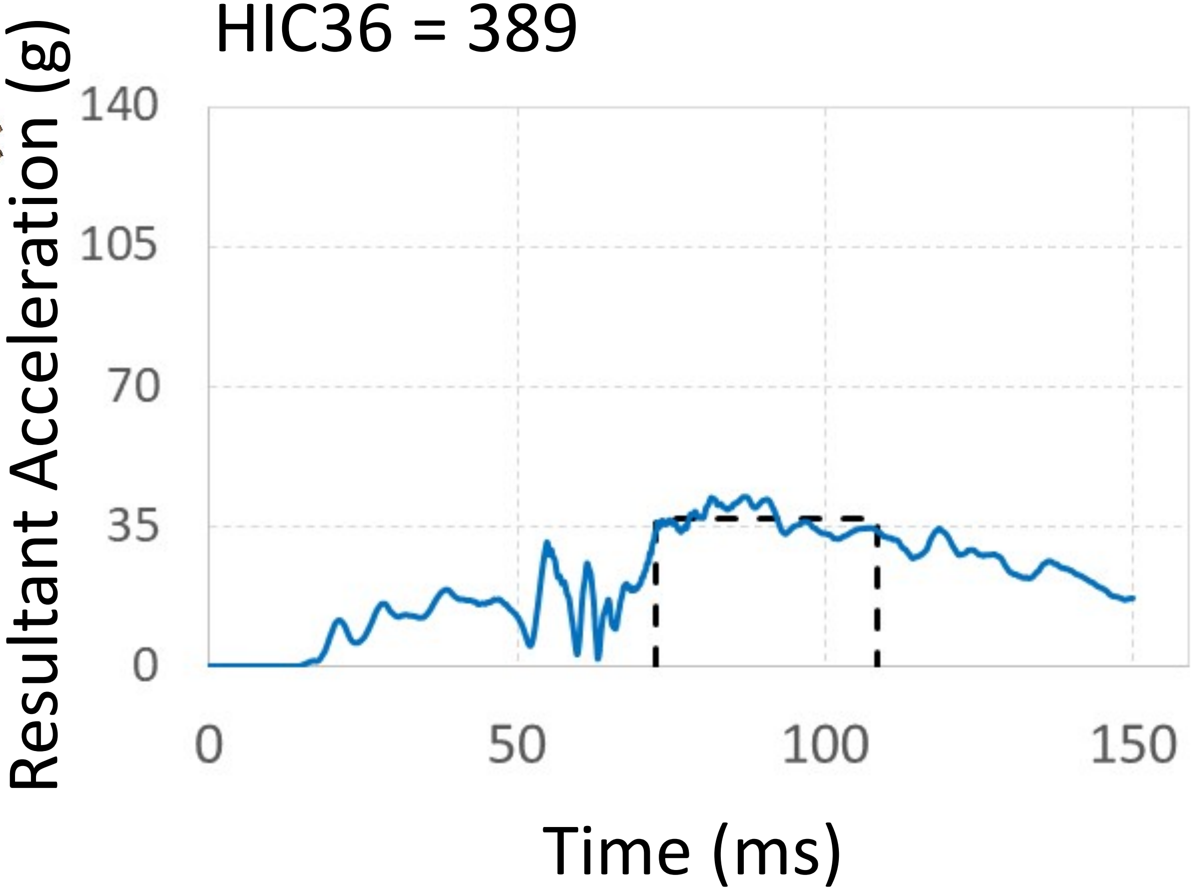
HIC36 = 693





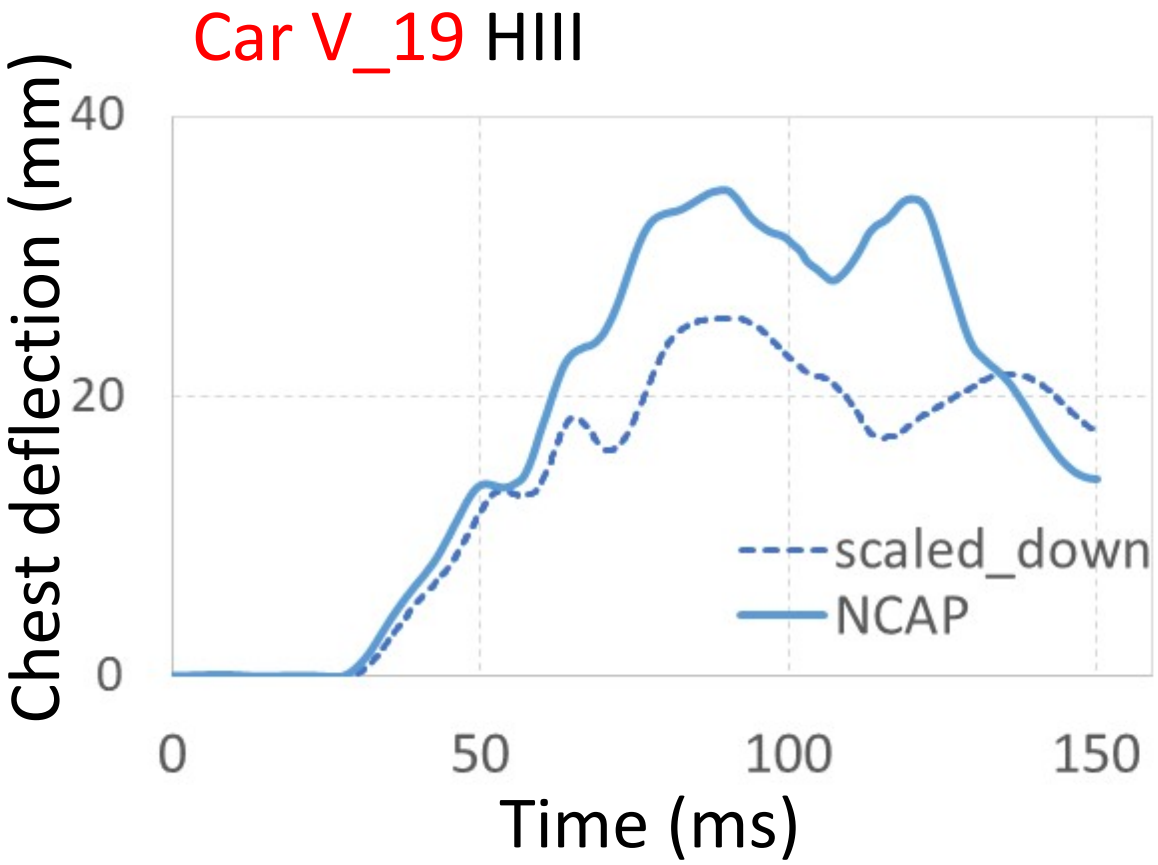
Car V_14 NCAP

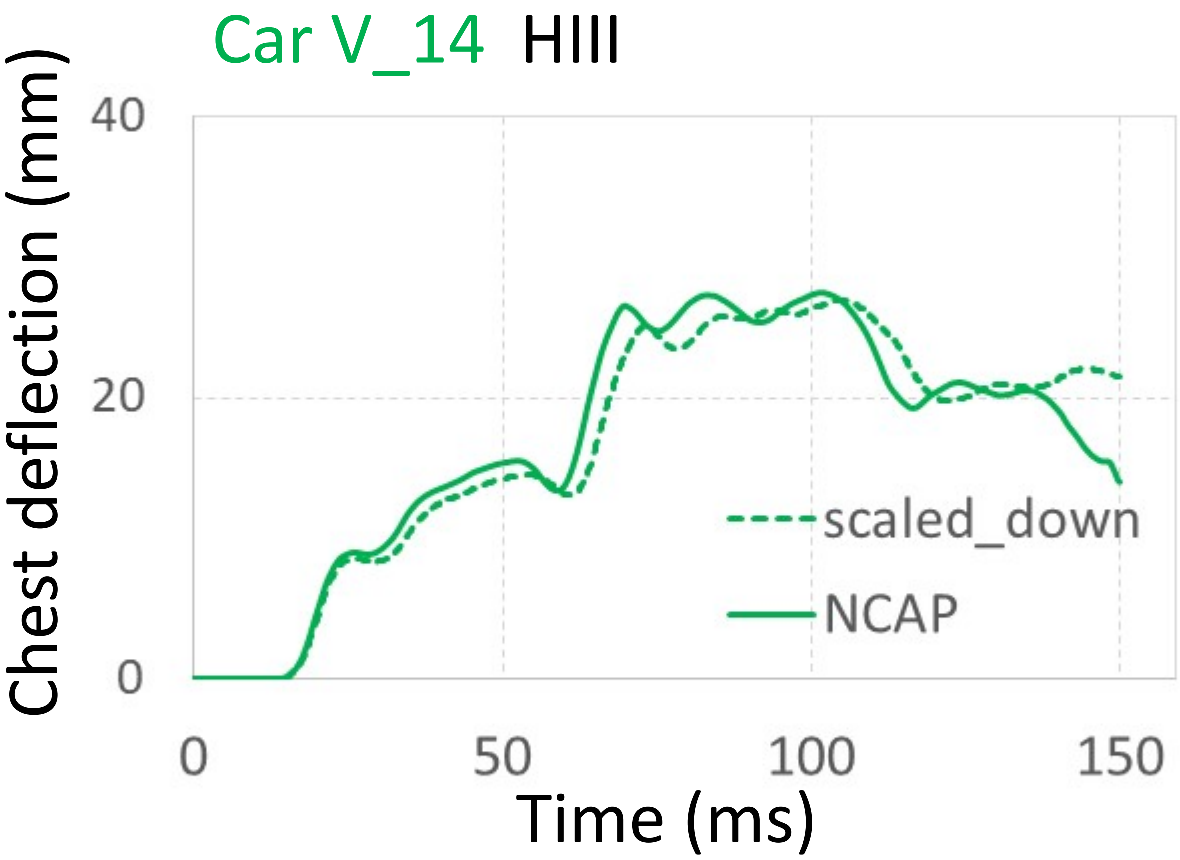
HIC36 = 389



Car V_14 shows better performance than Car V_19 (in terms of HIC)

Chest Deflection – HIII Predictions





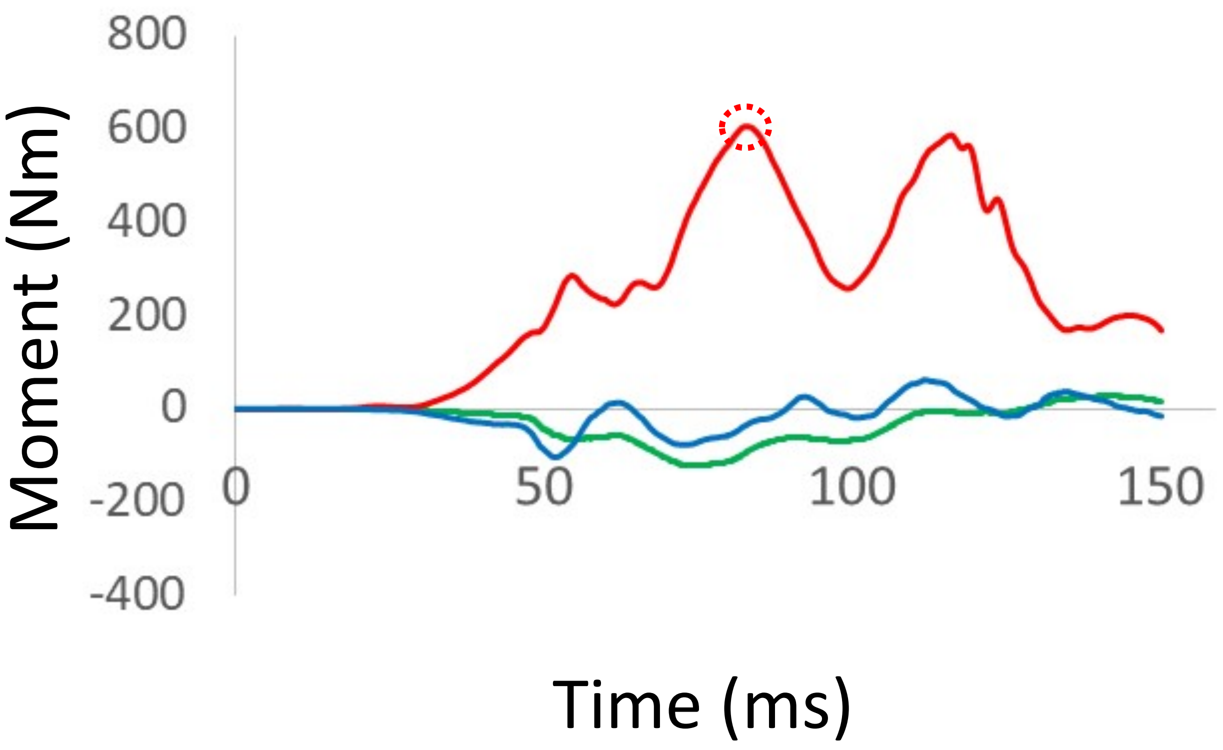
Higher Chest Deflection in Car V_19 than Car V_14 in NCAP simulation

Little sensitivity in Car V_14 relative to pulse is probably due to the pretensioner

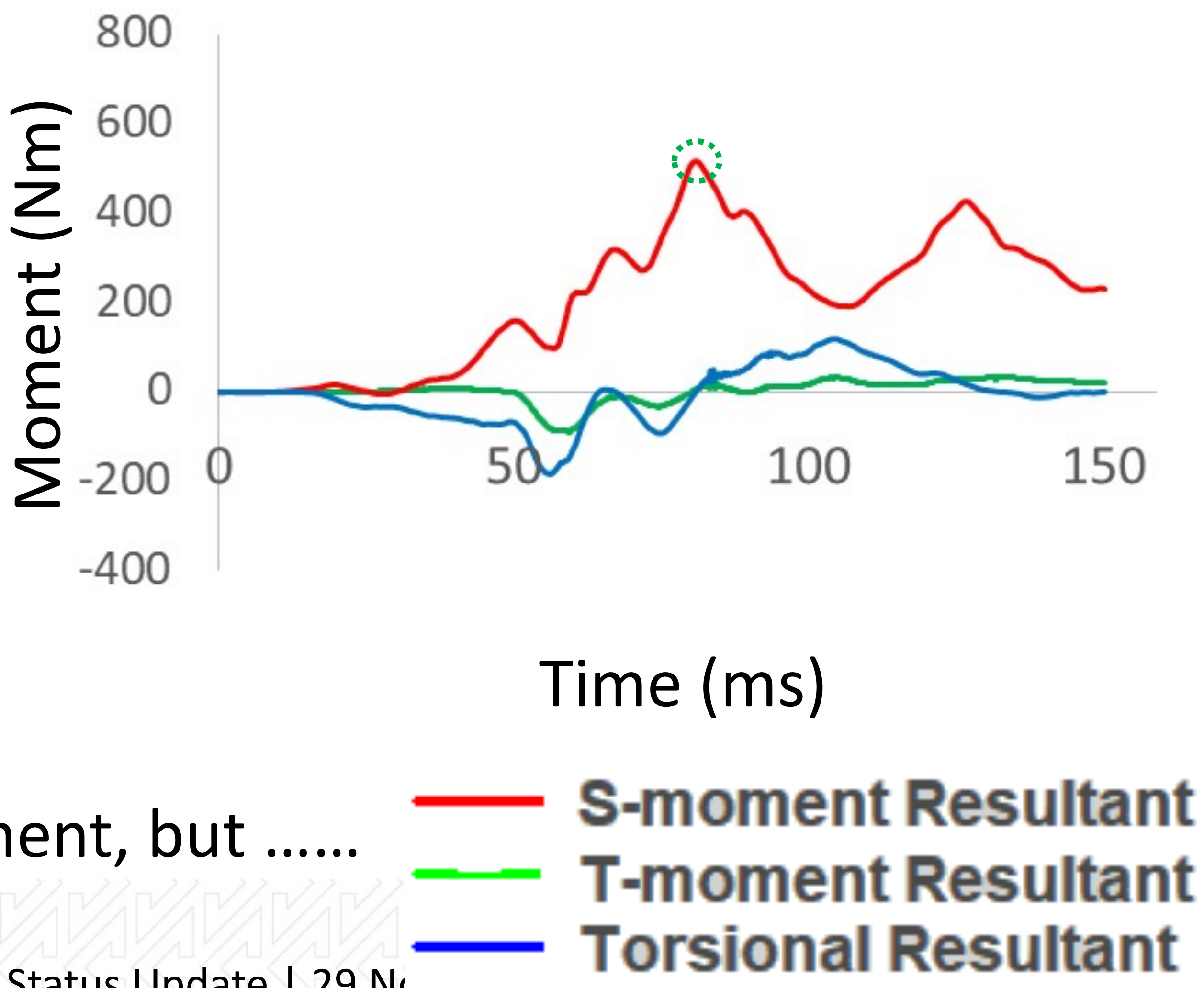
VIRGINIA TECH TRANSPORTATION INSTITUTE
Advancing Transportation Through Innovation

Lumbar Load: HIII Predictions

Car V_19 NCAP



Car V_14 NCAP



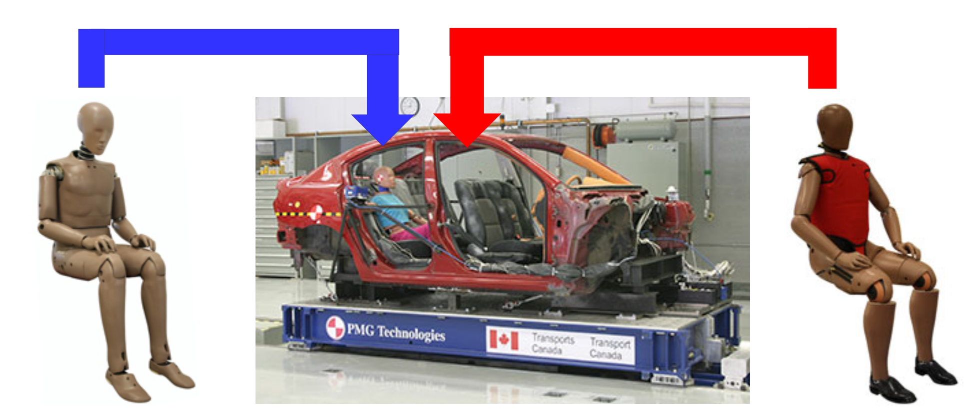
Car V_14 shows lower peak of moment, but ......

Part 4: ATD Testing

4.3 Conduct Paired ATD Sled Tests Using up to Five Vehicle Bucks and Two Speeds

The CIB ServoSled will be used to simulate frontal crashes using the previously fabricated vehicle bucks

- Two Crash Pulses
  - NCAP pulse (56 kph) for specific vehicles
  - Scaled pulse (32 kph) for each model
- Two ATDs (right and left outboard positions)
  - THOR-M 50th
  - Hybrid III 50th



http://www.humaneticsatd.com/ https://www.wingsmagazine.com/innovations/road-test-to-flight-test-10266 http://www.humaneticsatd.com/

Output: *Responses from Hybrid III and THOR for 10-14 sled tests using 5–7 bucks and 2 speeds*

Part 4: ATD Testing

4.4 Assess Relative Vehicle Platform Safety Performance for Rear Seats

4.4.1 Evaluate metrics

Existing FMVSS 208 requirements

Additional variables will also be assessed:

- Lower neck loads and moments
- Lumbar or T12 loads and moments
- Lap belt submarining and shoulder belt escape by the shoulder/torso
- Provisional IARVs for the abdomen will be computed

Part 4: ATD Testing

4.4 Assess Relative Vehicle Platform Safety Performance for Rear Seats

4.4.2 Compare ATDs to FE

Compare general kinematics as well as computed injury metrics between ATDs and FE

Output: *Summary comparison between test and model outcomes with examination of the nature of, and reasons for, observed differences*

4.4.3 Summarize findings

Generate a report summarizing the findings of the initial work. The ATD tests will inform potential future sled tests that will be used to evaluate the dummy findings via comparison to PMHS response

Output: *Summary of findings from both dummies from 10 sled tests*

Crashworthiness and Occupant Protection Rear-Seat Testing and Seating Location Selection

Seating Location Discussion

Presented by Warren N. Hardy

Current Rear-Seat Experience

- FMVSS No. 208 and NCAP do not include rear-seat occupant
- Traditionally, there has been a lower percentage of rear-seat occupants compared to front-seat occupants on US roadways
- 12.9% of person-trips had rear-seat occupants (Trowbridge and Kent, 2009)
- 34.5 billion trips annually and 399 billion vehicle miles traveled with a rear-seat passenger indicates that the national at-risk exposure to injuries/fatalities is high (Bose et al., 2017)
- Rear-seat occupants account for 23% of occupants with injuries and 9% of fatalities (NCSA, 2008)

Future Rear-Seat Experience

The percentage of rear seat passengers might increase dramatically

When occupants have no driving involvement in certain or all conditions, passengers may elect to sit in the rear seat because of

- Increased comfort
- Perceived safety
- Peace of mind
- Psychological predisposition (prior taxi experience)
- Desire to face the direction of travel

Rear-seat occupant protection can vary drastically between vehicles

Rear-Seat Safety

Kuppa et al. (2005)

- 48 kph and 56 kph, front- and rear-seat frontal barrier tests
- 5th female and 50th male Hybrid III ATDs
- ATDs in the rear seat had considerably higher head, neck, and chest injury risks, and the percentage of tests that had injury measures that exceeded threshold levels was substantially higher for rear-seat occupants

Rear-Seat Safety

Hu et al. (2015, 2017)

- 48 km/h, rear-seat frontal sled tests using two crash pulses: ‘soft’ and ‘severe’
- 6 yo, 5th female, and , 95th male Hybrid III, and 50th male THOR-NT
- Three-point belt, four-point belt, retractor/buckle pretensioners, load limiters, inflatable three-point belt, bag in roof (BiR), and bag in front seat (SCsRAB)
- Severe crash pulse: Both advanced restraint systems reduced nearly all IARVs for all ATDs but THOR

Rear-Seat Safety

Bilston, Du, and Brown, 2010

"…rear seat occupant protection has not kept pace with front seat safety improvements. . . . Adjusted rear to front risk ratios for AIS 3+ injury in adults range from 1.11–3.16"

Durbin, Jermakian, Kallan, McCartt, 2015

"Findings of an elevated risk of death for rear row occupants . . . in the newest model year vehicles provides further evidence that rear seat safety is not keeping pace with advances in the front seat."

Mitchell, Bambach, and Toson, 2015

"Rear seat car passengers are sustaining injuries of a higher severity compared to front seat passengers traveling in the same vehicle. . . . When considering only passengers 51+ years old, the odds ratio is significantly higher at 2.02 (1.68-2.43)."

Crashworthiness and Occupant Protection Rear-Seat Testing and Seating Location Selection

Novel Seating Configurations Panel Discussion

200-series Breakout: Novel Seating Configuration

Moderator: Warren Hardy, VT-CIB

Panelists:

- **Joe Kanianthra,** Active Safety Engineering LLC
- **Priya Prasad,** Auto Alliance
- **Douglas Stein,** Autoliv Inc.
- **Kurt Driscoll,** Faurecia Automotive Seating
- **Amanda Prescott,** Zoox Inc.

Scope

There will be significant considerations when translating current FMVSS to apply to the novel seating arrangements anticipated in the future in a meaningful way. FMVSS 208 and 214 are among the most concerning.

- What are the obstacles?
- What are the knowledge gaps?
- What are the enabling factors?
- What are the solutions?

Novel Seating Configuration Stakeholder Remarks

- Knowledge gaps – numerous – will require significant time, money, effort to close these gaps and expand the biomechanics database
- Development/validation and adoption of a new ATD as part of a revised standard is not practical (time)
- Human body and vehicle FE models needs to be advanced (development/validation)
- Integration of active and passive safety systems can go a long way to improving safety, but the functionality of such systems needs to be physically evaluated – it is not clear how this can be achieved using simulation for self-certification

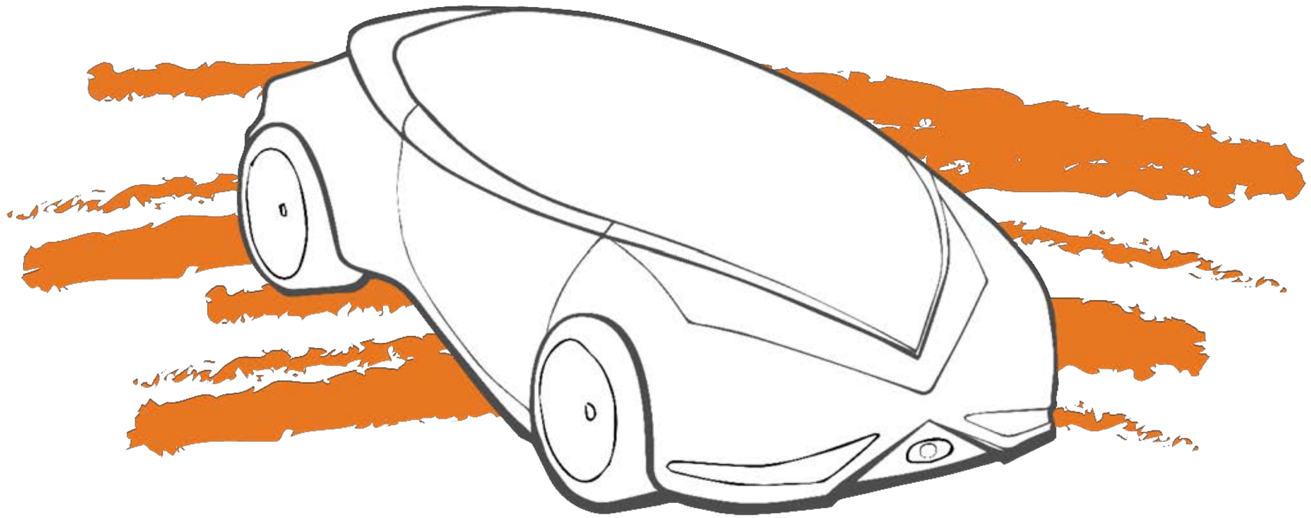
Novel Seating Configuration Stakeholder Remarks

- We cannot assume anything about the characteristics of a passenger in a particular seating location – anybody could be anywhere
- A nominal test configuration is needed – e.g., seat swivel and recline angles
- FMVSS need to accommodate the anticipated/intended use of vehicles with novel seating compartments
- Some are of the opinion that we will always have physical testing
- ADS-DVs can be deployed in vehicle categories that aren't covered by many standards

Novel Seating Configuration Stakeholder Remarks

- FMVSS 208, for example, might be able to be met for rear-facing front row occupant via air bag suppression, and paying attention to head/neck loading by using a HIII but the test would not be meaningful
- This is not a simple matter of language translation
- Safety intent and due care are of utmost importance

Thank You

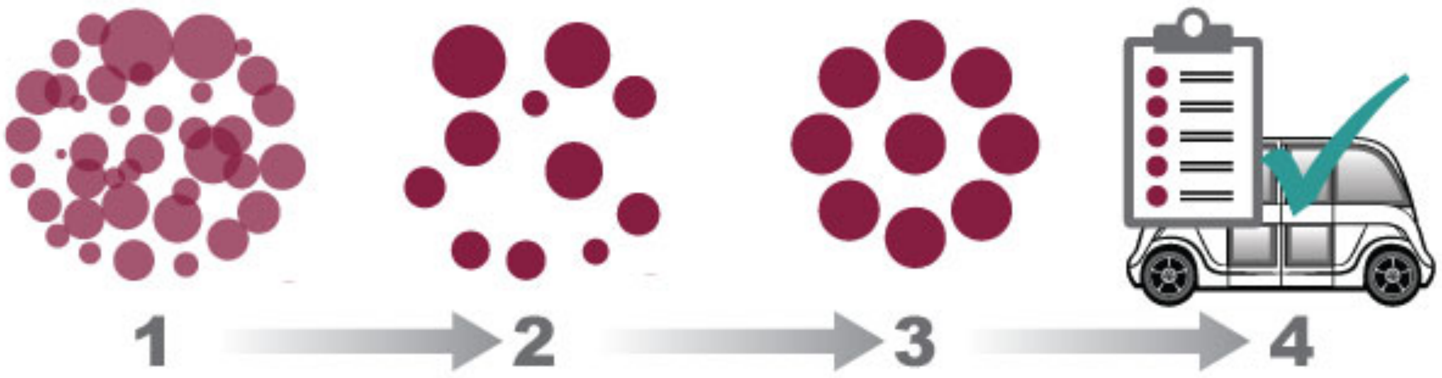


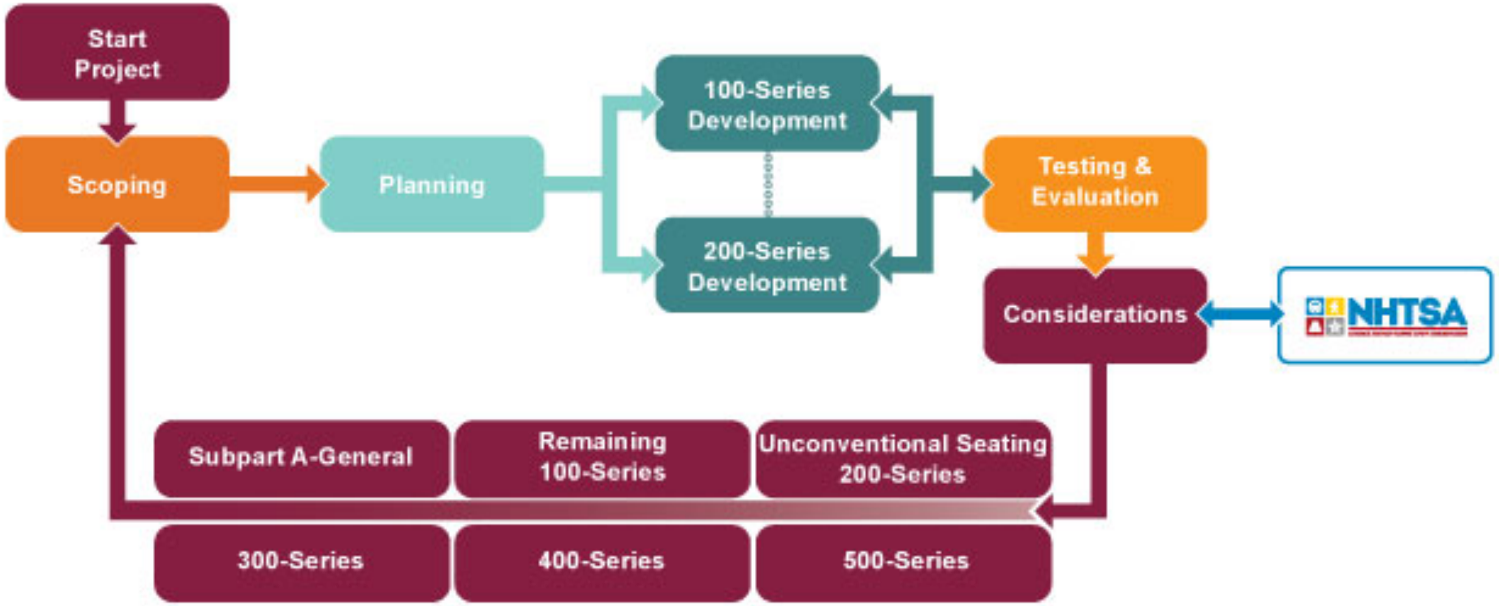
Crashworthiness and Occupant Protection Debrief

Next Steps

Myra Blanco, Director
Center for Public Policy, Partnerships, and Outreach
VTTI

Approach


1
2
3
4


Start Project
Scoping
Planning
100-Series Development
200-Series Development
Testing & Evaluation
Considerations
NHTSA
Subpart A-General
Remaining 100-Series
Unconventional Seating 200-Series
300-Series
400-Series
500-Series

Closing Remarks

Lori Summers, Interim Director

Office of Vehicle Crash Avoidance and
Electronic Controls Research, NHTSA

Thank You!

- Ellen Lee, COR (TO)
  - E-mail: ellen.lee@dot.gov
  - Phone: 202-366-1435
- Myra Blanco
  PI/Project Manager
  - E-mail: mblanco@vtti.vt.edu
  - Phone: 540-231-1551