Rear Seat Occupant Protection: Safety Beyond Seat Belts

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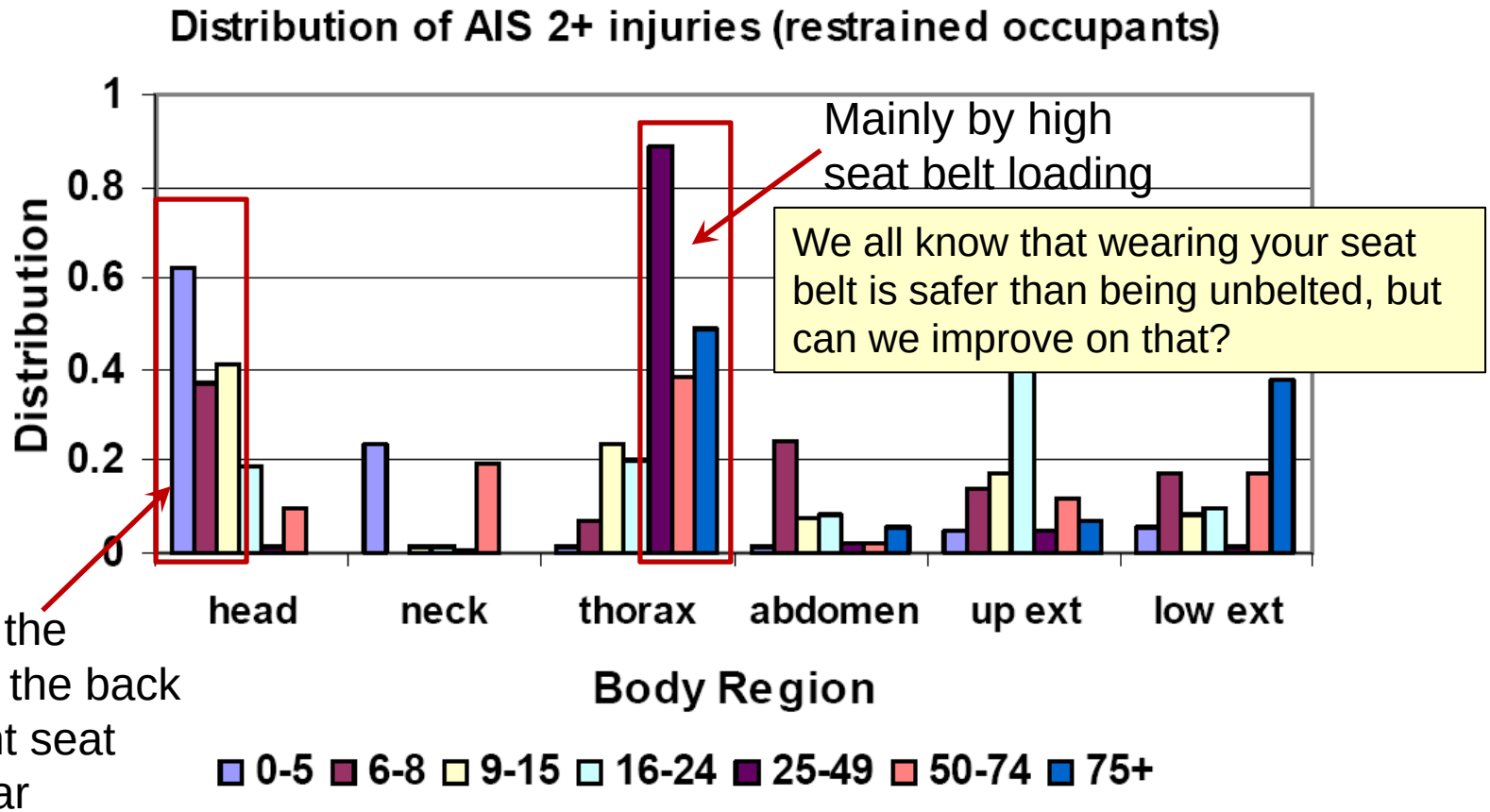
Background

- **What are the leading injuries in rear seat?**

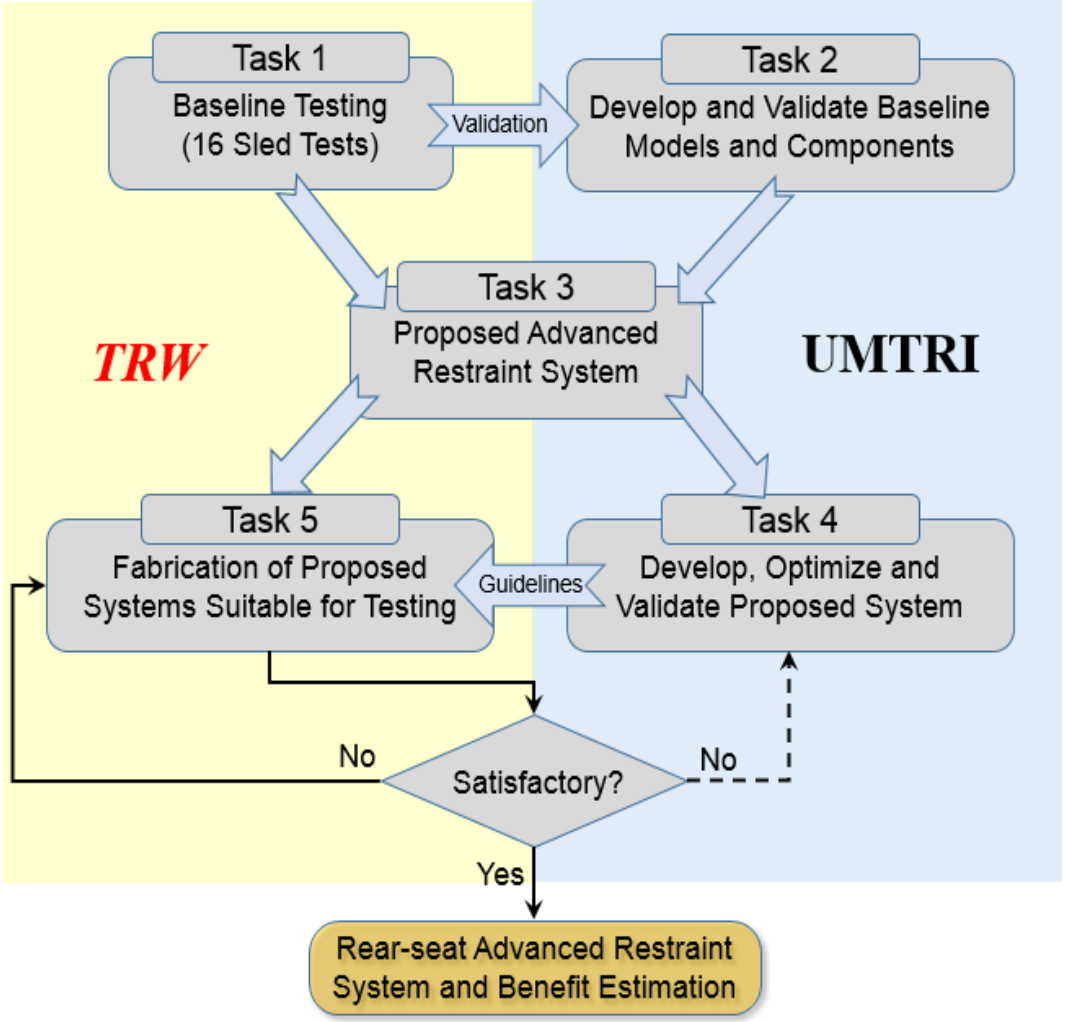


Data based on Kuppa et al. 2005 and Arbogast et al. 2012

Research Objective & Tasks

Objective:

- To design, optimize, and fabricate prototype advanced restraint systems to provide protection for rear seat occupants of different sizes in frontal crashes with different crash pulses and directions



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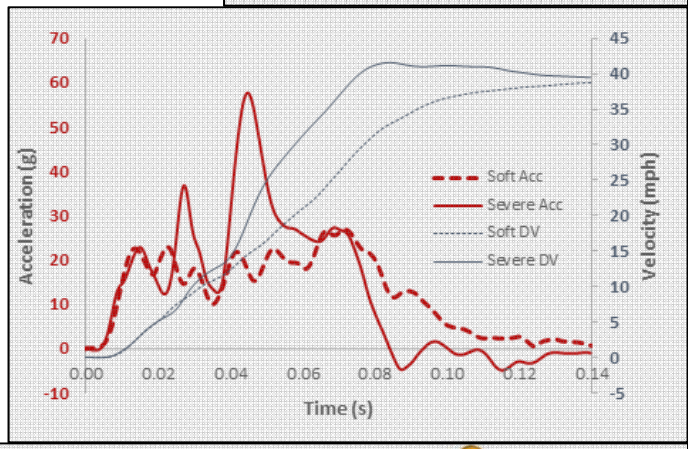
Crash Conditions

- Rear seat compartment
  - Based on a compact vehicle
- Crash pulse
  - NCAP fleet severe vs. NCAP fleet soft
- Crash angle
  - 0 deg vs. 15 deg to the right
- ATD Occupants
  - H-III 6YO / H-III 5th / THOR 50th / H-III 95th
- Front seat position
  - Mid (left) vs. more forward (right)



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Front Seat Position

	Driver		Passenger	
	Seat Back Angle	Seat Position (Knee/Seat Offset)	Seat Back Angle	Knee/Seat Offset
6 Year Old	12 deg	Mid	3 deg	150 mm
Small Female (5^{th})	12 deg	Mid (110 mm)	3 deg	150 mm (Mid seat track)
Mid Size Male (50^{th})	12 deg	Mid (70 mm)	3 deg	150 mm
Large Male (95^{th})	12 deg	2 notches FWD of MID (20 mm)	3 deg	150 mm (Approx full fwd)

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Objective & Constraints

- **Objective Function**
  - Chest injury probability for 5th, THOR, and 95th (based on chestD and associated injury risk curves for different sizes of ATDs)
- **Constraints**
  - Head: Head excursion, HIC, and BrIC
  - Neck: Neck C&T, NIJ
  - Chest: 6YO chestD

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Design Targets

	Head			Neck			Chest
	Excursion (mm)	HIC	BrIC	Neck T (kN)	Neck C (kN)	Nij	Chest D
6 Year Old	<480	<700	<0.87	<1.49	<1.82	<1.0	<40 mm
5th	<500	<700	<0.87	<2.62	<2.52	<1.0	Minimize
THOR	<580	<700	<0.87	<4.17	<4.00	<1.0	Minimize
95th	<600	<700	<0.87	<5.44	<5.44	<1.0	Minimize
Combined Probability of Chest Injury for 5th, THOR, & 95th							Minimize

*All injury measures should be less than those in the baseline tests

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Baseline Test Summary

- Crash pulse and occupant size are the two dominating factors affecting the rear-seated ATD kinematics and injury measurements.
- Most injury measures are over the IARVs, especially under the severe pulse.
- Submarining was observed in most tests with 6YO, 5th, and THOR.
- No head-to-front-seat contact occurred in any of the tests.

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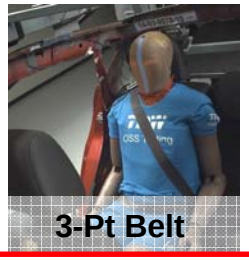
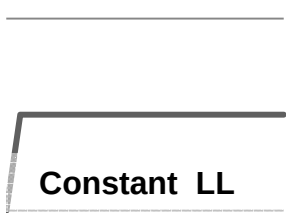
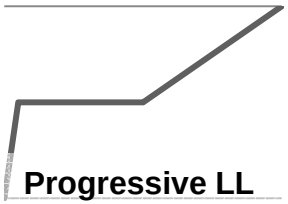
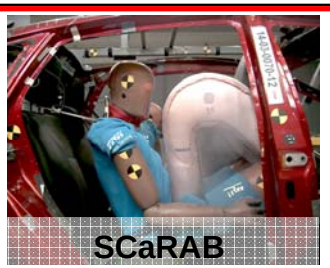
Restraint Technology Review

Belt Configurations	 3-Pt Belt	 4-Pt Belt 'X'		
Pre-Tensioning	 Retractor PT	 Buckle PT	 Anchor PT	
Load Limiting	 Constant LL	 Progressive LL	 Digressive LL	 Switchable LL
Inflatables	 Inflatable Belt	 Bag In Roof	 SCaRAB	

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Self Conforming Rearseat Air Bag - SCaRAB

- **Concept Description**
  - Low energy air bag: DI10.1G36/46 – Driver inflator
  - Small Bag Volume: 40-60 liters
  - Conforms to various front seat positions (enabled by open space)
  - Moves laterally minimizing head rotation
  - Mounted in the roof or front seat back (door mounting also possible)
  - Primary reaction surface is seat back regardless of mounting location.



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Sled Tests with 6YO - Videos

Baseline (w booster)	3-pt Belt with PT and LL
	
	
SCaRAB	Bag in Roof

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Crash condition: 0 deg with severe pulse

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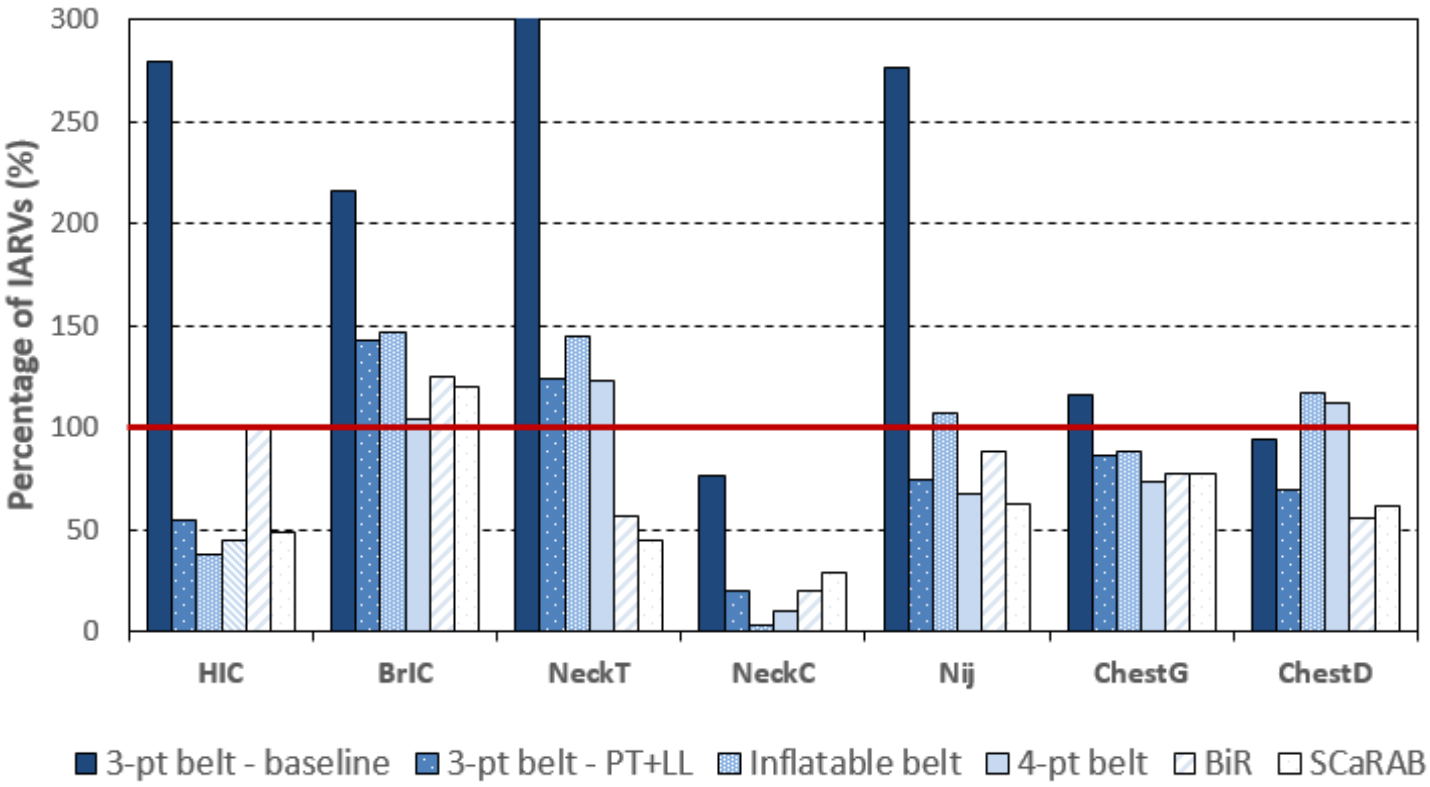
Sled Tests with 6YO – Injury Measures



The 3-pt baseline belt condition was without booster, and other conditions were with booster

Crash condition: 0 deg with severe pulse

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Sled Tests with 5th - Videos

Baseline	3-pt Belt with PT and LL
	
	
SCaRAB	Bag in Roof

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Crash condition: 0 deg with severe pulse

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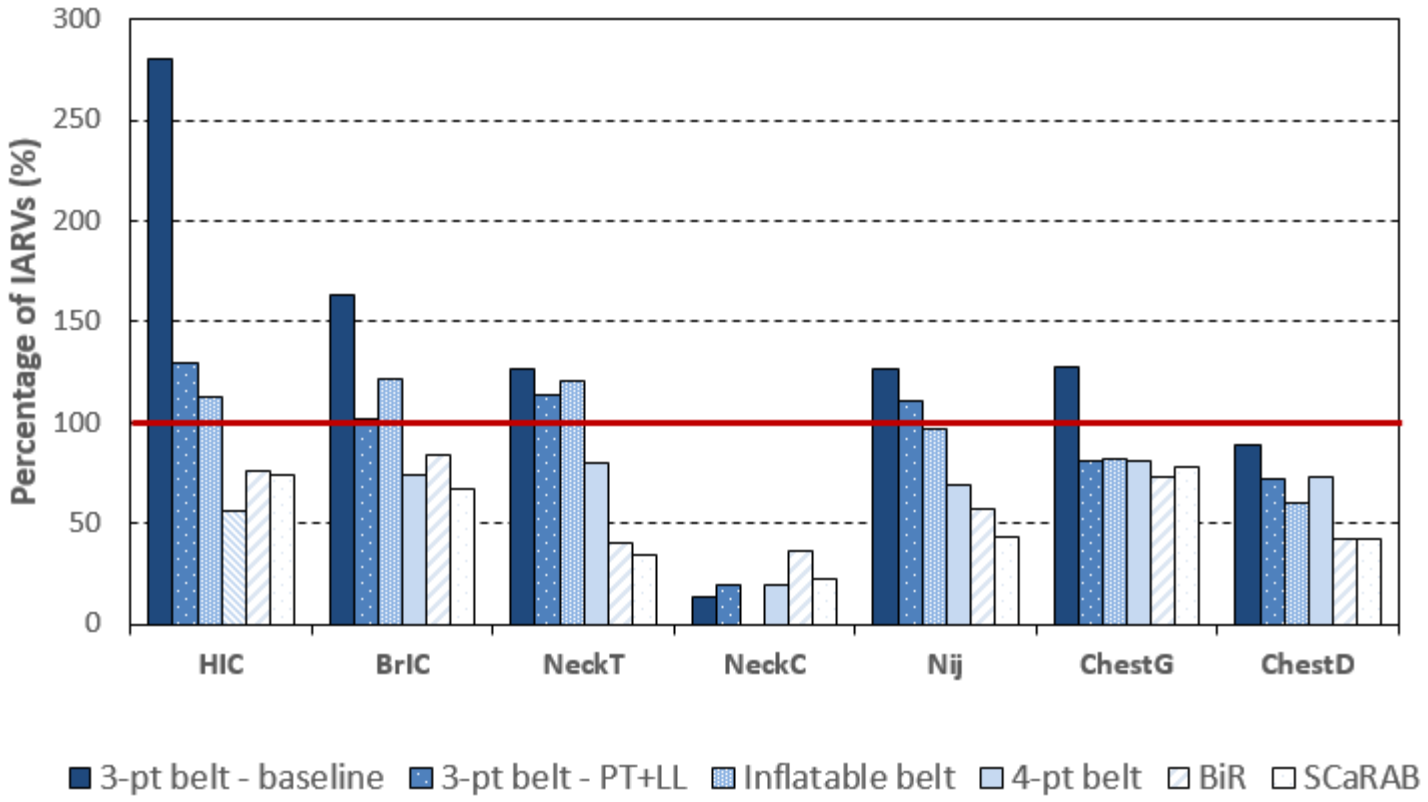
Sled Tests with 5th – Injury Measures



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Crash condition: 0 deg with severe pulse

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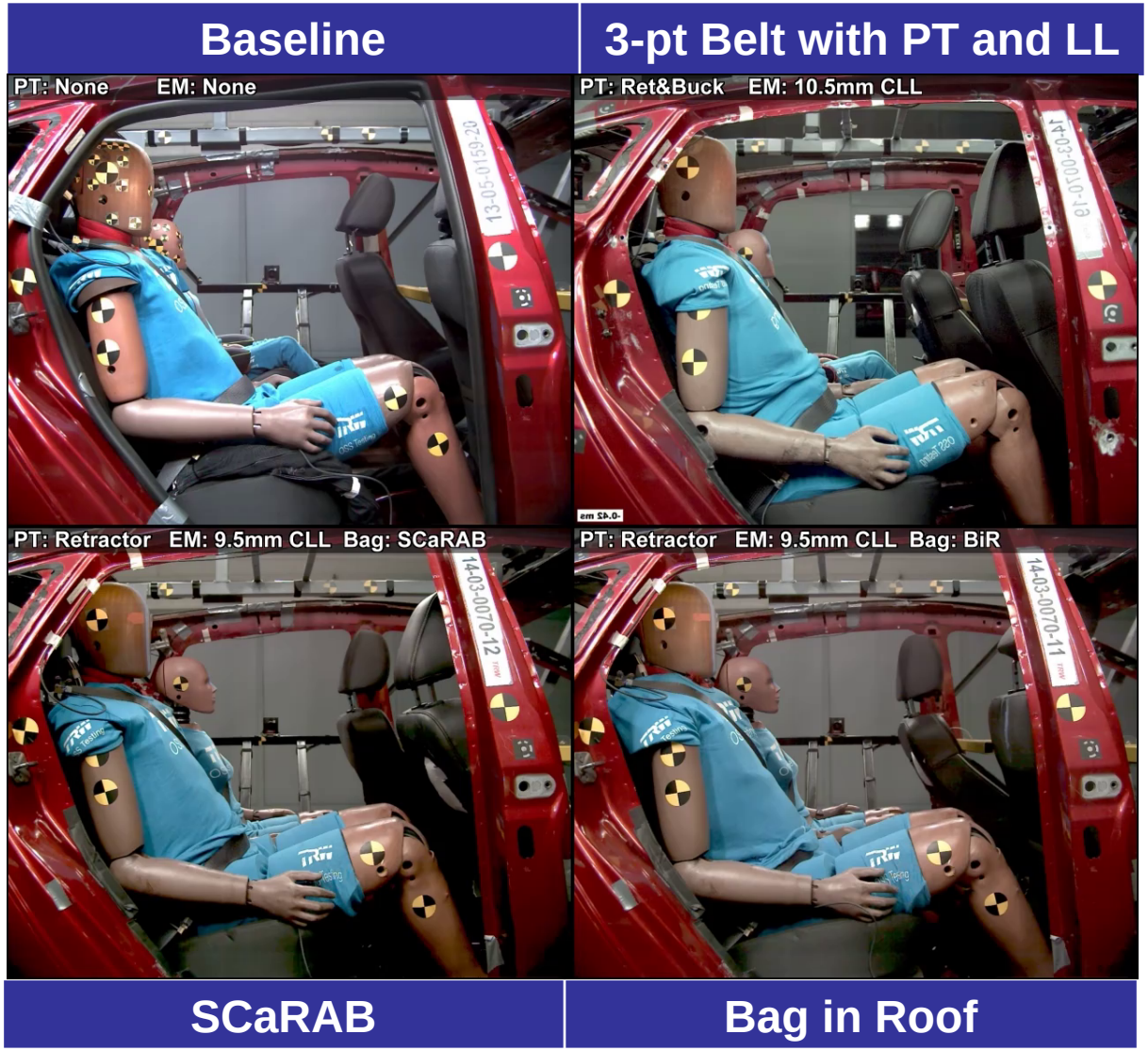
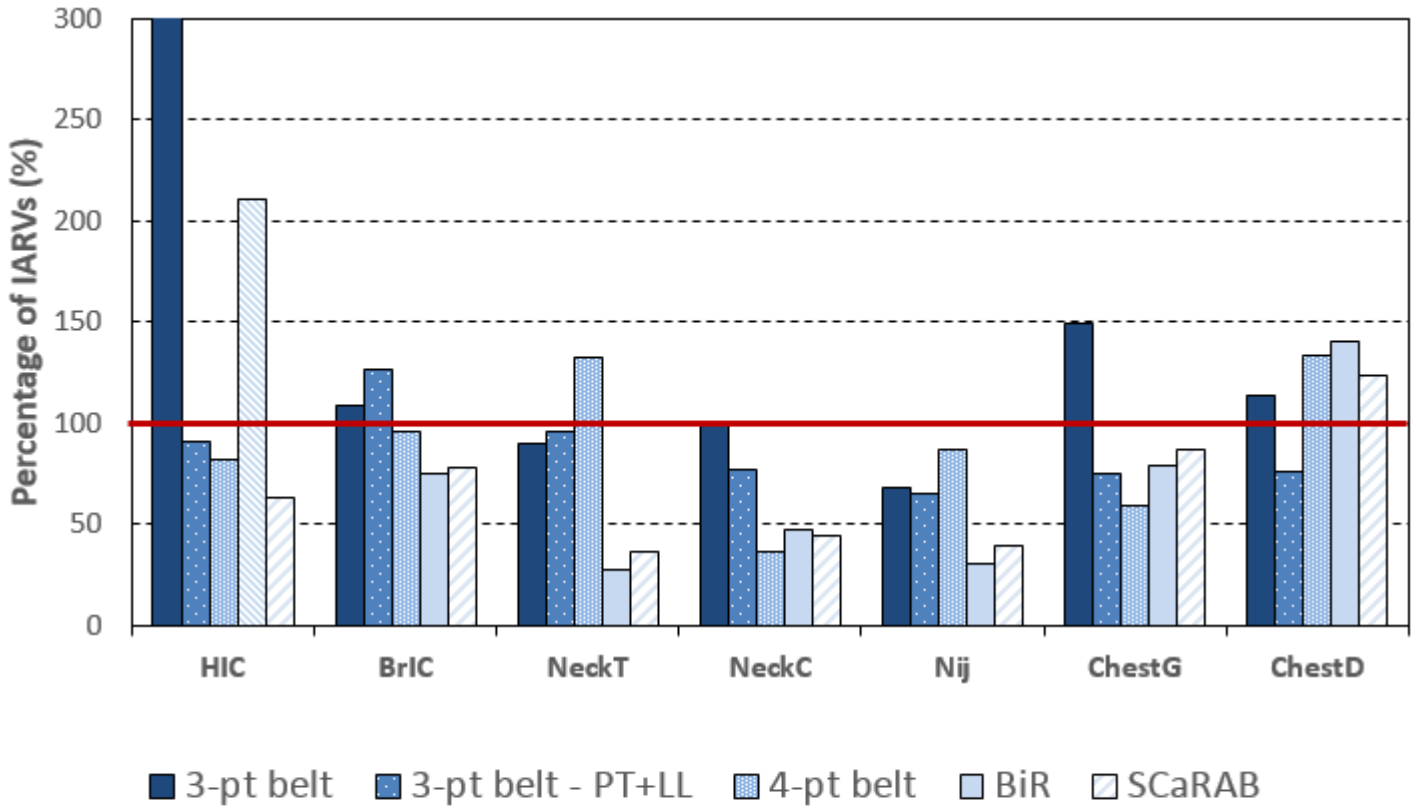
Sled Tests with THOR - Videos



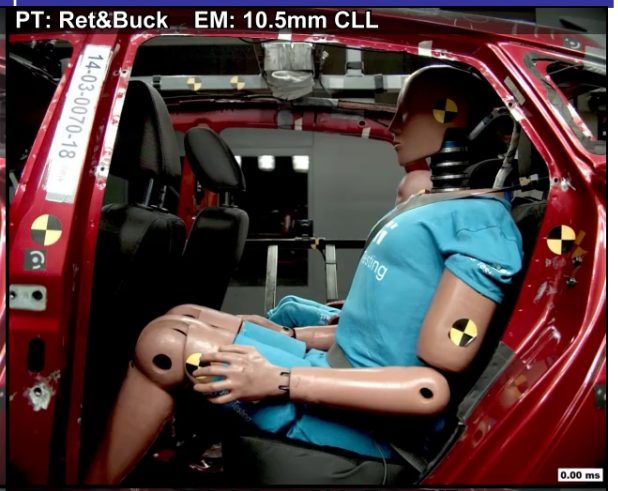
Crash condition: 0 deg with severe pulse

Sled Tests with THOR – Injury Measures



Crash condition: 0 deg with severe pulse

Sled Tests with 95th - Videos

Baseline	3-pt Belt with PT and LL
	
SCaRAB	**Bag in Roof**
	

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Crash condition: 0 deg with severe pulse

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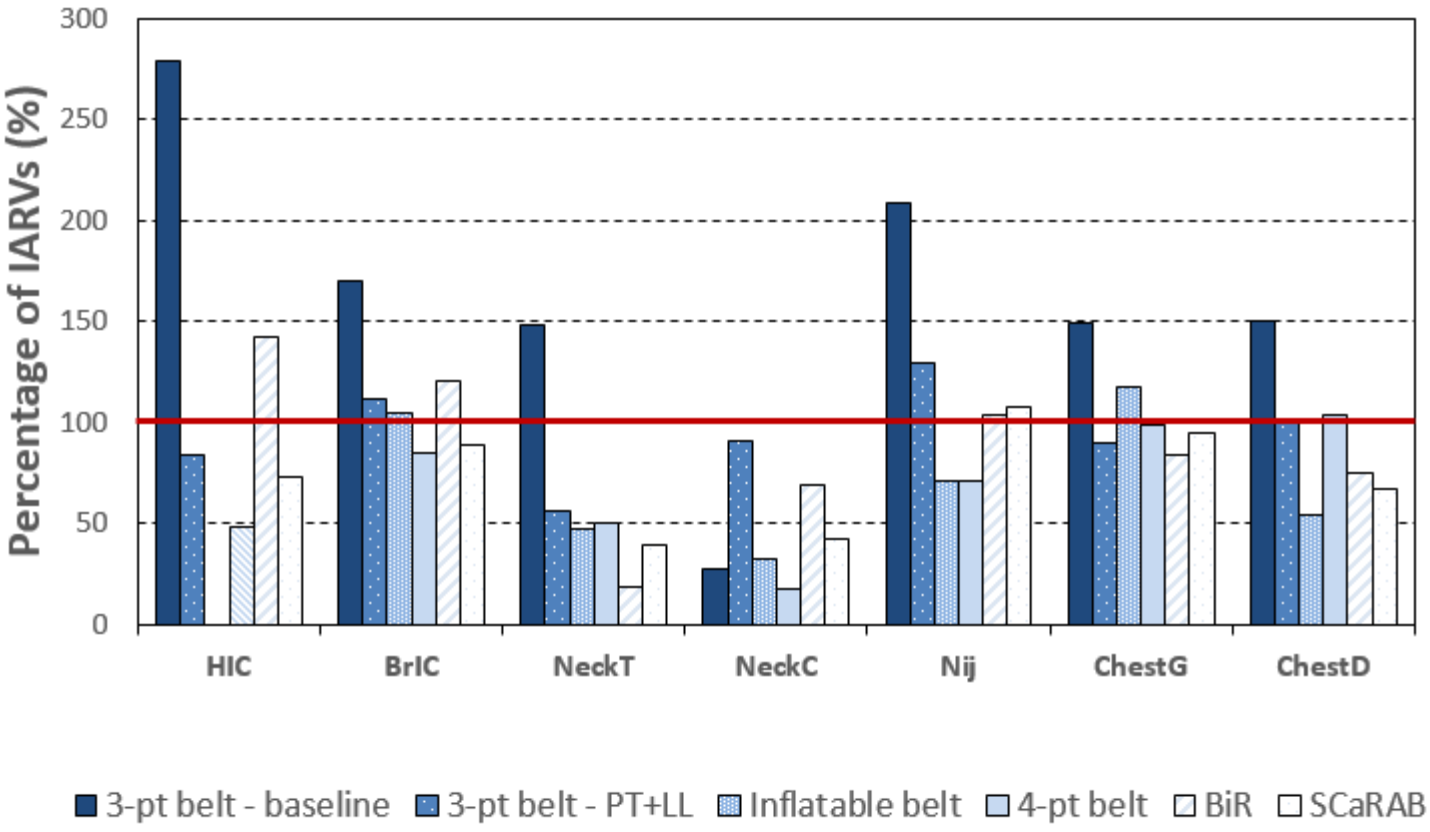
Sled Tests with 95th – Injury Measures



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Crash condition: 0 deg with severe pulse

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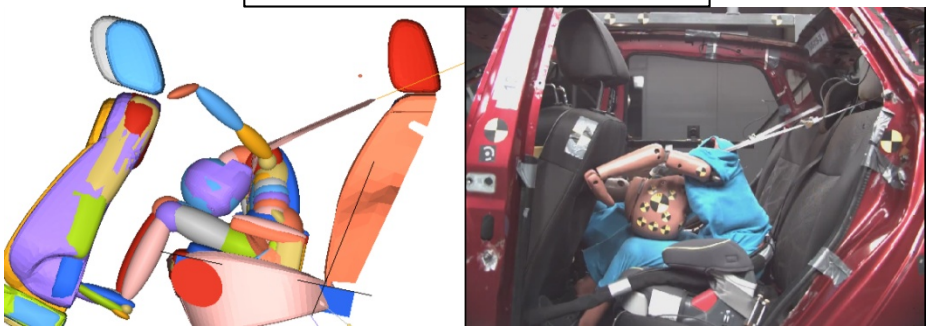
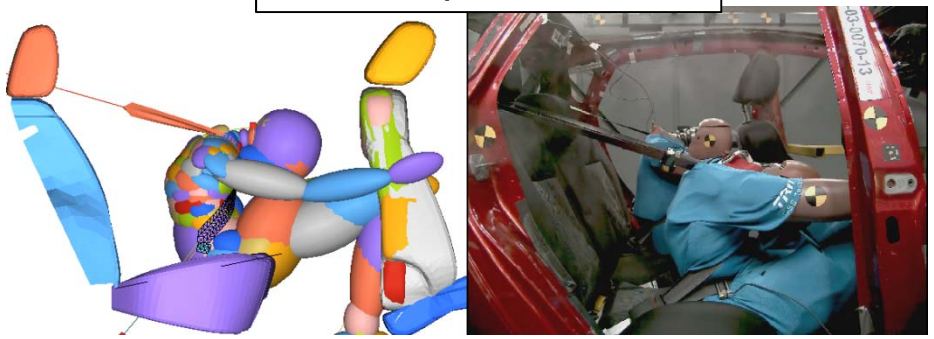
Model Validation

- Hundreds of simulations have been run.
- Generally, good correlations have been achieved for each ATD with each advanced restraint system.

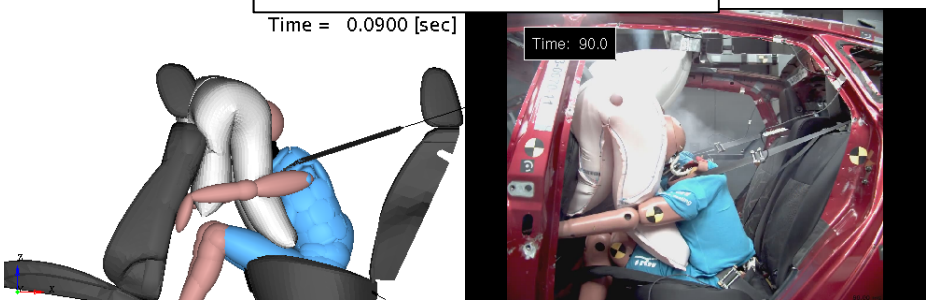
3pt belt with PT+LL



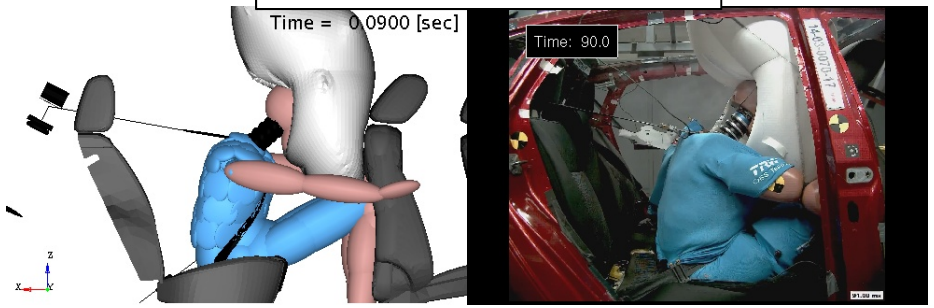
4pt belt



SCaRAB



Bag in Roof



3-Point Belt DoE - CLL

- **Baseline System**
  - Retractor Pre-tensioner
  - Constant Load Limiter (CLL)
- **Factors**
  - Additional Pre-tensioners: Anchor and/or Buckle
  - Load Limiter Levels: 8 to 10.5 mm torsion bar
  - Dynamic Locking Tongue (DLT)
- **Observations (768 simulations)**
  - Severe Pulse – None met the constraints
  - Soft Pulse – 10 % (QTY 5) met the constraints

Constraints Matrix

Pulse	6yo	5th	THOR	95th	Comb
Severe	0%	13%	0%	2%	0%
Soft	27%	75%	63%	67%	10%

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3-Point Belt DoE

- **Breakdown of Soft Pulse Configurations (CLL)**

Run No	Anchor PT	Buckle PT	DLT	Pulse	Type	Load Limiter Levels	Comb Chest Probability	System Costs
26	Yes	Yes	Yes	Soft	Frontal	9	10%	285%
122	No	Yes	Yes	Soft	Frontal	9	13%	206%
98	No	Yes	No	Soft	Frontal	9	14%	190%
123	No	Yes	Yes	Soft	Frontal	9.5	15%	206%
99	No	Yes	No	Soft	Frontal	9.5	20%	190%

System Cost based on material cost above current material cost of a rear seat system – standard retractor & buckle

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Airbag DoE – Adv Features

- **Baseline System**
  - Retractor Pre-tensioner
  - Constant Load Limiter
- **Factors**
  - Advanced Feature: SCaRAB or BiR
  - Additional Pre-tensioners: Anchor / Buckle
  - Load Limiter Levels: 8 to 9 mm torsion bar
  - Dynamic Locking Tongue (DLT)
- **Observations (384 simulations)**
  - 6 designs met all 4 occupants and left & right side constraints
  - 12 designs met all but one of the 4 occupants and left & right side constraints

Constraints Matrix

Constraints Met	SCaRAB	BiR
6yo	94%	58%
5th	79%	98%
THOR	58%	23%
95th	88%	100%

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0 deg Severe Pulse Only

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Airbag DoE Analysis

- **Breakdown of Severe Pulse Configurations (with Advanced Features)**

Run No	Advanced	Anchor PT	Buckle PT	DLT	Load Limiter Level	Constraints Met of 8	Comb Chest Probability	System Costs
56	SCaRAB	Yes	Yes	Yes	9	8	41.5%	520%
68	SCaRAB	Yes	No	Yes	9	8	44.4%	442%
55	SCaRAB	Yes	Yes	Yes	8.5	8	46.9%	520%
50	SCaRAB	Yes	Yes	No	9	8	48.5%	504%
62	SCaRAB	Yes	No	No	9	8	49.0%	426%
49	SCaRAB	Yes	Yes	No	8.5	8	50.7%	504%
104	BiR	Yes	Yes	Yes	9	7	44.8%	587%
79	SCaRAB	No	Yes	Yes	8.5	7	49.9%	442%
116	BiR	Yes	No	Yes	9	7	51.3%	508%
60	SCaRAB	Yes	No	No	8	7	52.9%	426%
67	SCaRAB	Yes	No	Yes	8.5	7	53.1%	442%
98	BiR	Yes	Yes	No	9	7	53.8%	570%
66	SCaRAB	Yes	No	Yes	8	7	53.9%	442%
61	SCaRAB	Yes	No	No	8.5	7	53.9%	426%
54	SCaRAB	Yes	Yes	Yes	8	7	54.4%	520%
110	BiR	Yes	No	No	9	7	57.2%	492%
48	SCaRAB	Yes	Yes	No	8	7	57.6%	504%
74	SCaRAB	No	Yes	No	9	7	60.7%	426%

System Cost based on material cost above current material cost of a rear seat system – standard retractor & buckle

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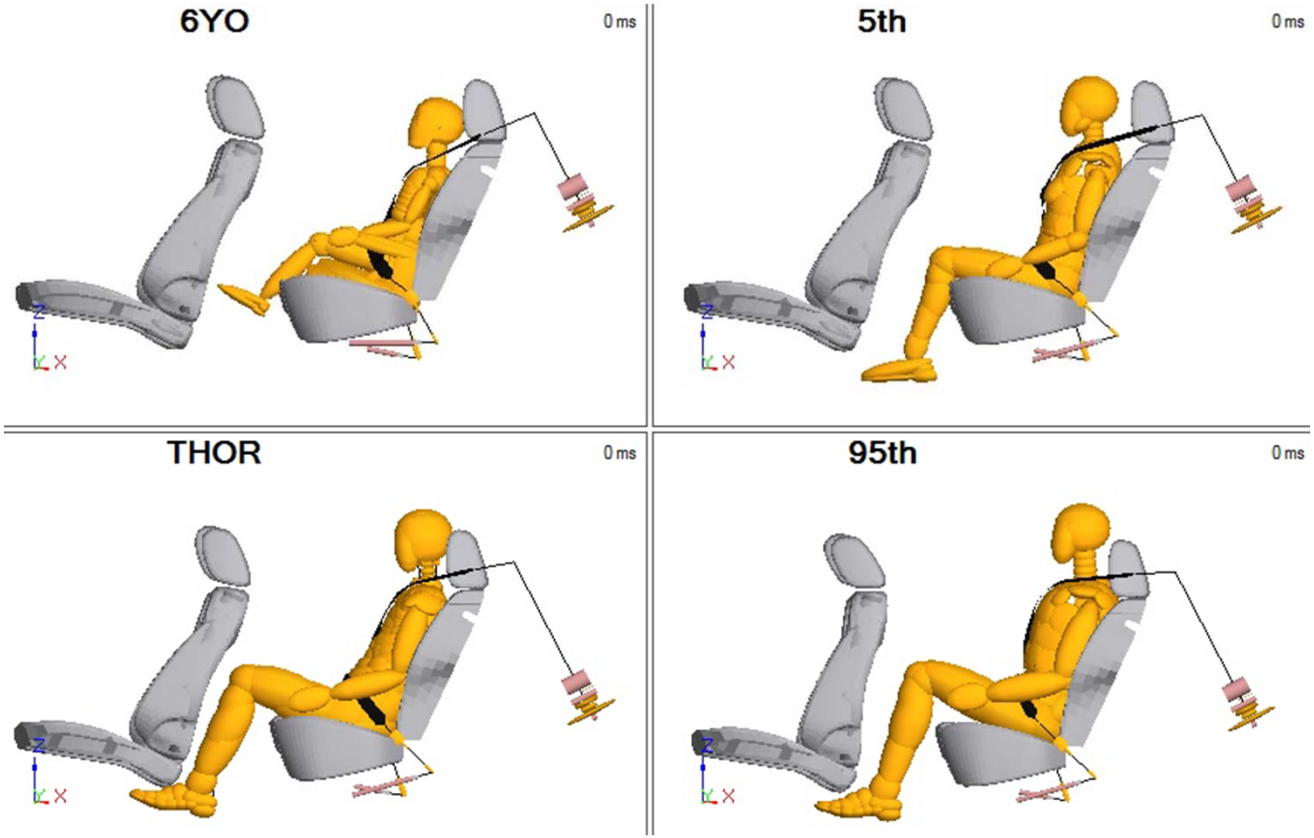
Recommendations – Soft Pulse

- Anchor PT / Buckle PT / 9mm TB / no airbag
  - Driver side / Passenger side



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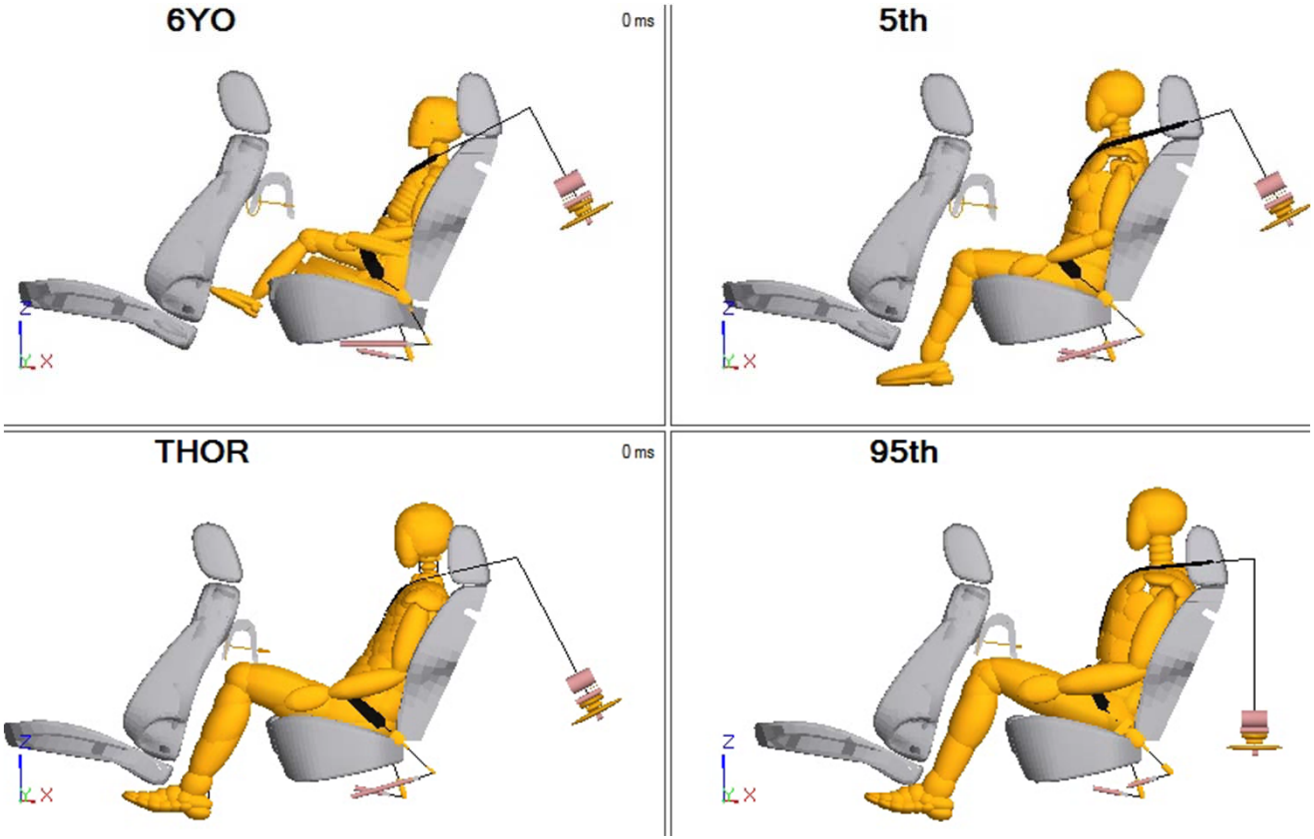
Recommendations – Severe Pulse

- Anchor PT / Buckle PT / DLT / 9mm TB / SCaRAB
  - Driver side



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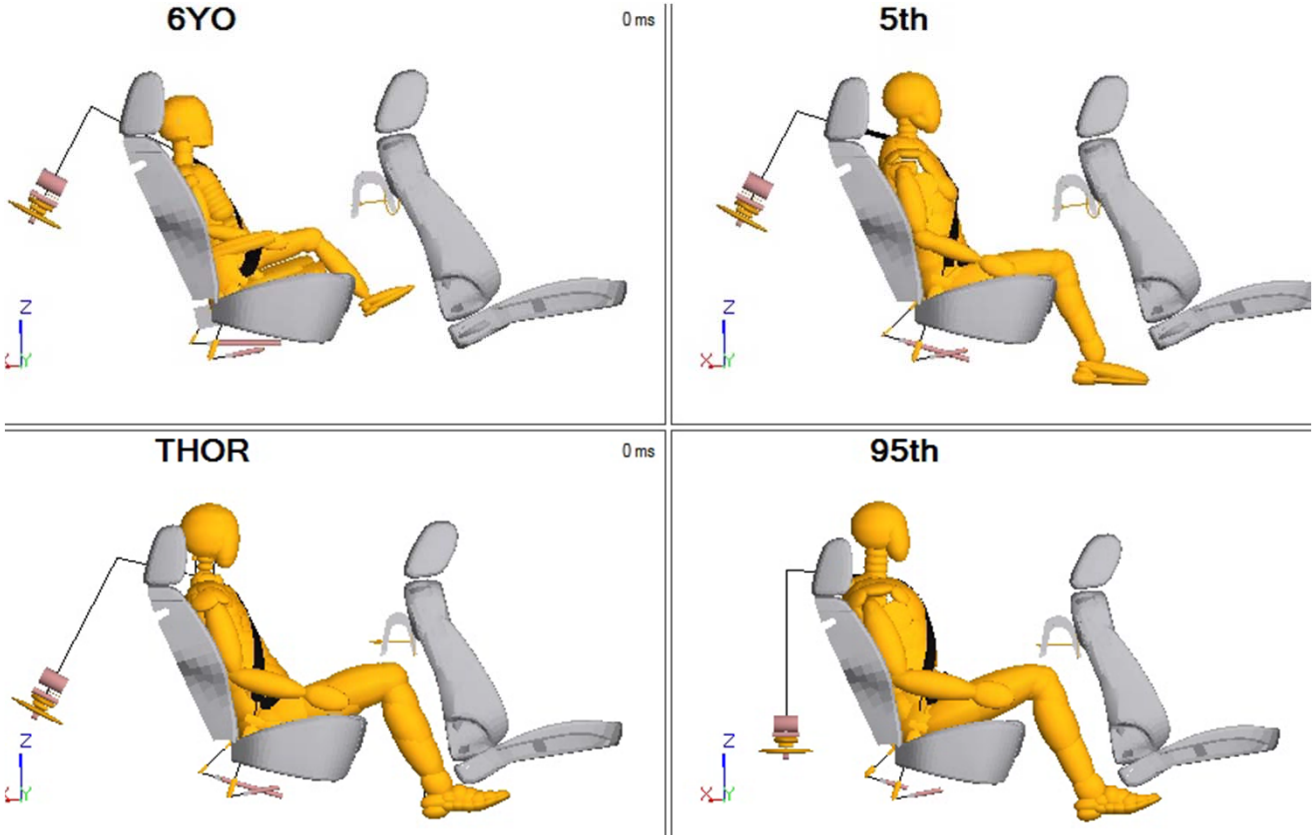
Recommendations – Severe Pulse

- Anchor PT / Buckle PT / DLT / 9mm TB / SCaRAB
  - Passenger side



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Summary

- Crash pulse and occupant size are the two dominating factors affecting the rear-seated ATD kinematics and injury measurements.
- Advanced seatbelt features, including pre-tensioner and load limiter, have the potential to help provide additional protection for rear-seat occupants with diverse occupant sizes. However, direct conflict exists between head excursion and chest deflection.
- Airbag concepts, including BiR and SCaRAB, have the potential to allow further reduction of seat belt load limit without resulting in a hard head contact to the front seat, when compared to 3-point seatbelt only designs.

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This analysis only represents a compact vehicle, and does not represent the whole vehicle fleet.

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Thanks! Questions?

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