Use of FE Simulations to Parametrically Evaluate and Compare Seat Belt Restraint Systems and Related Injury Risk in Heavy Truck Frontal Crash Conditions

Chiara Silvestri Dobrovolny, Ph.D.
Associate Research Scientist, TTI

Nathan Schulz
Graduate Research Assistant, TTI

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Order of Presentation

- Background
- Objective
- Methodology
- FE Computer Models (Vehicle, ATD, Passive Restraint Systems)
- FE Computer Frontal Impact Simulations
- Results
- Future Research

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Background

- Approximately 340,000 medium/heavy trucks involved in traffic crashes per year in U.S.
- 600 fatalities; 20,000 injuries to truck drivers
- Aggregate cost of crashes to society is $3.1 billion

- No existing standards for truck cab crashworthiness or occupant protection in heavy truck crashes (although being discussed)
- Need of additional characterization of crash-injury, current heavy truck crashworthiness, potential benefits of crashworthy structures in heavy truck cabs

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Objectives

TTI and UMTRI proposed jointly effort devoted to collect & develop required information by:

- ***analyzing crash & travel datasets available at UMTRI and TTI;***
- ***identify frequencies & costs of types of heavy truck crashes;***
- ***estimate benefits of crashworthy structures in heavy trucks to reduce death, injury, & societal costs of heavy truck crashes***

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Methodology

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Methodology – Big Picture

FE Computer Models

Heavy Truck

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ATD

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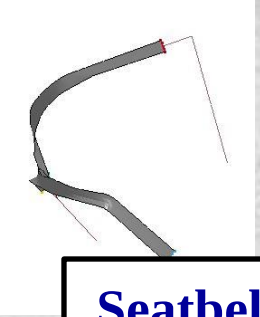

Seatbelt

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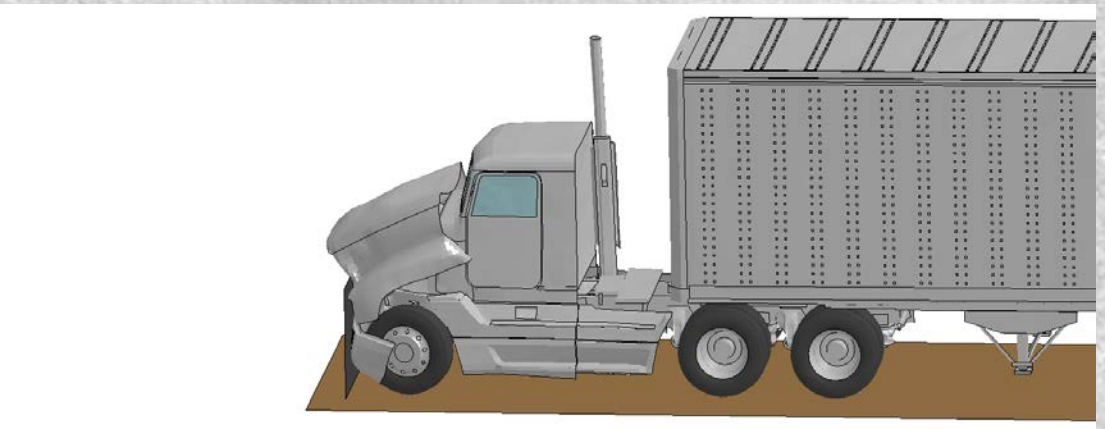
Airbag

FE Computer Simulations



- Frontal Impact (Wall)
- Parametric Variation Seatbelt Properties
- ATD Injury Criteria

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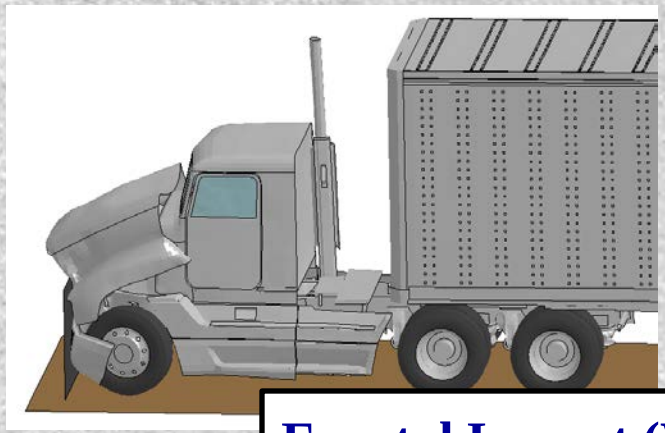
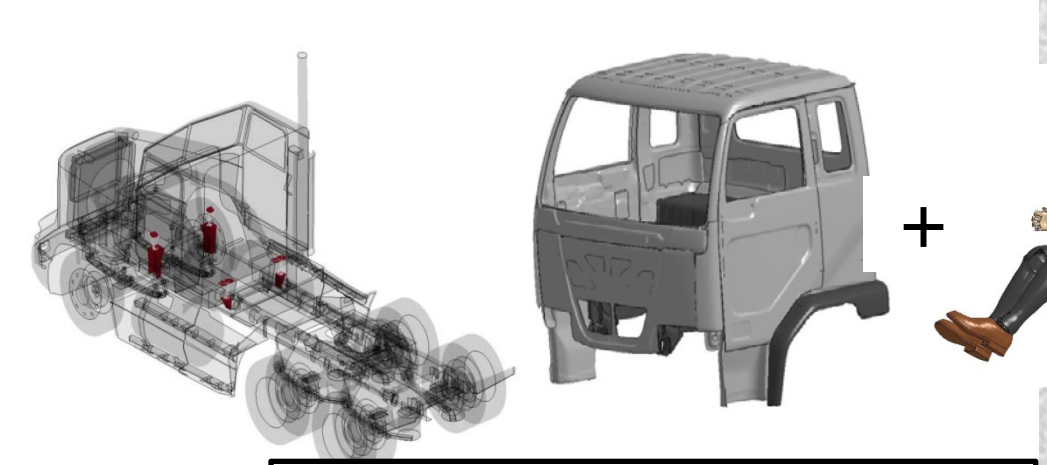
Simplified Methodology



Frontal Impact (Wall)



Crash pulse applied to cab mounts

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ATD

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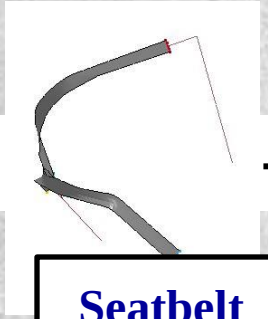

Seatbelt

+

Airbag

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Step 1

Develop Heavy Truck Cabin Model

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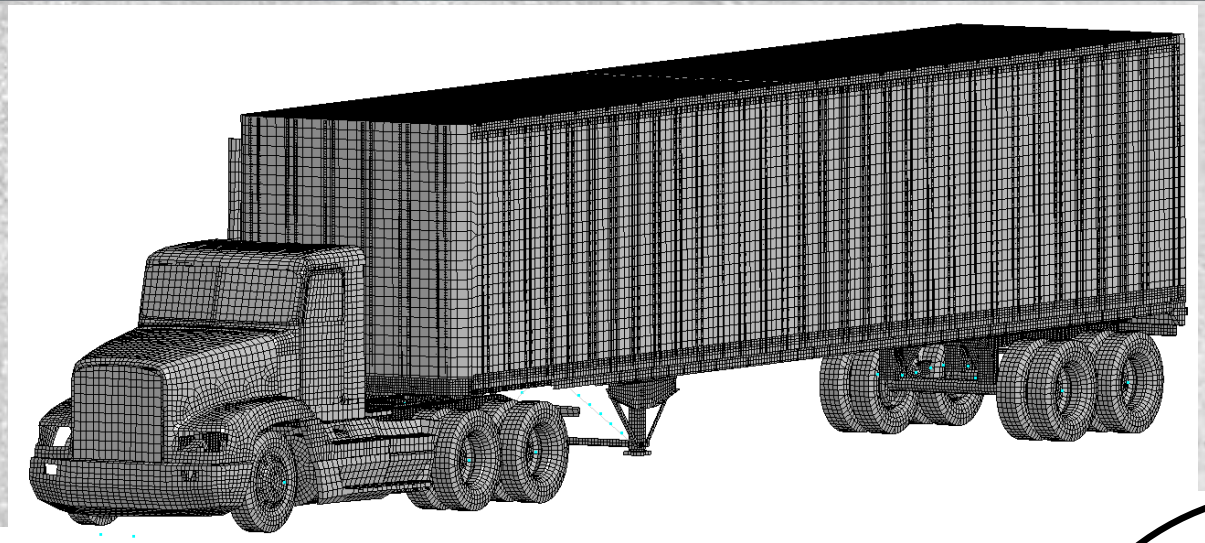
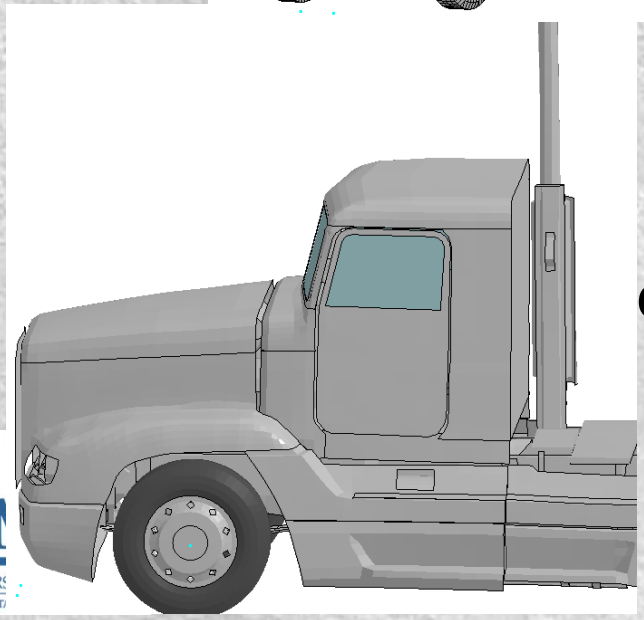
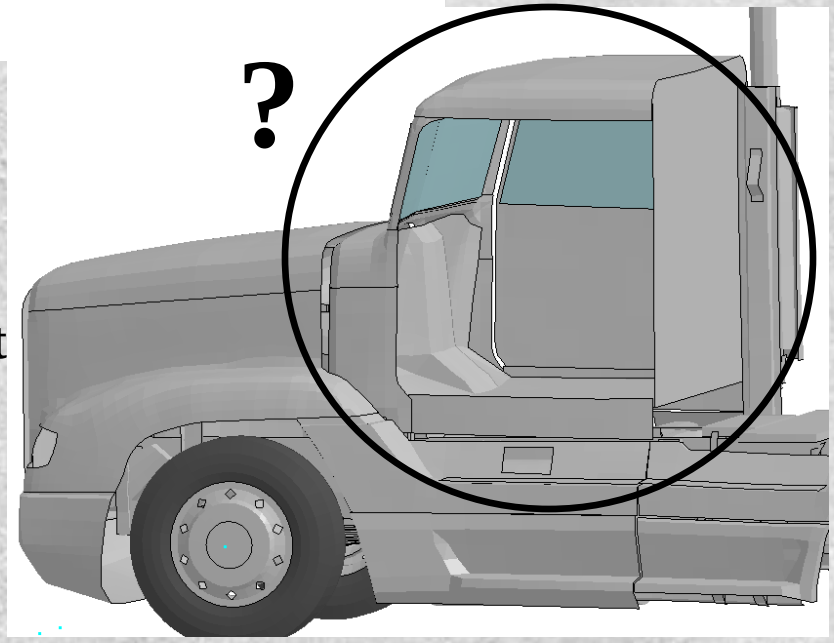
Computer Model – Heavy Truck



Current FE Computer Model



Need for Occupant Compartment Interior



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Heavy Truck Cabin Model

FE Model of Cab-Over-Engine Cabin*

* Developed by TTI under project funded by Department of State

Morphed Conventional Cab*

* As of Peterbilt 387

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Step 2

Develop Heavy Truck Interior Compartment

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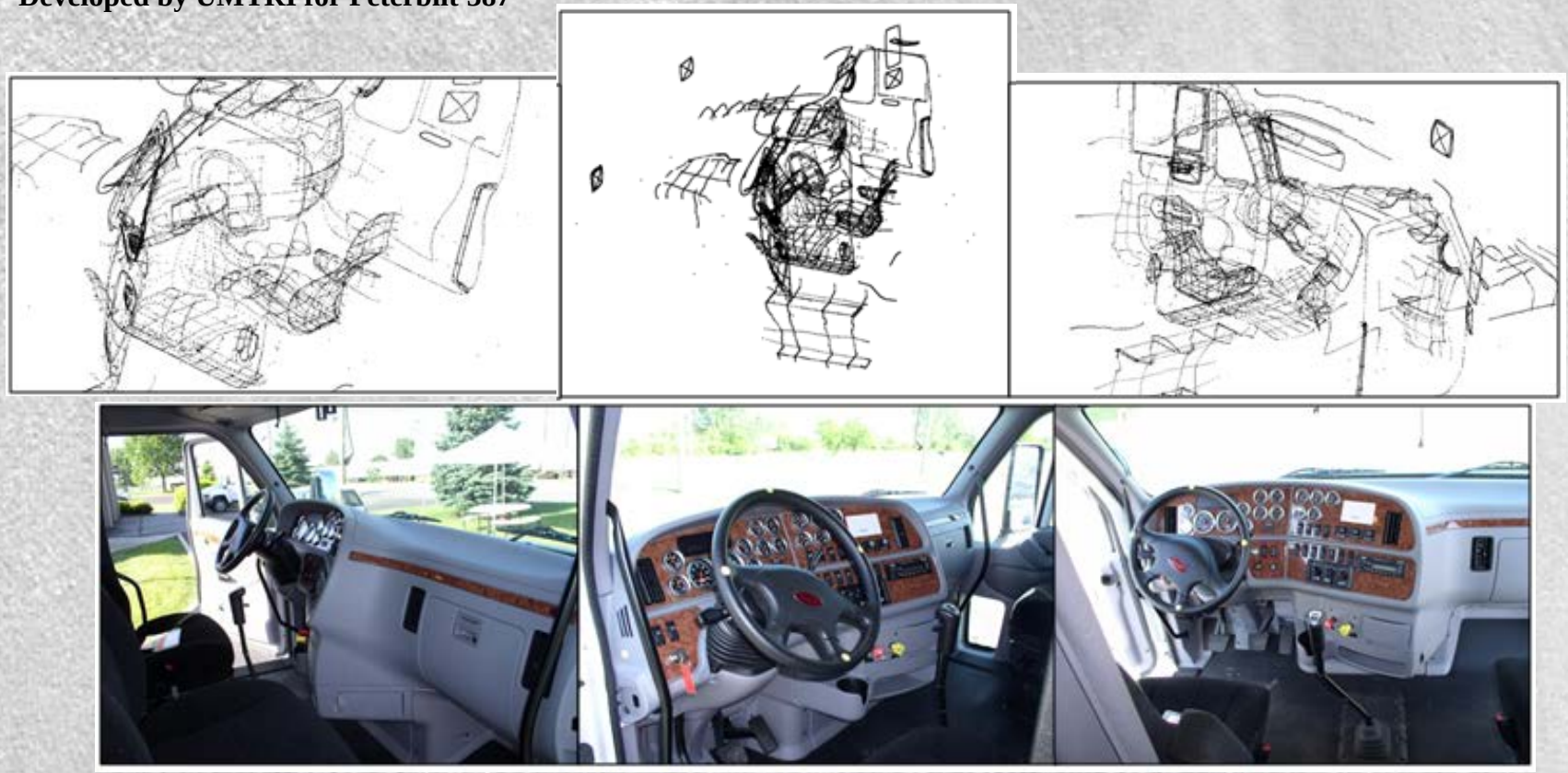
Heavy Truck Interior Compartment

Cloud Point Scans*

*** Developed by UMTRI for Peterbilt 387**



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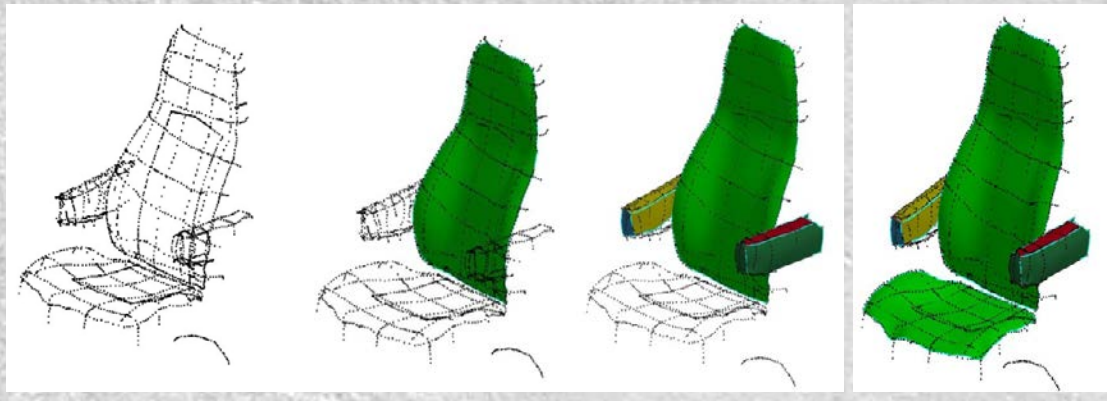
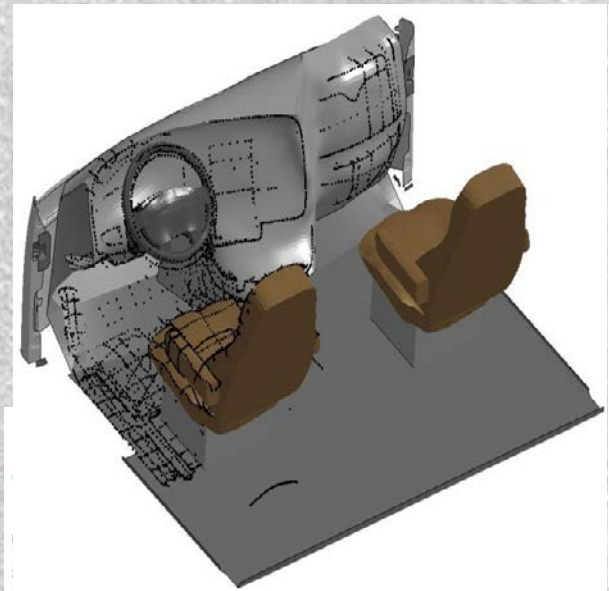
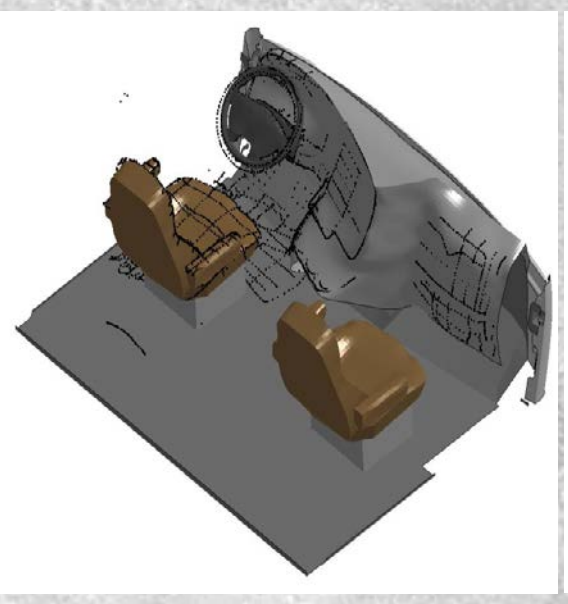
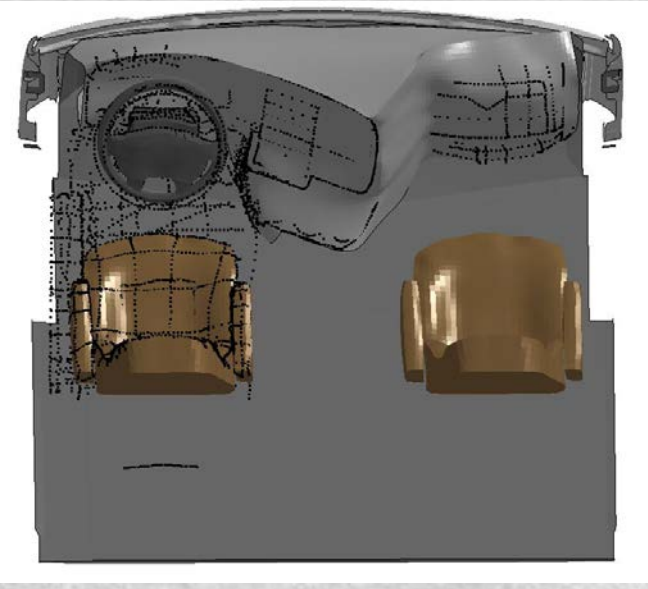
Heavy Truck Interior Compartment

Models developed applying mesh grid over cloud points









Step 3

Inclusion of ATD

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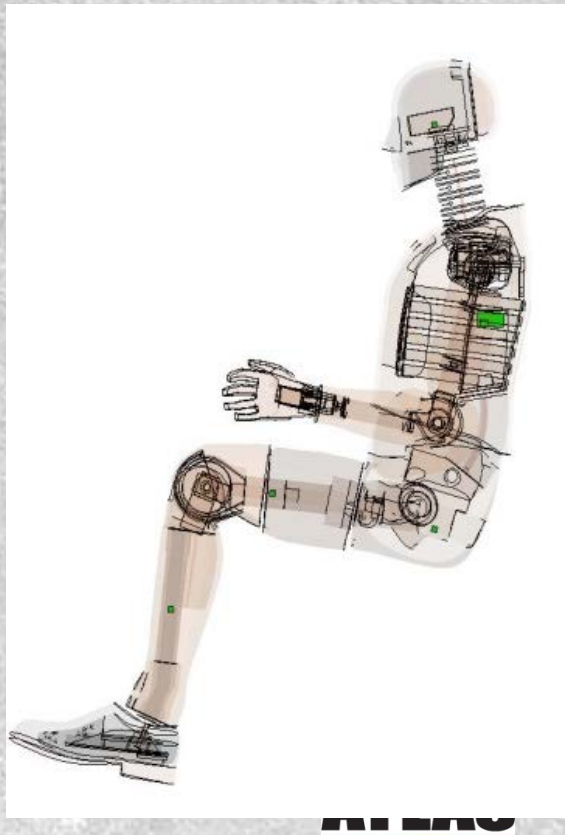
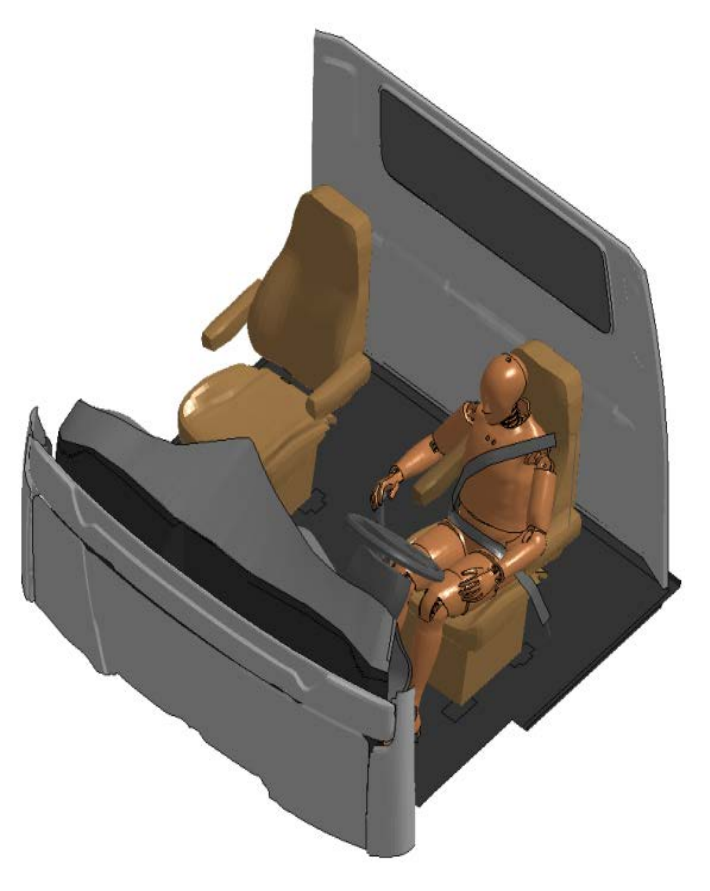
ATD Inclusion and Pre-Positioning

Existing LSTC Hybrid III 50% Male ATD





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Step 4

Addition of Passive Restraint Systems

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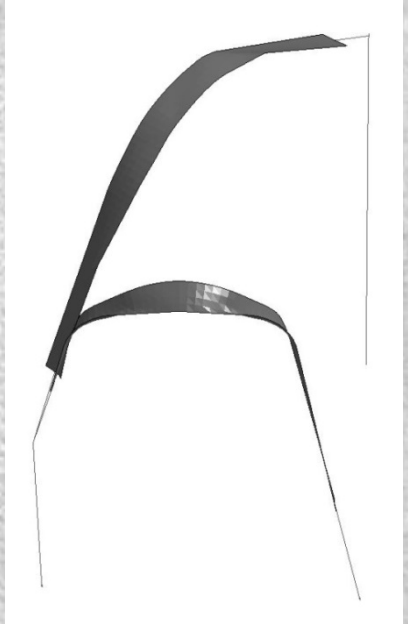
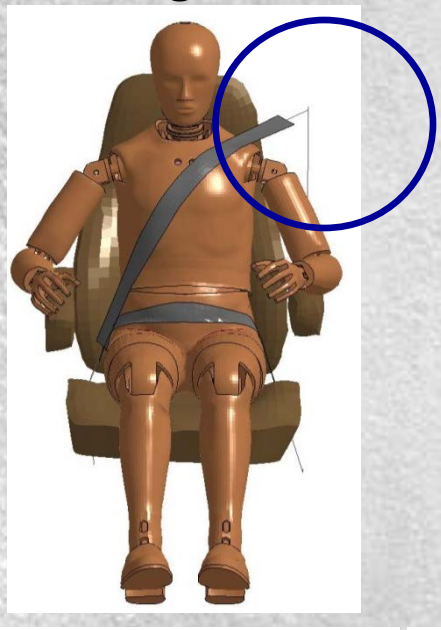
Seatbelt Model

Original
***Developed by LSTC for Passenger Car**



Modified
***To fit Heavy Truck Geometry**

Original



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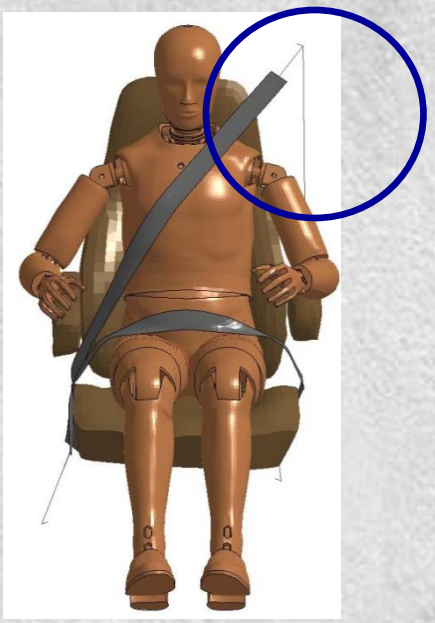

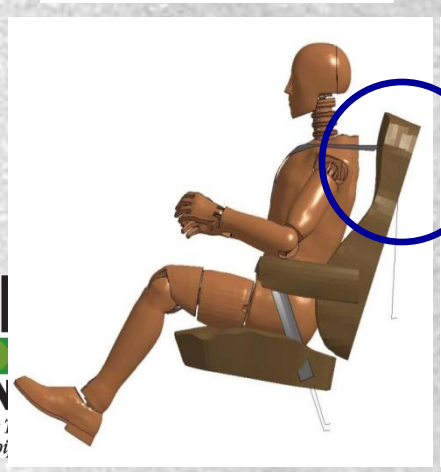

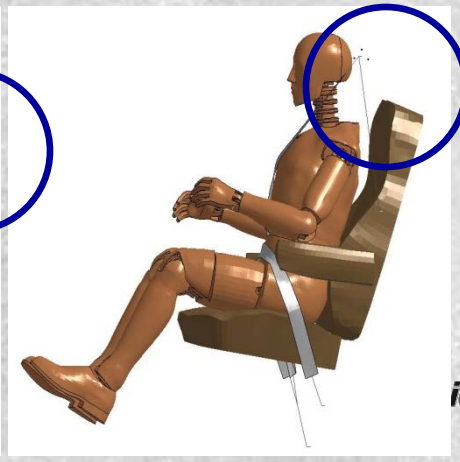

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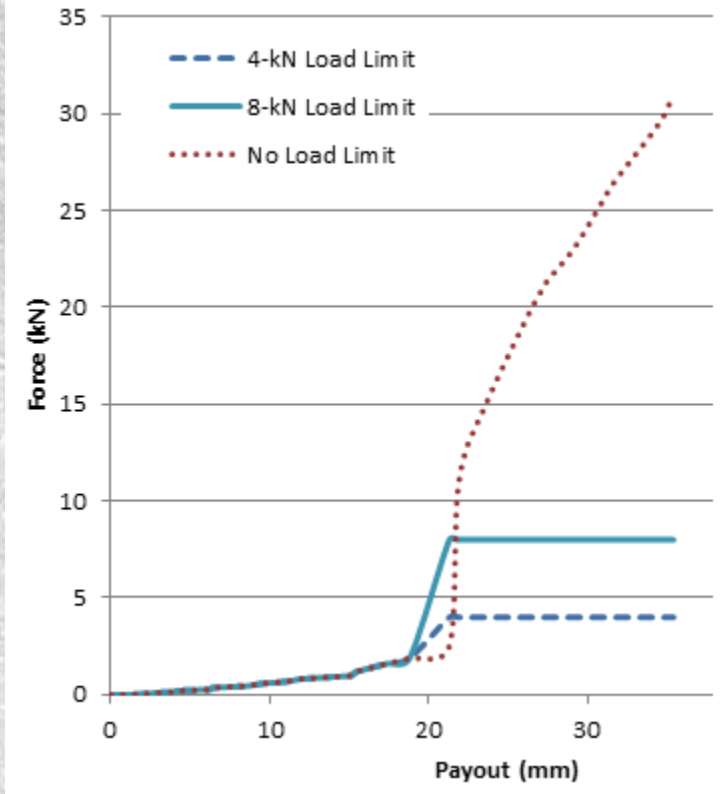
Seatbelt Model

Modified

***To fit Heavy Truck Geometry**



Event	Action
1 ms	Retractor sensor fires – enters locked mode
10 ms	Pretensioner sensor fires – enters locked mode
1.8 kN tension reached	Pretensioner disengages – retractor active
4 kN tension reached	Load limiter 1 engages (load limit case 1 only)
8 kN tension reached	Load limiter 2 engages (load limit case 2 only)

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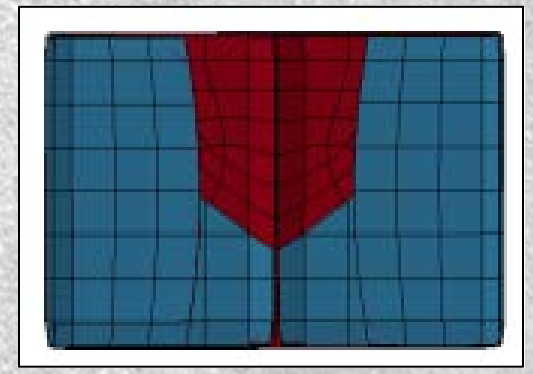
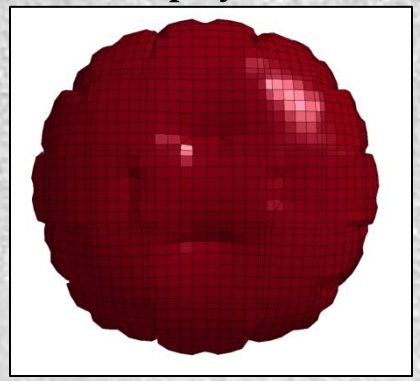
Airbag Model

Airbag - *Developed by NCAC

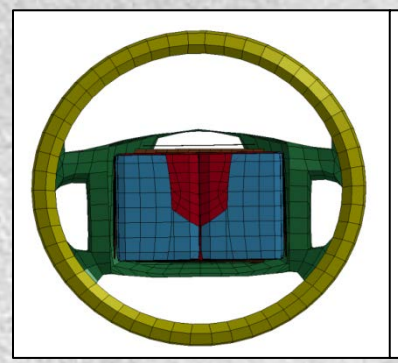
Folded



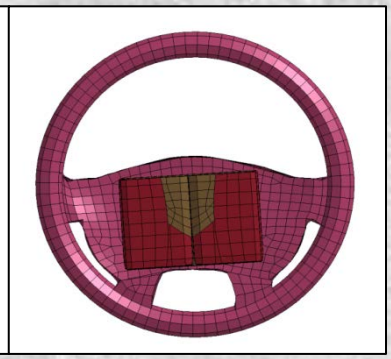
Deployed



NCAC



Heavy Truck



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Step 5

Crash Pulse

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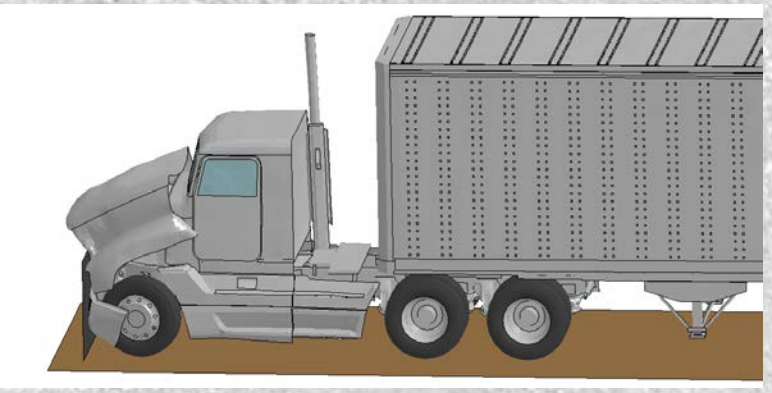
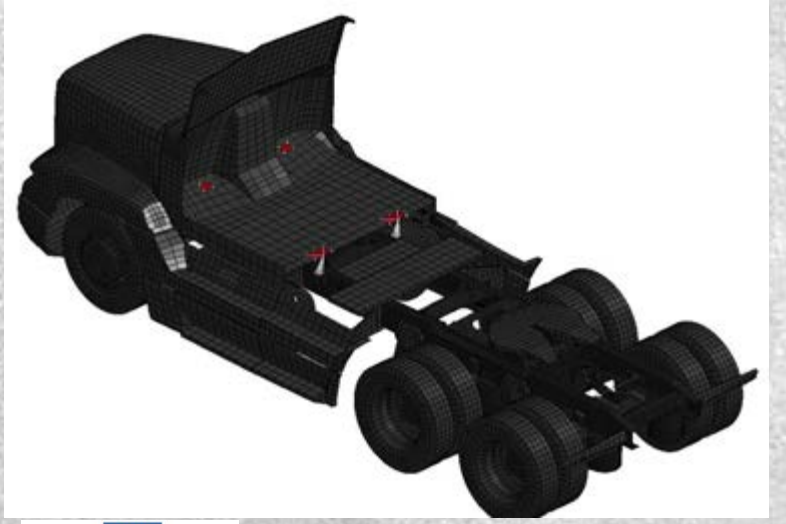
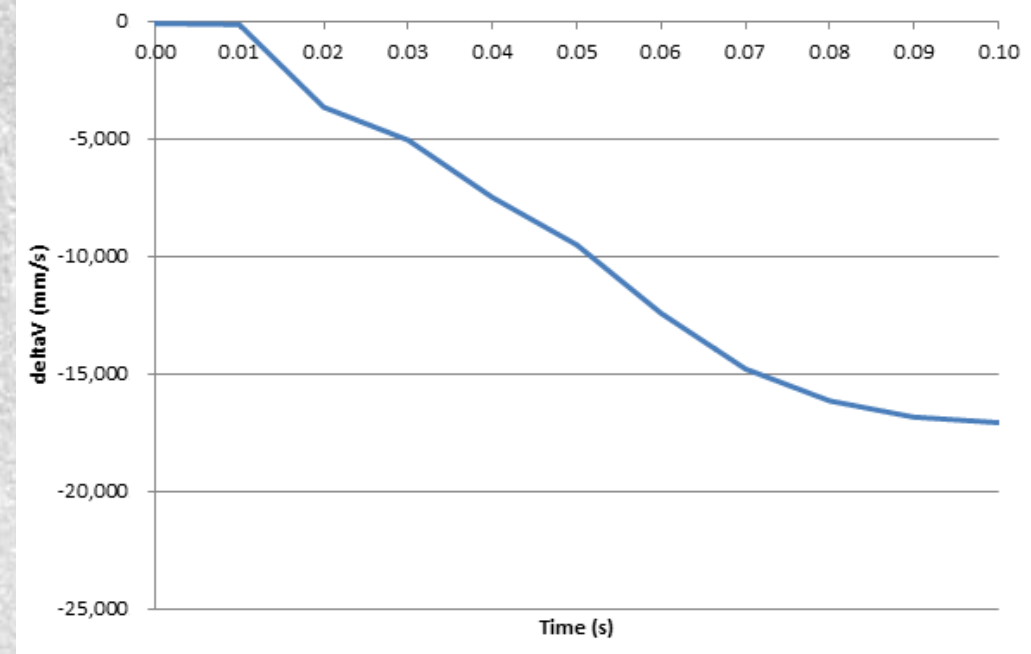
Crash Pulse – 35 mph Frontal







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Step 6

FE Parametric Simulations of Frontal Impacts

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Frontal Impacts – 35 mph

- Baseline
- No Pretensioner
- 4 kN Load Limiter
- 8 kN Load Limiter
- Lowered D-Ring

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Step 7

ATD Injury Criteria Evaluation

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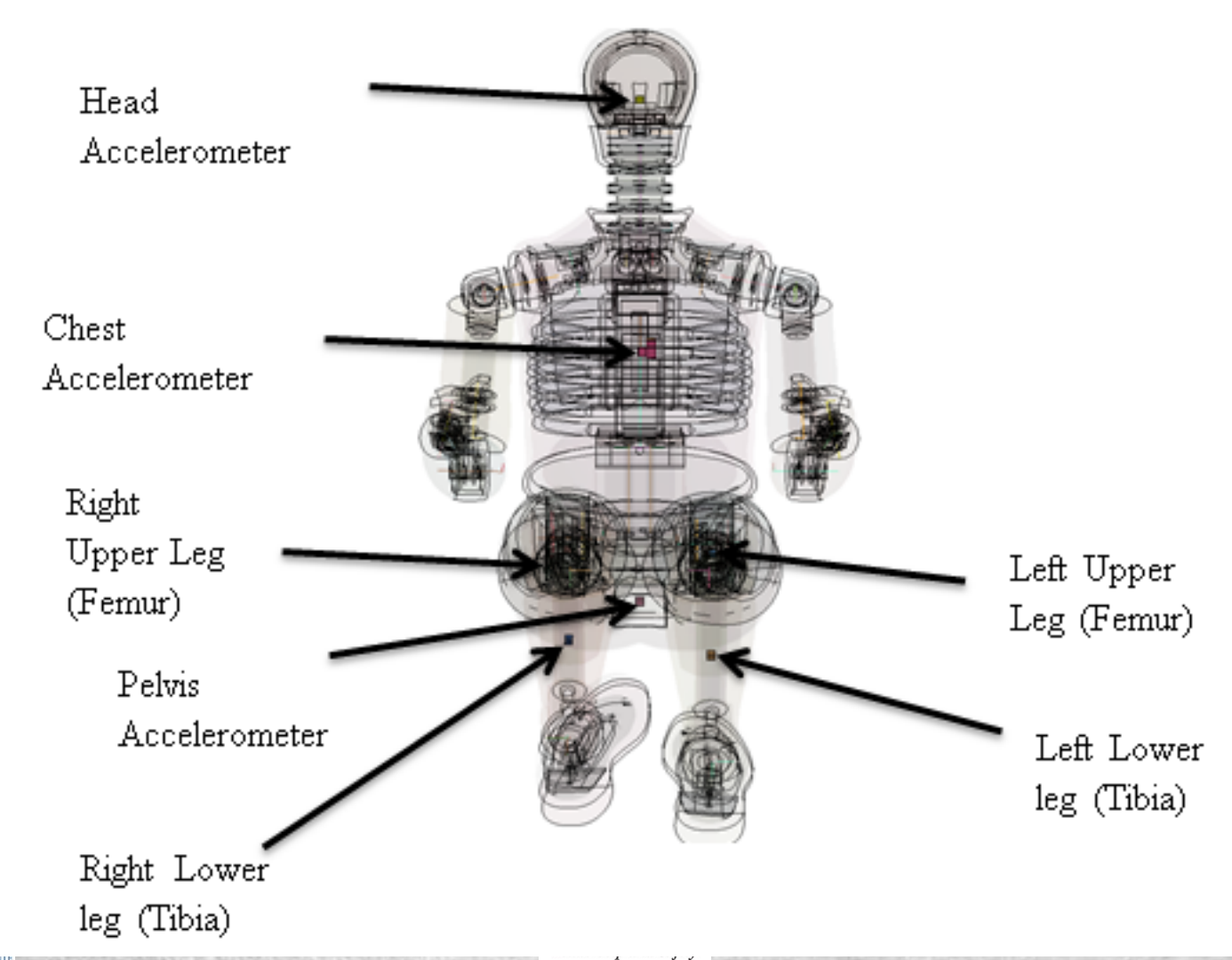
ATD Modeled Instrumentation



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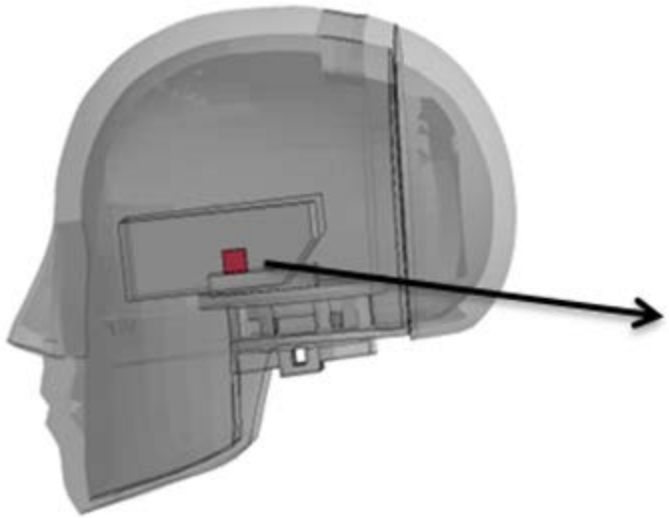
ATD Injury Criteria

Head Injury Criteria (HIC)

Head acceleration recorded during impact event
employed to calculate HIC
representing probability of head injury



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

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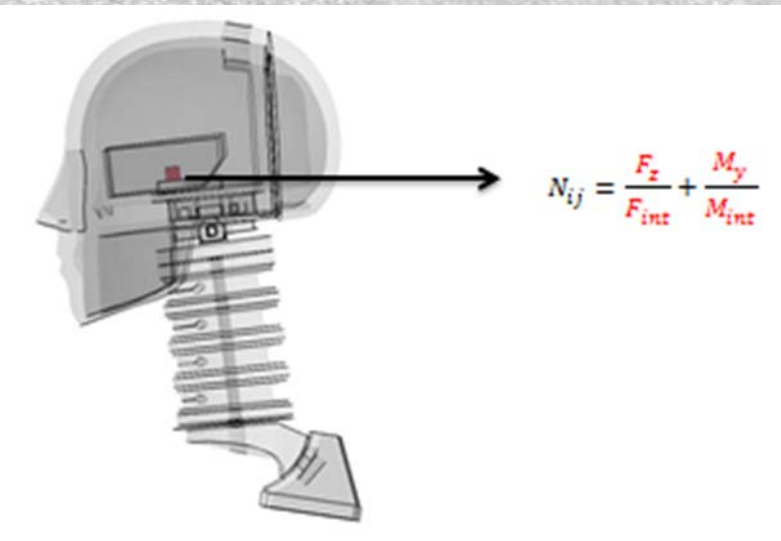
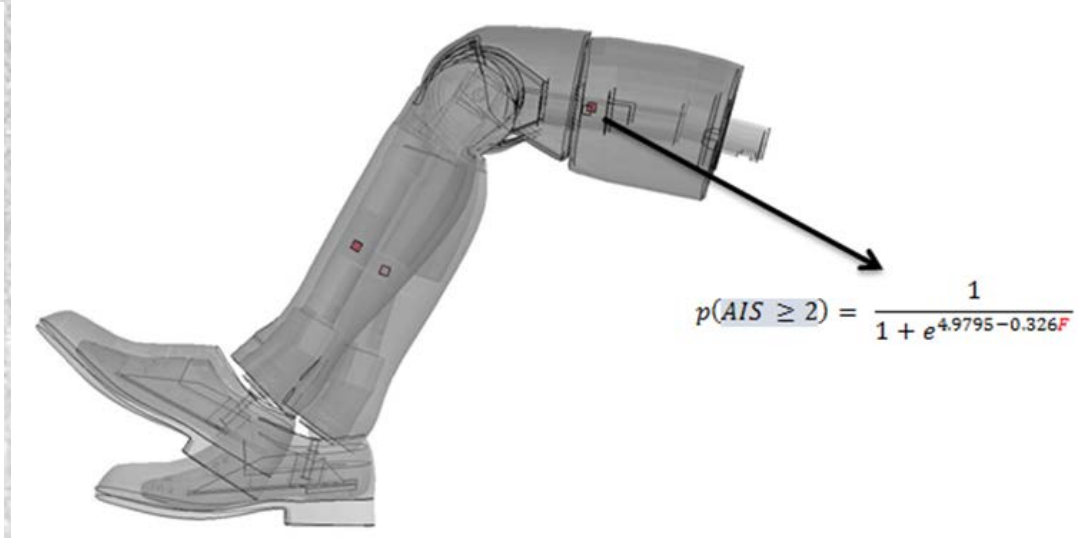
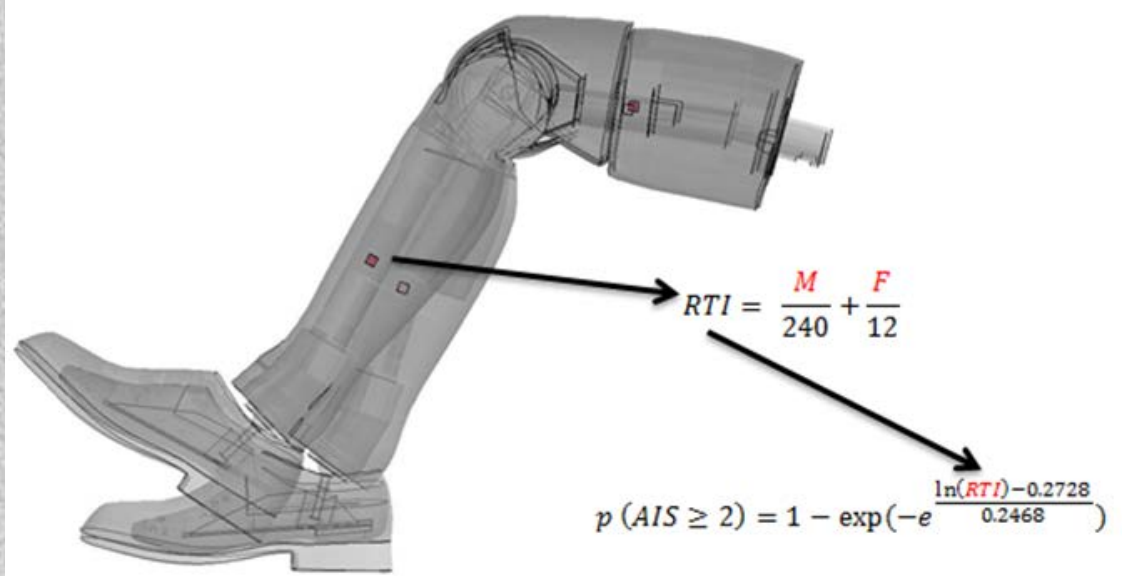
ATD Injury Criteria



$$N_{ij} = \frac{F_z}{F_{int}} + \frac{M_y}{M_{int}}$$



$$p(AIS \geq 2) = \frac{1}{1 + e^{4.9795 - 0.326F}}$$



$$RTI = \frac{M}{240} + \frac{F}{12}$$

$$p\,(AIS \geq 2) = 1 - \exp\left(-e^{\frac{\ln(RTI) - 0.2728}{0.2468}}\right)$$

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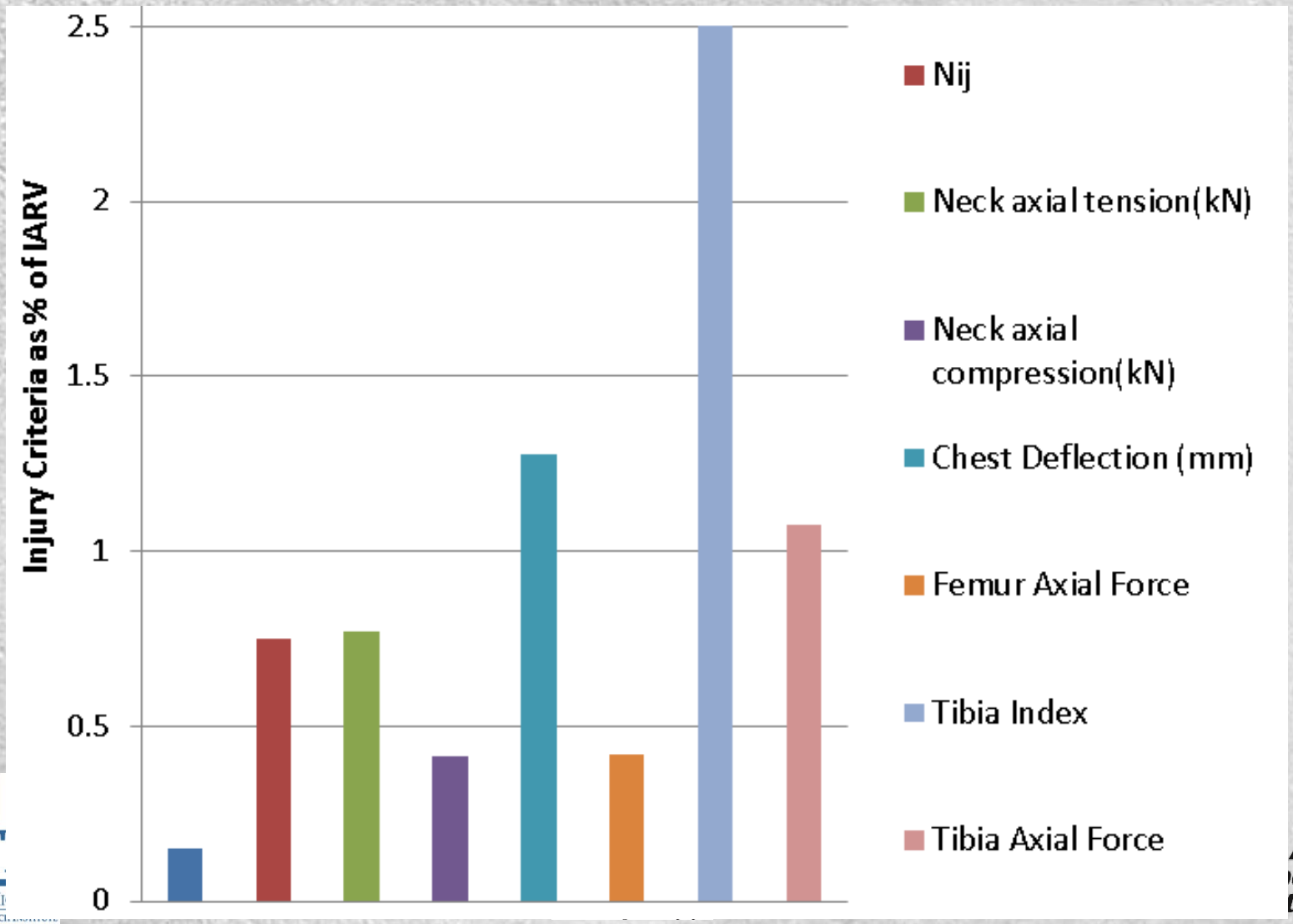
Comparison to IARV

Injury Assessment Reference Values (IARVs)

Injury event termed "unlikely" if associated injury value does not exceed IARVs

Body Region	Parameter	IARV	Injury Criteria	% of Critical Value
Head	HIC	700	104	0.15
Neck	Nij	1	0.78	0.78
	Neck axial tension(kN)	4.17	2.8	0.68
Chest	Deflection (mm)	63	85	1.36
Lower Extremity	Femur axial force(kN)	-10	-4.7	0.47
	Tibia Index	1	2.3	2.26
	Tibia axial force(kN)	-8	-9.3	1.16

Comparison to IARV



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Examples of Computer Simulations

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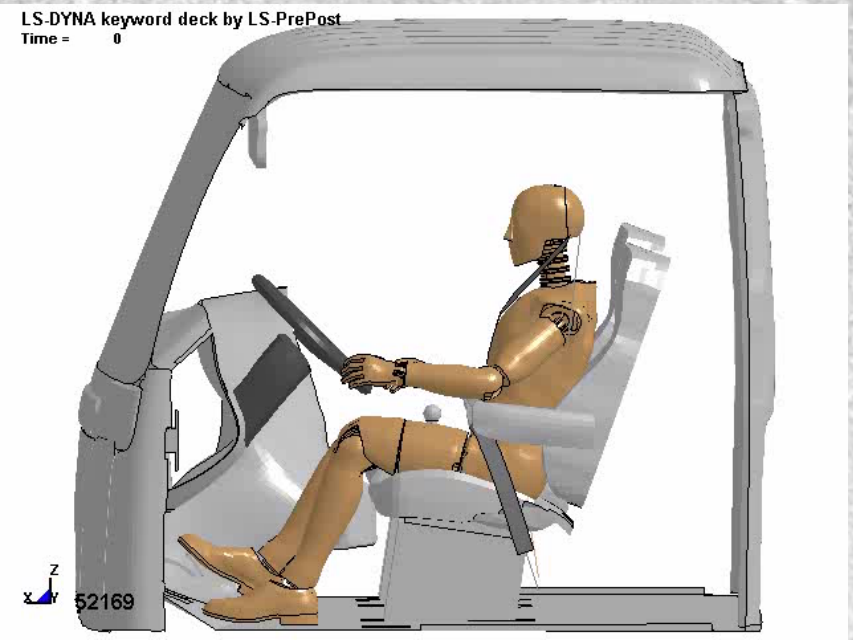
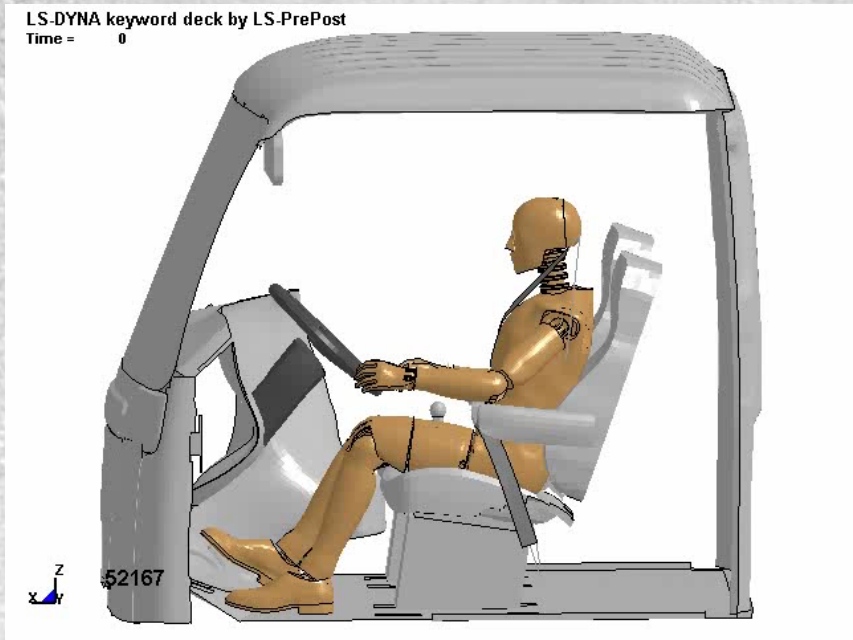
Frontal Simulations – No Airbag

No Airbag - Baseline



No Airbag – No Pretensioner



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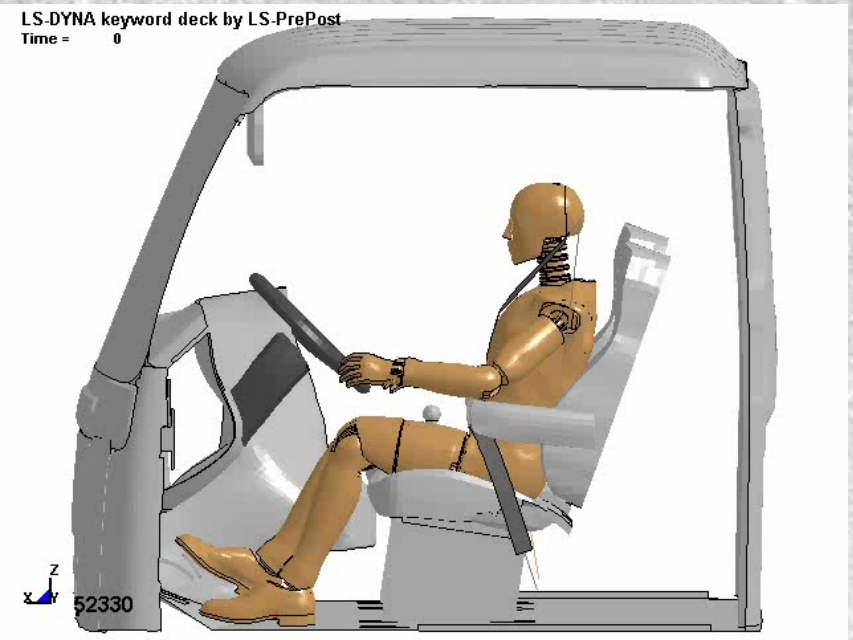
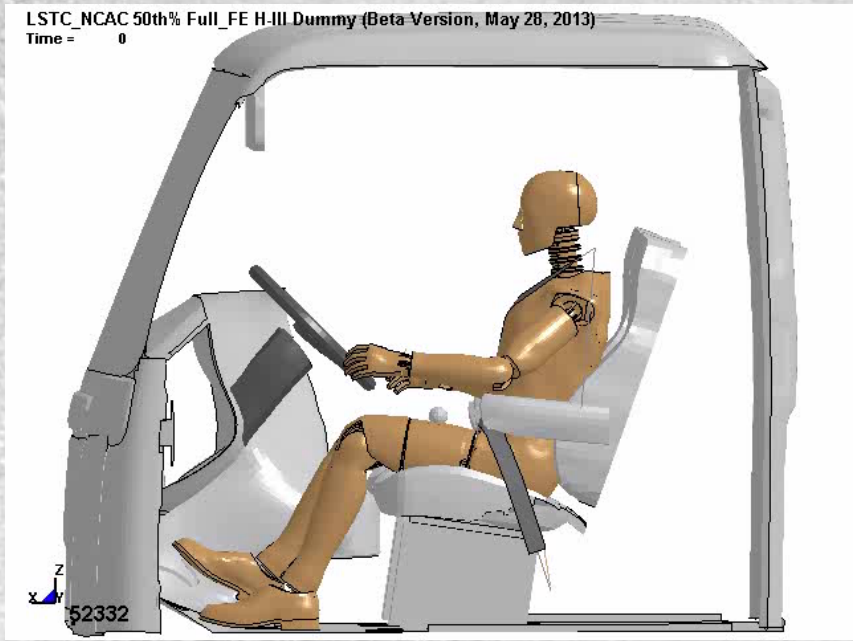
Frontal Simulations – No Airbag

No Airbag – 4 kN Limit Load



No Airbag – Lowered D-Ring



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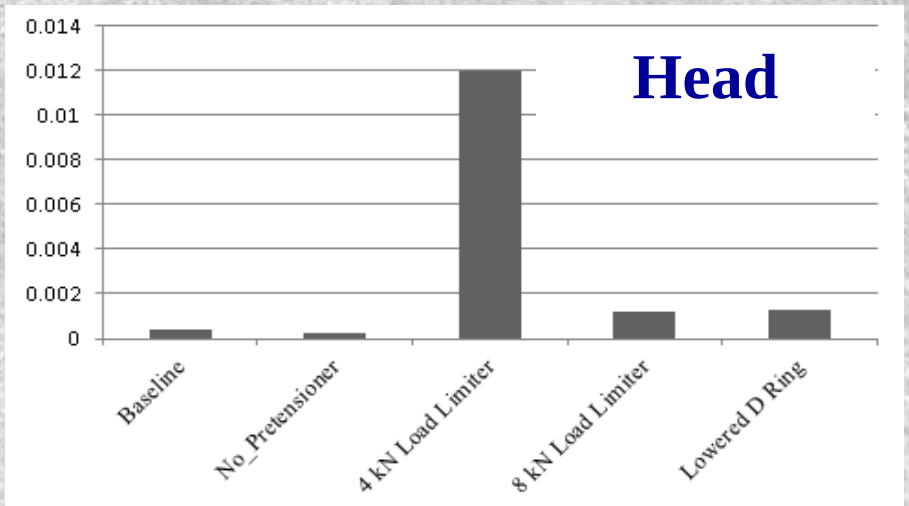
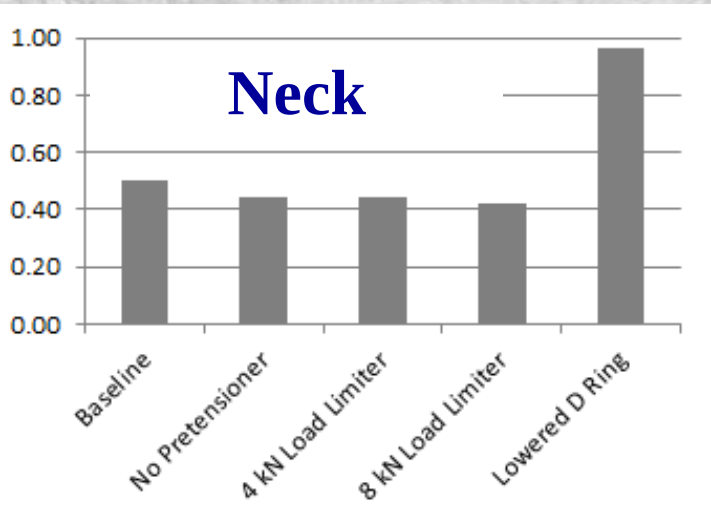
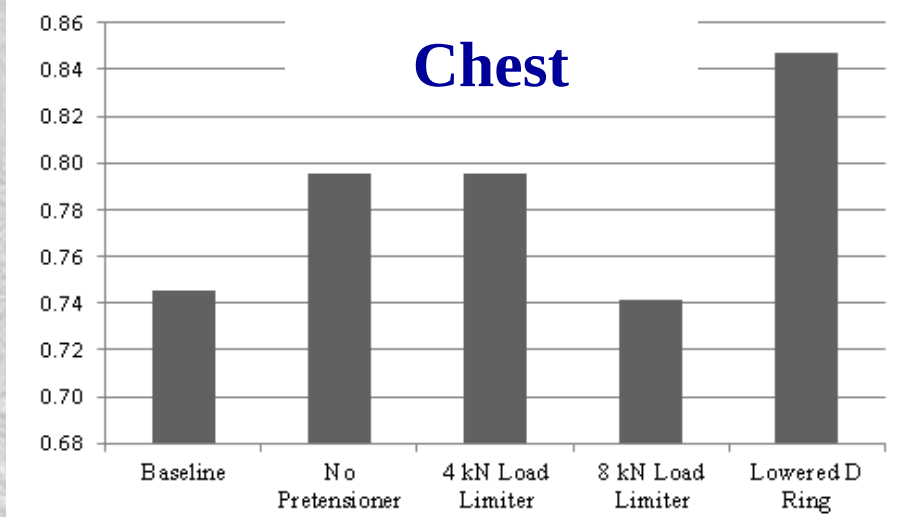
No Airbag – Injury Probability







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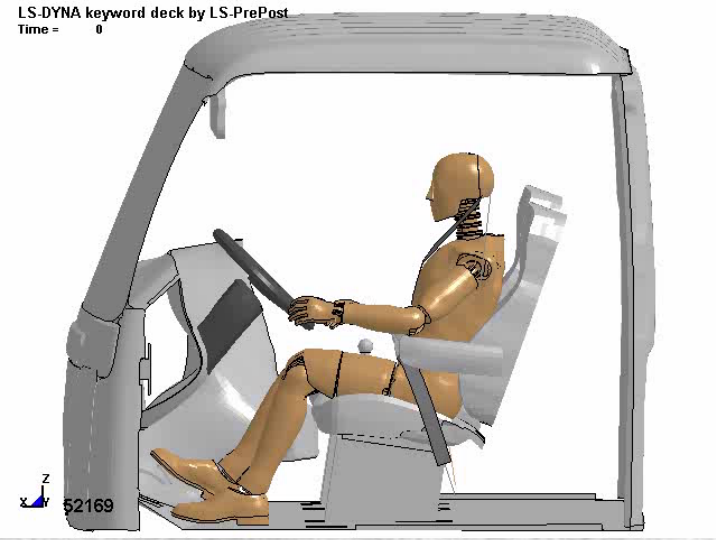
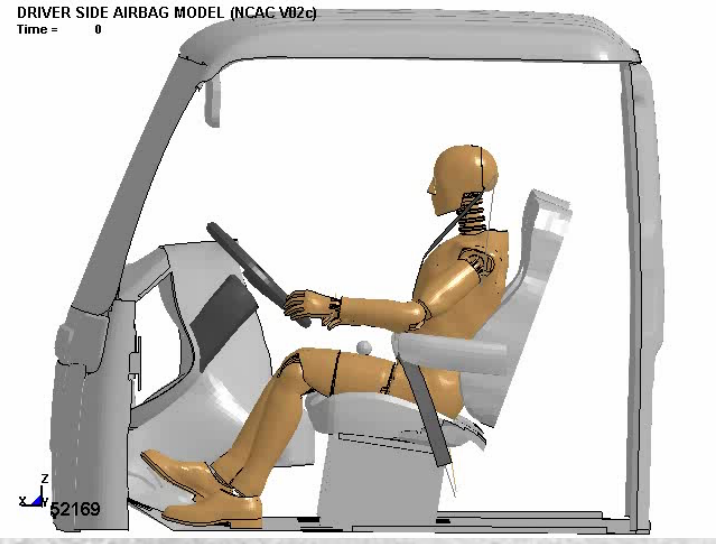
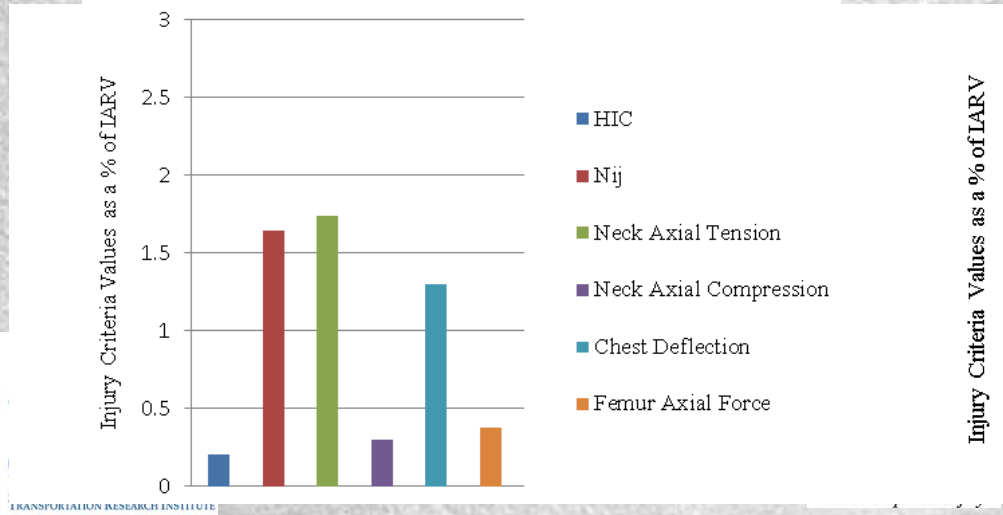
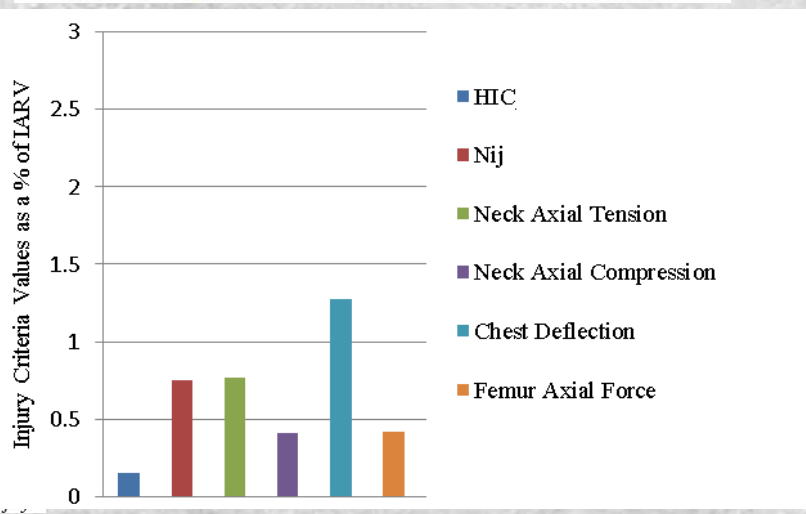
When Adding Airbag…

Baseline



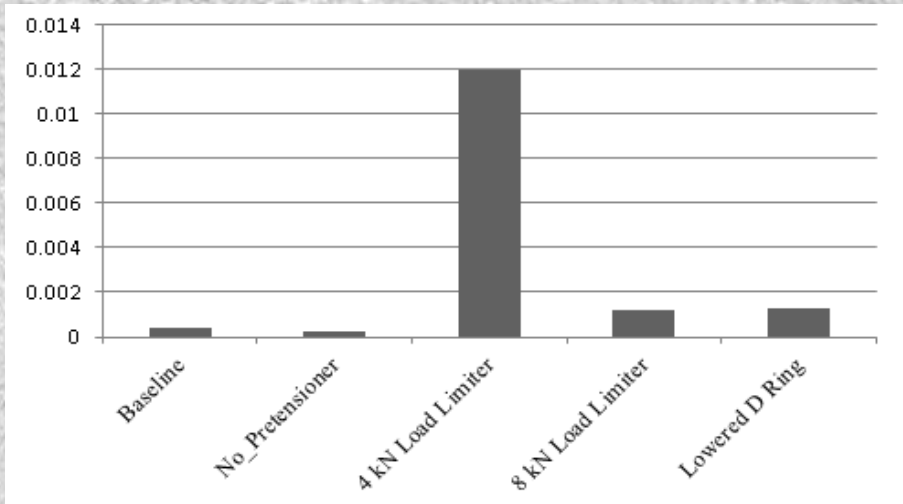




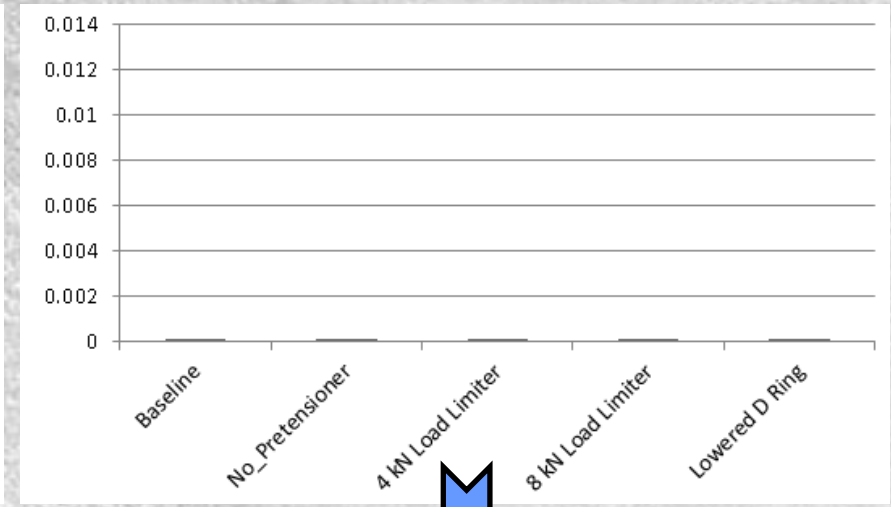


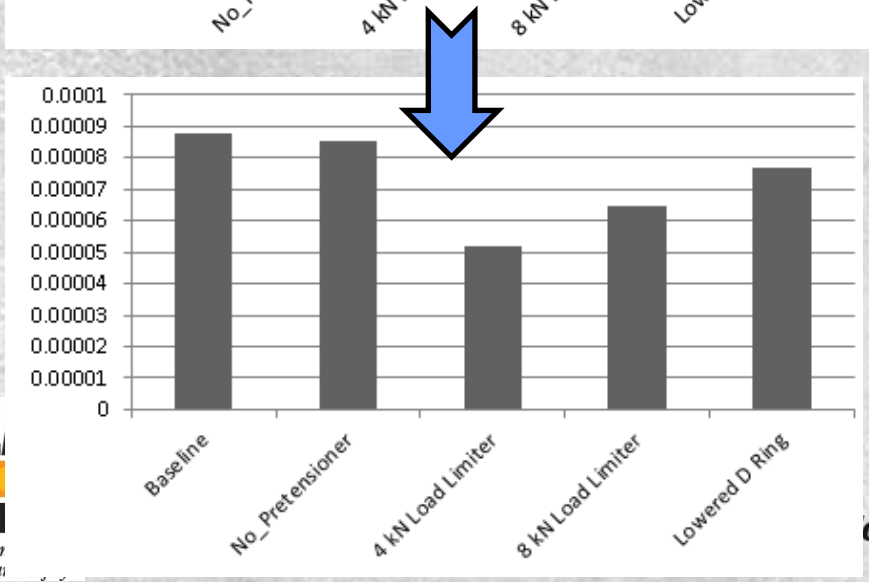
Head Injury Probability

No Airbag



Airbag





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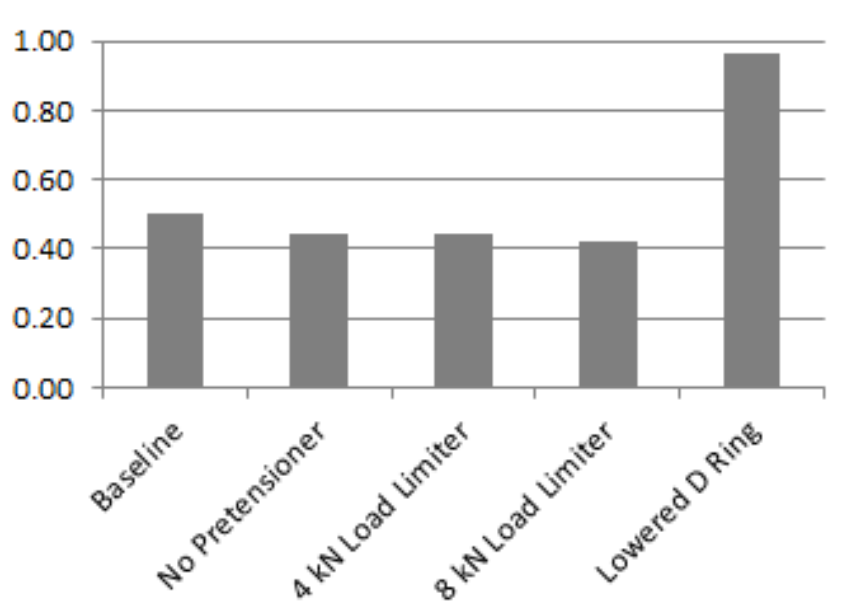
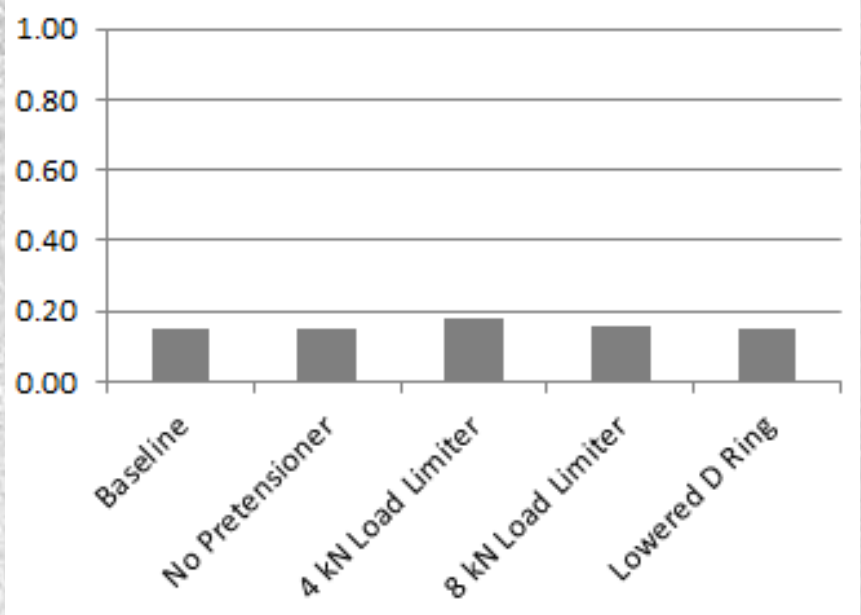
Neck Injury Probability

No Airbag



Airbag



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Conclusions

- 35 mph w/OUT airbag and 8 kN load limiter produced lowest injury criteria results for ATD.
- 35 mph w/airbag and 4 kN load limiter produced lowest injury criteria results for ATD.
- Inclusion of airbag resulted in significant reduction in probability of neck injury

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Future Research

- **Validation of interior component material modelling (for accurate deformation response of truck cabin interior)**
- **Realistic seat characteristics (suspensions)**
- **Development and analysis of additional restraint systems**
  - ***side curtain airbag system***
  - ***five point seatbelt***
  - **…**

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Chiara Silvestri Dobrovolny
E-mail: c-silvestri@ttimail.tamu.edu
Phone: 979-845-8971

Questions?

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