NHTSA
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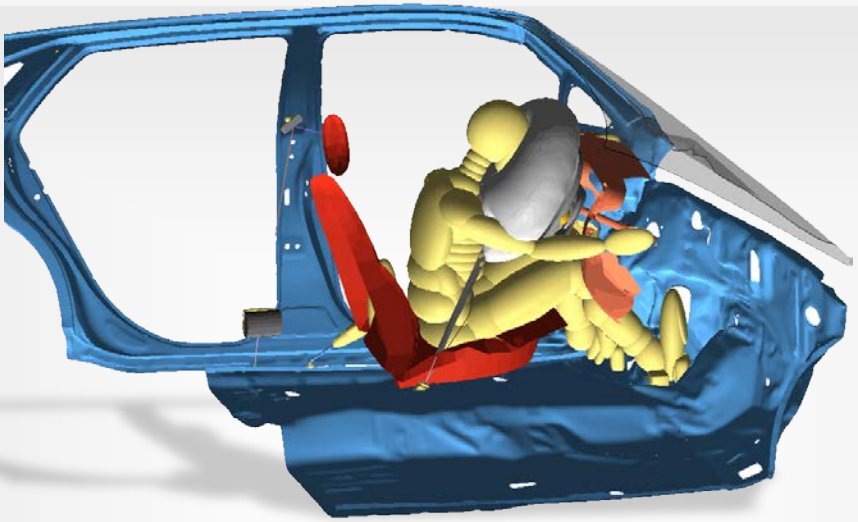
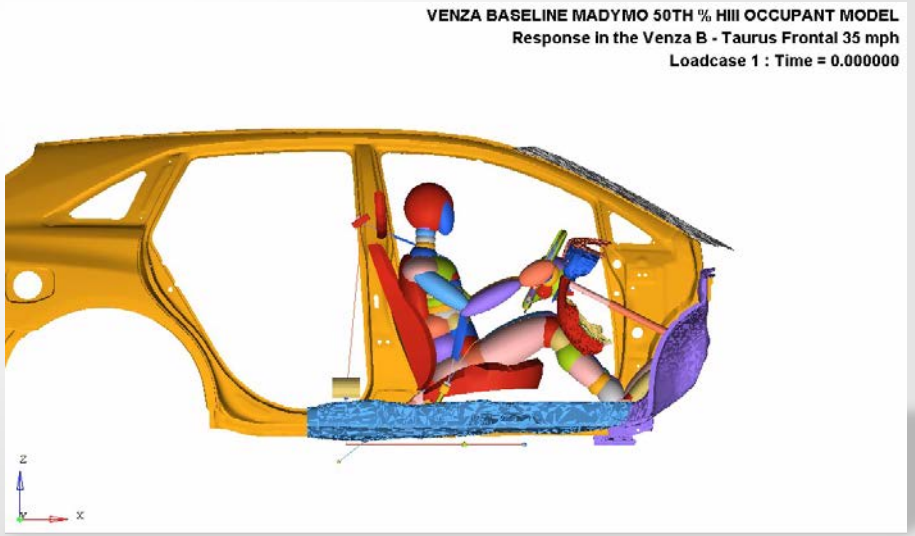


Fleet Safety Evaluation Methodology: Application to Lightweight Vehicle Designs

Stephen Ridella
Office of Vehicle Crashworthiness Research
Mass-Size-Safety Symposium
May 13, 2013

Presentation Agenda

- Goals of the Study
- Field Crash Assessment
- Computer Simulation Approach
- Injury Assessment
- Modeling Results
- Societal Injury Risk
- Conclusions

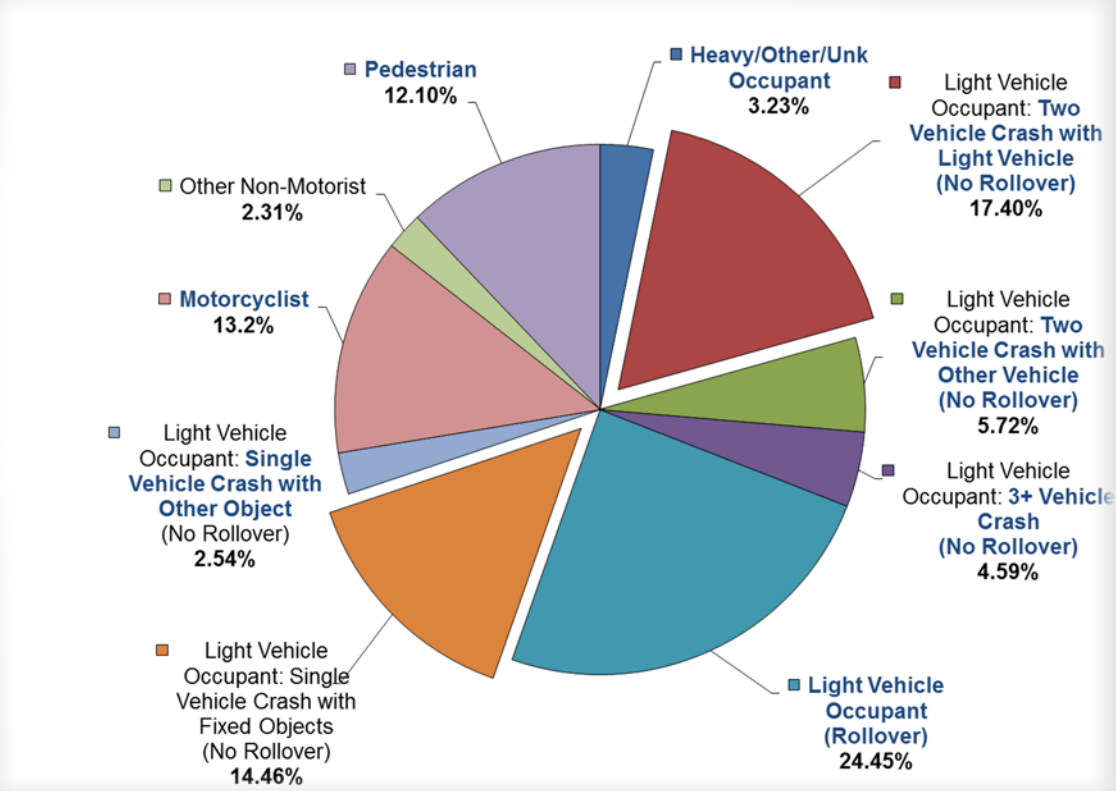


Fleet Crash Simulation Goals

- Utilize new and existing vehicle crash models to evaluate safety of future light-weighted vehicles
  - Vehicle-to-vehicle and vehicle-to-structure crashes
    - Belted occupants only
  - Non-Regulated, non-standard crash conditions
    - Vehicle speeds from 15mph – 40 mph;
    - Represent real world crash conditions and risk of occurrence
  - Interaction between light-weighted and existing vehicles
  - Evaluate opportunities for countermeasures
    - Potentially different air-bag deployment timing for light-weighted vehicles
    - Adaptive occupant restraint systems

2009 US Traffic Fatalities

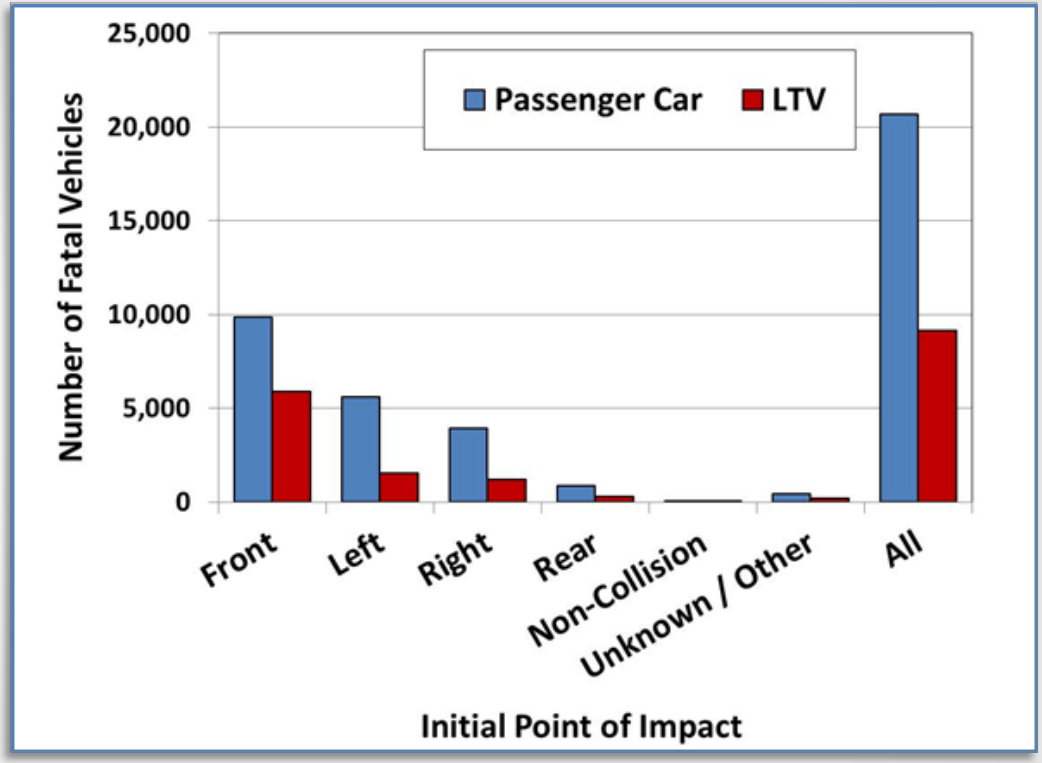
- Light Vehicles
  - V to V
  - V to Object
  - No Rollover
  - Only light passenger vehicles
- 31.86% of 2009 fatal crashes



Fatal Crashes by Initial Point of Impact

Frontal crashes represent 50.9% of fatal, non rollover crashes, 1 or 2 vehicle crashes

Study evaluates 16.2% (50.9% of the 31.86%) of 2009 fatalities, or 5,482 2009 fatal crashes



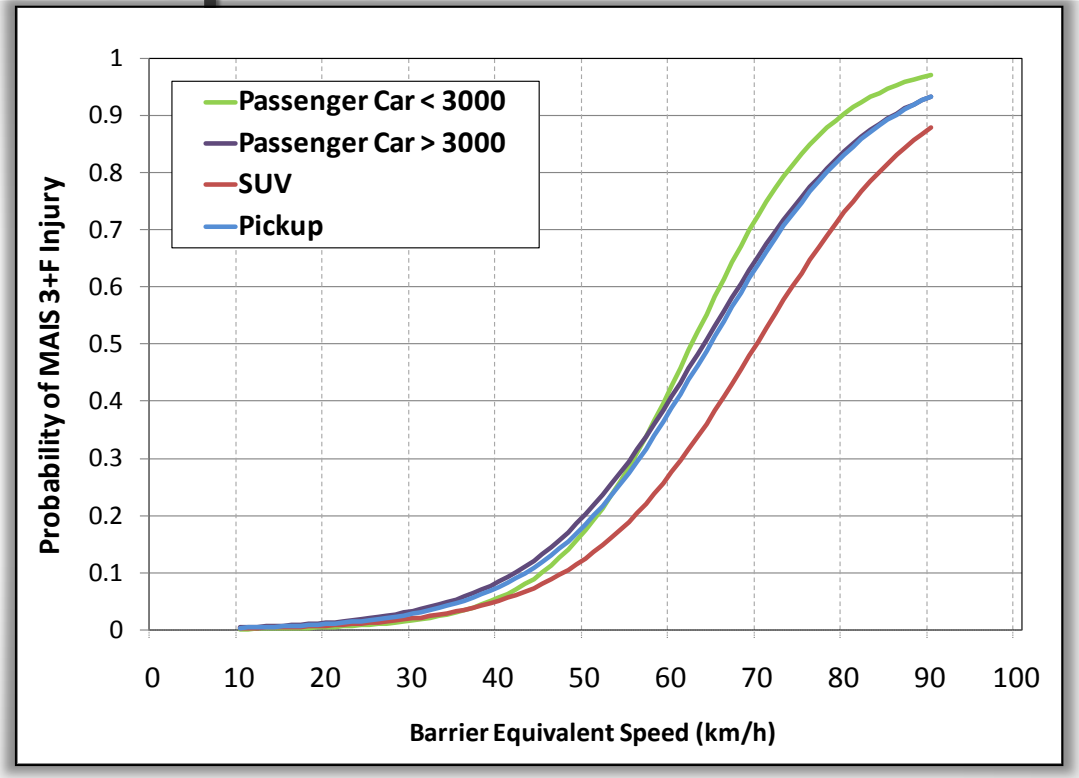
MY1998+, planar non-rollover crashes with restrained occupants

Barrier Equivalent Speed

Speeds are broken out by vehicle type and crash configuration

Selected BES instead of NASS Delta V due to increased reporting 68% vs 59%

Simulation speeds were limited to 64 kph

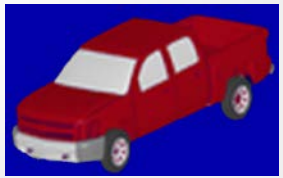


NASS/CDS 1998-2009 – MAIS 3+F Injury Risk by Vehicle Class and Barrier Equivalent Speed (weighted)

Fleet Vehicle Models

4 existing full vehicle FEA models will be used to represent the fleet

Each model was evaluated against available test data

Initial Status		
2001 Ford Taurus • Different versions validated to frontal NCAP, side NCAP, IIHS ODB, and roof crush tests • **Model includes vehicle interior components**		
2003 Ford Explorer • Validated to frontal NCAP • **Interior components available but not included**		
2007 Chevy Silverado • Validated to frontal NCAP test • **Interior digitized but not yet incorporated in the model**		
2010 Toyota Yaris • Validated to frontal NCAP • **Expected frontal NCAP validation**		

Lightweight Vehicle Models

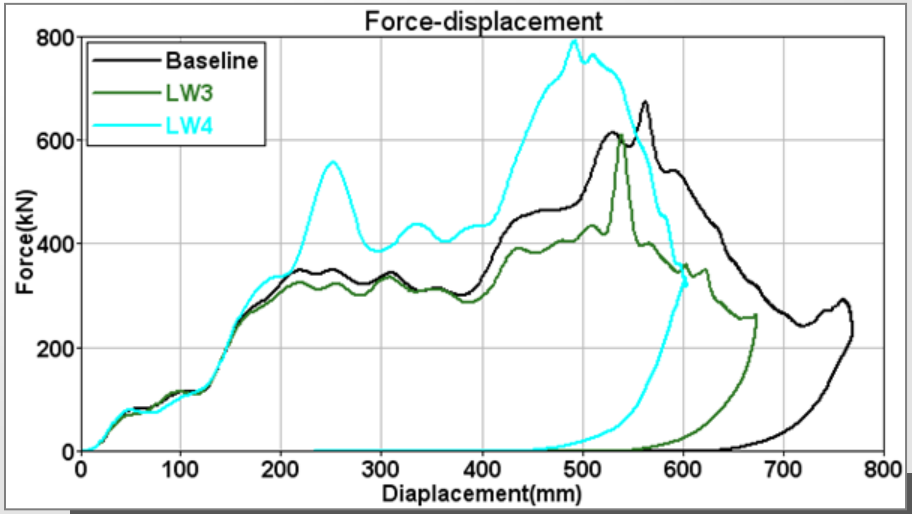
- Baseline and lightweight vehicle FEA models were developed in support of the 2017-2025 CAFE rule
- Variations of Taurus model were developed to evaluate methodology

	Taurus			Venza			Accord	
	Baseline	LW3	LW4	Baseline	Low Option	High Option	Baseline	Light Weight
weight (kg)	1515	1138	1515	1806	1503	1151	1670	1345
weight (lb)	3339	**2508**	3339	3980	3313	**2537**	3681	**2964**

Taurus Model Variations

- Alternative models developed to evaluate methodology
  - LW3: 25% lightweight, same stiffness
  - LW4: same weight, increased stiffness

35 mph barrier results

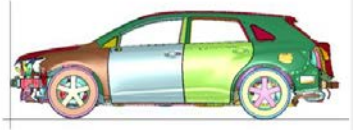
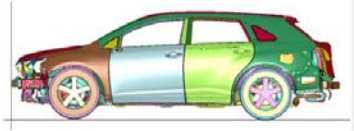
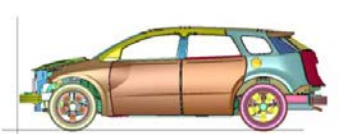


http://www.ncac.gwu.edu/vml/models.html

Venza FEA Models

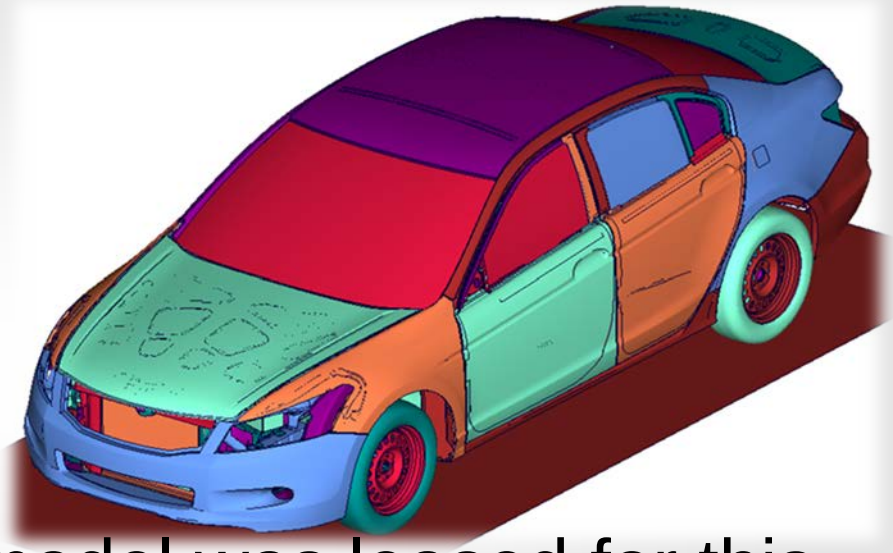
- FEV \ EDAG models
  - Venza baseline
  - Venza Low Option, 18% lightweight
- Lotus Engineering Model
  - Venza High Option , 31% lightweight

FEV Venza FEA at
http://www.epa.gov/otaq/climate/solutions-vehicle.htm

Venza Finite Element Models	Vehicle Mass
	Baseline 3980 lbs
	Low Option 3313 lbs
	High Option 2537 lbs

Accord Model

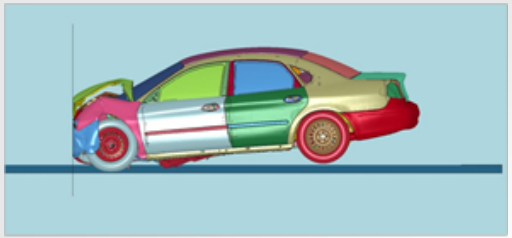
- Electricore \ EDAG developed the lightweight Honda Accord Model



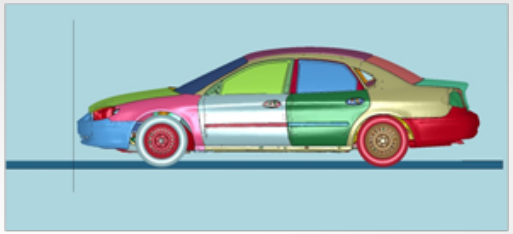
- Baseline Accord FEA model was leased for this project
  - Only LS-Dyna simulation output available to NHTSA

http://www.nhtsa.gov/Laws+&+Regulations/CAFE+-+Fuel+Economy/Research+Supporting+2017-2025+CAFE+Final+Rule

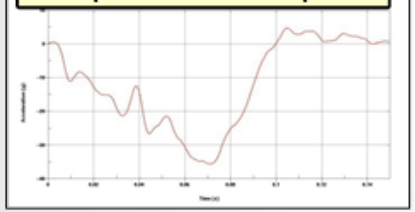
Fleet Simulation Overview



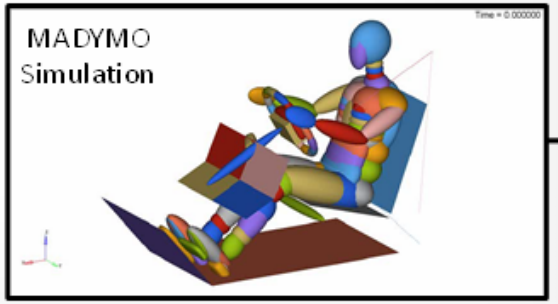
FEM Simulation



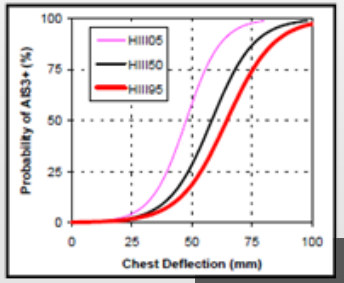
compartment crash pulse



MADYMO Simulation



HIC15
Chest Deflection
Femur Load

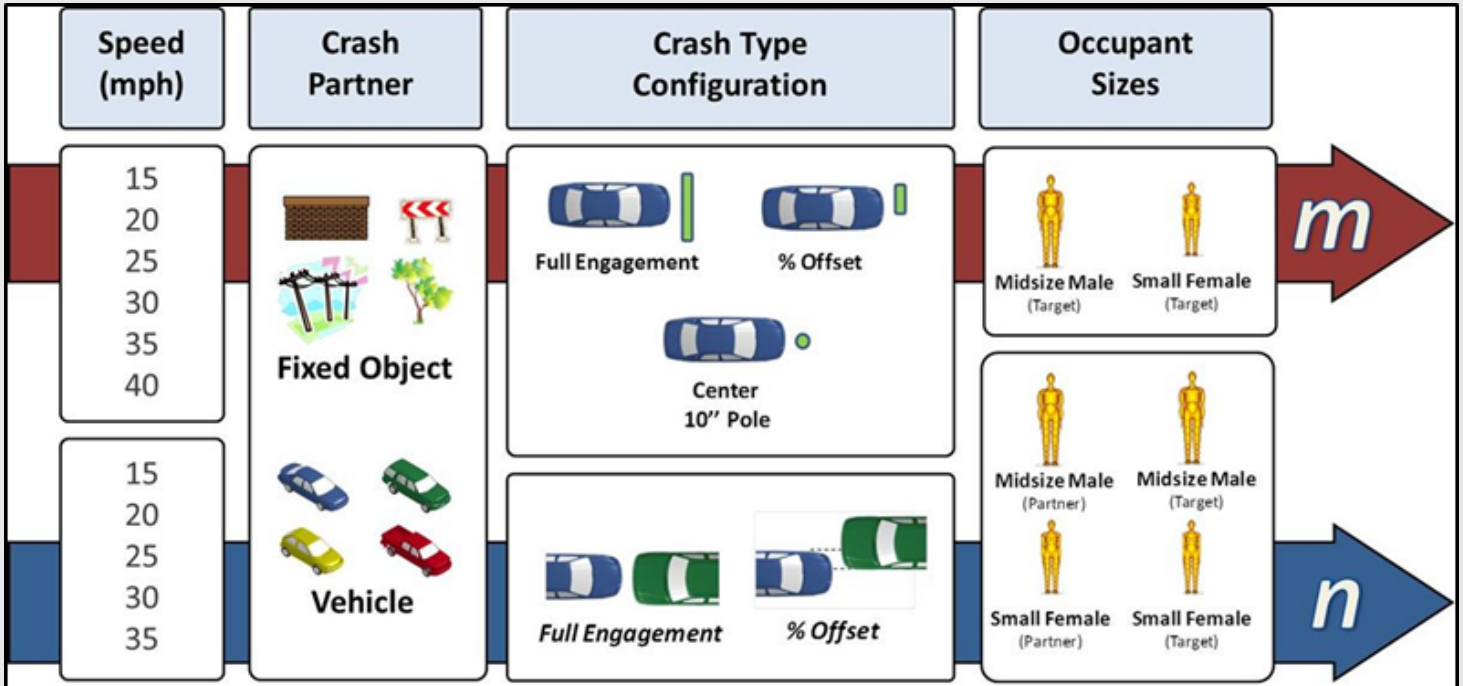


R_{head}^{AIS3+}

R_{chest}^{AIS3+}

$R_{lower-ext}^{AIS2+}$

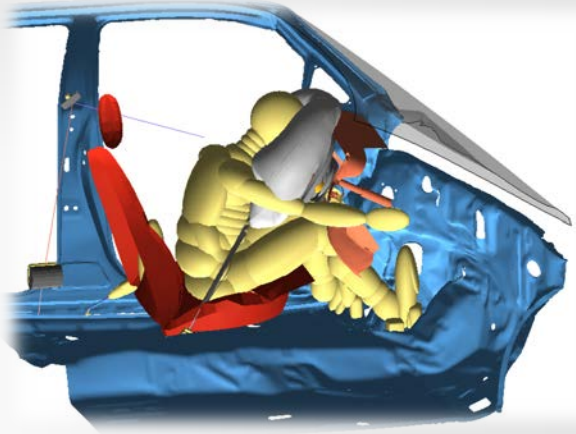
Simulation Matrix

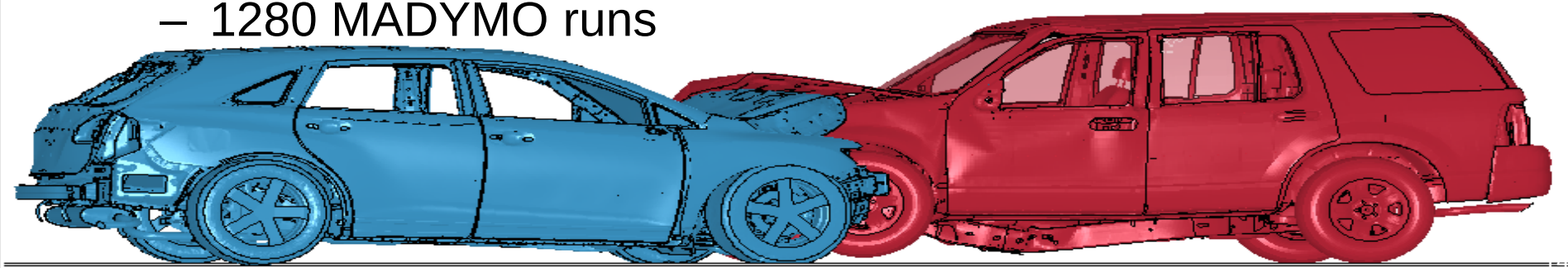


$$AccIR(s) = \sum_{i=1}^{\substack{m=6Speeds \\ n=5Speeds}} \sum_{j=1}^{\substack{m=2CrashPartners \\ n=2CrashPartners}} \sum_{k=1}^{\substack{m=3CrashTypes \\ n=2CrashTypes}} \sum_{l=1}^{\substack{m=2OccupantTypes \\ n=4OccupantTypes}} W_i(s) * \max\left[R_{ijkl}^{AIS3+}(s)\right]$$

Finite Element Simulations

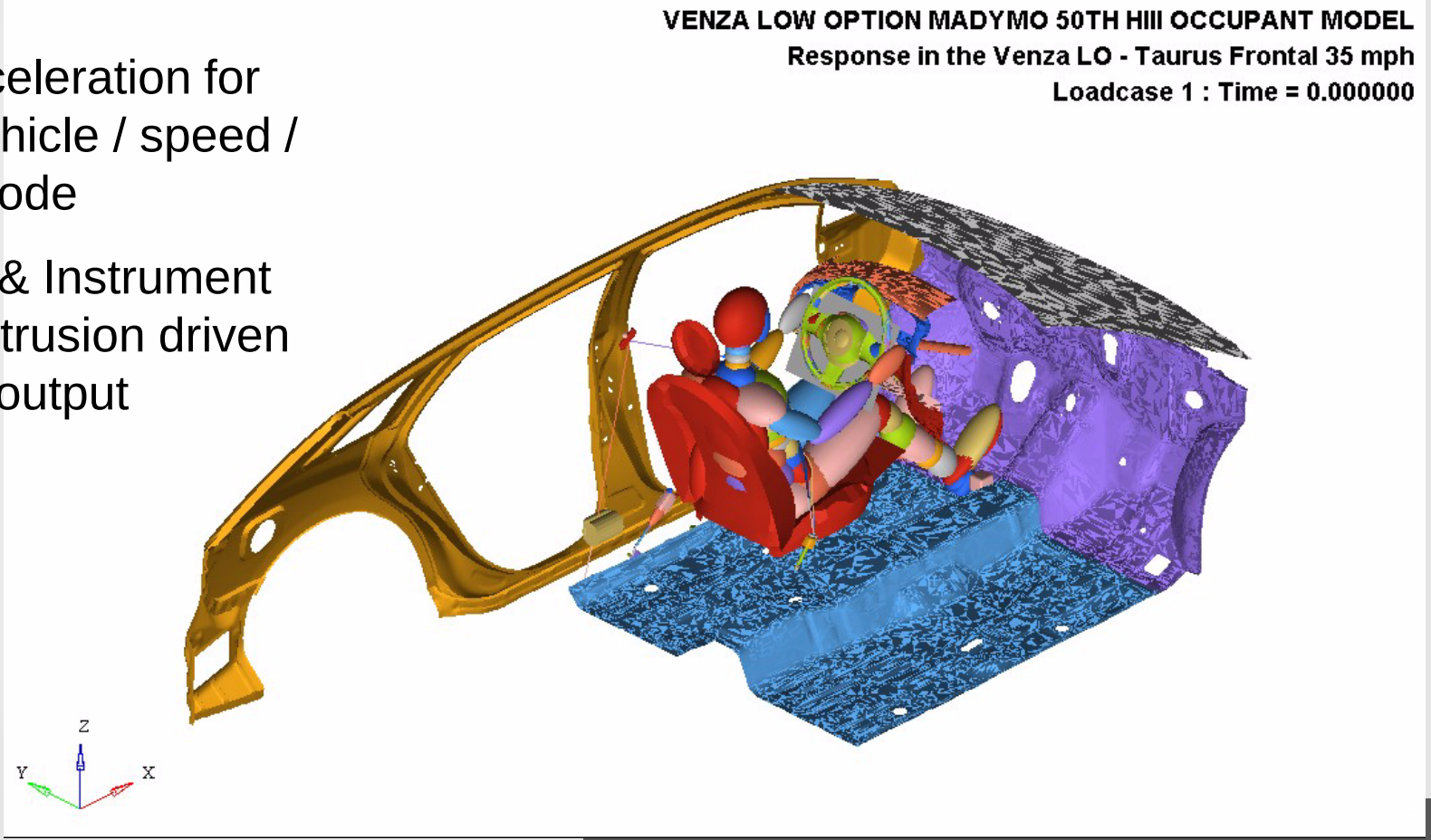
- Single-vehicle crash simulations:
  - 120 LS-DYNA runs
  - 240 MADYMO runs
- Two-vehicle crash simulations:
  - 320 LS-DYNA runs
  - 1280 MADYMO runs





MADYMO Occupant Simulations

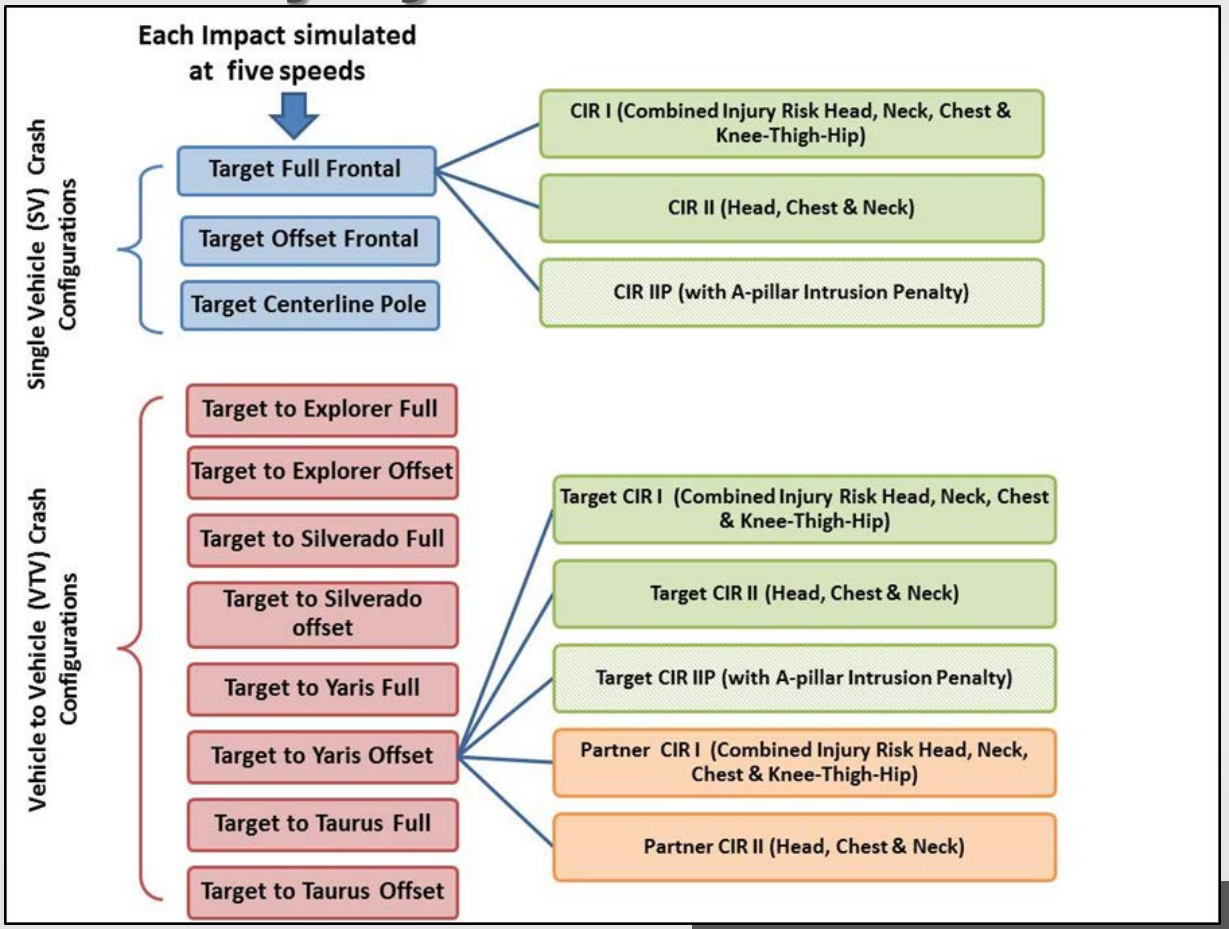
- FEA acceleration for each Vehicle / speed / crash mode
- Toepan & Instrument Panel intrusion driven by FEA output



Injury Risk Computation

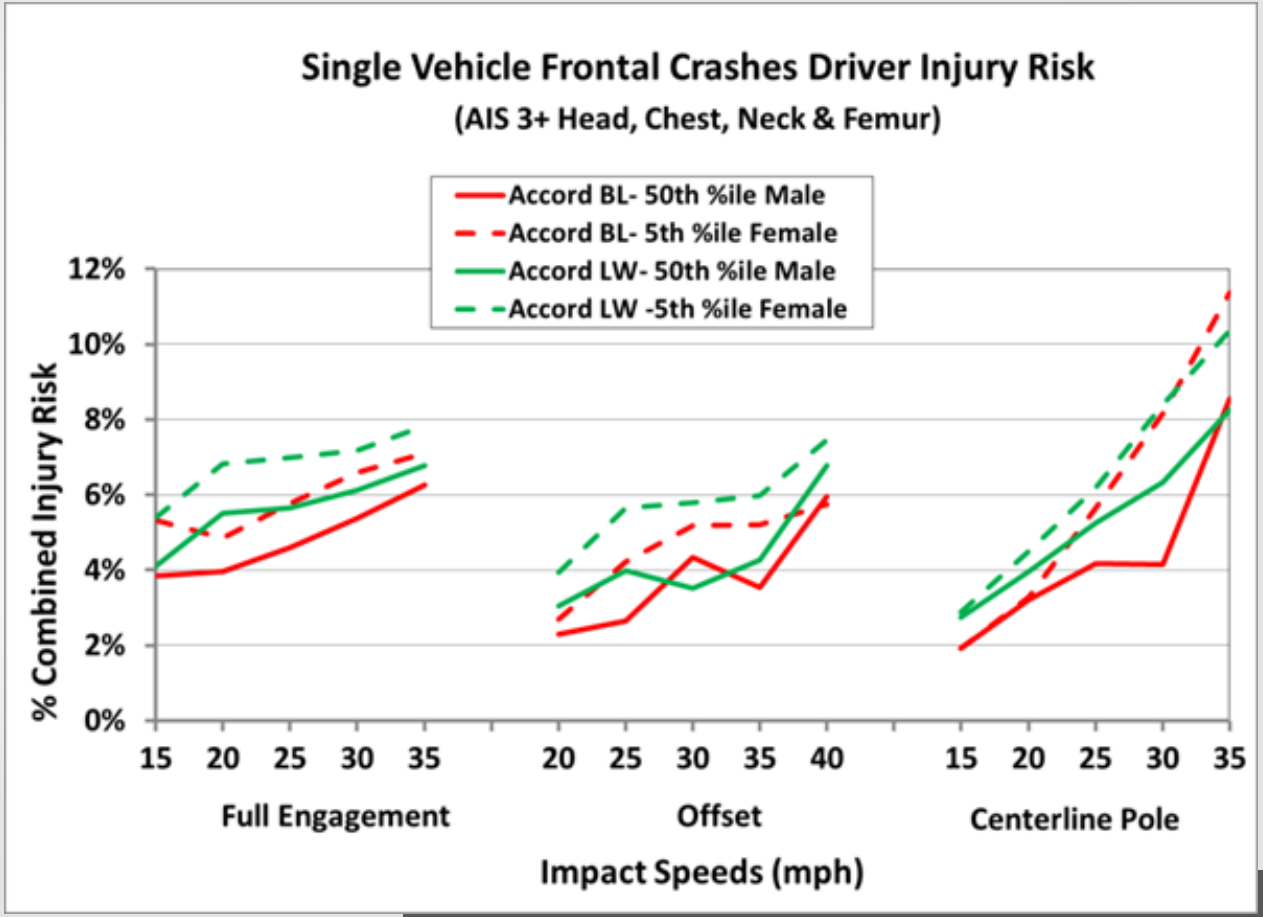
- NCAP Injury Risk functions
  - Separate risk functions for 50th male and 5th female
  - AIS 3+ risk Head, chest, neck, and femur
- 3 methods for combining injury risks
  - Head, Neck, Chest, & Femur
  - Head, Neck & Chest
  - Head, Neck, Chest, and intrusion penalty function

Combined Injury Risk



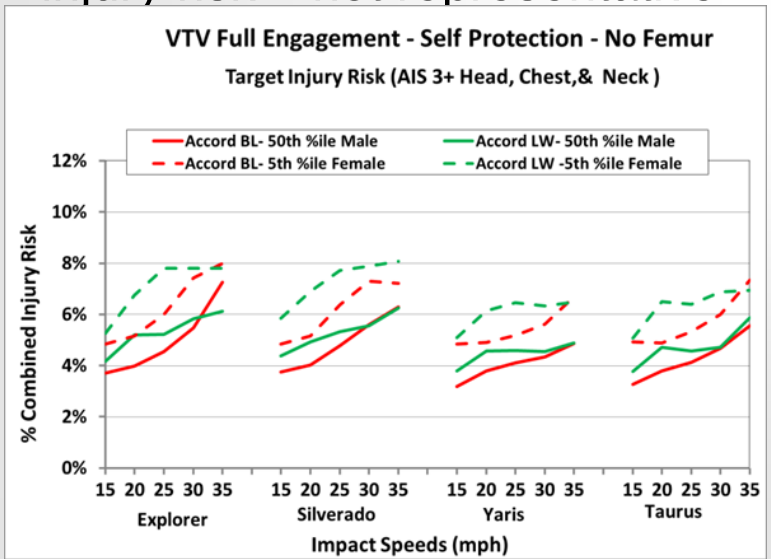
Combined Injury Risk – Single Vehicle

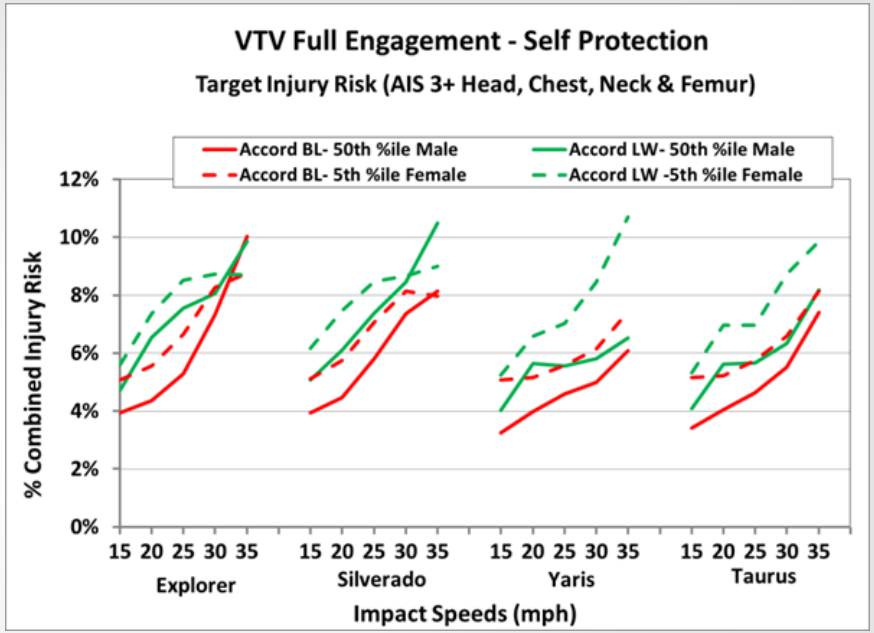
- Increased risk for LW vehicles at most speeds
- 5th female has higher risk



Occupant Injury Risk – Two Vehicle

- V to V Injury risk evaluated by crash mode, partner & speed
- Risk at high speeds from femur injury risk – not representative





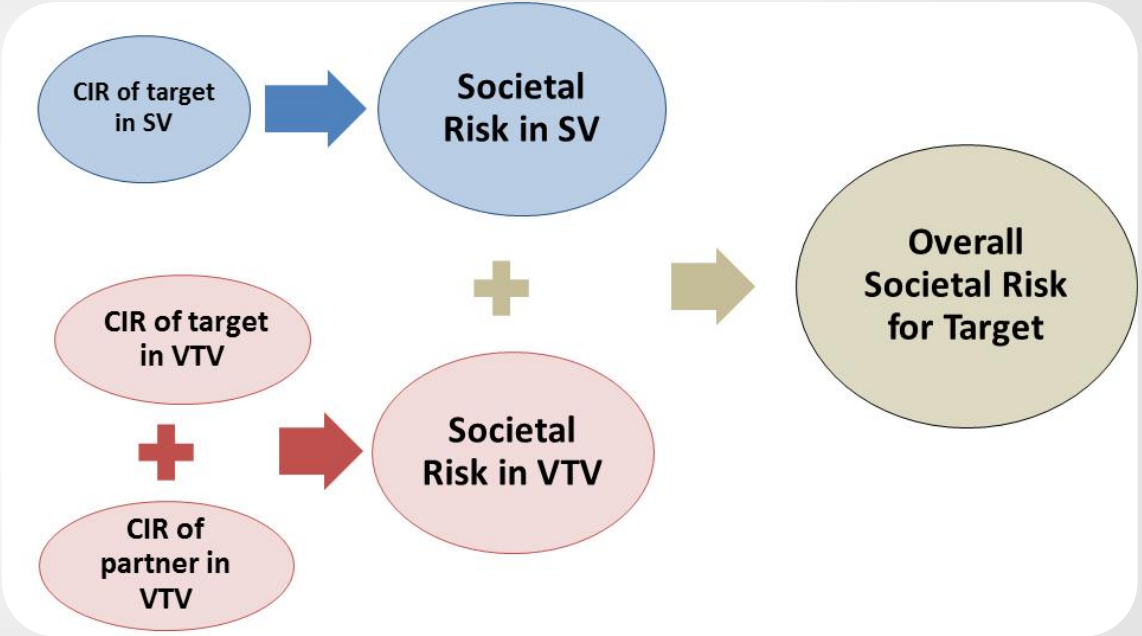
Alternate combined injury measures used to evaluate model sensitivity

Societal injury Risk

Individual crash risks combined with the risk of crash occurring to get overall crash injury risk

Result reflects Societal Risk

Comparison between lightweight and baseline risk to identify safety considerations



Societal Risk

Societal Risk I- Target Combined AIS3+ risk of Head, Neck, Chest & Femur				
Single Vehicle Crashes	Target	Overall Risk in SV	Total Risk 50th male	Total Risk 5th female
	Taurus BL	0.15%	0.10%	0.28%
	LW3	0.18%	0.14%	0.31%
	LW4	0.19%	0.17%	0.24%
	Accord BL	0.22%	0.20%	0.25%
	Accord LW	0.25%	0.24%	0.29%
	Venza BL	0.20%	0.12%	0.44%
	Venza Low Option	0.21%	0.14%	0.44%
	Venza High Option	0.22%	0.15%	0.42%

2 vehicle crashes computed target and partner risk separately then summed

Baseline NASS injury risk is 1.25% to 1.56% for studied crashes

Risks were computed separately for 50th and 5th

Risks were combined based on occupancy

Societal Risk I - Target + Partner Combined AIS3+ risk of Head, Neck, Chest & Femur				
Two Vehicle Crashes	Target	Overall Risk in VTV	Total Risk 50th male	Total Risk 5th female
	Taurus BL	1.10%	0.82%	1.96%
	LW3	1.23%	0.91%	2.17%
	LW4	1.29%	1.05%	2.00%
	Accord BL	1.34%	1.13%	1.98%
	Accord LW	1.48%	1.30%	2.04%
	Venza BL	1.16%	0.81%	2.20%
	Venza Low Option	1.24%	0.83%	2.49%
	Venza High Option	1.35%	0.87%	2.77%

Societal Risk – Frontal Crashes

Target Vehicle	Taurus Baseline	LW3	LW4	Accord Baseline	Accord LW	Venza Baseline	Venza Low Option	Venza High Option
Weight (lbs)	3339	2508	3339	3681	2964	3980	3313	2537
reduction		831			716		668	1444
% mass reduction		**25%**	**0%**		**19%**		**17%**	**36%**
Societal Risk I	1.25%	1.41%	1.48%	1.56%	1.73%	1.36%	1.43%	1.57%
Risk Increase		12%	18%		11%		5%	15%
Societal Risk II	1.01%	1.14%	1.22%	1.43%	1.57%	1.14%	1.20%	1.30%
Risk Increase		13%	21%		10%		5%	14%
Societal Risk IIP	1.01%	1.16%	1.23%	1.44%	1.59%			
Risk Increase		14%	21%		10%			

Societal Risk I - Target + Partner Combined AIS3+ risk of Head, Neck, Chest & Femur
Societal Risk II - Target + Partner Combined AIS3+ risk of Head, Neck, and Chest
Societal Risk IIP - Target + Partner Combined AIS3+ risk of Head, Neck, and Chest with A-Pillar Intrusion Penalty

Conclusions

- Methodology successfully evaluated vehicle designs for a range of crash configurations and speeds.
  - Results are sensitive to vehicle interior and occupant modeling.
  - Additional refinement of occupant models.
- Evaluate mass and stiffness changes independently.
  - Both factors affect safety risk.
- Highlight importance of crash safety at speeds lower than the regulatory and consumer information testing.
- Self and partner protection in two-vehicle crashes

Future Fleet Safety Research

- Incorporate steering column and A-pillar intrusion into occupant model.
- Evaluate advanced occupant restraints.
- Additional vehicle types for fleet study.
- Improve correlation between fleet model and real world crash data.
- Combine the occupant and the vehicle structure in the same simulation environment.

Acknowledgements

Authors:
Randa Radwan Samaha, Priya Prasad
Dhafer Marzougui, Chongzhen Cui
Kennerly H. Digges, Cing-Dao (Steve) Kan
George Washington University

Aida Barsan-Anelli
Information Systems and Services Inc

Stephen Summers, Lixin Zhao
National Highway Traffic Safety Administration