STRUCTURAL DESIGN CONSIDERATIONS FOR A LIGHTWEIGHTED VEHICLE TO ACHIEVE "GOOD" RATING IN IIHS SMALL OVERLAP

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SAE INTERNATIONAL

NHTSA
www.nhtsa.gov

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The **Center for Collision Safety and Analysis (CCSA)** at George Mason University brings together a strong and richly experienced team of scientists and engineers focused on using advanced technology to understand collisions involving transport vehicles and to develop means to avoid or mitigate them to enhance safety and security. CCSA is associated with the College of Science at George Mason University and the National Center for Manufacturing Science (NCMS).

Presentation Objective

1. The presentation will discuss effective design strategies to identify structural design modifications to achieve ‘good’ rating for the IIHS Small Overlap Crash.
2. The results of a recent study funded by NHTSA will be presented.
3. Additional mass and cost implications to meet the IIHS requirement for a Mid-Size Sedan vehicle will be discussed.

Small Overlap Frontal Crashworthiness Evaluation Crash Test Protocol (Version I)

August 2012

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

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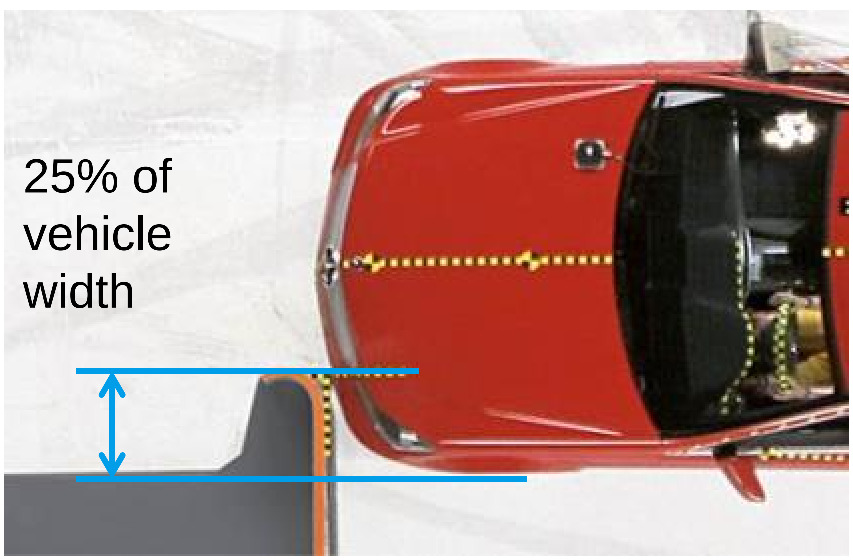
PHONE 703/247-1500 FAX 703/247-1678
www.iihs.org

IIHS Small Overlap (SOL) Test

1. The IIHS SOL test is designed to reproduce what happens when the front corner of a vehicle hits another vehicle or an object like a tree or utility pole, missing the structure rail/frame.
2. In this test, a vehicle travels at 40 mph toward a 5-foot tall rigid barrier. A Hybrid III dummy representing an average-size man is positioned in the driver seat. Twenty-five percent of the total width of the vehicle strikes the barrier on the driver side.



NHTSA Project Tasks

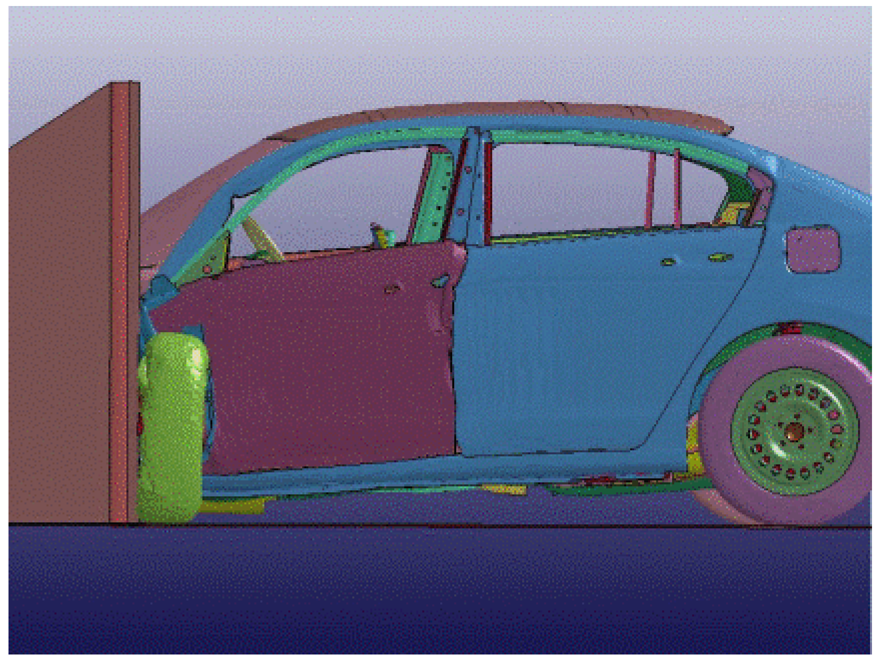
1. First task to build and refine a baseline vehicle LSDYNA crash simulation model and correlate with IIHS test results
2. Update NHTSA Light Weight Vehicle (LWV) LSDYNA model to accurately predict SOL crash performance
3. Design and optimize the LWV structure design so that it will achieve “good” rating for the structural performance and estimate the vehicle mass and cost increase due to this requirement

Light Weighted Vehicle (LWV) was created for NHTSA under contract DTNH22-11-C-00193[1] , to identify vehicle mass reduction for years 2017-2025 in support of CAFE standards.

[1] Full report can be accessed at ftp://ftp.nhtsa.dot.gov/CAFE/2017-25_Final/811666.pdf.

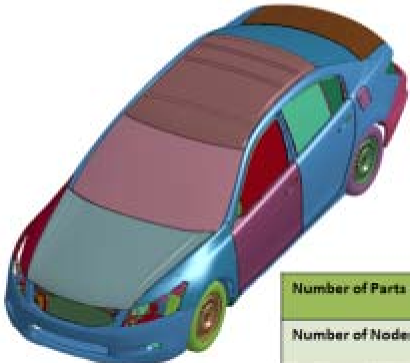
Baseline Vehicle 2009 Honda Accord
LSDYNA Model Build and Correlation with IIHS SOL Test Results

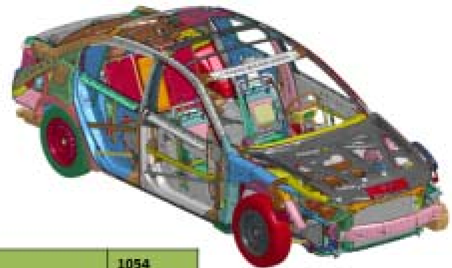
First task to build and refine a baseline vehicle LSDYNA crash simulation model and correlate with IIHS test results



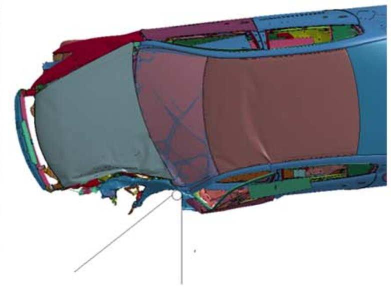
animation

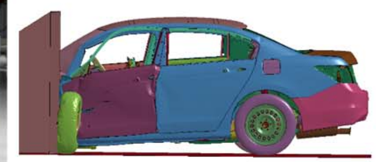
Baseline Vehicle 2009 Honda Accord
LSDYNA Model Build and Correlation with IIHS SOL Test Results



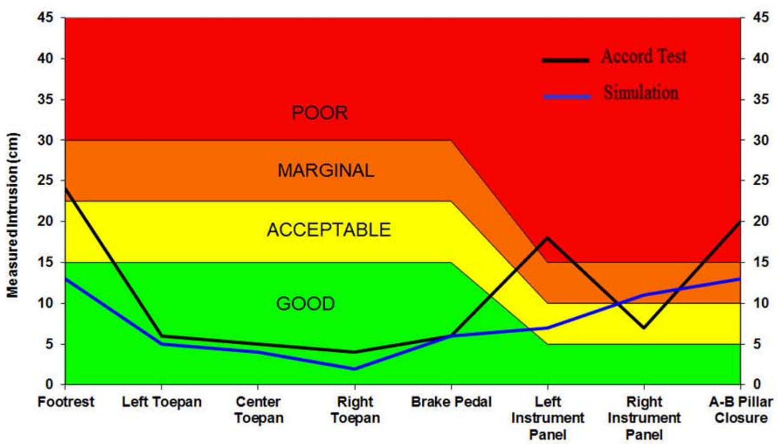


Number of Parts	1054
Number of Nodes	1,969,784
Number of Shell Elements	1,815,276
Number of Beam Elements	659
Number of Solid Elements	98,716
Total Number of Elements	1,914,659





Post-test laboratory vehicle and model of the 2009 Honda Accord for IIHS SOL test



Maximum intrusion in laboratory test and finite element simulation in IIHS SOL frontal impact.

Honda Accord 2008, 2009 & 2013
IIHS SOL Tests & Results

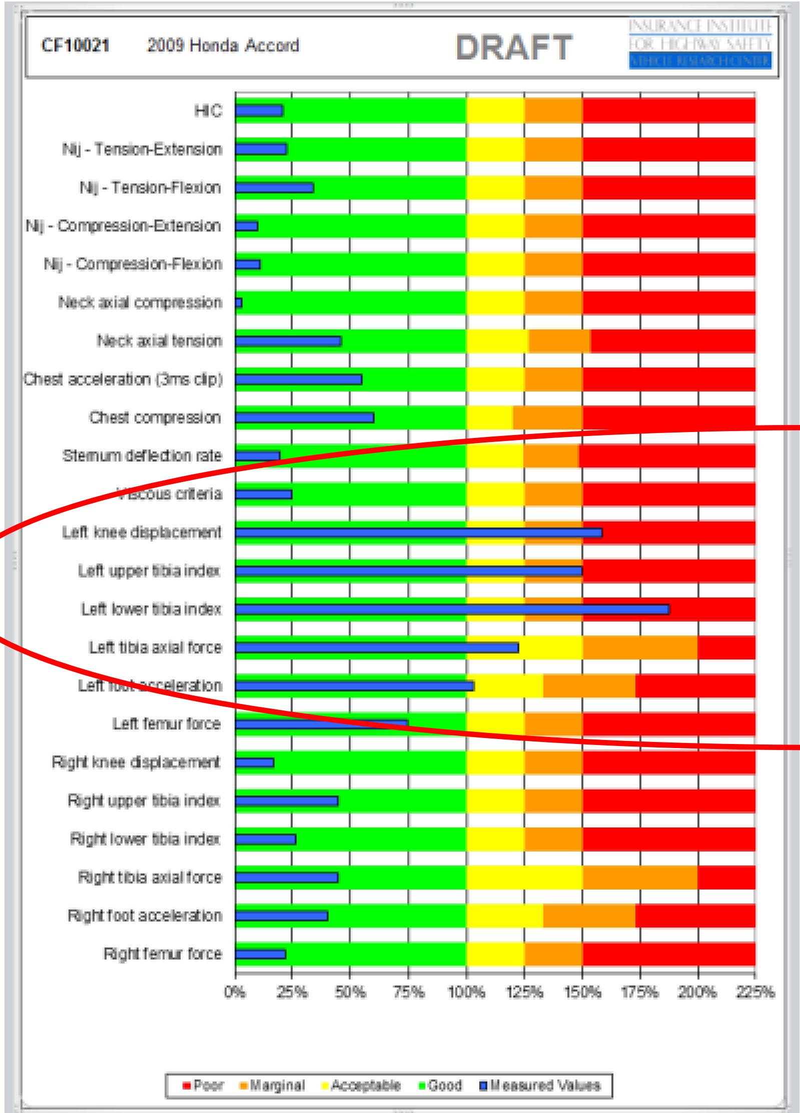
CF1001
2008 – 4 Door

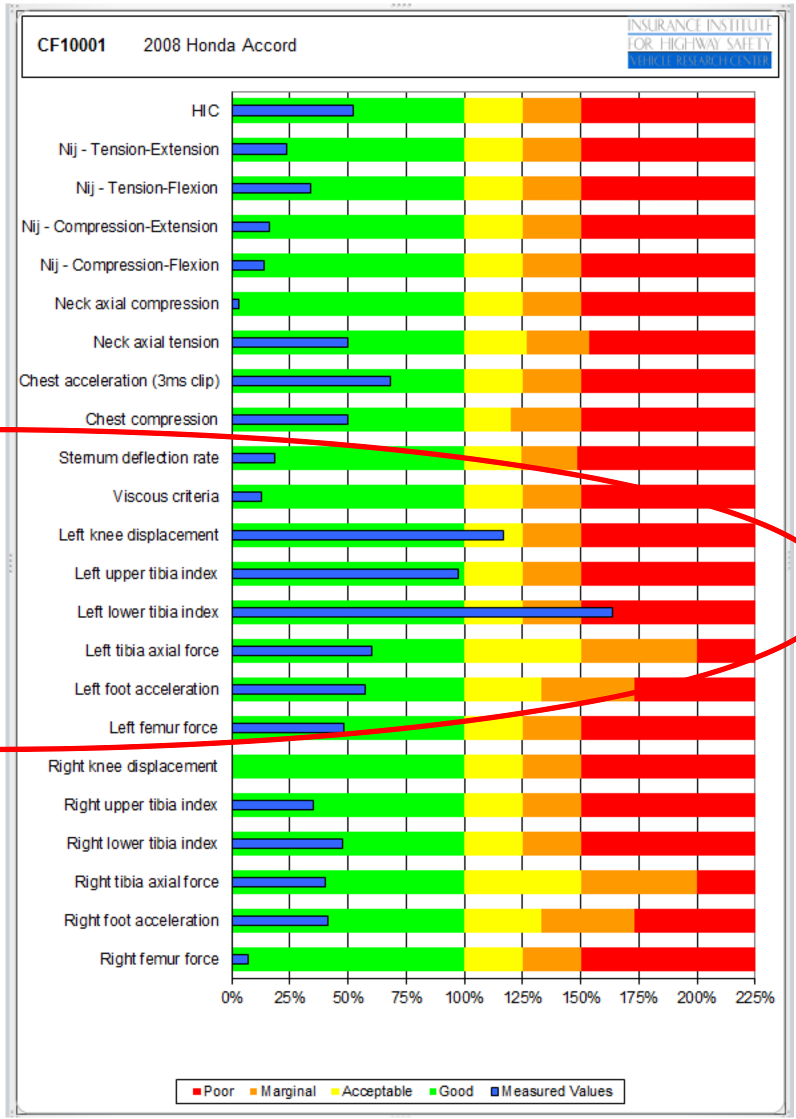
CF10021
2009 – 4 Door

CEN1229
2013 – 4 Door

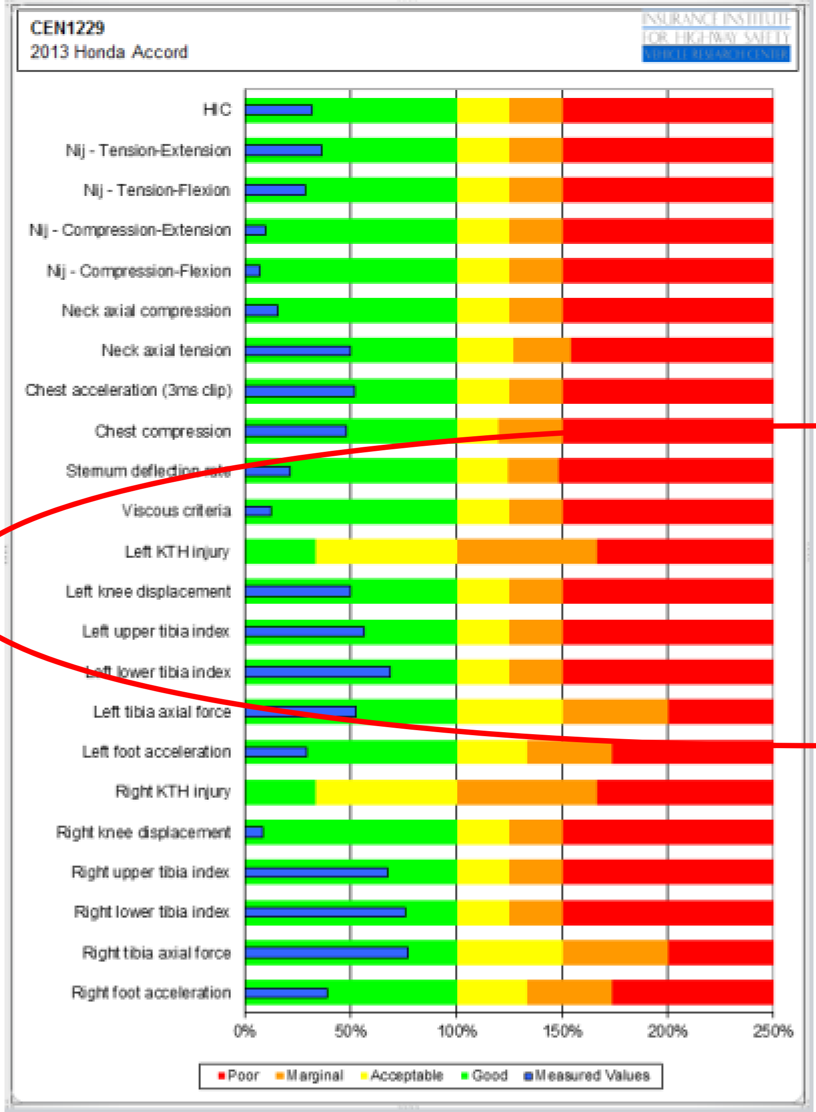
CEN1234
2013 – 2 Door

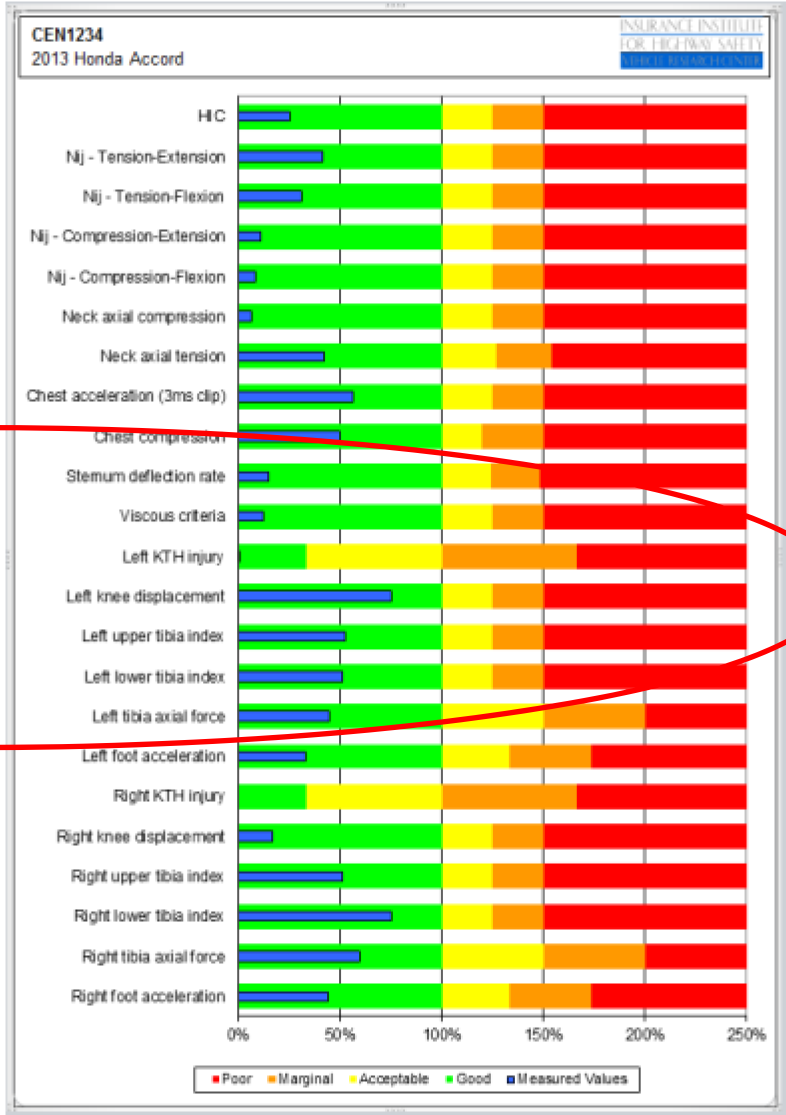
Honda Accord 2008, 2009
IIHS SOL Tests Results





Honda Accord 2013
IIHS SOL Tests Results



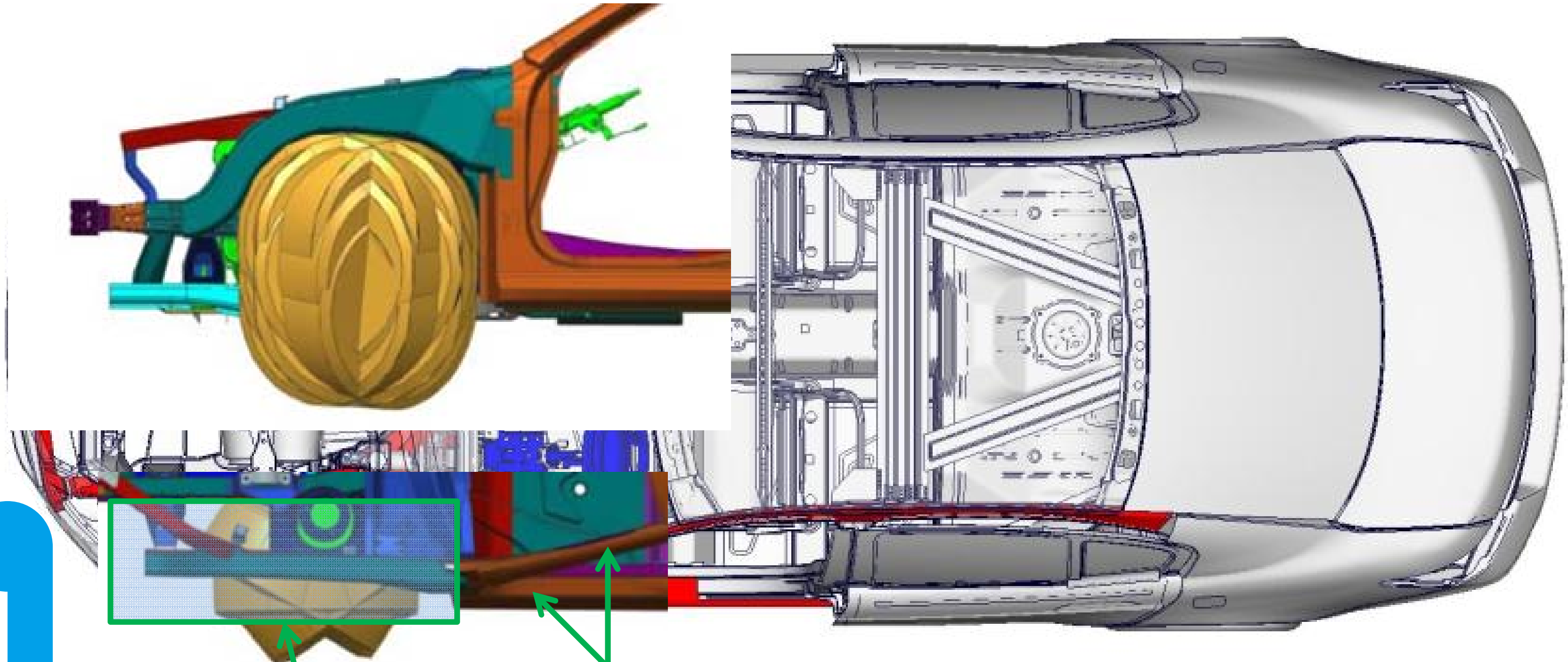


IIHS SOL Tests Results; Main Observations

On most vehicles the 25 percent offset barrier is out-board of the main front-rail structure of the vehicle. On review of several IIHS crash videos, it was noticed that vehicles that do not perform well in the test shows the following characteristics:

- The front frame rail structure does not engage the barrier and hence does not play a significant role in slowing the vehicle down.
- There is significant failure of the suspension and drive components, such as control arm, knuckle, drive-shaft, steering link, ball joints, wheel rim and tire.
- The tire wheel assembly is pushed hard into the 'Front Body Hinge Pillar' structure, causing the "A Pillar' and 'Rocker Section' to collapse
- The failures of the 'A Pillar' and the 'Rocker' lead to excessive penetration of the Dash Panel, Instrument Panel and Steering Column/Wheel into the passenger compartment. This collection of structural failures also leads to lateral movement of the steering wheel thus displacing the driver airbag.

IIHS SOL Tests Results; Main Observations



Rocker and A Pillars premature collapse on most pre 2013 vehicles during the test

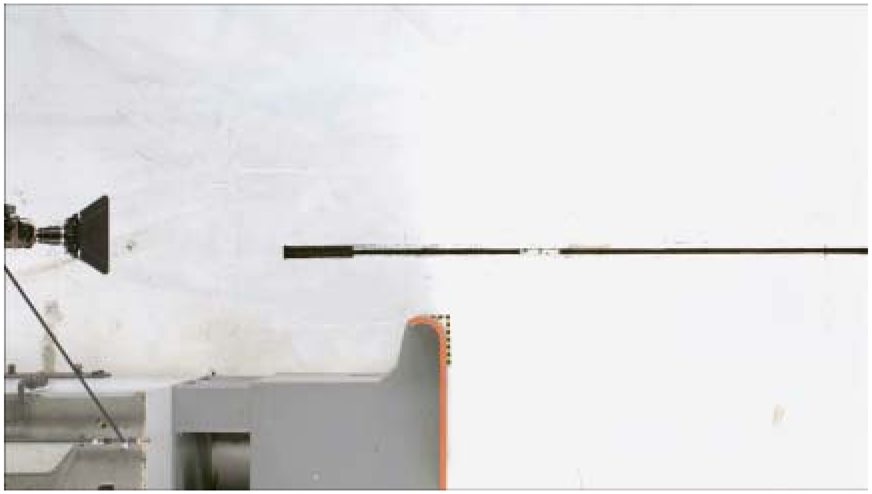
Energy absorbing structural elements not designed for 25% Overlap (pre 2013 vehicles)

IIHS SOL Tests
Vehicle Structure Design Strategy

1. Redesign front structure to 'Deflect' vehicle off the barrier (reduce impact velocity)
2. Add structure to 'Absorb' energy
3. 'Reinforce' the passenger compartment structure to reduce excessive deformation

Chevrolet 2014 Equinox – Rating Good
Test Video (CEN1401)

Acura 2014 MDX – Rating Good
Test Video (CEN1339)

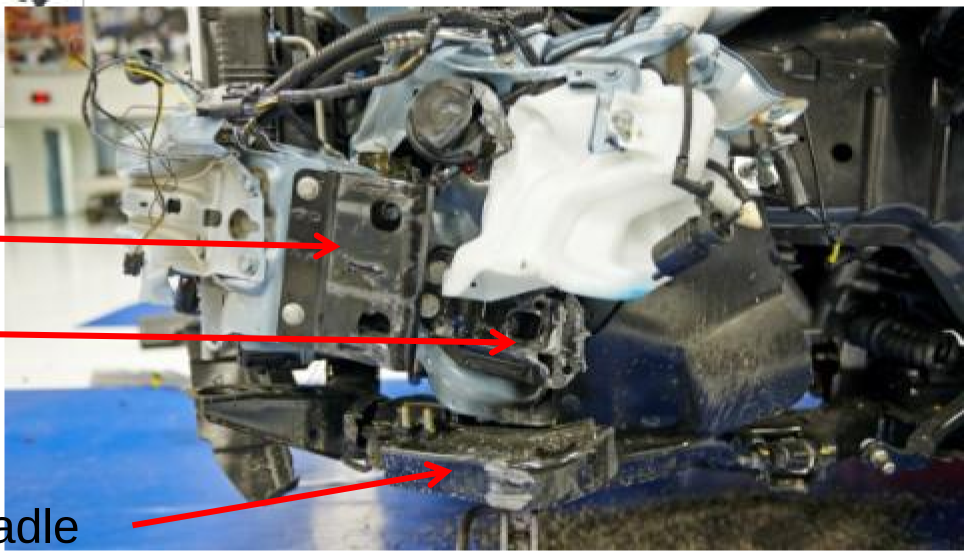


IIHS SOL Test – 2014 Chevrolet Equinox (CEN1401) Vehicle Structure Design Strategy

No A Pillar collapse

2014 Chevrolet Equinox
Rating Good

Roof Strength SWR – 4.17



Deflector 1 - Bumper

Deflector 2 – attached to front rail

Deflector 3 – attached to engine cradle

IIHS SOL Test – 2014 Chevrolet Equinox (CEN1339)
Vehicle Structure Design Strategy

2014 Acura MDX – Rating Good

Roof Strength SWR – 5.87

No A Pillar collapse

Hot stamped UHSS

Triangular tie in below rail

Bumper beam bolt on attachment

Minimal Door Damage

Minimal Rocker(Sill) Damage

IIHS SOL Test – Light Weight Vehicle
Vehicle Structure Design Strategy

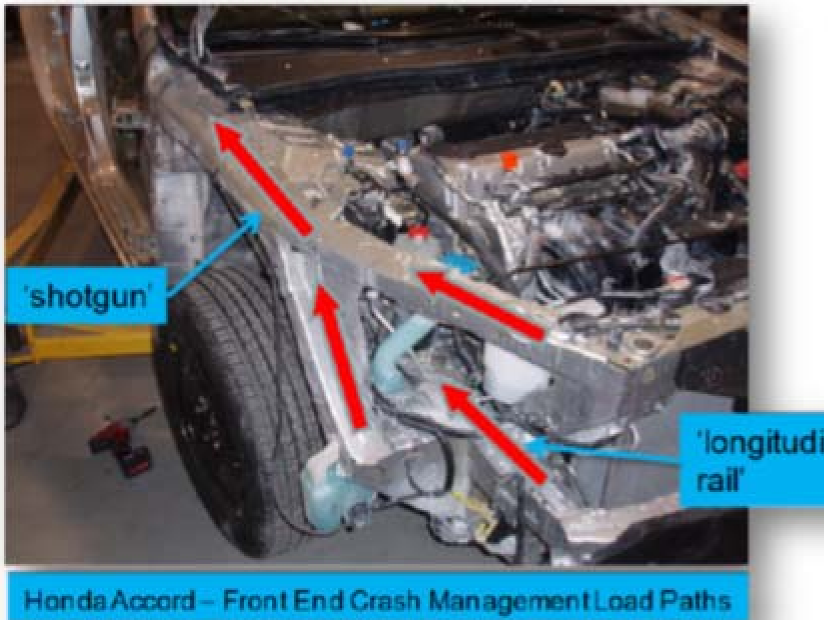


Figure 88: Honda Accord Front Structure

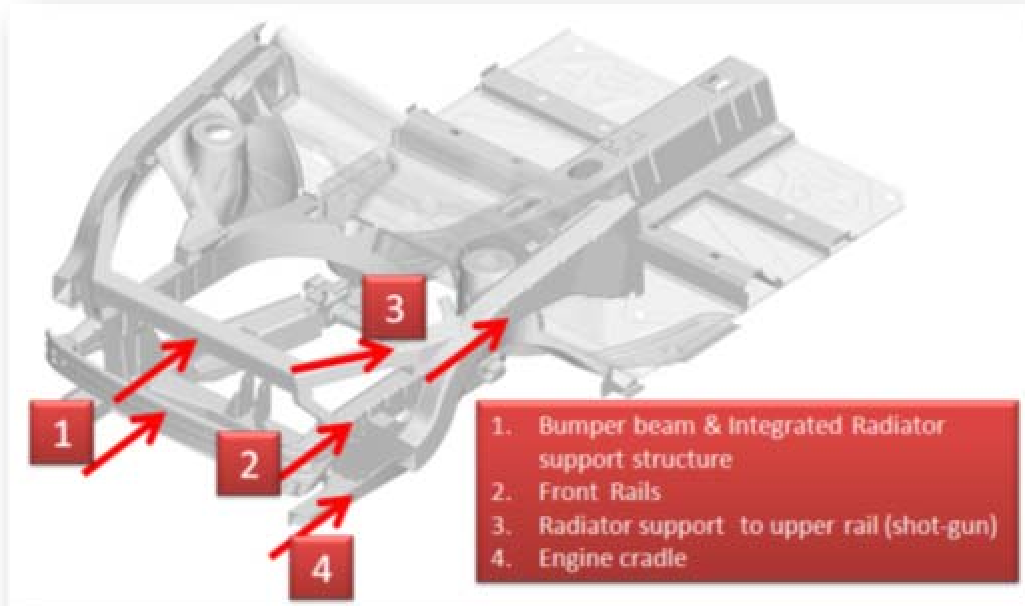
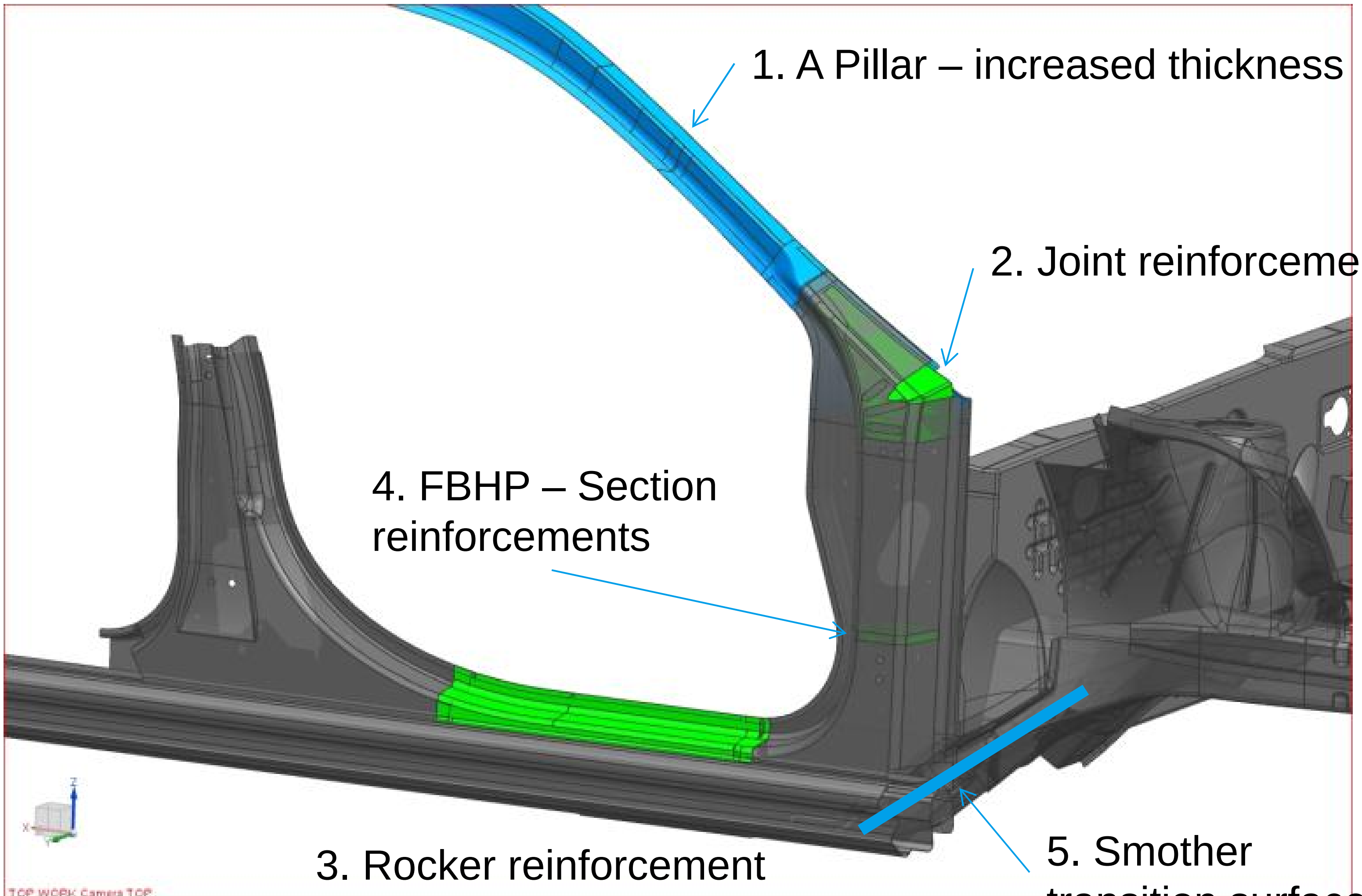


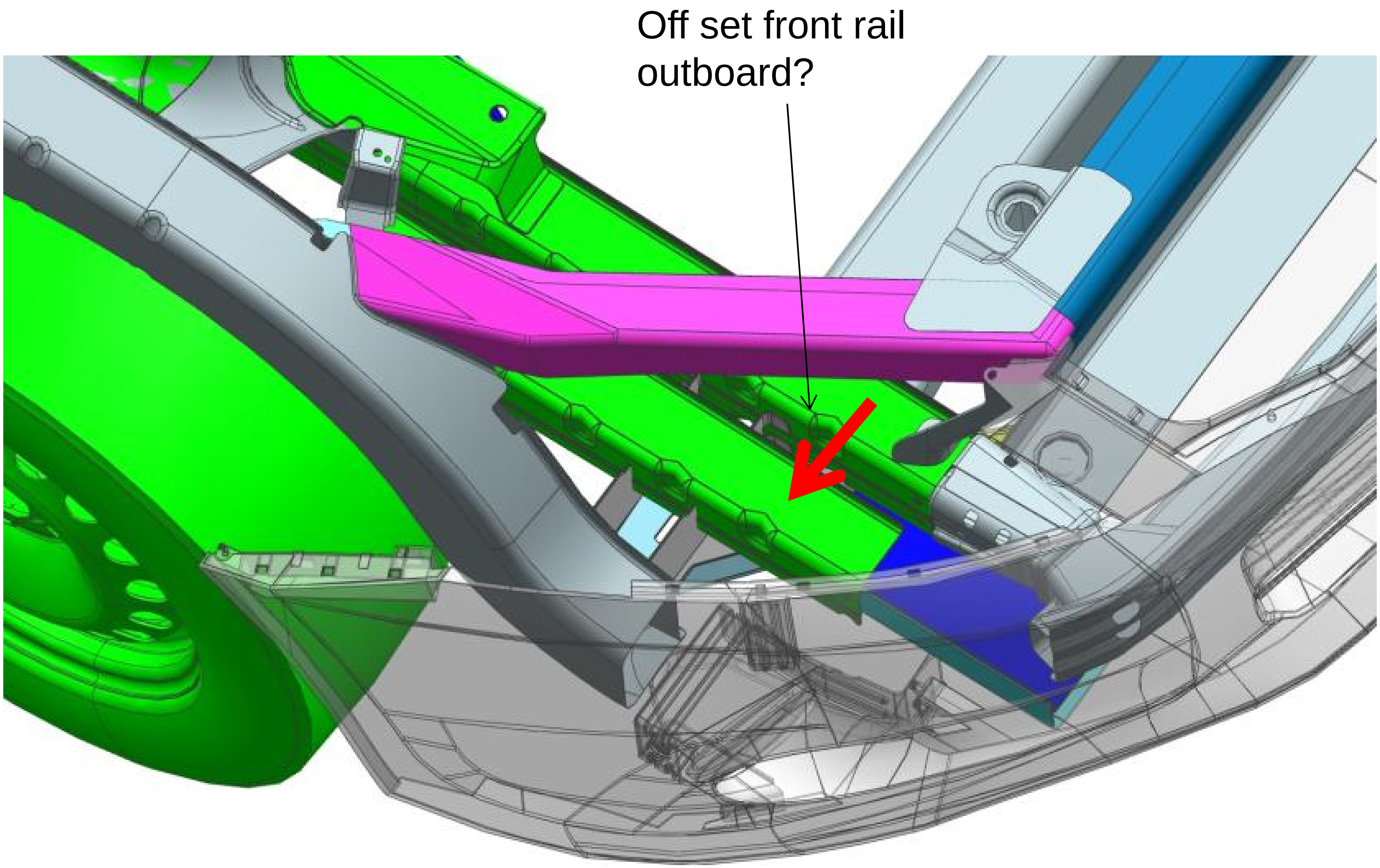
Figure 89: LWV Front Structure Load Paths

1. Redesign front structure to 'Deflect' vehicle off the barrier (reduce impact velocity)
2. Add structure to 'Absorb' energy
3. 'Reinforce' the passenger compartment structure to reduce excessive deformation

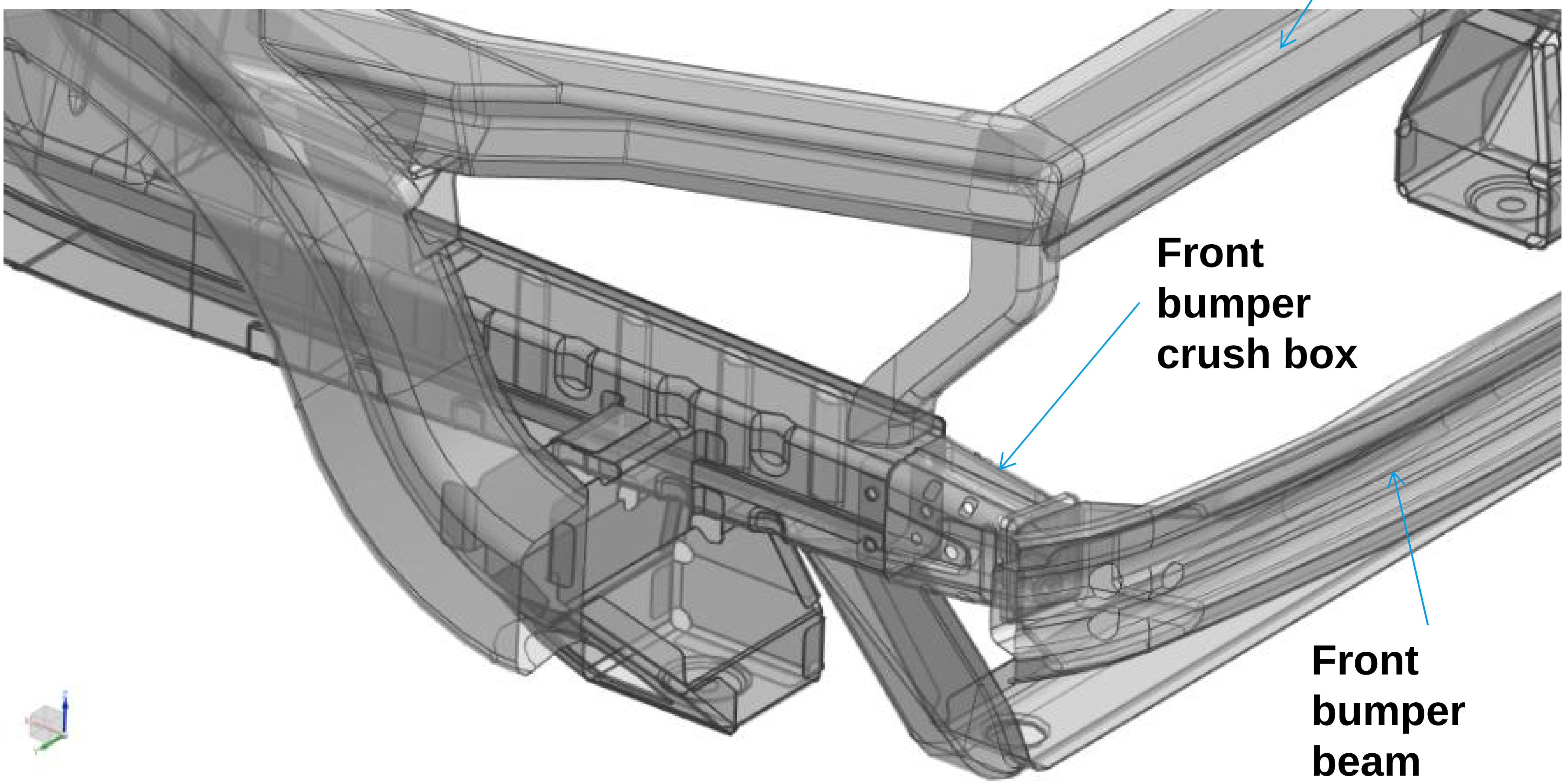
IIHS SOL Test – Light Weight Vehicle
Vehicle Structure Design Ideas



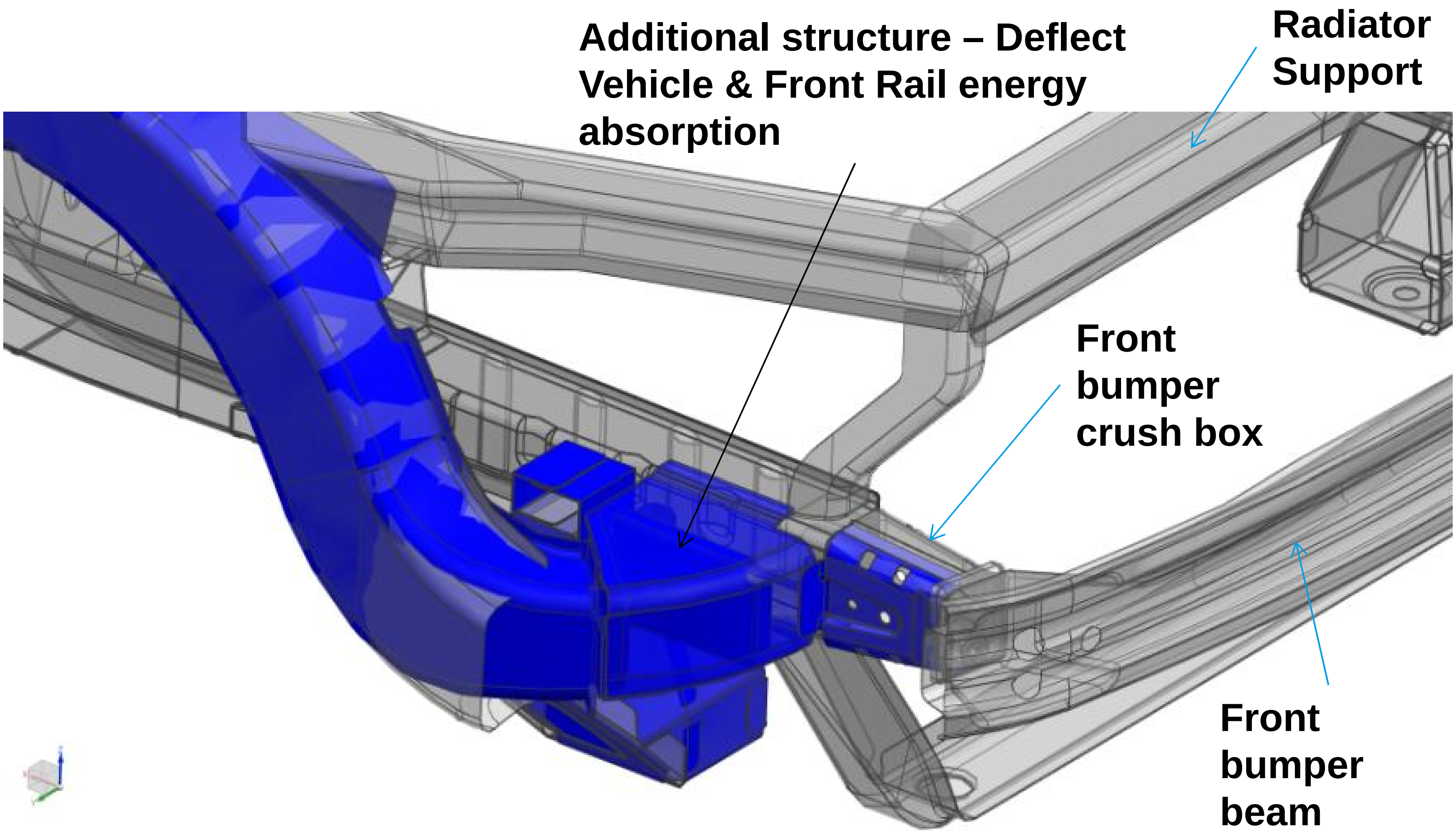
IIHS SOL Test – Light Weight Vehicle
Vehicle Structure Design Ideas



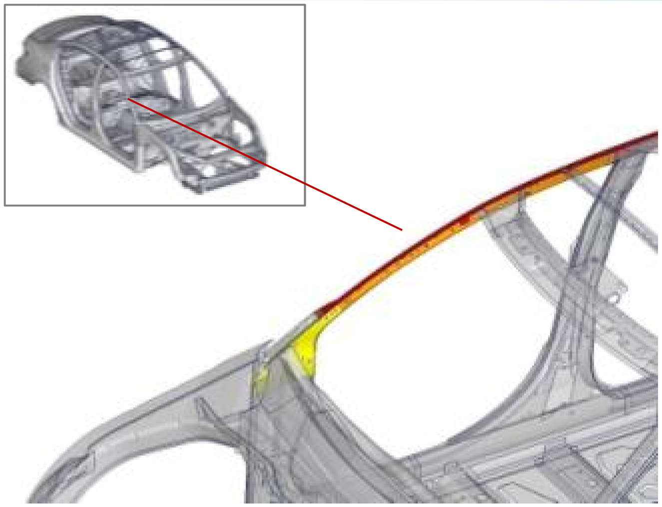
IIHS SOL Test – Light Weight Vehicle
Vehicle Structure Design Ideas



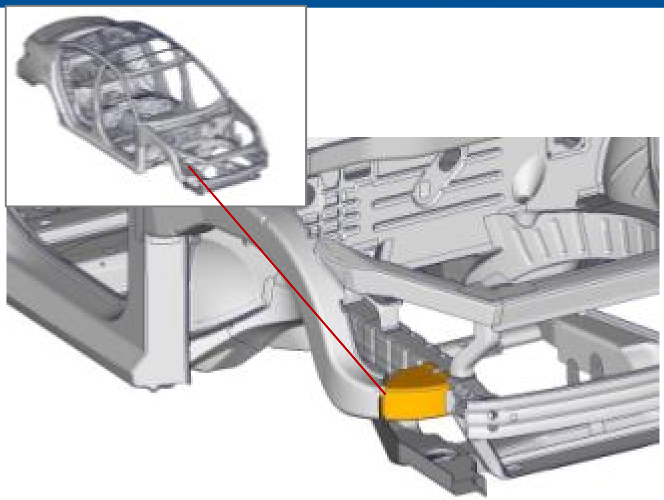
IIHS SOL Test – Light Weight Vehicle
Vehicle Structure Design Ideas



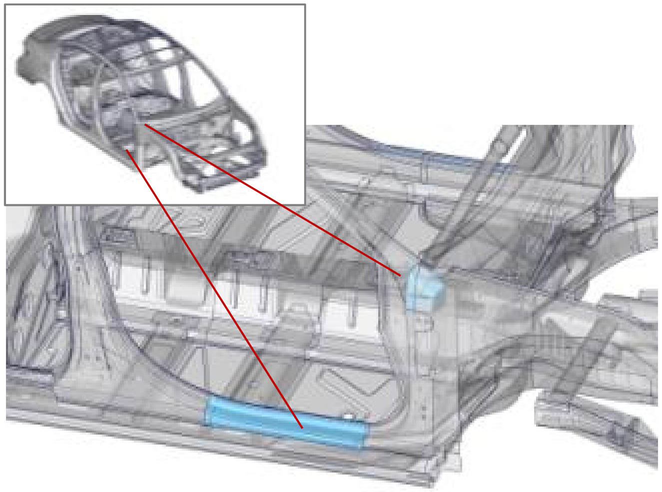
IIHS SOL Test – Light Weight Vehicle
Vehicle Structure Design Ideas



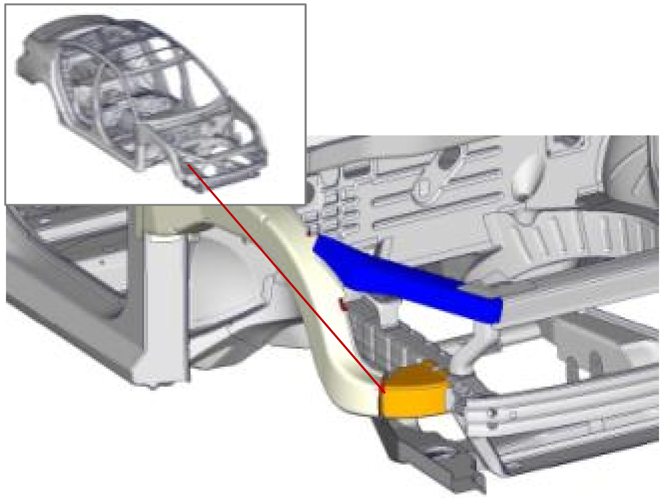
V001
+ 4.84 kg



V003
+ 4.32 kg

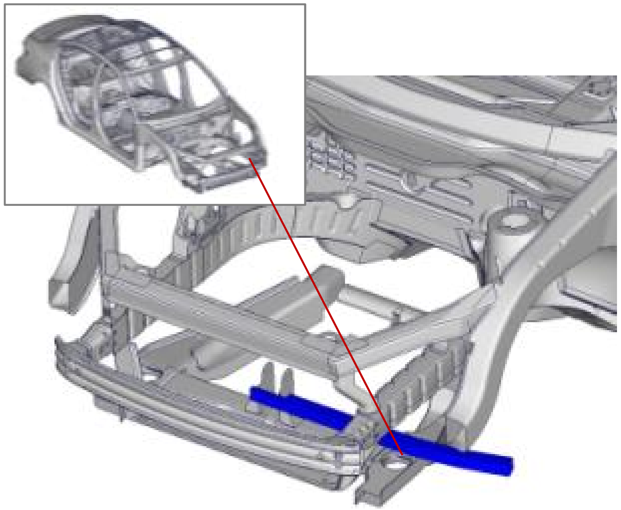


V002
+ 1.81 kg

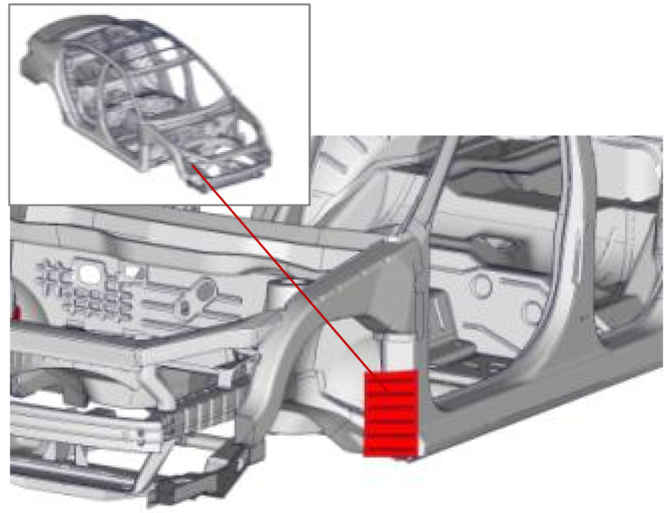


V003a
+ 13.36
kg

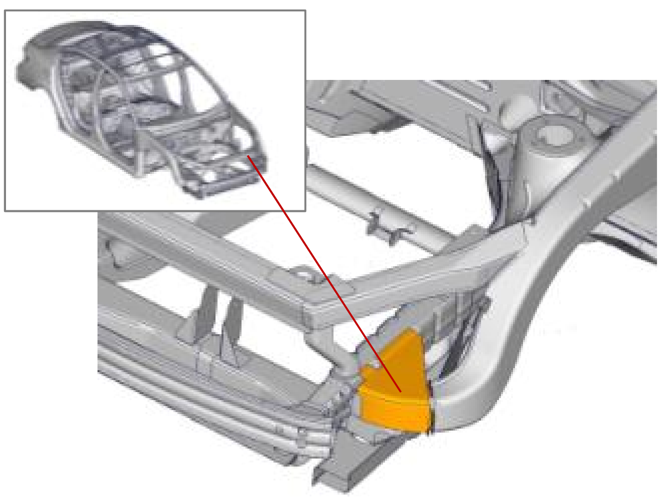
IIHS SOL Test – Light Weight Vehicle
Vehicle Structure Design Ideas



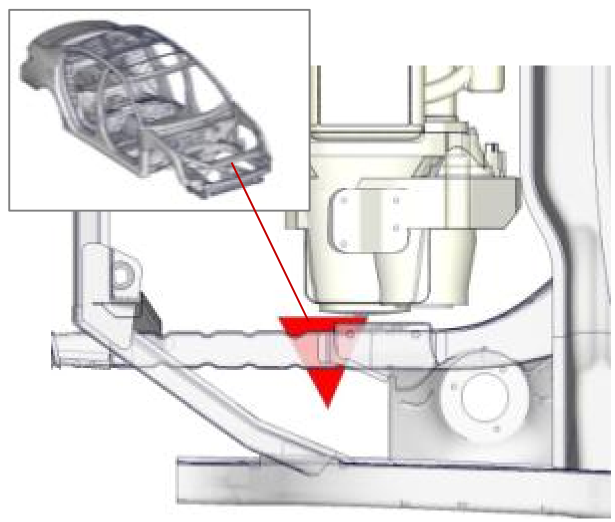
V004
+ 2.12 kg



V006
+ 1.31 kg



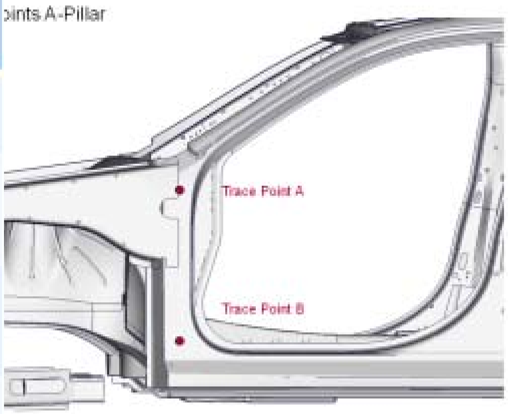
V005
+ 5.72 kg



V007
+ 0.54 kg

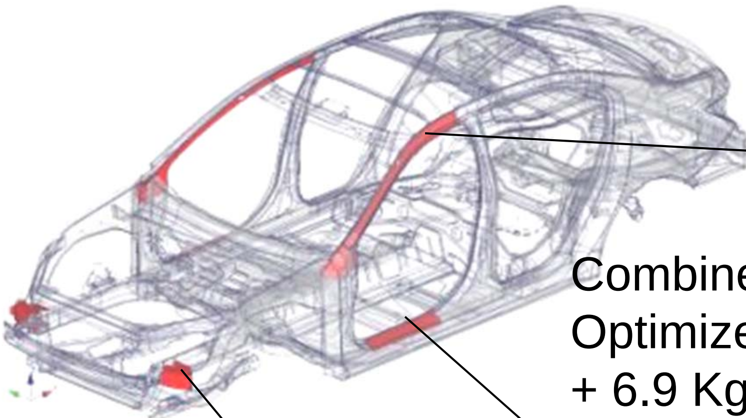
IIHS SOL Test – Light Weight Vehicle
Design Ideas- Selected for detailed design and optimization

Variant			X-Displ A In mm	X- Displ B In mm	Add Weight In Kg	
V000 Baseline Model			95.4	59.6		
V001		R	39.2	34.0	4.84	★
V002		R	68.0	41.5	1.81	★
V003		D, A	67.8	51.8	4.32	★
V003a		D, A	73.1	25.4	13.36	
V004		R, A	68.6	30.9	2.12	
V005		D, A	69.1	50.3	5.72	
V006		D	129.5	53.4	1.31	
V007		D	67.4	46.6	0.54	

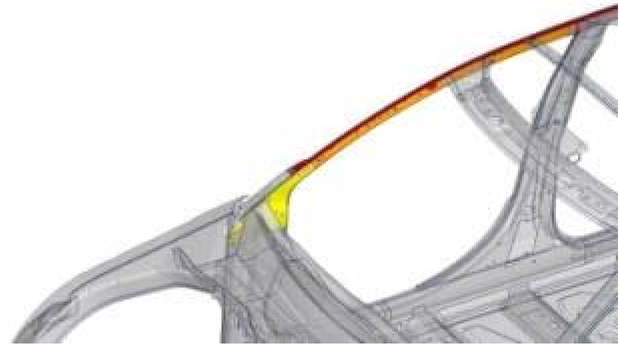


D – Deflect
A – Absorb
R – Reinforce

IIHS SOL Test – Light Weight Vehicle Design Ideas- Optimized Design Solutions

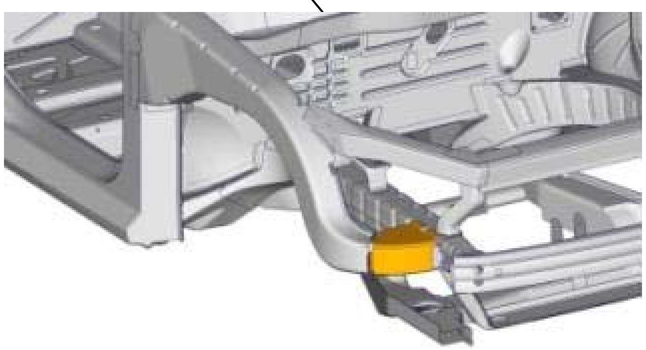


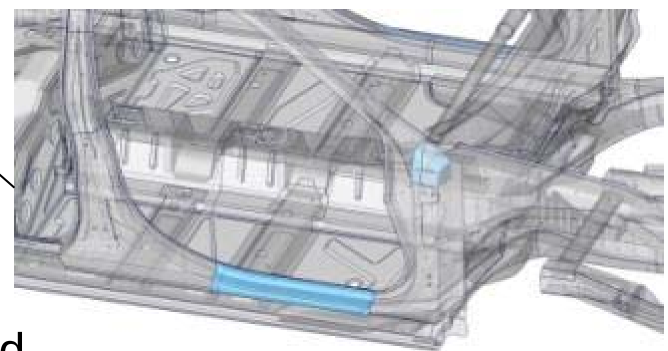
Combined
Optimized Design
+ 6.9 Kg



Panel thicknesses increased

1.1 > 2.0, 0.9 > 1.8

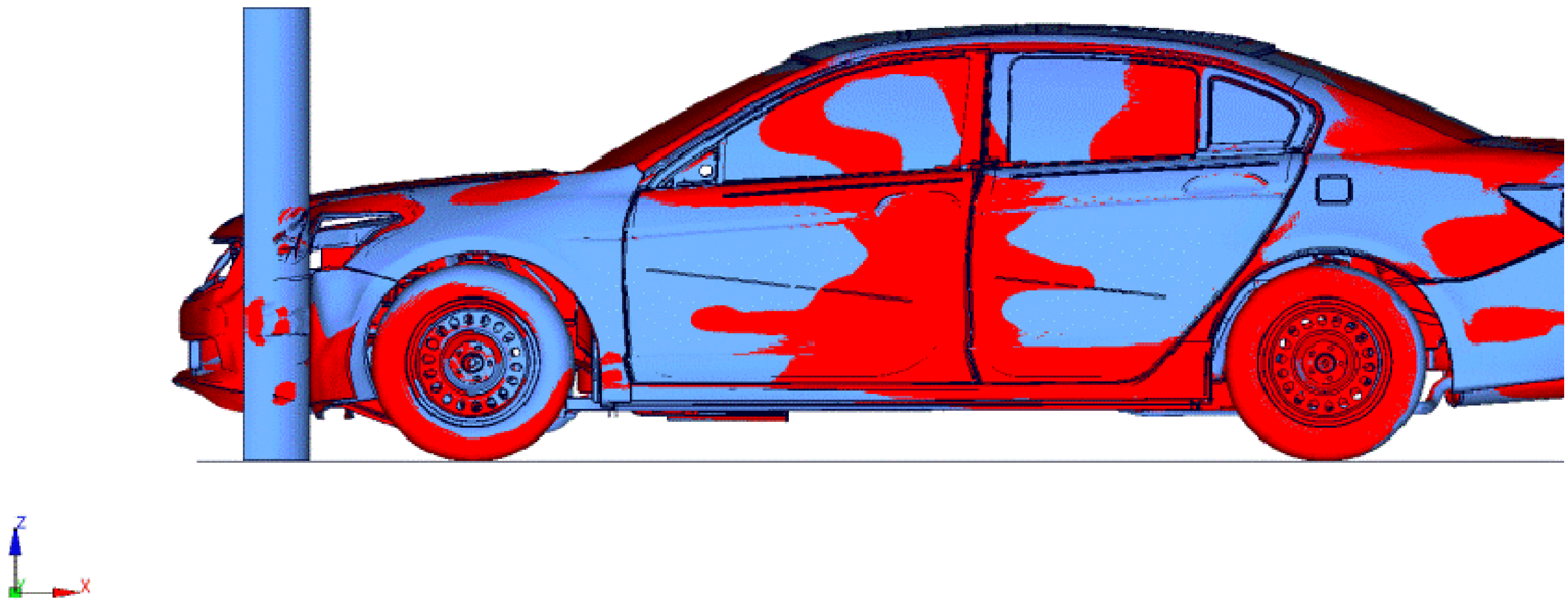




Additional parts and
parts integration

IIHS SOL Test – Light Weight Vehicle
Optimized Design Solutions: Results Comparison

- LWV 1.1 - baseline model
- LWV 1.2 – baseline with SOL changes



animation

IIHS SOL Test – Light Weight Vehicle
Optimized Design Solutions: Results Comparison

- LWV 1.1 - baseline model
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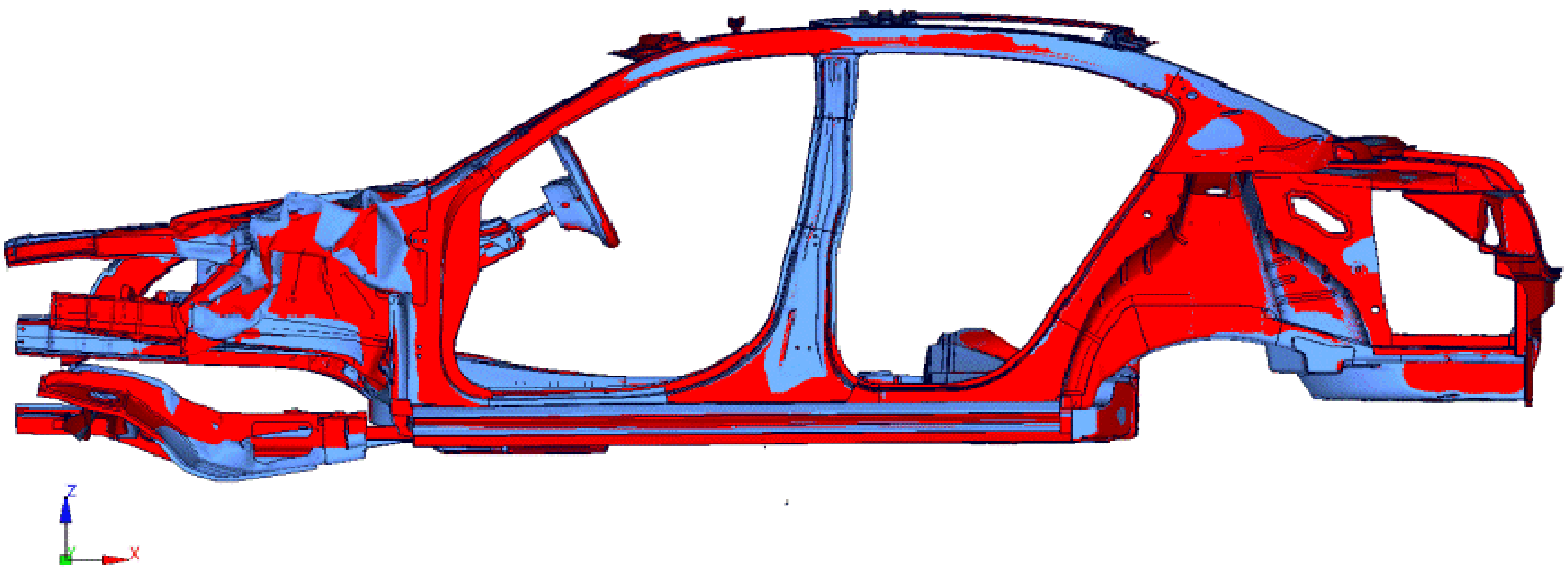

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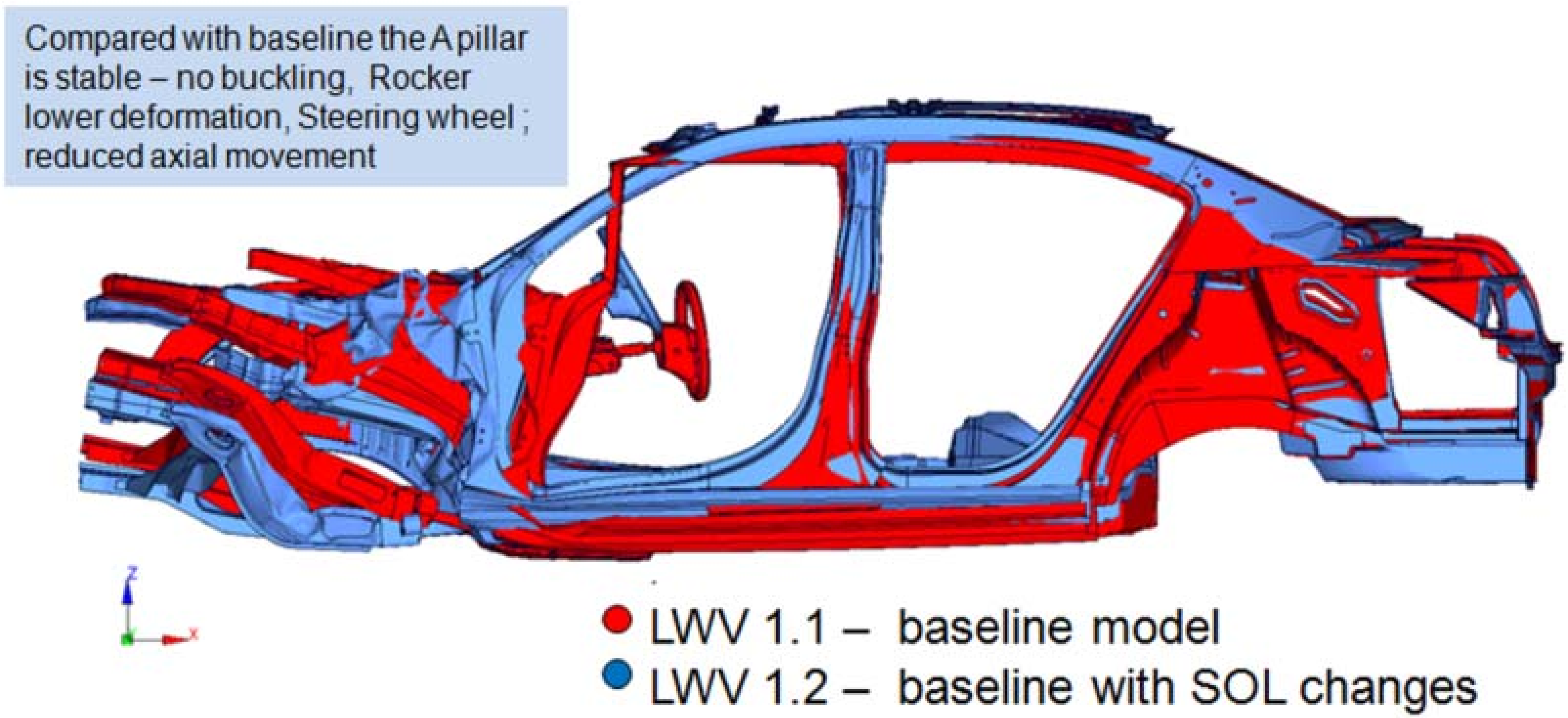
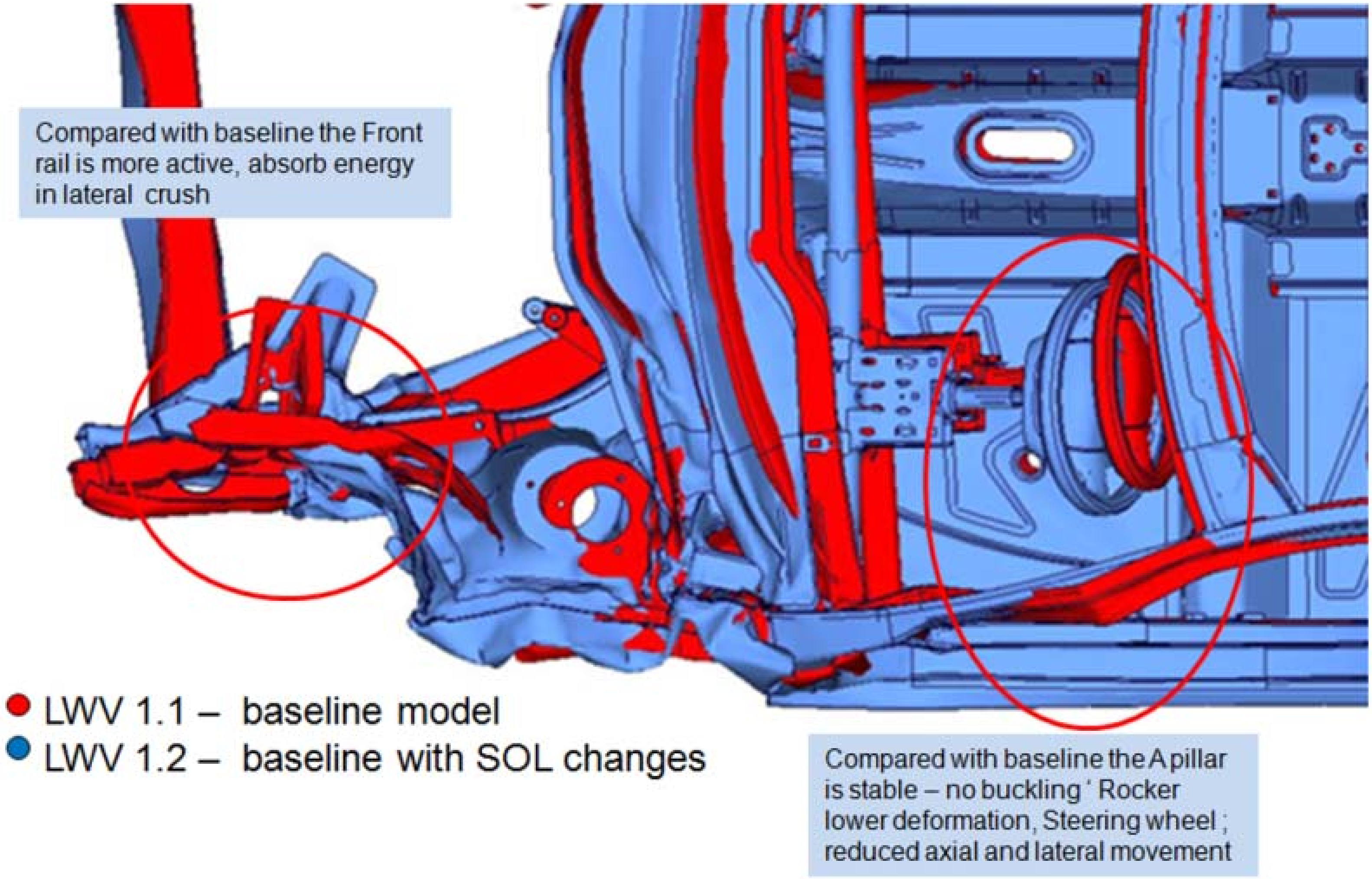
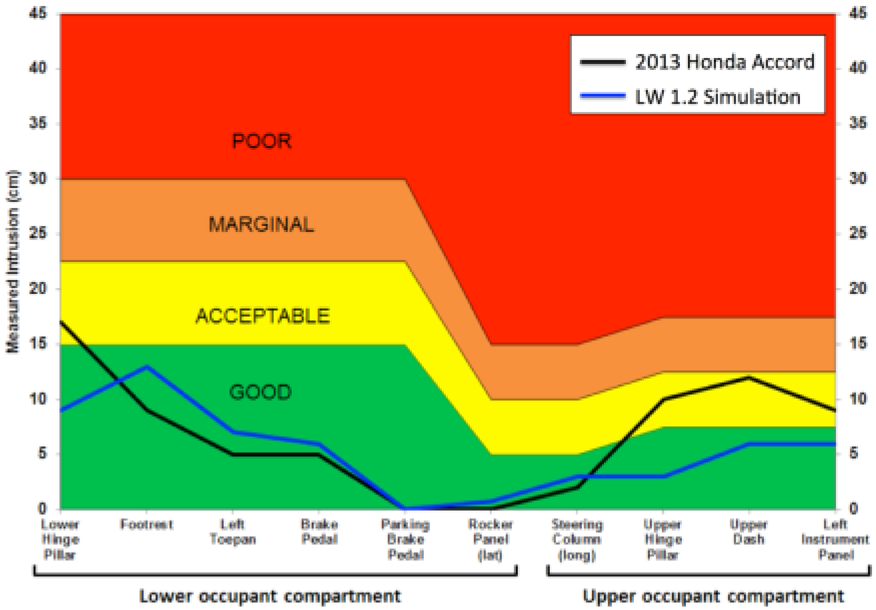
IIHS SOL Test – Light Weight Vehicle
Optimized Design Solutions: Results Comparison

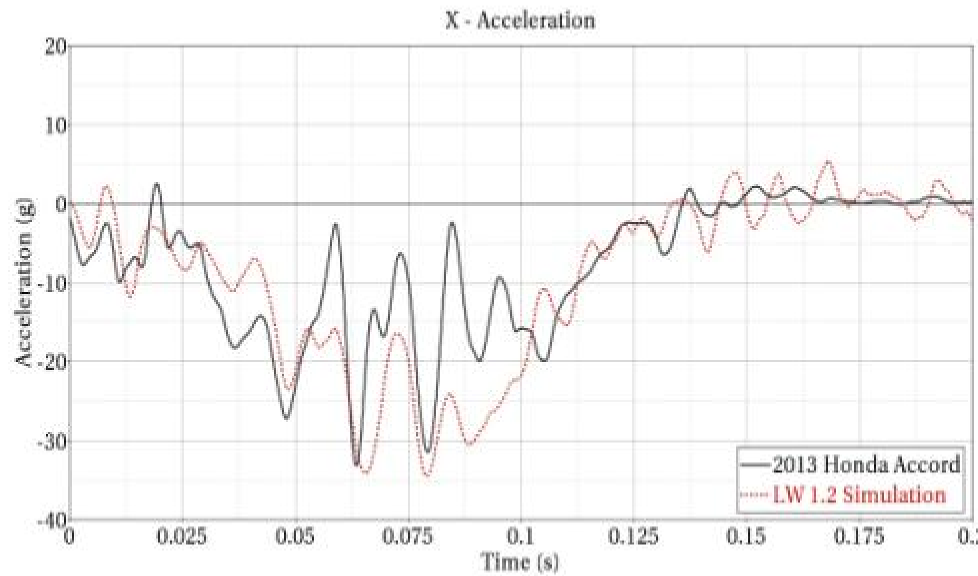


IIHS SOL Test – Light Weight Vehicle
Optimized Design Solutions: Results Comparison



IIHS SOL Test – Light Weight Vehicle
Results Comparison with 2013 Honda Accord test (CEN1229)





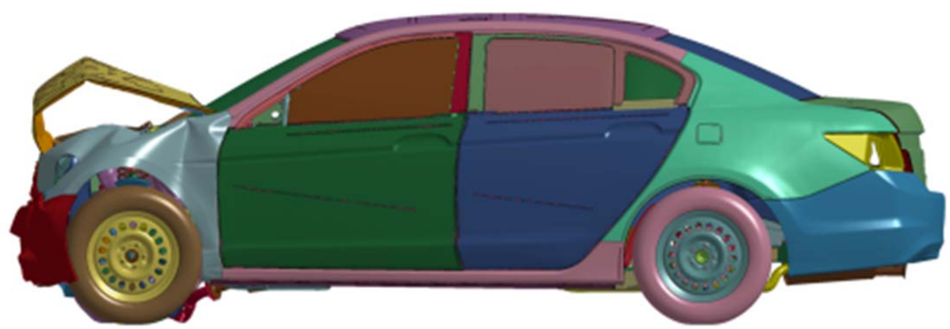
Intrusions of MY2013 Accord and the LWV 1.2 on the IIHS structural measuring scheme

Crash pulse in the x-direction for the center of gravity of the MY2013 Honda Accord and the LWV 1.2 in IIHS SOL impact

Light Weight Vehicle LSDYNA crash model
Simulation Comparation for Other Impact Conditions

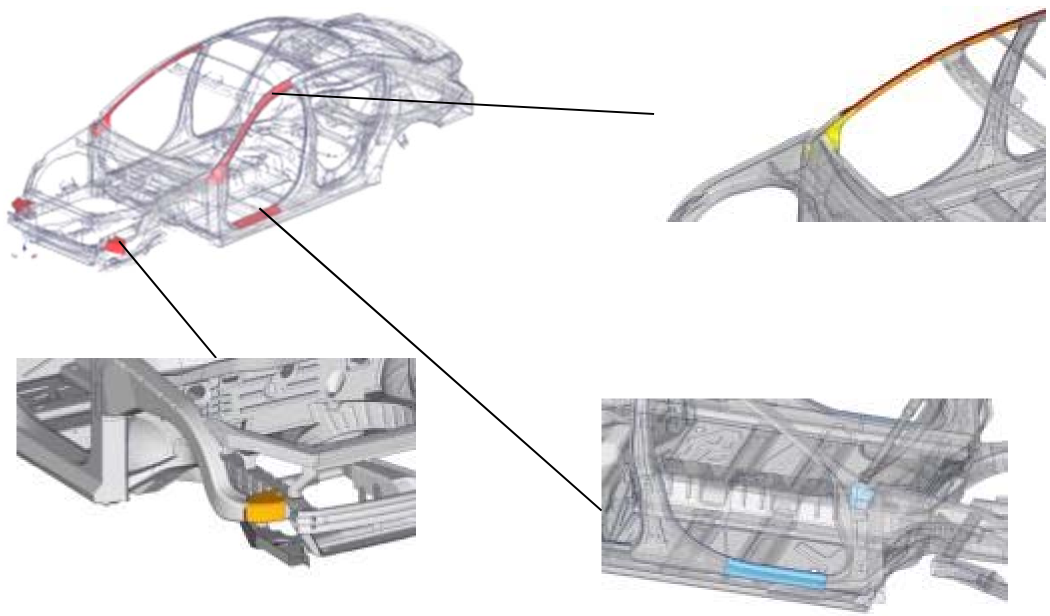
Simulation under different impact conditions were performed and results compared to the following full-scale crash tests:

1. Frontal Full Wall – 56 km/h
2. Lateral NCAP MDB – 62 km/h
3. Frontal 40% Offset – 64 km/h
4. IIHS Lateral MDB – 50 km/h
5. Side Pole Impact –   km/hr
6. Roof Crush – Quasi-static
7. Small Overlap (SOL) – 64 km/h



IIHS SOL Test – Light Weight Vehicle
Weight and Cost Increase to Meet SOL Requirements

Due to the design changes made to the LWV structure to meet SOL test requirements, the mass of the body structure increased by 6.90 kg with a cost increase of $26.88. The cost is calculated for part manufacture and assembly to the body structure during body build (production volume 200,000 annual).



Thank you for your time

Questions?

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