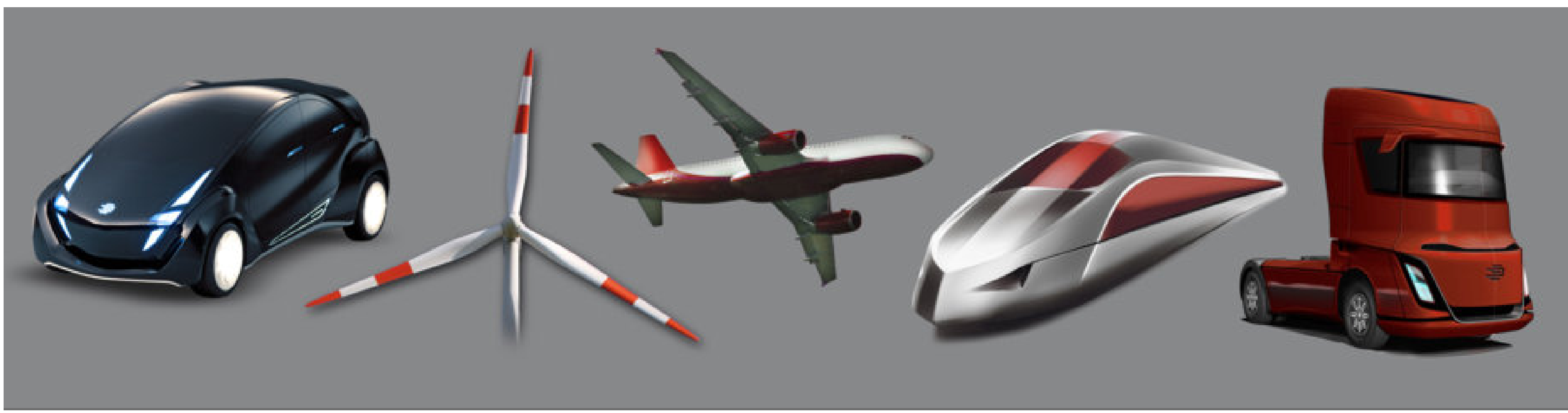
Feasible Amount of Mass Reduction for Light Duty Vehicles for Model Years 2017-2025

Under Contract DTNH22-11-C-00193



NHTSA Workshop - May 2013 – H. Singh (harry.singh@edag-us.com)

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Presentation Content

Range of EDAG and FFT Services

PRODUCT DEVELOPMENT

Design concepts

Vehicle development

Function development

Vehicle validation

Electrics / electronics

Project management

Quality and documentation management

IT services

Process consulting

FEYNSINN

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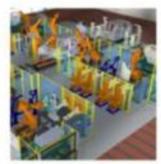
PRODUCTION SOLUTIONS

Control engineering and automation technology

Production engineering



Production process planning

Factory and logistics planning

Tooling and vehicle body systems

PLANT CONSTRUCTION

FFT

Turnkey systems, body in white and assembly

System technologies and products

Wherever You Need Us - Worldwide

Partner Companies

Chartered in 1992, the NCAC at The George Washington University's Virginia Campus is one of the nation's leading authorities in automotive and highway safety research.

Since its inception, Electricore has had a successful history of collaboration with the departments of Defence, Energy and Transportation in the development, demonstration and deployment of advanced technologies.

Lightweighting Program Setup

Electricore:
Management & Communications

NHTSA Interface

EDAG CAE Support:
- Optimization
- Crashworthiness
- Torsional Stiffness
- Normal Modes
- Durability
- Ride & Handling

EDAG Computer (USA):
- 480 CPU – Cluster
- 10 Full vehicle crash models can be run at the same time. Typical run time 3 hours for 10 runs
- 20 – High performance work stations for local analysis of smaller FEA models
- Additional computer resource available from Germany Fulda

EDAG

Design, Engineering & CAE Support

EDAG Engineering
- Bench Marking
- Material Selection
- Technology assessment
- Costing

GWU – Support
- Crashworthiness – Equivalent NCAP & IIHS safety ratings
- Final deliverable CAE models

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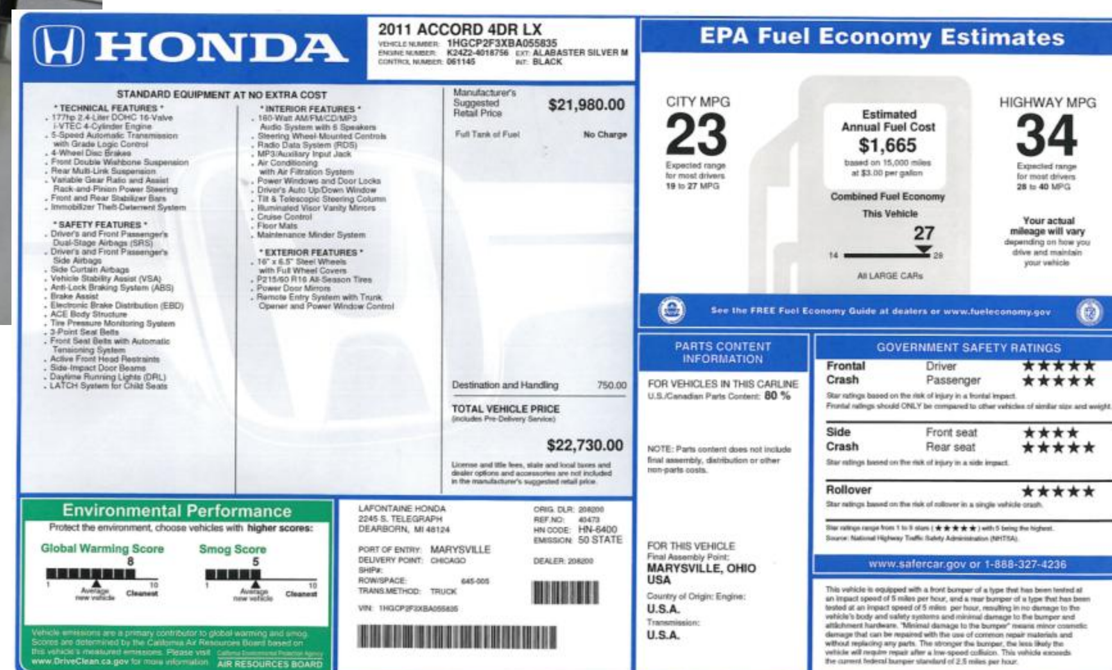
Major Boundary Conditions

1. Baseline vehicle 2011 Honda Accord
2. Maintain retail price parity (±10%* variation) with the baseline vehicle ($21,980 MSRP)
3. Maintain vehicle performance and functionalities, including
   1. Safety: NHTSA's New Car Assessment Program (NCAP) frontal, side, side pole and IIHS test programs through appropriate crash simulations.
   2. Powertrain may be downsized
   3. Alternate powertrain configurations (i.e. hybrid electric, battery electric, and diesel) will not be considered.
4. All advanced design, material, technologies and manufacturing processes must be realistically projected to be available for fleet wide production in time frame of model years 2017-2025 and capable of high volume production (200,000 units per year).
5. Achieve the maximum feasible amount of mass reduction within the constraints.
6. Deliver a detailed CAE model to NHTSA suitable for further occupant safety related work.

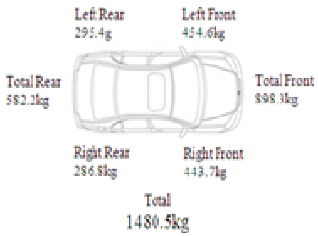
*10% of the baseline MSRP equals to $2198 or $1495 direct manufacturing cost using RPE of 1.47; based on 2011 Honda Accord 4DR-LX

Baseline Vehicle 2011 Accord 4DR LX



BENCHMARKING

Vehicle Benchmark/Teardown Process



Determine and acquire baseline vehicle

Review, weigh and photo vehicle

Exterior and interior scan

Vehicle teardown

Vehicle structure exterior & interior re-scan

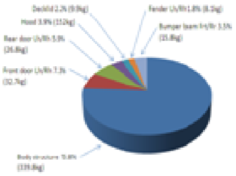
Body structure test. Normal modes, torsion & bending

Data to design team for interpretation & evaluation

Part data collection

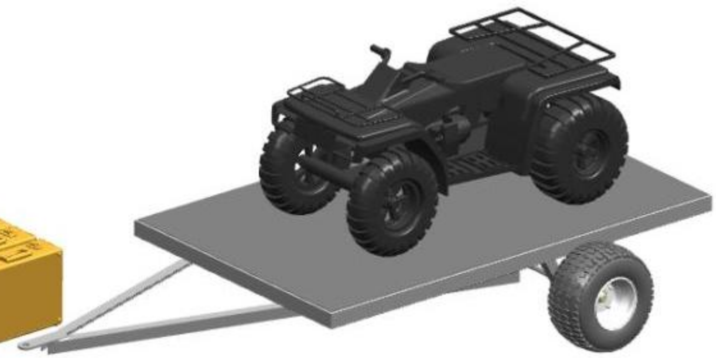
Analysis of collected data

Generate Bill Of Material (BOM) with collected data



Vehicle Pay Load – Mid Size Sedan (Baseline Vehicle)

Occupants
Luggage
Towing (occasional up-to 1000 lbs)

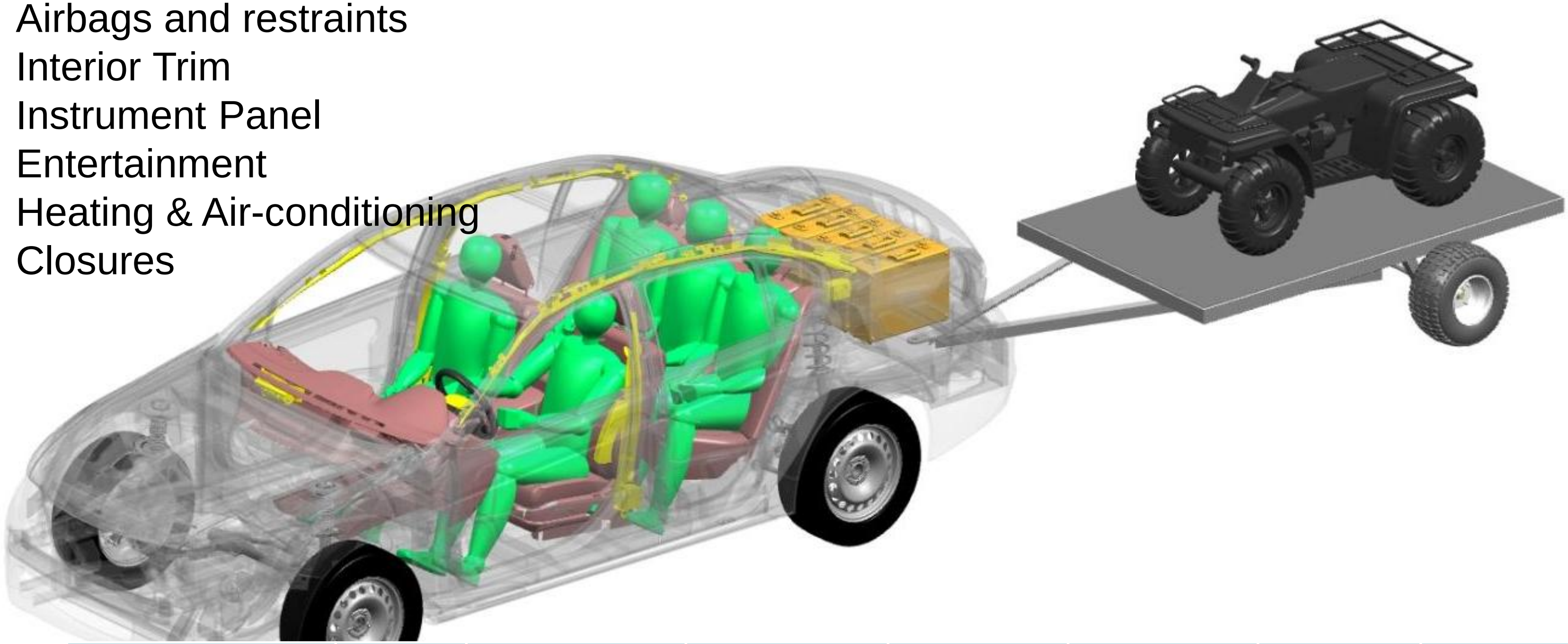


Carry Pay load over 500 miles: Comfort, Safety, Entertainment, Day or Night, Rain or Shine, Max vehicle speed 112 MPH, 0-60 MPH in 8-10 seconds

Mass (kg)	Pay-load	Non Structural	Body Structure	Chassis	Power train	CVW	GVWR
Baseline Vehicle	470	465.1	343.8	287.8	383.3	1480	1950
% of GVWR	24%	24%	18%	15%	20%		

Non Structural Weight

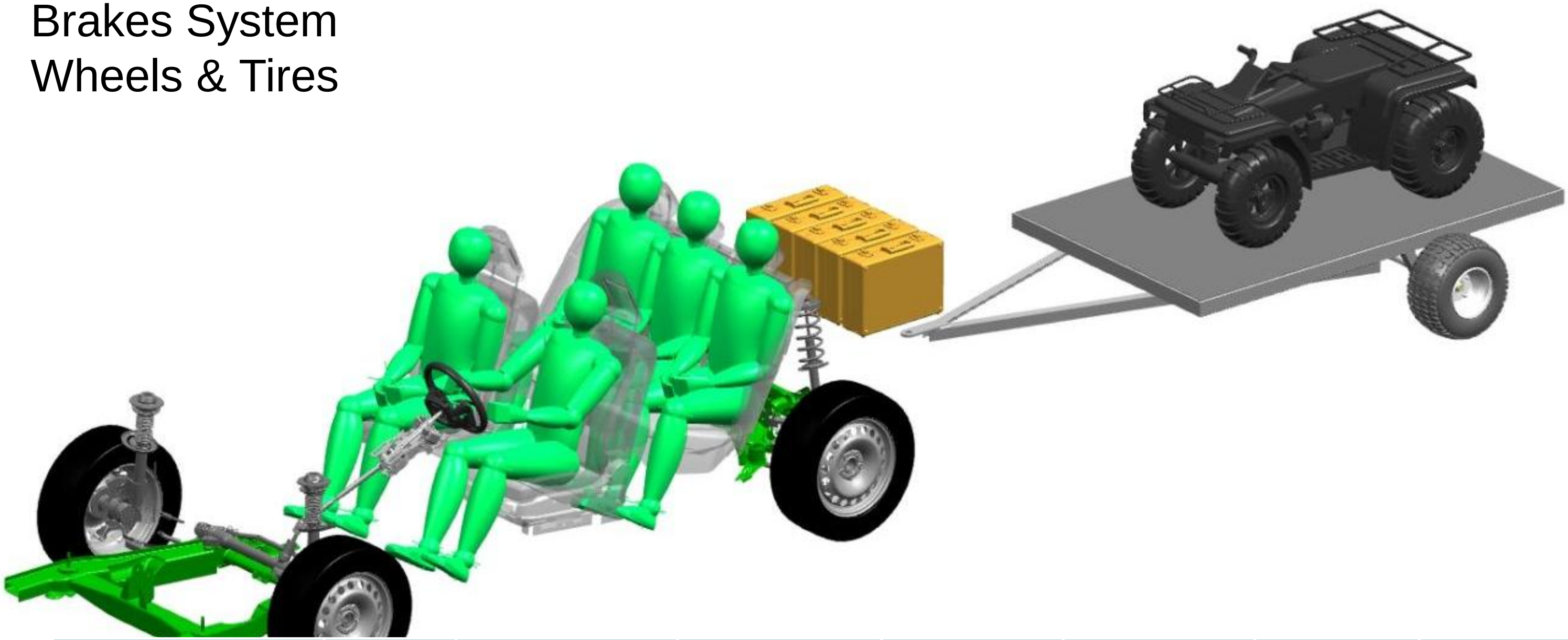
- Seats
- Airbags and restraints
- Interior Trim
- Instrument Panel
- Entertainment
- Heating & Air-conditioning
- Closures



Mass (kg)	Pay-load	Non Structural	Body Structure	Chassis	Power train	CVW	GVWR
Baseline Vehicle	470	465.1	343.8	287.8	383.3	1480	1950
	24%	24%	18%	15%	20%		

Chassis Weight

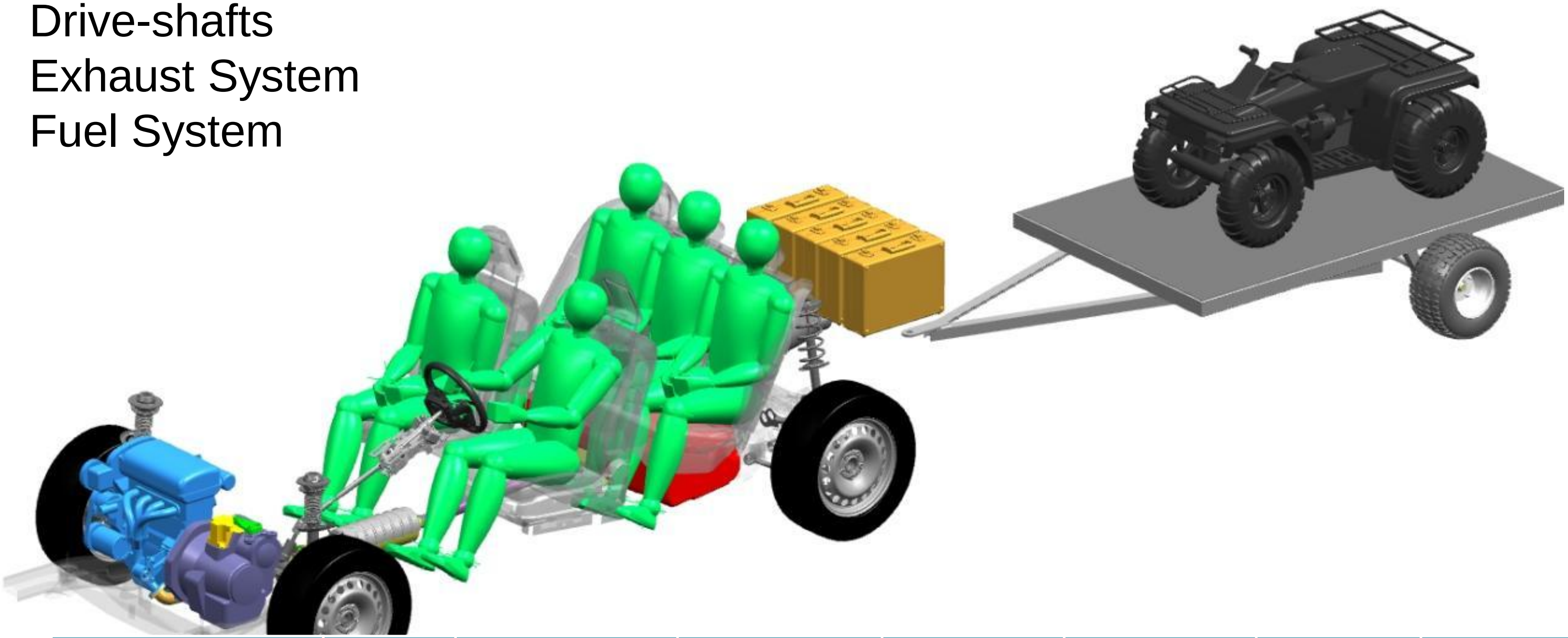
Front and rear suspensions
Brakes System
Wheels & Tires



Mass (kg)	Pay-load	Non Structural	Body Structure	Chassis	Power train	CVW	GVWR
Baseline Vehicle	385	465.1	343.8	287.8	383.3	1480	1950
	21%	24%	18%	15%	20%		

Powertrain Weight

Engine & Transmission
Drive-shafts
Exhaust System
Fuel System

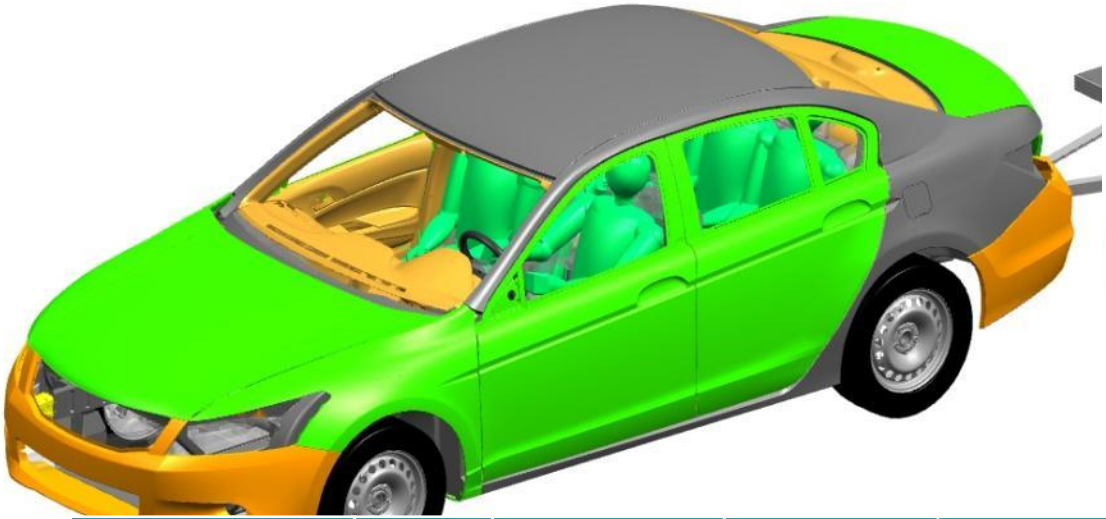


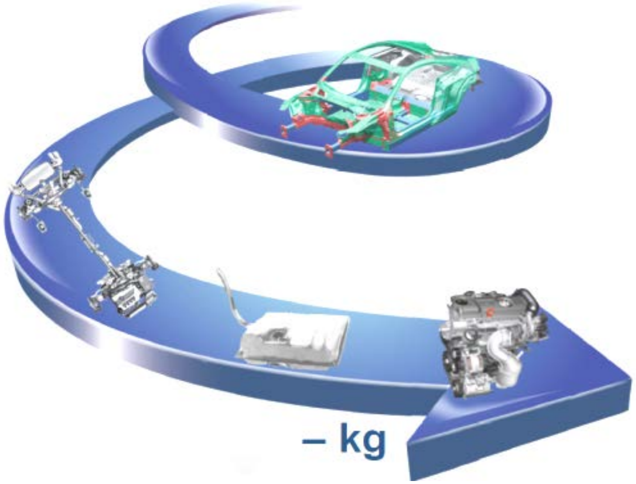
Mass (kg)	Pay-load	Non Structural	Body Structure	Chassis	Power train	CVW	GVWR
Baseline Vehicle	385	465.1	343.8	287.8	383.3	1480	1950
	21%	24%	18%	15%	20%		

Body Structure Weight

Body Structure
Front & Rear Bumpers

For 1 kg primary Mass reduction, there is up to 0.5 to 0.7 kg of secondary mass reduction





Mass (kg)	Pay-load	Non Structural	Body Structure	Chassis	Power train	CVW	GVWR
Baseline Vehicle	470	465.1	343.8	287.8	383.3	1480	1950
	24%	24%	18%	15%	20%		

LIGHT- WEIGHTING DESIGN OPTIONS

Material & Manufacturing Technologies

M - Mature	Available now for high volume production - time base learning
MT - Mid term	At present suitable for low volume (up to 50,000) production - for high volume require further development
LT - Long Term	At present suitable for very low volume (up to 10,000) production - for high volume require further development

		Body Structure		Closures		Chassis, Engine, Transmission	
		2011	2020	2011	2020	2011	2020
Steel	Steel	M	M	M	M	M	M
	Stamping	M	M	M	M	M	M
	Regular	M	M	M	M	M	M
	LWB	M	M	M	M	M	M
	TRB	M	M	M	M	M	M
	Hot	M	M	M	M	M	M
	Roll Forming	M	M	M	M	M	M
	Hydroforming	M	M	M	M	M	M
	Forging					M	M
	Casting					M	M
	Powder Metal					M	M
Aluminum	Aluminum	MT	M	M	M	M	M
	Stamping	M	M	M	M	M	M
	Regular	M	M	M	M	M	M
	LWB	M	M	M	M	M	M
	Super forming	LT	MT	LT	MT	LT	MT
	Roll forming	M	M	M	M	M	M
	Hydroforming	M	M	M	M	M	M
	Extrusion	M	M	M	M	M	M
	Casting HPD	M	M	M	M	M	M
	Forgings	M	M	M	M	M	M

Material & Manufacturing Technologies

M - Mature	Available now for high volume production - time base learning
MT - Mid term	At present suitable for low volume (up to 50,000) production - for high volume require further development
LT - Long Term	At present suitable for very low volume (up to 10,000) production - for high volume require further development

		Body Structure		Closures		Chassis, Engine, Transmission	
		2011	2020	2011	2020	2011	2020
Magnesium	**Magnesium**	LT	MT	MT	M	MT	MT
	Casting HPD	LT	MT	MT	M	MT	MT
	Forgings			MT	MT	MT	MT
	Stamping			LT	LT	LT	LT
	Warm forming			LT	LT	LT	LT
Plastics	**Plastics**	M	M	M	M	M	M
	Injection Molding	M	M	M	M	M	M
	PP + Glass	M	M	M	M	M	M
	Over Moulding (with insert)	MT	MT	MT	MT	MT	MT
	SMC	MT	MT	M	M	M	M
Composites	**Composites**	LT	LT	LT	LT	LT	LT
	FGRC (thermo-set)	LT	LT	LT	LT	LT	LT
	CFRC (Thermo Plastic)	LT	LT	LT	LT	LT	LT
	SMC	LT	LT	LT	LT	LT	LT
	RTM	LT	LT	LT	LT	LT	LT

Assembly Technologies

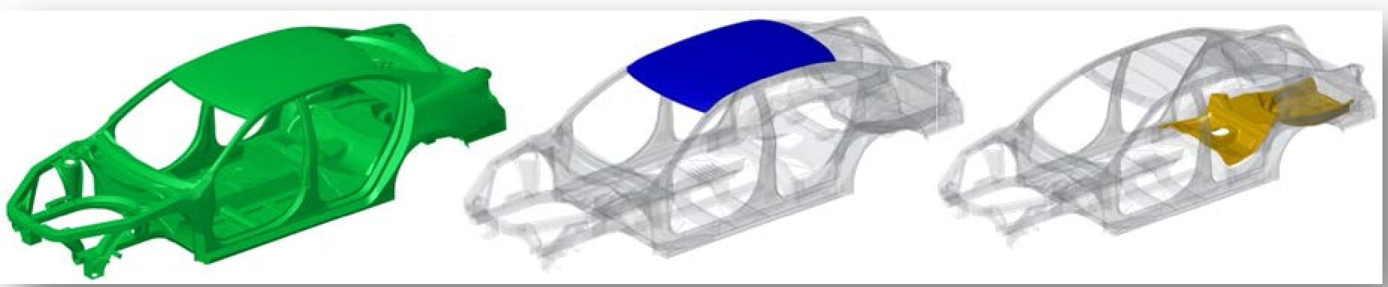
M - Mature	Available now for high volume production - time base learning
MT - Mid term	At present suitable for low volume (up to 50,000) production - for high volume require further development
LT - Long Term	At present suitable for very low volume (up to 10,000) production - for high volume require further development

		Body Structure		Closures		Chassis, Engine, Transmission	
		2011	2020	2011	2020	2011	2020
Manufacturing Assembly	Spot Welding	M	M	M	M		
	Laser Welding	MT	M	MT	M		
	Mig Welding	M	M	M	M	M	M
	Laser Brazing	M	M	M	M		
	Adhesive Bonding	MT	M	MT	MT		
	Mechanical Fastenings	LT	MT	MT	MT	M	M

Only mature (M) and limited number of mid-term (MT) technologies are used for the light-weighted design.

Body Structure Options

Options	Body Structure Construction Material	Baseline Honda Accord Mass	Mass Reduction			Incremental Cost Increase ($)	Cost Increase Premium ($ / kg)	Incremental from Option 1 ($ / kg)
			%	LWV Mass (kg)	Mass Savings (kg)			
Option 1	AHSS	328	22%	255.2	72.8	$147	$2.02	
Option 2	Body Structure - AHSS	306.79	23%	236.2	70.6	$142.30	$2.02	
	Roof Panel - Aluminum	10.5	45%	5.8	4.7	$17.20	$3.63	
	Floor –Glass Fibre Reinforced Composite	10.71	47%	5.7	5	$16.30	$3.23	
	Total: AHSS + Aluminum + Glass Fiber Reinforced Composite	328	24.5%	247.7	80.3	$175.70	$2.19	$3.84
Option 3	Aluminum Intensive	328	35%	213.2	114.8	$720.20	$6.27	$13.65
Option 4	Composite	328	50%	164	164	$2,512.10	$15.32	$25.94

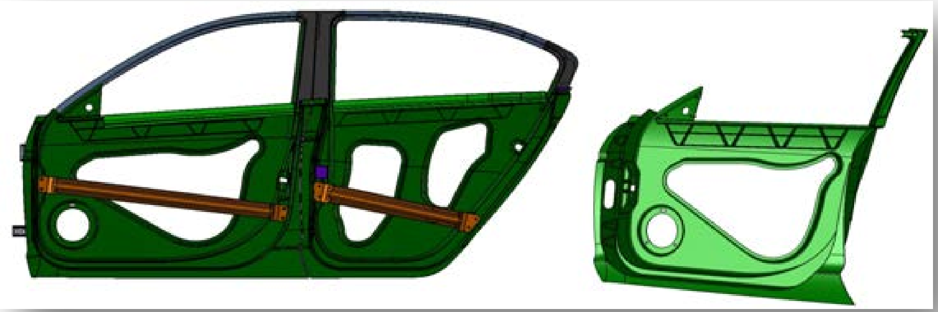


Closure – Baseline Accord

	Total Mass (kg)	Structural Mass (kg)	Construction
Front Doors	58.99	32.78	Steel Stamping Outer & Laser Welded Blank Inner
Rear Doors	47.46	26.76	Steel Stamping Outer & Laser Welded Blank Inner
Hood	17.89	15.20	Steel Stamping Outer & Inner
Deck Lid	12.37	9.95	Steel Stamping Outer & Inner
Fenders	7.35	7.35	Steel
Total	144.06	92.04	

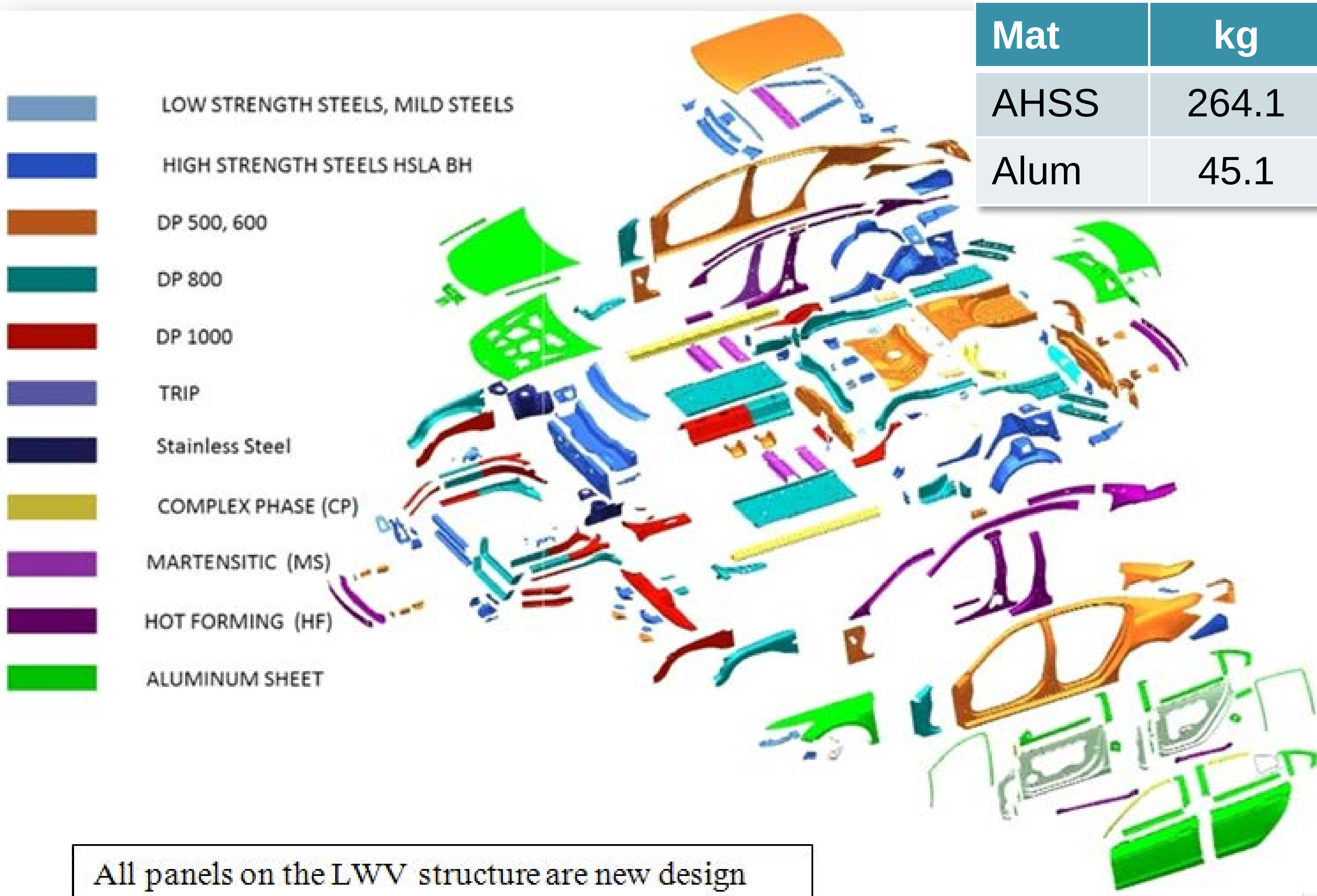
Closure – Front Door Frame Options

Design	Strategy	Honda Accord Mass (kg)	LWV Mass Per Door (kg)	Mass Savings Per Door (kg)	Mass Savings (%)	Cost Increase Per Door ($ USD)	Cost Increase Premium Per Door ($/kg)
Option 1	AHSS	16.40	13.94	2.46	15	5.12	2.08
Option 2	Aluminum Stamping	16.40	8.45	7.95	48	24.80	3.12
Option 3	Aluminum Stamping (Outer)	5.60	2.70	2.90	52	9.0	3.12
	Magnesium Casting (Inner)	6.50	3.31	3.19	49	16.67	5.22
	Other Parts (Aluminum)	4.30	2.58	1.72	40	8.23	4.79
	Total	16.40	8.59	7.81	48	33.9	4.35

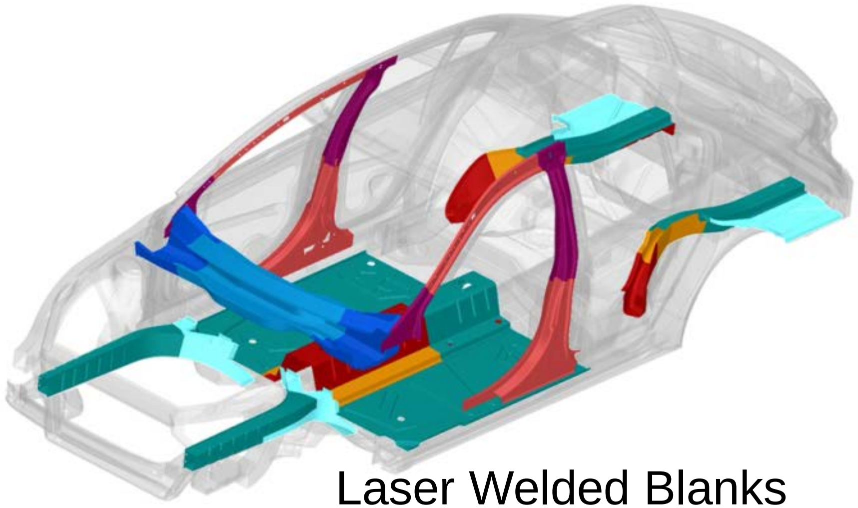


LWV Material Portfolio (including Closures)

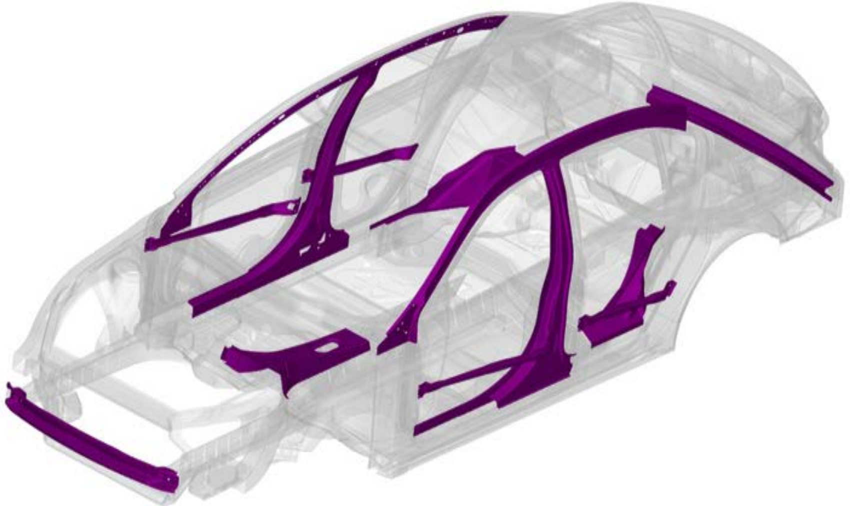
Mat	kg
AHSS	264.1
Alum	45.1



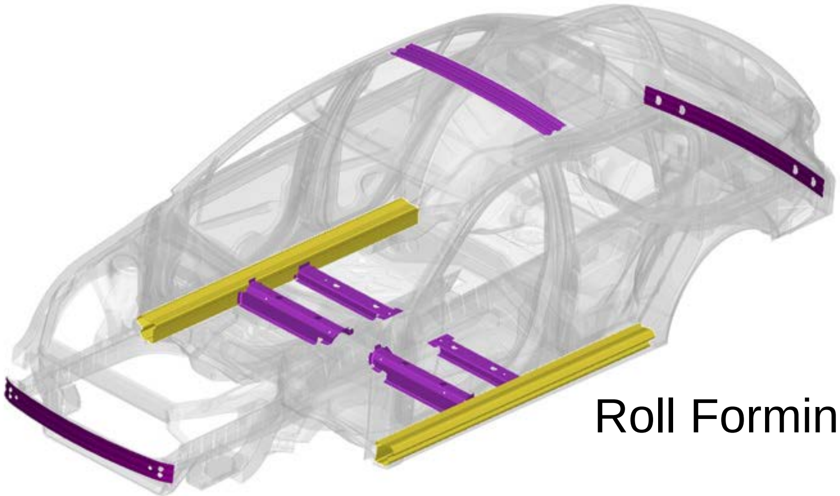
All panels on the LWV structure are new design



Laser Welded Blanks



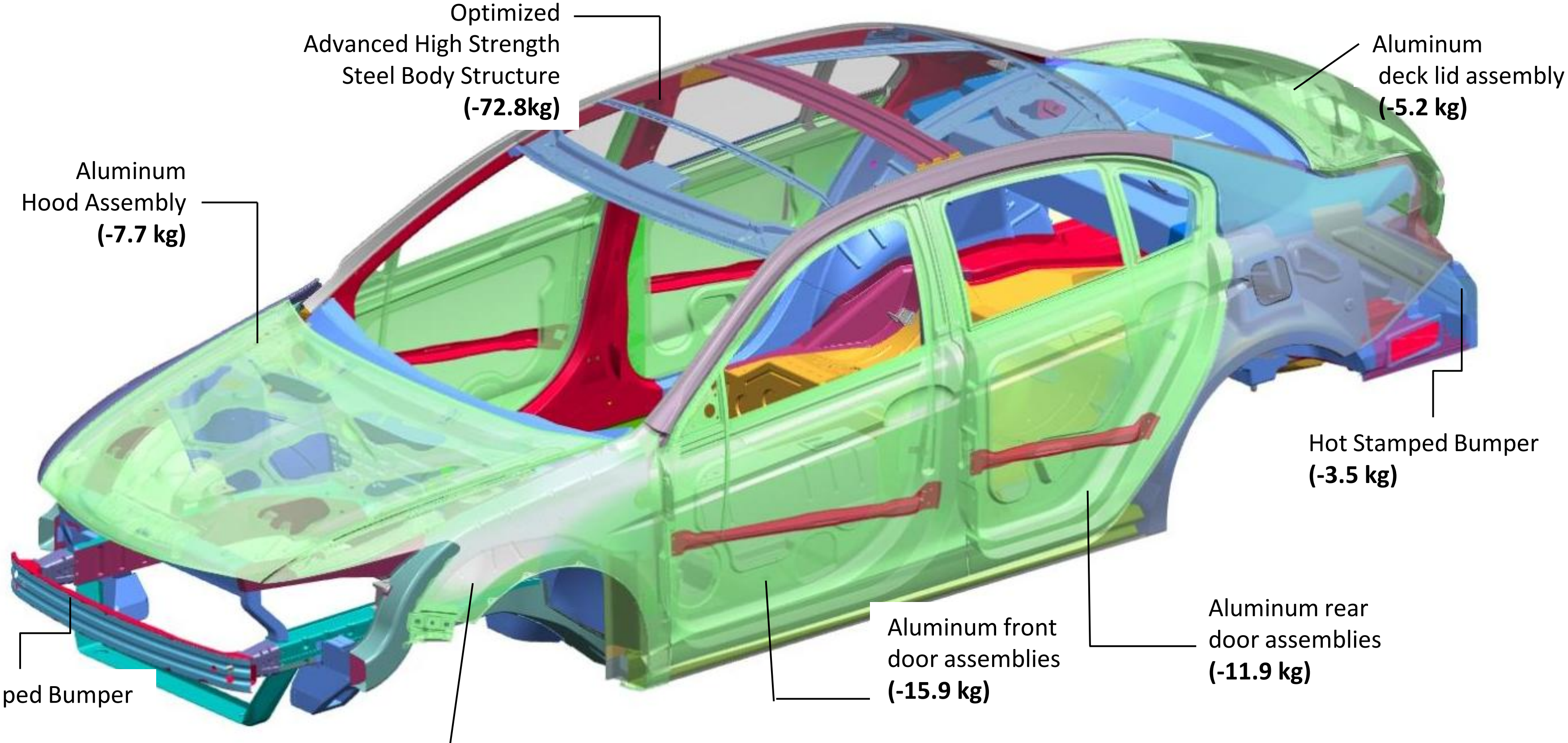
Hot Stamping (Press Hardened)



Roll Forming

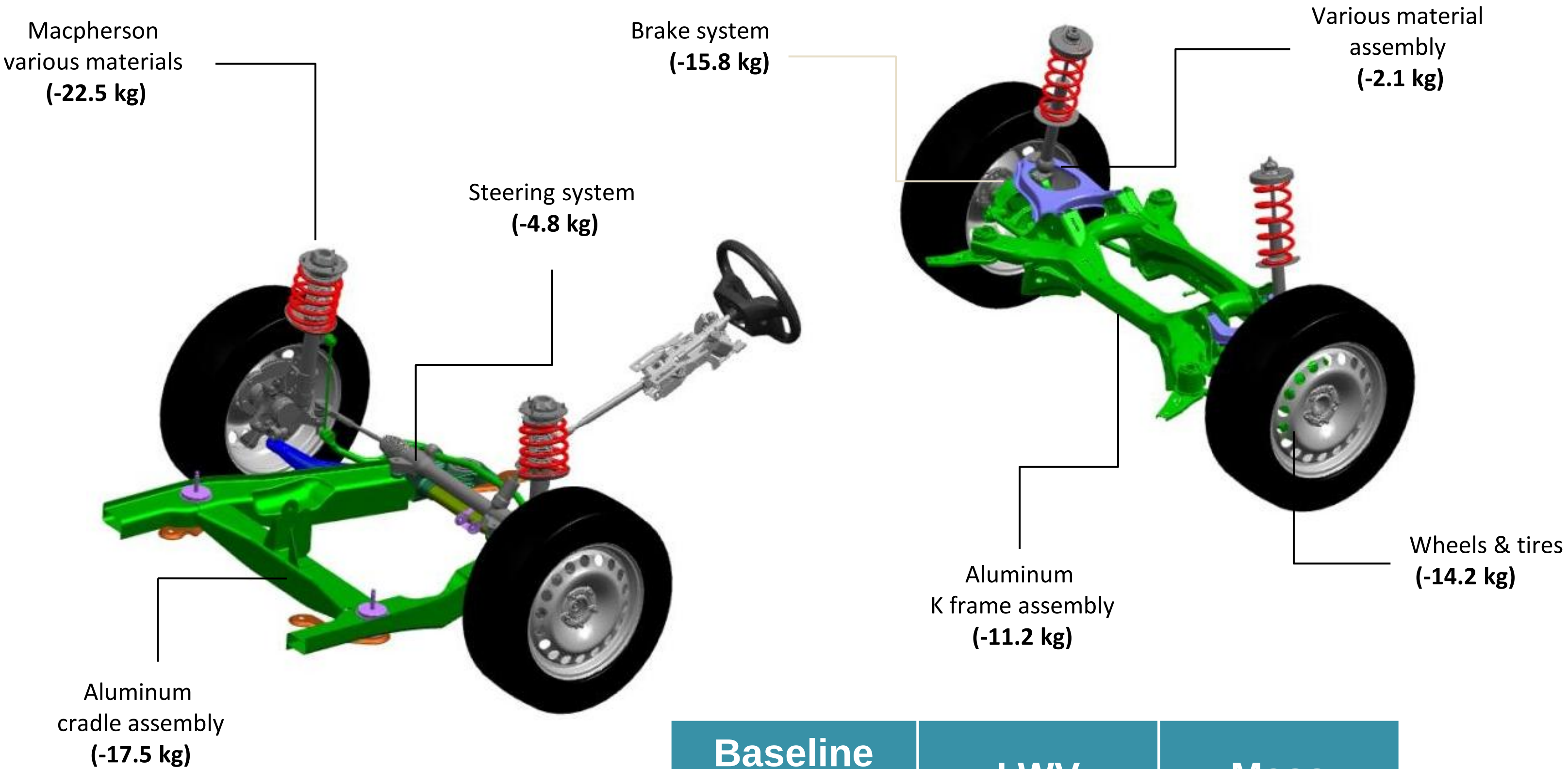
The chosen manufacturing processes for LWV are already in high volume production. Additional facilities /infrastructure will ramp up as per demand for years 2017 to 2025

Light Weight Vehicle - Body and Closures



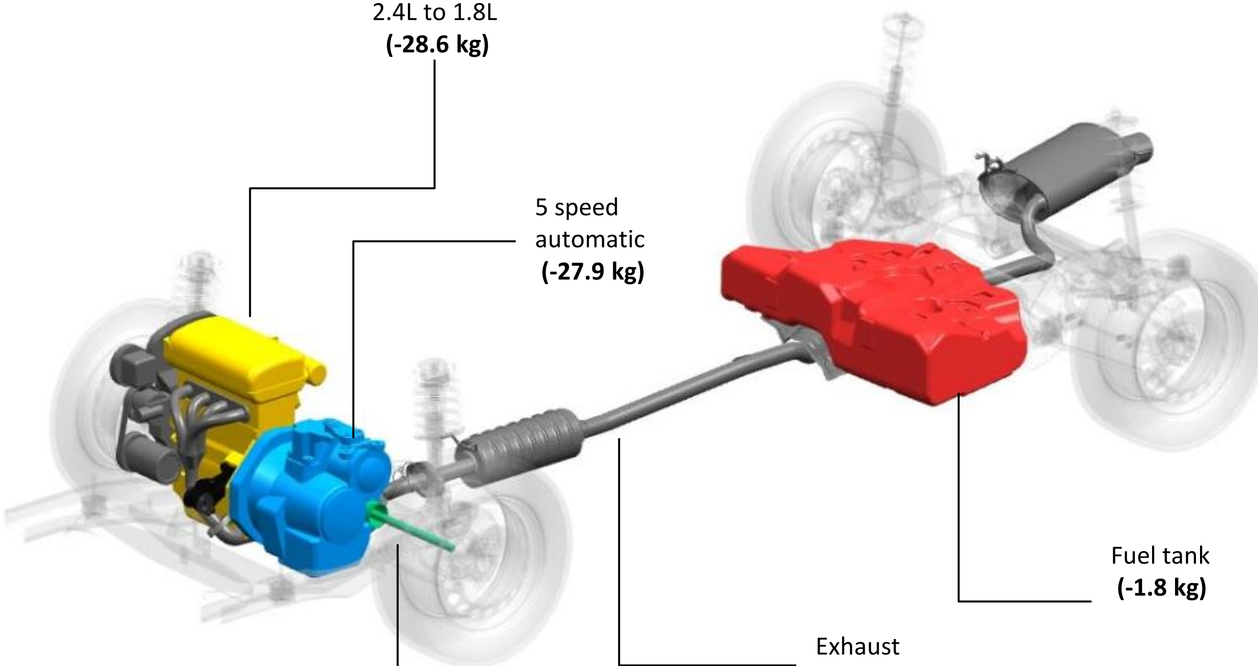
Baseline Vehicle (kg)	LWV (kg)	Mass Reduction
435.9	312.0	-28.4%

Light Weight Vehicle Chassis



Baseline Vehicle (kg)	LWV (kg)	Mass Reduction
308.1	220.0	-28.6%

LWV – Powertrain resized for same performance & Range



Baseline Vehicle (kg)	LWV (kg)	Mass Reduction
314.6	251.1	-20.2%

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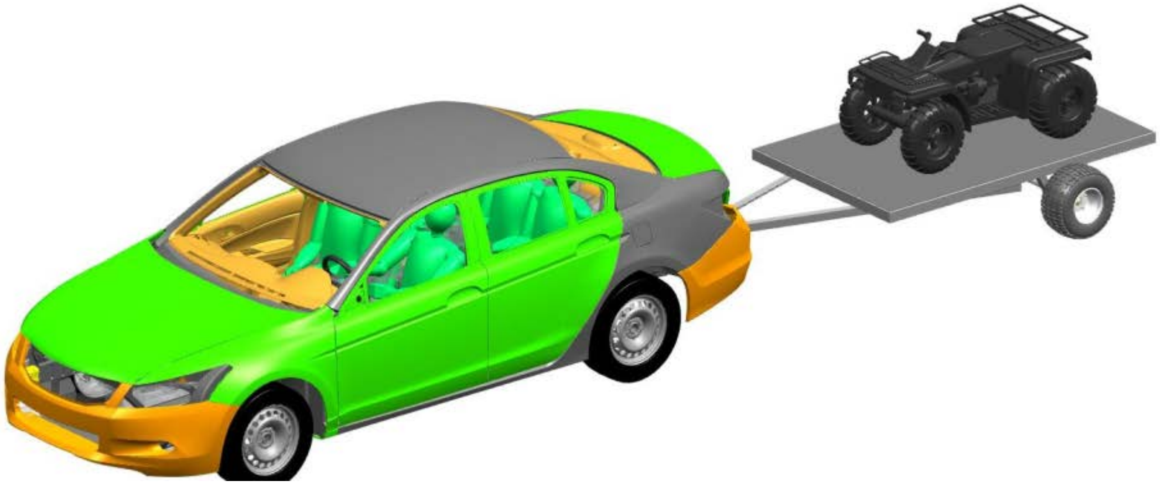
Light Weight Vehicle – Seats & Instrument Panel

Baseline Vehicle (kg)	LWV (kg)	Mass Reduction
98.8	69.3	-30.0%

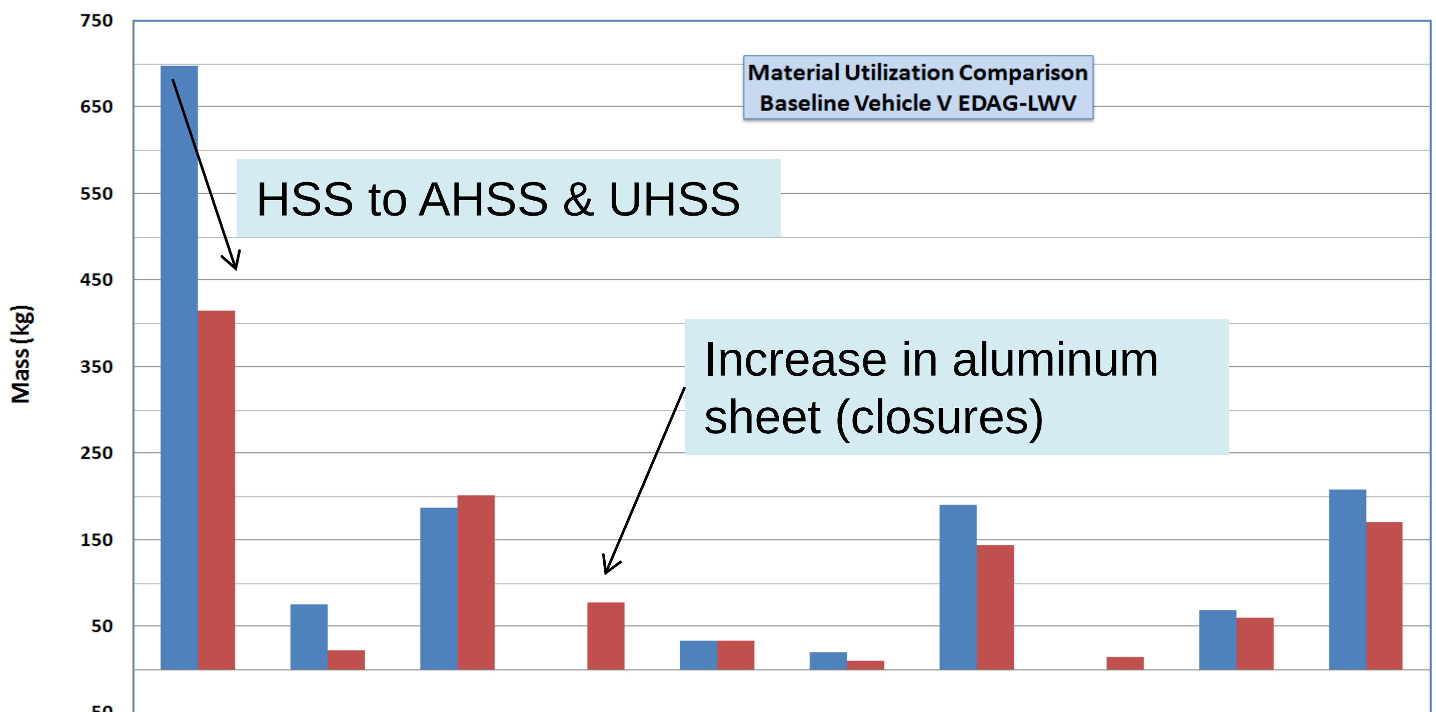
Summary of Mass Reduction



Mass (kg)	Payload	Non-Structure	Body Structure	Chassis	Powertrain	GVWR	CVW	MSRP ($)
Baseline Vehicle	470	465.1	343.8	287.8	383.3	1950	1480	21,980
EDAG-LWV	470	366.5	261.1	206.1	311.7	1615	1148	22,449
Reduction (%)		-21%	-24%	-28%	-19%	-17%	-22.4%	2.13%

Material usage Baseline v LWV

The chosen materials for LWV are readily available and will be available as per demand for years 2017 to 2025

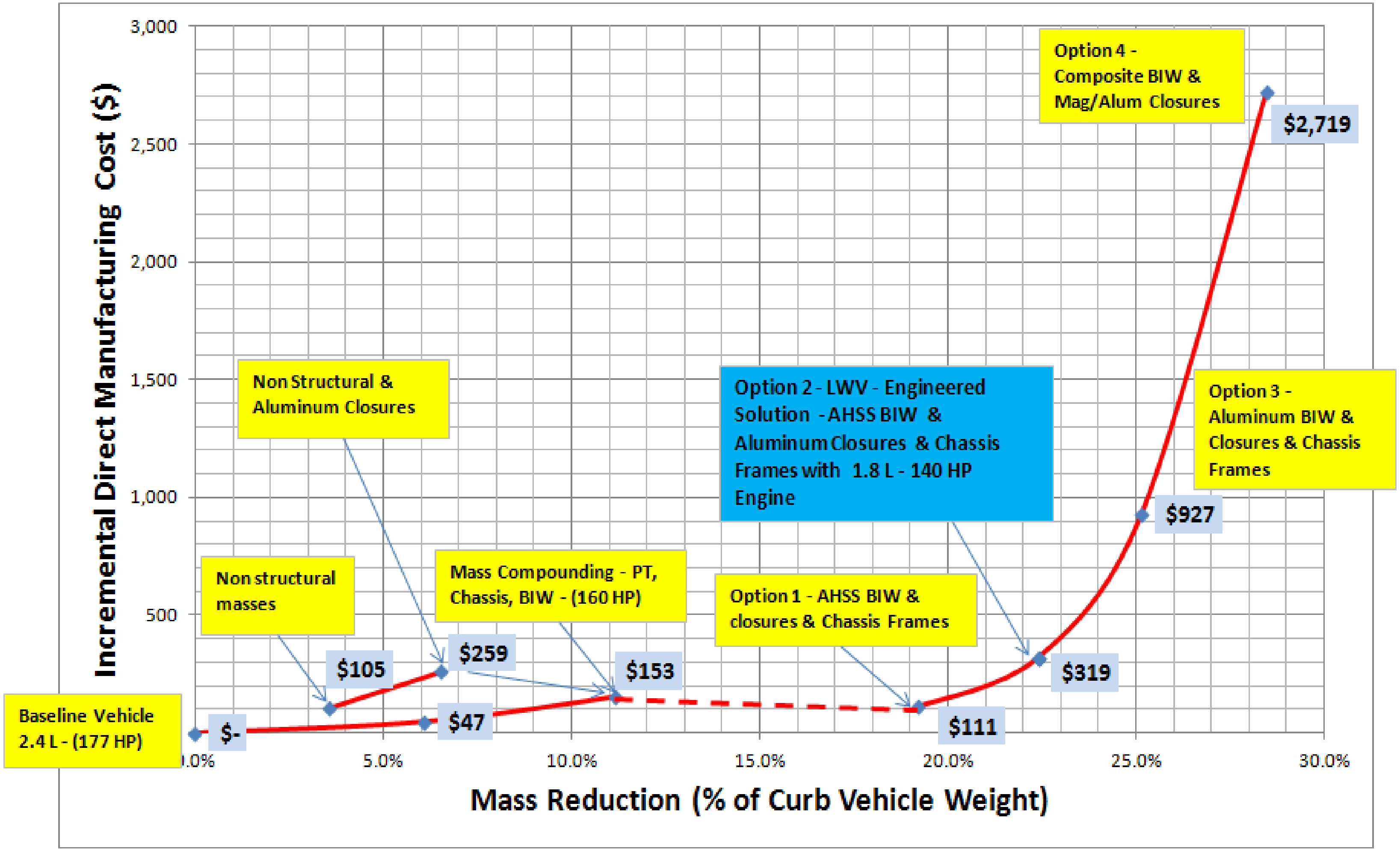


	Steel	Cast/Forge Iron	Alum Cast / Forging	Aluminum Sheet	Glass	Copper	Plastics	Magnesium	Fluids	Misc
Baseline Vehicle	698	76	187	0	34	20	191	0	69	208
EDAG - LWV	415	23	201	78	34	10	145	15	61	171

Vehicle build options for increasing mass reduction

Vehicle System	Honda Accord System Mass (kg)	1 AHSS BIW, Closures, Chassis Frames & Seats		2 AHSS BIW & Aluminum Closures, Chassis Frames, Mag Seats		3 Aluminum BIW, Closures, Chassis Frames, Mag Seats		4 Composite BIW & Mag/Alu Closures, Aluminum Chassis	
		Mass Saving (kg)	Mass Saving (%)	Mass Saving (kg)	Mass Saving (%)	Mass Saving (kg)	Mass Saving (%)	Mass Saving (kg)	Mass Saving (%)
Body Structure	328.0	72.8	-22.2%	72.8	-22.2%	114.8	-35.0%	164.0	-50.0%
Doors Front	32.8	4.9	-15.0%	15.9	-48.5%	15.6	-47.6%	15.6	-47.6%
Doors Rear	26.8	4.0	-15.0%	11.9	-44.6%	12.3	-45.7%	12.3	-45.7%
Hood	15.2	1.5	-9.8%	7.7	-50.7%	7.0	-46.3%	7.0	-46.3%
Decklid	10.0	1.5	-15.0%	5.2	-52.4%	4.5	-45.0%	4.5	-45.0%
Fenders	7.3	2.3	-30.6%	3.3	-44.5%	3.3	-44.5%	3.3	-44.5%
Bumpers	15.8	7.1	-44.9%	7.1	-44.9%	7.1	-44.9%	7.1	-44.9%
Front Suspension	81.3	35.8	-44.0%	39.9	-49.1%	39.9	-49.1%	39.9	-49.1%
Rear Suspensions	53.2	13.3	-25.0%	13.3	-25.0%	13.3	-25.0%	13.3	-25.0%
Seats Front	45.7	4.6	-10.0%	13.7	-30.0%	13.7	-30.0%	13.7	-30.0%
Seat Rear	21.0	2.1	-10.0%	6.3	-30.0%	6.3	-30.0%	6.3	-30.0%
Instrument Panel	31.9	9.5	-29.6%	9.5	-29.6%	9.5	-29.6%	9.5	-29.6%
Engine Transmission	266.6	56.5	-21.2%	56.5	-21.2%	56.5	-21.2%	56.5	-21.2%
Fuel System	12.0	1.8	-14.6%	1.8	-14.6%	1.8	-14.6%	1.8	-14.6%
Fuel, oil, coolant	68.7	8.1	-11.8%	8.1	-11.8%	8.1	-11.8%	8.1	-11.8%
Wheels	93.9	14.2	-15.2%	14.2	-15.2%	14.2	-15.2%	14.2	-15.2%
Trim	26.3	3.0	-11.6%	3.0	-11.6%	3.0	-11.6%	3.0	-11.6%
Wiring	21.7	4.3	-20.0%	4.3	-20.0%	4.3	-20.0%	4.3	-20.0%
Battery	12.4	1.1	-9.0%	1.1	-9.0%	1.1	-9.0%	1.1	-9.0%
Headlights	9.4	2.4	-25.0%	2.4	-25.0%	2.4	-25.0%	2.4	-25.0%
Exhaust	20.7	1.7	-8.2%	1.7	-8.2%	1.7	-8.2%	1.7	-8.2%
Brakes	59.0	15.8	-26.8%	15.8	-26.8%	15.8	-26.8%	15.8	-26.8%
Brake Fliuid	0.5	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Drive Shafts	15.2	3.5	-23.1%	3.5	-23.1%	3.5	-23.1%	3.5	-23.1%
HVAC & Cooling System	37.9	4.5	-11.8%	4.5	-11.8%	4.5	-11.8%	4.5	-11.8%
Ducting- HVAC & Engine Intake	0.0	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Safety Systems	19.3	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Steering System	20.3	4.8	-23.6%	4.8	-23.6%	4.8	-23.6%	4.8	-23.6%
Front & Rear Fascia	13.5	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Wiper system	6.0	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Window Washer Fluid	4.8	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Paint	12.0	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Noise Insulation	9.4	3.2	-34.2%	3.2	-34.2%	3.2	-34.2%	3.2	-34.2%
Glass	33.5	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Latches/fastners/mirrors-Misc	47.8	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Total - with Powertrain	1,480	284	-19.2%	332	-22.4%	372	-25.1%	421	-28.5%
Total - without Powertrain	1,112	216	-19.4%	264	-23.7%	304	-27.4%	353	-31.8%

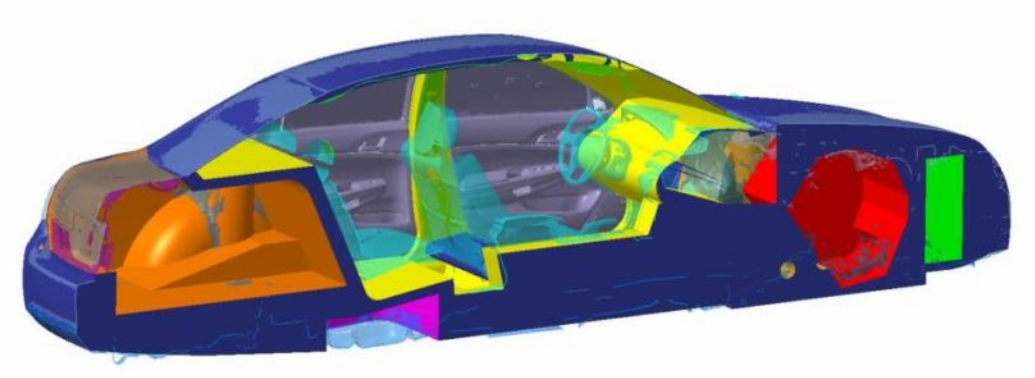
Cost Curve for increasing mass reduction

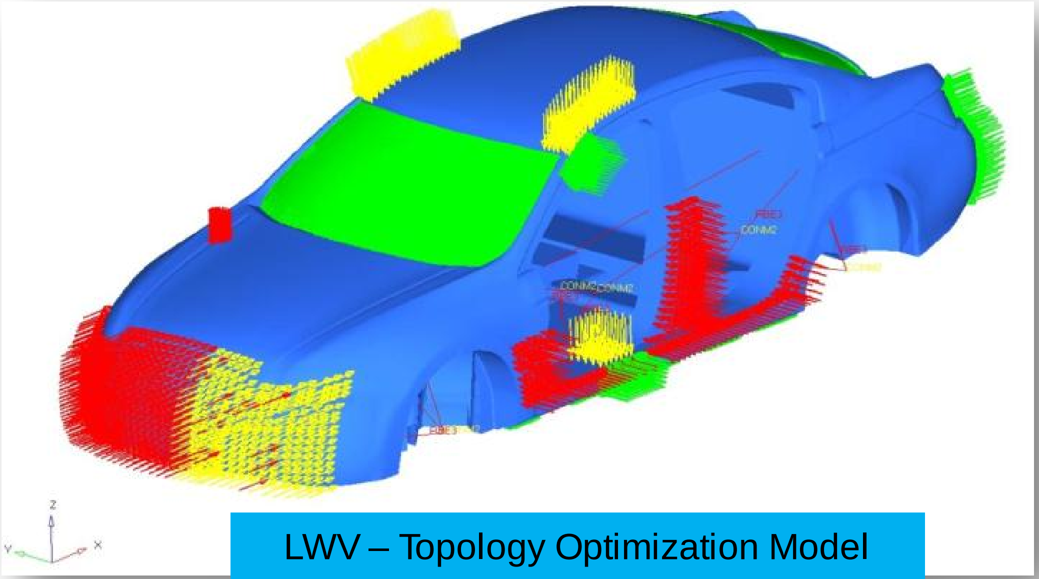


COMPUTER OPTIMIZATION

Load Cases for Optimization

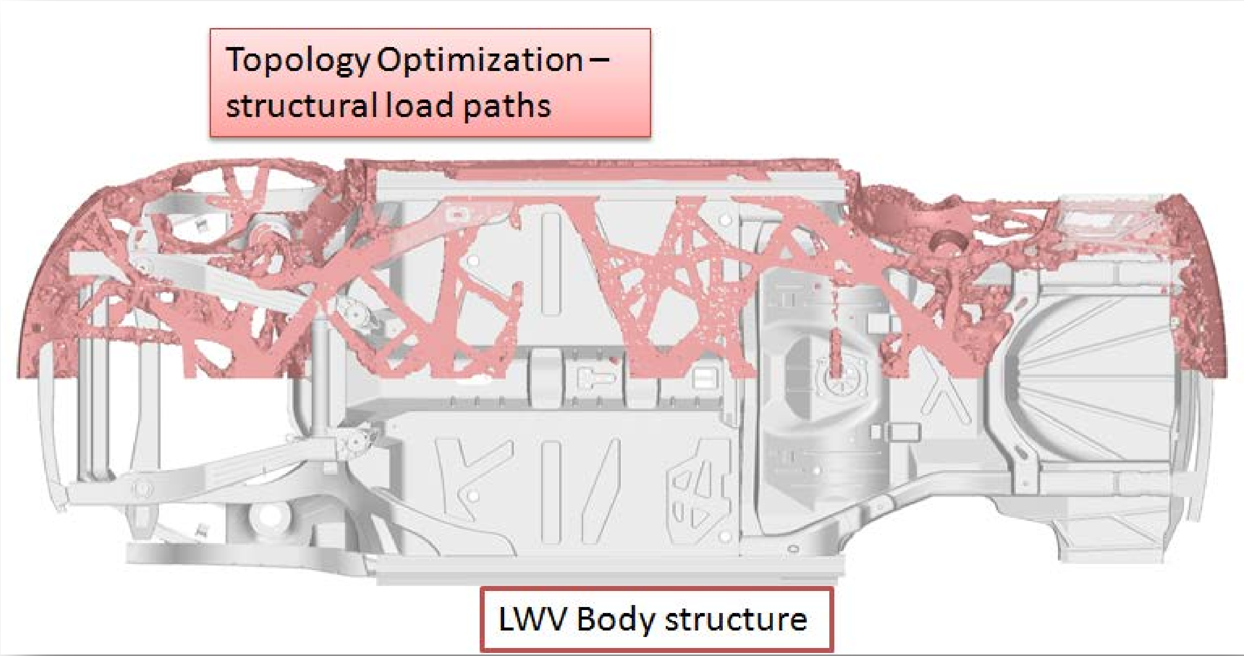
- Load cases used to identify optimized structural load paths for the LWV:
  - Stiffness Bending & Torsion
  - Frontal NCAP Full Barrier
  - IIHS 40% ODB Front Crash
  - IIHS Side
  - FMVSS No. 214 (Pole Impact)
  - FMVSS No. 301 (Rear Crash)
  - FMVSS No. 216 (Roof Crush)





LWV – Topology Optimization Model

Topology Optimization Results



The topology optimization results are interpreted by technical experts for the following factors to ensure manufacturability

- Design
- Engineering
- Manufacturing

Identifying "Optimal Technology Choices"
3G Optimization (Gauge, Grade & Geometry)

ELECTRICORE POWERING THE FUTURE

THE GEORGE WASHINGTON UNIVERSITY

EDAG

Material Portfolio

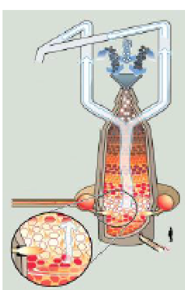
Mild 140/270	DP 300/500
BH 210/340	DP 350/600
BH 260/370	DP 500/800
BH 280/400	DP 700/1000
IF 260/410	DP 1150/1270
IF 300/420	CP 500/800
HSLA 350/450	CP 600/900
HSLA 420/500	CP 750/900
HSLA 490/600	CP 800/1000
HSLA 550/650	CP 1000/1200
SF 570/640	CP 1050/1470
SF 600/780	MS 950/1200
TRIP 350/600	MS 1150/1400
TRIP 400/700	MS 1250/1500
TRIP 450/800	TWIP 500/980
TRIP 600/980	HF 1050/1500
FB 450/600	(22MnB5)
FB 330/450	

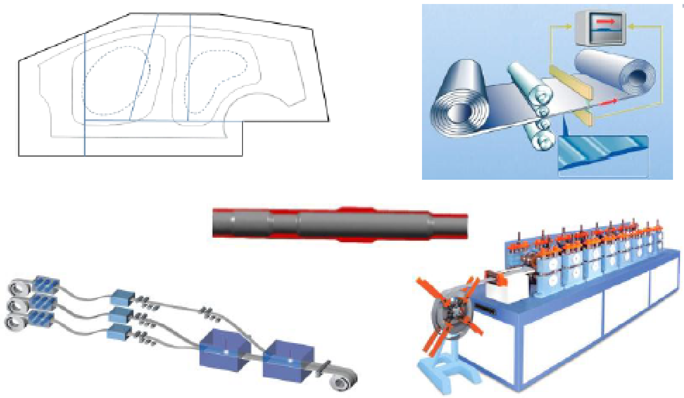
Steel Processing & Technology Portfolio

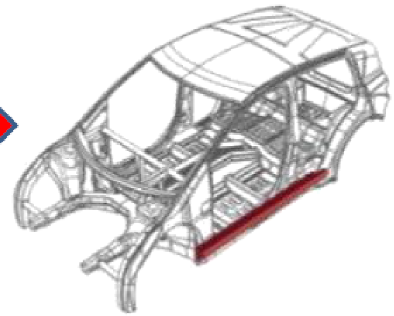
Conventional Coils
Laser Welded Coils
Tailor Rolled Coils
Conventional Blanks
Laser Welded Blanks
Tailor Rolled Blanks
Laser Welded Tubes
Variable Walled Tubes
High Frequency Induction Welded Tubes
Variable Walled Profiles

- Stamping
  - Conventional Blank
  - Laser Welded Blank
  - Tailor Rolled Blank
- Hot Stamping - Direct & Indirect
  - Conventional Blank w/wo Tailor Quench
  - Laser Welded Blank w/wo Tailor Quench
  - Tailor Rolled Blank w/wo Tailor Quench
- Roll Forming
  - Conventional Coil
  - Laser Welded Coil
  - Tailor Rolled Blank
- Hydroforming
  - Laser Welded Tube
  - Tailor Rolled Tube
  - Multi Walled Tube
  - HFI Welded Tubes *
- Laser Welded Finalized Tubes / T^3 Process

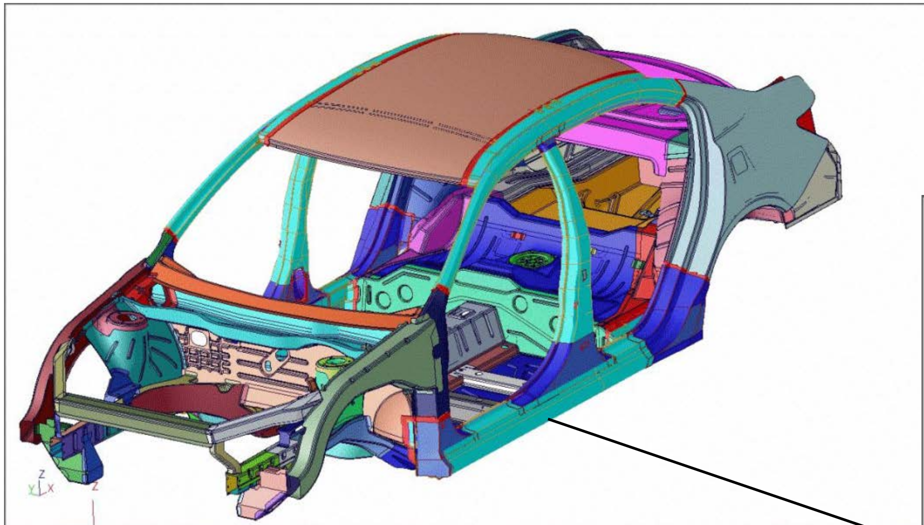
* HFI - High Frequency Induction

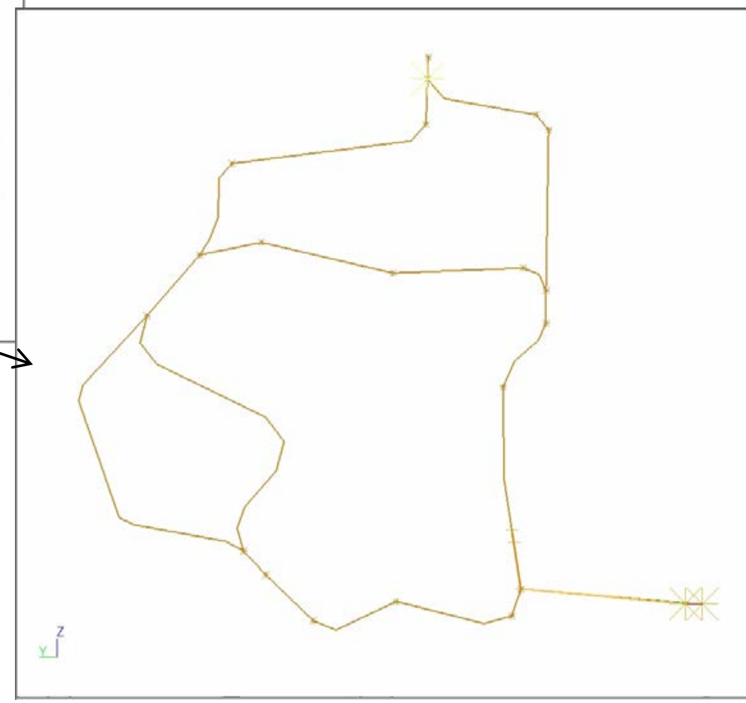






NHTSA www.nhtsa.gov





LSDYNA: Crash & Non-linear load-cases
NASTRAN: Torsion & bending

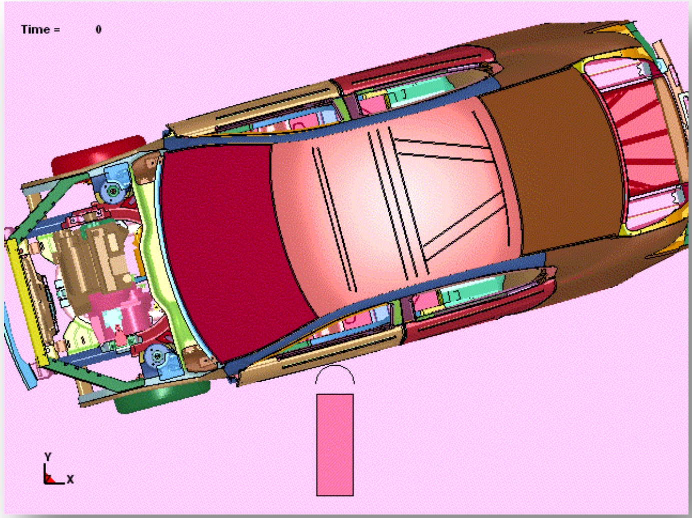
Results

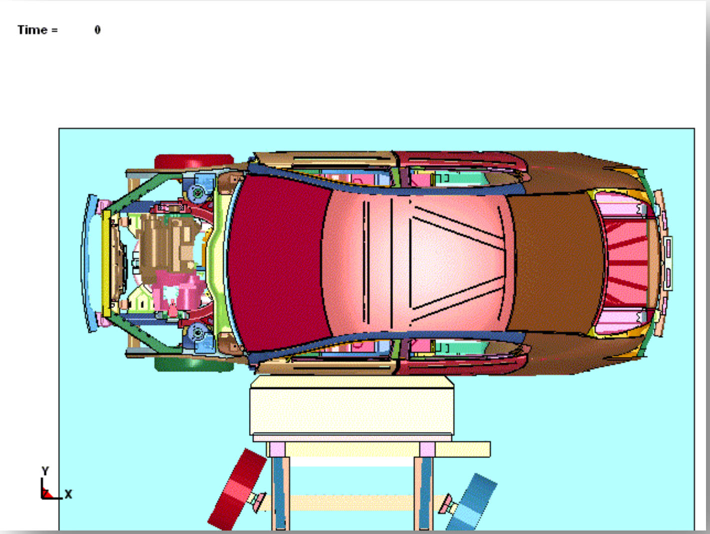
HEEDS: Compare results with targets and Determine new set of variables (Geometry, Gage, Grade)

SFE: Generate Model and create Data decks for LSDYNA & NASTRAN

1. HEEDS (Red Cedar Technologies, Inc.)
2. SFE CONCEPT software

Vehicle Light Weighting
3G Optimization (Gauge, Grade & Geometry)





LSDYNA: Crash & Non-linear load-cases
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Results

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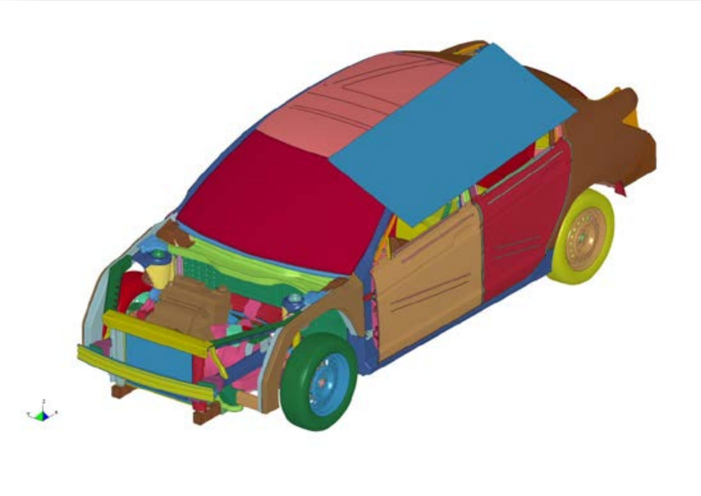
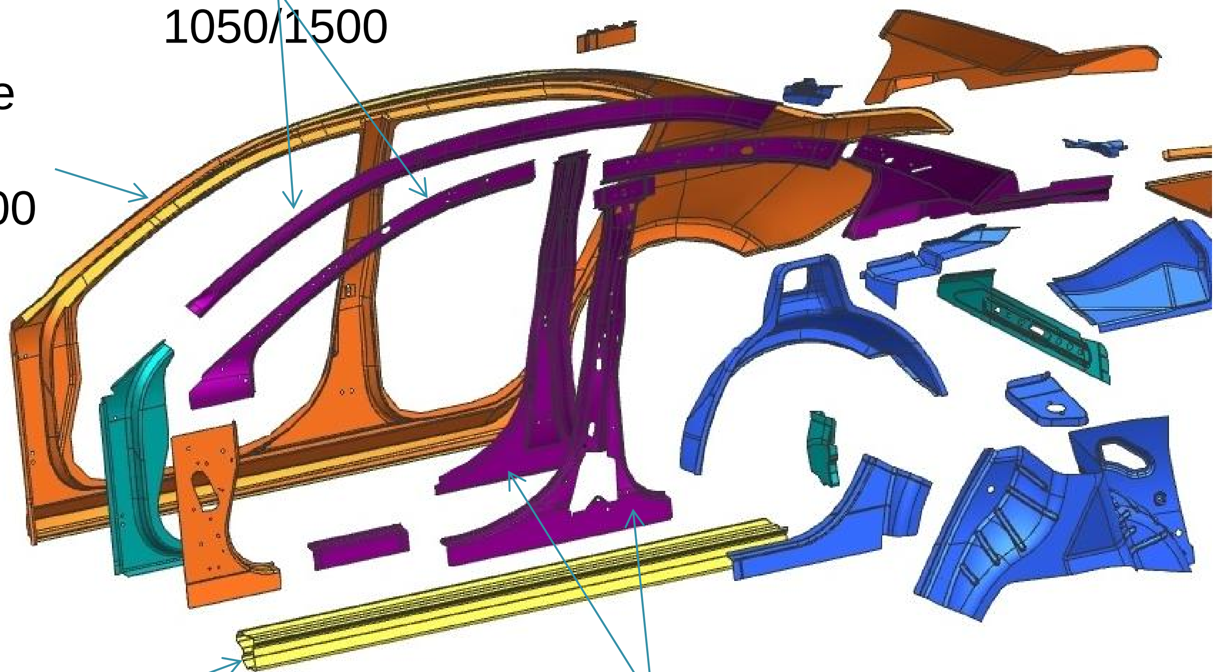
SFE: Generate Model and create Data decks for LSDYNA & NASTRAN



Body Side Structure - Details

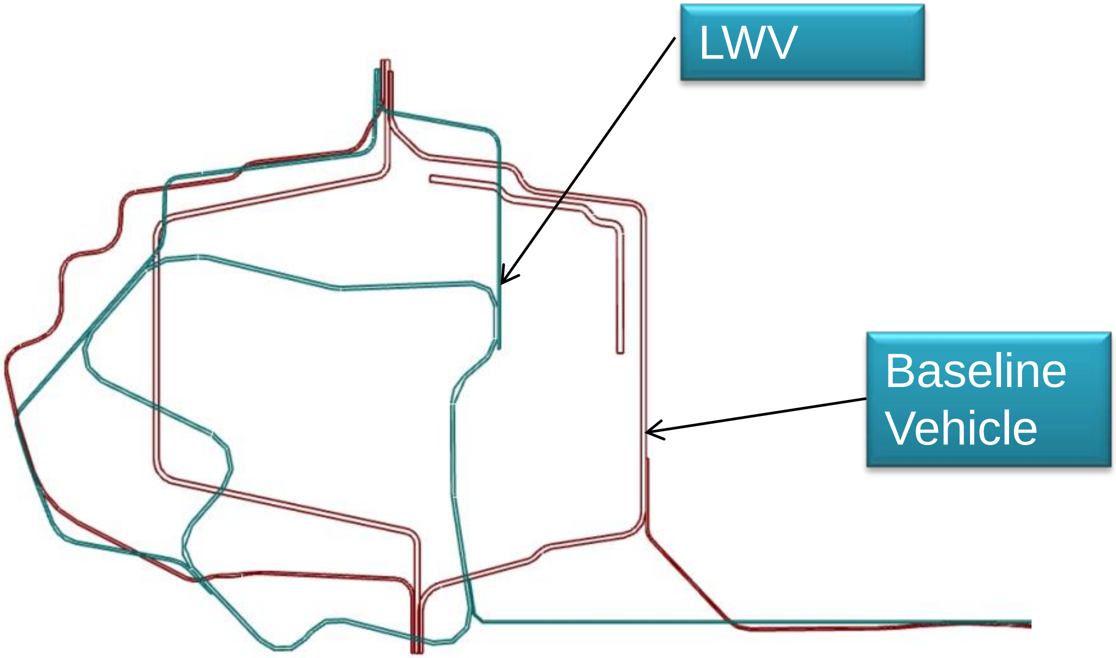
Roof Rail Inner & Reinf. – LWB & Hot Stamped – HF 1050/1500

Body Side Outer DP300/500



Rocker Section - Roll formed CP1000/1200

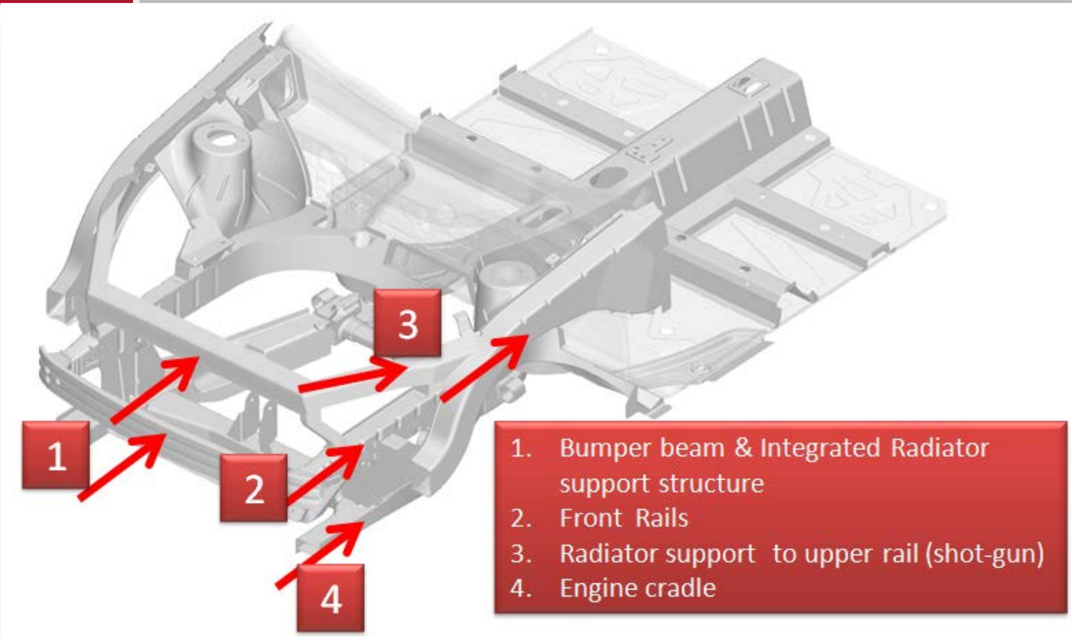
B Pillar Inner & Reinf. – LWB & Hot Stamped – HF 1050/1500 (inner – tailor quench)

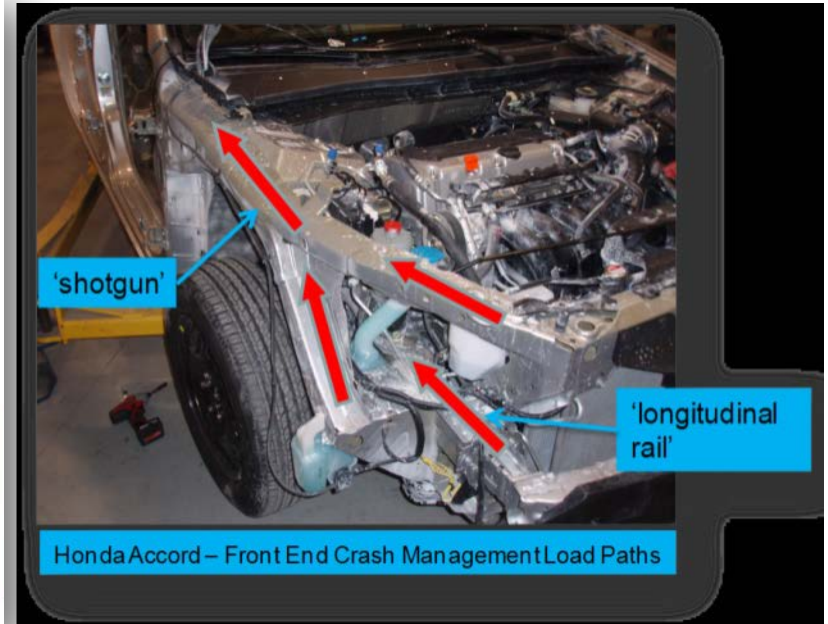


Rocker Section Comparison – Body structure

LIGHT WEIGHT VEHICLE CRASH CAE MODEL & RESULTS

LWV - Design Strategy for Front End

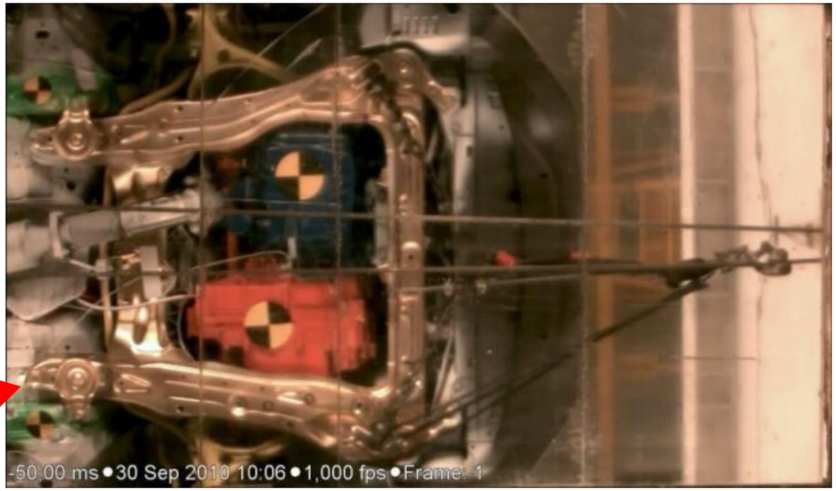




LWV – Load paths (1,2,3) similar to Honda ACE concept

LWV – Engine Cradle (4) active in front impact early on and rear mounts designed not to fail.

2011 Accord Mounts designed to fail at predetermined load

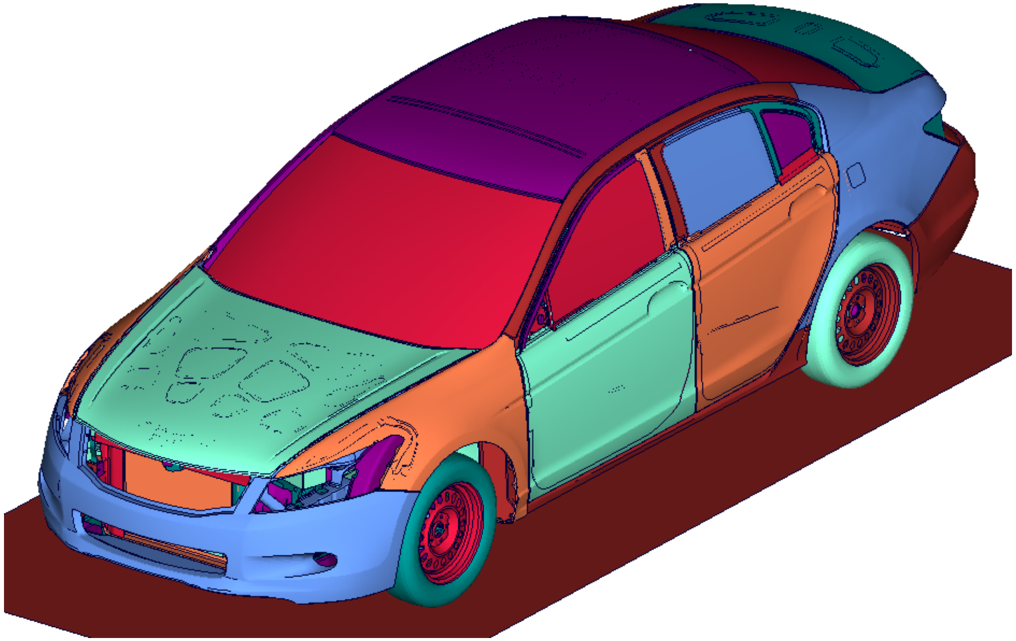


New Car Assessment Program (NCAP) Frontal Barrier Impact Test 2011 Honda Accord LX Sedan, Report No. NCAP-MGA-2011-027, October 28, 2010.

www.nhtsa.gov

Light Weight Vehicle Crash FEA Model

Number of Parts	702
Number of Beams	4,763
Number of Solids	272,214
Number of Shells	1,210,307
Number of Nodes	1,403,378
Total Number of Elements	1,487,424



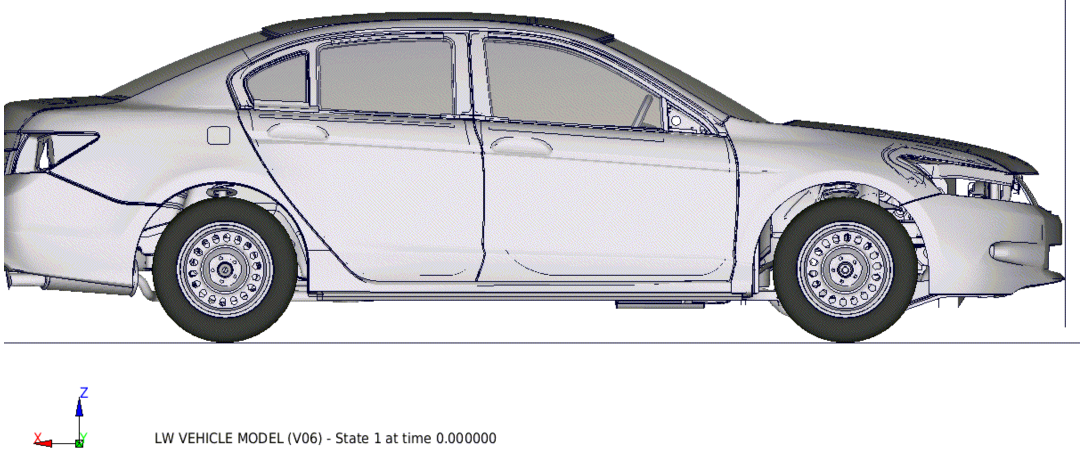
CAE Analysis on LWV is performed and compared with Honda Accord 2011 for following crash and Stiffness tests:

- ✓ **USNCAP Frontal Rigid Barrier 35 mph test**
- ✓ **IIHS offset barrier 40 mph deformable barrier test (Crosstour)**
- ✓ **USSINCAP Lateral side impact test**
- ✓ **IIHS Side Impact 50 km/h test**
- ✓ **NCAP Rigid Side Pole 20 mph test**
- ✓ **IIHS Roof crush test**
- ✓ **Rear 301 fuel tank integrity 50 mph test**
- ✓ **Torsional and Bending Stiffness**
- ✓ **Normal Mode Frequencies**

USNCAP Frontal Rigid Barrier 35 mph Test Baseline Vehicle V EDAG - LWV

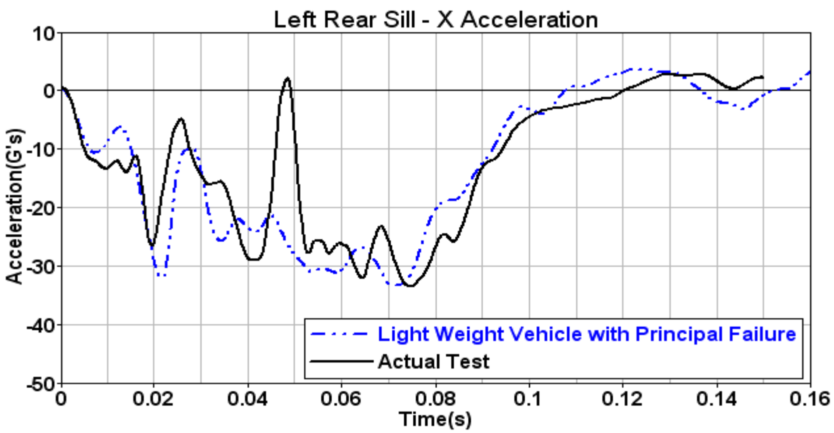
Honda Accord 2011
Test # 7078

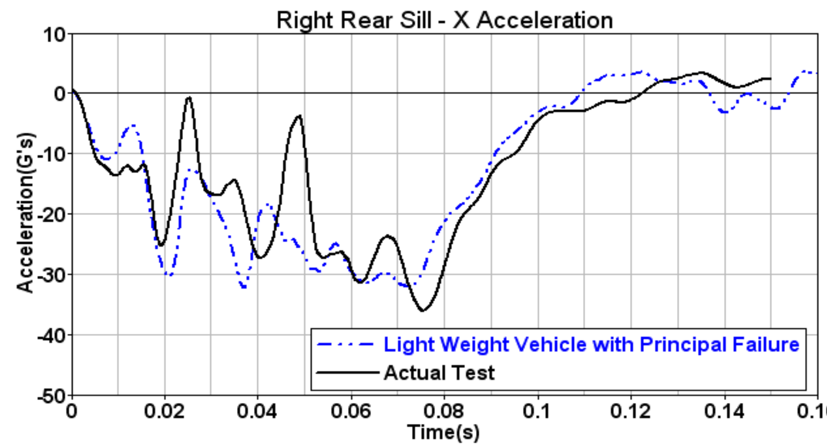
	Mass (kg)
CVW	1,480



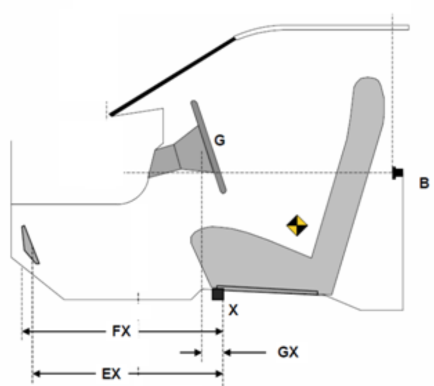
EDAG – LWV
CAE Simulation

	Mass (kg)
CVW	1,148
	-22%





Crash pulse comparison of the Honda Accord 2011(Actual Test) and EDAG LWV

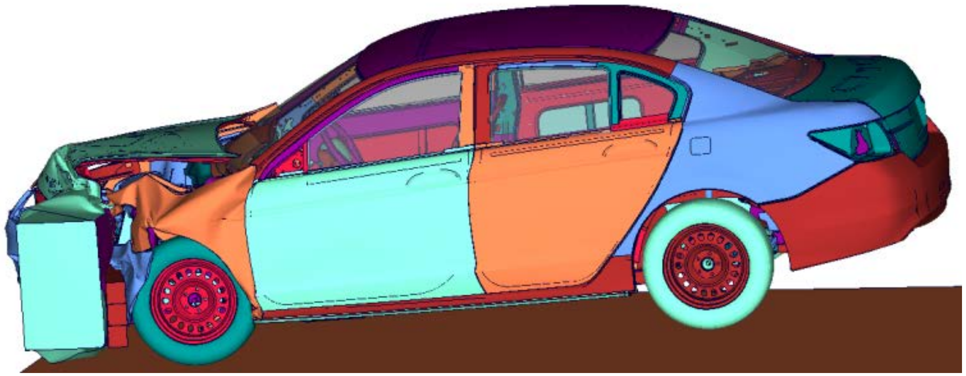


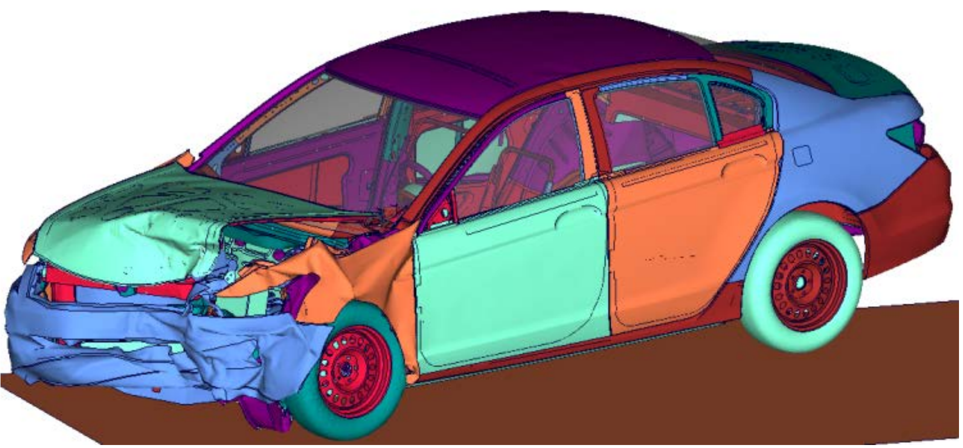
DRIVER COMPARTMENT

Item	EDAG LWV (mm)	Honda 2011 (mm)
FX-Foot Rest to X	14	8
EX-Brake Pedal to X	-16	-3

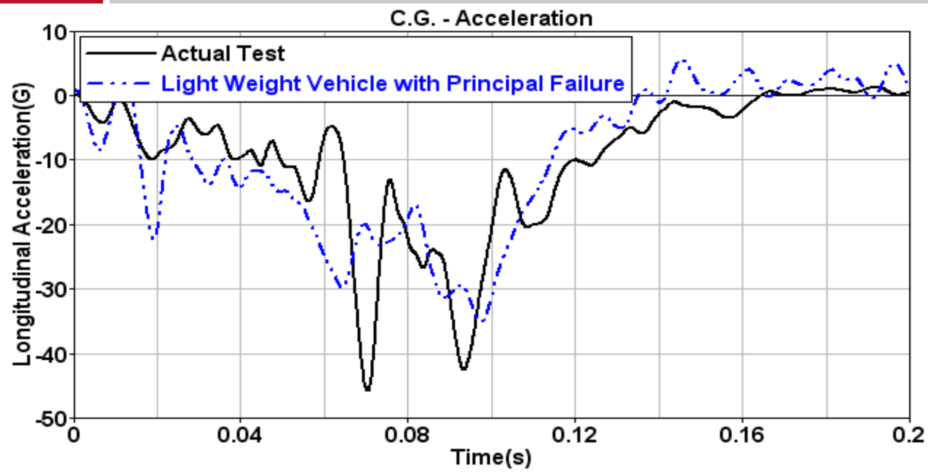
Occupant compartment intrusion comparison

IIHS offset barrier 40 mph deformable barrier test

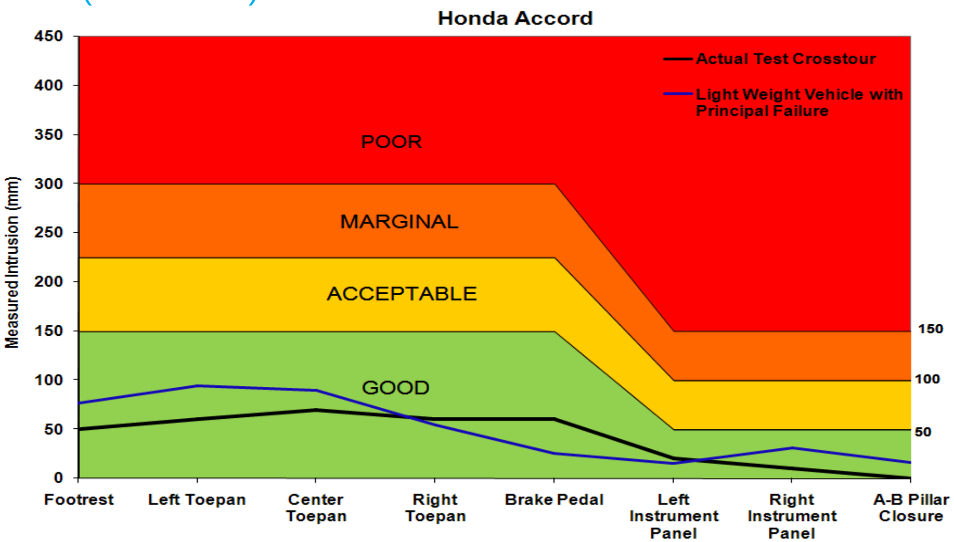




IIHS offset barrier 40 mph deformable barrier test

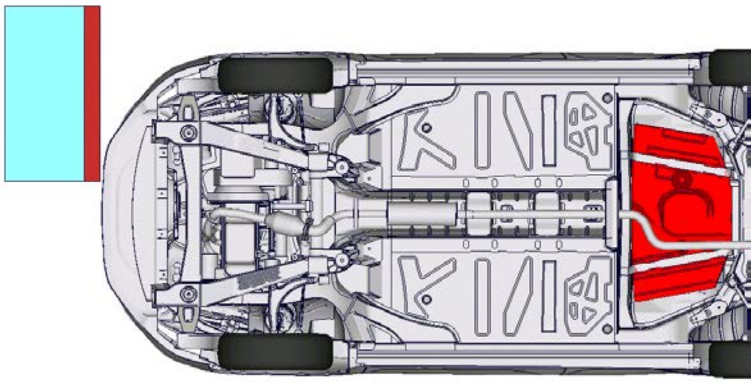


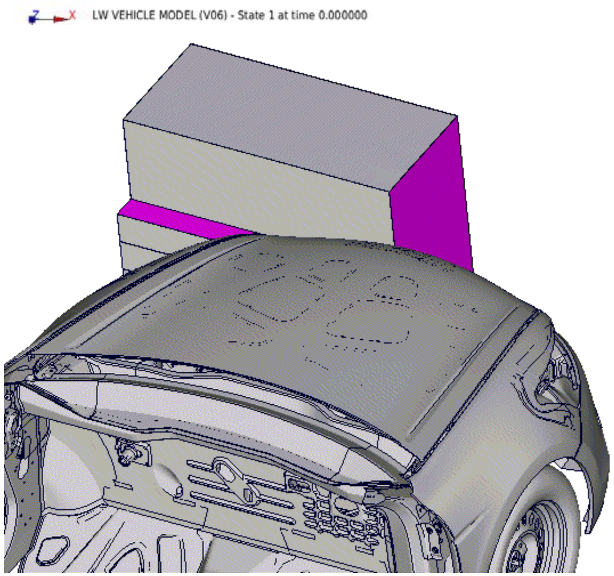
Crash pulse comparison of the Honda Crosstour 2010 (Actual Test) and EDAG LWV



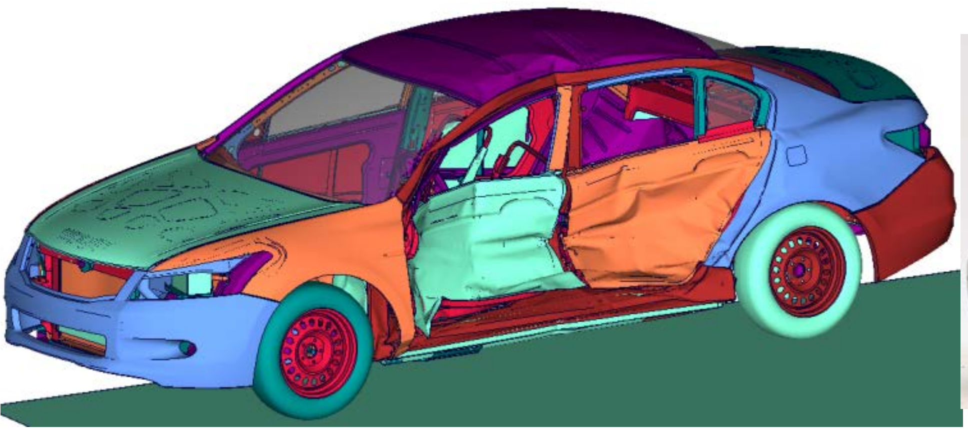
Occupant compartment intrusion comparison

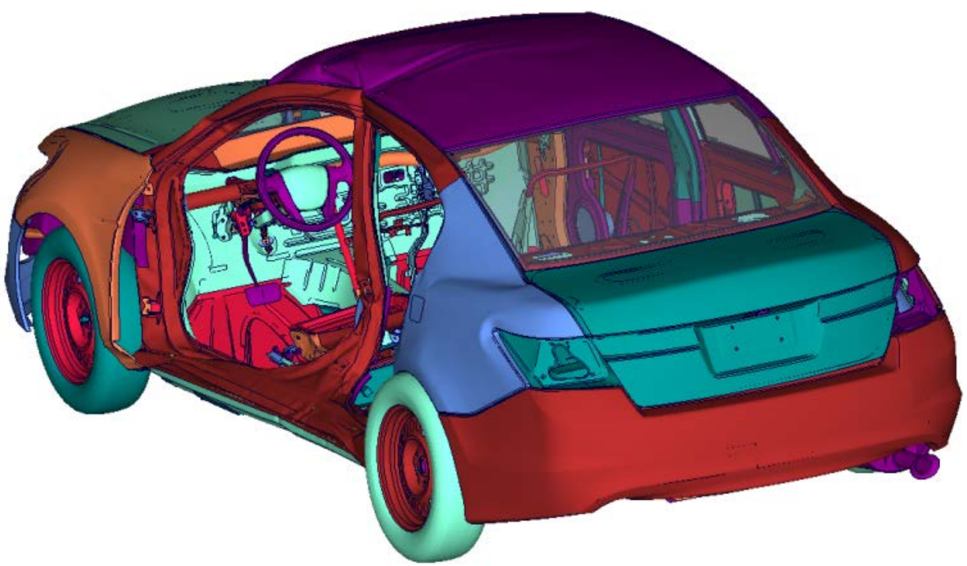
LWV CAE Simulation



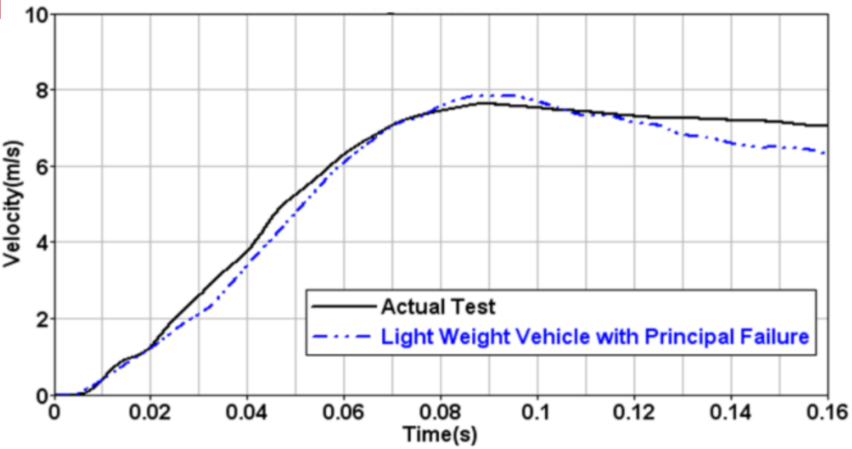


IIHS Side Impact 50 kmh test

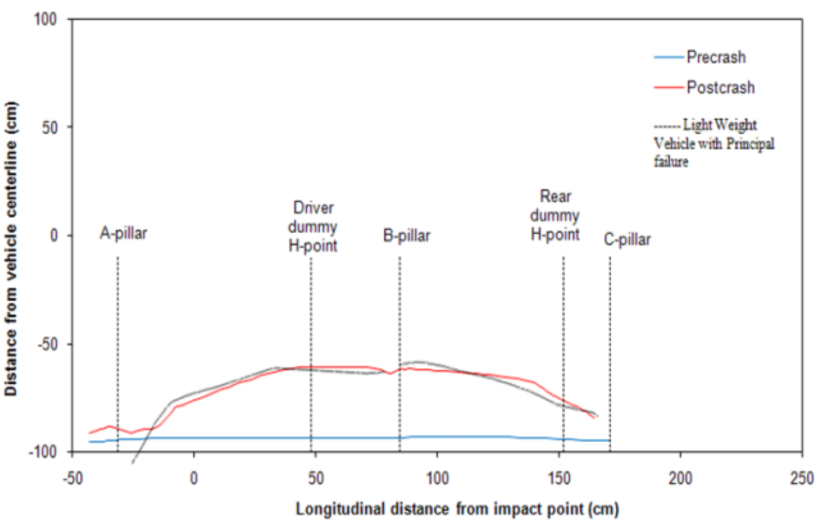




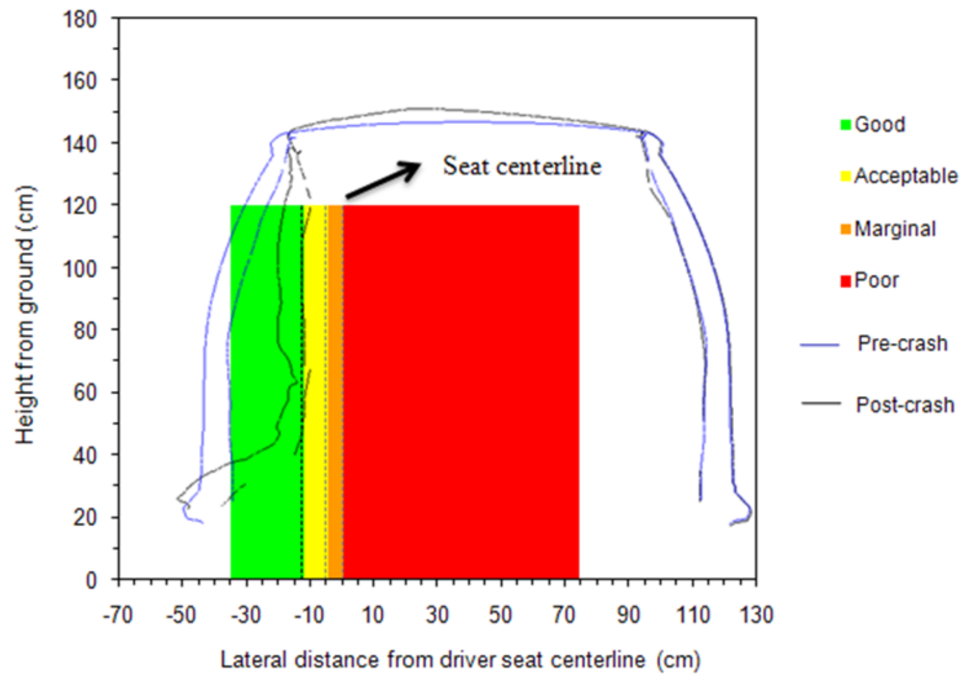
IIHS Side Impact 50 kmh test



Velocity comparison at mid B pillar on the struck side

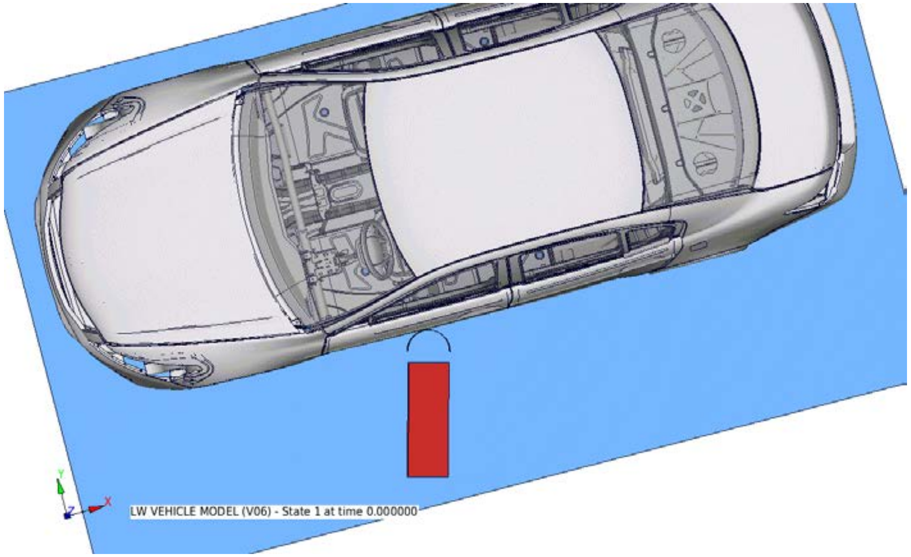


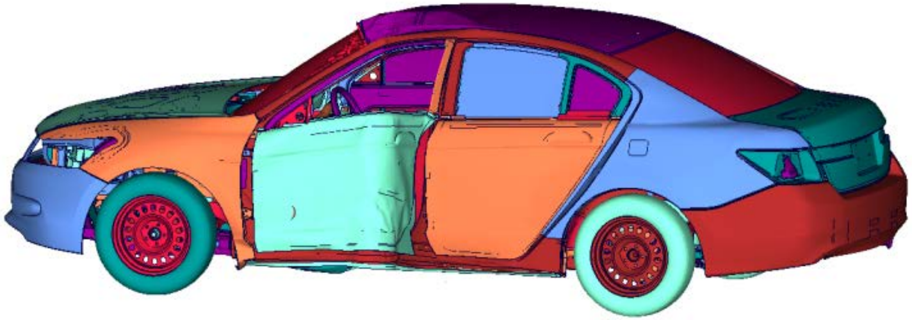
Exterior crush comparison at the mid-door level on struck side



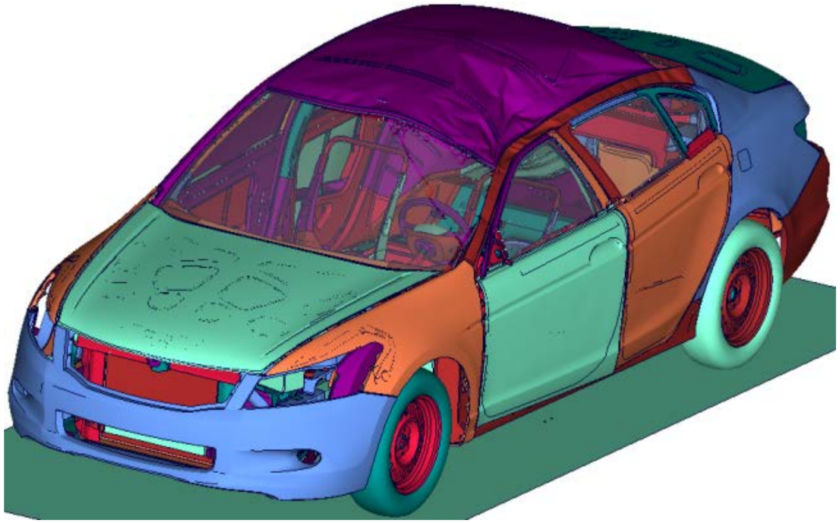
Rating comparison for the IIHS lateral test

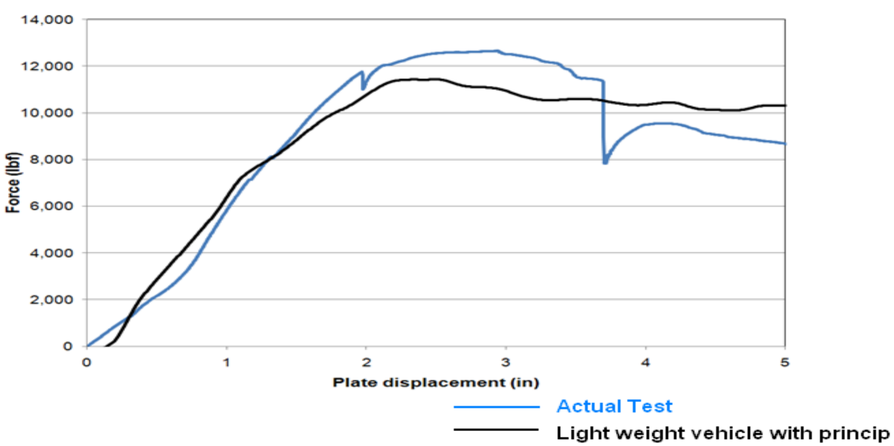
NCAP Rigid Side Pole 20 mph test





IIHS Roof crush test



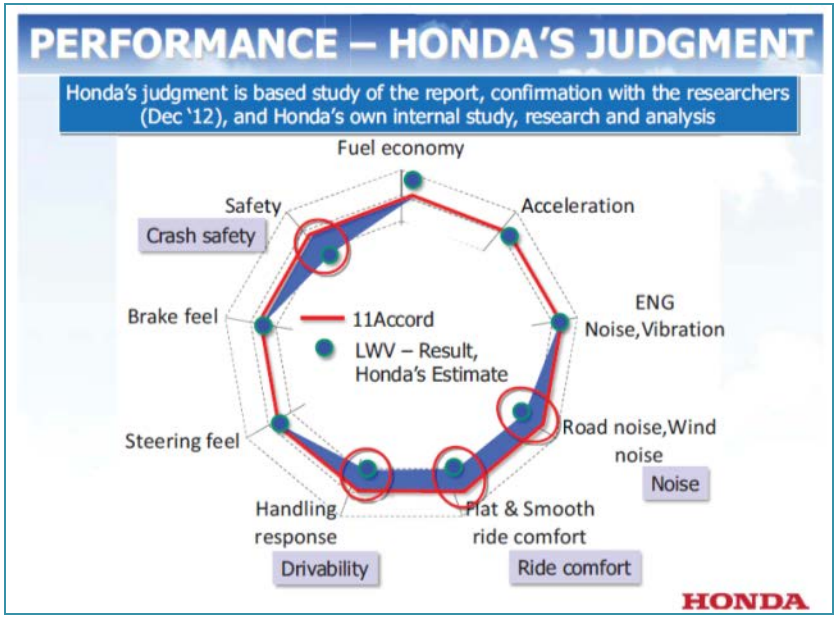


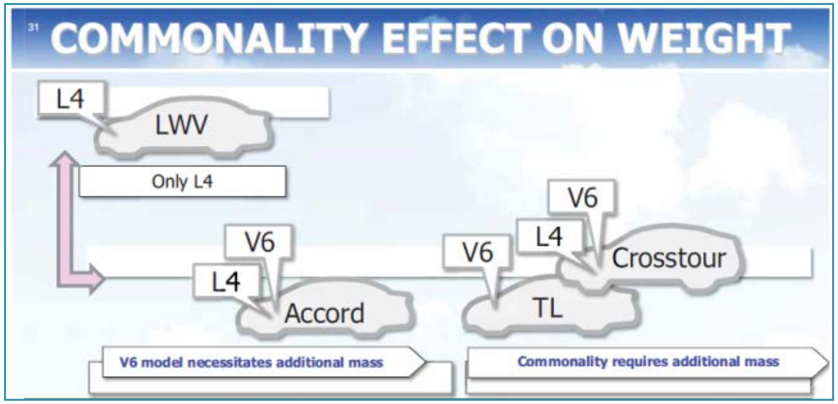
SWR versus platen displacement for Honda Accord and LWV

Shortfall in performance:

1. Crash safety:
   - IIHS Offset Barrier – Excessive intrusion
   - Side Impact – Material failure (design borderline)
   - Rear Impact – clearance to fuel filler line
2. Drivability – handling response due to ground clearance, LWV Lower torsional stiffness
3. Ride Comfort – flat & smooth road surfaces
4. Noise – road and wind, lighter steel wheel rim and additional insulation in aluminum doors

- Platform Sharing – allowance for additional mass impact?



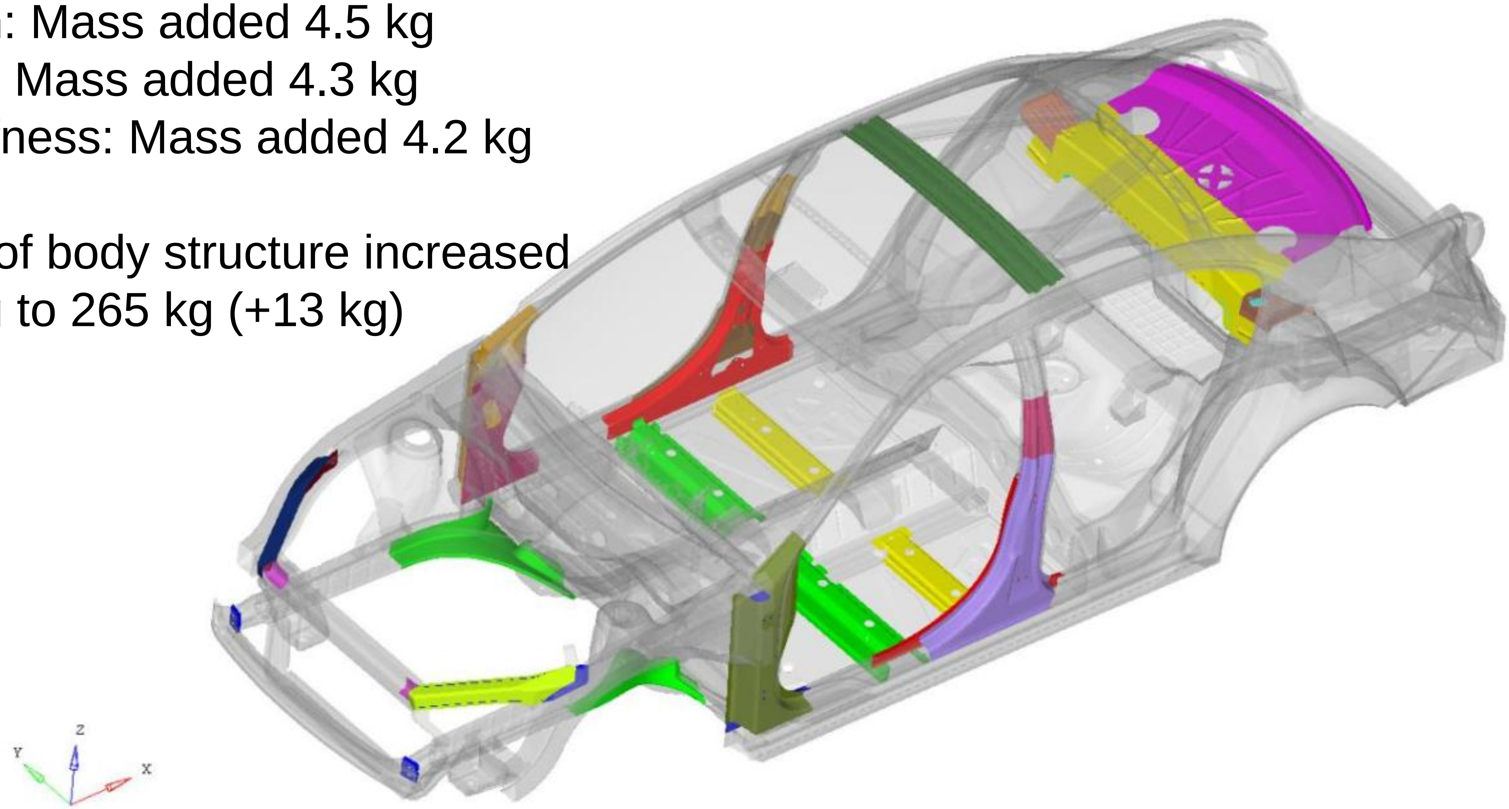


LWV – Improved Design: Changes to body structure – based on feedback

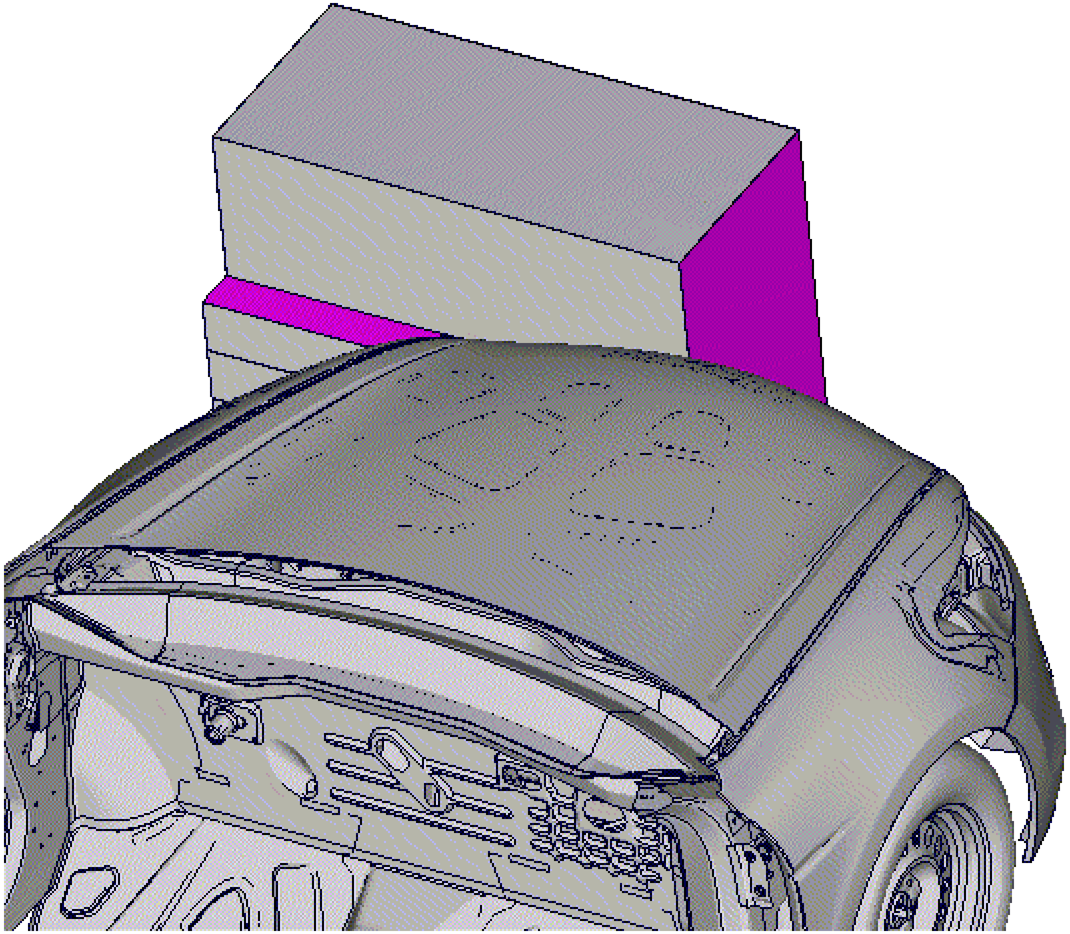
The thickness and /or grade of material was modified for the highlighted panels.

Front Crash: Mass added 4.5 kg
Side Crash: Mass added 4.3 kg
Torsion Stiffness: Mass added 4.2 kg

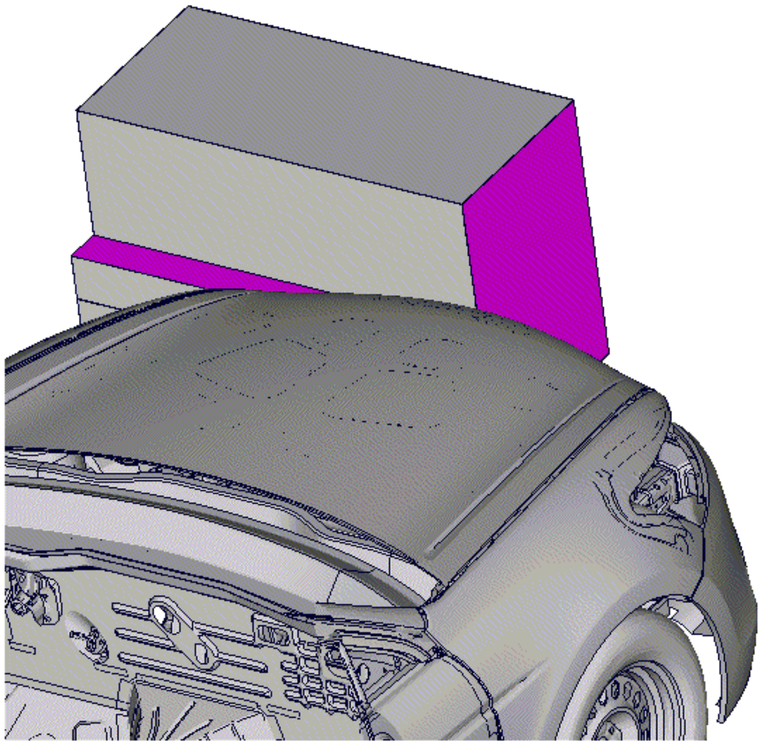
Total mass of body structure increased from 252 kg to 265 kg (+13 kg)



LWV - IIHS offset barrier 40 mph deformable barrier test

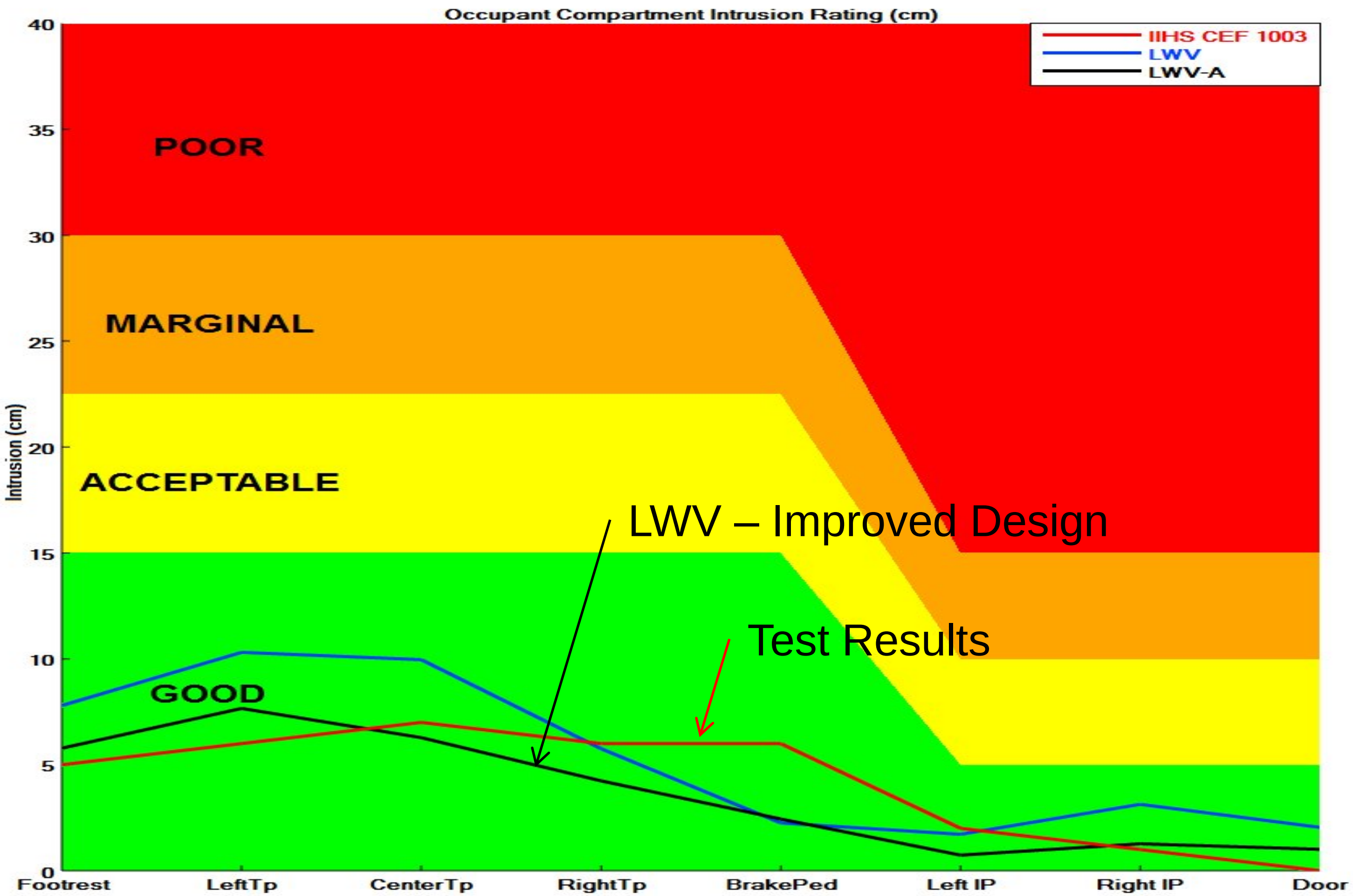


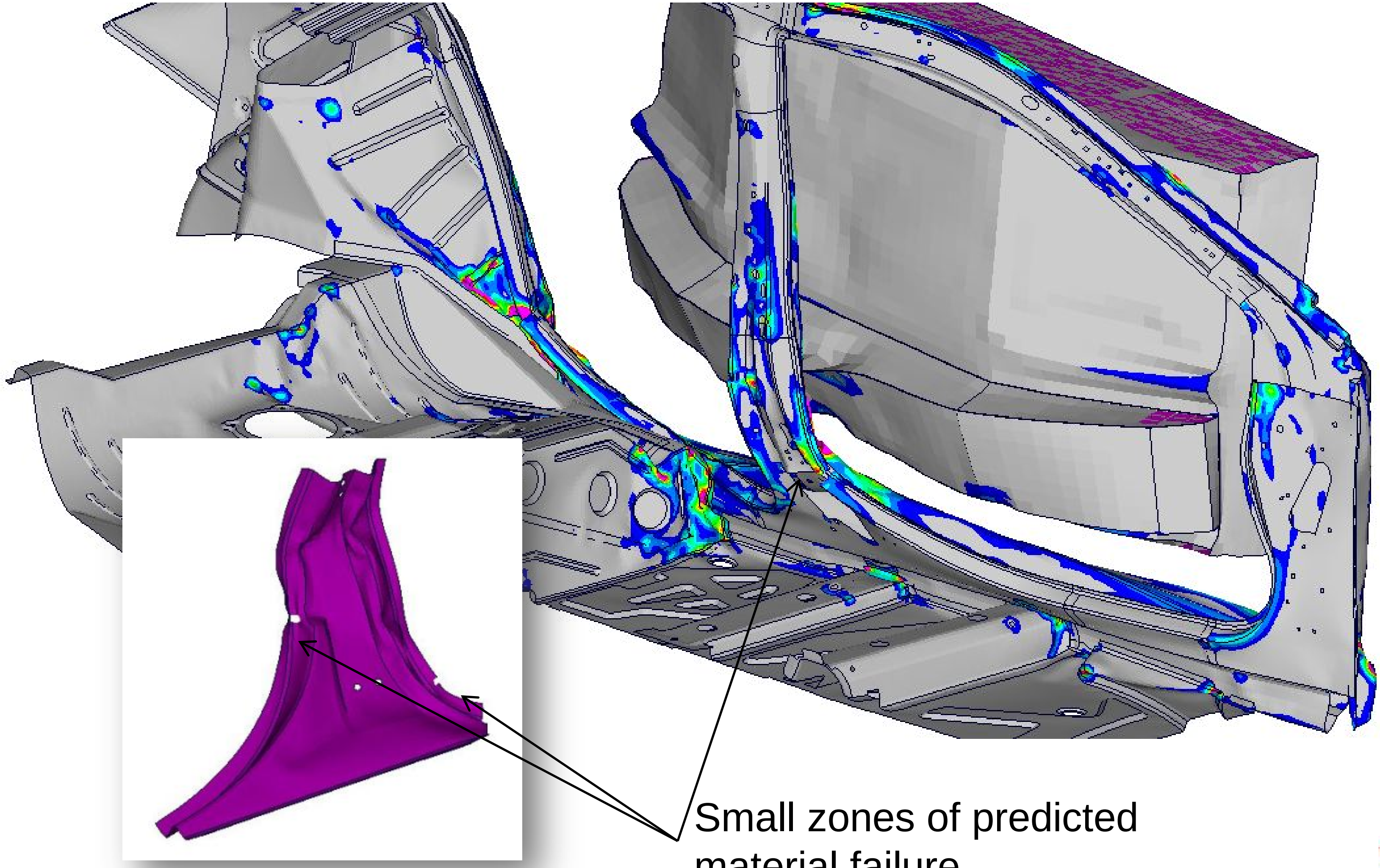
Compartment Intrusions – Front B Pillar and Upper Dash and side of tunnel

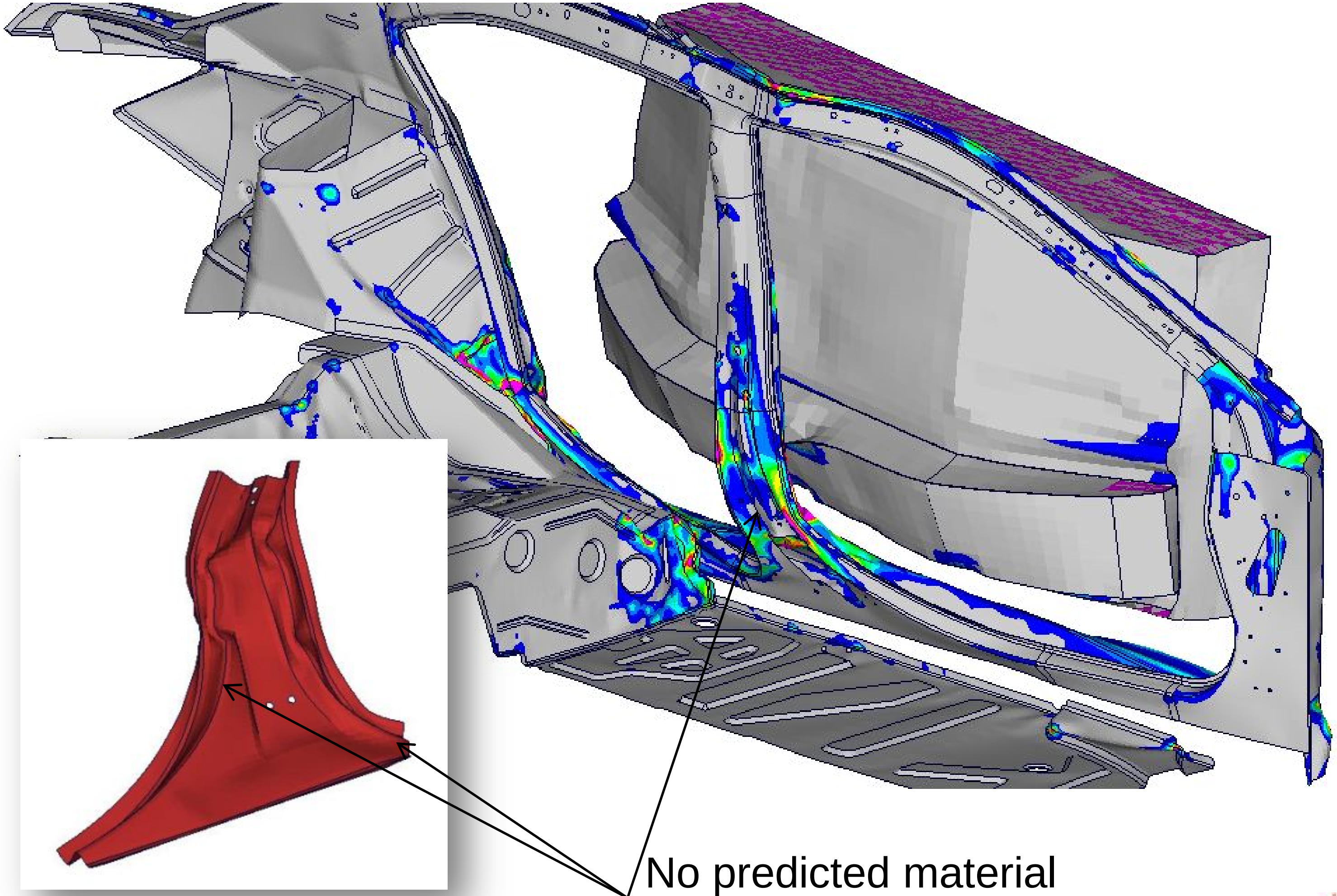


Compartment Intrusions – Front B Pillar and Upper Dash and side of tunnel - Reduced

LWV – IIHS Offset Barrier – Intrusion Results

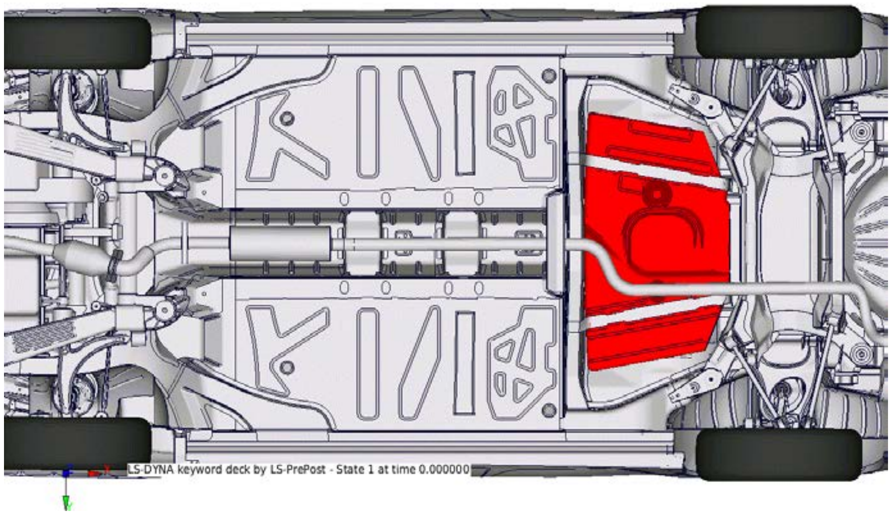



Small zones of predicted
material failure

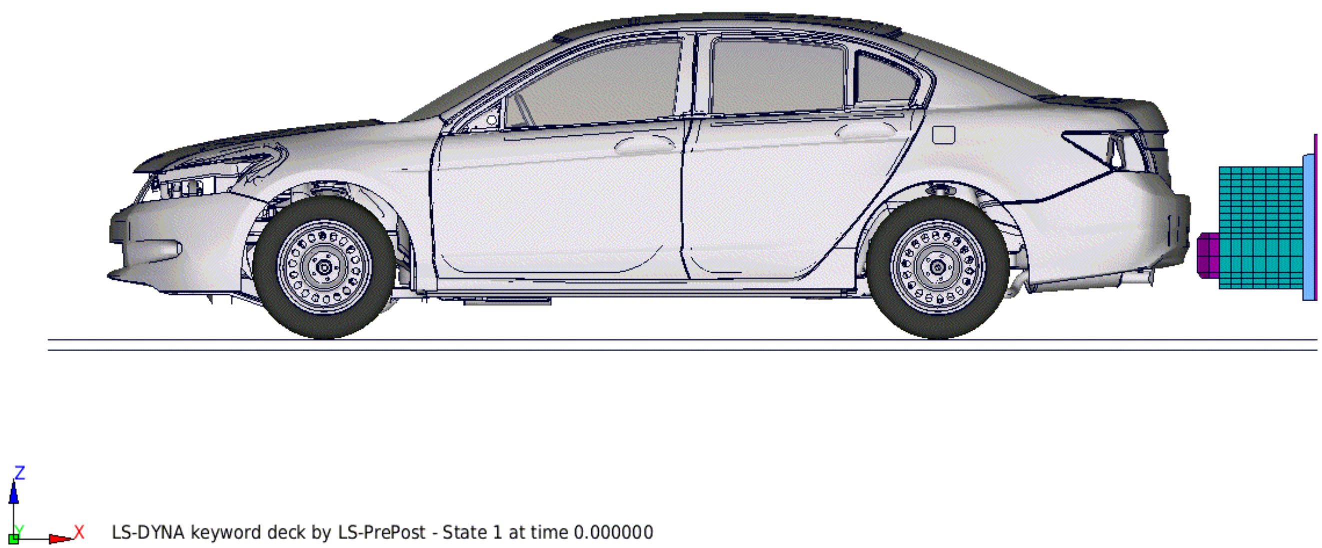


No predicted material failure

Rear 301 fuel system integrity
50 mph offset barrier

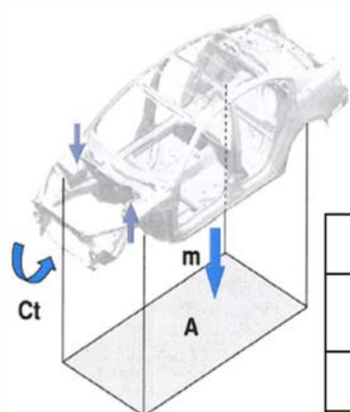


Fuel tank no structural intrusions. The fuel filler pipe can be rerouted or offending suspension component can be modified to create the required clearance. Require detailed design, no mass impact.



LWV – Improved Design: Torsion Stiffness Comparison Test v FEA Prediction

Description	Torsional Stiffness KN m/deg		
	Baseline Vehicle Test	LWV	LWV Improved
Constrained at Rear Rail	**12.33**	**14.40**	**16.99**
Constrained at Rear Top of Shock Tower		**16.25**	**21.16**



$$L = \frac{m}{A \times Ct}$$

m: Body mass (Kg)
A: Wheel base x Tread (m^2)
Ct: Static rigidity (KNm/deg)

	Honda Accord 2011	LWV
BIW Mass (kg)	327	252
Torsional Stiffness (kNm/deg)	12.33	16.25
Area A (m^2)	4.45	4.45
Light Weight Index	5.96	3.48

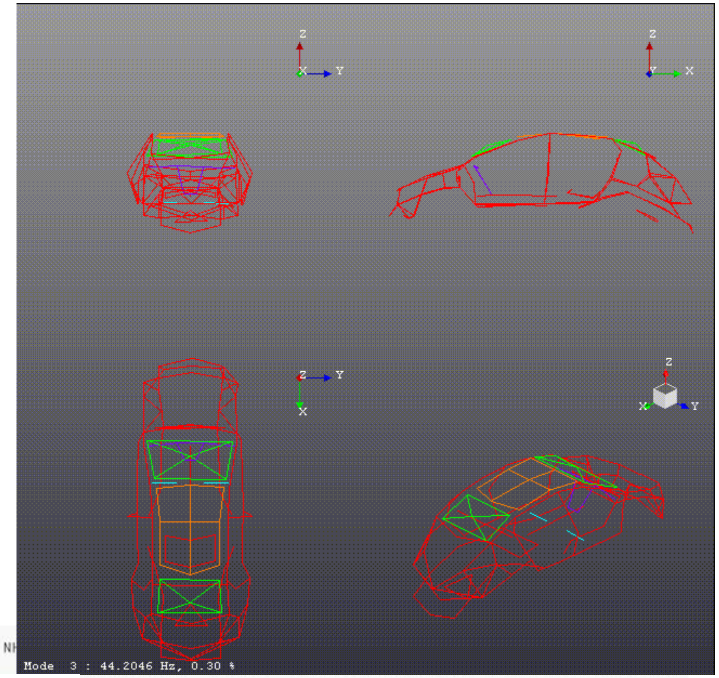
	Honda Accord 2011	LWV	LWV - Improved
BIW Mass (kg)	327	252	265
Torsional Stiffness (Nm/deg)	12.33	14.40	16.99
Area A (m^2)	4.45	4.45	4.45
Light Weight Index	**5.96**	**3.93**	**3.51**

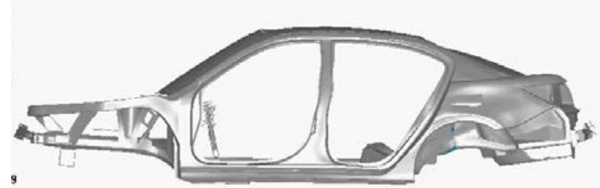
Revised Value

LWV – Improved Design: Bending Stiffness Comparison Test v FEA Prediction

Description	Bending Stiffness N / mm		
	Baseline Vehicle Test	LWV	LWV Improved
Constrained at Rear Rail	**8,690**	**11,760**	**13,030**
Constrained at Rear Top of Shock Tower		**12,636**	**15,302**

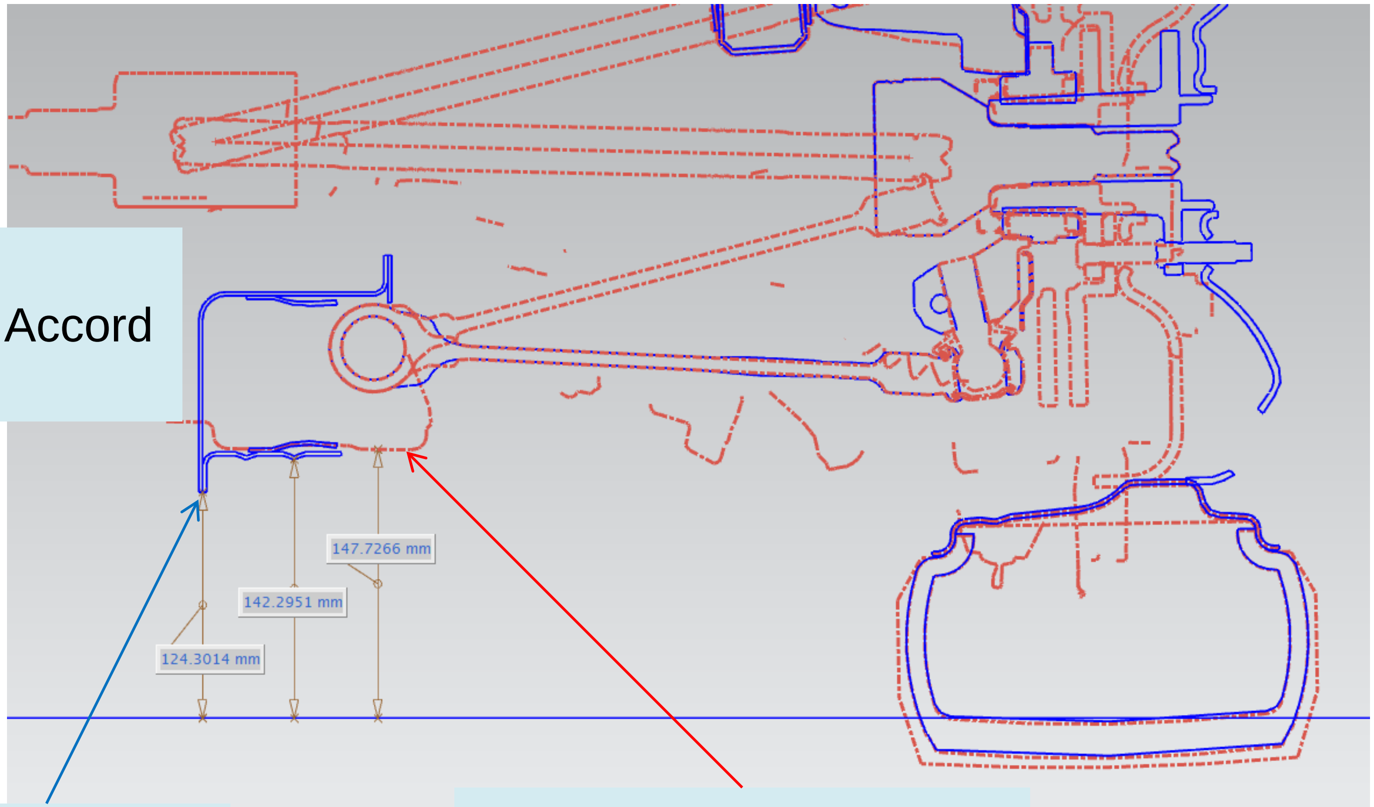
LWV – Improved Design: Resonance freq. Comparison Test v FEA Prediction





Mode Shape	Resonance Frequency (Hz)		
	Test	LWV	LWV Improved
Front end lateral mode	35.10	40.48	40.59
Second order bending mode	39.30	40.75	41.98
First order bending mode	44.20	46.29	46.63
Torsion mode	50.10	48.69	51.77

LWV – Ground Clearance

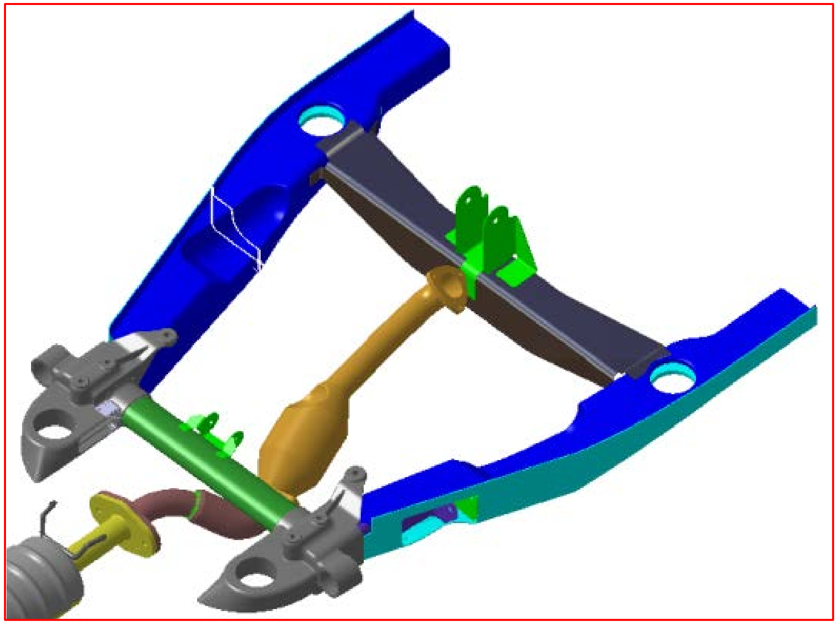


Engine Cradle:
Red Lines: Honda Accord
Blue Lines: LWV

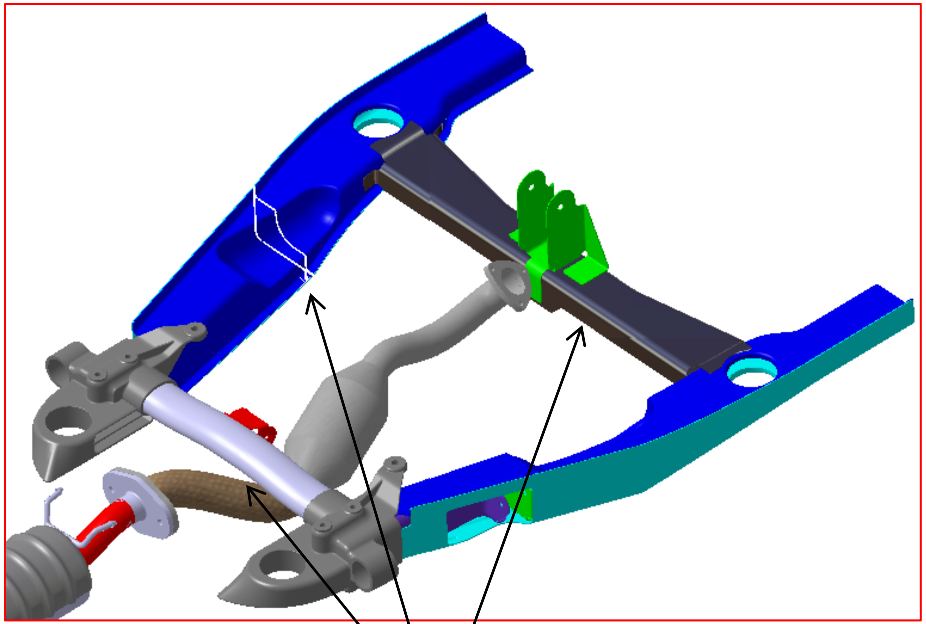
LWV – 124mm

Honda Accord – 148mm

LWV – Ground Clearance: Engine Cradle Redesigned



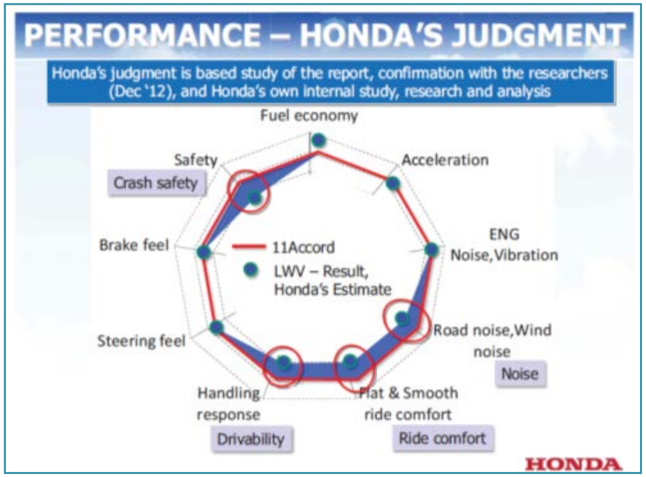
LWV – Engine Cradle



LWV – Improved
Engine cradle design modified
Ground Clearance – 148 mm
Mass Increase + 0.95 kg

Shortfall in performance: (Total mass impact +22.7 kg)

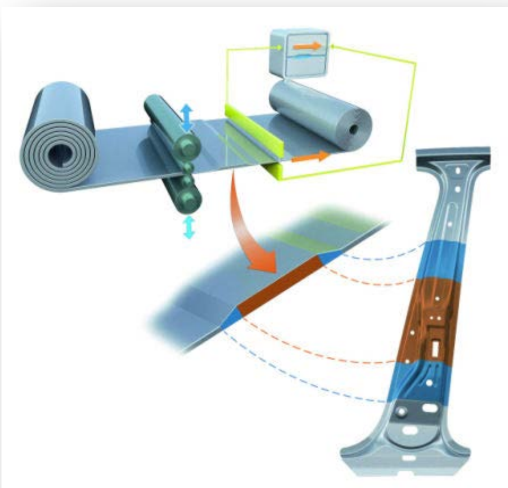
1. Crash safety:
    - IIHS Offset Barrier – Excessive intrusion (mass impact + 4.5 kg)
    - Side Crash – Material failure (mass impact +4.3 kg)
    - Rear Impact – clearance to fuel filler line (reroute fuel filler pipe to create required clearance – no mass impact)
2. Drivability – handling response due to ground clearance, LWV Lower torsional stiffness (mass impact +5.2 kg)
3. Ride Comfort – flat & smooth road surfaces (HONDA recommendations hydraulic mounts - mass impact +3.5 kg)
4. Noise – road and wind, lighter steel wheel rim and additional insulation in aluminum doors and hood (mass impact + 5.2 kg)



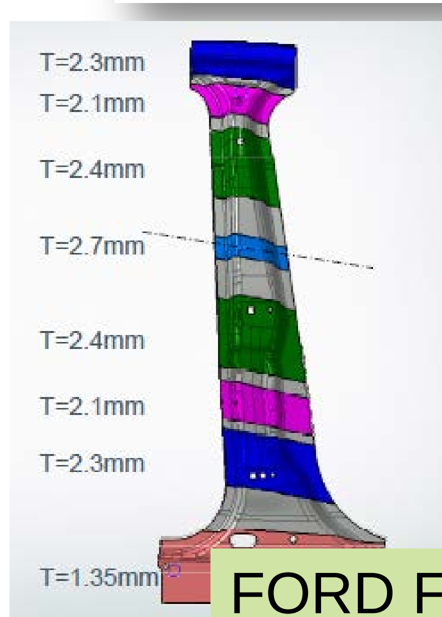
ADDITIONAL OPPORTUNITIES FOR MASS SAVING

Use of Tailor Rolled Blanks

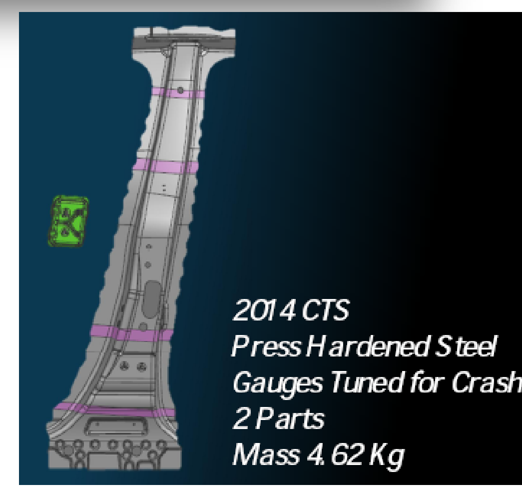
Tailor rolled coils were not used on LWV (available from only one supplier). Potential for another 13.0 kg of mass saving



VW - Golf Mk VII



FORD Focus



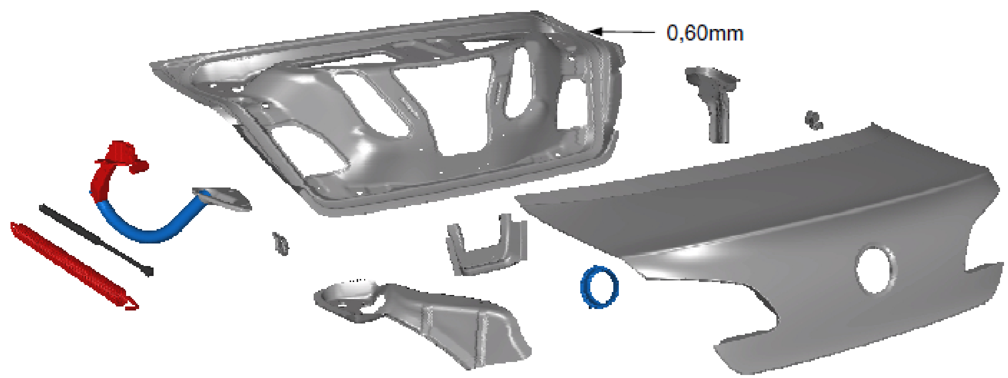
Reduce minimum thickness to 0.55mm

LWV - minimum thickness used for body panels 0.60mm

Potential for another 4.5 kg of mass saving by reducing thickness to 0.55mm for selective panels.

BIW-Structure
Boot lid

- High-quality feel with deep-drawing qualities in outer area and the hidden "grey zone"
- High structural stiffnesses for long-term quality and feeling of comfort
- Innovation through integrated fold-out badge



ECB Bad Nauheim
21 – 23 October 2008

The Passat CC

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Das Auto

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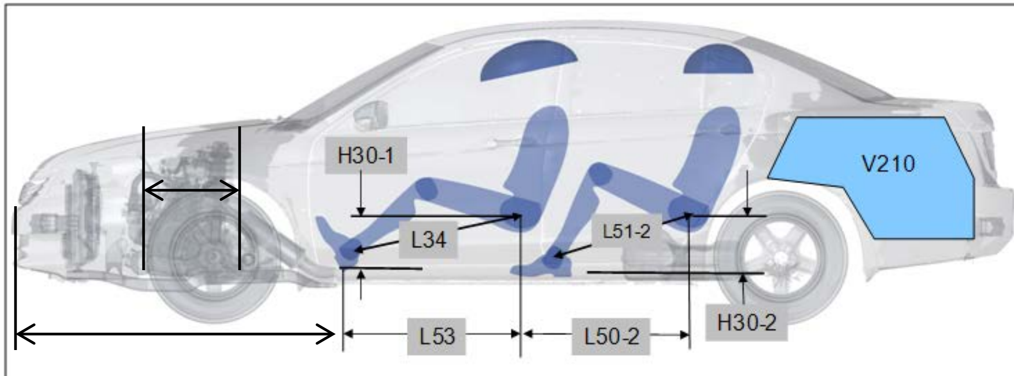
Vehicle Package Optimization - Length

Smaller Powertrain – free up space, the front end can be reduced in size for same crush distance and vehicle functionality. Potential weight savings of approximately 5.0 kg in the body structure.



	L34	L53	H30-1	L50-2	L51-2	H30-2	V210
Dimensions MM	1080	945	275	800	825	325	425 L

A vehicle fitted with ComfortThin seats can be shortened by 35 millimeters amounting to weight savings of approximately 4.5 kg in the body structure of a lower medium segment vehicle. ComfortThin seats will be available for the 2015 model year. (JCI – Announcement)

LWV 2013 – Mass estimate after all feedback

Vehicle System	Baseline Vehicle System Mass (kg)	AHSS BIW & Aluminum Closures, Chassis Frames, Mag Seats (2011 LWV)		Mass Estimate After Feedback (2013 LWV - Improved)		
		Mass Saving (kg)	Mass Saving (%)	Mass Impact (kg)	Mass Saving (%)	
Body Structure	328.0	75.6	-23.0%	11.5		
Doors Front	32.8	15.9	-48.5%	-0.6		Additional sound insulation
Doors Rear	26.8	11.9	-44.6%	-0.6		Additional sound insulation
Hood	15.2	7.7	-50.7%	-0.8		Additional sound insulation
Decklid	10.0	5.2	-52.4%			
Fenders	7.3	3.3	-44.5%			
Bumpers	15.8	7.1	-44.9%			
Front Suspension	81.3	39.9	-49.1%	-4.45		Engine cradle and hydraulic mounts
Rear Suspensions	53.2	13.3	-25.0%			
Seats Front	45.7	13.7	-30.0%			
Seat Rear	21.0	6.3	-30.0%			
Instrument Panel	31.9	9.5	-29.6%			
Engine Transmission	266.6	56.5	-21.2%	10.5	5.0%	140 HP Engine and transmission by 2020
Fuel System	12.0	1.8	-14.6%			
Fuel, oil, coolant	68.7	8.1	-11.8%			
Wheels	93.9	14.2	-15.2%			
Trim	26.3	3.0	-11.6%			
Wiring	21.7	4.3	-20.0%			
Battery	12.4	1.1	-9.0%			
Headlights	9.4	2.4	-25.0%			
Exhaust	20.7	1.7	-8.2%			
Brakes	59.0	15.8	-26.8%			
Brake Fluid	0.5	0.0	0.0%			
Drive Shafts	15.2	3.5	-23.1%			
HVAC & Cooling System	37.9	4.5	-11.8%			
Ducting- HVAC & Engine Intake	0.0	0.0	0.0%			
Safety Systems	19.3	0.0	0.0%	1.0	5.0%	Design optimization by 2020
Steering System	20.3	4.8	-23.6%			
Front & Rear Fascia	13.5	0.0	0.0%	0.7	5.0%	
Wiper system	6.0	0.0	0.0%	0.6	10.0%	
Window Washer Fluid	4.8	0.0	0.0%			
Paint	12.0	0.0	0.0%			
Noise Insulation	9.4	3.2	-34.2%	-3.2		Additional sound insulation - thinner panels
Glass	33.5	0.0	0.0%	1.7	5.0%	Design optimization by 2020
Latches/fasteners/mirrors-Misc	47.8	0.0	0.0%	4.8	10.0%	Design optimization by 2020
Total - with Powertrain	1,480	332	-22.5%	21	-1.4%	
Total - without Powertrain	1,112	264	-23.8%	11	-0.9%	

LWV - Improved	TRB	.55mm Gage	Optimize Package Reduce Length
-13.0	10.5	4.5	9.5

21 kg – additional mass saving (contingency: can be applied towards "Platform sharing" etc.

LWV - Mass estimate for other sizes of vehicles 2010 & 2020 Averages

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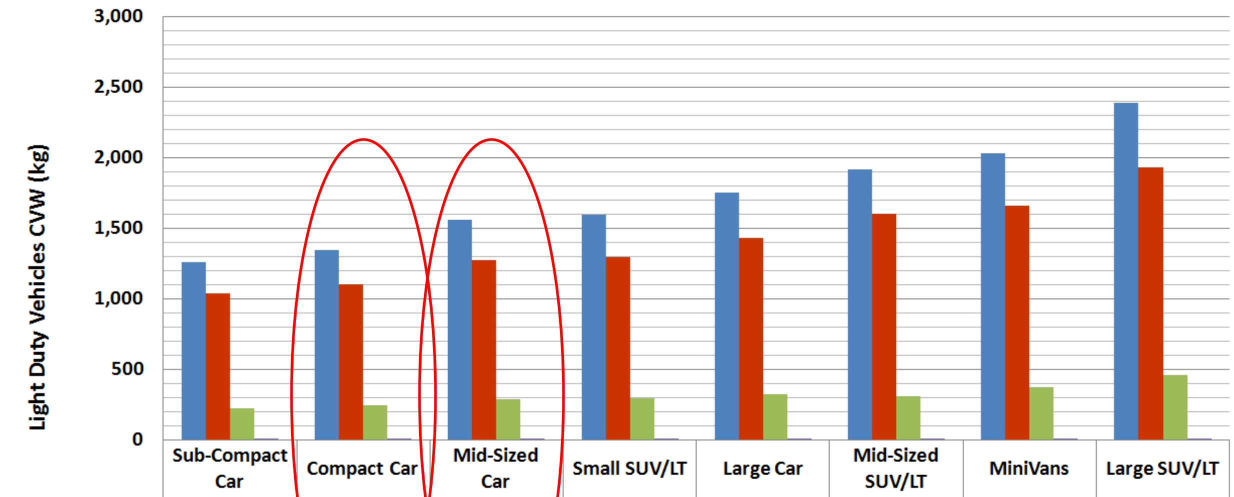
VW – Golf Mk VII



	Sub-Compact Car	Compact Car	Mid-Sized Car	Small SUV/LT	Large Car	Mid-Sized SUV/LT	MiniVans	Large SUV/LT
2010 - Class Average CVW (kg)	1,261	1,345	1,561	1,592	1,752	1,916	2,035	2,391
2020 - Class Average CVW (kg)	1,038	1,100	1,272	1,296	1,429	1,605	1,661	1,929
Mass Reduction (kg)	223.3	245.1	288.8	295.7	323.0	311.4	374.4	462.0
Mass Reduction (%)	17.7%	18.2%	18.5%	18.6%	18.4%	16.3%	18.4%	19.3%

Compact: LWV - Mass reduction over the next two generations : 245 kg(18.2% mass saving)

VW Golf Mk VII (2014 USA) - Platform shared with 3 vehicles – **achieved 100 kg weight reduction.** Weight reduction in the new Golf was achieved as follows:

Up to -6.0 kg = Electrical
Up to -40.0 kg = Engines
Up to -26.0 kg = Running gear
Up to -37.0 kg = Superstructure

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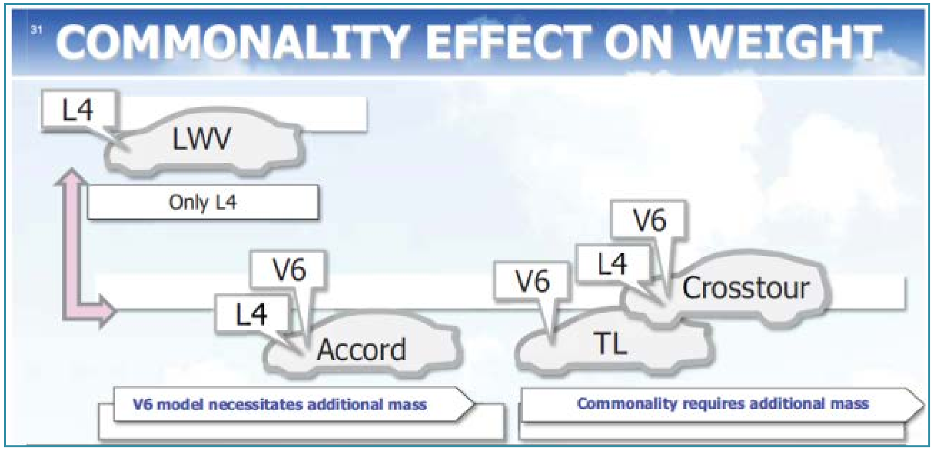
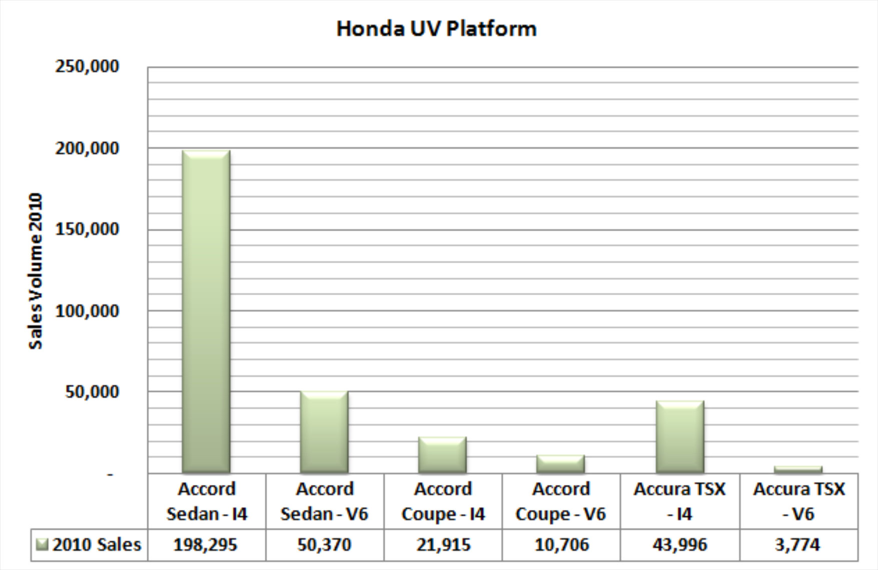
Mass Allowance for Platform Sharing?





"Change in strategy may be required"

Mary Barra, GM's global product chief :
"We are maniacal about mass."

In the biggest break from past practice, GM engineers built the ATS platform with only the highest-volume model in mind. Initially, they didn't incorporate weightier, more durable parts for, say, a V-6 engine or all-wheel-drive version, says ATS chief engineer Dave Masch. Automotive News -- February 18, 2013

Conclusions

1. This study helps to demonstrate that mass reduction of up to 22% is likely feasible, that maintains performance and safety functionality and MSRP at ±10% of the original baseline midsize sedan.

2. The approach for this study is an evolutionary implementation of advanced materials and manufacturing technologies currently used in the automotive industry.

3. The recommended materials (Advanced High Strength Steels, Aluminum, Magnesium and Plastics) manufacturing processes (Stamping, Hot Stamping, Die Casting, Extrusions, Roll Forming, Hydroforming) and assembly methods (Spot welding, Laser welding and Adhesive Bonding) are at present already used, some to a lesser degree than others.

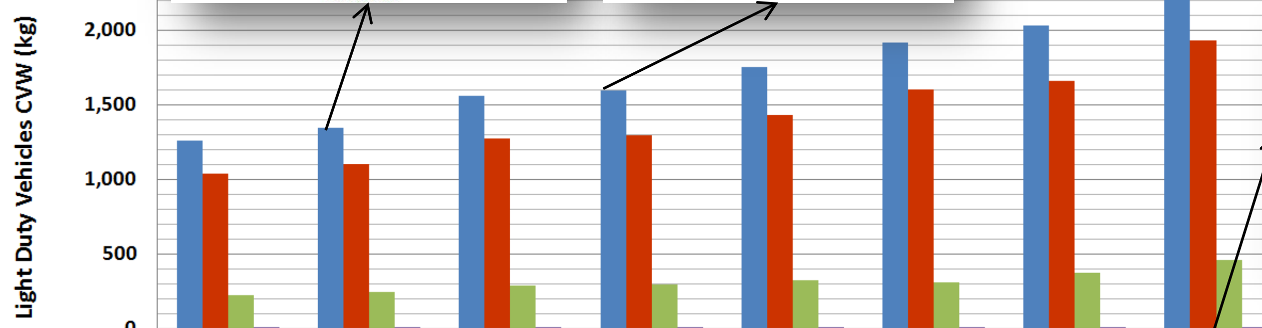
4. The recommended technologies should be able to be fully developed within the normal 'product design cycles' using the current 'design and development' methods prevalent in the automotive industry.

Thank you for your Attention

Links to Lightweighting Report:
Mass reduction study with Electricore/EDAG/George Washington University
Singh, Harry. (2012, August). Mass Reduction for Light-Duty Vehicles for Model Years 2017-2025. (Report No. DOT HS 811 666)
ftp://ftp.nhtsa.dot.gov/CAFE/2017-25_Final/811666.pdf

harry.singh@edag-us.com

LWV - Mass estimate for other sizes of vehicles 2010 & 2020 Averages



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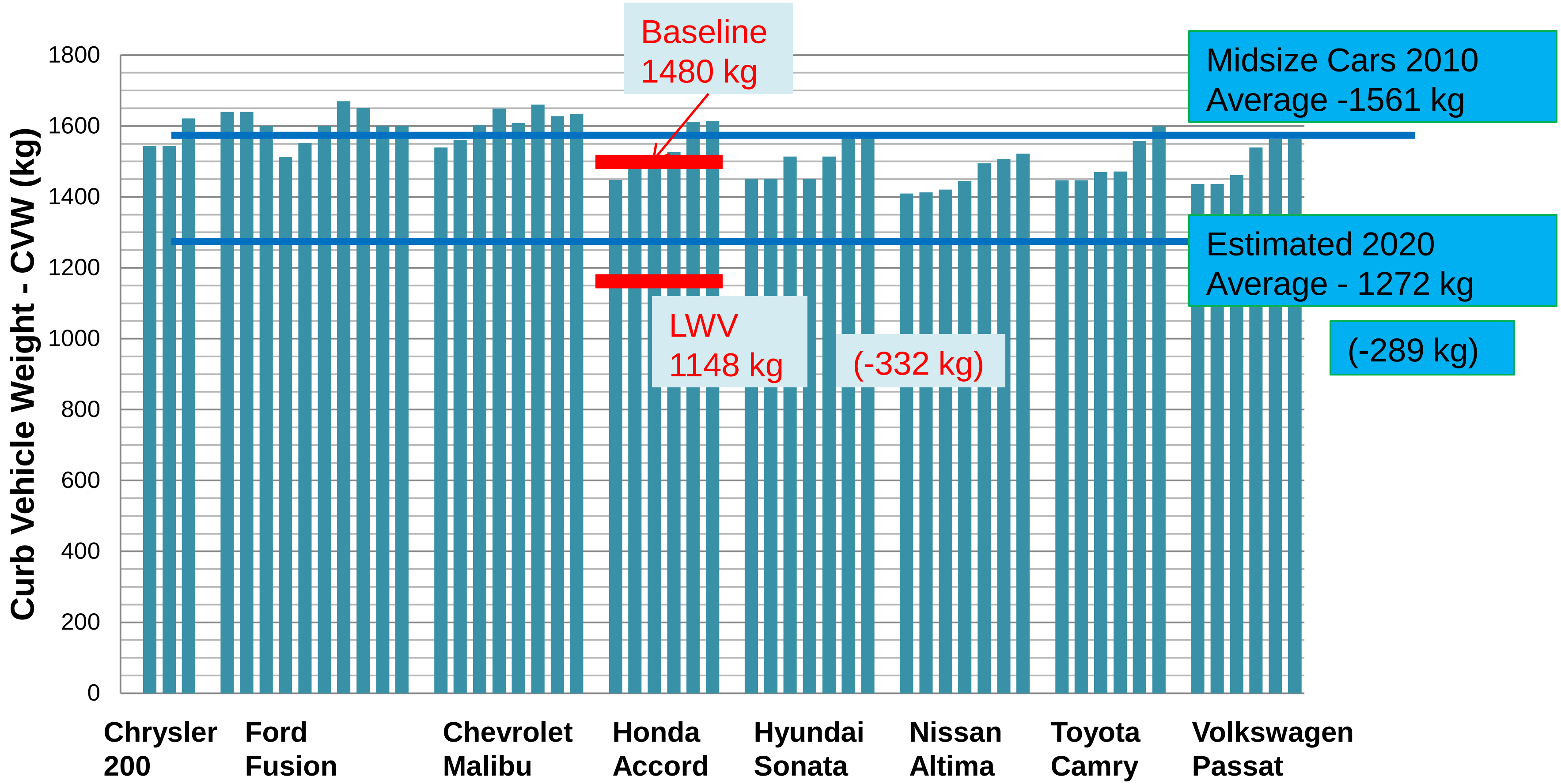
Mass Reduction (%)	17.7%	18.2%	18.5%	18.6%	18.4%	16.3%	18.4%	19.3%

LWV - Mass estimate for Midsize Cars 2010 & 2020 Averages



Mass Data for 2013 Mid Size Sedans