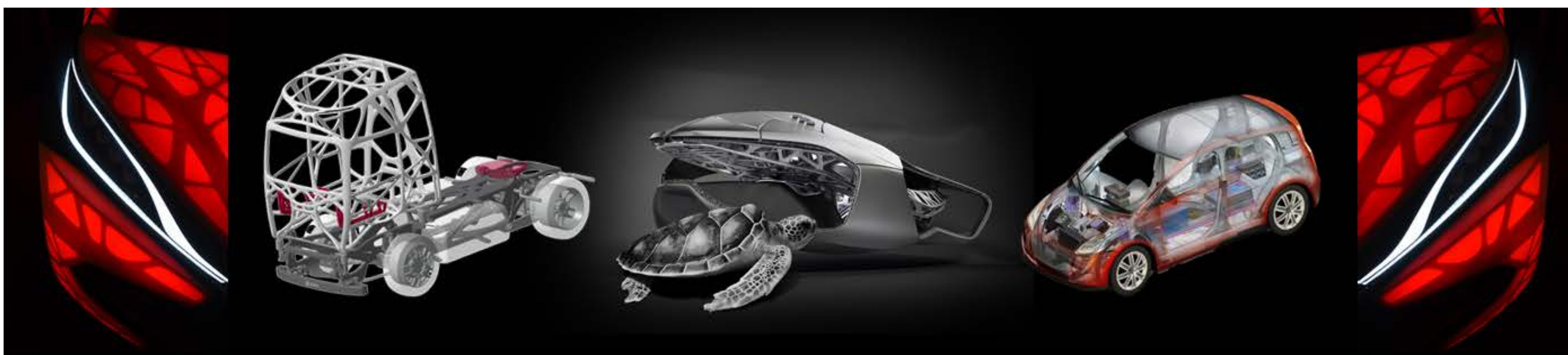
ATG Silverado Lightweighting Study

Final Report February 2nd, 2017

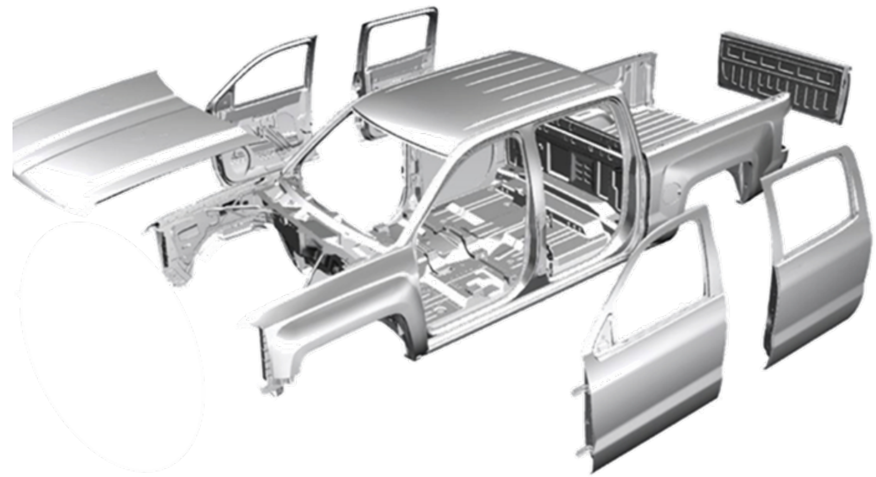


Harry Singh – Director Lightweighting, Vikrant Mogal – CAE Engineer, Pranesh Jayakumar – CAE Engineer

Contents

1.0 Introduction

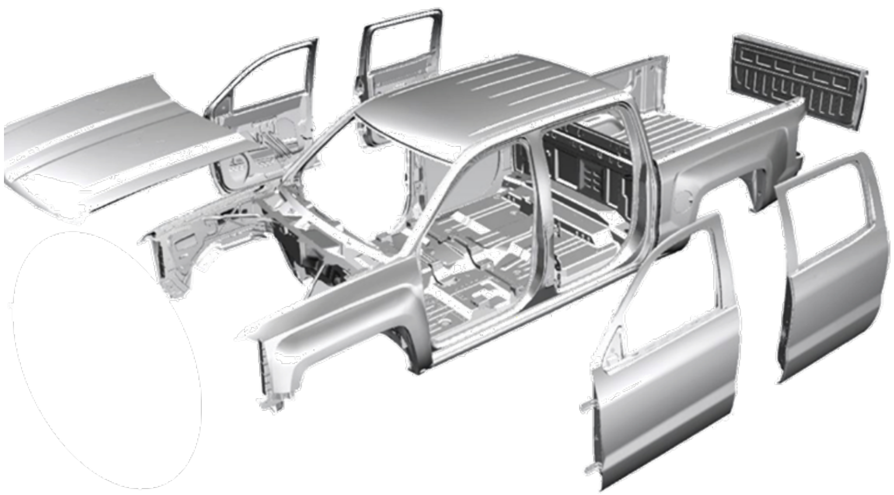
EDAG has recently completed a comprehensive lightweighting study for NHTSA. The baseline vehicle for the study was a 2014 Silverado 1500. The sheet metal body structure of the Silverado comprises of cab, front end sheet metal, hood, doors, pickup box and rear gate. For the NHTSA study the weight of these systems was reduced by 39% by use of Aluminum, AHSS reinforcements, AHSS door inner structure & Magnesium radiator support structure.



The objective of this project is to utilize ATG recommended advanced grades of aluminum to these systems to identify additional mass saving. This will highlight the mass saving potential of the latest grades of aluminum for light trucks such as Chevrolet Silverado, Dodge Ram and even for the aluminum based Ford F-150.

Executive Summary

Use of advanced ATG grades of aluminum leads to an additional 32.5 kg (10.6%) mass reduction compared with the NHTSA EDAG LWT proposed design for the subsystems shown in the Figure below. This is equivalent to a total mass saving of 46% when compared with the equivalent subsystems of the baseline vehicle MY2014 Chevrolet Silverado 1500.



Subsystem	Baseline 2014 Silverado 1500 Mass (Kg)	NHTSA EDAG LWT Mass (Kg)	EDAG ATG LWT	
			Mass (Kg)	Mass Saving Compared with NHTSA LWT (Kg)
CAB	**240.1**	140.94	130.97	-9.97
FENDERS	**32.47**	16.20	14.96	-1.24
CARGOBOX	**108.95**	65.03	60.10	-4.93
FRT_DOOR_L	**23.50**	16.32	12.40	-3.92
FRT_DOOR_R	**23.50**	16.41	12.49	-3.92
RR_DOOR_L	**21.74**	14.48	10.23	-4.25
RR_DOOR_R	**21.74**	14.54	10.29	-4.25
HOOD	**11.16**	11.21	11.21	0.00
TAILGATE	**21.30**	11.01	11.01	0.00
TOTAL	**504.46**	**306.14**	**273.66**	**-32.48**
	Saving Compared with Baseline	**-39.3%**	**- 45.8%**	
	Mass Saving Compared with NHTSA EDAG LWT		- 10.6%	

- Baseline vehicle MY2014 Silverado 1500 – material predominantly AHSS
- NHTSA EDAG LWT designed for MY2025 mainly aluminum for the CAB, Fenders & Pickup Box, with front & rear doors steel inner structure with aluminum outer panels
- EDAG ATG LWT designed for MY2025 using advanced grades of aluminum provided by ATG

2.0 Program Steps

The following program steps are considered for this study:

1. Reviewed design and bill of materials for the CAB, Closures and Pickup Box of Baseline vehicle MY2014 Silverado 1500 and NHTSA EDAG MY2025 lightweight design

2. Prepare CAE Models:
   - With updated designs for aluminum
   - With ATG recommended grades of aluminum

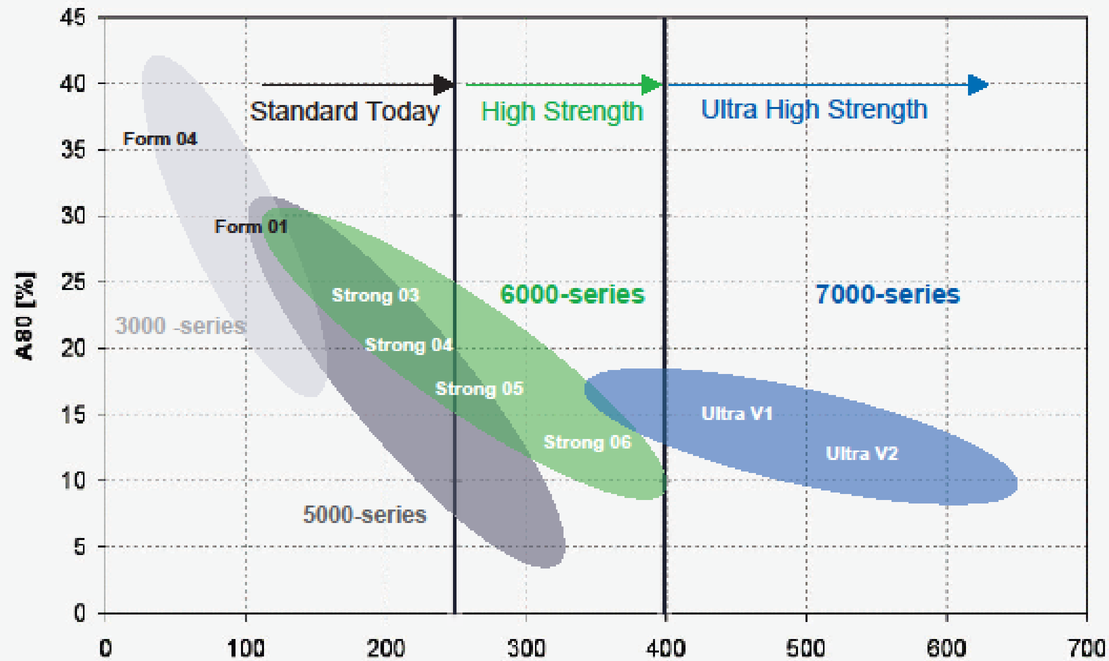
3. CAE Crash Analysis using LSDYNA:
   - NCAP frontal impact
   - NCAP side impact
   - NCAP side pole impact
   - FMVSS No. 216 Roof Crush
   - FMVSS No. 301 Rear Impact
   - IIHS side impact
   - IIHS moderate overlap
   - IIHS small overlap

4. CAE Analysis using NASTRAN:
   - Torsional Stiffness (CAB)
   - Bending Stiffness (CAB)
   - Strength and Durability loads (Pickup Box)

3.0 ATG Aluminum Grades used for EDAG ATG LWT
For Stamped Panels and Extrusions

Grade	UTS (Mpa)		YS (Mpa)		E (%)		Comments
	Min	Typ	Min	Typ	Min	Typ	
Stiffness dependent panels							
5XXX - O 105/185	185	200	105	120	15	20	General purpose structural for stiffness
5XXX - O 125/250	250	275	125	145	15	20	Inner panel for body or high formability "door inner"
5XXX-H34 220/290	290	305	220	240	5	16	Structural - non clas "A"
Strength dependent panels							
6XXX-T6 240/285	285	310	240	260	10	12	Standard Body Sheet
6XXX-T6 240/280	280	305	240	260	10	12	Improved hemming
6XXX-T61 180/230	230	255	180	200	12	19	Deep draw (door inner)
6XXX-T6 250/285	285	310	250	275	10	12	Improved Dent Resistance and hemming- Door Skins
6XXX-T6 295/340	340	365	295	320	10	12	Strength - structures
6XXX-T6 265/340	340	365	265	290	10	12	Strength - structures
6XXX-T6 340/370	370	390	340	360	8	10	High Strength -structures
6XXX-T6 360/380	380	400	360	380	6	8	Very High Strength - structures
6XXX-T8 160/230	230	255	160	185	15	20	High formability, Deep draw (door inner)
6XXX-T8 230/270	270	290	230	250	12	15	Improved hemming
6XXX-T8 240/285	285	305	240	260	10	12	Standard Body Sheet
6XXX-T8 260/295	295	315	260	275	10	12	Higher Strength Improved Dent Resistance and hemming- Door Skins
7XXX-T76 530/565	565	590	530	550	8	10	High strength
Extrusions alloys (structural)							
6XXX-T6 260/290	290	310	260	275	9	17	Typical automotive
6XXX-T6 270/310	310	340	270	315	10	14	Typical automotive
6XXX-T7 280/305	305	320	280	300	10	14	Energy absorbtion (e.g. front crash rails)
6XXX-T6 340/355	355	375	340	365	8	10	High Strength (e.g. bumper beams)
7XXX-T5 320/345	345	385	320	330	10	16	Weld recovery
7XXX-T6 360/400	400	435	360		8	14	Bumpers, structures
7XXX-T6 475/530	530	570	475	505	7	11	Door Beam ($)

3.0 ATG Aluminum Grades Advancements

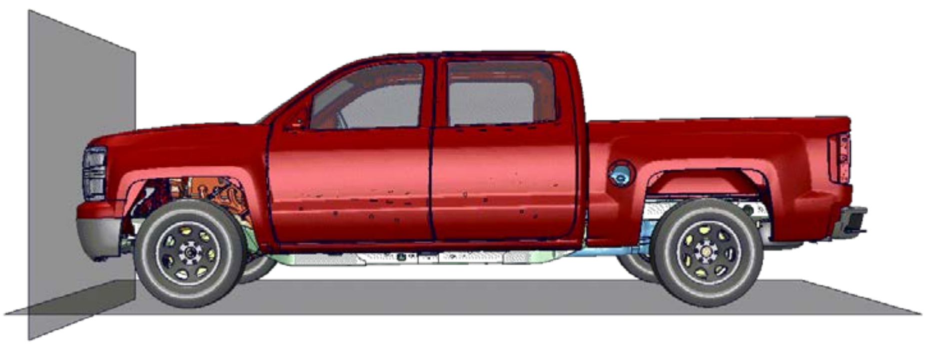


Courtesy Constellium – Alex Graph

3.0 Aluminum Grades used for NHTSA EDAG LWT For Stamped Panels and Extrusions

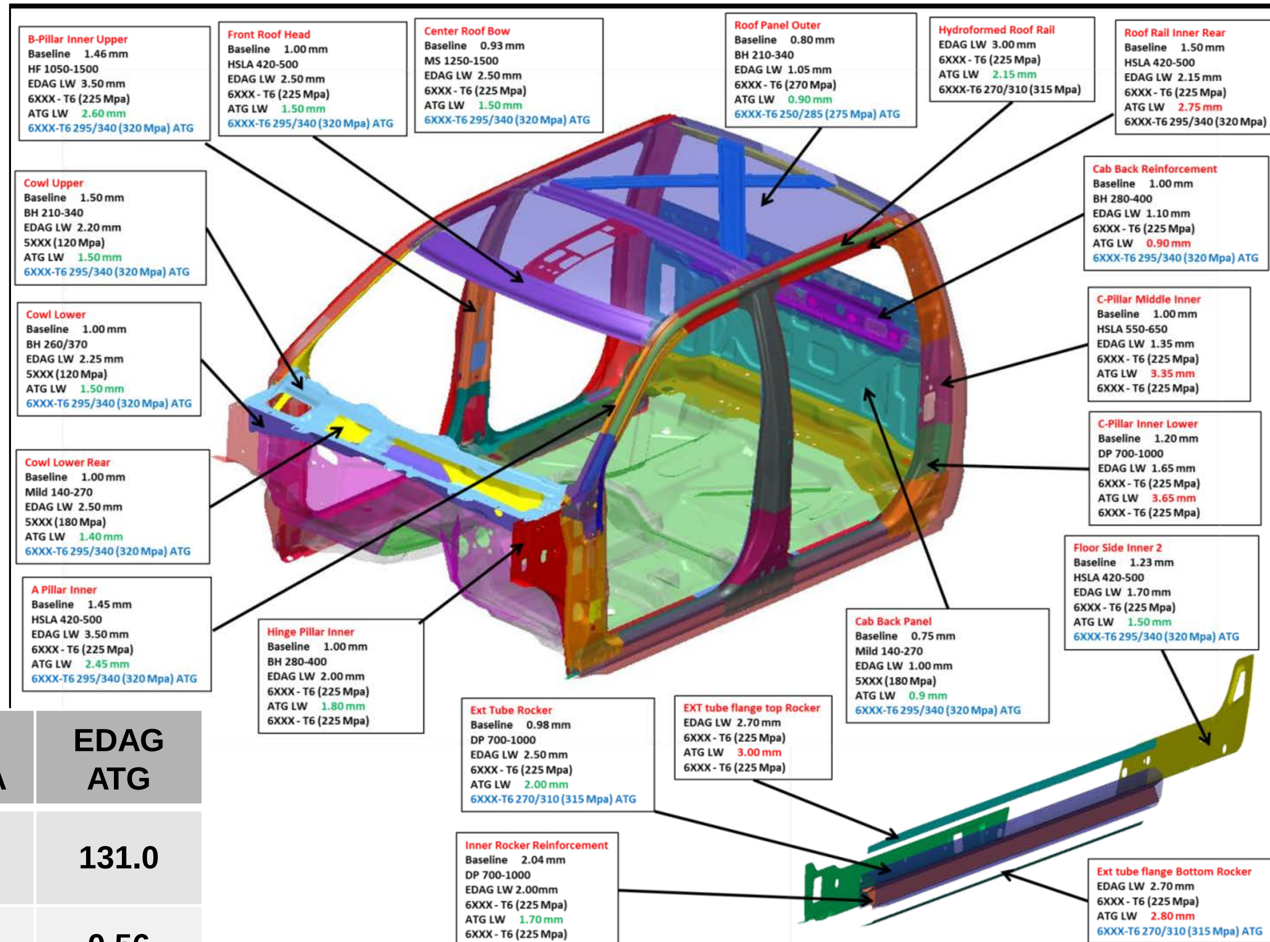
Aluminum Alloy Grades used in NHTSA EDAG LWT		Density (kg/m3)	Poisson's ratio	Modulus of Elasticity (MPa)	Typ Yield Strength (MPa)	Typ Ultimate Tensile Strength (MPa)	CAE Model Failure Elongation (%)
5XXX (120 Mpa)	AL 5754	2,700	0.33	71,000	120	250	16
6XXX - T7 (200 Mpa)	AA 6014-T7	2,700	0.33	71,000	200	270	17
6XXX - T6 (225 Mpa)	AA 6014-T6	2,700	0.33	71,000	225	294	18
	AA 356-T6 CAST	2,700	0.33	71,000	232	302	10
6XXX - T6 (270 Mpa)	AA 6111-T6	2,700	0.33	71,000	270	355	16

- Baseline vehicle MY2014 Silverado 1500 – material predominantly AHSS
- NHTSA EDAG LWT designed for MY2025 mostly aluminum with front & rear doors steel inner structure with aluminum outer panels
- EDAG ATG LWT designed for MY2025 using advanced grades of aluminum provided by ATG
- The CAB, Pickup Box & Closures structure was redesigned utilizing aluminum extrusions and stampings, assembled using SPR (self piercing rivets) and adhesive bonding
- The structure was optimized using CAE computer simulation for crashworthiness and stiffness load cases

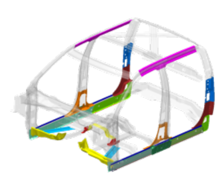


5.1 Gauge and Material Grades for the CAB Structure

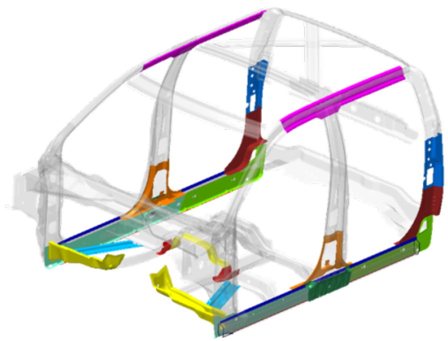
- The CAB structure was redesigned utilizing aluminum extrusions and stampings, assembled using SPR (self piercing rivets) and adhesive bonding
- The structure was optimized using CAE computer simulation for crashworthiness and stiffness load cases



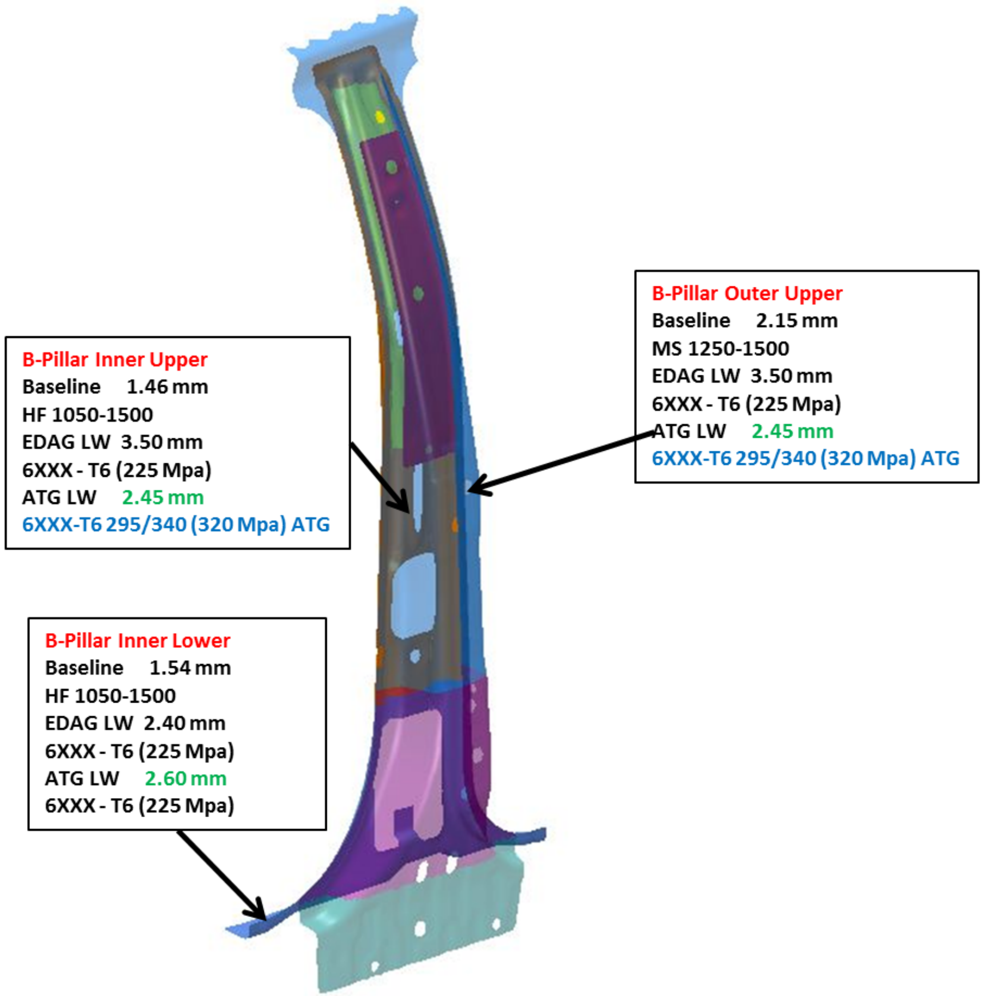
	Baseline Steel	EDAG NHTSA	EDAG ATG
Mass (kg)	240.1	141.0	131.0
	1	0.59	0.56
	1.70	1	0.93



5.1 Gauge and Material Grades for the CAB Structure

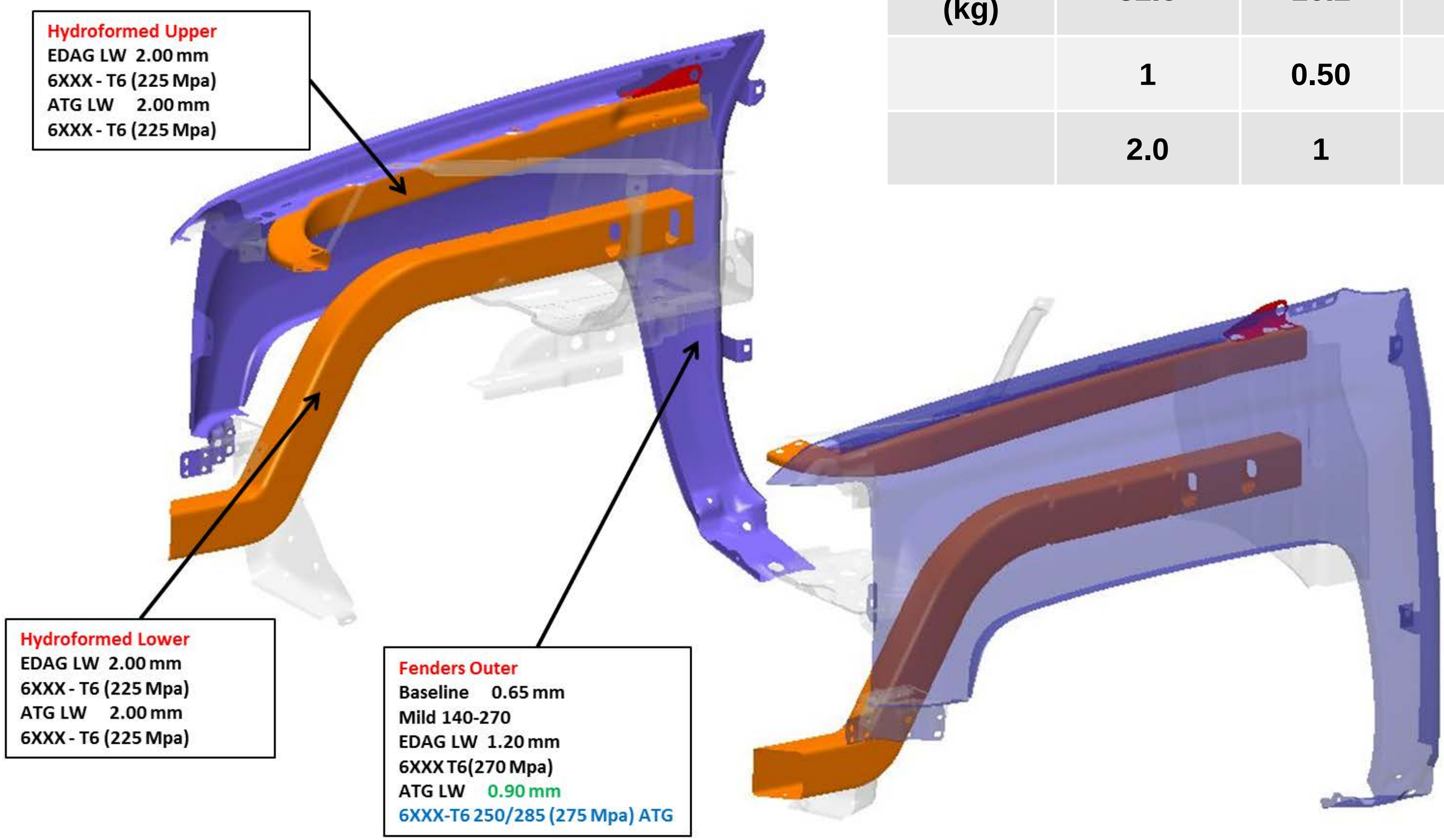


B-Pillar Details



5.1 Gauge and Material Grades for the Front End Sheet Metal

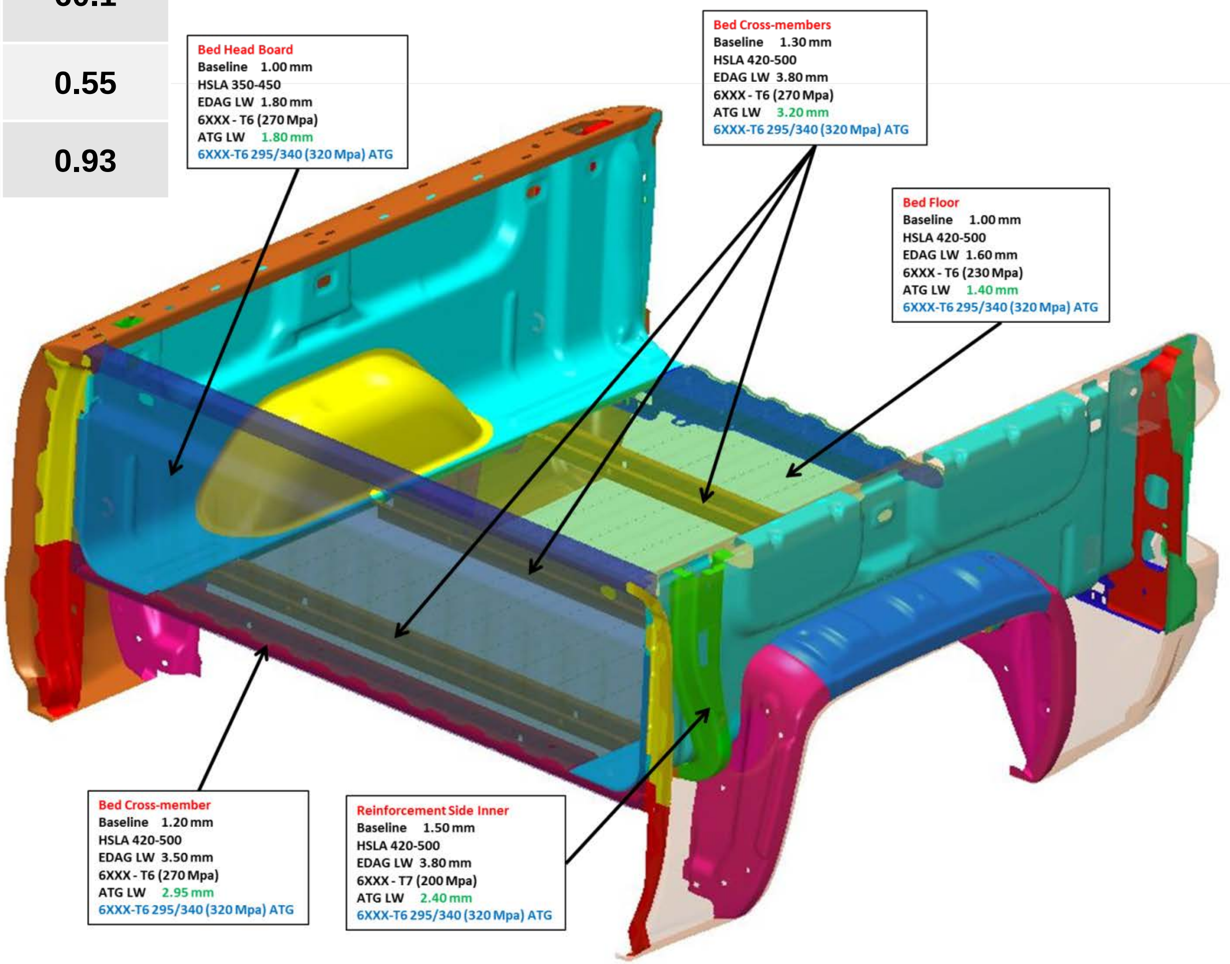
	Baseline Steel	EDAG NHTSA	EDAG ATG
Mass (kg)	32.5	16.2	15.0
	1	0.50	0.46
	2.0	1	0.93



5.2 Gauge and Material Grades for the Pick-Up Box

Reference: 2015 FORD F-150
Pickup Box 57.11 kg (painted A2Mac1)

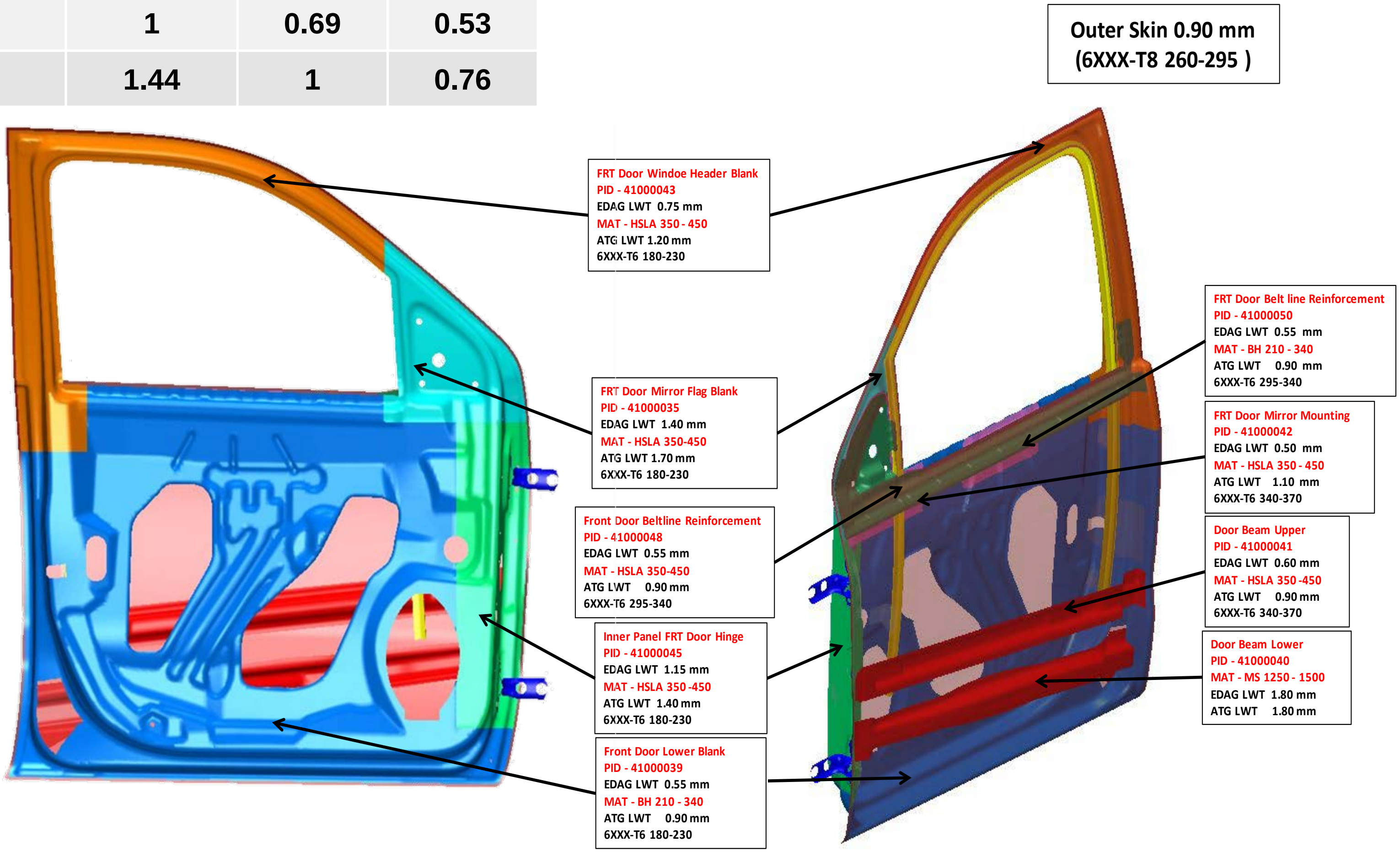
	Baseline Steel	EDAG NHTSA	EDAG ATG
Mass (kg)	109.0	65.0	60.1
	1	0.60	0.55
	1.68	1	0.93



5.3 Gauge and Material Grades for the Front Door

	Baseline Steel	EDAG NHTSA	EDAG ATG
Mass (kg)	23.50	16.32	12.40
	1	0.69	0.53
	1.44	1	0.76

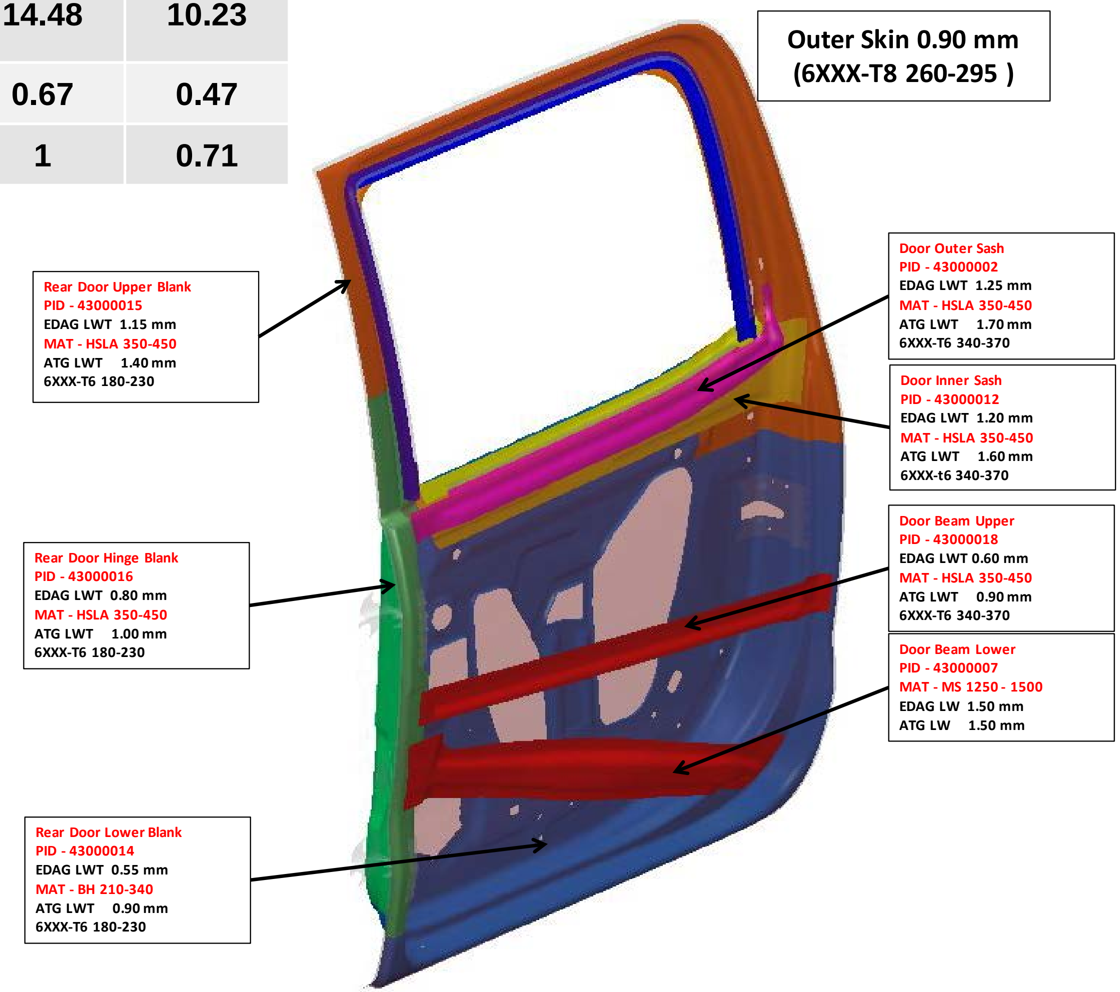
Reference: 2015 FORD F-150 Front Door Frame 14.15 kg (painted A2Mac1)



5.4 Gauge and Material Grades for the Rear Door

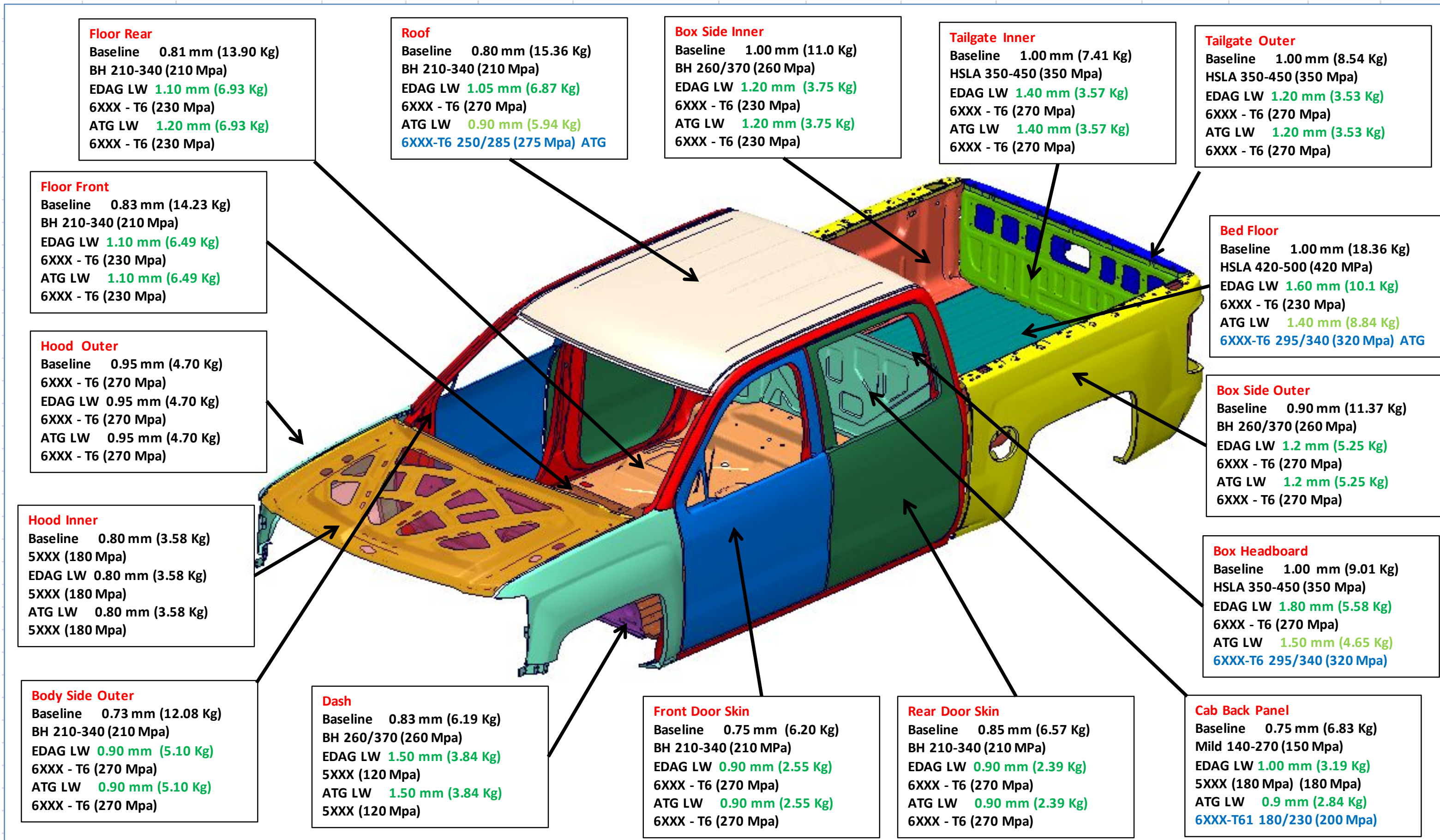
	Baseline Steel	EDAG NHTSA	EDAG ATG
Mass (kg)	21.74	14.48	10.23
	1	0.67	0.47
	1.50	1	0.71

Reference: 2015 FORD F-150
Rear Door Frame 11.18 kg (painted A2Mac1)



5.5 Comparison of Large Panels

	Baseline Steel	EDAG NHTSA	EDAG ATG
Mass (kg)	210.0	102.84	99.09
		-3.75	



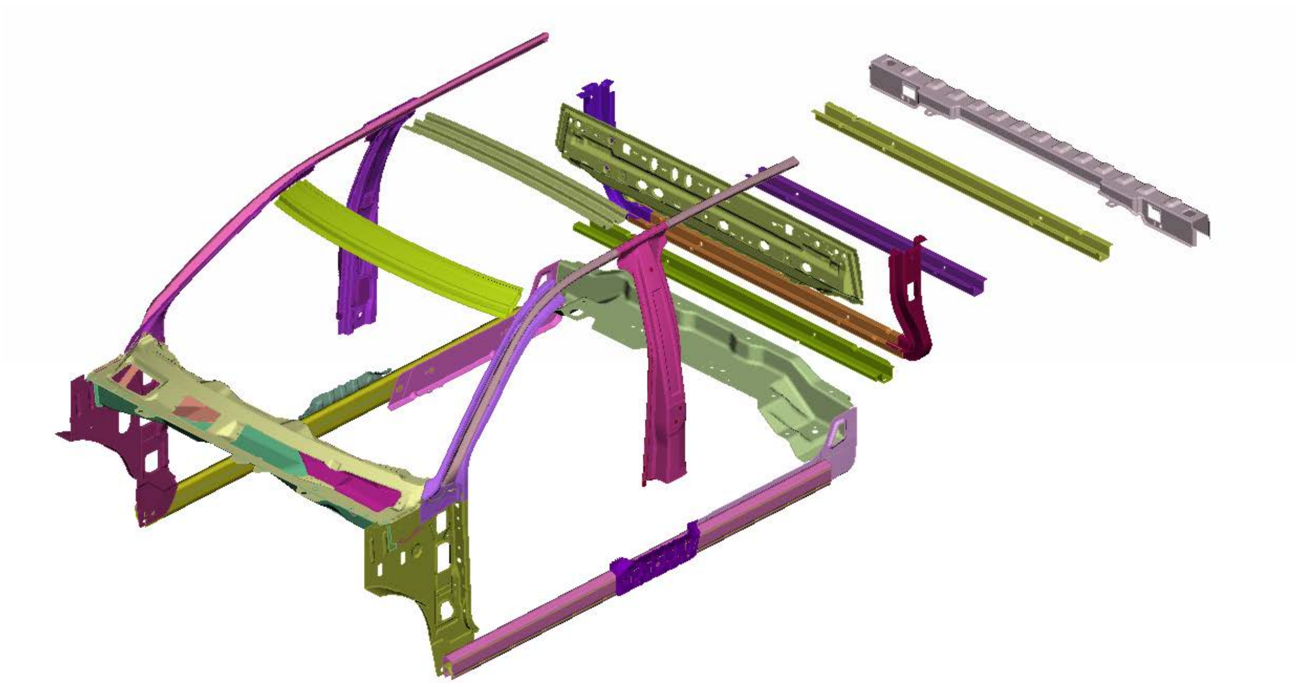
5.5 Comparison of Large Panels - Table

Part Name	EDAG BASELINE				EDAG NHTSA LWT				EDAG ATG LWT			
	Guage (mm)	Grade	Typ Yield (Mpa)	Mass (Kg)	Guage (mm)	Grade	Typ Yield (Mpa)	Mass (kg)	Guage (mm)	Grade	Typ Yield (Mpa)	Mass (Kg)
Body Side Outer RH	0.73	BH 210-340	210	12.08	0.9	6XXX - T6 (270)	270	5.10	0.9	6XXX - T6 (270)	270	5.10
Dash	0.83	BH 260/370	260	6.19	1.5	5XXX (120)	120	3.84	1.5	5XXX (120)	120	3.84
Front Floor	0.83	BH 210-340	210	14.23	1.1	6XXX - T6 (230)	230	6.49	1.1	6XXX - T6 (230)	230	6.49
Rear Floor	0.81	BH 210-340	210	13.90	1.1	6XXX - T6 (230)	230	6.53	1.1	6XXX - T6 (230)	230	6.53
Roof	0.8	BH 210-340	210	15.36	1.05	6XXX - T6 (270)	270	6.87	0.9	6XXX-T6 250/285	275	5.94
Back of Cab	0.75	Mild 140-271	150	6.83	1	5XXX (180)	180	3.19	0.9	5XXX (180)	180	2.84
Body Side Outer LH	0.73	BH 210-340	210	12.08	0.9	6XXX - T6 (270)	270	5.10	0.9	6XXX - T6 (270)	270	5.10
RH FENDER OUTER	0.65	Mild 140-270	150	3.71	1.2	6XXX - T6 (270)	270	2.48	0.9	6XXX-T6 250/285	275	1.86
LH FENDER OUTER	0.65	Mild 140-271	150	3.66	1.2	6XXX - T6 (270)	270	2.48	0.9	6XXX-T6 250/285	275	1.86
BOX HEAD BOARD	1	HSLA 350-450	350	9.01	1.8	6XXX - T6 (270)	270	5.58	1.5	6XXX-T6 295/340	320	5.25
BOX SIDE OUTER RH	0.9	BH 260/370	260	11.46	1.2	6XXX - T6 (270)	270	5.25	1.2	6XXX - T6 (270)	270	5.25
BOX SIDE INR RH	1	BH 260/370	260	11.00	1.2	6XXX - T6 (230)	230	3.75	1.2	6XXX - T6 (230)	230	3.75
BOX SIDE INR LH	1	BH 260/370	260	11.00	1.2	6XXX - T6 (230)	230	3.75	1.2	6XXX - T6 (230)	230	3.75
BOX SIDE OUTER LH	0.9	BH 260/370	260	11.37	1.2	6XXX - T6 (270)	270	5.21	1.2	6XXX - T6 (270)	270	5.21
BED FLOOR	1	HSLA 420-500	420	18.36	1.6	6XXX - T6 (230)	230	10.1	1.4	6XXX-T6 295/340	320	8.84
wheel housing LH					1.2	6XXX - T6 (230)	230	0.93	1.2	6XXX - T6 (230)	230	0.93
Wheel Housing RH					1.2	6XXX - T6 (230)	230	0.93	1.2	6XXX - T6 (230)	230	0.93
HOOD OUTER	0.95	6XXX - T6 (270)	270	4.70	0.95	6XXX - T6 (270)	270	4.70	0.95	6XXX - T6 (270)	270	4.70
HOOD INNER	0.8	5XXX (180)	180	3.58	0.8	5XXX (180)	180	3.58	0.8	5XXX (180)	180	3.58
FRT DR SKIN	0.75	BH 210-340	210	6.20	0.9	6XXX - T6 (270)	270	2.55	0.9	6XXX - T6 (270)	270	2.55
FRT DR SKIN	0.75	BH 210-340	210	6.20	0.9	6XXX - T6 (270)	270	2.55	0.9	6XXX - T6 (270)	270	2.55
RR DOOR SKIN	0.85	BH 210-340	210	6.57	0.9	6XXX - T6 (270)	270	2.39	0.9	6XXX - T6 (270)	270	2.39
RR DOOR SKIN	0.85	BH 210-340	210	6.57	0.9	6XXX - T6 (270)	270	2.39	0.9	6XXX - T6 (270)	270	2.39
Tail Gate Inner	1	HSLA 350-450	350	7.41	1.4	6XXX - T6 (270)	270	3.57	1.4	6XXX - T6 (270)	270	3.57
Tail Gate Outer	1	HSLA 350-450	350	8.54	1.2	6XXX - T6 (270)	270	3.53	1.2	6XXX - T6 (270)	270	3.53
	TOTAL			210.03	TOTAL			102.84	TOTAL			99.09

Link to Excel File: ATG Large Panels Comparison - EDAG

5.5 Mass Reduction Parts (take advantage of high strength)

	Baseline Steel	EDAG NHTSA	EDAG ATG
Mass (kg)	**-**	**70.15**	**54.39**
		-15.76	



5.5 Mass Reduction Parts (take advantage of high strength)

Name	EDAG NHTSA LWT				EDAG ATG LWT				
	Guage (mm)	Grade	Typ Yield (Mpa)	Mass (kg)	Guage (mm)	Grade	Typ Yield (Mpa)	Mass (Kg)	Mass Saving (kg)
A Cowl Top	2.2	5XXX (120 Mpa)	120	3.35	1.5	6XXX-T6 295/340	320	2.29	1.07
Front Roof Header	2.5	6XXX - T6 (225 Mpa)	225	2.60	1.5	6XXX-T6 295/340	320	1.56	1.04
A Cowl Lower Front	2.25	5XXX (120 Mpa)	120	2.74	1.5	6XXX-T6 295/340	320	1.82	0.91
BOX CROSSMEMBER	4.2	6XXX - T6 (270 Mpa)	270	5.34	3.55	6XXX-T6 295/340	320	4.52	0.83
Extruded Rocker Tube	2.5	6XXX - T6 (225 Mpa)	225	3.80	2	6XXX-T6 270/310	315	3.04	0.76
Extruded Rocker Tube	2.5	6XXX - T6 (225 Mpa)	225	3.80	2	6XXX-T6 270/310	315	3.04	0.76
B-Pillar Outer RH	3.5	6XXX - T6 (225 Mpa)	225	2.38	2.45	6XXX-T6 295/340	320	1.67	0.71
B-Pillar Outer LH	3.5	6XXX - T6 (225 Mpa)	225	2.37	2.45	6XXX-T6 295/340	320	1.66	0.71
Center Roof Bow .93mm	2.5	6XXX - T6 (225 Mpa)	225	1.59	1.5	6XXX-T6 295/340	320	0.96	0.64
Reinf - Roof Rail Frt RH	3	6XXX - T6 (225 Mpa)	225	2.24	2.15	6XXX-T6 270/310	315	1.61	0.63
Reinf - Roof Rail Frt LH	3	6XXX - T6 (225 Mpa)	225	2.24	2.15	6XXX-T6 270/310	315	1.61	0.63
B-Pillar Inner Upper LH	3.5	6XXX - T6 (225 Mpa)	225	1.82	2.45	6XXX-T6 295/340	320	1.27	0.55
B-Pillar Inner Upper RH	3.5	6XXX - T6 (225 Mpa)	225	1.82	2.45	6XXX-T6 295/340	320	1.27	0.54
REINF SIDE INNER RH	3.8	6XXX - T7 (200 Mpa)	200	1.41	2.4	6XXX-T6 295/340	320	0.89	0.52
REINF SIDE INNER LH	3.8	6XXX - T7 (200 Mpa)	200	1.41	2.4	6XXX-T6 295/340	320	0.89	0.52
BOX CROSSMEMBER 01	3.5	6XXX - T6 (270 Mpa)	270	3.28	2.95	6XXX-T6 295/340	320	2.77	0.52
BOX CROSSMEMBER 04	3.8	6XXX - T6 (270 Mpa)	270	2.82	3.2	6XXX-T6 295/340	320	2.38	0.45
Crossmember - Rear Floor	3.25	6XXX - T6 (230 Mpa)	230	5.58	3	6XXX - T6 (230 Mpa)	320	5.15	0.43
BOX CROSSMEMBER 02	3.8	6XXX - T6 (270 Mpa)	270	2.72	3.2	6XXX-T6 295/340	320	2.29	0.43
A-Pillar Inner LH	3.5	6XXX - T6 (225 Mpa)	225	1.30	2.45	6XXX-T6 295/340	320	0.91	0.39
A-Pillar Inner RH	3.5	6XXX - T6 (225 Mpa)	225	1.30	2.45	6XXX-T6 295/340	320	0.91	0.39
BOX CROSSMEMBER 03	3.8	6XXX - T6 (270 Mpa)	270	2.23	3.2	6XXX-T6 295/340	320	1.88	0.35
Cowl Lower Rear LH	2.5	5XXX (180 Mpa)	180	1.39	1.9	6XXX-T6 295/340	320	1.06	0.33
Reinf - Back of Cab	1.1	6XXX - T6 (225 Mpa)	225	1.56	0.9	6XXX-T6 295/340	320	1.27	0.28
Cowl Lower Rear RH	2.5	5XXX (180 Mpa)	180	1.01	1.9	6XXX-T6 295/340	320	0.77	0.24
Hinge Plr Inr LH	2	6XXX - T6 (225 Mpa)	225	1.73	1.8	6XXX - T6 (225 Mpa)	320	1.56	0.17
Rocker Ribs RH	2	6XXX - T6 (225 Mpa)	225	1.13	1.7	6XXX - T6 (225 Mpa)	315	0.96	0.17
Rocker Ribs LH	2	6XXX - T6 (225 Mpa)	225	1.13	1.7	6XXX - T6 (225 Mpa)	315	0.96	0.17
Hinge Plr Inr RH	2	6XXX - T6 (225 Mpa)	225	1.67	1.8	6XXX - T6 (225 Mpa)	320	1.51	0.17
Reinf - B-Pillar LH_LWB_2	3	6XXX - T6 (225 Mpa)	225	0.50	2.11	6XXX-T6 295/340	320	0.35	0.15
Reinf - B-Pillar RH_LWB_1	3	6XXX - T6 (225 Mpa)	225	0.50	2.11	6XXX-T6 295/340	320	0.35	0.15
Floor Side Inr Rear LH	1.68	6XXX - T6 (225 Mpa)	225	0.70	1.5	6XXX-T6 295/340	320	0.62	0.07
Floor Side Inr Rear RH	1.68	6XXX - T6 (225 Mpa)	225	0.70	1.5	6XXX-T6 295/340	320	0.62	0.07
	Total			**70.15**	**Total**			**54.39**	**15.76**

5.5 Mass Increase Parts (due to stiffness/NVH performance)

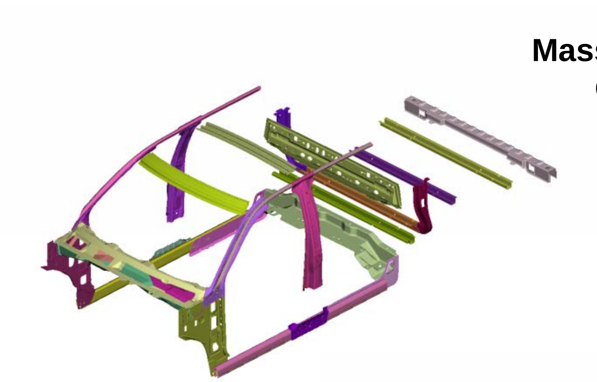
	Baseline Steel	EDAG NHTSA	EDAG ATG
Mass (kg)	-	7.31	10.86
		+3.56	

5.5 Mass Increase Parts (due to stiffness/NVH performance)

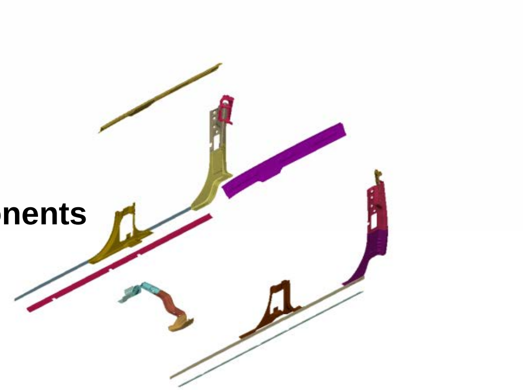
Name	EDAG NHTSA LWT				EDAG ATG LWT				
	Guage (mm)	Grade	Typ Yield (Mpa)	Mass (kg)	Guage (mm)	Grade	Typ Yield (Mpa)	Mass (Kg)	Mass Increase (kg)
C-Pillar Inner Lower LH	1.65	6XXX - T6 (225 Mpa)	225	0.49	3.63	6XXX - T6 (225 Mpa)	320	1.08	-0.59
C-Pillar Inner Lower RH	1.65	6XXX - T6 (225 Mpa)	225	0.49	3.63	6XXX - T6 (225 Mpa)	320	1.08	-0.59
C-Pillar Inner Mid LH	1.35	6XXX - T6 (225 Mpa)	225	0.28	3.36	6XXX - T6 (225 Mpa)	320	0.71	-0.42
C-Pillar Inner Mid RH	1.35	6XXX - T6 (225 Mpa)	225	0.28	3.36	6XXX - T6 (225 Mpa)	320	0.69	-0.41
Roof Rail Inner RH	2.15	6XXX - T6 (225 Mpa)	225	0.89	2.75	6XXX-T6 295/340	320	1.14	-0.25
Roof Rail Inner LH	2.15	6XXX - T6 (225 Mpa)	225	0.89	2.75	6XXX-T6 295/340	320	1.14	-0.25
A Reinf - Tunnel LH	1.55	6XXX - T6 (225 Mpa)	225	0.17	3	6XXX - T6 (225 Mpa)	320	0.34	-0.16
Reinf -Longitudinal Rail LH	1.4	6XXX - T6 (225 Mpa)	225	0.10	3.5	6XXX - T6 (225 Mpa)	320	0.25	-0.15
Reinf -Longitudinal Rail	1.4	6XXX - T6 (225 Mpa)	225	0.09	3.5	6XXX - T6 (225 Mpa)	320	0.23	-0.14
Reinf - Tunnel RH	1.5	6XXX - T6 (225 Mpa)	225	0.12	3	6XXX - T6 (225 Mpa)	320	0.25	-0.12
Rear Cab Brace LH	1.1	6XXX - T6 (270 Mpa)	270	0.06	3.12	6XXX - T6 (270 Mpa)	320	0.18	-0.12
Rear Cab Brace RH	1.1	6XXX - T6 (225 Mpa)	225	0.06	3.12	6XXX - T6 (225 Mpa)	320	0.17	-0.11
B-Pillar Inner Lower RH	2.4	6XXX - T6 (225 Mpa)	225	0.68	2.6	6XXX - T6 (225 Mpa)	320	0.74	-0.06
B-Pillar Inner Lower LH	2.4	6XXX - T6 (225 Mpa)	225	0.68	2.6	6XXX - T6 (225 Mpa)	320	0.74	-0.06
Extruded Rocker Flange Top RH	2.7	6XXX - T6 (225 Mpa)	225	0.39	3	6XXX - T6 (225 Mpa)	315	0.44	-0.04
Extruded Rocker Glange Top LH	2.7	6XXX - T6 (225 Mpa)	225	0.39	3	6XXX - T6 (225 Mpa)	315	0.44	-0.04
Extruded Rocker Flange Lower LH	2.7	6XXX - T6 (225 Mpa)	225	0.61	2.8	6XXX-T6 270/310	315	0.63	-0.02
Extruded Rocker Flange Lower RH	2.7	6XXX - T6 (270 Mpa)	270	0.61	2.8	6XXX-T6 270/310	315	0.63	-0.02
	Total			**7.31**	**Total**			**10.86**	**-3.56**

5.5 Mass Reduction / Increase Parts

Mass Reductions:
Grade, Gauge



Mass Increases:
Restore Stiffness
Efficient stiffness components



Observations - Strength Dependent components:
Gauge limitations – Component stiffness constraints
Global Stiffness constraints
20% Strength increase: net 3.7% mass reduction

Mass Reduction Parts

	EDAG NHTSA	EDAG ATG	Reduction
Mass (kg)	70.2	54.4	- 15.8
% NHTSA B Mass	21 %		- 4.8 %

Mass Increase Parts

	EDAG NHTSA	EDAG ATG	Reduction
Mass (kg)	7.3	10.6	+ 3.6
% NHTSA B Mass	2 %		+ 1.1 %

Net Mass Reduction

	EDAG NHTSA	EDAG ATG	Reduction
Mass (kg)	62.9	43.5	- 12.2
% NHTSA B Mass	19 %		- 3.7 %

5.5 Conclusions – ATG LWT Study

Mass Reduction (Kg) (ATG LWT: NHTSA LWT)		
Large Panels	3.75	
Mass reduction Parts	15.76	
Mass increase Parts	-3.56	
Doors: Steel to Alum Inner Structures	16.34	
Total Mass Savings	32.29	(9.7)%

Conclusions:

- Strength driven Mass reduction limited by
  - stiffness - Local and Global
  - gauge limitations: Manufacturing (Mill, Fabrication)
- Aluminum strength increases 2011-16 ~ 15 % - 20 %
  - Body Mass reduction increase ~5% over NHTSA LWT
- Largest mass reduction (50% of total)
  - conversion of steel door inner to aluminum
- 7XXX (50% higher strength) limited
  - stiffness, gauge limitations

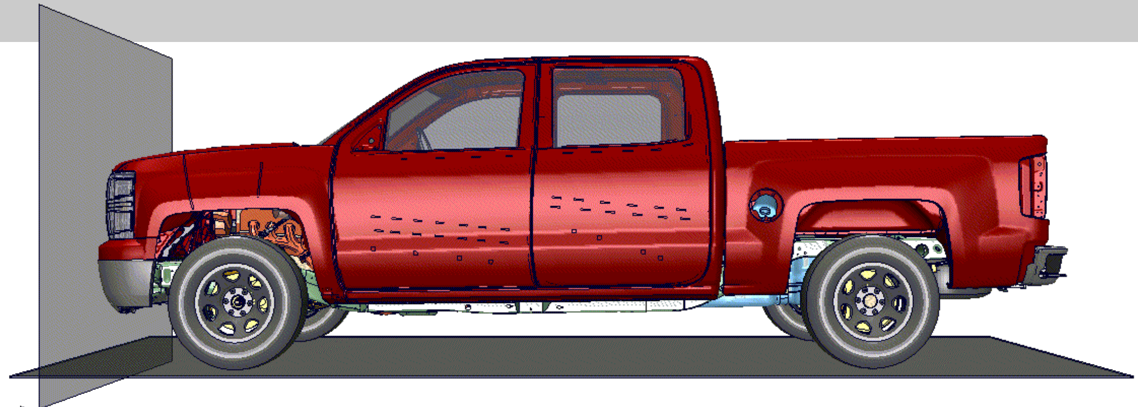
6.0 CAE - Crashworthiness Performance

CAE Crash Analysis using LSDYNA:

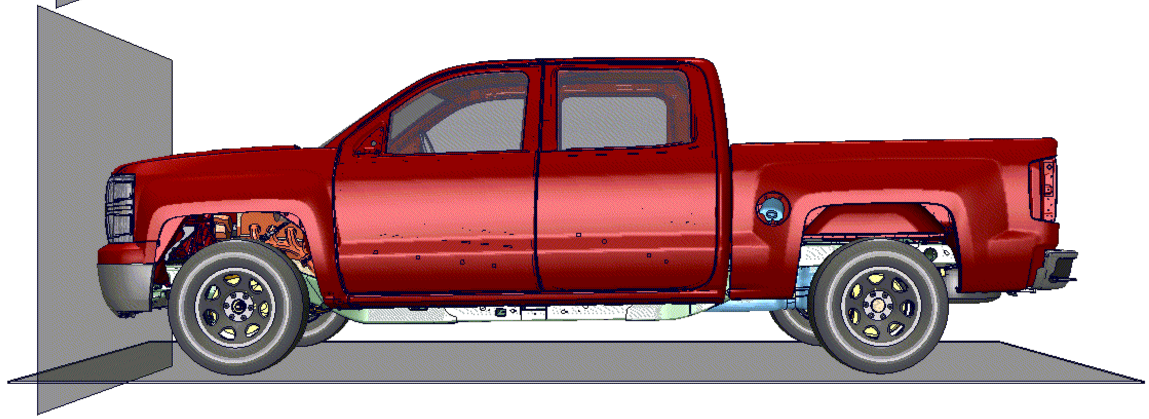
1. NCAP Frontal Impact
2. NCAP Side Impact
3. NCAP Side Pole Impact
4. IIHS Roof Crush
5. FMVSS No. 301 Rear Impact
6. IIHS Side Impact
7. IIHS Moderate Overlap
8. IIHS Small Overlap
9. Summary of Results

NCAP Frontal Impact

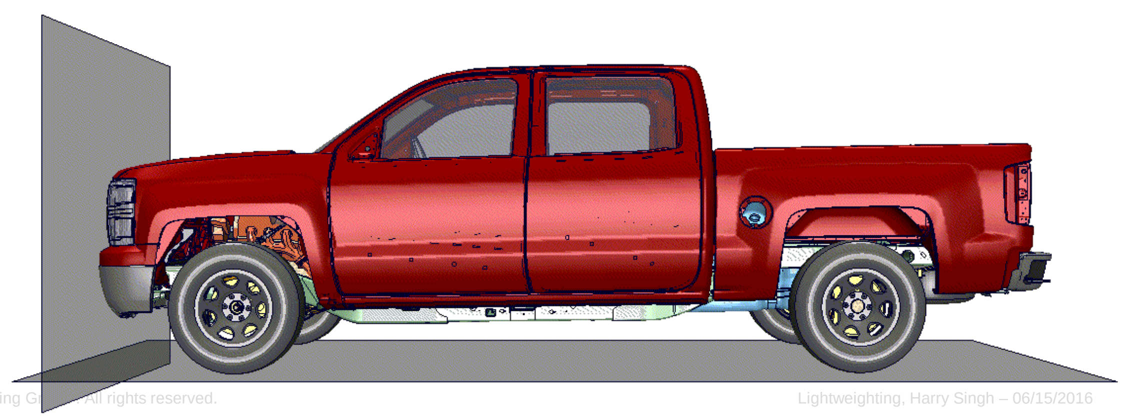
Baseline
2014 Silverado
Test Mass 2,710 kg



NHTSA EDAG
LWT (2025)
Test Mass 2,309 kg

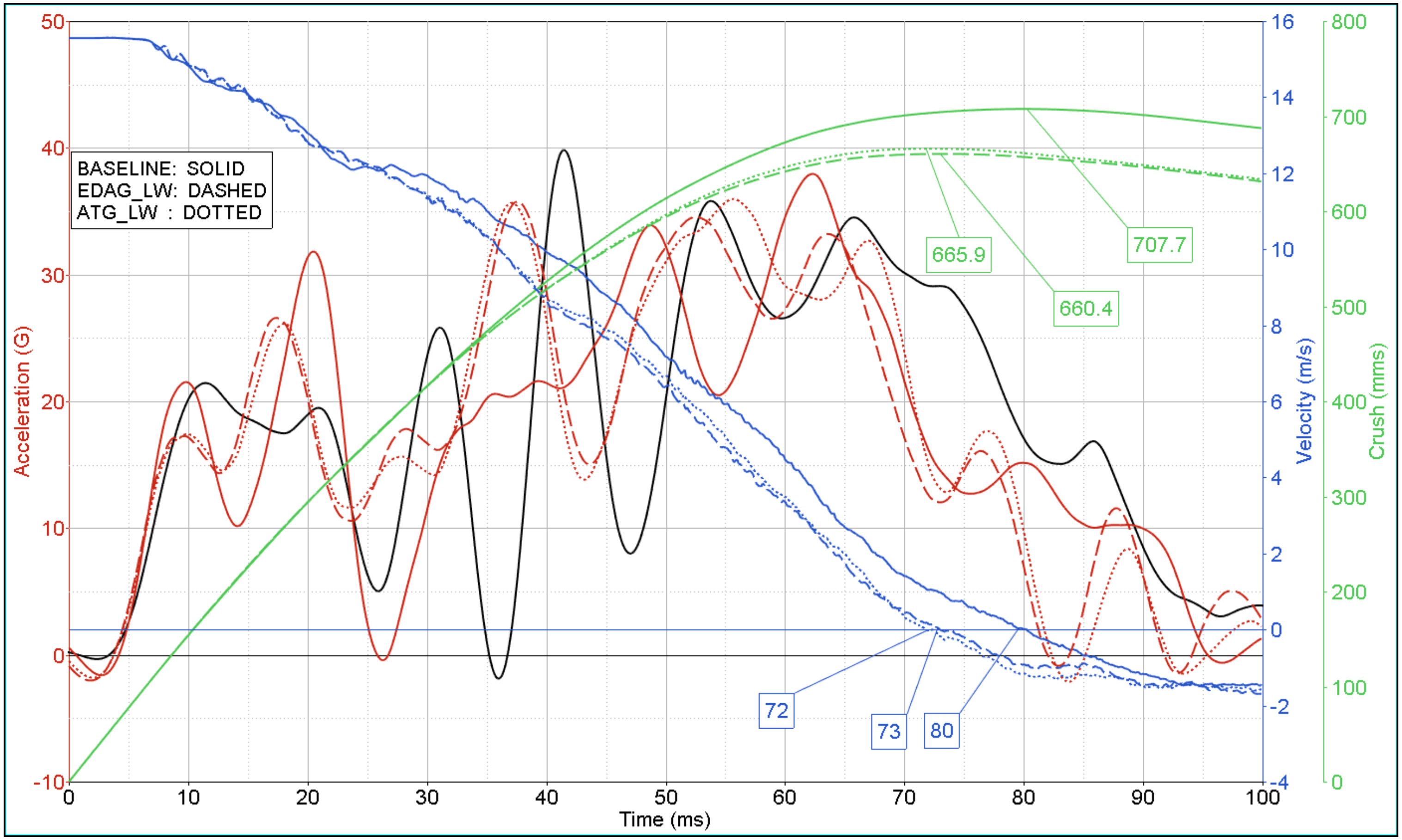


ATG EDAG
LWT (2025)
Test Mass 2,276 kg



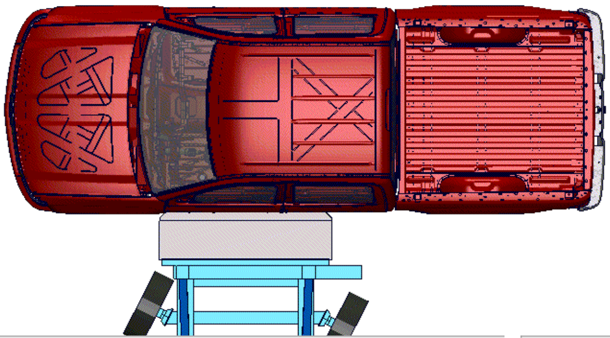
6.1 CAE - Crashworthiness Performance

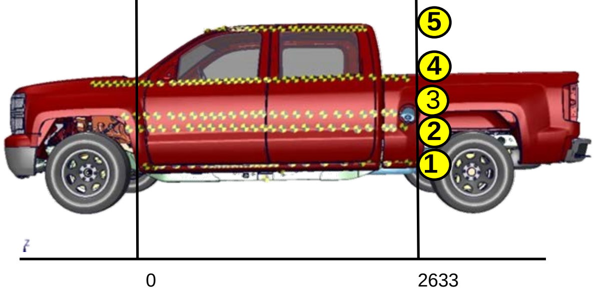
NCAP Frontal Impact

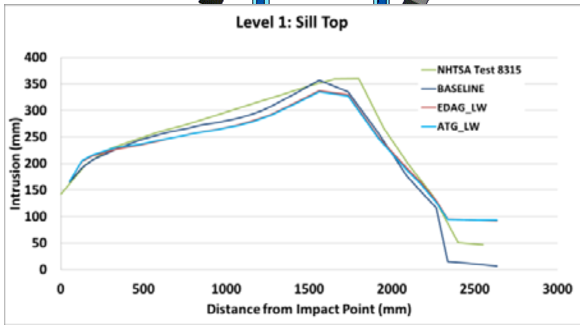


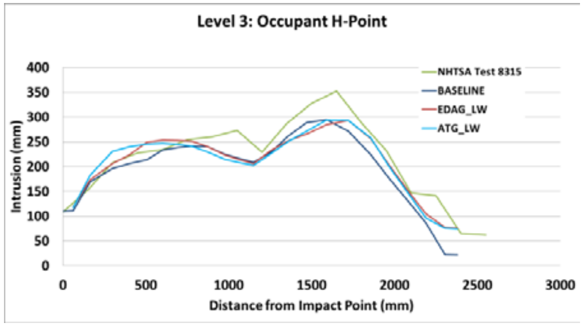
	AVG Pulse (Gs)	Rebound Time (ms)	Dynamic Crush (mm)
Baseline	20	80	708
EDAG LW	22	73	660
ATG LW	22	72	666

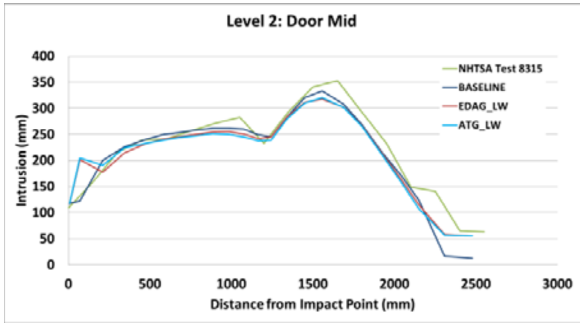
6.2 CAE - Crashworthiness Performance
NCAP Side Impact

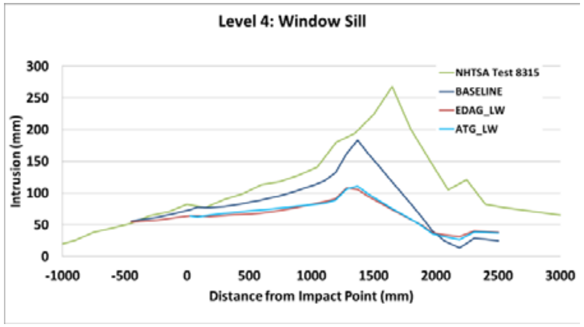










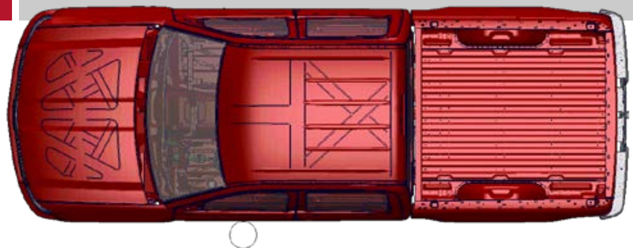


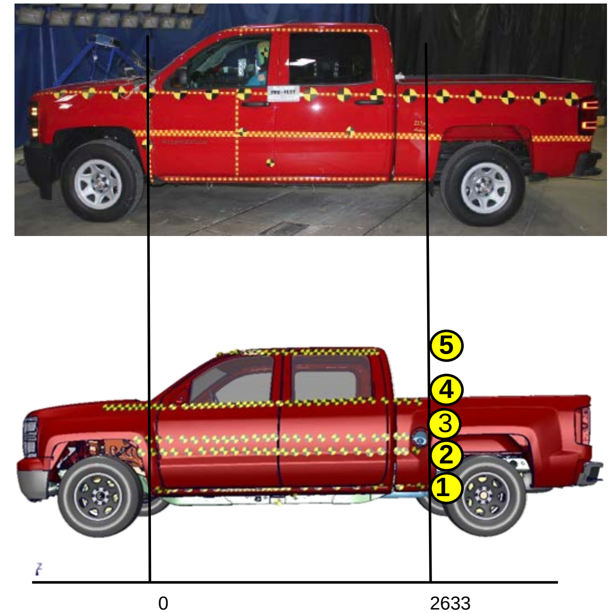
Intrusions				
	Baseline (mm)	EDAG_LW (mm)	ATG_LW (mm)	Diff (mm)
Level 1	357	332	335	3
Level 2	333	318	320	2
Level 3	295	293	294	1
Level 4	184	108	111	3

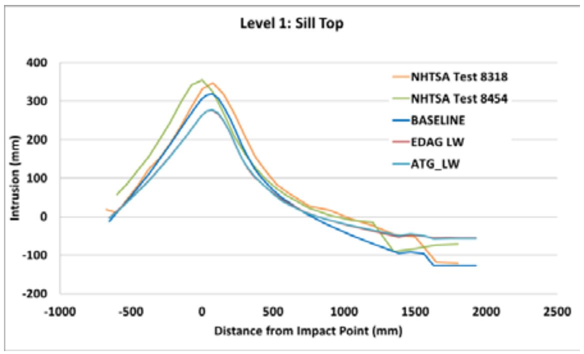
Intrusion Curves for NHTSA_LWT and ATG_LWT models are overlapping
There is negligible difference between intrusion values of these models

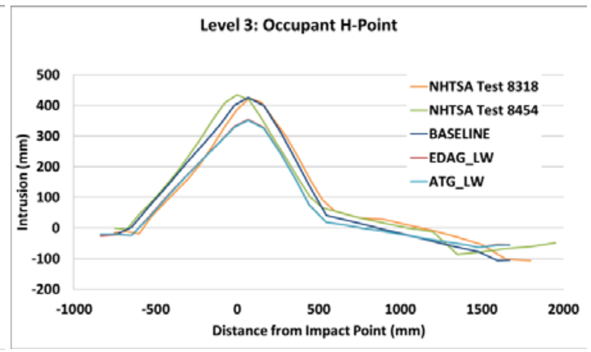
6.3 CAE - Crashworthiness Performance

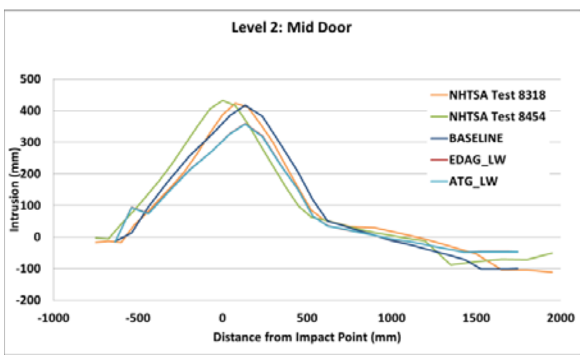
NCAP Side Pole Impact

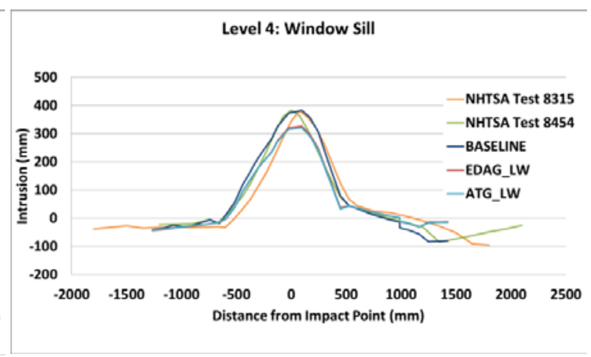










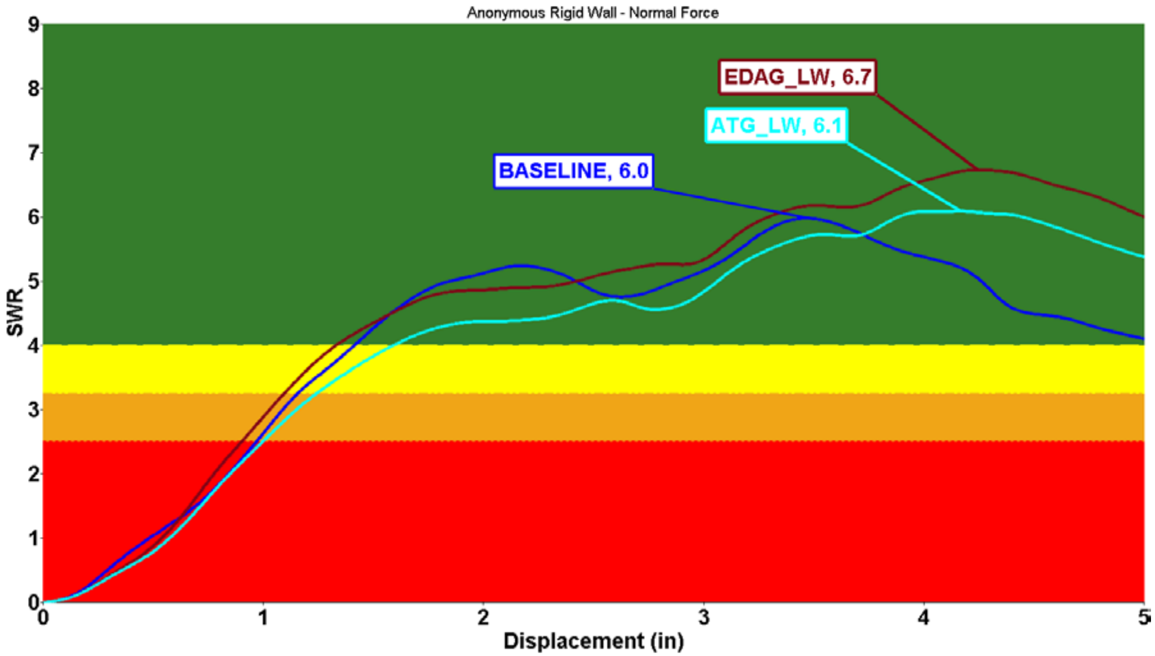


Intrusions				
	Baseline (mm)	EDAG_LW(mm)	ATG_LW(mm)	Diff (mm)
Level 1	319	273	277	4
Level 2	417	368	357	-11
Level 3	425	359	351	-8
Level 4	383	328	321	-7

Intrusion Curves for NHTSA_LWT and ATG_LWT models are overlapping
There is negligible difference between intrusion values of these models

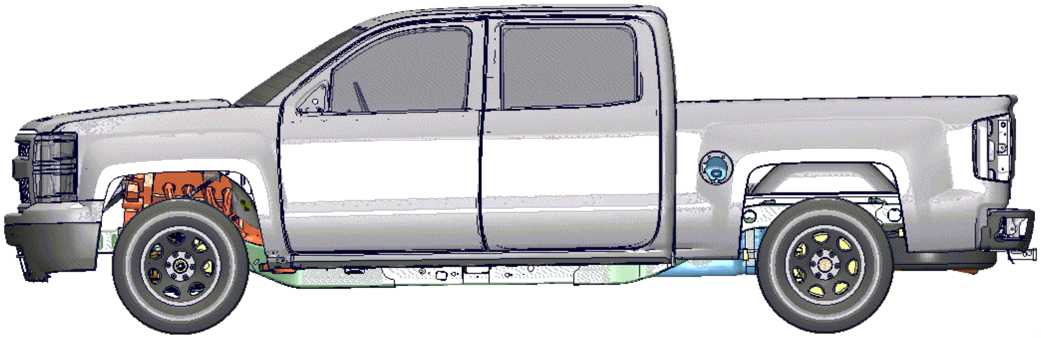
6.4 CAE - Crashworthiness Performance

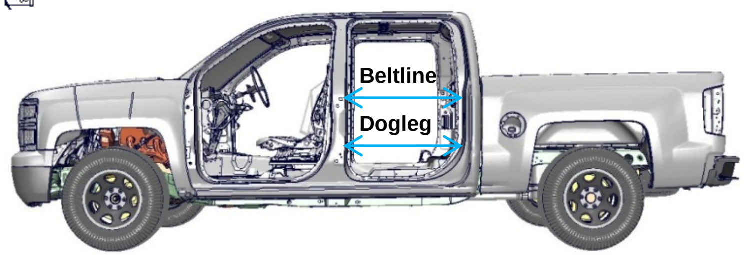
IIHS Roof Crush

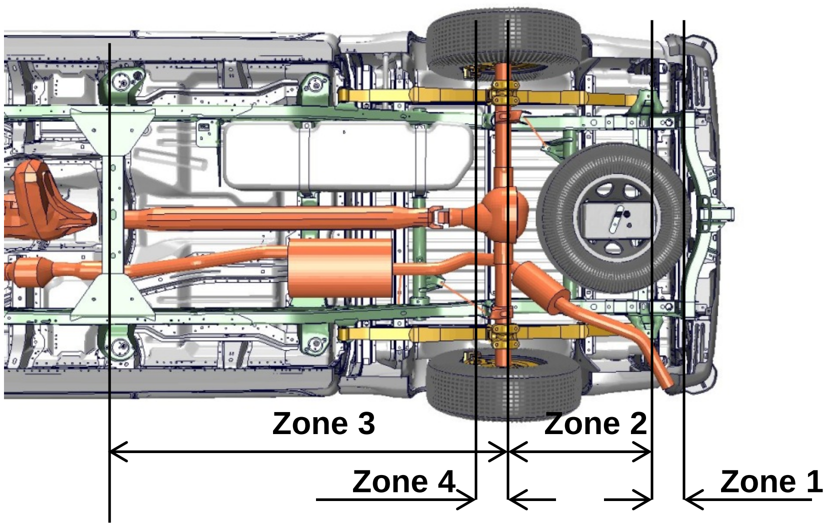


	SWR	Max Force (KN)
Baseline	6.0	126
EDAG LWT	6.7	134
ATG LWT	6.1	121

6.5 CAE - Crashworthiness Performance
FMVSS No. 301 Rear Impact





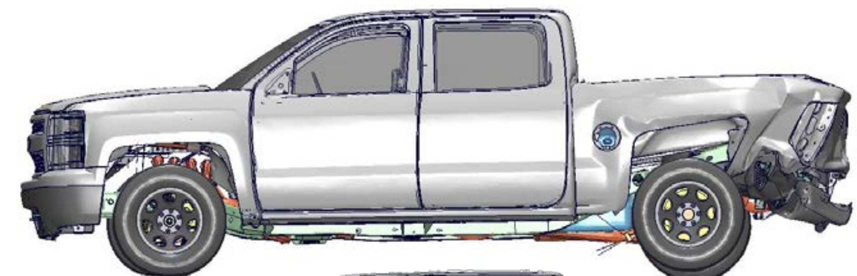


Zone	Crush (mm)		
	Baseline	EDAG LW	ATG LW
Zone 1	119	93	106
Zone 2	274	238	251
Zone 3	118	3	10
Zone 4	91	0	0
Beltline	2	7	5
Dogleg	2	9	6

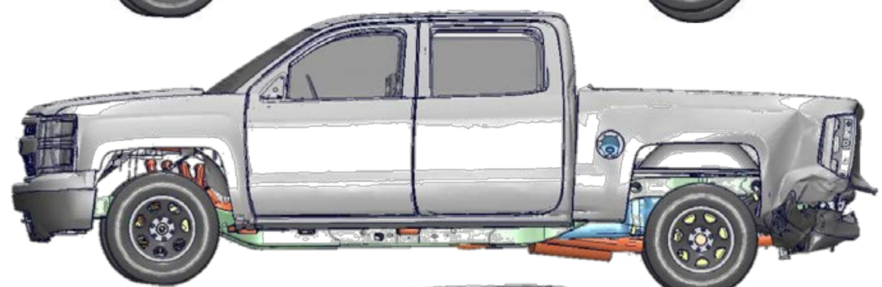
Post-Crash Comparison

Test Vehicle

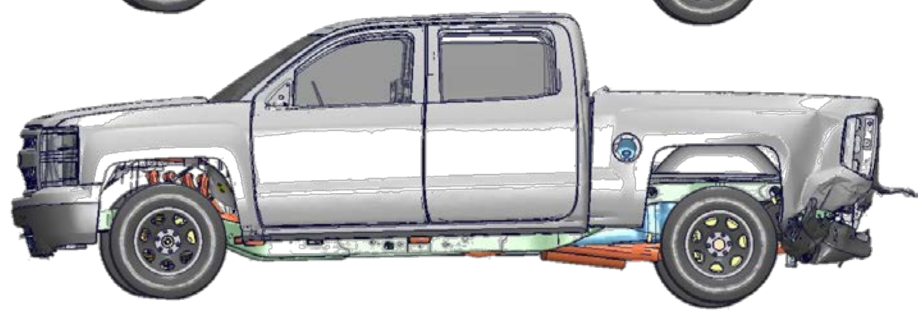
Baseline
CAE



NHTSA
EDAG LWT
CAE

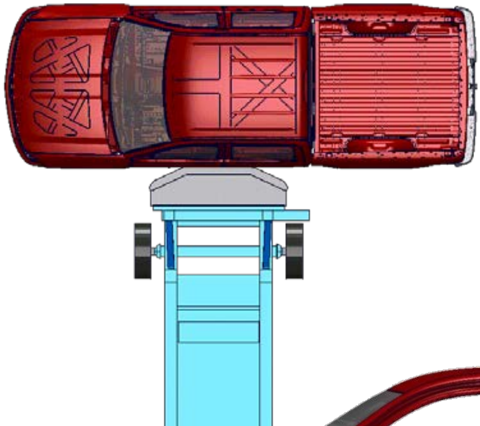


EDAG ATG
LWT CAE



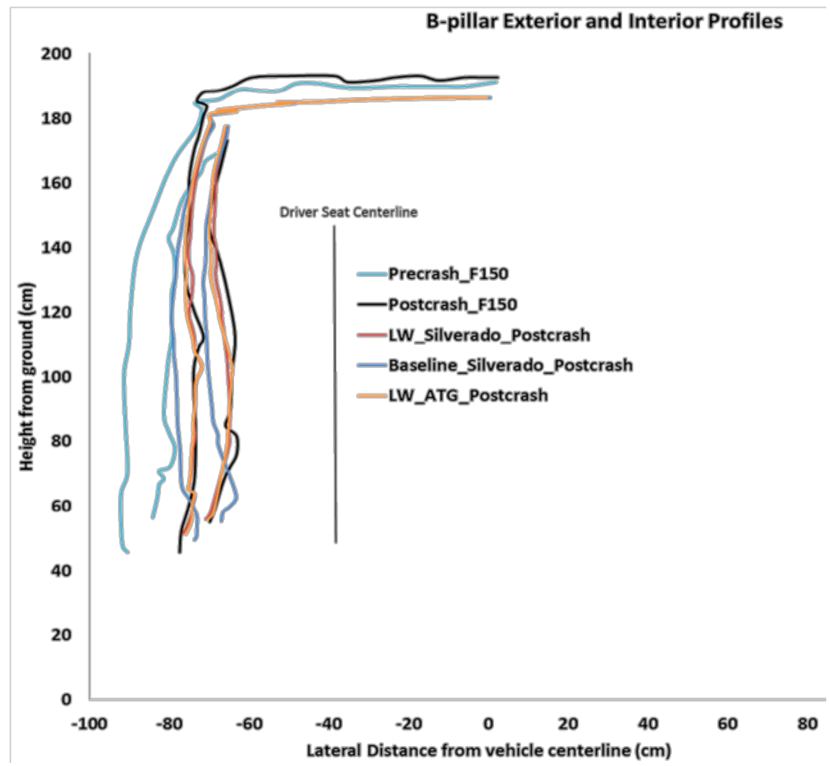
6.6 CAE - Crashworthiness Performance

IIHS Side Impact



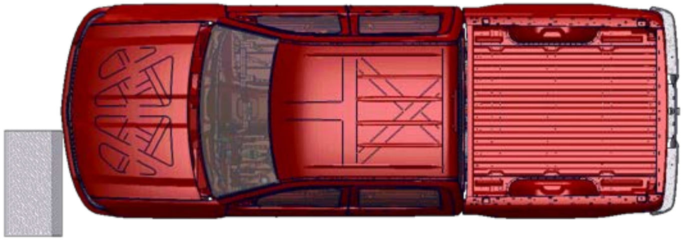
NHTSA LWT

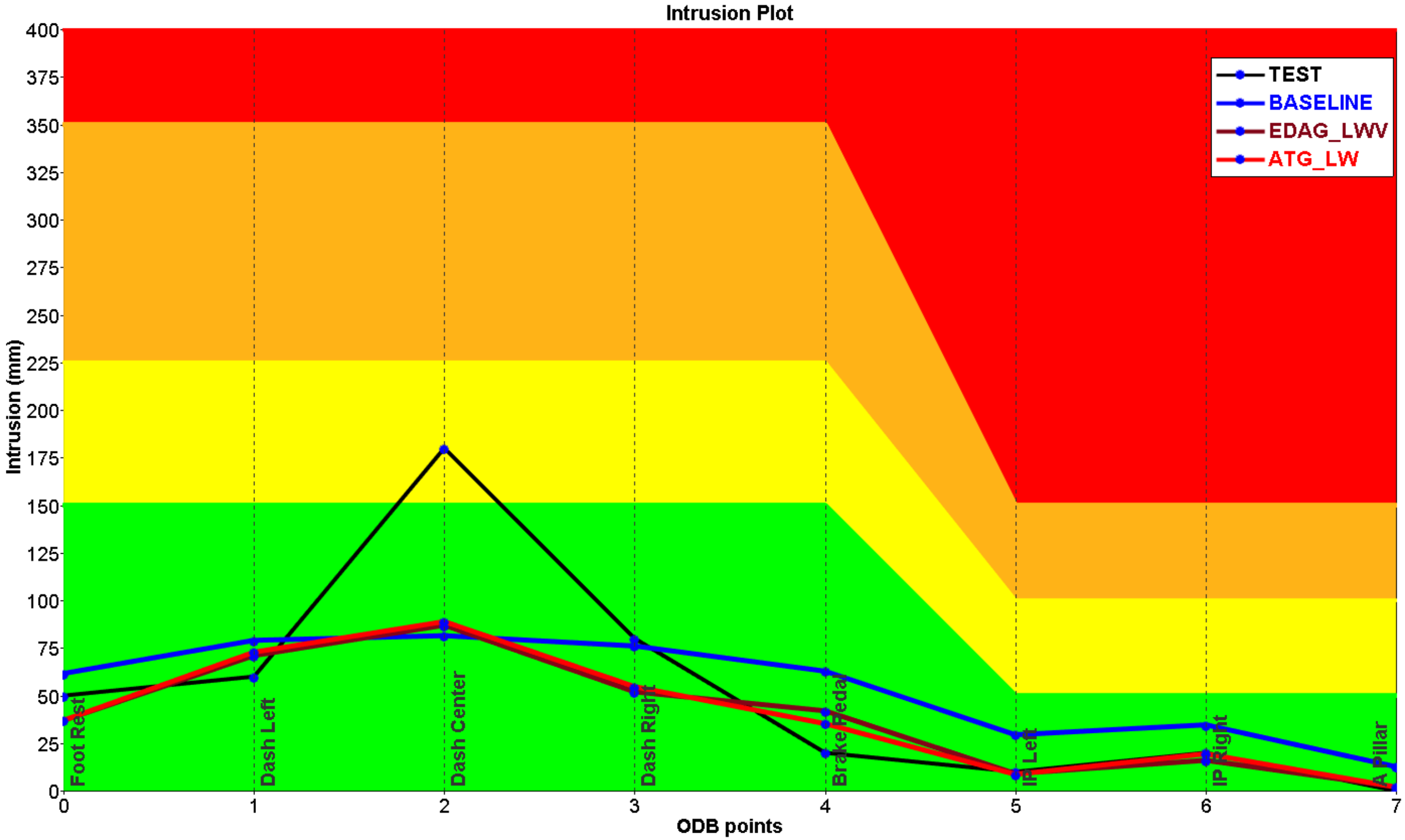
ATG LWT



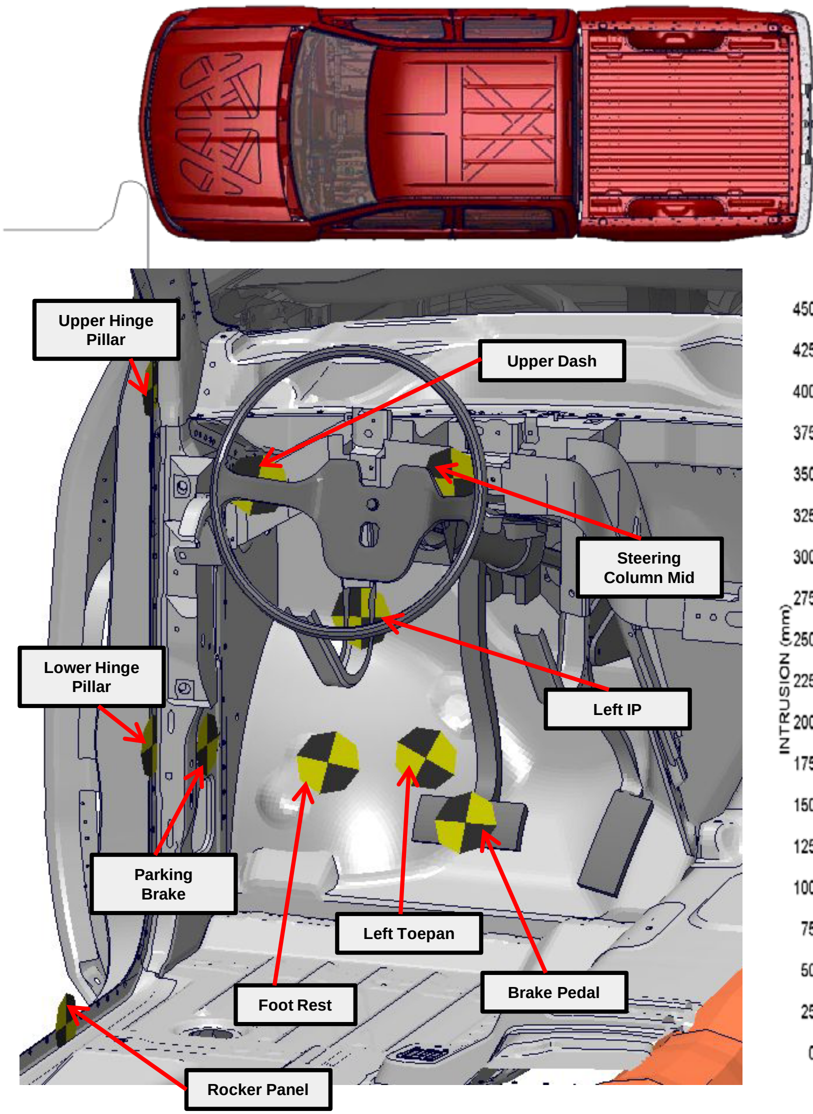
6.7 CAE - Crashworthiness Performance

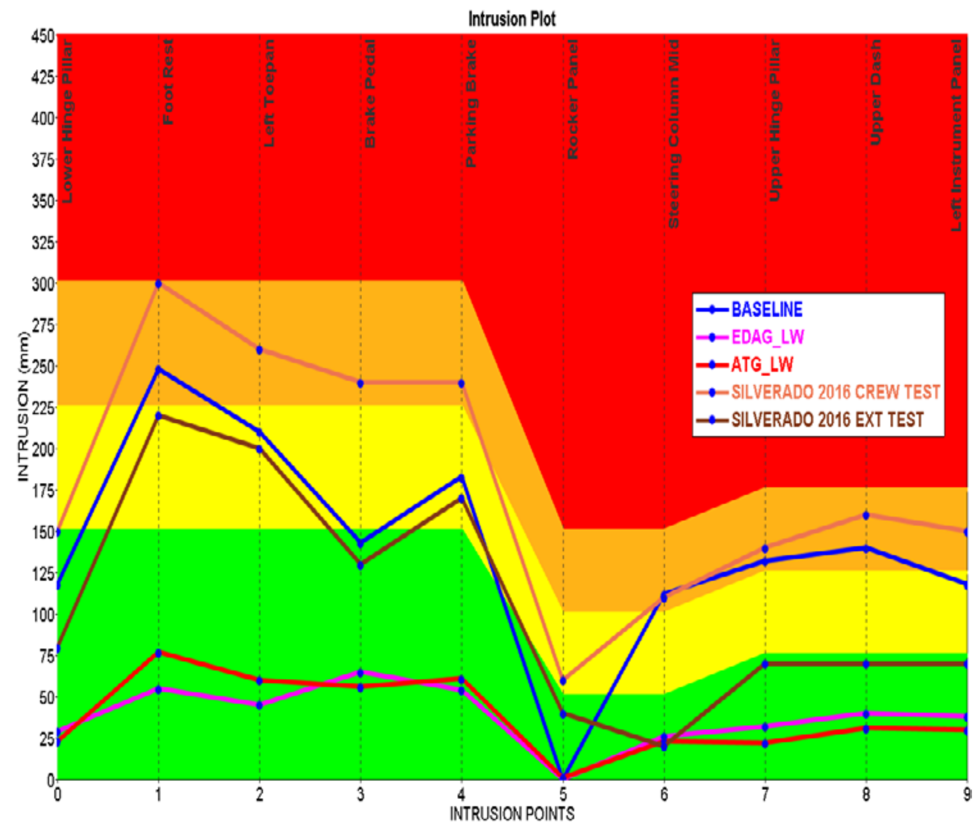
IIHS Moderate Overlap





6.8 CAE - Crashworthiness Performance
IIHS Small Overlap



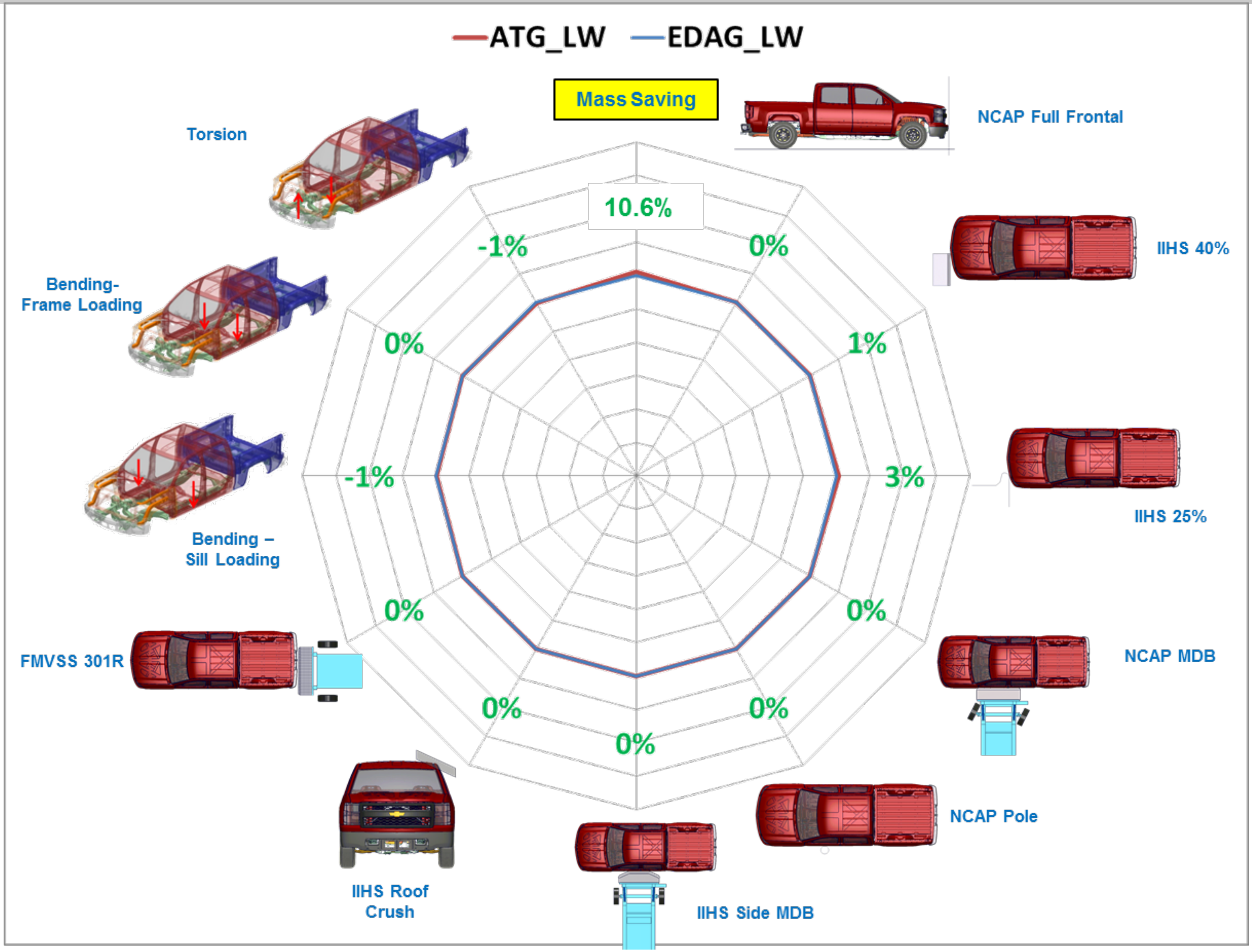


6.9 CAE - Crashworthiness Performance

Results Summary

Test	Parameters		Baseline	NHTSA_LWT	ATG_LWT	Difference (NHTSA_LWT and ATG_LWT)
NCAP Frontal	Tme Data	Avg Pulse (G)	20	22	21.5	-0.5
		Rebound Time (ms)	79	73	72	-1
		Dyn Crush (mm)	707	660	666	6
	Intrusion (mm)	Door	-1	-2	-4	2
		Footrest	-12	-4	0.5	-4.5
		Toepan Left	-28	-11	-2	-9
		Toepan Center	-31	-8	-10.1	2.1
		Toepan Right	-56	-26	-23.4	-2.6
		IP Left	-4	-3	-7.9	4.9
		IP Center	-2	-4	-9.8	5.8
		IP Right	0	-4	-10.3	6.3
		Brake Pedal	23	19	11	8
IIHS 40 %	Intrusion (mm)	Footrest	62	37	37	0
		Driver Toepan Left	79	73	71	-2
		Driver Toepan Center	81	89	87	-2
		Driver Toepan Right	76	55	52	-3
		Brake Pedal	63	35	42	7
		Left IP	29	9	9	0
		Right IP	35	19	16	-3
		Door	13	2	2	0
IIHS 25 %	Intrusion (mm)	Lower Hinge Pillar	118	29	23	-6
		Footrest	248	55	77	22
		Toepan Left	210	45	60	15
		Brake Pedal	143	65	56	-9
		Parking Brake	183	54	61	7
		Rocker Panel	0	0	1	1
		Steering Column	112	26	23	-3
		Upper Hinge Pillar	132	32	22	-10
		Upper Dash	140	40	31	-9
		Left IP	118	38	30	-8
NCAP MDB	Intrusion (mm)	Level 1	357	332	335	3
		Level 2	333	318	320	2
		Level 3	295	293	294	1
		Level 4	184	108	111	3
NCAP Pole	Intrusion (mm)	Level 1	319	273	277	4
		Level 2	417	368	357	-11
		Level 3	425	359	351	-8
		Level 4	383	328	321	-7
IIHS MDB	Survival Gap (mm)		63	65	64	1
IIHS Roof Crush	Max SWR		6	6.6	6	-0.6
FMVSS 301 R	Fuel tank Strain		11 %	8 %	7 %	

6.9 CAE - Crashworthiness Performance
Results Summary

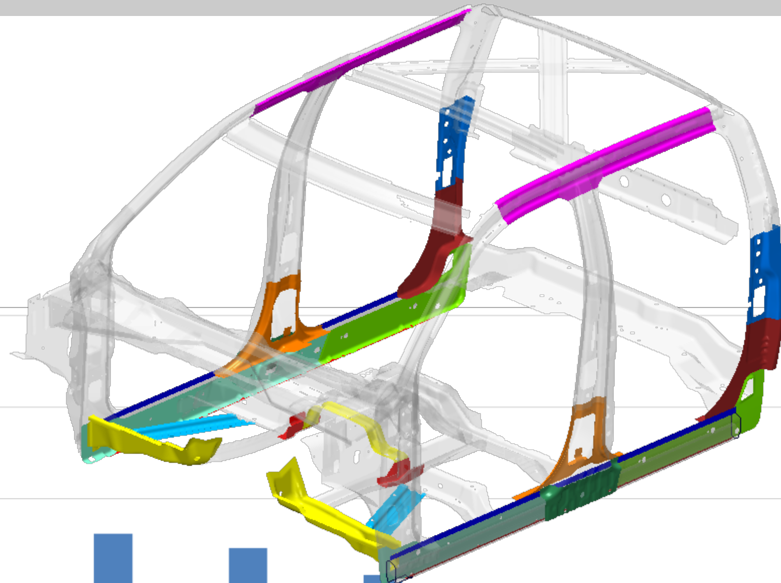


7.0 CAE - Strength and Stiffness Performance

CAE Analysis using NASTRAN, ABAQUS & LSDYNA:

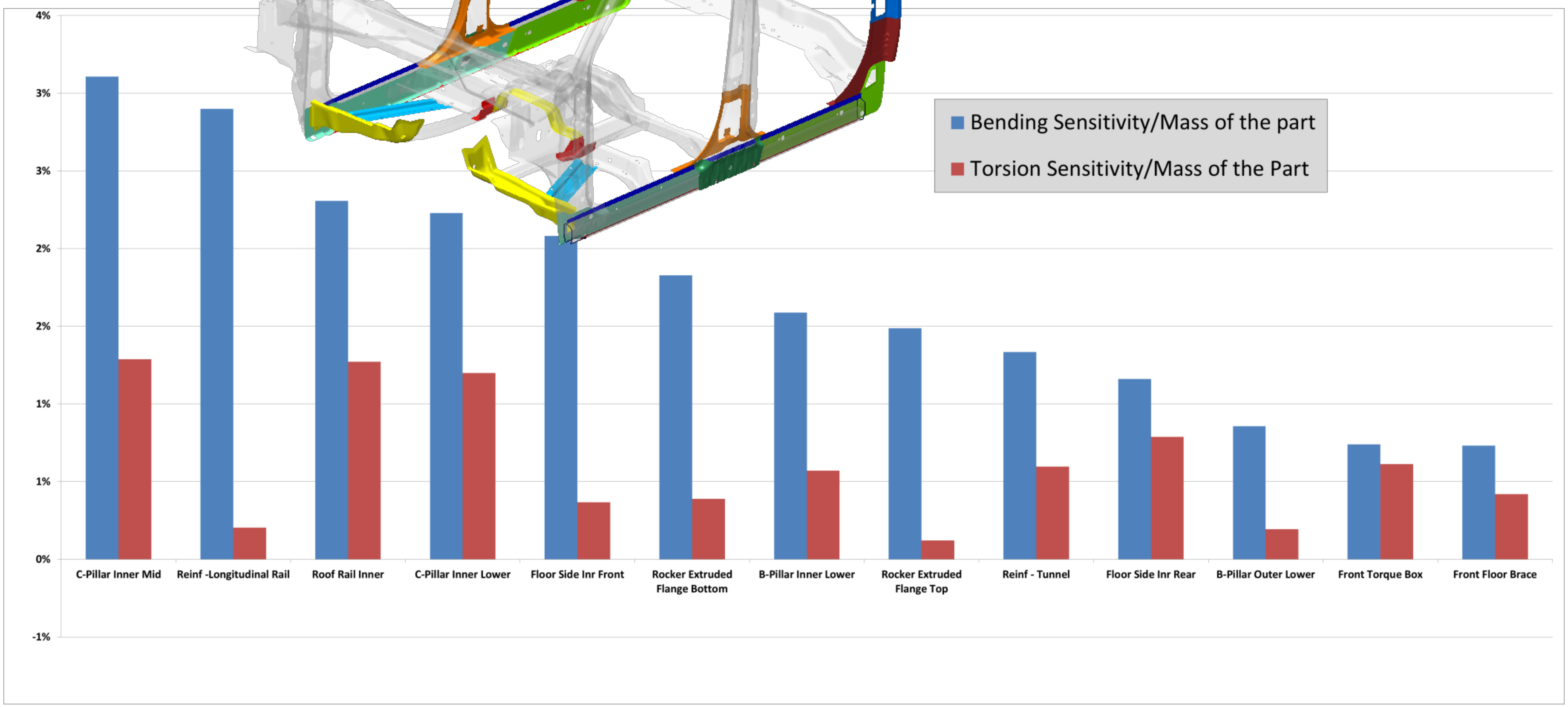
1. Global Sensitivity Study for Torsion and Bending Stiffness
2. Torsion and Bending Stiffness Comparison
3. Pickup Box Performance Evaluation)
4. Front & Rear Door – Frame and Sag Stiffness & Strength

7.1 Stiffness Sensitivity Percentage Per Unit Mass (kg)



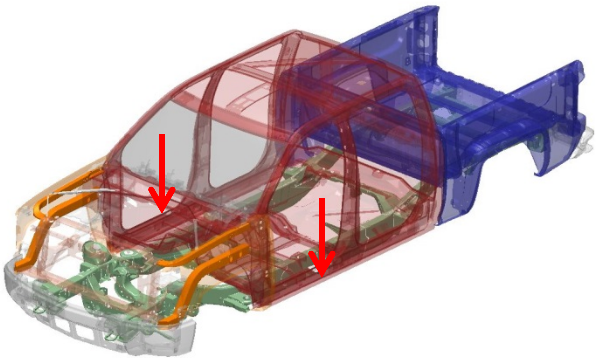
Picture shows all the parts considered for sensitivity analysis

Highlighted parts are the major contributors to stiffness

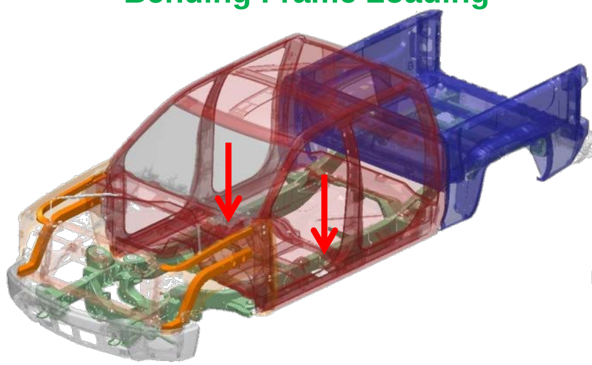


7.2 Torsion and Bending Stiffness Comparison

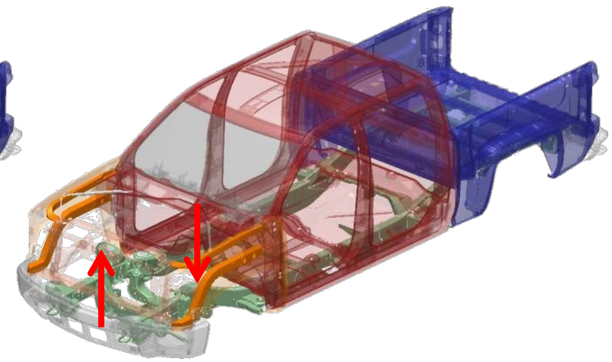
Bending Sill Loading



Bending Frame Loading

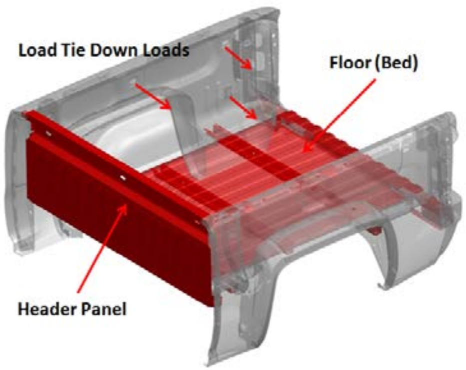


Torsion



	EDAG NHTSA	EDAG ATG	Difference
Bending Sill Loading (N/mm)	3034	2990	-1.4%
Bending Frame Loading (N/mm)	3577	3578	0 %
Torsion (KN-m/DEG)	6.97	6.92	-0.7%

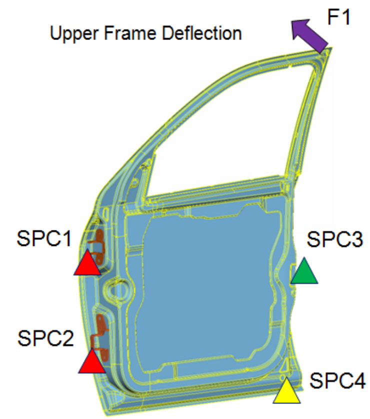
7.3 Pickup Box Performance Evaluation – CAE Model Results



Load Case	Evaluation	Loading	Targets	Baseline Design Results	NHTSA EDAG LWT Design Results	ATG EDAG LWT Design Results
Distributed Load Bed	Bed Floor Strength Evaluation	9 kN (2020 lbs) distributed on the bed floor	< 1mm Permanent Set	No Permanent Set	No Permanent Set	No Permanent Set
Abusive Drop Load Bed	Bed Floor Strength Evaluation	2.5 Kg drop from 1.2M height	< 7.5 mm Permanent Set	6 mm Permanent Set	5.2 mm Permanent set	2.8 mm Permanent set
Header Panel Strength	Header Strength on Impact	2,225 N Load applied to a 150mm x 150mm Area	< 25 mm deformation	26 mm deformation	24 mm deformation	24 mm deformation
Tie Down Load	Side Wall Strength	2,225N load to side hooks	< 1 mm Permanent Set	0.03mm Permanent Set	0.31 mm Permanent Set	0.07 mm Permanent set
Box Modal Frequencies	Torsion and Bending Modes	Normal Modes	Baseline or Higher	Torsion 32.6 Hz; Lateral Bending 26.6 Hz	Torsion 47.7Hz; Lateral Bending 36.2 Hz	Torsion 44.2Hz; Lateral Bending 34.2 Hz

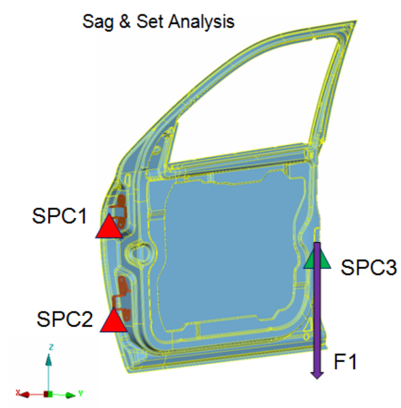
7.4 Front & Rear Door Structure Performance Evaluation – CAE Model Results

Front Door	Baseline Design	NHTSA EDAG LWT Design	ATG EDAG LWT Design
Door Frame Stiffness N/mm	36.7	37.1	37.0
Door Sag Stiffness N/mm	353.5	354.3	371.7
Door Sag Max Von-Mises Stress MPa	437.0	256.0	253.0



	Hinge SPC 1,2	DOF= 12345
	Latch SPC 3	DOF= 23
	Bump Stop SPC 4	DOF= 2
	Hanger Load F1	200 N (normal to surface)

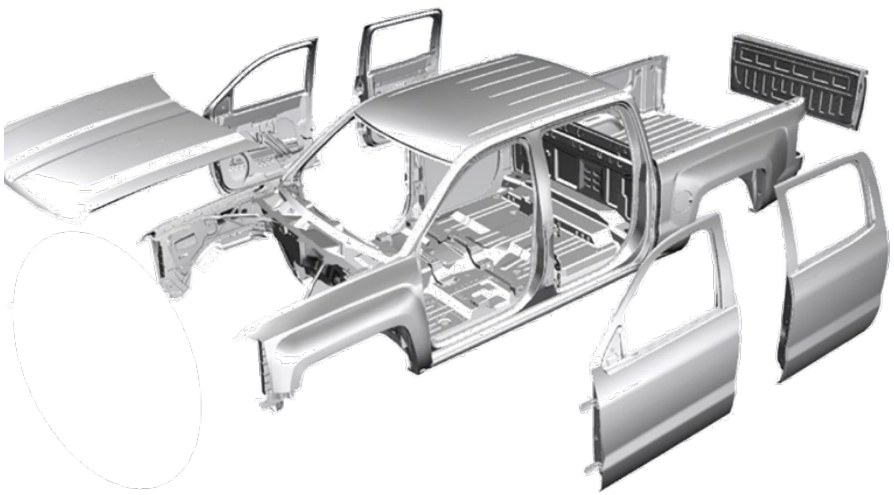
Rear Door	Baseline Design	NHTSA EDAG LWT Design	ATG EDAG LWT Design
Door Frame Stiffness N/mm	53.7	53.7	58.4
Door Sag Stiffness N/mm	217.9	217.6	221.7
Door Sag Max Von-Mises Stress MPa	359.0	398.0	406.0



	Hinge SPC 1,2	DOF= 12345
	Latch SPC 3	DOF= 2
	Hanger Load F1	800 N (-Z direction)

8.0 Summary of Results & Conclusion

Use of advanced ATG grades of aluminum leads to an additional 32.5 kg (10.6%) mass reduction compared with the NHTSA EDAG LWT proposed design for the subsystems shown in the Figure below. This is equivalent to a total mass saving of 46% when compared with the equivalent subsystems of the baseline vehicle MY2014 Chevrolet Silverado 1500.



Subsystem	Baseline 2014 Silverado 1500 Mass (Kg)	NHTSA EDAG LWT Mass (Kg)	EDAG ATG LWT	
			Mass (Kg)	Mass Saving Compared with NHTSA LWT (Kg)
CAB	**240.1**	140.94	130.97	-9.97
FENDERS	**32.47**	16.20	14.96	-1.24
CARGOBOX	**108.95**	65.03	60.10	-4.93
FRT_DOOR_L	**23.50**	16.32	12.40	-3.92
FRT_DOOR_R	**23.50**	16.41	12.49	-3.92
RR_DOOR_L	**21.74**	14.48	10.23	-4.25
RR_DOOR_R	**21.74**	14.54	10.29	-4.25
HOOD	**11.16**	11.21	11.21	0.00
TAILGATE	**21.30**	11.01	11.01	0.00
TOTAL	**504.46**	**306.14**	**273.66**	**-32.48**
	Saving Compared with Baseline	**-39.3%**	**- 45.8%**	
	Mass Saving Compared with NHTSA EDAG LWT		- 10.6%	

- Baseline vehicle MY2014 Silverado 1500 – material predominantly AHSS
- NHTSA EDAG LWT designed for MY2025 mainly aluminum for the CAB, Fenders & Pickup Box, with front & rear doors steel inner structure with aluminum outer panels
- EDAG ATG LWT designed for MY2025 using advanced grades of aluminum provided by ATG

8.0 Summary of Results & Conclusion

- A study has been performed to assess weight saving capability of light pick up truck structure using advanced Aluminum grades provided by Aluminum Transportation Group (ATG)
- EDAG's lightweight Silverado model was used as the baseline design for the study
- Stress/Strain rate curves were calculated using data provided for Aluminum grades and LS-DYNA material cards were created for the same
- Crashworthiness and NVH performance was assessed for the structure after substituting new advanced grades of Aluminum
- Thickness sensitivity study was conducted to optimize the CAB structure more efficiently without losing the global stiffness of the structure
- Use of advanced ATG grades of aluminum leads to an additional 32.5 kg (10.6%) mass reduction compared with the NHTSA EDAG LWT proposed design. This is equivalent to a total mass saving of 46% when compared with the equivalent subsystems of the baseline vehicle MY2014 Chevrolet Silverado 1500.

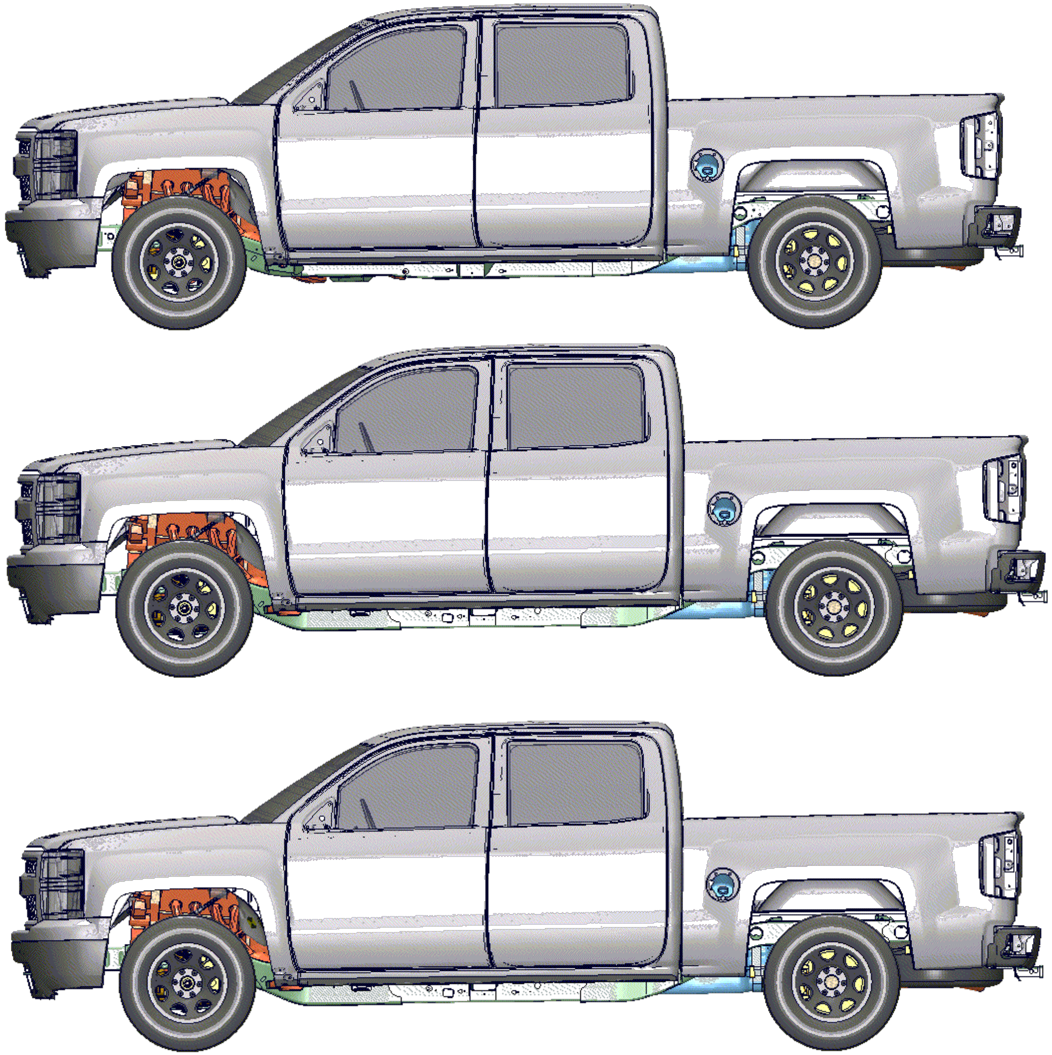
Additional Slides

6.14 FMVSS 301R – REAR IMPACT TEST
Animation

Baseline

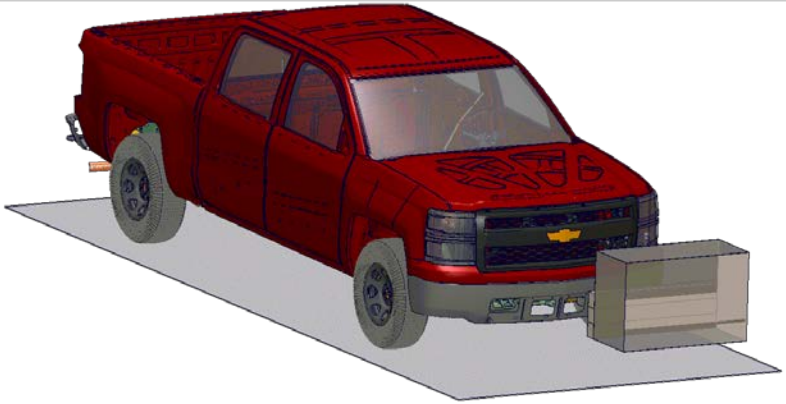
NHTSA LWT

ATG LWT



6.7 CAE - Crashworthiness Performance

IIHS Moderate Overlap

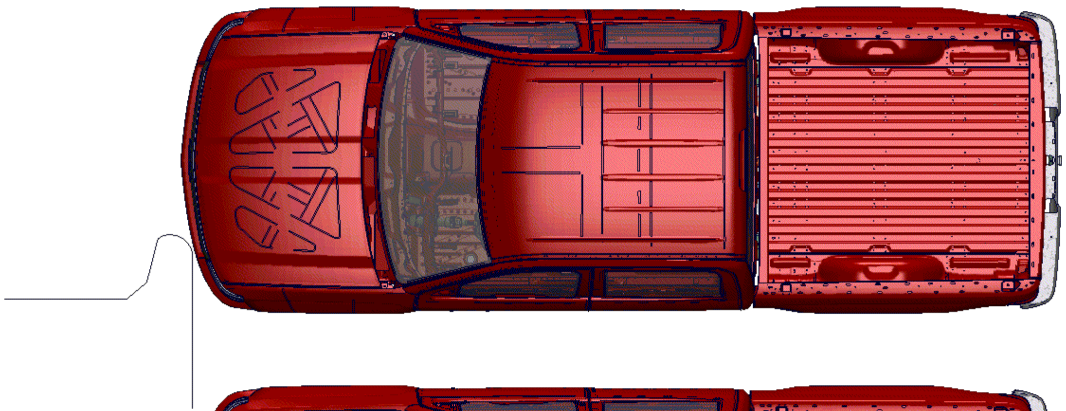


Baseline

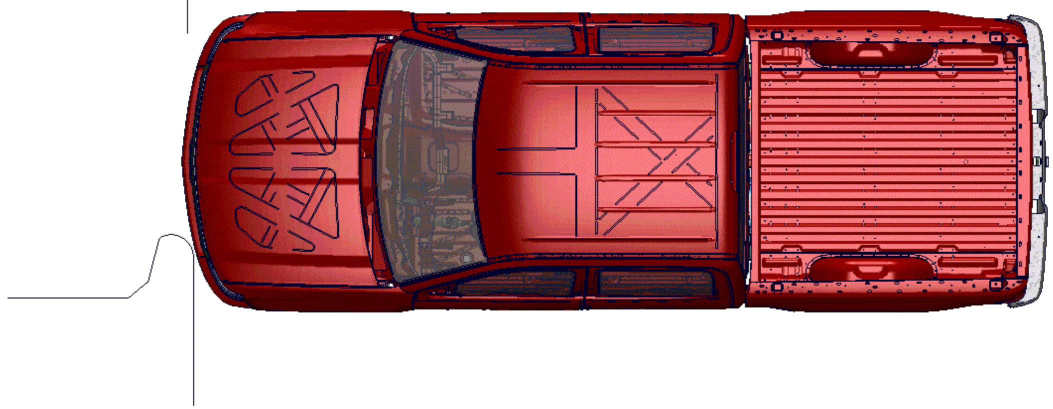
NHTSA LWT

ATG LWT

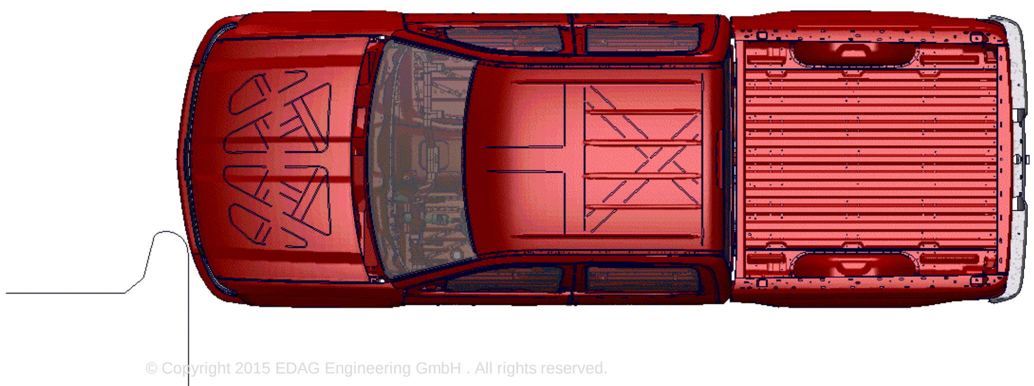
6.7 IIHS 25% FRONTAL OFFSET BARRIER 64KMH



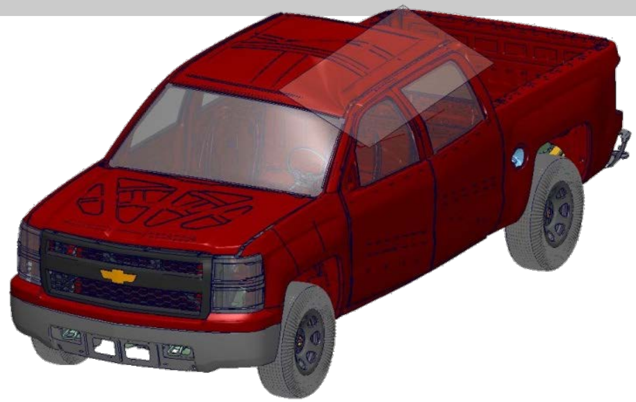
Baseline



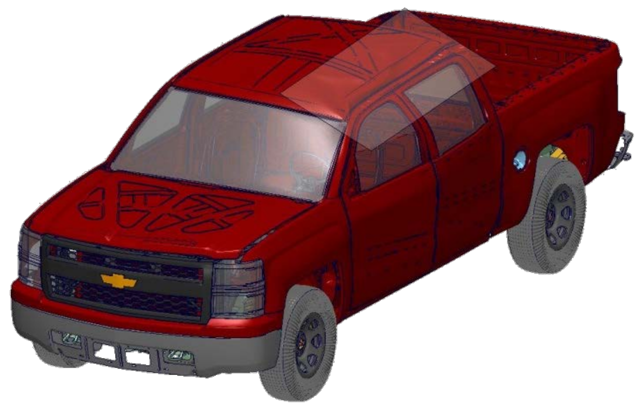
NHTSA LWT



ATG LWT



Baseline



NHTSA LWT

ATG LWT

BASELINE: NHTSA / EDAG Light Weight Truck (LWT) Study

Draft Final Report

Mass Reduction for Light-Duty Vehicles for Model Years 2017-2025

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Objectives:
- Maximum Feasible Mass Reduction
  - Total Vehicle
- Maintain Safety, Functionality
- Cost increase < 10 %

Results:
- Total Vehicle - 406 Kg (- 17 %)
- Body - 184 Kg (- 36 %)
  - Aluminum - sheet/extrusions
  - AHSS - reinforcements, door inner
  - Magnesium/Aluminum - Rad. Supp.