Body Structure Light-Weighting *at Cadillac*

Warren J. Parsons

Engineering Group Manager Body Structures

General Motors Company

*LAST YEAR--**WHAT'S AN ATS??***

VEHICLE OVERVIEW

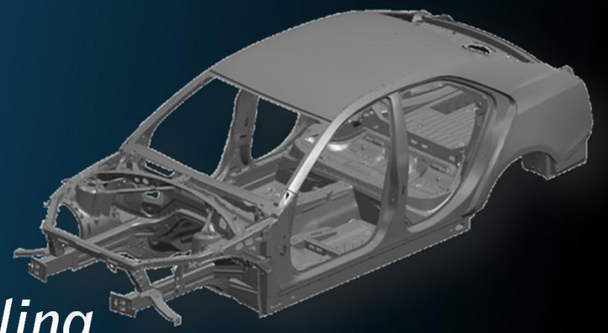
ATS AWARDS AND ACCOLADES

- Popular Mechanics Top Gadgets of 2012 - CUE
- Esquire Magazine Car of the Year
- Popular Mechanics Automotive Excellence Award - Luxury
- Urban Wheels Car of the Year
- Motor Press Guild Vehicle of the Year
- Men’s Journal Gear of the Year Award
- Wards Auto 2013 10 Best Engine Award - 2.0L Turbo
- NHTSA 5*, 5*, 5* Safety Ratings
- Detroit Free Press 2013 Car of the Year
- Hispanic Motor Press Award
- Autobytel 2013 Luxury Car of the Year
- PBS Motorweek Driver’s Choice Award “Best Sport Sedan”
- Connected World Magazine Connected Car of the Year
- Automotive Journalist Association of Canada 2013 Best New Luxury Car
- Auto123.com - 2013 Luxury Compact Car of the Year
- Autos.ca -2013 Top Pick Luxury Car
- Sharp Magazine (Canada) - "Best Reason to Buy American" Award
- 2013 ALG Residual Value Award (Canada) - Premium Midsize Car
- Motor Trend Head-to-Head Comparison Win - ATS 3.6L over the BMW 335i and MB C350
- Finalist for AOL Autos Technology of the Year - CUE
- Vanity Fair Top Five New Cars of 2012
- AutoTrader.com “Must Test Drive” List
- Detroit News Reader’s Choice Award – Best Luxury Car
- Golden Klaxton Award – Middle Class (Russia)
- Culture Map Houston – Car of the Year

BODY STRUCTURE DEVELOPMENT

Objectives of the Body in White Design

- *Performance goals of the BIW:*
  - *Achieve high ratings on all global governmental and consumer safety metrics.*
  - *Class competitive overall and local stiffness's for handling and isolation*
  - *Best in Class BIW mass*
- *Manufacturing Goals*
  - *Integrate into GM's Global Manufacturing Bill of Process*
  - *Quality of Execution*
  - *Investment and Overall Cost Reduction*



Design Optimization Methodology

1. *Architectural optimization for the bandwidth of gross vehicle mass, powertrains and performance requirements*
2. *Integration of efficient load paths and geometry*
3. *Assessment of sub-system targets; CAE optimization*
4. *Additive part design; Design details*

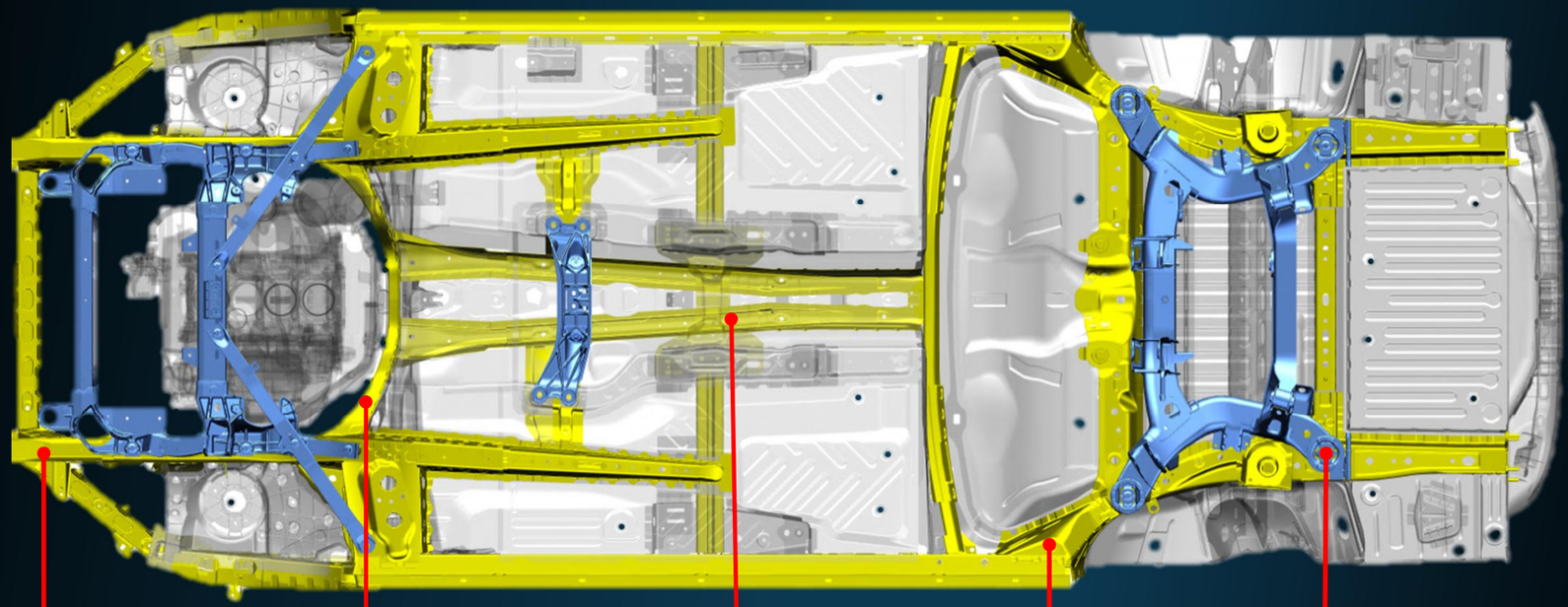
Design Strategy--Topology

Focus on Efficient Fundamentals

Body structure
Chassis structure

Side impact loads

Front impact loads



Rear impact loads

Straight primary structure

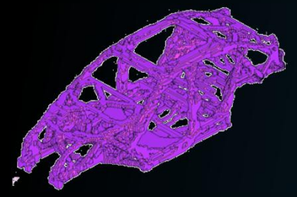
Package space for effective topology

Load-paths free from discontinuity

High stiffness joints

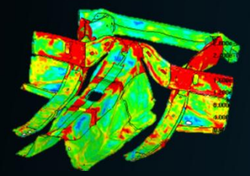
Cross members aligned

CAE Tools and Methods

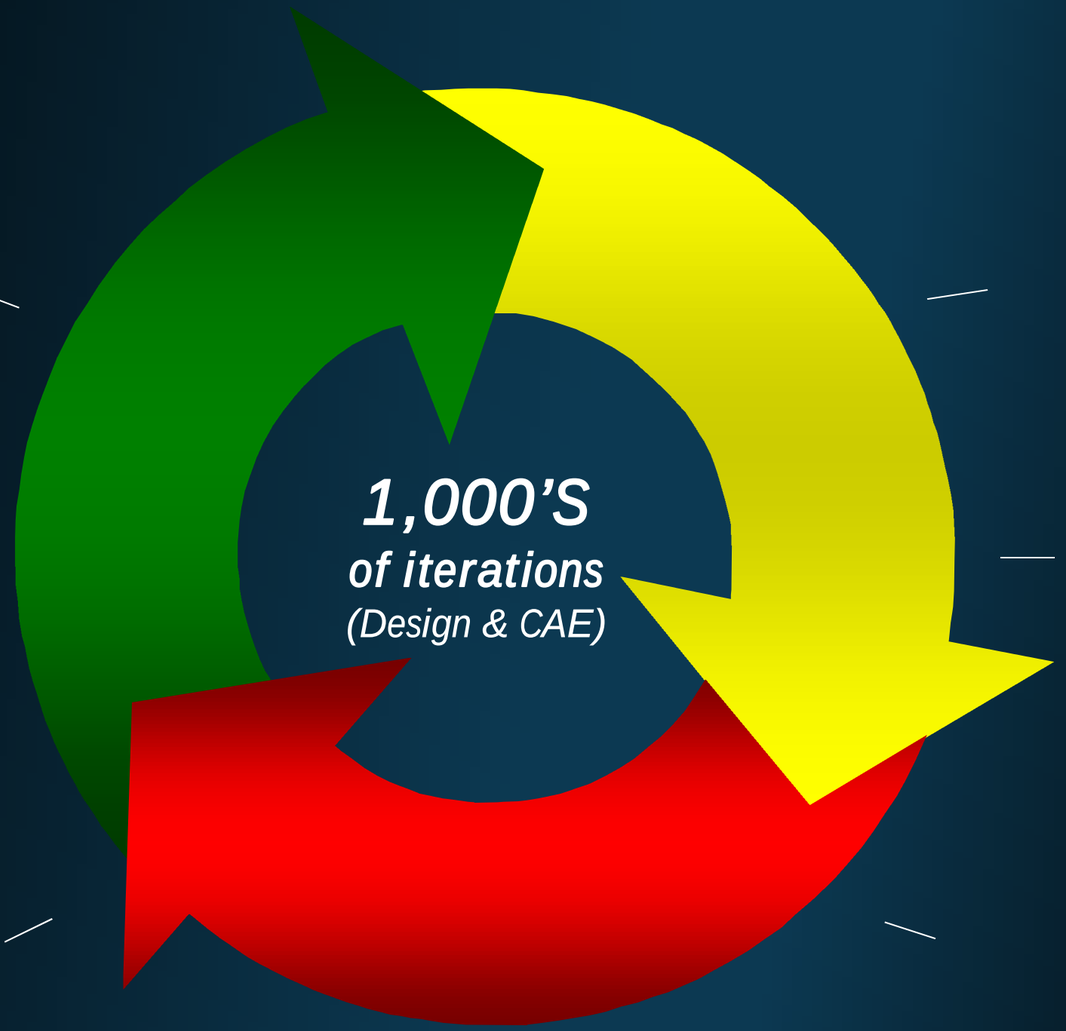


Coarse topology optimization

Multi load case gauge optimization

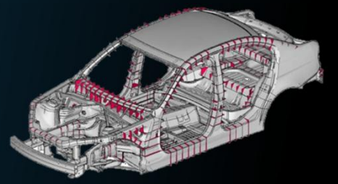


Expert interpretation of deformation modes



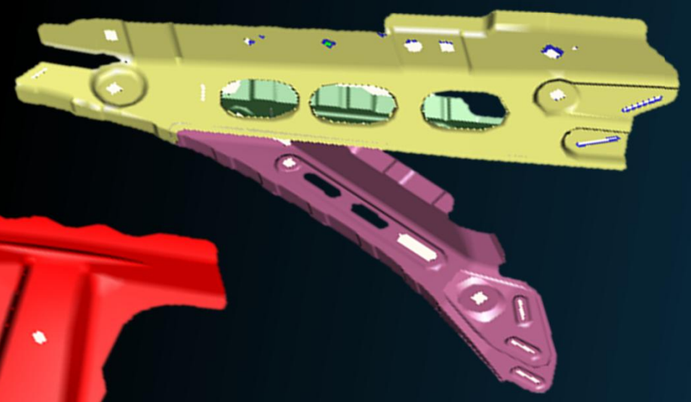
Local topology optimization

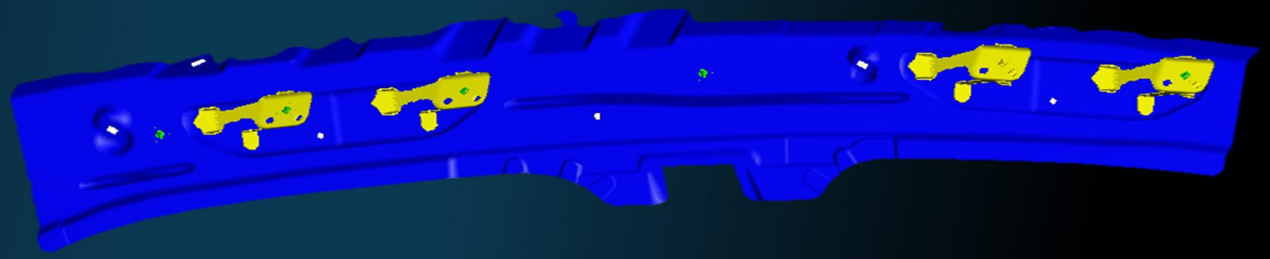
Casting shape optimization



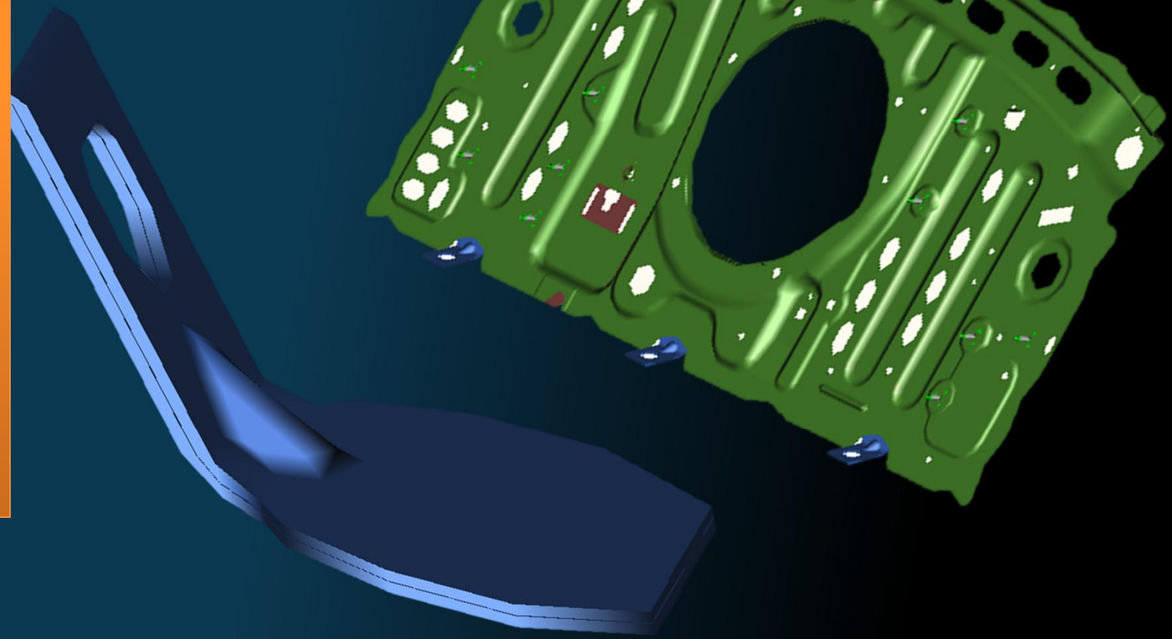
Bulkhead optimization

Design Strategy--Part Details

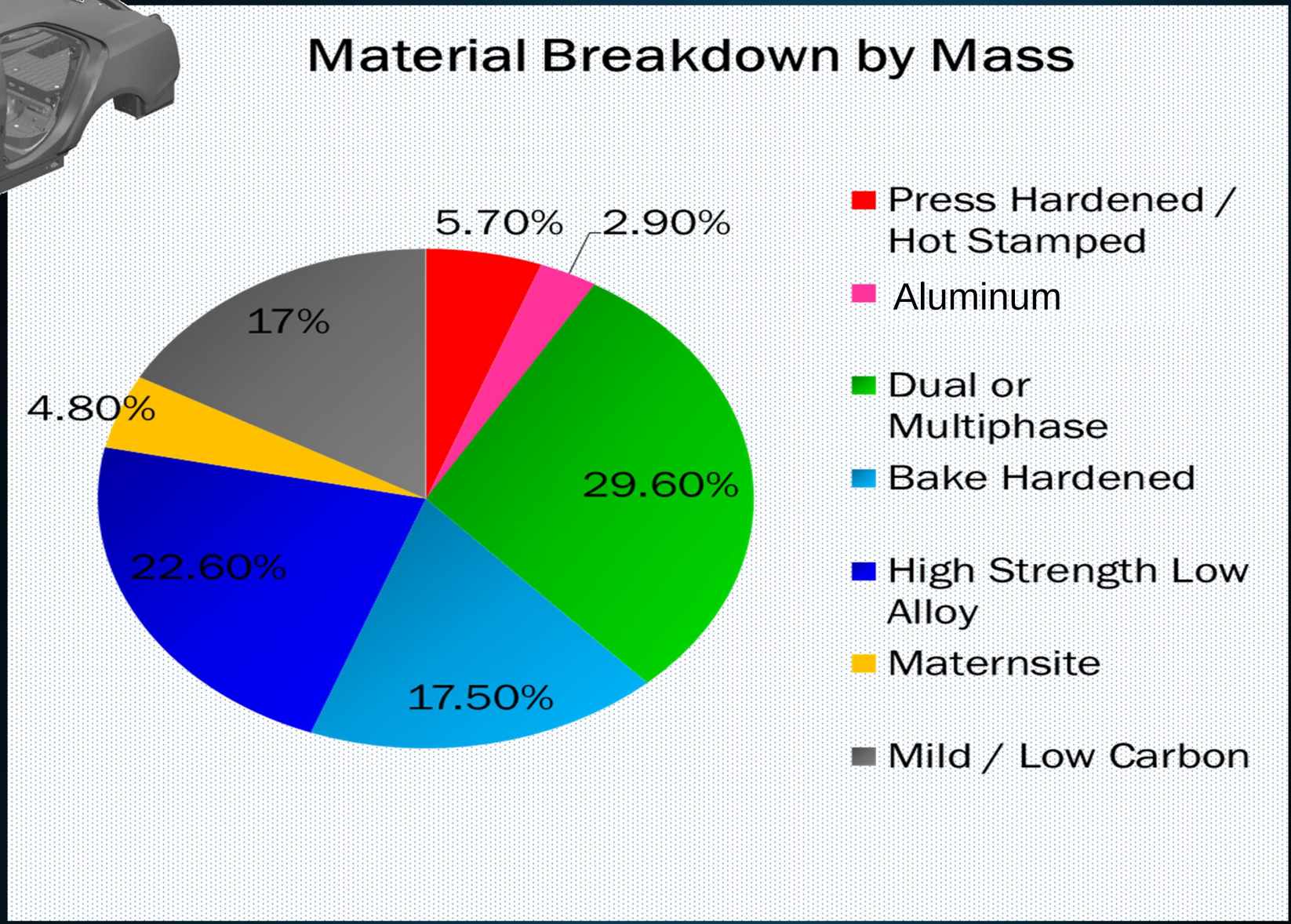




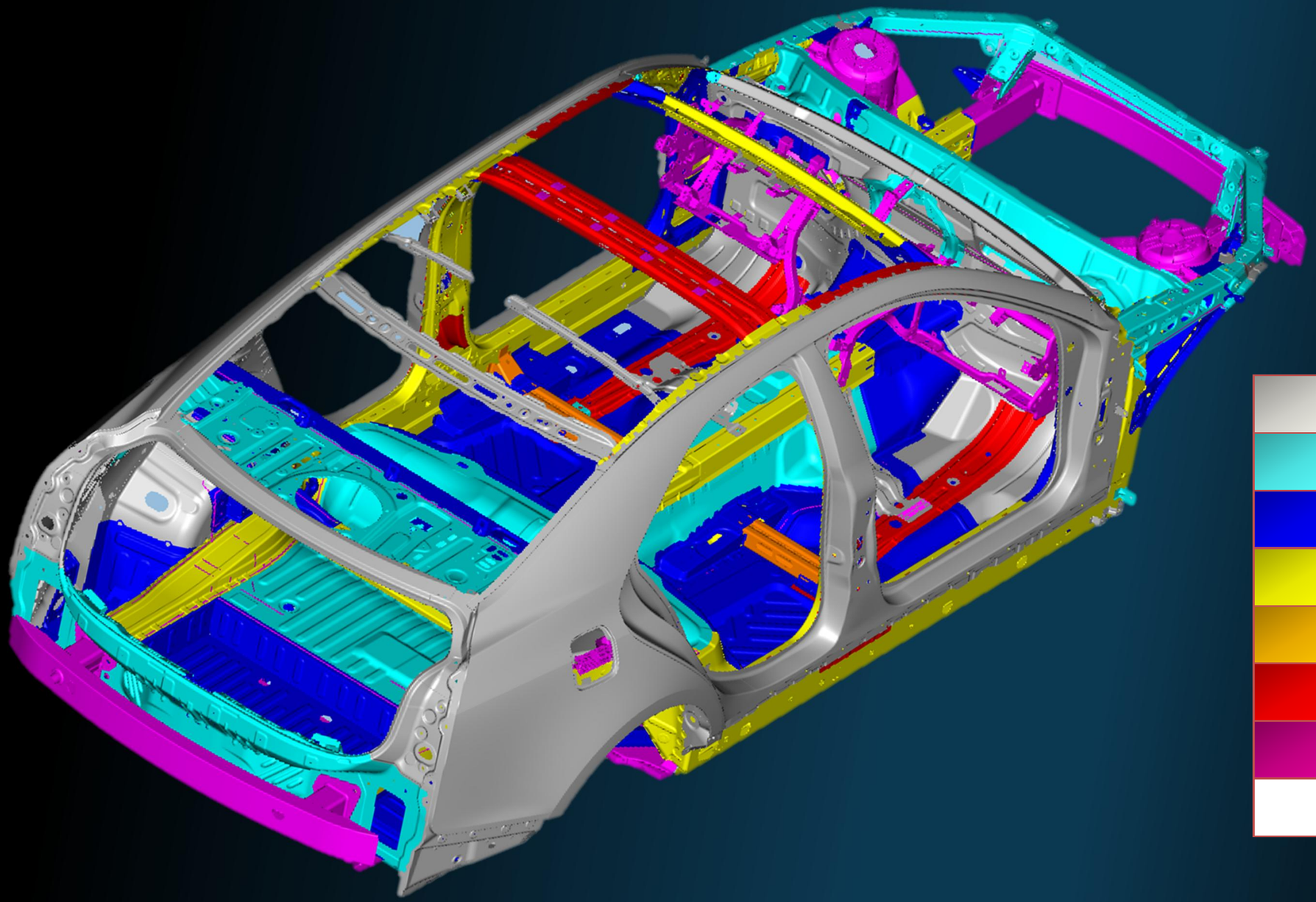
- *Scalloped flanges*
- *Lightening holes*
- *Smallest parts possible*
- *Part designs modified to enable gage reduction of mating parts; i.e., folded bracket for welding ratio*



Design Strategy--Material Selection

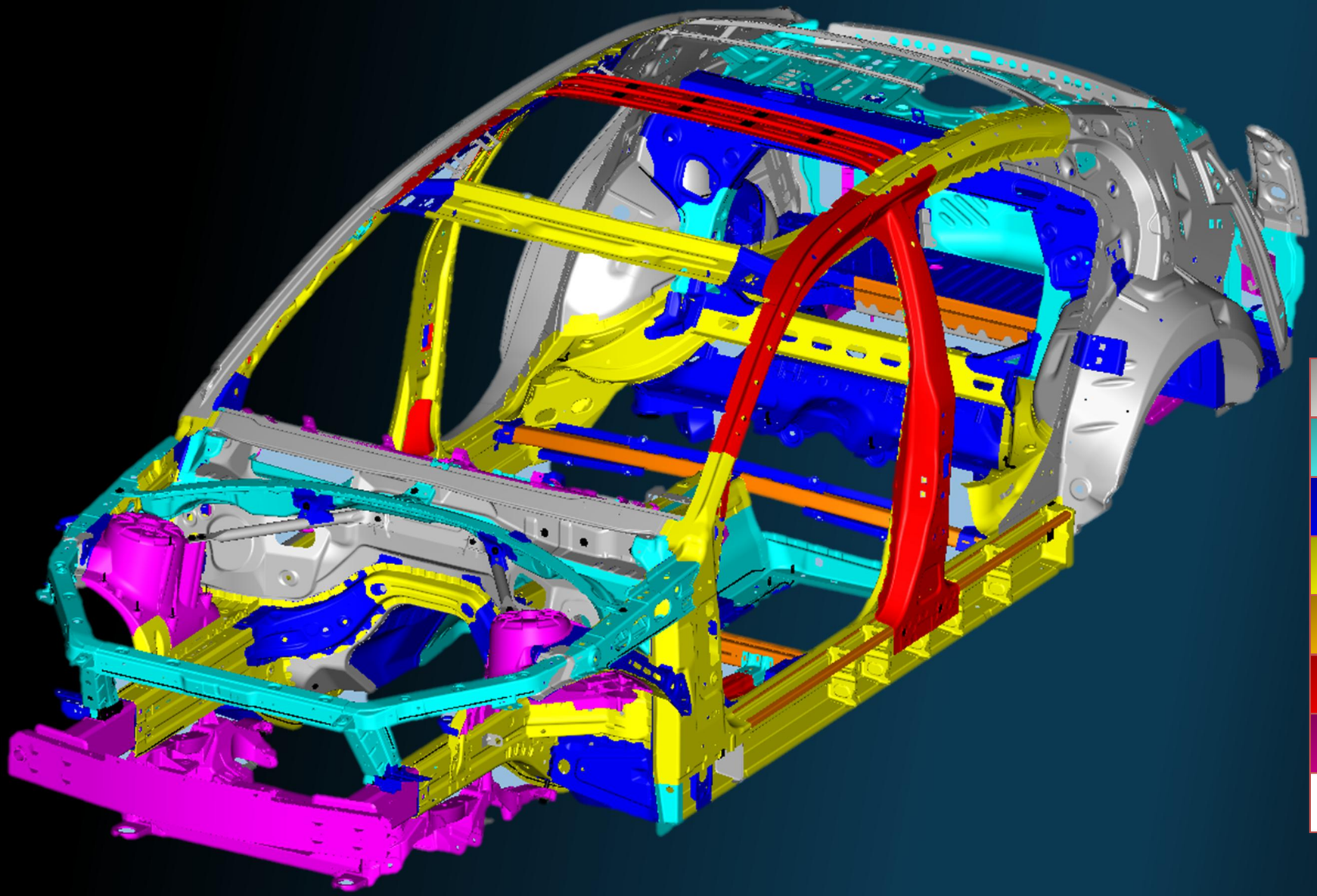


Design Strategy--Material Selection



	Mild Steel
	Bake Hardenable
	HSLA
	Dual-Phase/Multi-Phase
	Martensitic
	Press Hardened Steel
	Aluminum

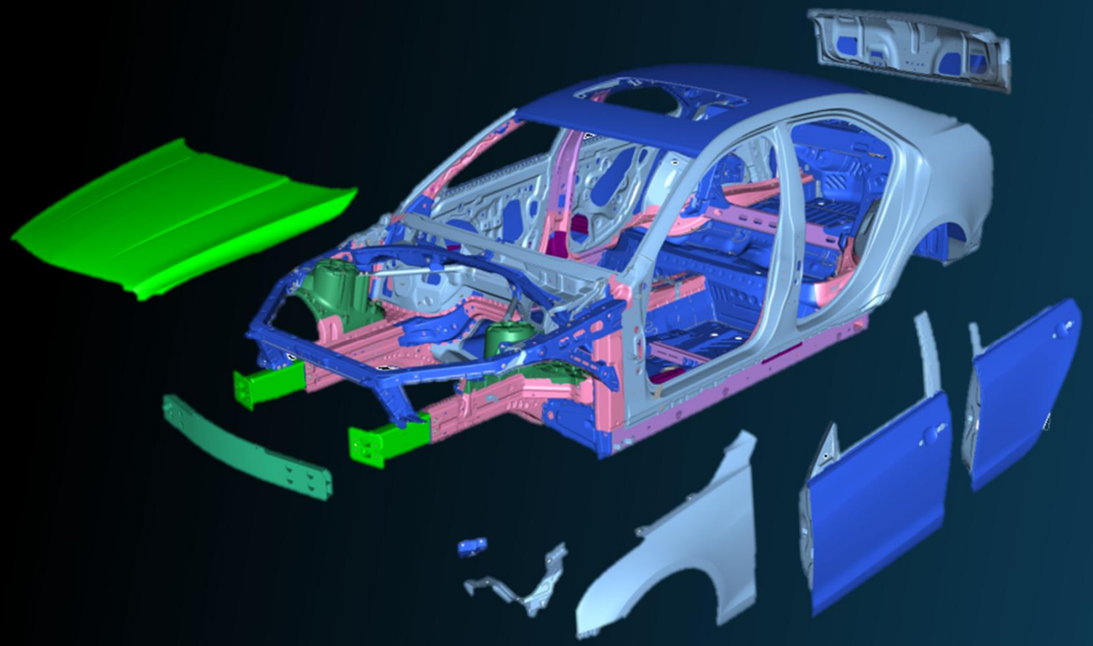
Design Strategy--Material Selection



	Mild Steel
	Bake Hardenable
	HSLA
	Dual-Phase/Multi-Phase
	Martensitic
	Press Hardened Steel
	Aluminum

Material Strategy

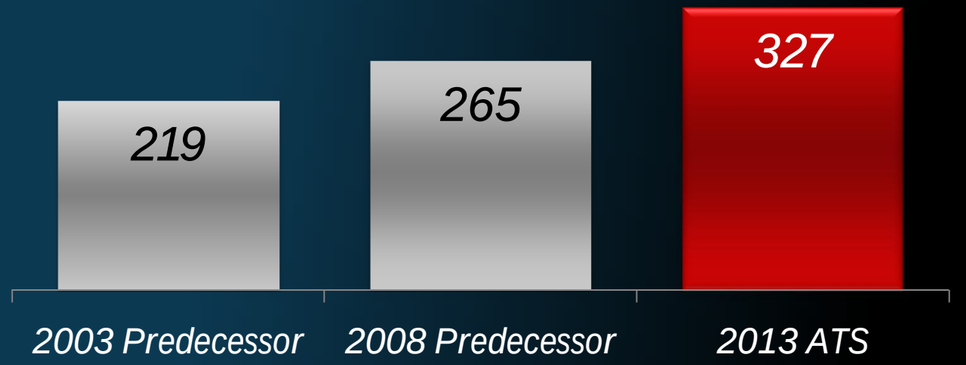
Cadillac steel strength trends



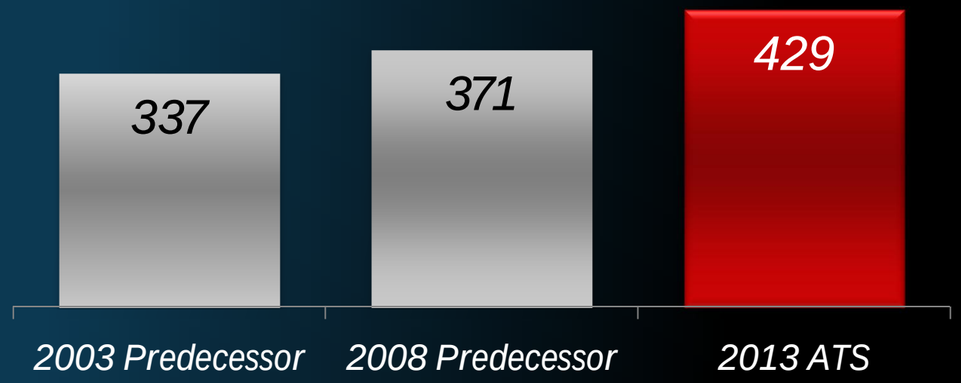
YS_{avg} = 23% increase

TS_{avg} = 16% increase

Yield strength (average MPa)



Tensile strength (average MPa)



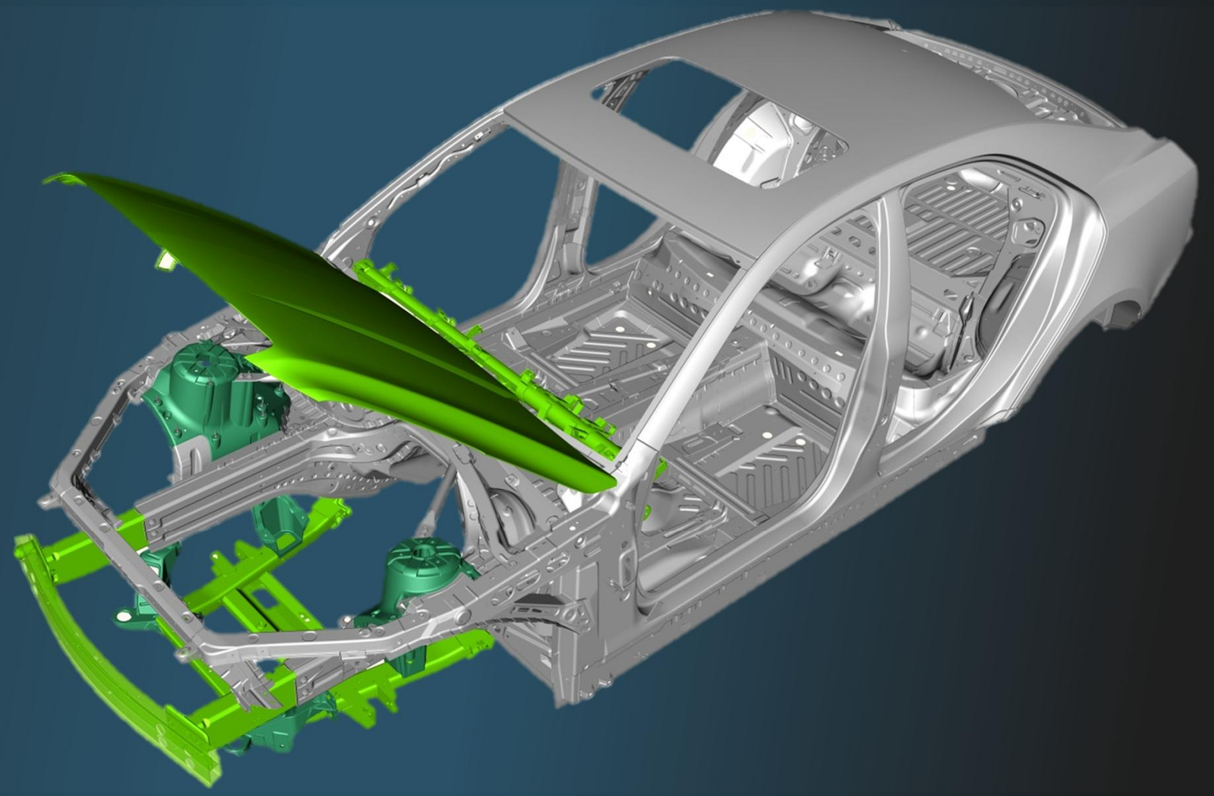
Material Strategy

Aluminum Specification

Al castings

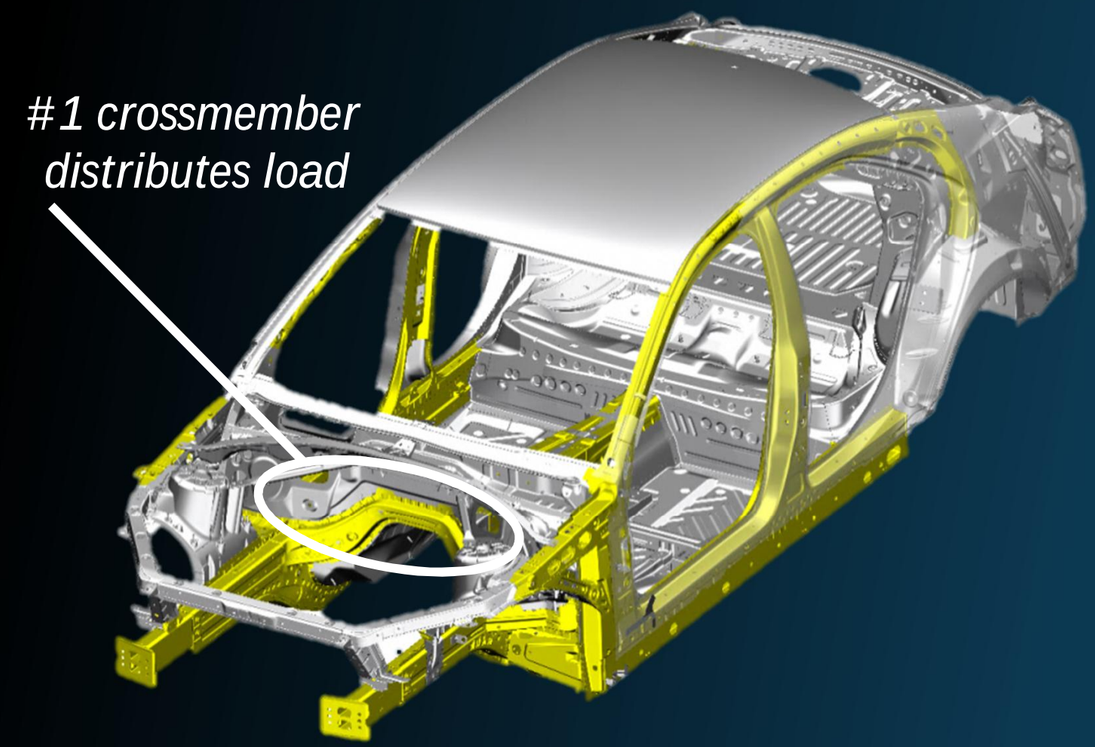
Al extrusions & stampings

- Based on cost / kg saved
- Higher cost allowed near front of vehicle
- 50% - 50% mass distribution



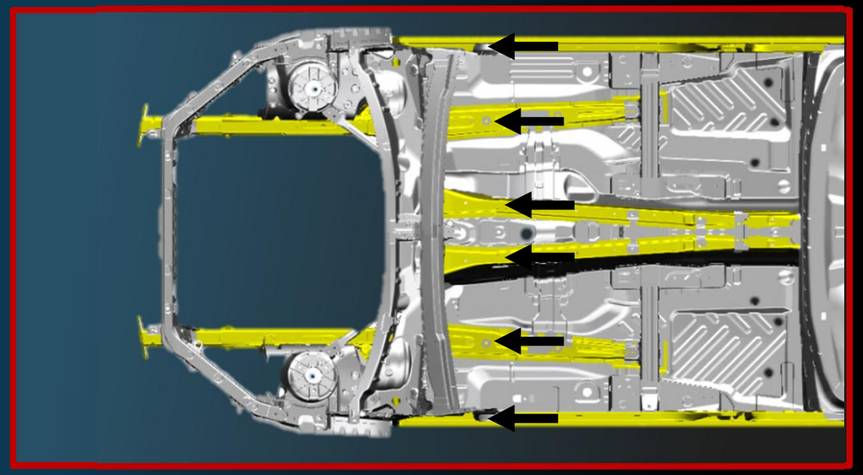
Design Strategy--Crash Performance

Global Front Load-paths

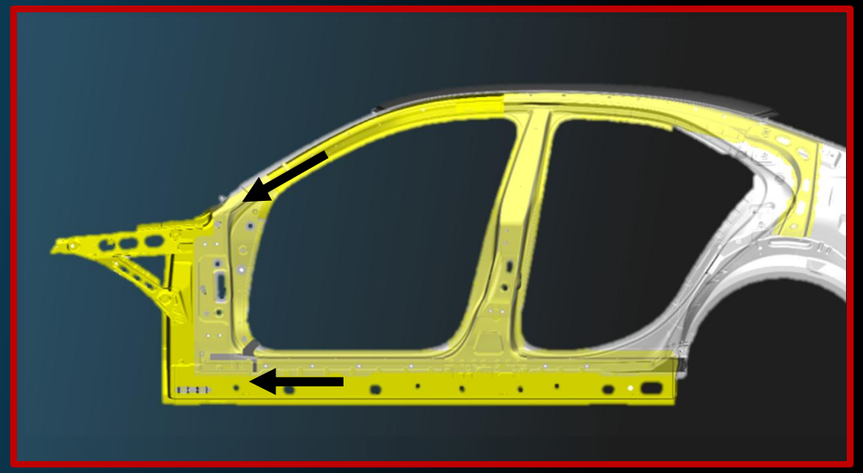


- 75 % load managed by lower body
- 25 % load managed by upper body

Underbody reaction

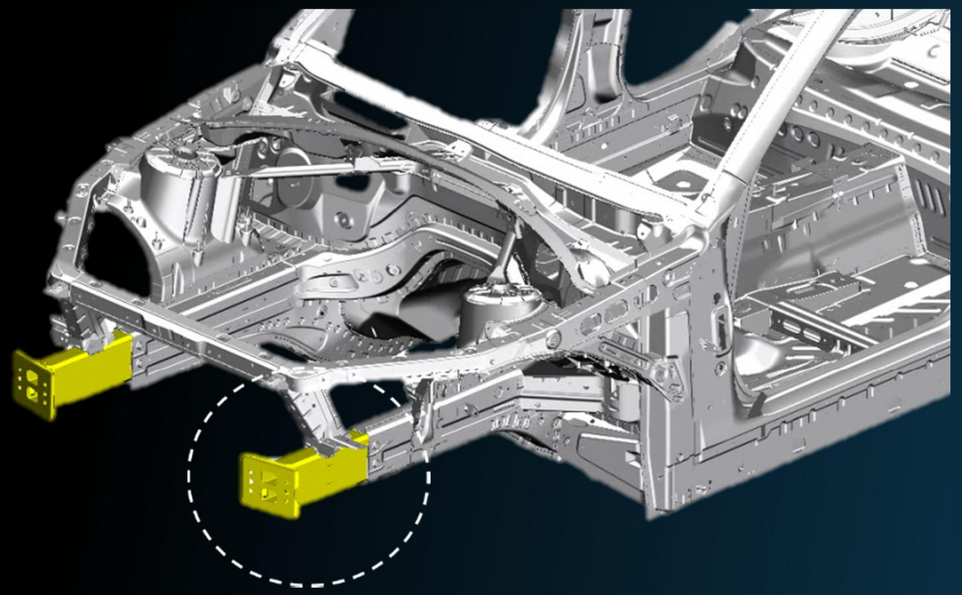


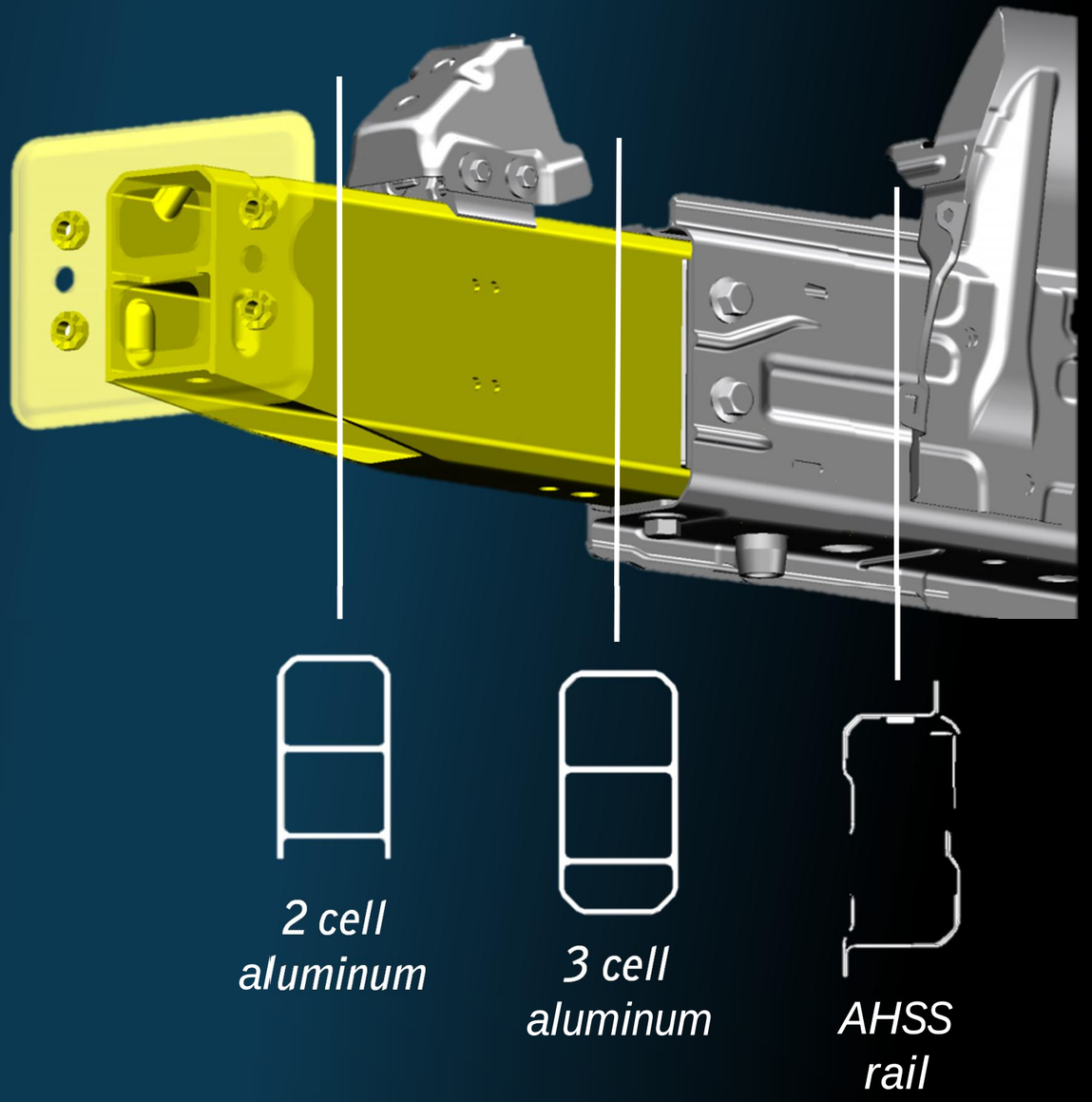
Crash ring reaction



Design Strategy--Crash Performance

Multi-stage Crush Box

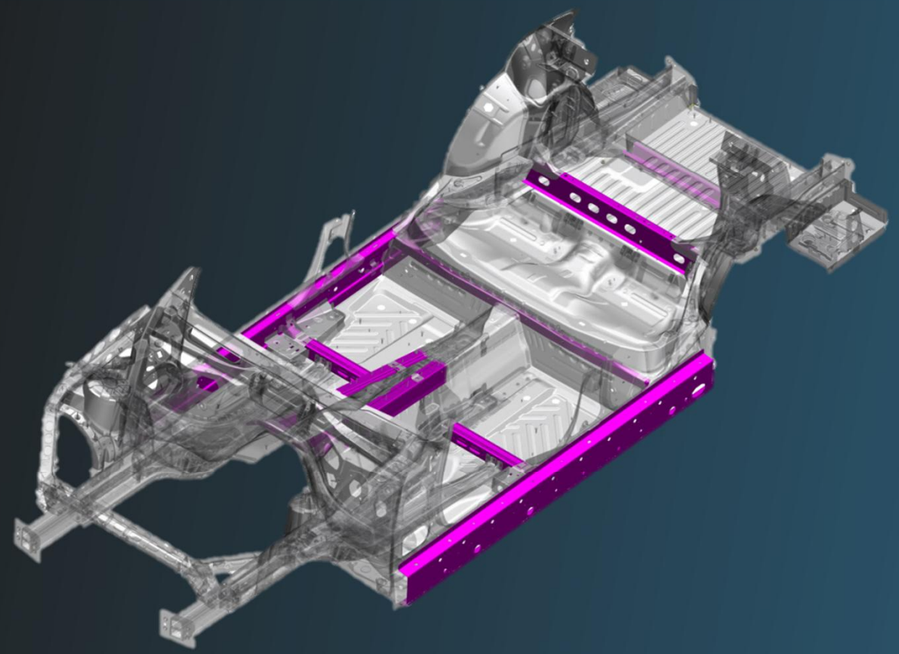




- *Three cell aluminum extrusion*
- *Elongated for low and high speed*
- *Saw cut allows multi-stage crush*

Design Strategy--Crash Performance

Ultra High Strength Roll Forming

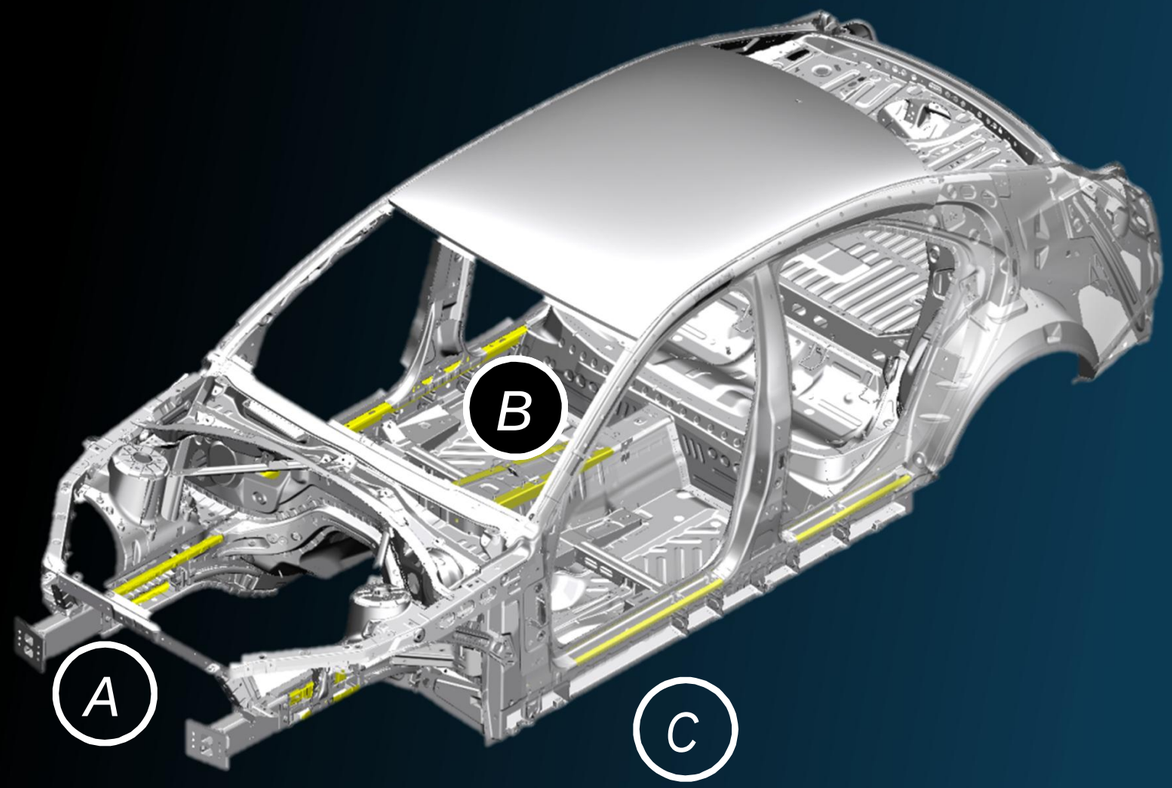


- Constant & bent sections
- High impact strength
- Cost effective
- Cold formed

Roll formed UHSS parts

Design Strategy--Crash Performance

High Performance Corner Doublers



- Lighter overall solution
- Tuning flexibility for variants

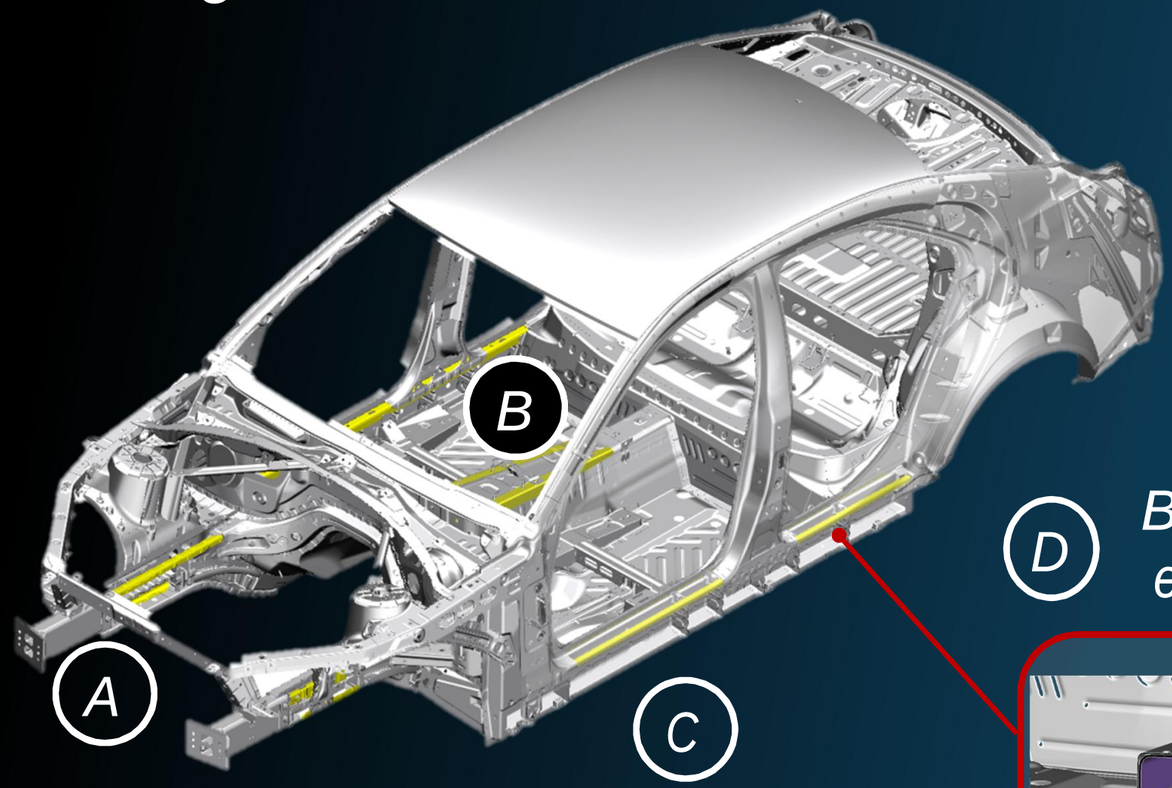
A Motor rail example

B Tunnel cap example

C Rocker example

Design Strategy--Crash Performance

Stabilizing Bulkheads



D Bulkhead example

- Lighter overall solution
- Tuning flexibility for variants

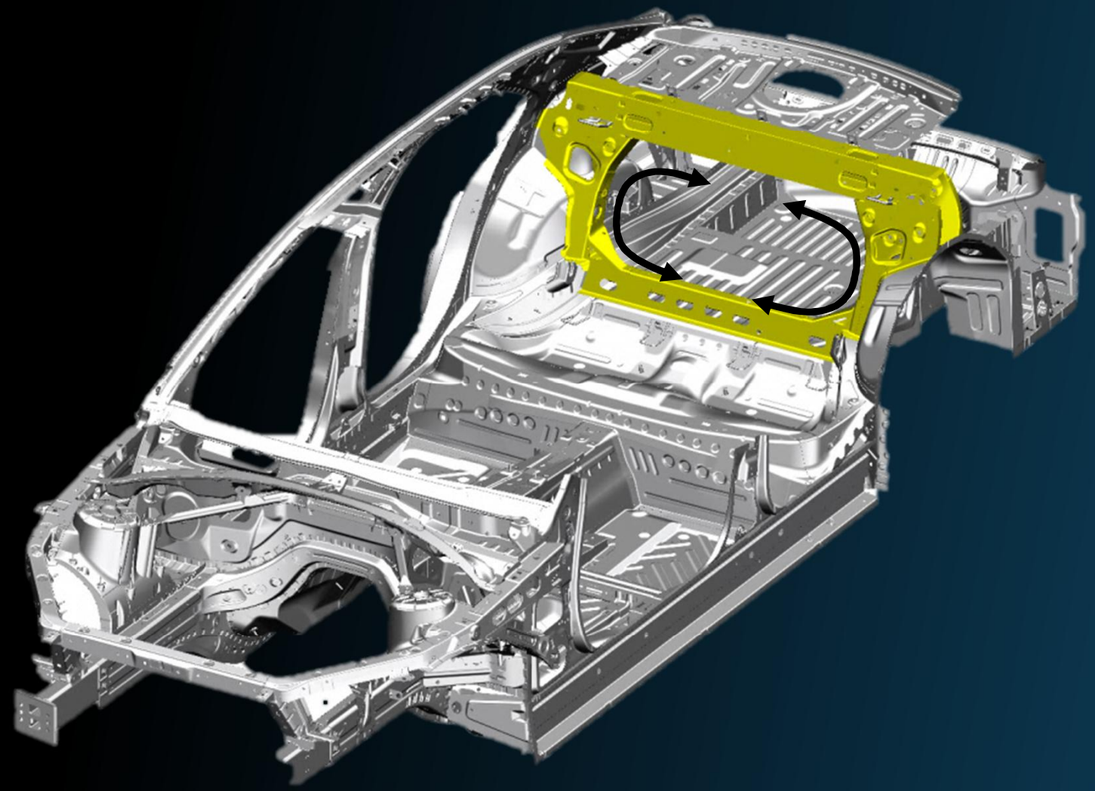
A Motor rail example

B Tunnel cap example

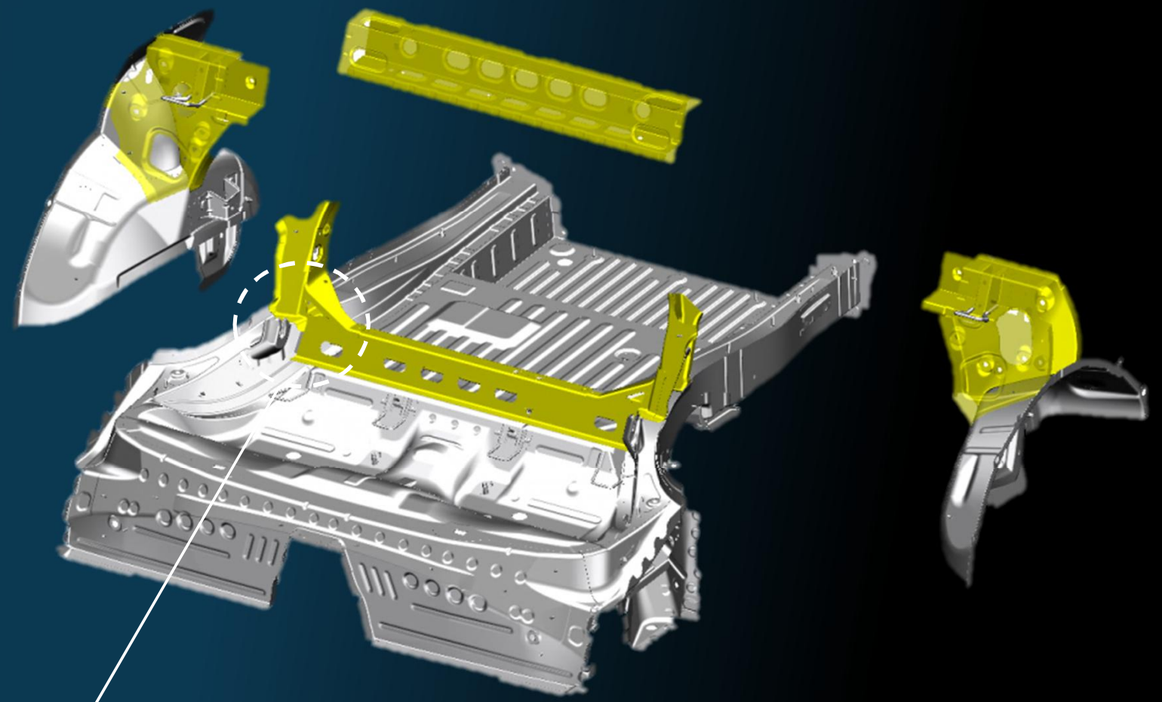
C Rocker example

Design Strategy--NVH

High Stiffness Seatback Ring



- *Box sections*
- *Lightening holes*
- *Large pass-through*



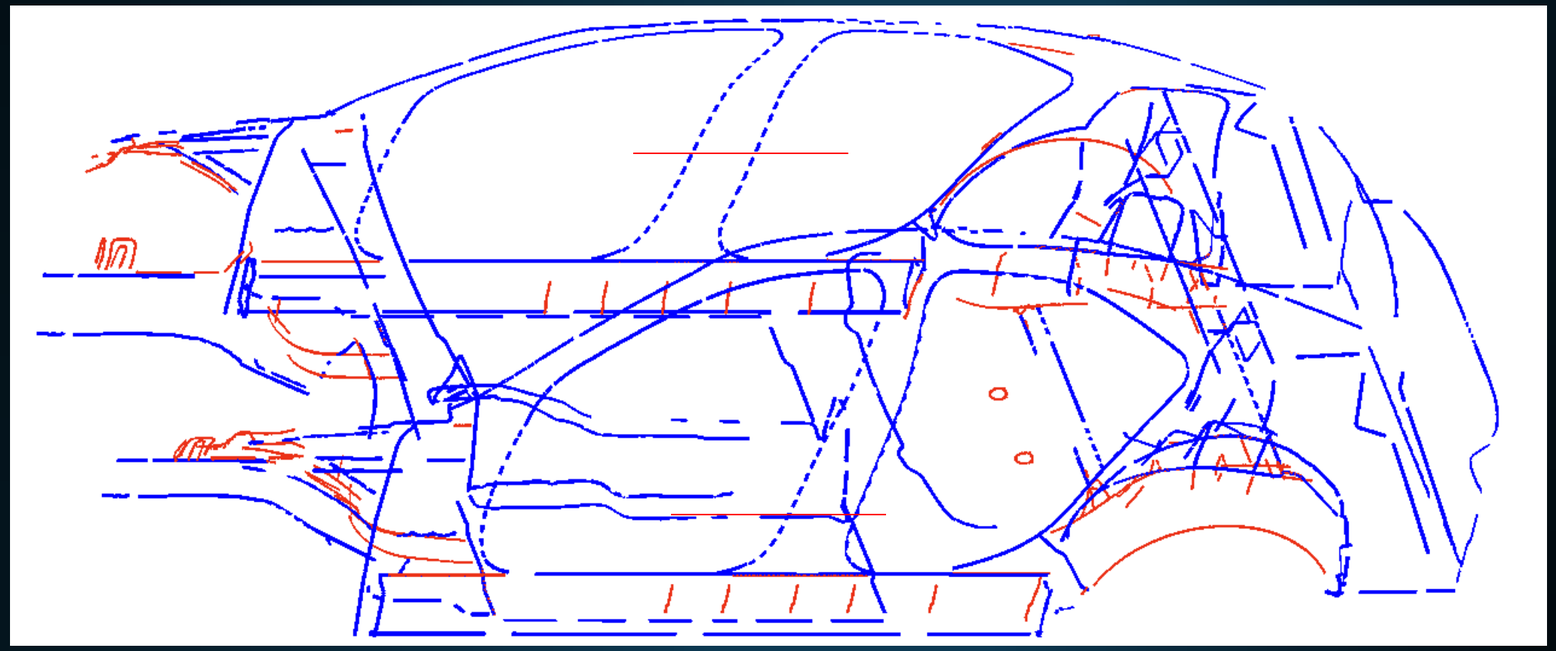
Pre-assembled
for high stiffness

Design Strategy--NVH

Weld Bonding

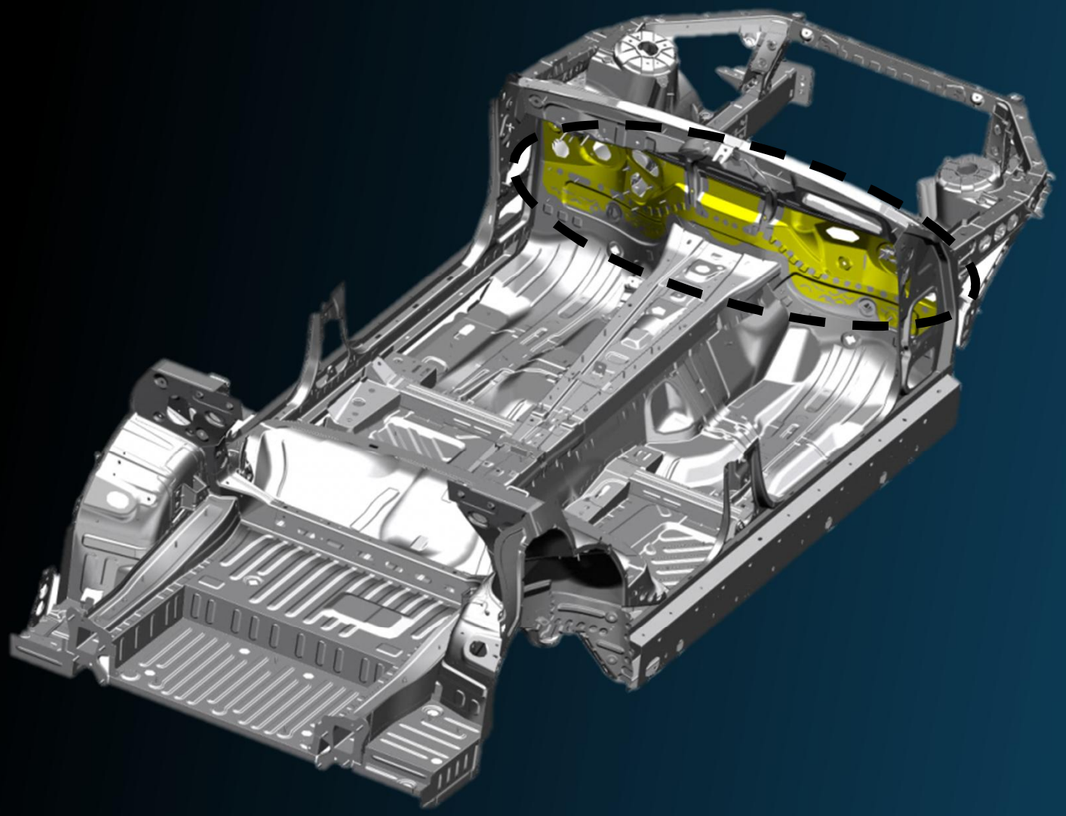
Legacy	
New to ATS	

88 Meters Total



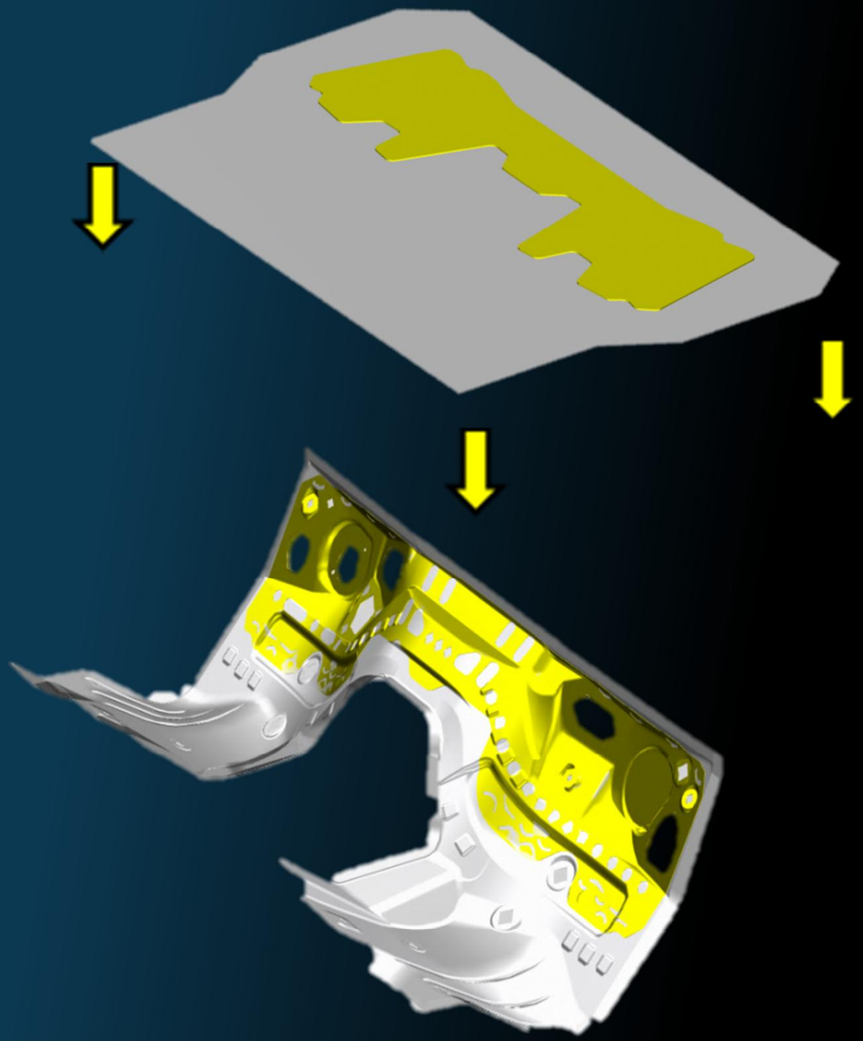
Design Strategy--NVH

Patch Laminated Dash



Concentrated mass, stiffness & damping in critical noise radiating area

Patch laminated visco – elastic blank

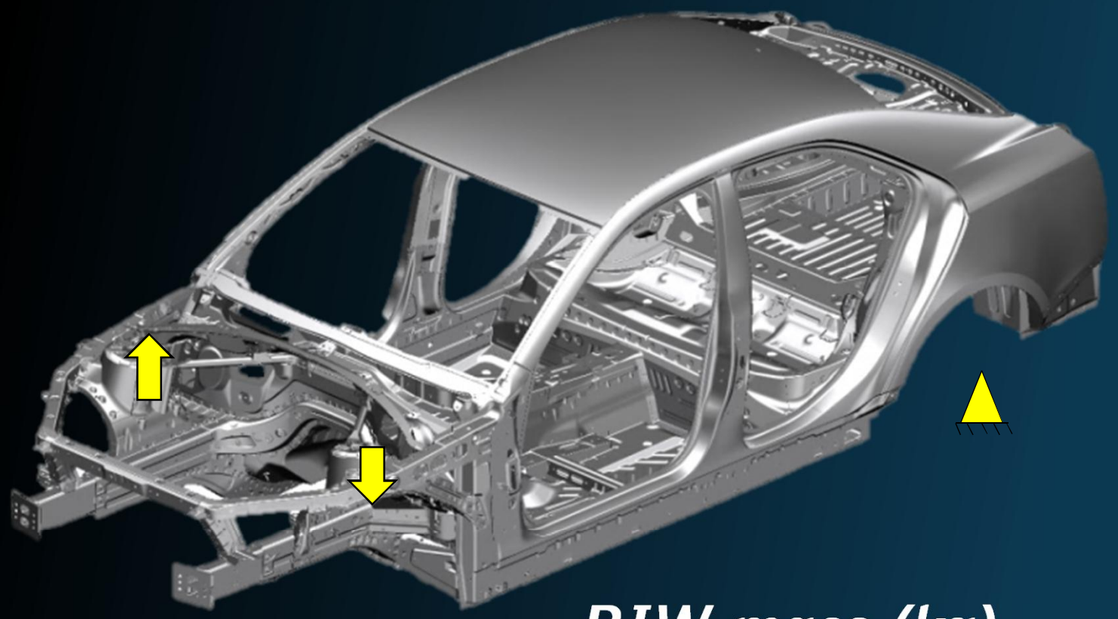


Co-formed in die

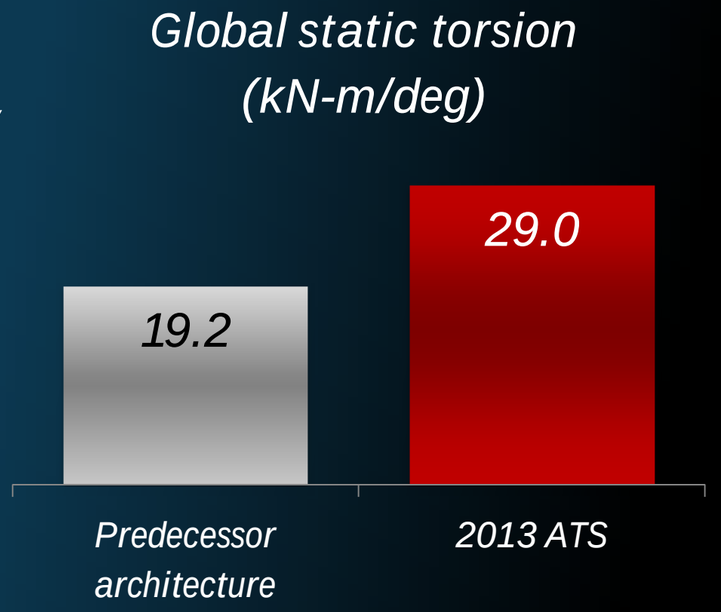
Summary

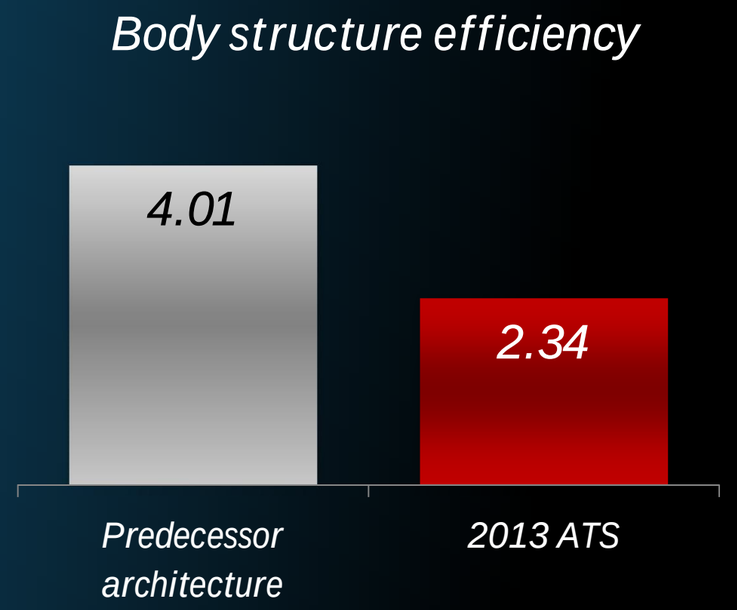
- *Narrow the bandwidth*
- *Package the vehicle to control loads and avoid compromising load paths and part geometry*
- *Be realistic in setting and meeting targets; balance is critical to meet requirements without waste*
- *WORK THE DESIGN DETAILS*

The Result--Stiffness & Efficiency

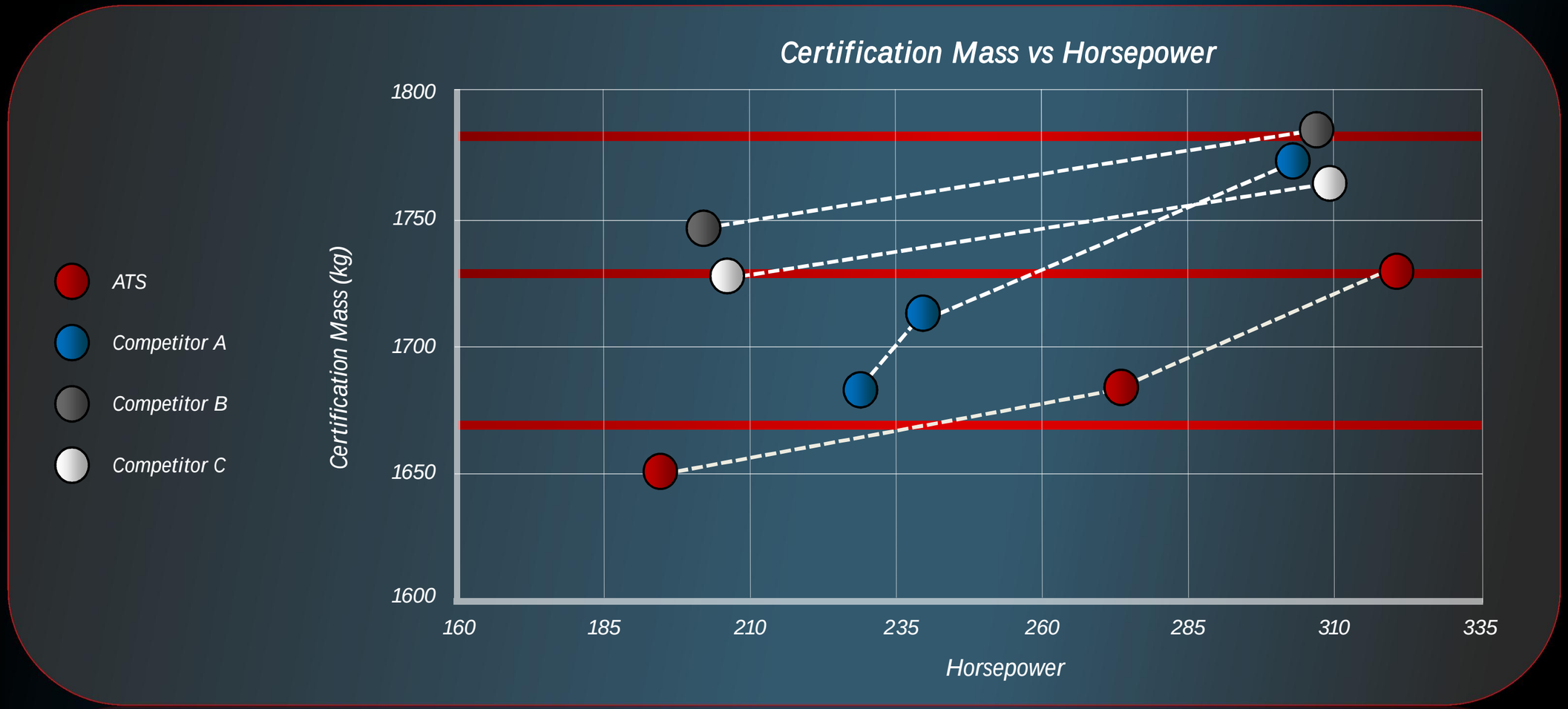


$$\text{Body structure efficiency} = \frac{\text{BIW mass (kg)}}{\text{Area } (m^2) \times \text{Torsion (kN-m/deg)}}$$





The Result--Efficiency and Performance



The Next Challenge: The 2014 CTS

The Next Challenge: The 2014 CTS

The Next Challenge: The 2014 CTS

The 2014 CTS is a larger car:

v. 2013 ATS

- *Wheelbase is +135 mm*
- *Overall Length is +321mm*

v. 2013 CTS:

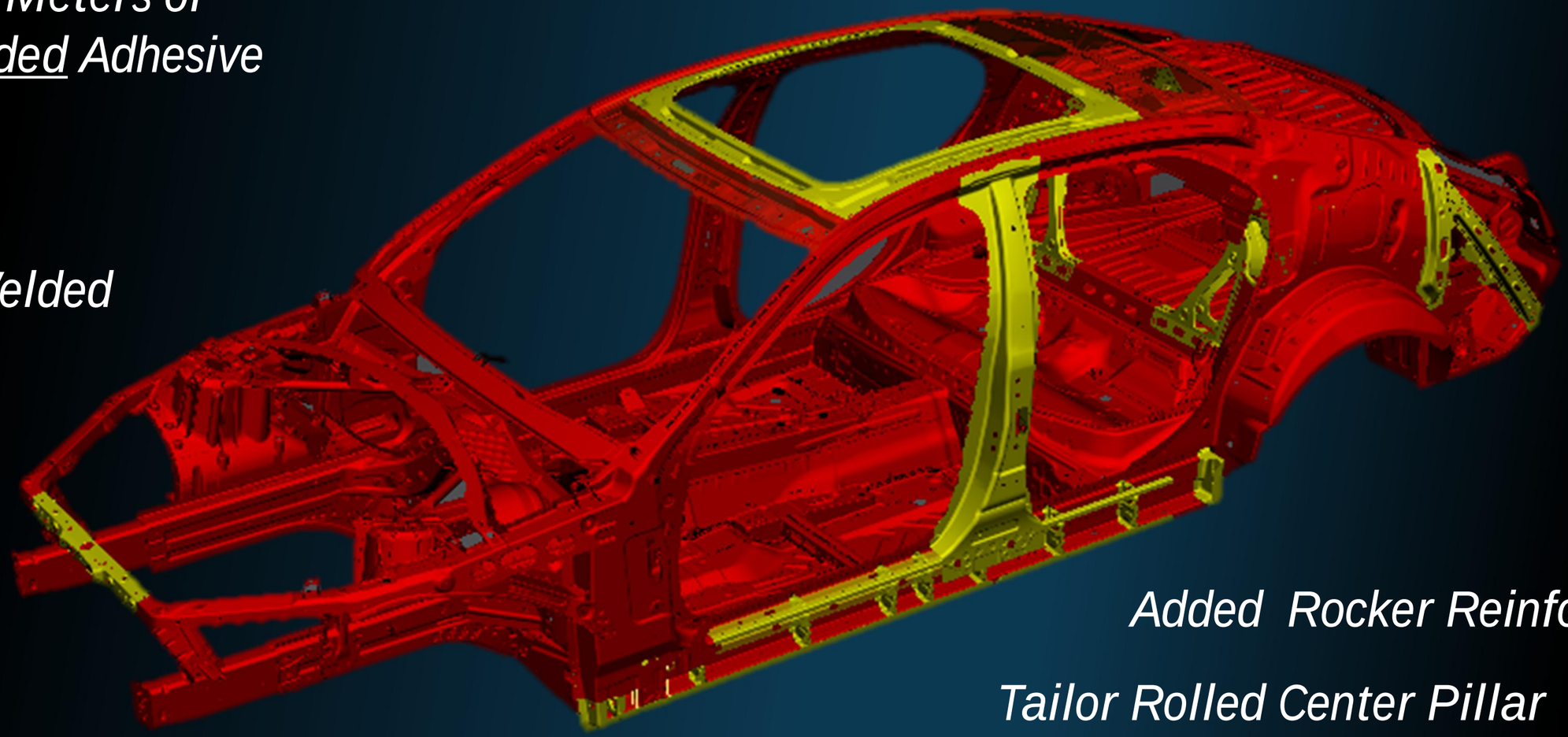
- *Wheelbase is +30mm*
- *Overall Length is + 127mm*

2014 CTS Structural Enhancements

Stiffened Sun Roof Reinforcements

Revised Seatback Structure and Bracing

30 Meters of Added Adhesive



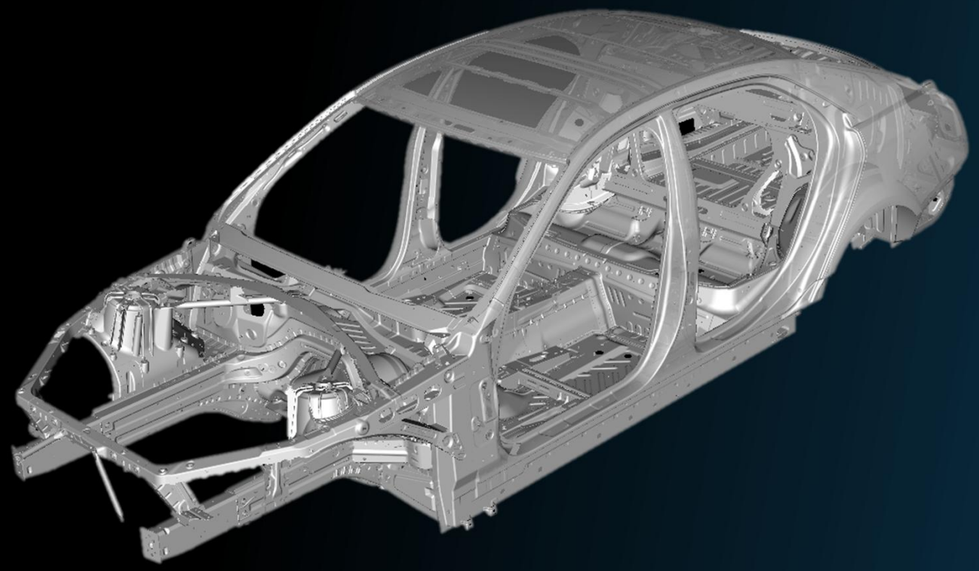
Laser Welded Tie Bar

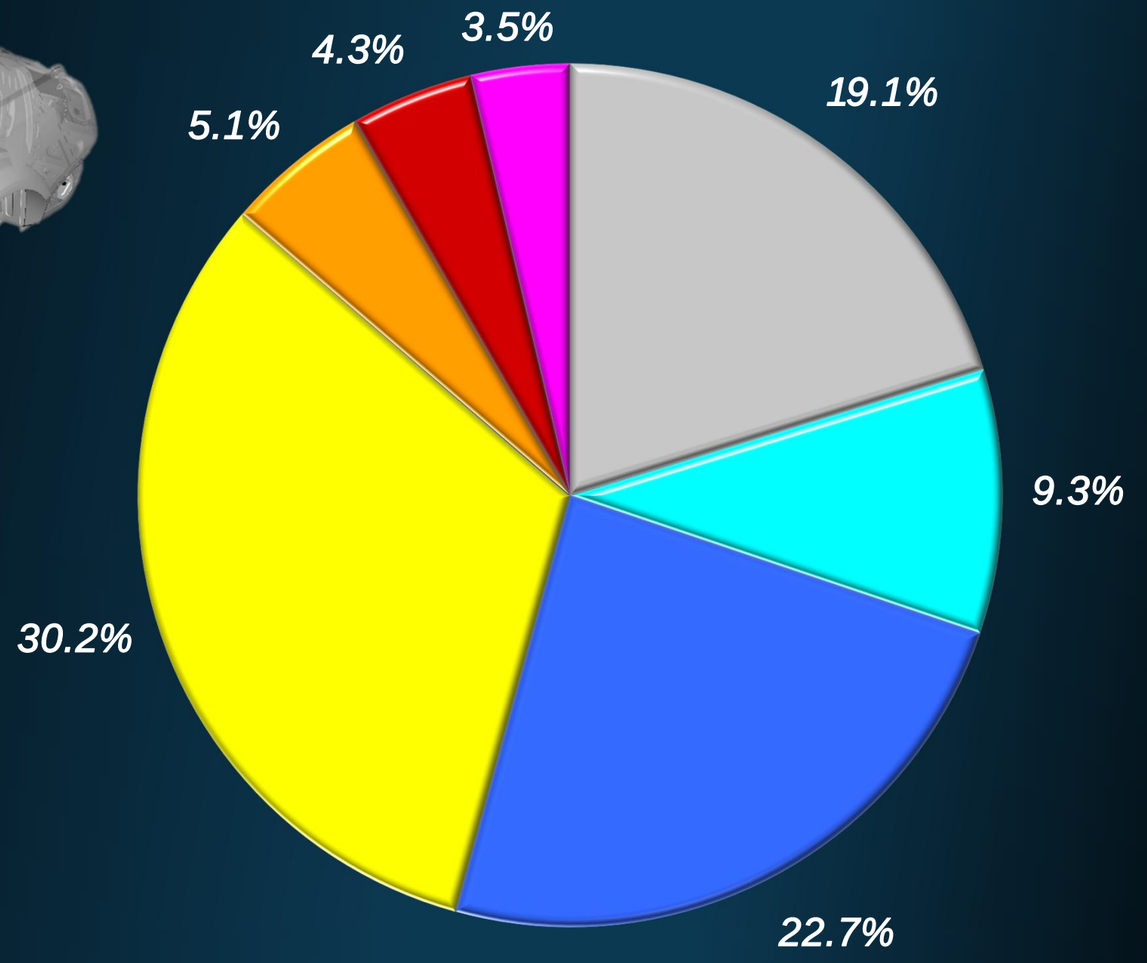
Added Rocker Reinforcements

Tailor Rolled Center Pillar

Stiffened Cradle Attachments

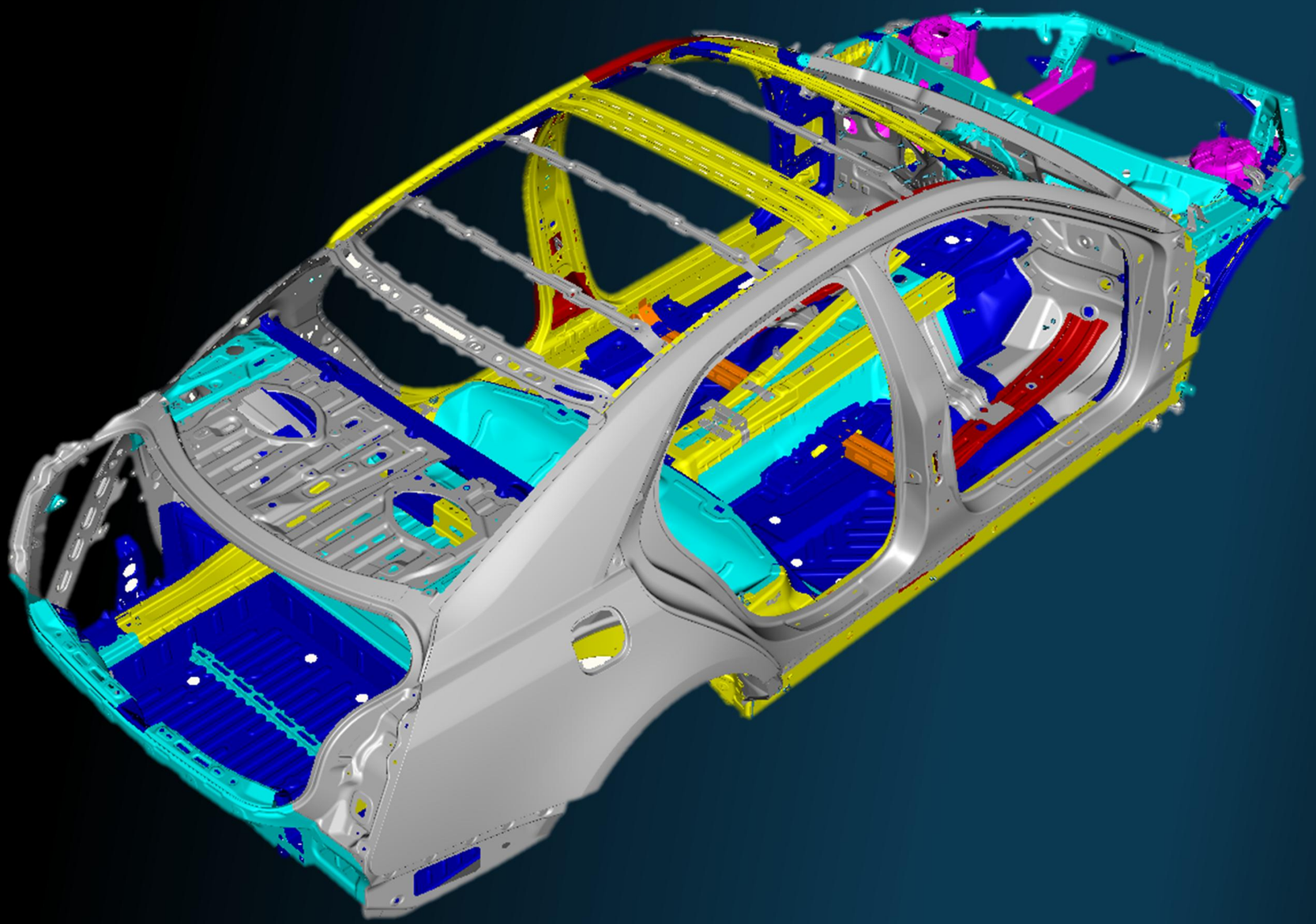
Design Strategy - CTS Material Selection





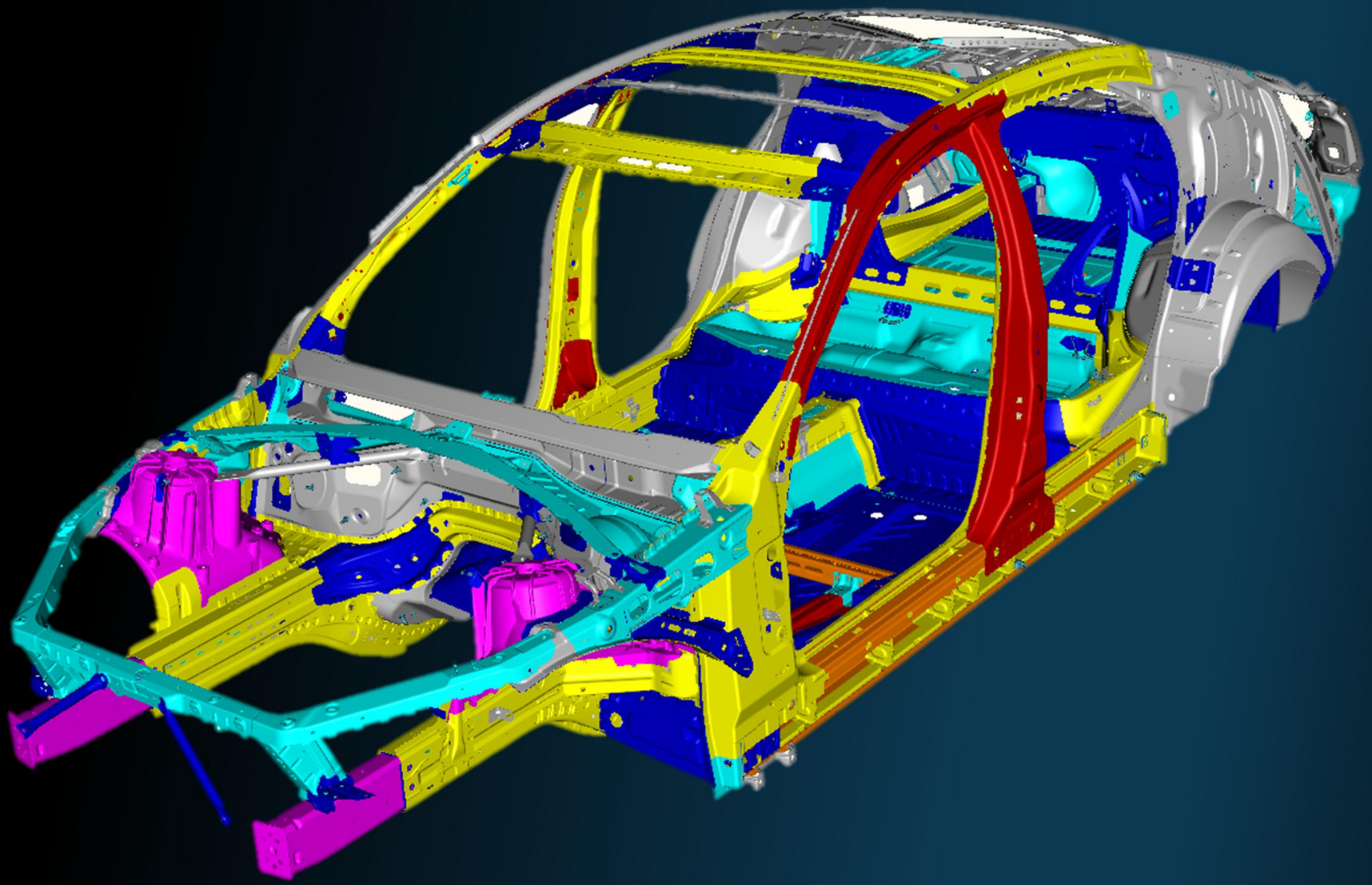
PERCENTAGE BY MASS

Design Strategy - CTS Material Selection



	Mild Steel
	Bake Hardened
	HSLA
	Dual-Phase/Multi-Phase
	Martensitic
	Press Hardened Steel
	Aluminum

Design Strategy - CTS Material Selection



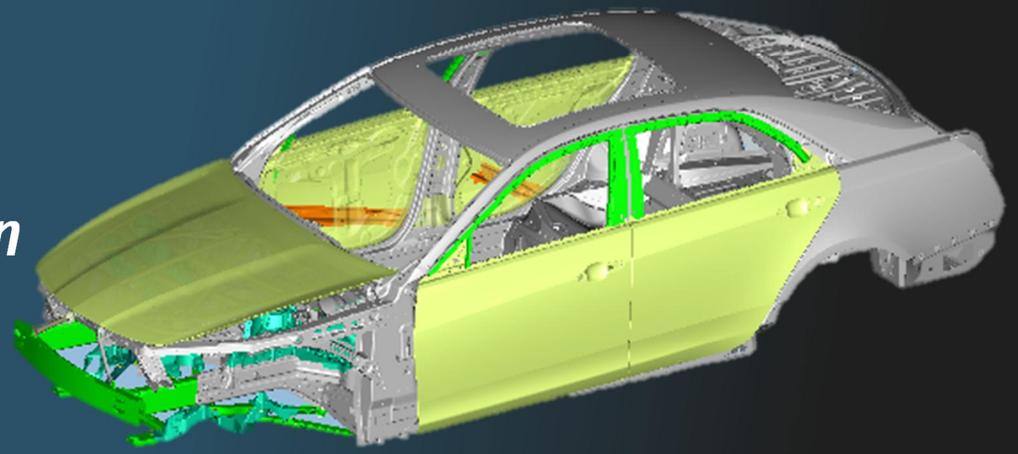
	Mild Steel
	Bake Hardened
	HSLA
	Dual-Phase/Multi-Phase
	Martensitic
	Press Hardened Steel
	Aluminum

Material Strategy

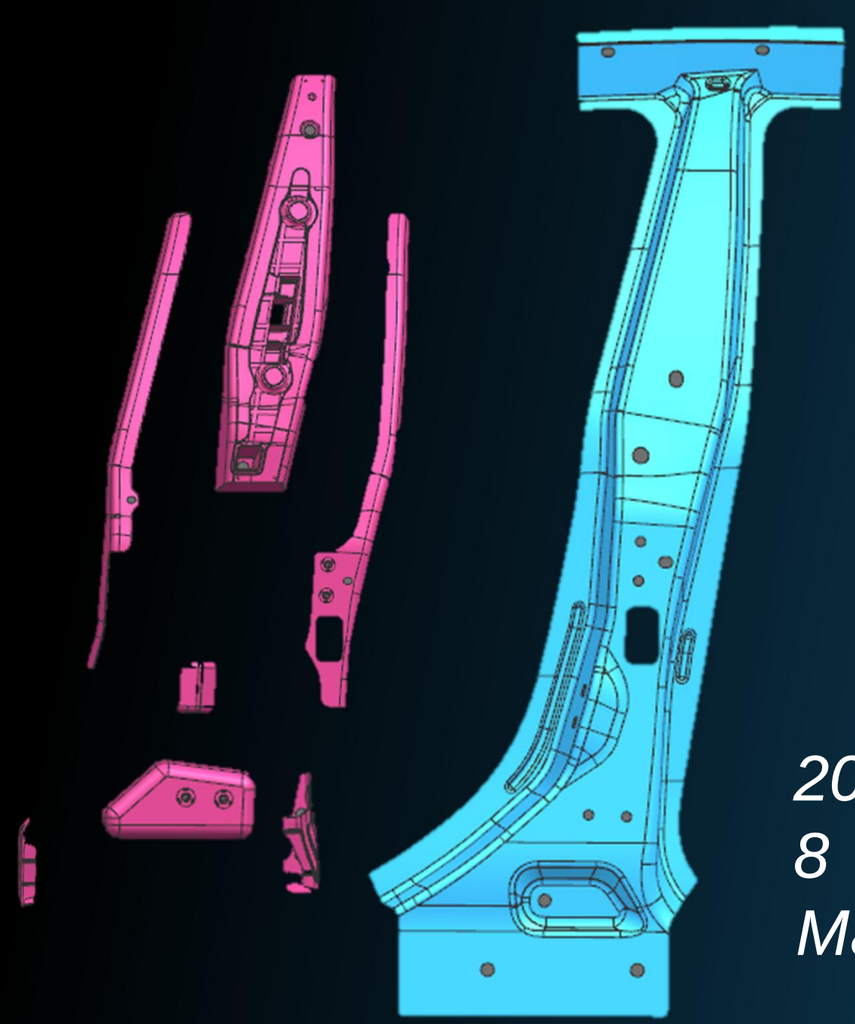
Increased Aluminum Specification from ATS

Al castings
Al extrusions
Al sheet

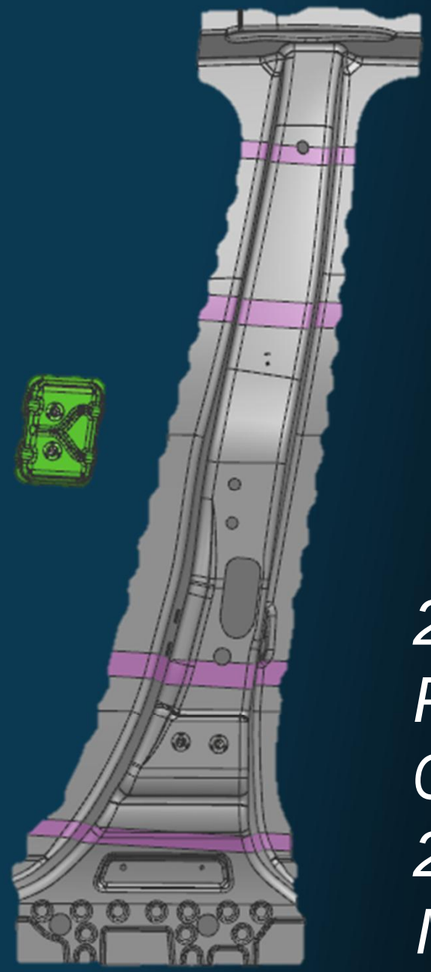
- 2014 CTS doors are aluminum
  - Doors are larger than in 2013
  - Steel door beams--bolted
  - Mass reduction of 26 kg. v. 2013 CTS
  - Mass reduction of 18 kg. v. best steel design
- ATS Al applications retained
- Material selection is based on cost / kg saved
- Total vehicle Al usage has increased :
  - 2013: 15%
  - 2014: 18%



Design Strategy--Tailor Rolled Center Pillar



2013 CTS
8 Parts
Mass 6.36Kg



2014 CTS
Press Hardened Steel
Gauges Tuned for Crash
2 Parts
Mass 4.62 Kg

THE RESULTS:

The New CTS Body is 8.5% LIGHTER and 40% STIFFER than the Previous Body

2013 CTS Body Mass: 352.1 Kg (sunroof) / 349.3 kg (base)
2014 CTS Body Mass: 322.0 Kg (sunroof) / 323.9 kg (base)

2013 CTS Stiffness: 17.4 (sunroof) / 19.2 (base) kN-m/deg
2014 CTS Stiffness: 24.7 (sunroof) / 26.8 (base) kN-m/deg

2013 CTS Body Structure Efficiency: 4.46 (sunroof) / 4.01(base)
2014 CTS Body Structure Efficiency: 2.87 (sunroof) / 2.66 (base)

Cadillac

THANK YOU