Advanced High-Strength Steel Technologies in the 2013 Ford Fusion

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Agenda

- Background
- Material Usage
- Design Approach
- Functional Performance
  - Static Stiffness
  - Dynamic Stiffness
  - Safety

Global Footprint

★ **Engineering:** Original Platform developed in Sweden & Germany
Platform Updates and New Top Hats developed in Dearborn

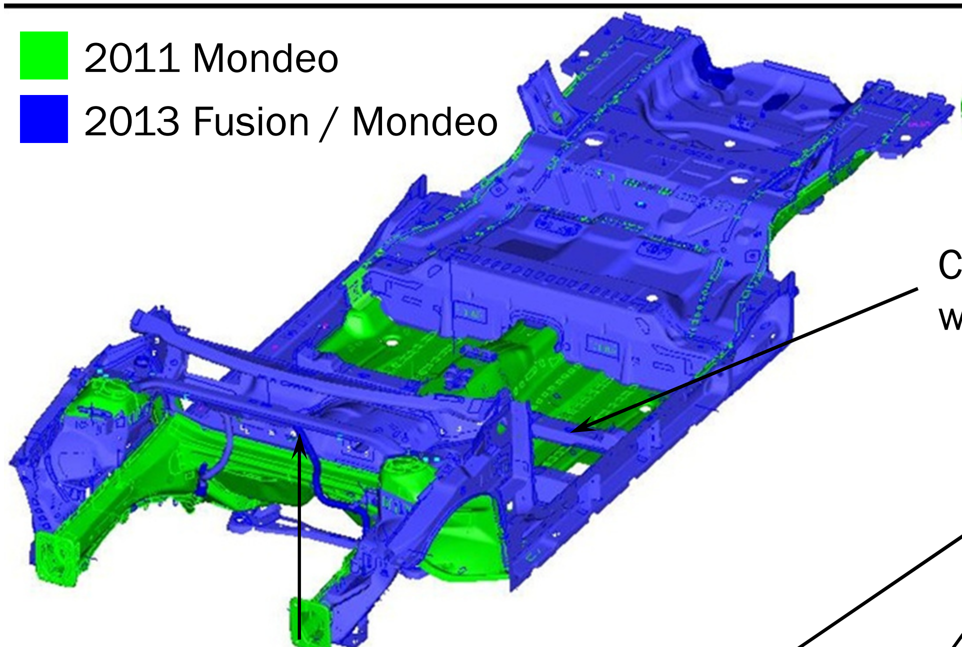
★ **Manufacturing:**

NA	2 Models	/ 2 Manufacturing Sites
EU	3 Models	/ 2 Manufacturing Sites
APA	1 Model	/ 1 Manufacturing Site

Platform Development

2011 Mondeo

2013 Fusion / Mondeo



Based on current EU CD Platform currently used for the Mondeo, S-Max, and Galaxy

Cross members redesigned for new seating and wiring requirements

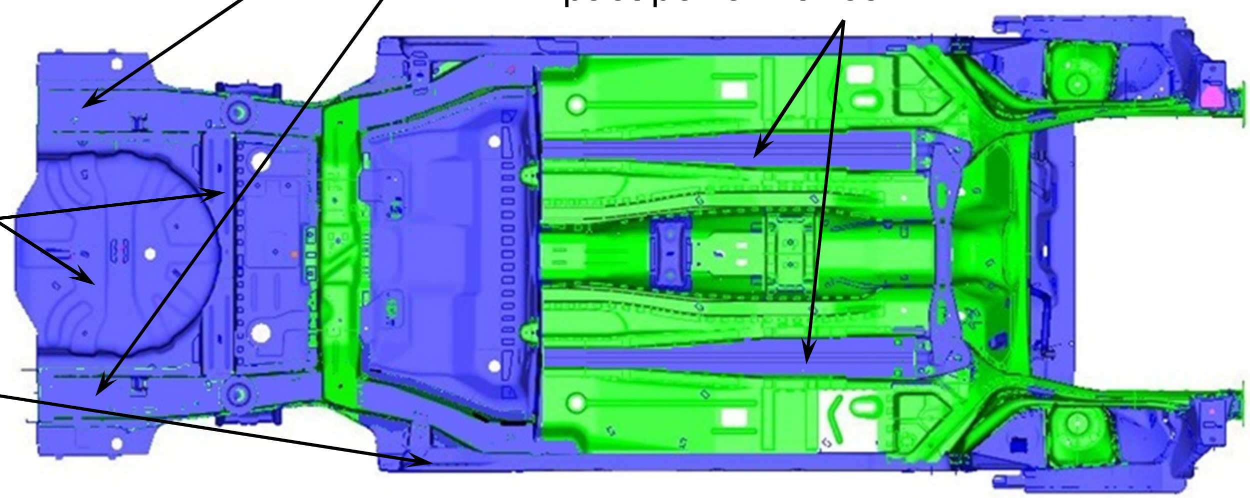
Rear Rails modified for implementation of integral link rear suspension and mass reduction

Sled Runners up-gauged for Front Impact performance

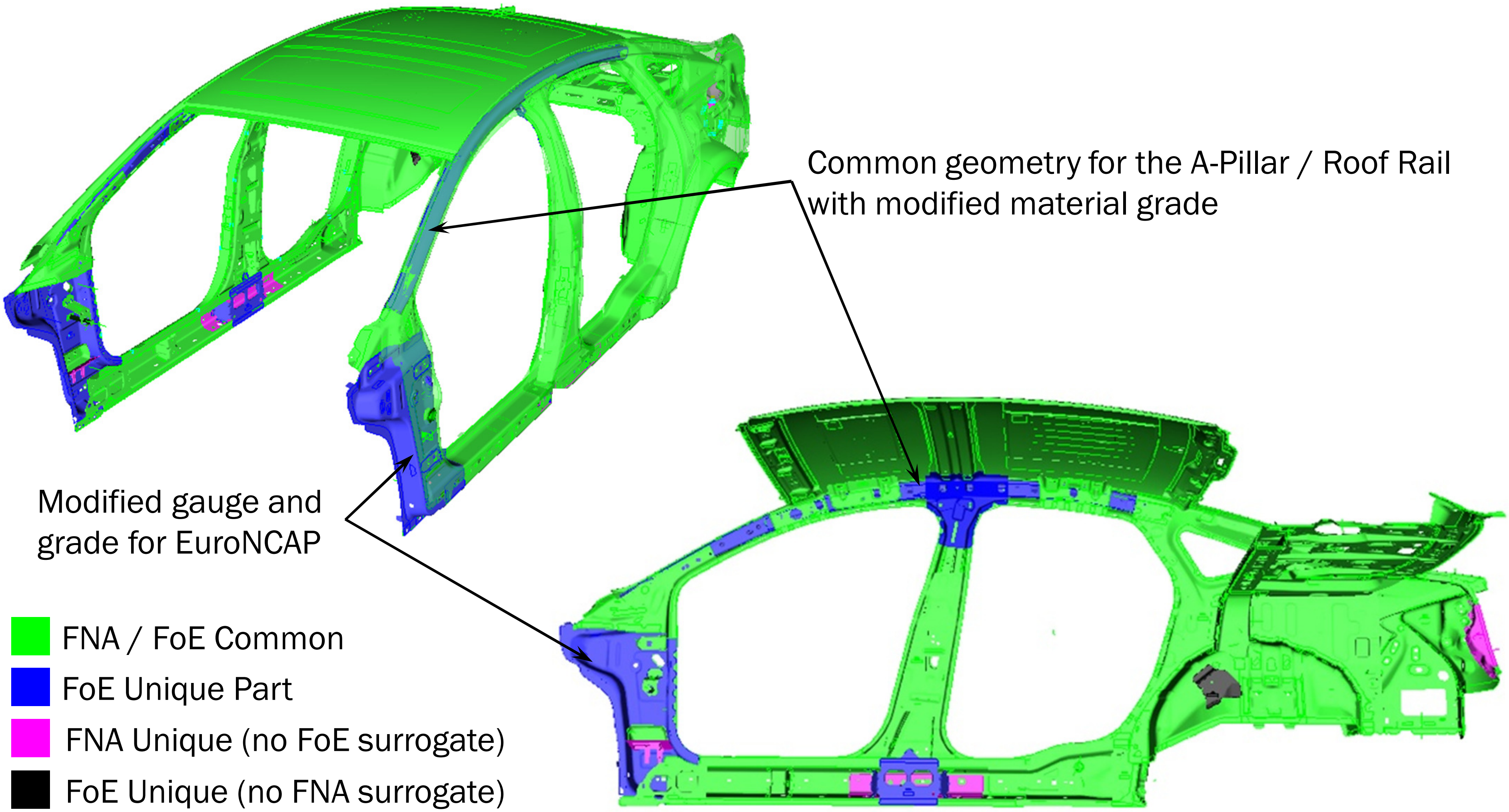
Cowl Structure modified for Ped Pro

Rear Pan and Cross Member modified for improved NVH

Floor Side Inner joints modified for improved side impact performance

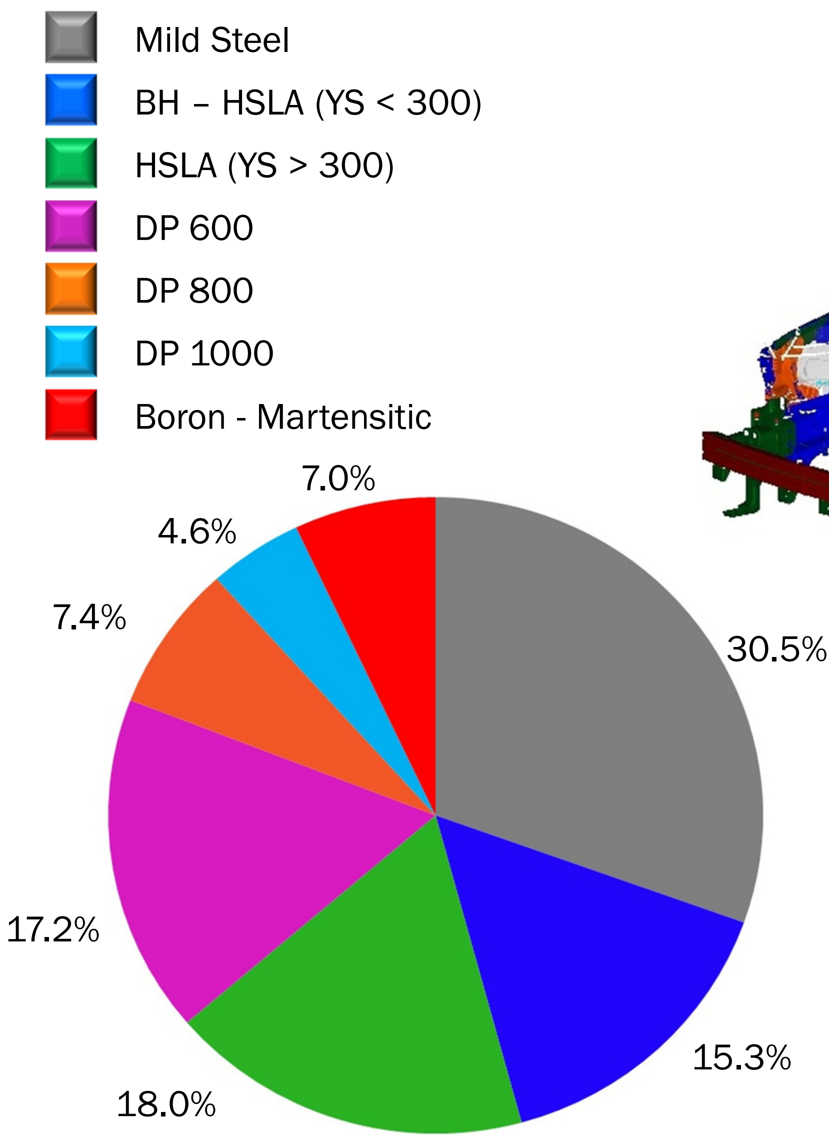


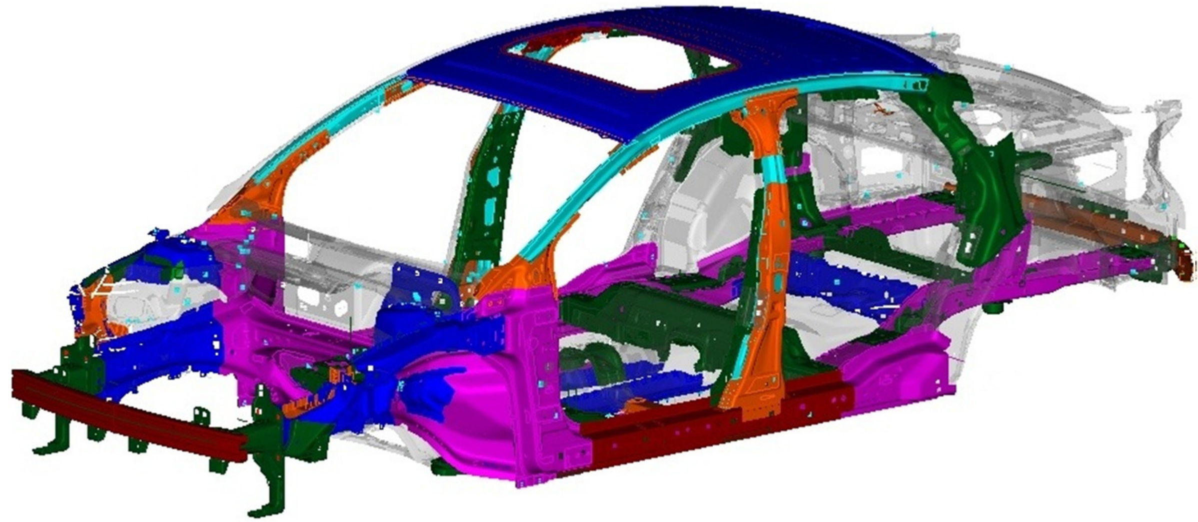
Upper Body – Global Commonality



Material Usage

Material - BIW

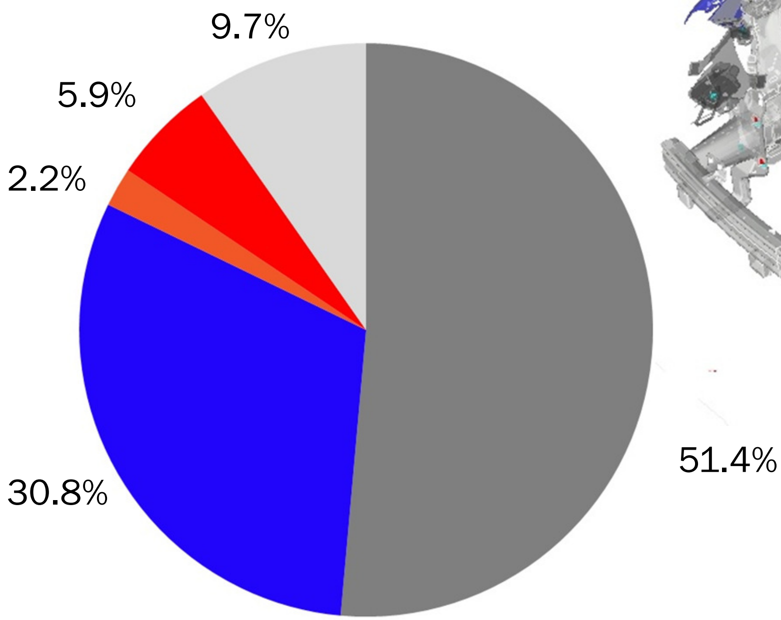


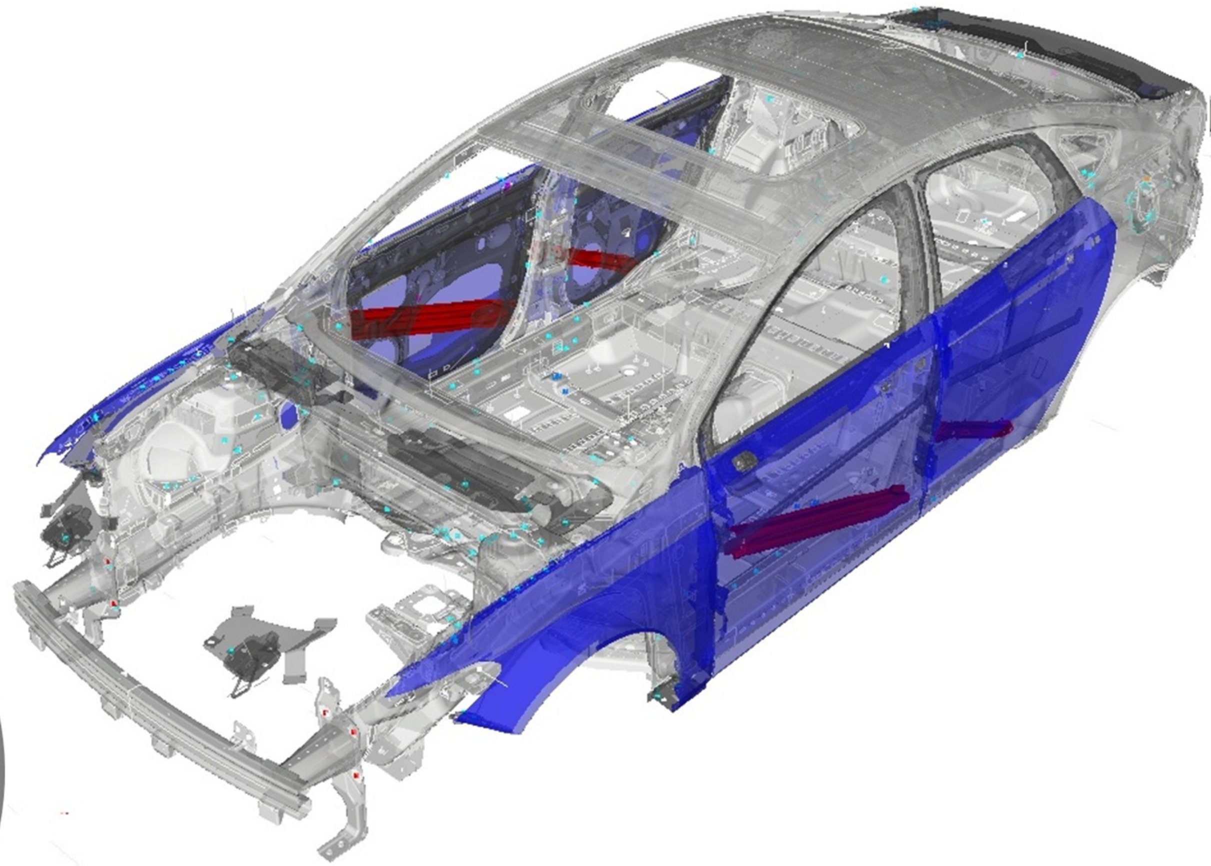


Average Yield Strength = 348 MPa

Material - Closures

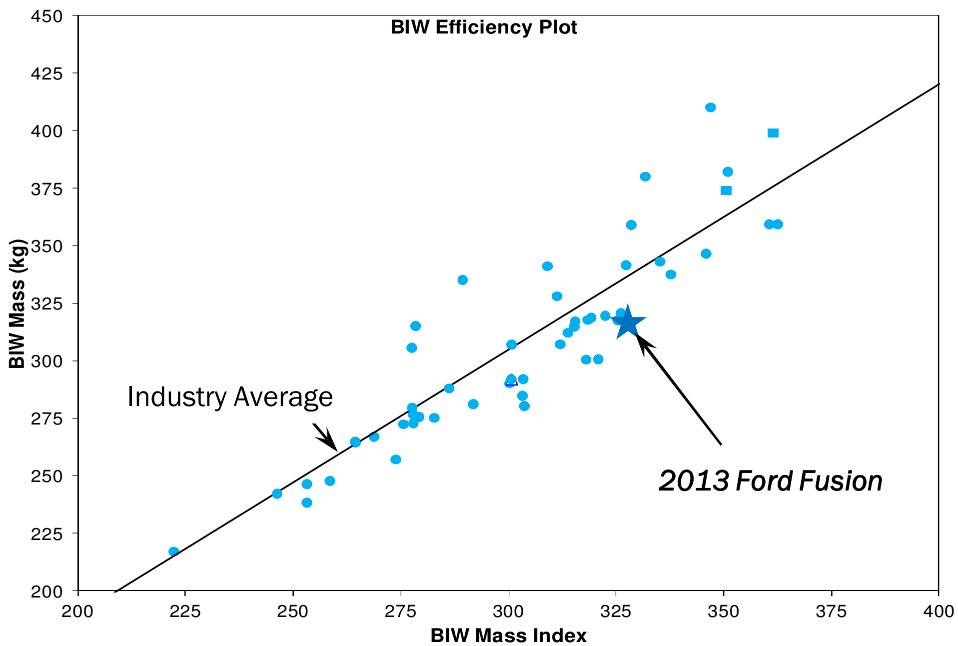
- Mild Steel
- BH – HSLA (YS < 300)
- DP 800
- Boron - Martensitic
- Other

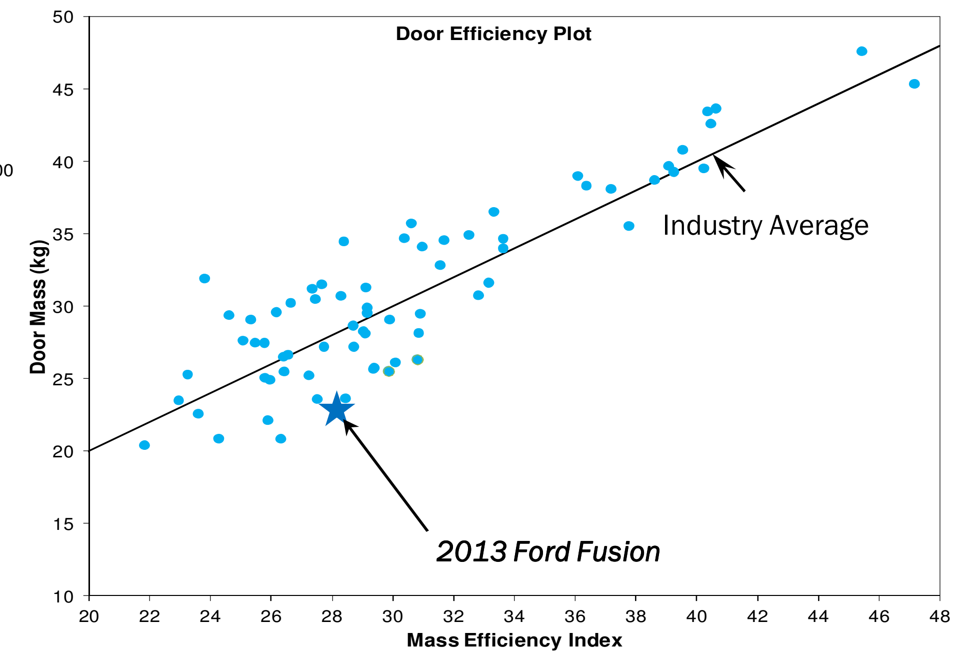




Design Approach

Design Efficiency

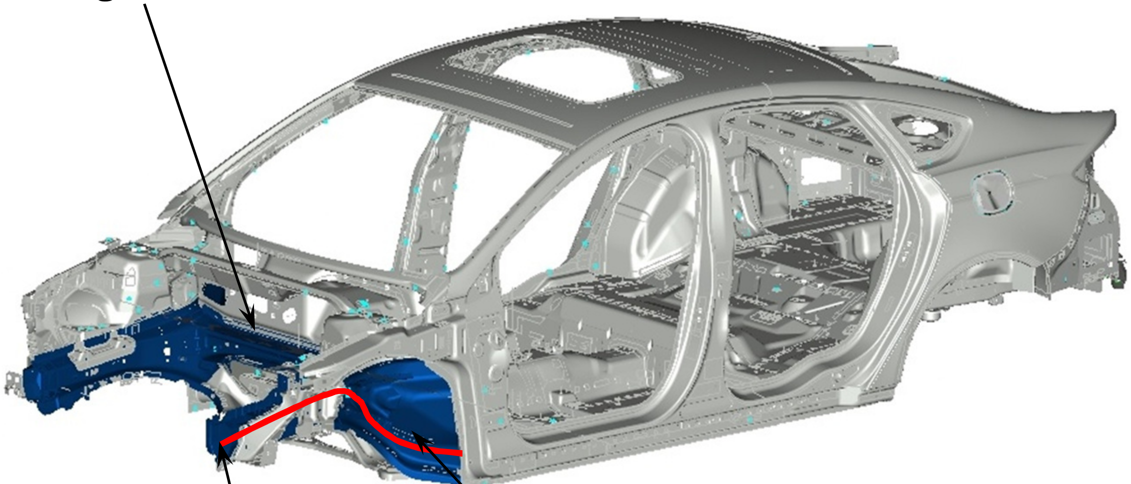


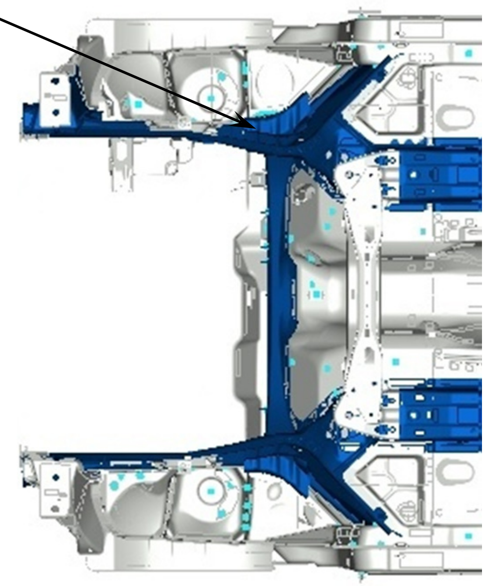


Front Structure Design

Dash Cross Member acts as a compression member during loading to stabilize the Front Rail

Y-Brace replaces the typical Torque Box to distribute load to the rocker and the sled runners





S-Brace Rail section angles toward the rocker as it transitions under the dash for improved load path

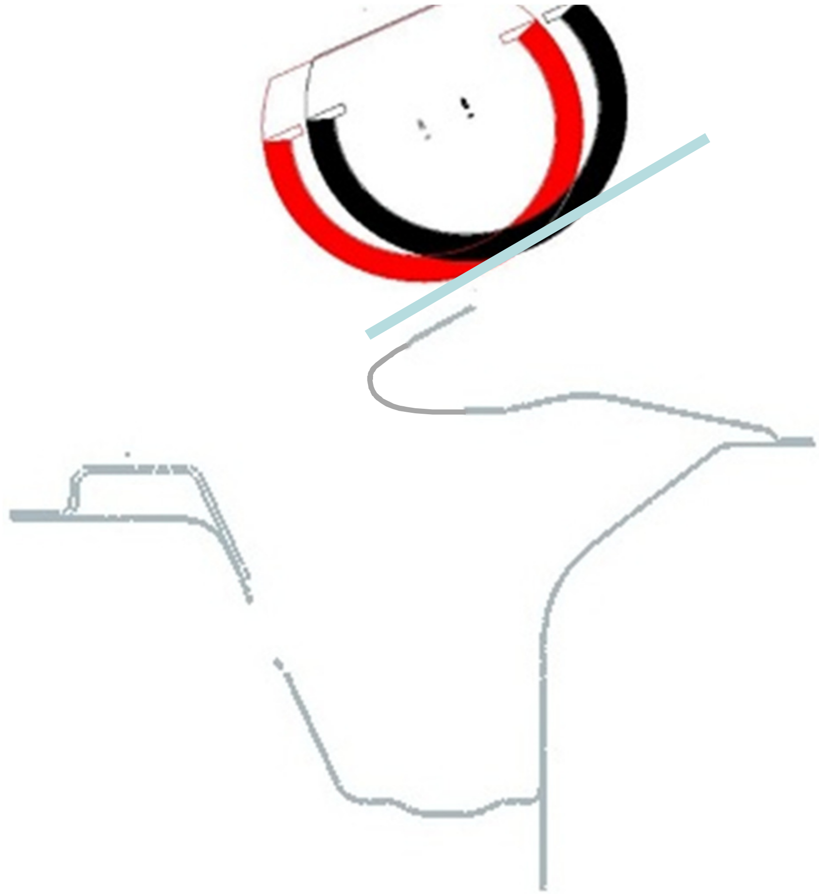
Hexagonal Front Rail section for improved axial crush performance allowing for the use of lower strength material with no loss of performance

Energy Absorbing Cowl Design

Vehicle needed to be designed to meet both EuroNCAP - Gen II and proposed Global (GTR) requirements for Head Impact

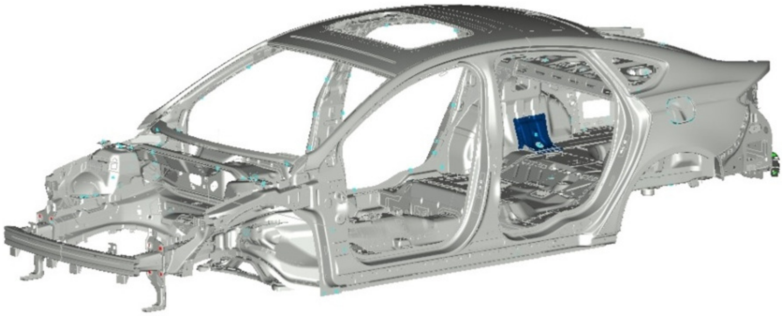
Proposed styling prevented the use of conventional Cowl designs for meeting HIC requirements during windshield impacts

Patent Pending design allowed for the achievement of the targeted HIC values

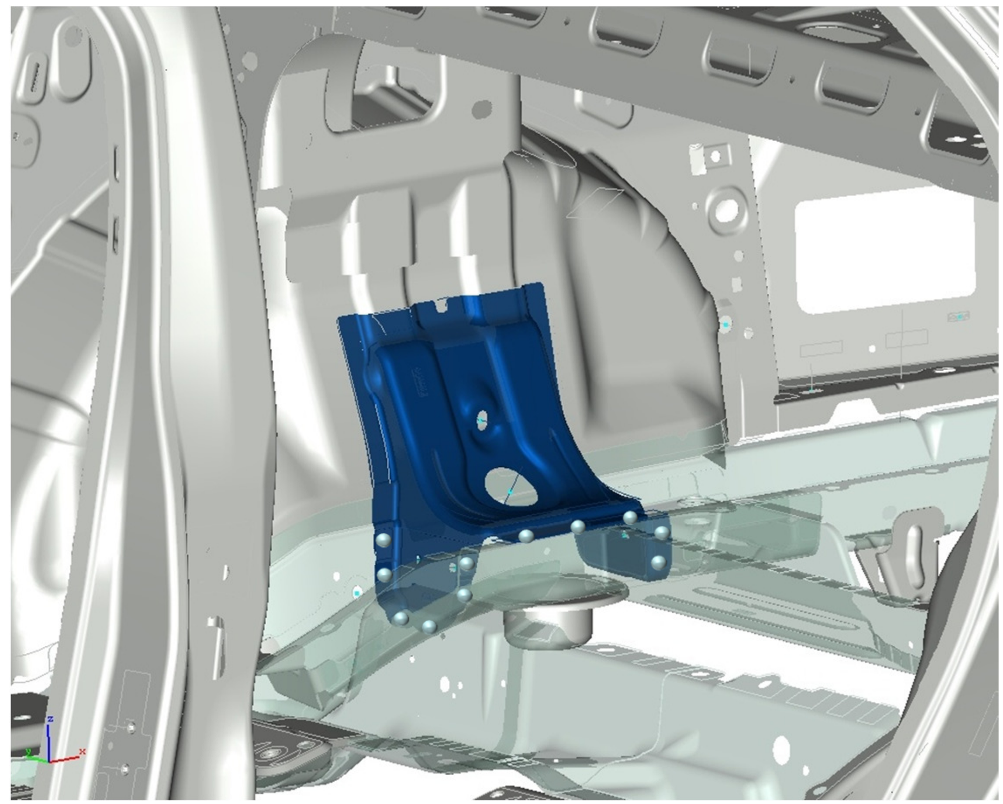


Flange design allows for the structure to flex under impact loading and increase energy absorption

Rear Under Body – Lion's Foot



Typical "lions foot" set on pan and joined to rail section only at the weld flanges



Integrated into the rail section for optimal load transfer to improve joint stiffness – elimination of flange flex

Improved joint resulted in the following improvements in BIW torsional stiffness:
4-Door: 13%
Other: 25%

Local and equivalent stiffness for Subframe and Shock attachments were increased 10%

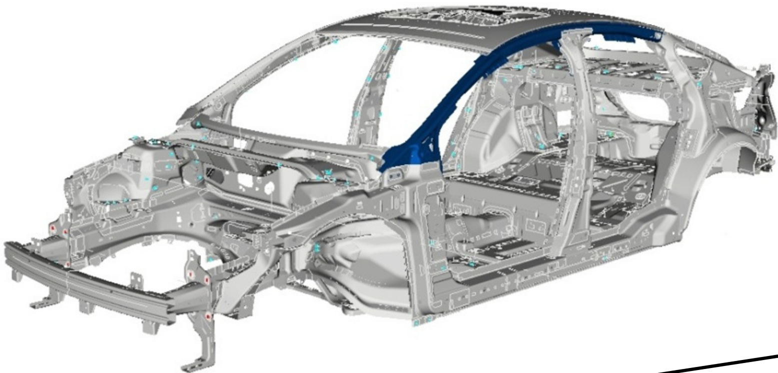
Benefits of Hydro-Forming

1. Increased structural performance (strength to weight ratio, improved torsion and bending stiffness) due to:
   - Continuous closed section optimizes sectional properties
   - Optimal section in a given package envelope due to lack of weld flanges
   - Elimination of joints provides better structural continuity
2. Improved material utilization (<5% Engineered Scrap)
3. Part consolidation
4. Improved tolerance & process control
5. Material gauge changes without modifying forming die

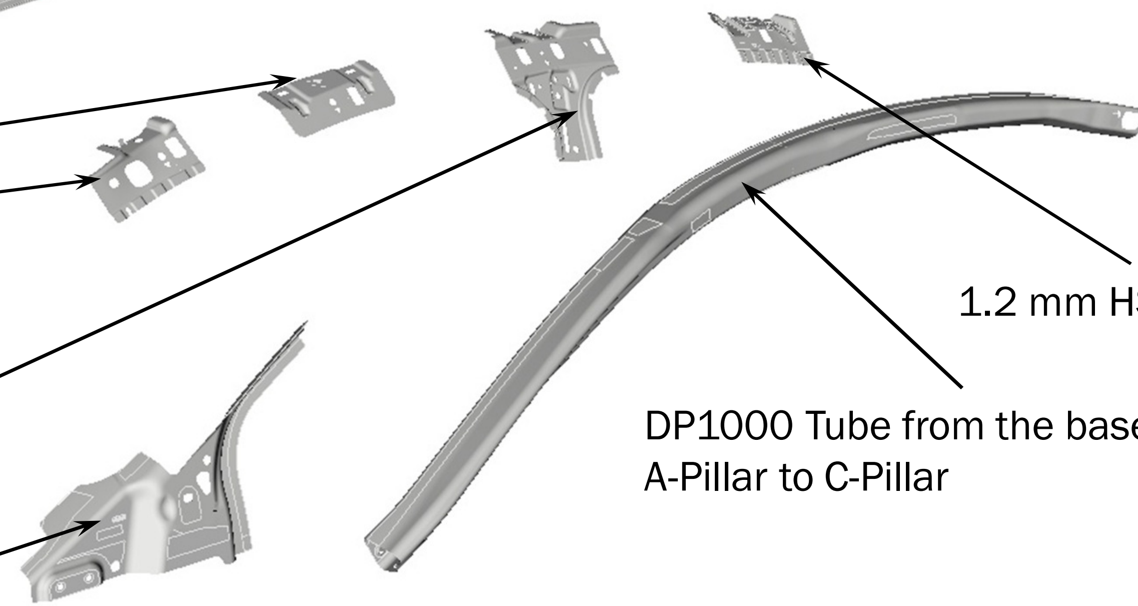
All of these advantages lead to:

- *Reduced cost*
- *Reduced weight*
- *Lower tooling investment*

A-Pillar / Roof Rail Design



Added brackets allow for the continuation of standard Bill of Process – Resistance Spot Welding

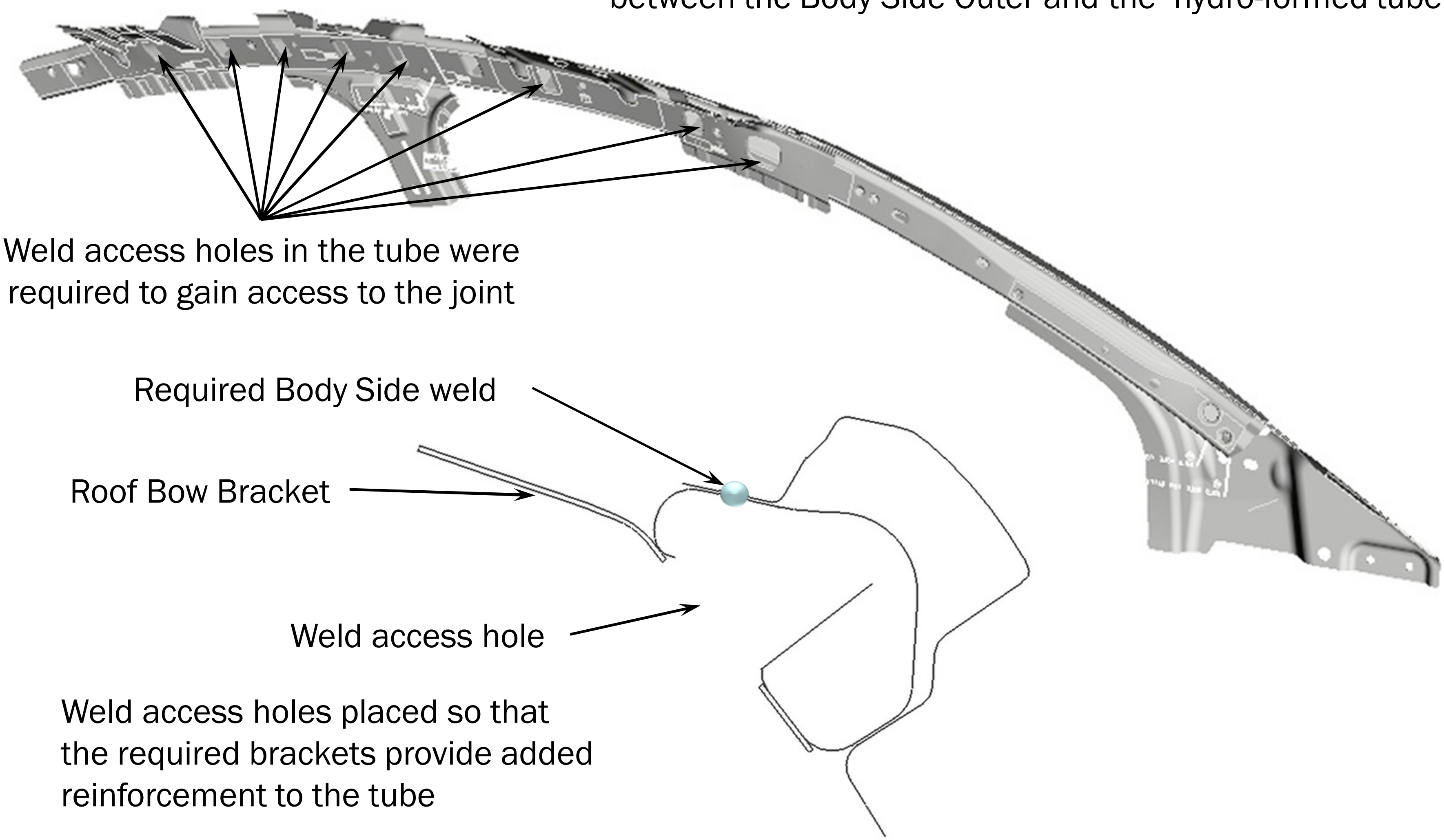


Extension of the design concept used for the F-150 into a unibody structure

Advantages associated with the performance of continuous closed sections resulted in a 2.1 kg /side save and significant cost reduction compared to a Press Hardened, stamped design

A-Pillar / Roof Rail Design Continued

Bill of Process drove the use of RSW for the connection between the Body Side Outer and the hydro-formed tube



Weld access holes in the tube were required to gain access to the joint

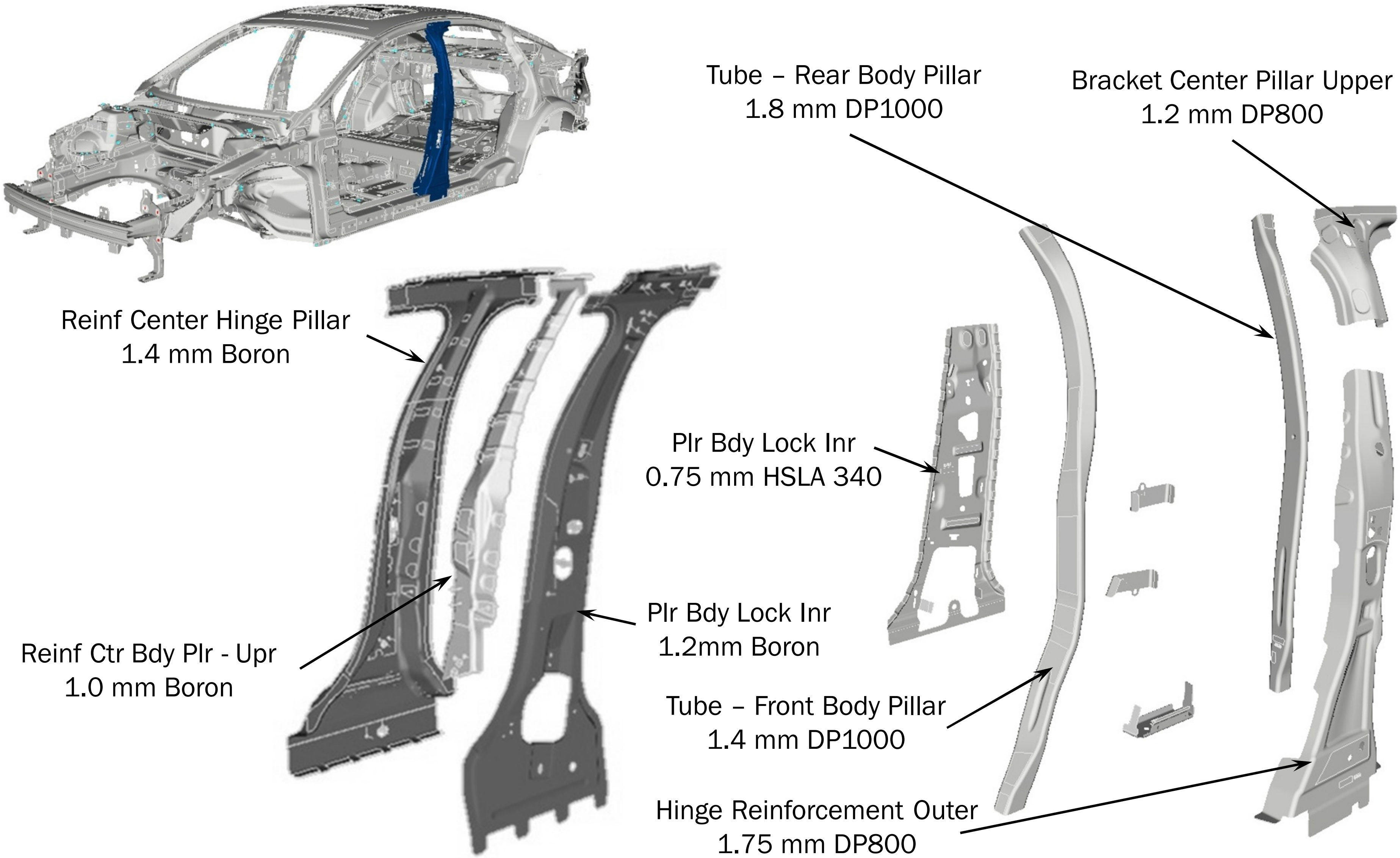
Required Body Side weld

Roof Bow Bracket

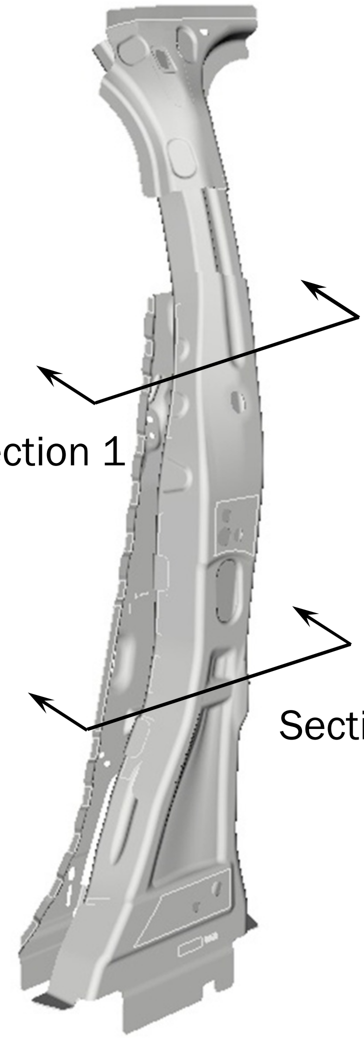
Weld access hole

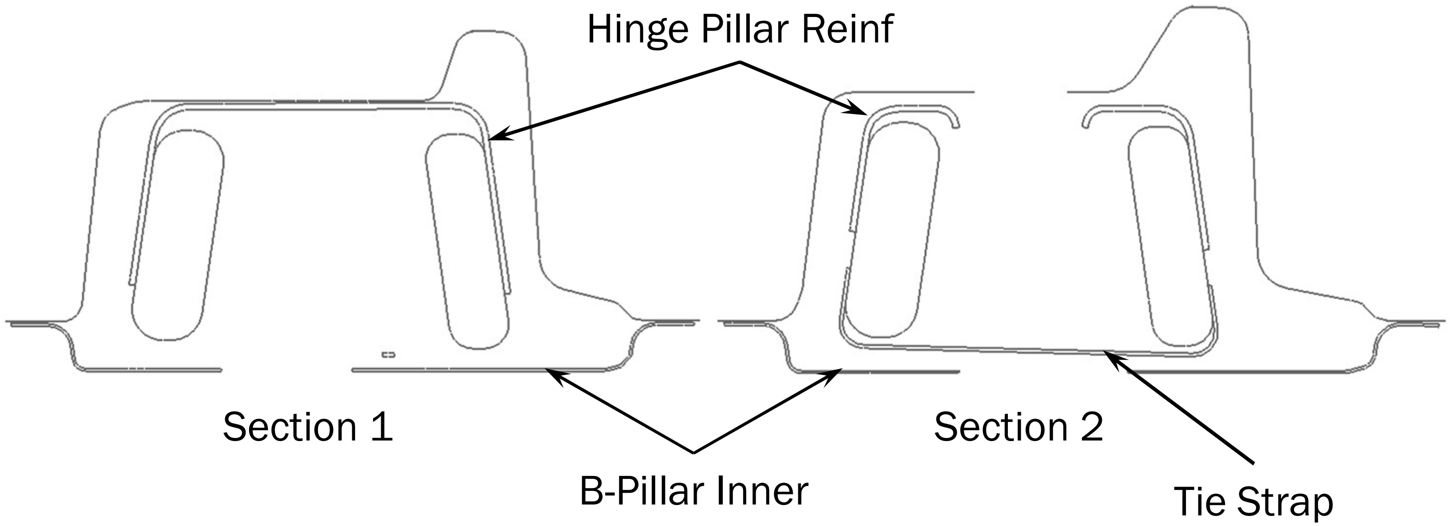
Weld access holes placed so that the required brackets provide added reinforcement to the tube

B-Pillar Design



B-Pillar Design Continued

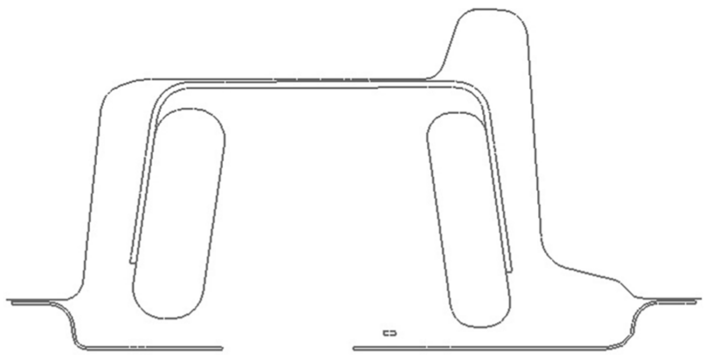




Tubular design provides significant benefit, but required additional components to perform complete function of a B-Pillar

- B-Pillar Inner required for Retractor and Trim attachment
- Hinge Pillar Reinforcement required for hinge attachment
- Tie Straps added to control deformation during loading
- All added components optimized to improve performance during Roof Strength and Side Impact loading

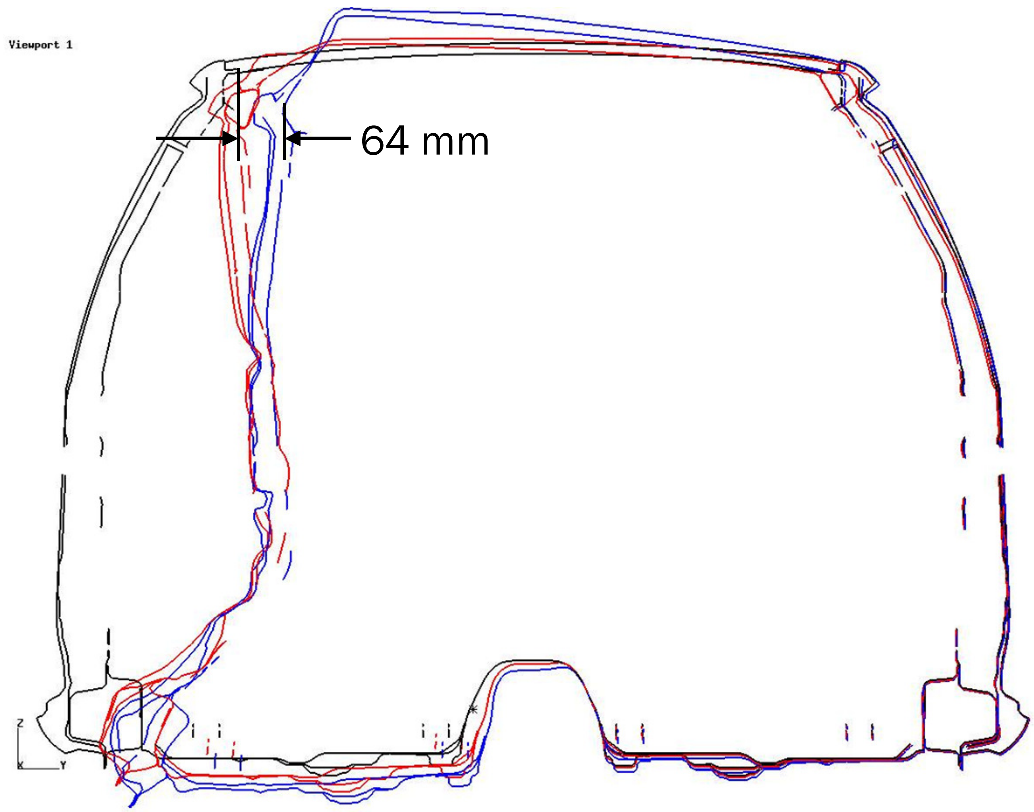
B-Pillar Performance Comparison



- Continuous closed section of the tubes provides increase in section performance
- Additional "walls" of the hydro-formed tubes improve bending performance of the pillar at lower mass
- Reduced dimension in fore/aft direction delays the onset of buckling on the compressive face during axial loading

Attribute	Concept Stamped Boron	Current CD4	Guideline When to Use
Critical Bending Moment	4732	5042 (~Same of Boron)	Bending Failure (Roof Strength, Side Impact)
Moment of Inertia	1,364,402	311,352 (~23% of Boron)	Stiffness
Critical Axial Load	27.66	362 (~13x Boron)	Column Loading (Roof Strength)

B-Pillar Performance Benefits



Black – Un-deformed

Blue – CD4 Baseline

Red – Hydro-formed Tube

IIHS Side Impact Performance :

- Max intrusion is similar at the beltline
- Intrusion with the tube is 64 mm lower than the baseline vehicle at the roof rail.

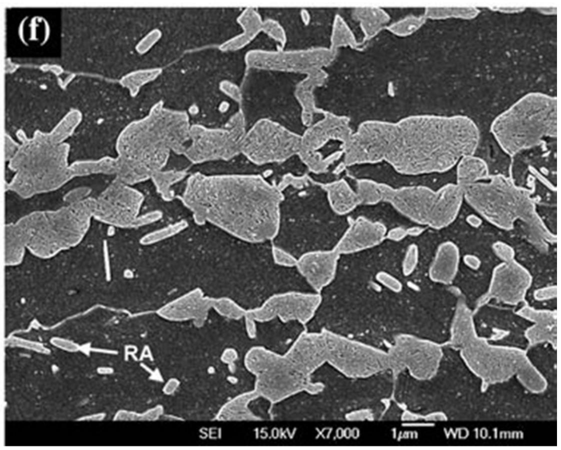
Mass Savings:

- 6 kg over a conventional Press Hardened design
- 4 kg over a Press Hardened design with TRB

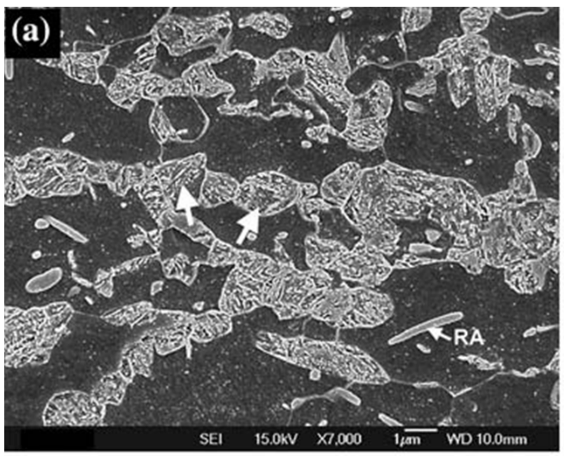
Cost Savings: Significant

GMAW vs Laser Welding

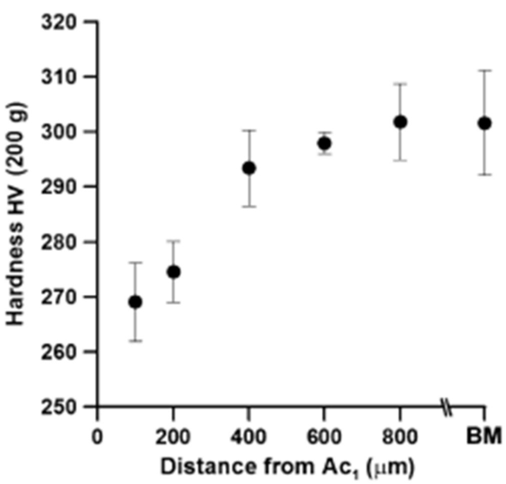
- Mechanical properties of Dual Phase materials is impacted significantly by the rapid heating and cooling associated with welding processes
- Within the Heat Affected Zone (HAZ) the presence of decomposed martensite has been credited with a softening of the material
- Hardness reductions of 10% - 40% have been documented within the HAZ indicating a reduction in yield and tensile strengths
- Gas Metal Arc Welding inputs more heat than laser welding resulting in a larger HAZ



Base DP800 Microstructure



Microstructure within HAZ

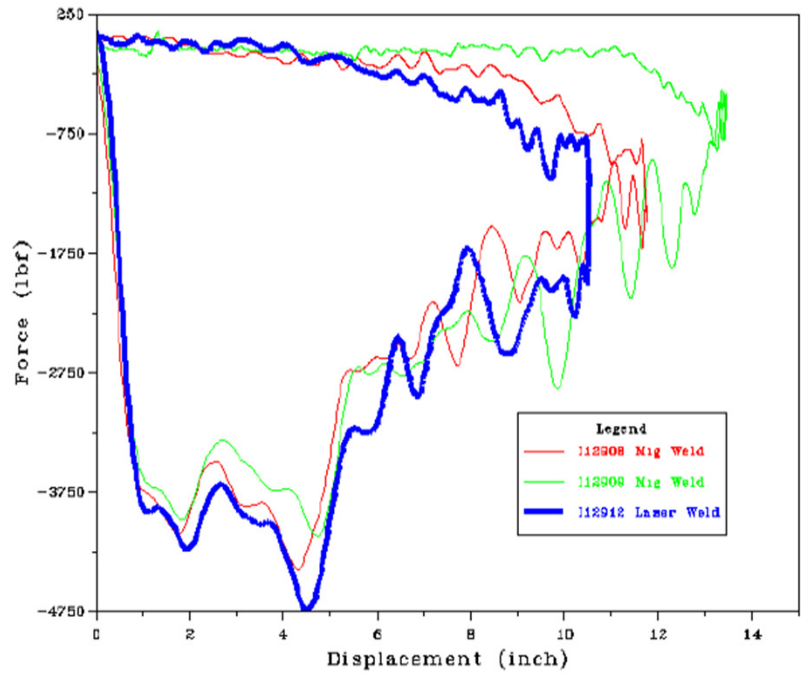


Photos and graph taken from *A Study on Heat Affected Zone Softening in Resistance Spot Welded Dual Phase Steel by Nanoindentation*, Journal of Material Science, Vol 45

Performance Benefits of Laser Welding

GMAW Assembly

Weld separation

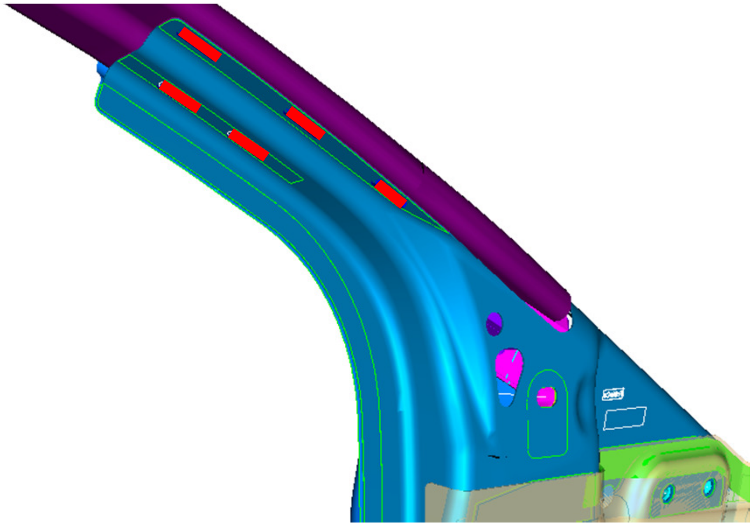


Laser welded samples have increase buckling and peak loads and reduced displacements

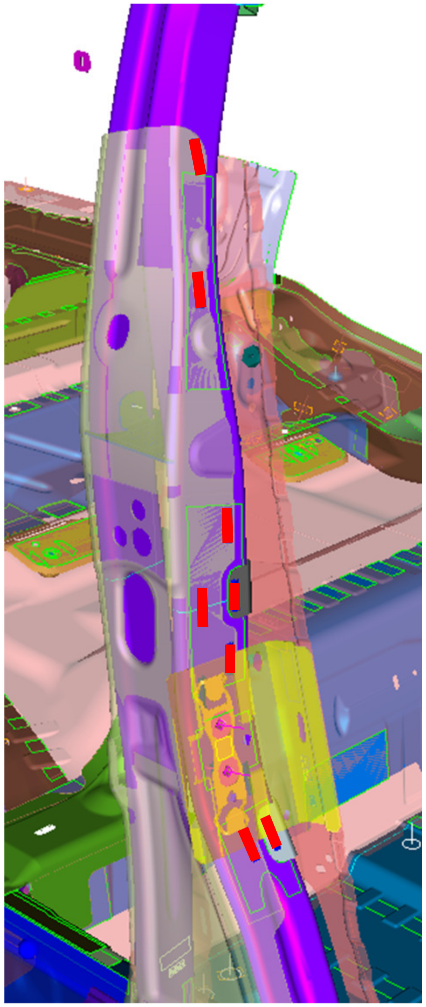
Laser Welded Assembly

Reduced and more controlled deformation at impact point

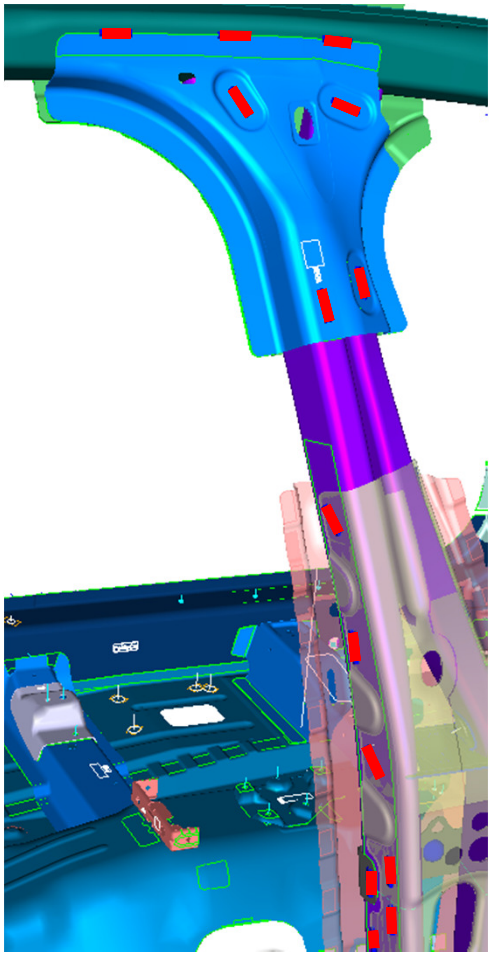
Body Side Laser Welding



A-Pillar

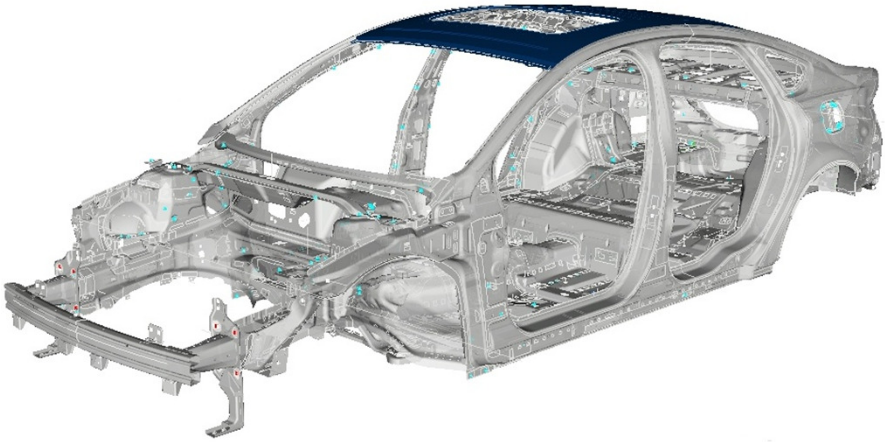


B-Pillar



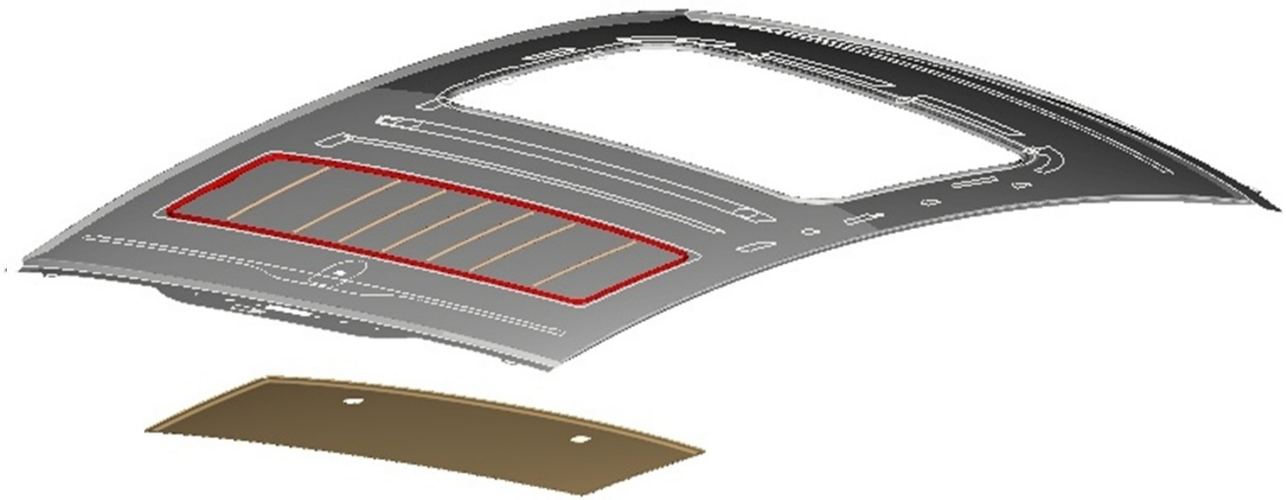
Ring Assembly

Roof Design – Low Gauge



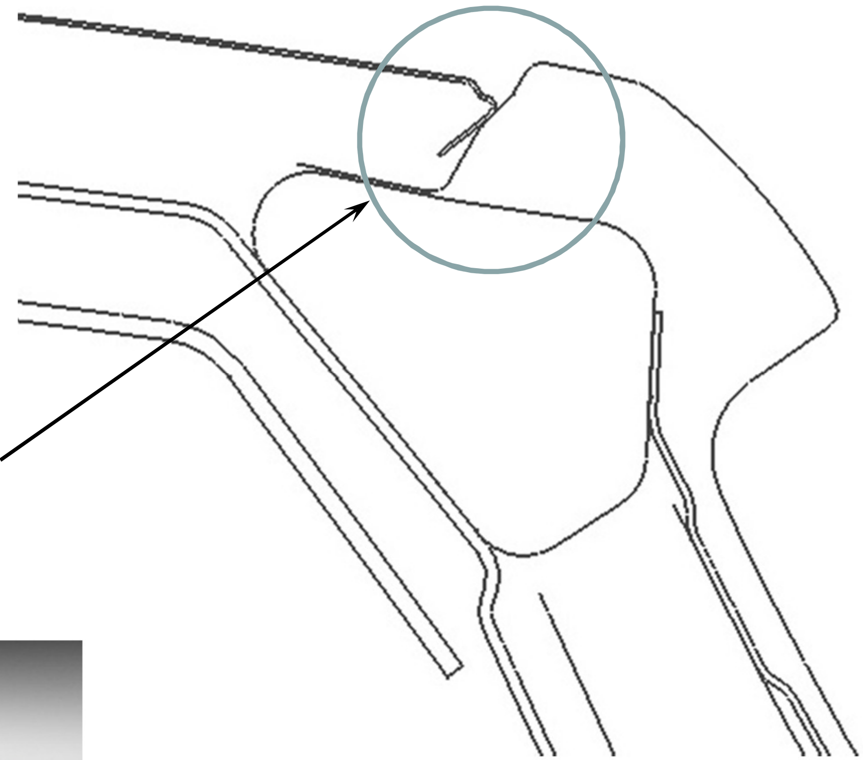
- Gauge reduced to 0.65 mm from standard 0.75mm
- Strength dominated performance recouped by use of BH210 material over mild steel
- Stiffness increased through use of DVD pads
- DVD pads are bonded to the roof panel in trim with urethane

- 0.51 kg mass savings associated with the gauge reduction and elimination of NVH bows
- Additional mass reduction is achievable with further gauge reduction

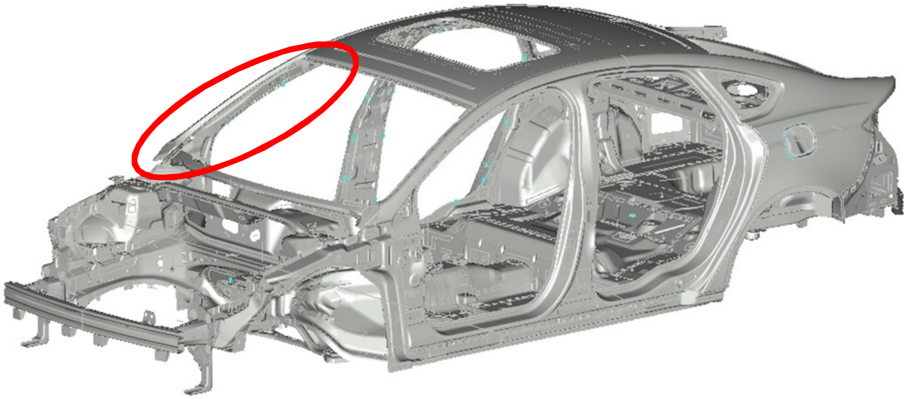


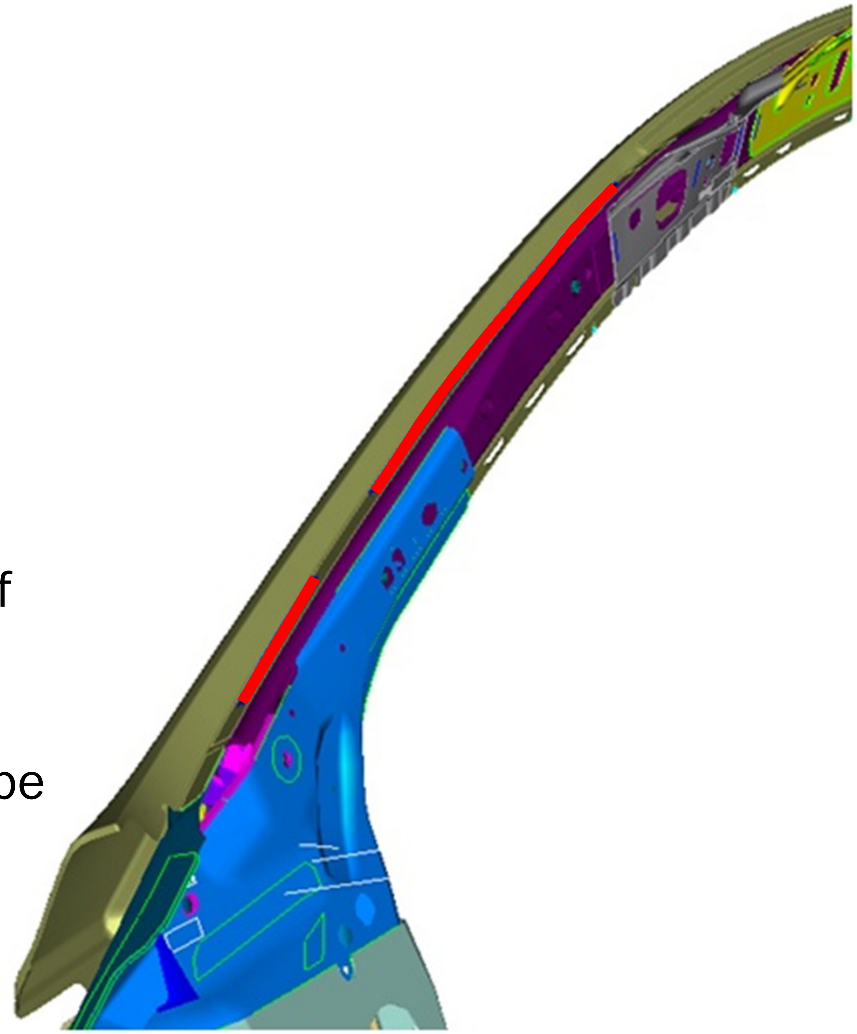
Roof Design – Laser Braze

- Utilization of the braze joint at the body side interface resulted in:
  - Improved craftsmanship
  - Reduced cost
  - Reduced mass
- Roof was designed with a “back flange” at the body side interface to allow for dimensional variability without a quality effect on the braze operation



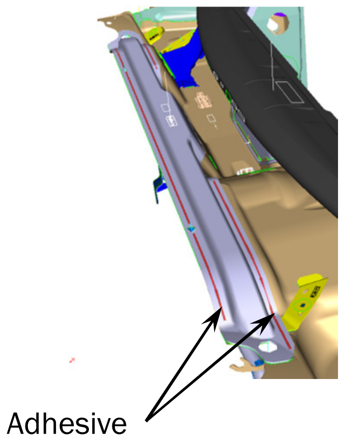
In Plant Laser Welding



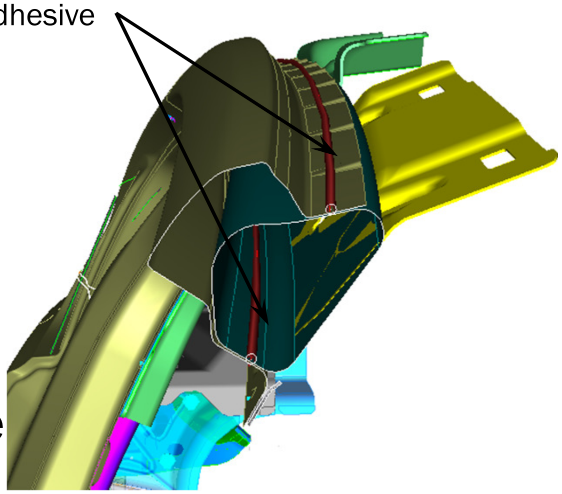


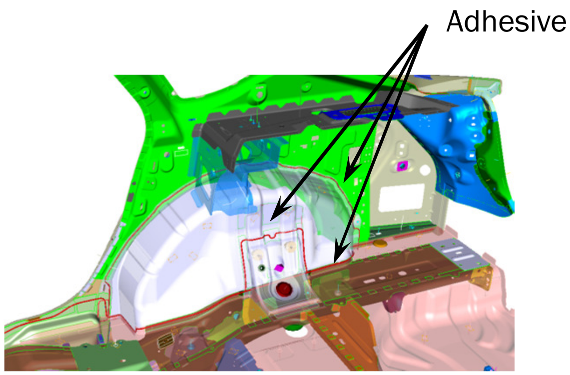
- Body Side Outer is laser welded to the hydro-form tube along the A-Pillar
- Prevented the use of access holes that would have been required for the use of Resistance Spot Welding (RSW)
- Preservation of the continuity of the A-Pillar tube allowed the pillar section to be minimized
- Enabled “*Refined and Light*” look required by the studio

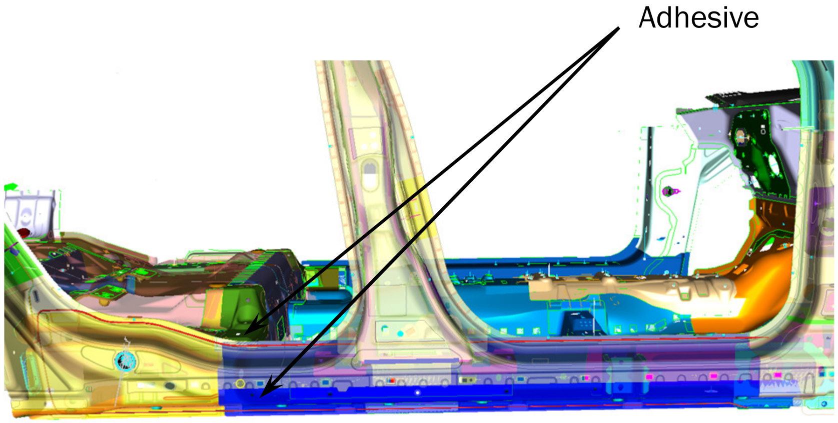
Structural Adhesive



- Total of 21 m of adhesive added
- Adhesive added primarily to improve body stiffness
- Resulted in a torsional stiffness increase of ≈ 3%
- Body Side adhesive added for joining to tubular components with reduce reliance on thermal joining

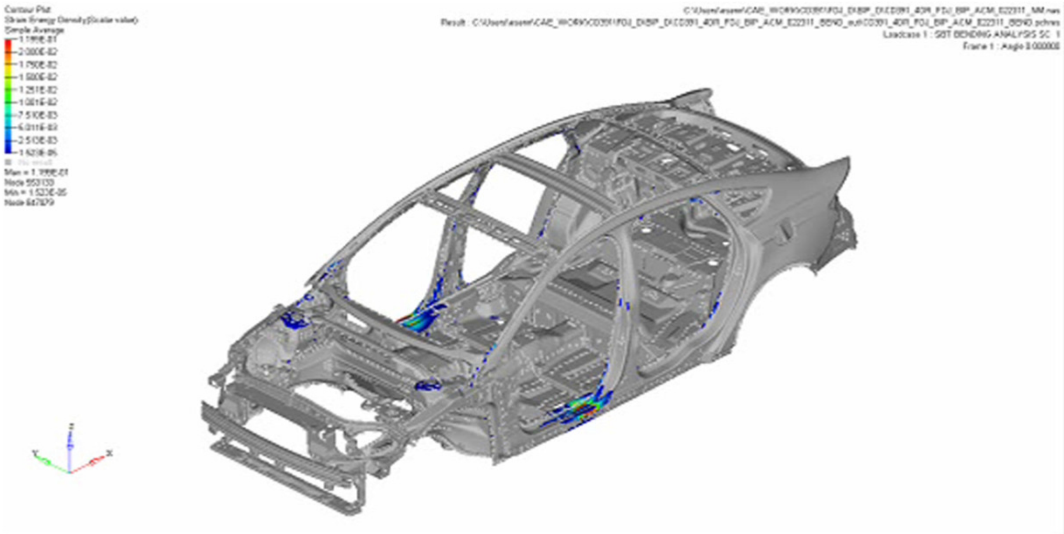


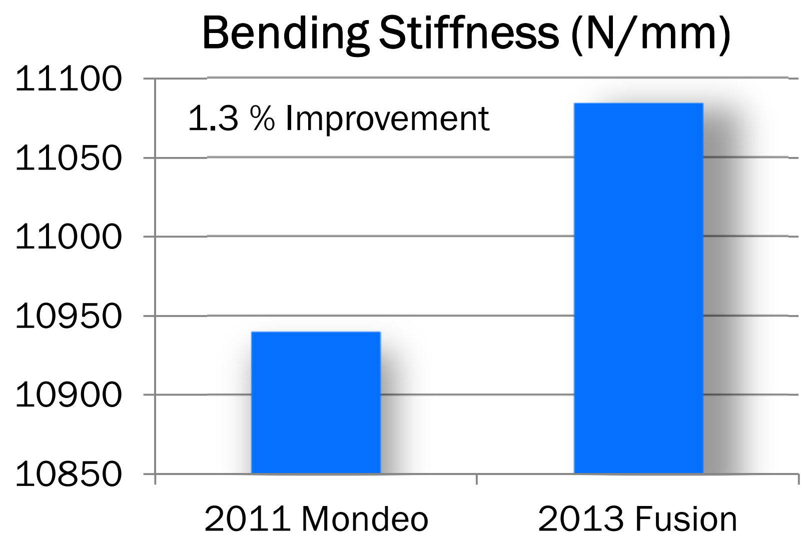


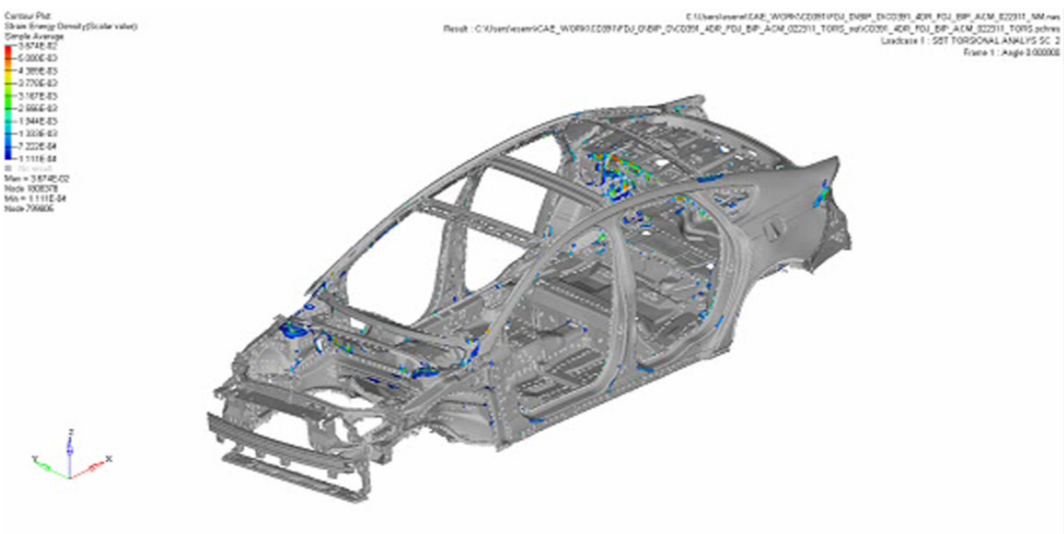


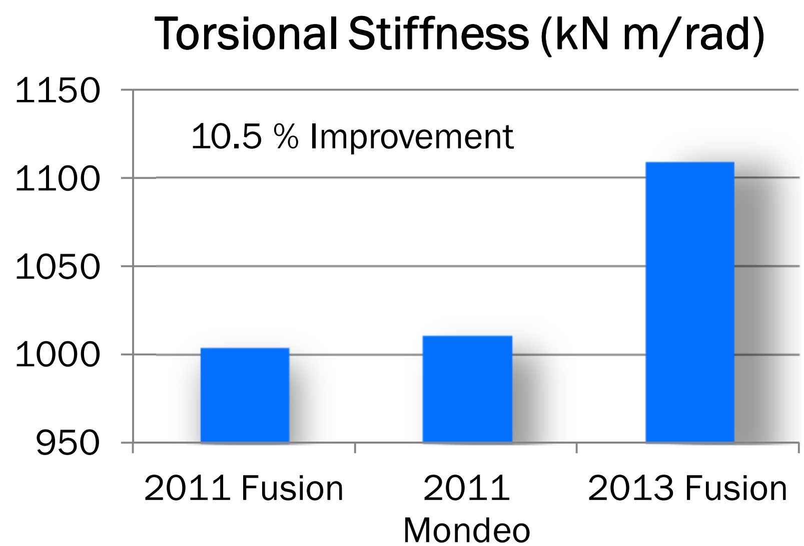
Performance

Static Stiffness









BIP Dynamic Modes