American Iron and Steel Institute

# Use of UHSS and AHSS for Cost Effective Production of Automotive Body, Chassis, Battery Pack and Closure Structures


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Global Automotive Lightweight Materials & Manufacturing Innovation


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# The Existing Material Paradigm

TRUE or False?

Higher-strength materials have lower ductility

*TRUE*

*Civilization is rife with examples of the impact of heating metals to reduce strength and improve ductility (improve malleability). The paradigm of higher-strength equating with lower ductility remains.*

# Steel Facts

- The steel industry over the past several decades has been actively engaged in implementing state-of-the-art processes and modernizing its infrastructure.

- These upgrades focused on very precise control of the thermomechanical processes to produce ***NEW*** steel grades with ***BOTH*** high strength and high ductility.

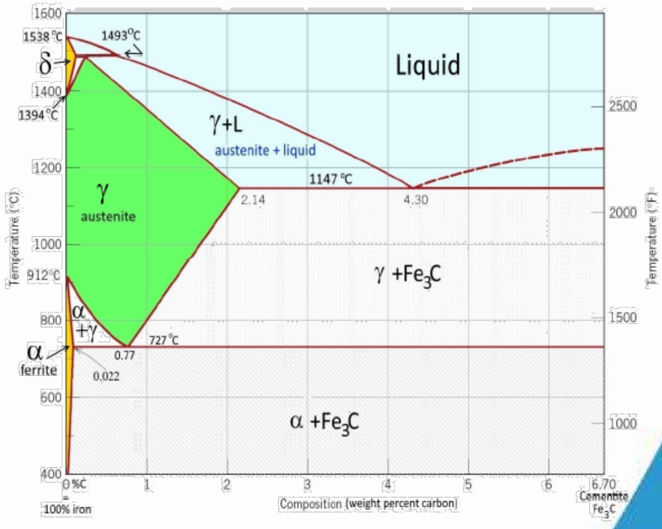
- The ***Time*** to process steel in the ***Temperature*** range of 1300ºF - 1700ºF (725ºC to 900ºC) and the ***Speed*** with which the steel is cooled creates different phases and content ratio of phases.

*In Short …*
*The Steel Industry Continues to improve its product value!*

**Time/Temperature/Speed manipulation to achieve steel grades with variety of properties**

BH – Bake Hardenable
DP – Dual Phase
MP – Multi Phase
CP – Complex Phase
TRIP –High Austenite content MP
MS – Martensite
PHS – Press Hardened Steel

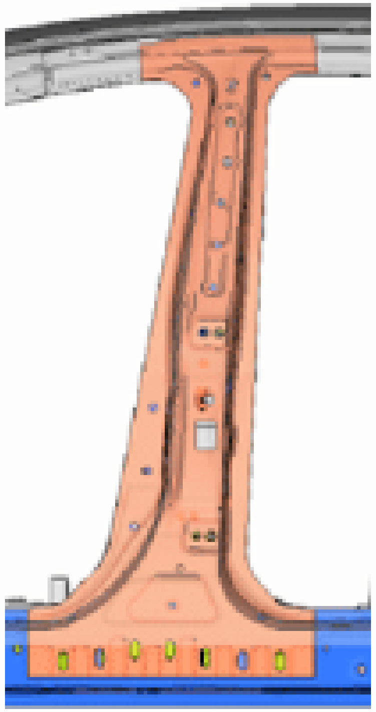
Iron-Carbon Equilibrium Phase Diagram

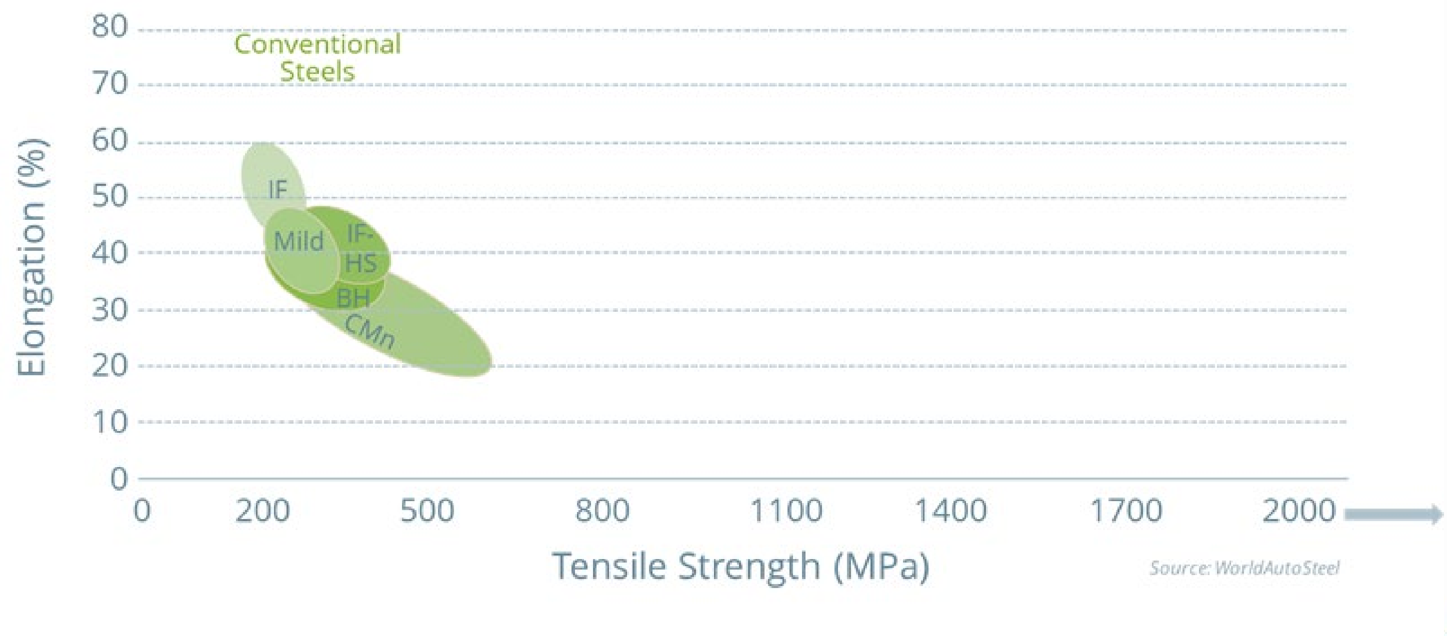



Source: Engineering Quality Solutions, Inc.

# Historical Progression of Automotive Structural Applications

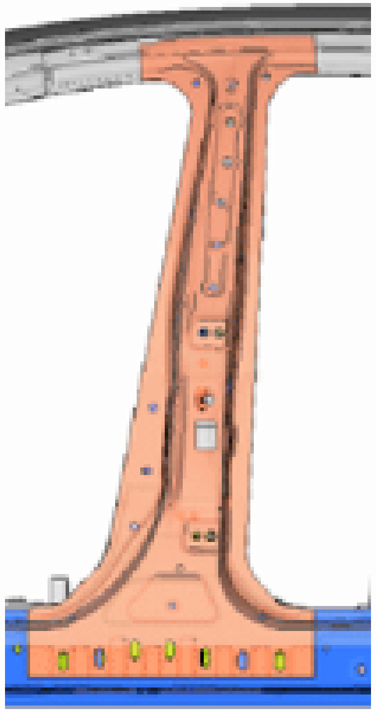
- Baseline low carbon “structural” steel grade
  - Carbon limited for weldability.
  - Conventionally rolled, not heat treated or thermo-mechanically processed
  - Typically heavy thicknesses for stiffness
  - Often required reinforcement “patches” for door locks and strikers/hinge plates.

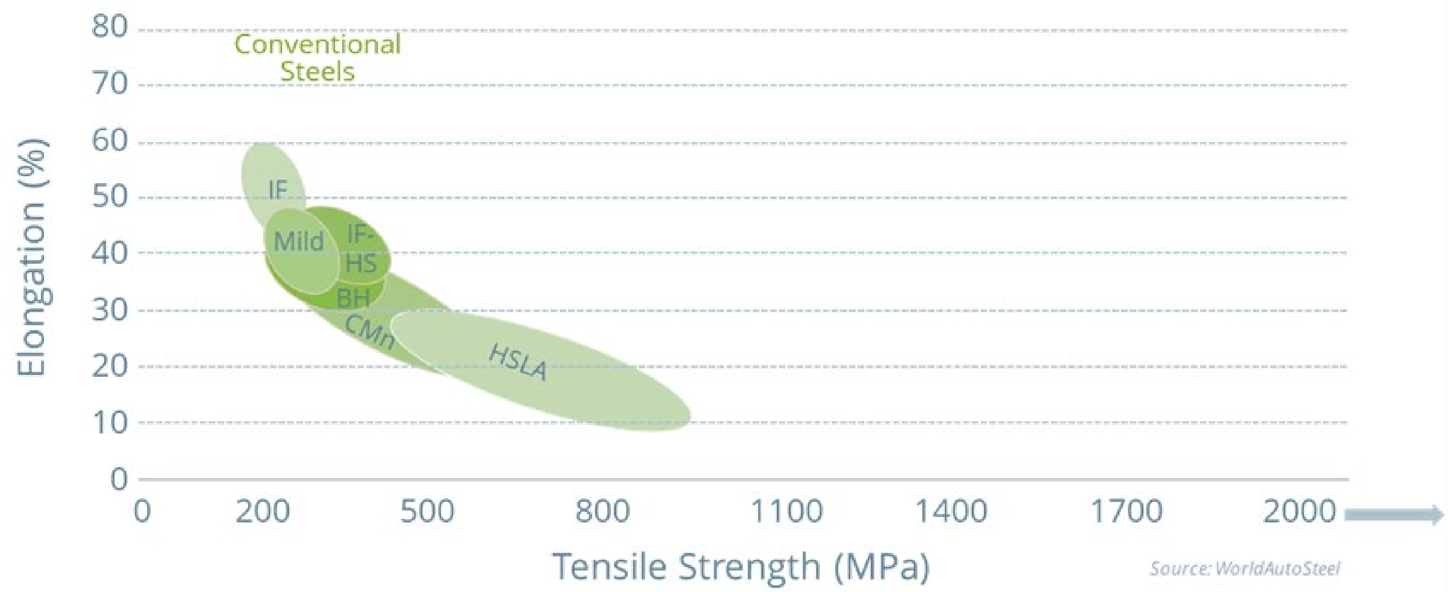




# Historical Progression of Automotive Structural Applications

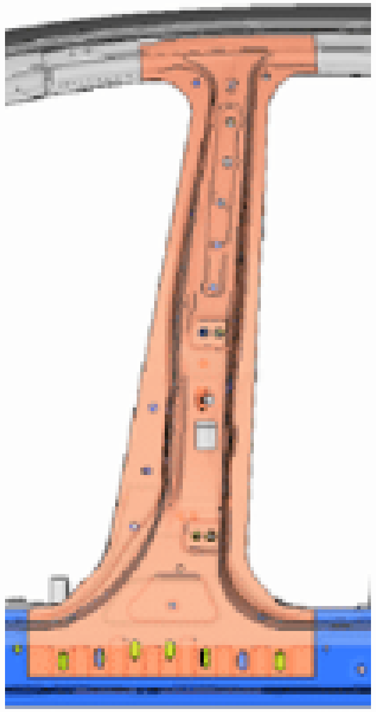
- Application of High-Strength Steel grades (HSS)
  - A low carbon alloy with some substitutional alloying elements (Manganese, Silicon)
  - Small additions of Micro-alloys (Nb, V, Ti) added to aid in precipitation hardening.
  - Strength levels increased allowing some downgauging for formability and weight reduction.
  - Called High-Strength Low Alloy (HSLA) as an indicator of differentiation from structural steel

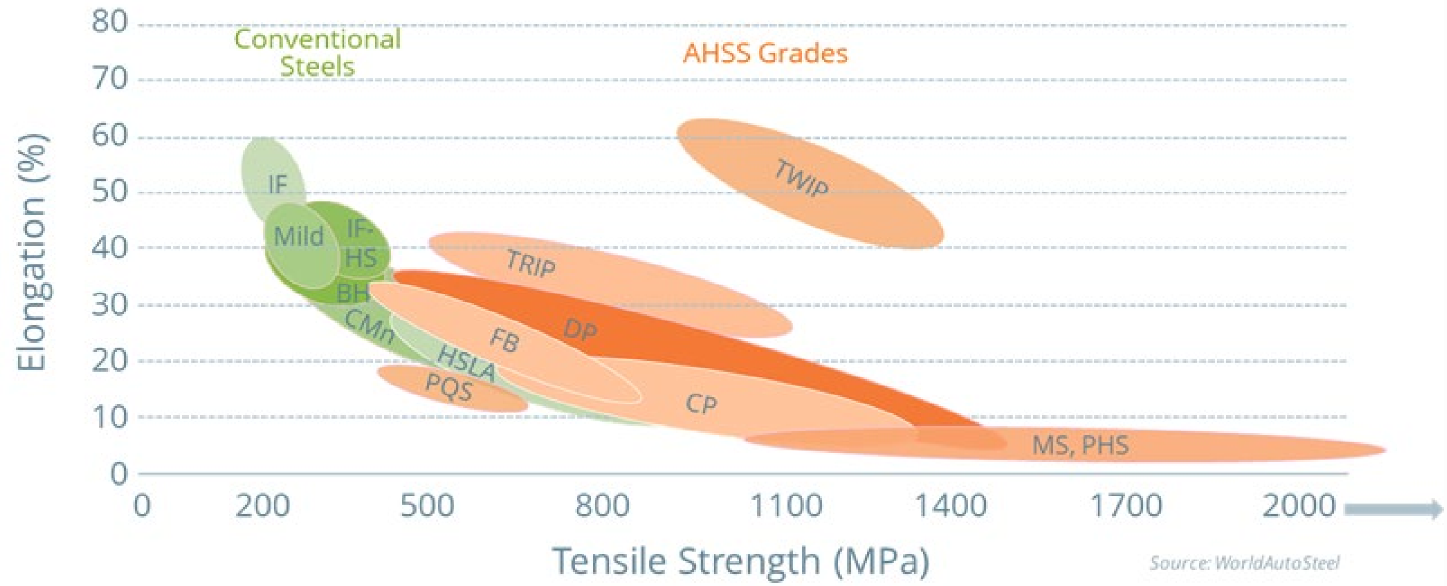




# Historical Progression of Automotive Structural Applications

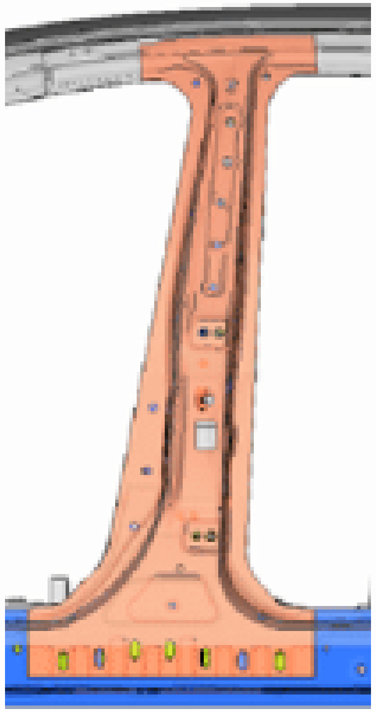
- **Application of 2nd Gen AHSS and UHSS**
  - Improved steelmaking process design and facilities allow for these grades of steel.
  - These are precisely alloyed with substitutional elements to increase strength (Manganese, Silicon) and thermo-mechanically processed with continuous annealing to create multiple phases in the microstructure adding strength (limits of strength vs ductility remain a challenge).
  - Hot Stamping (Press Hardening) became an effective path to create complex shapes with Ultra-High Strengths but require significant additional part processing.

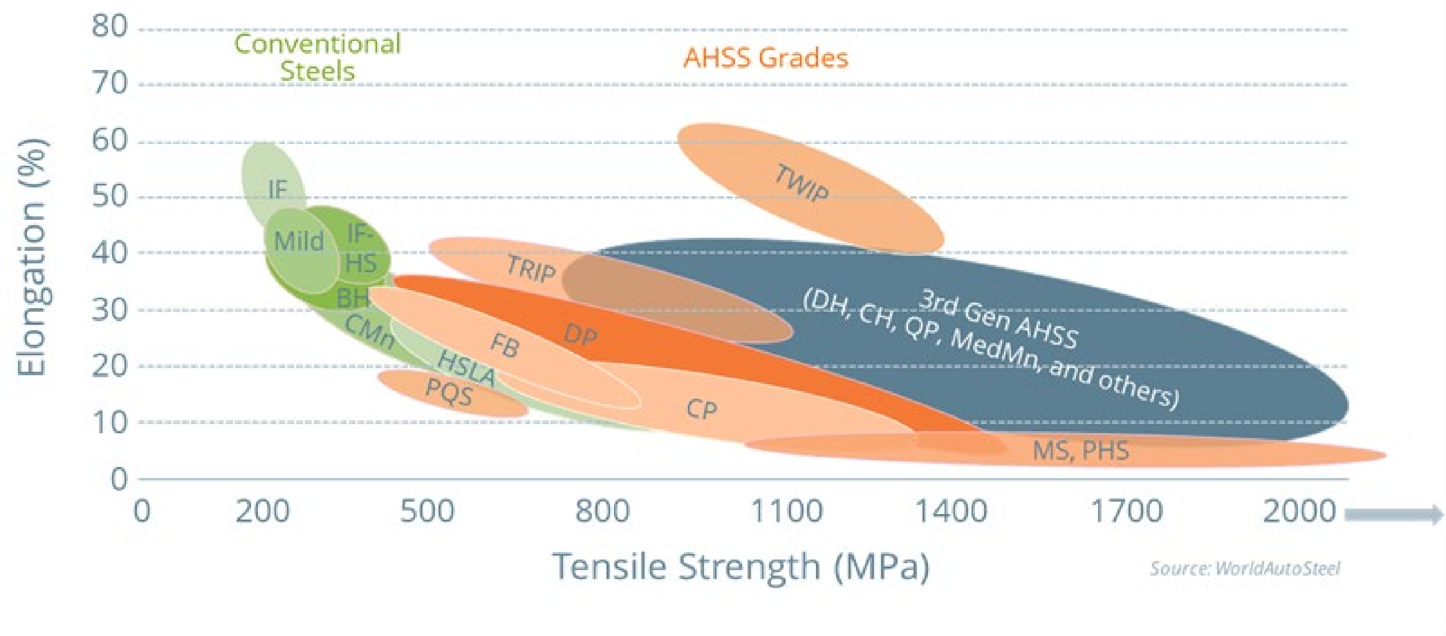




# Historical Progression of Automotive Structural Applications

- Introduction of 3rd Gen Steel
  - The most modern steel grades, referred to as Generation 3 steels, utilize processing techniques that improve the typical strength/ductility relationship, can be cold or hot formed and are downgauged due to increased material strength.
  - They possess high strength and have sufficient ductility to be formed in typical stamping operations.
  - These are the product of significant R&D on the part of the steel industry and facility upgrades to be capable of the required thermo-mechanical cycles and process control capability.





# Automotive Steel Processing line (AHSS, UHSS and 3rd Gen)

AHSS, UHSS

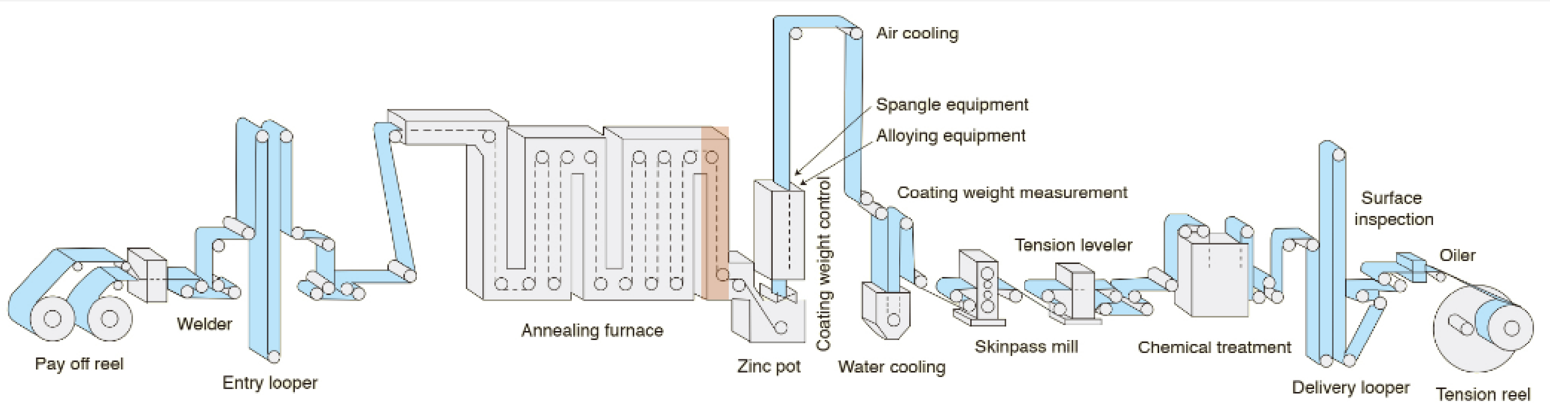



Figure 1: Schematic of a typical hot dipped galvanizing line with galvanneal capability.

AHSS, UHSS and 3rd Gen

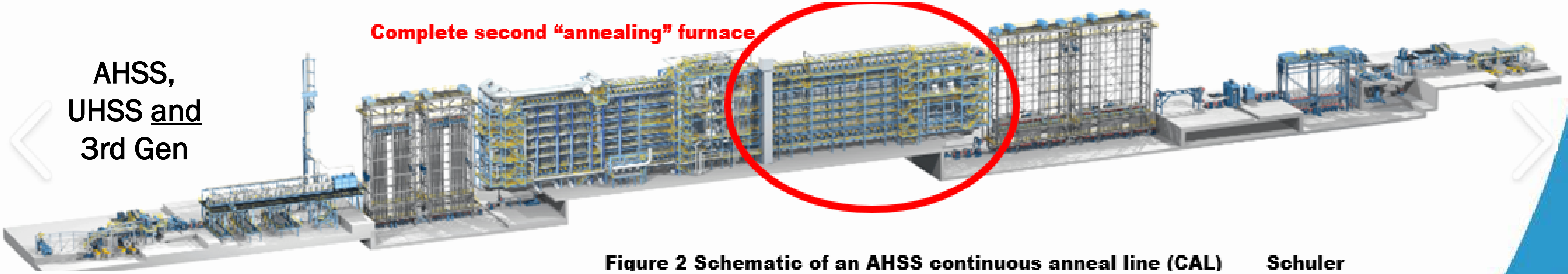


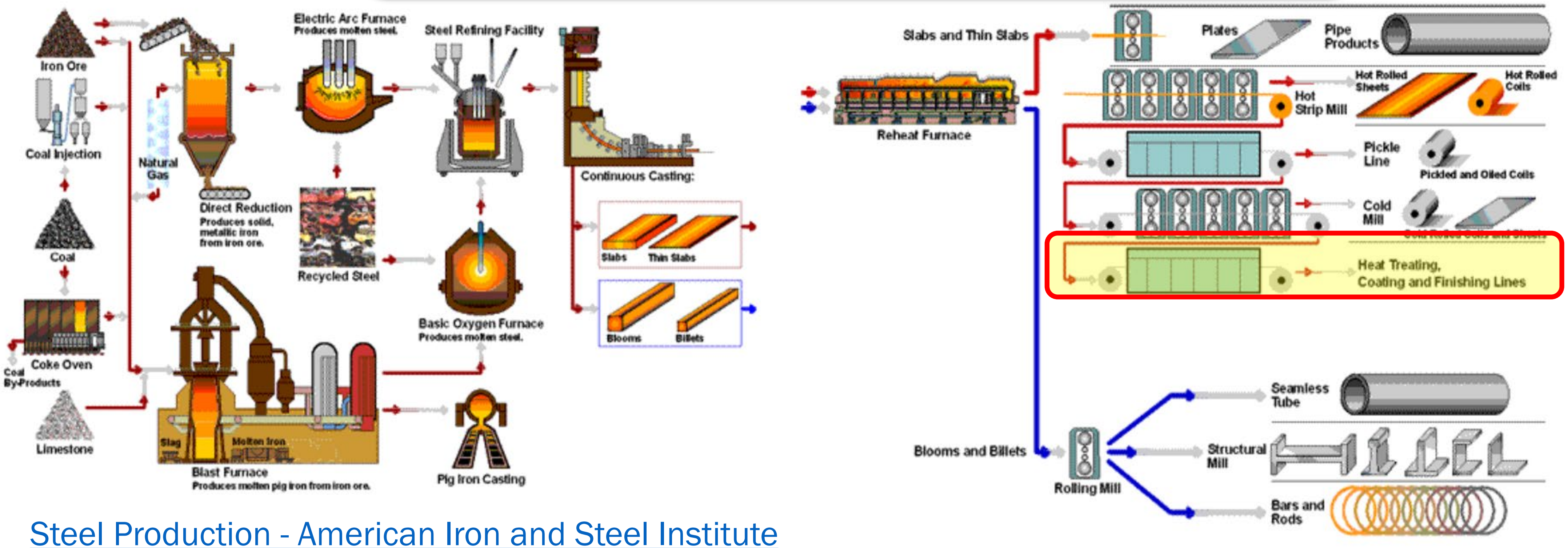

Figure 2 Schematic of an AHSS continuous anneal line (CAL) Schuler

*3rd Gen CAL lines are very large, complex, and highly advanced in process control and automation.*
*These lines are in production now.*

# Steel Processing is Modern Beyond Perception of People

*Advanced process controls that support the production of "new" AHSS steels exist throughout the steelmaking and finishing operations.*

## Steel Flowlines




[Steel Production - American Iron and Steel Institute]

# Existing Paradigm is Challenged by Modern Steel Mills

TRUE or False?

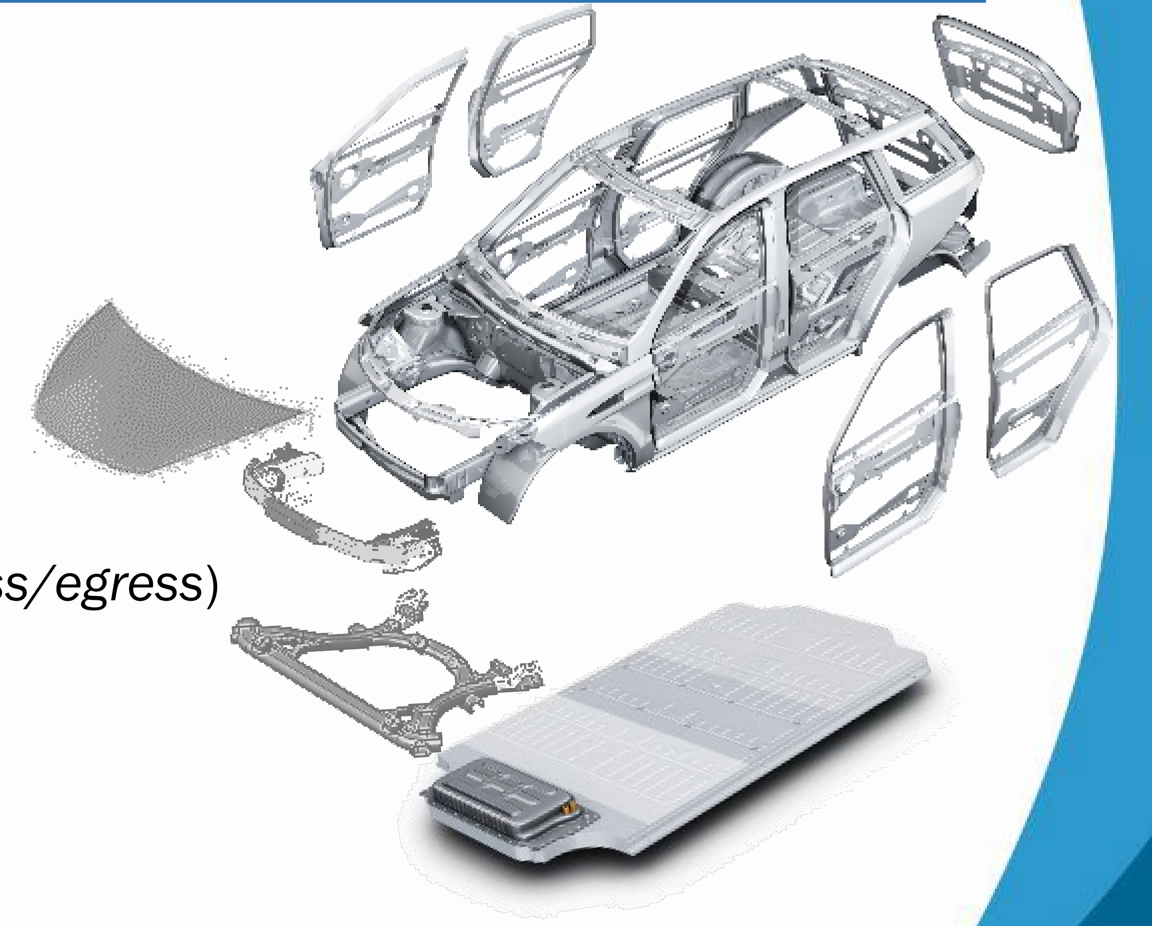
Higher-strength materials have lower ductility

*FALSE*

*Modern thermo-mechanical steel processing with precise automation and control can produce high-strength material with vastly improved ductility to allow for the cost and mass efficient use of Advanced High-Strength Steel in automotive Body in White designs*

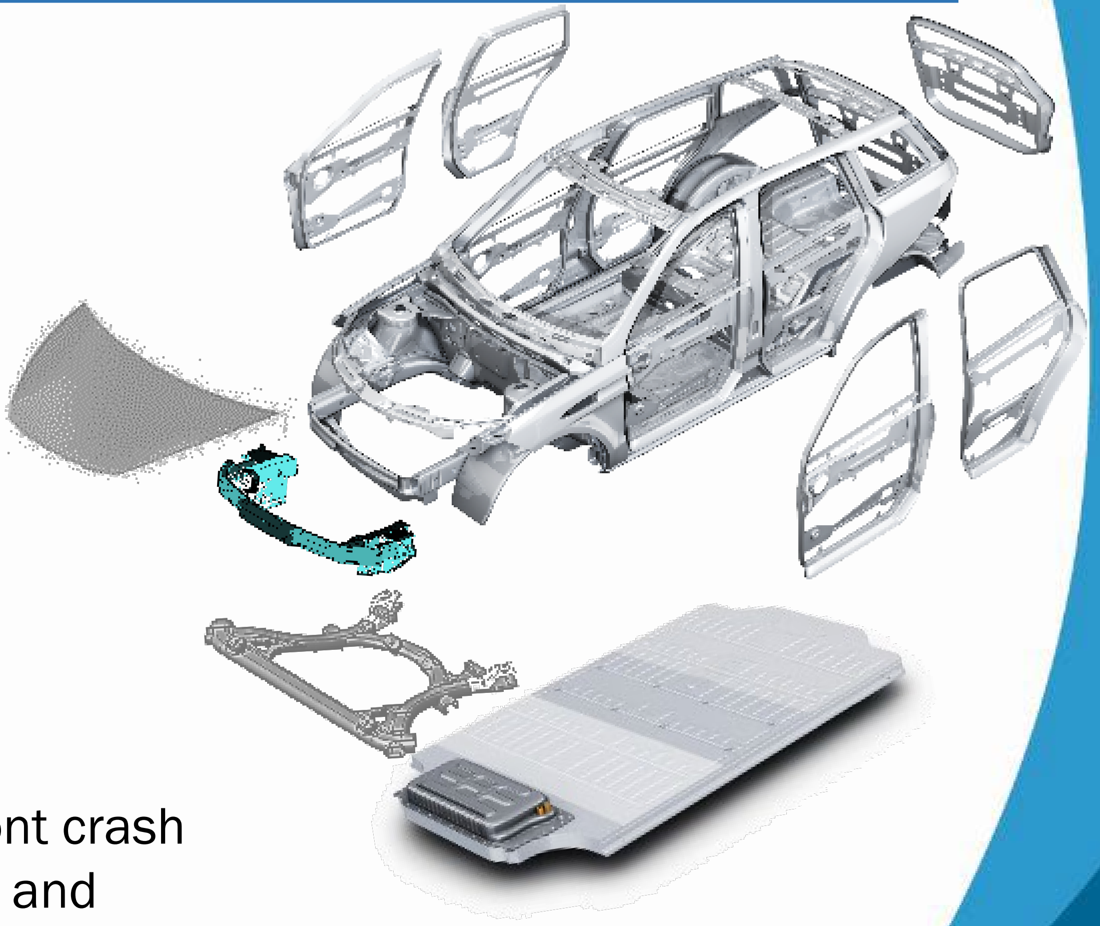
# Factors Influencing Material/Grade Selection

- **Vehicle Performance Targets**
  - Crash energy management (*occupant safety*)
  - Strength requirements (*intrusion reduction*)
  - Durability
- **Vehicle Integration**
  - Exterior and interior styling
  - Compact sections (*obscuration, packaging, ingress/egress*)
- **Manufacturing Considerations**
  - Forming / Joining / Painting / Infrastructure
- **Vehicle Program Imperatives**
  - Cost / Mass / Sustainability and environmental impact
  - Global production footprint / supply base
  - Competitive positioning within segment



# Bumper Systems

- **Bumper System Low Speed Impacts**
  - Regulatory:
    - Front and rear impacts (4 kph)
      - *Component damage*
  - Consumer Tests:
    - RCAR* front and rear impacts (15 kph)
      - *Repair cost estimates*
  - Pedestrian Protection:
    - Lower and upper leg



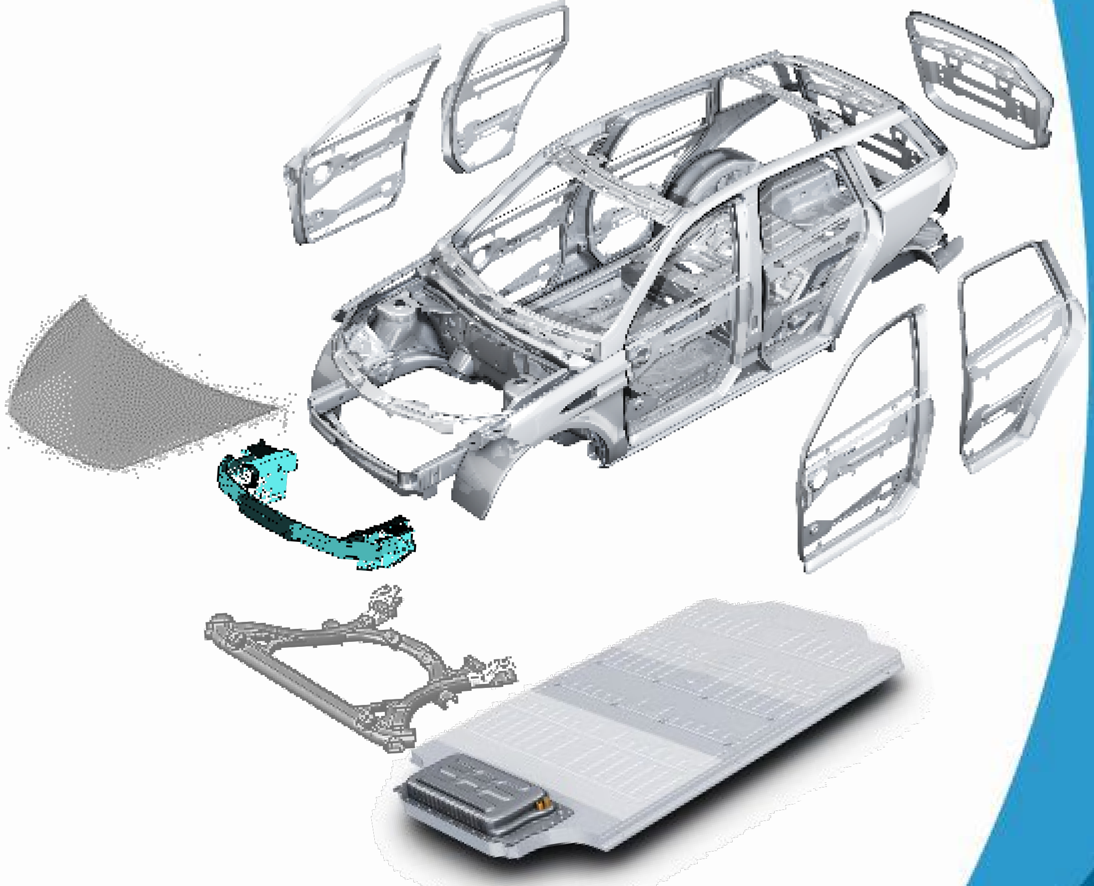
- **Bumper System High-Speed Impact**
  - Bumper reinforcement bars (front and rear) and front crash cans are integral to the vehicle structure (or frame) and contribute to its performance in all regulatory and consumer high speed crash tests

** Research Council for Automotive Repair*

# Example Grade Families & Technologies - Bumpers

- **Reinforcement beam:**
  - DP, MS, PHS, 3rd Gen
  - Cold stamping, Hot stamping, Roll forming, Hot Forming

- **Crash Cans:**
  - DP, HSLA, 3rd Gen
  - Cold stamping, Laser welded blanks, Hydroforming



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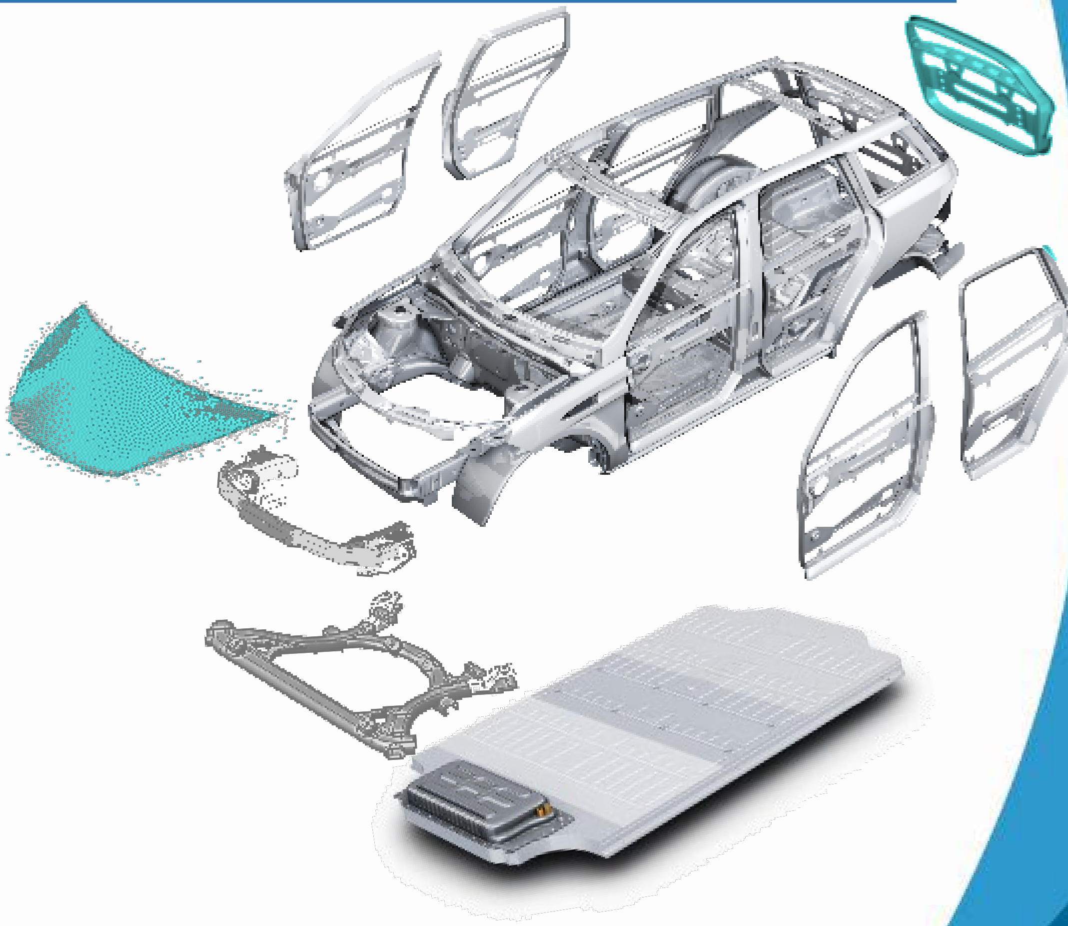
| CP | – Complex Phase |
| BH | – Bake Hardenable |
| MS | – Martensite |
| HSLA | – High Strength Low Alloy |
| PHS | – Press Hardened Steel |

# Front and Rear Closures

- Front Closures
  - Torsional and lateral stiffness
  - Palm denting / Oil canning / Panel flutter
  - Local durability
  - Pedestrian protection (head impact)

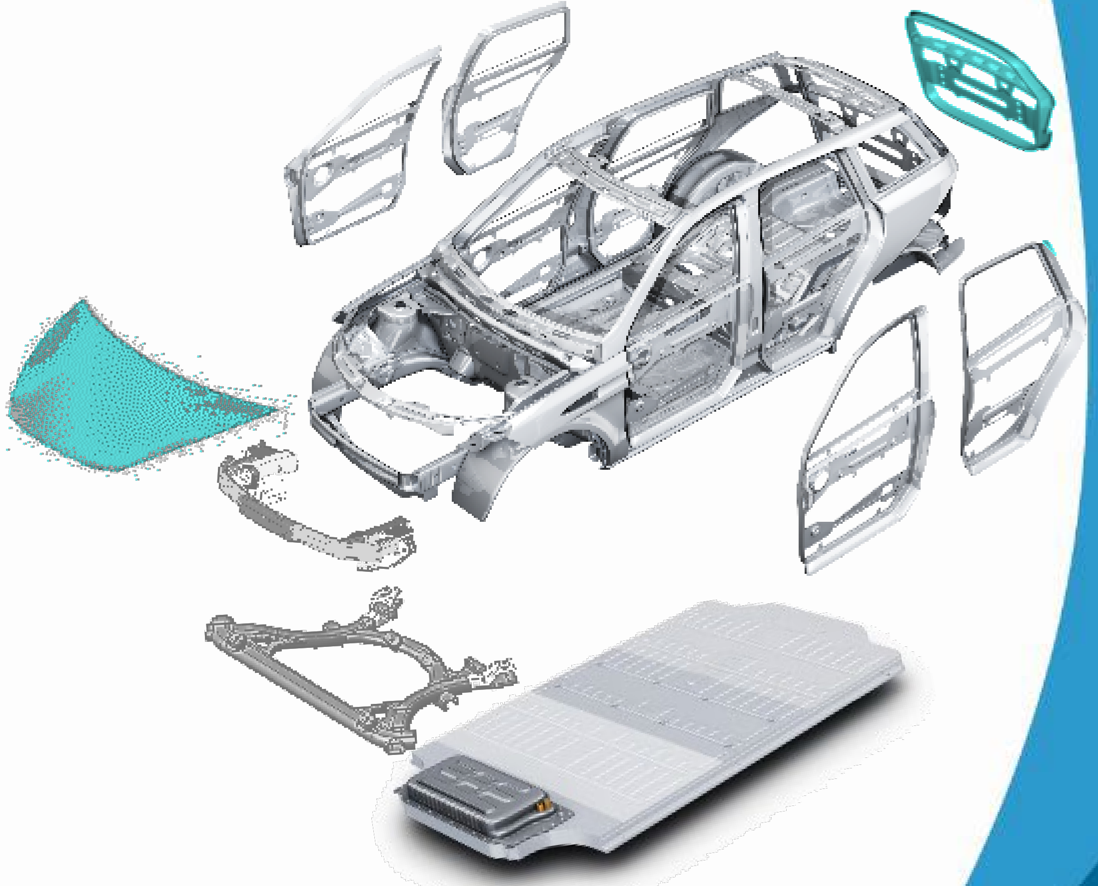
- Rear Closures
  - Torsional and lateral stiffness
  - Palm denting / Oil canning
  - Local durability



# Example Grade Families & Technologies – Fr/Rr Closures

- **Outer Panels:**
  - BH, DP
  - Cold stamping

- **Inner Panels:**
  - DP, HSLA, 3rd Gen
  - Cold stamping, Laser welded blanks, Patch blanks



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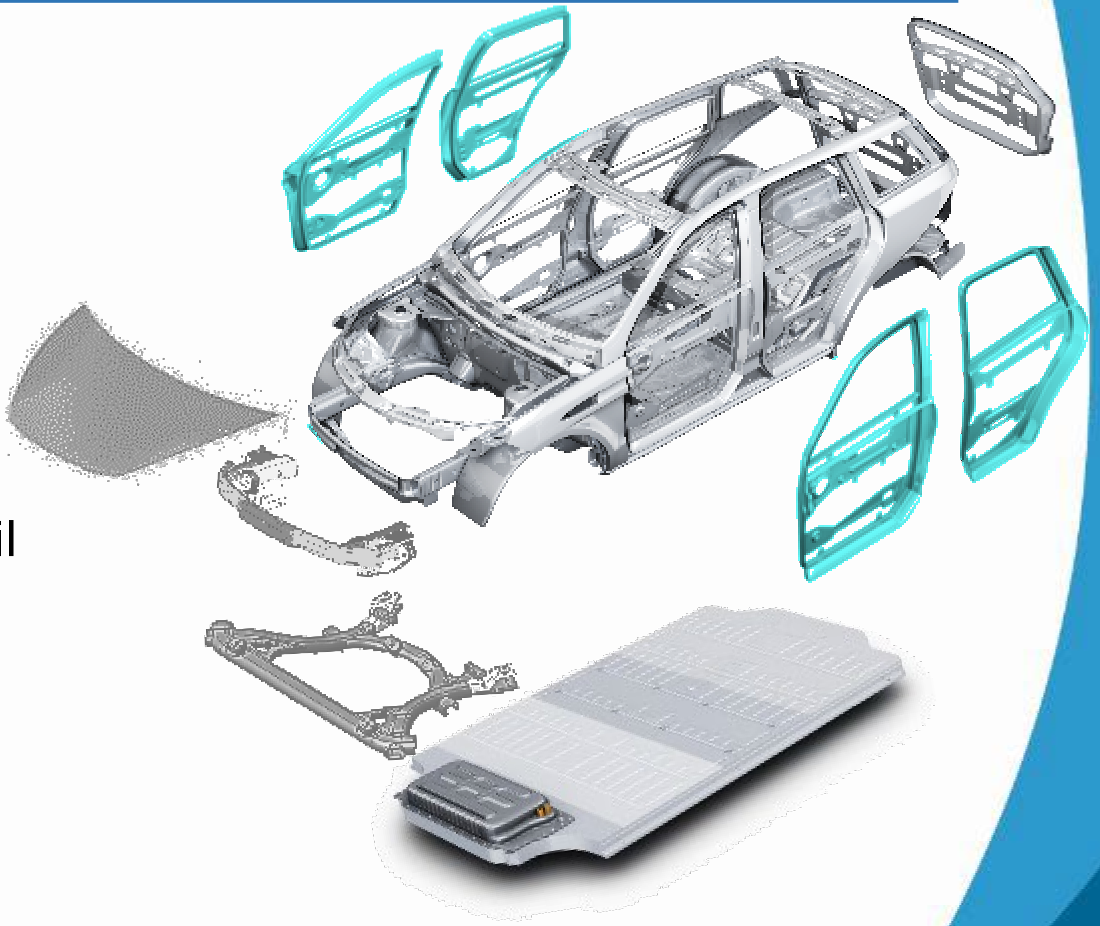
# Side Closures

- **Side Closures**
  - Crash: FMVSS 214 (Static & MDB*) side impact, side pole impact
  - Strength: (door sag, wind gust, panel denting)
  - Durability: hinge / latch / check link
  - Stiffness: (frame, beltline, mirror mounting, torsional stiffness, resonance frequencies, panel oil canning)
  - Acoustics: wind and road noise isolation



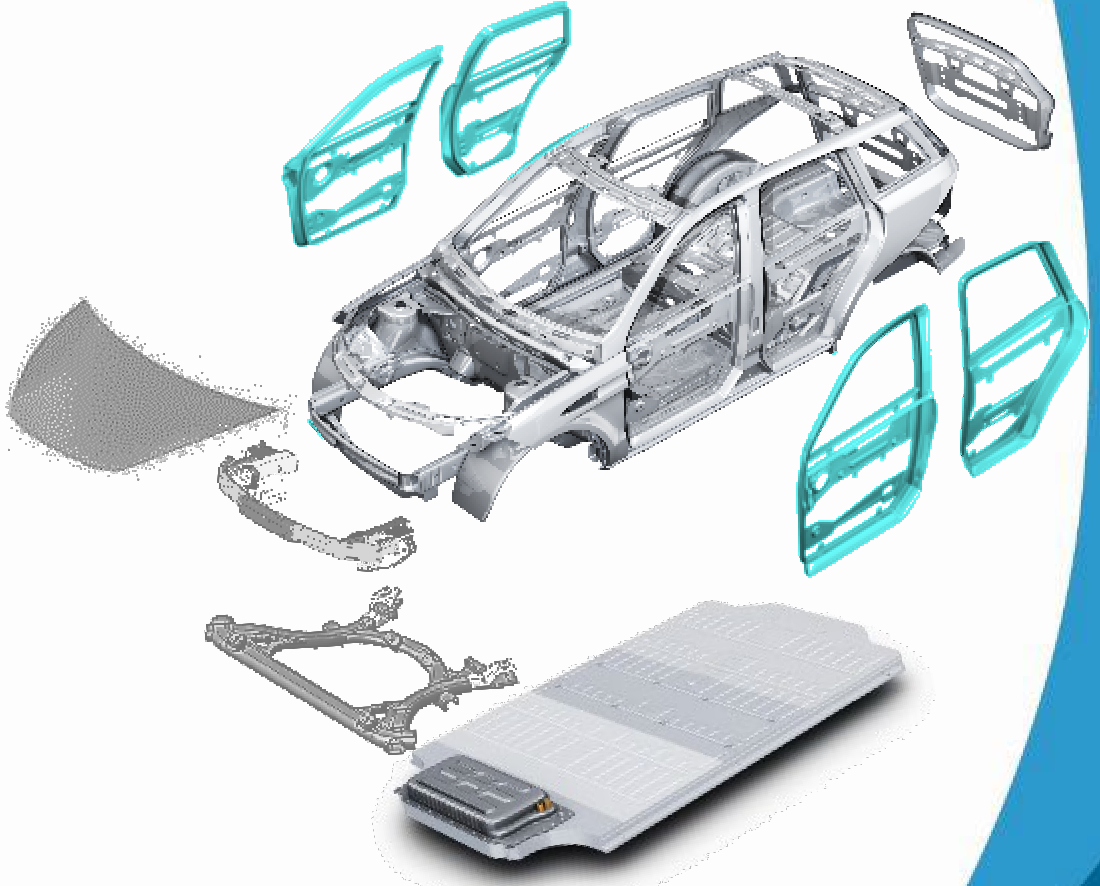
* *Mobile Deformable Barrier*

# Example Grade Families & Technologies – Side Closures

- **Outer Panels:**
  - BH, DP
  - Cold stamping

- **Inner Panels:**
  - DP, HSLA, 3rd Gen
  - Cold stamping, Laser welded blanks, Patch blank

- **Door Structural Members:**
  - DP, HSLA, 3rd Gen, PHS, MS
  - Cold stamping, Hot stamping, Laser welded blanks, Roll forming



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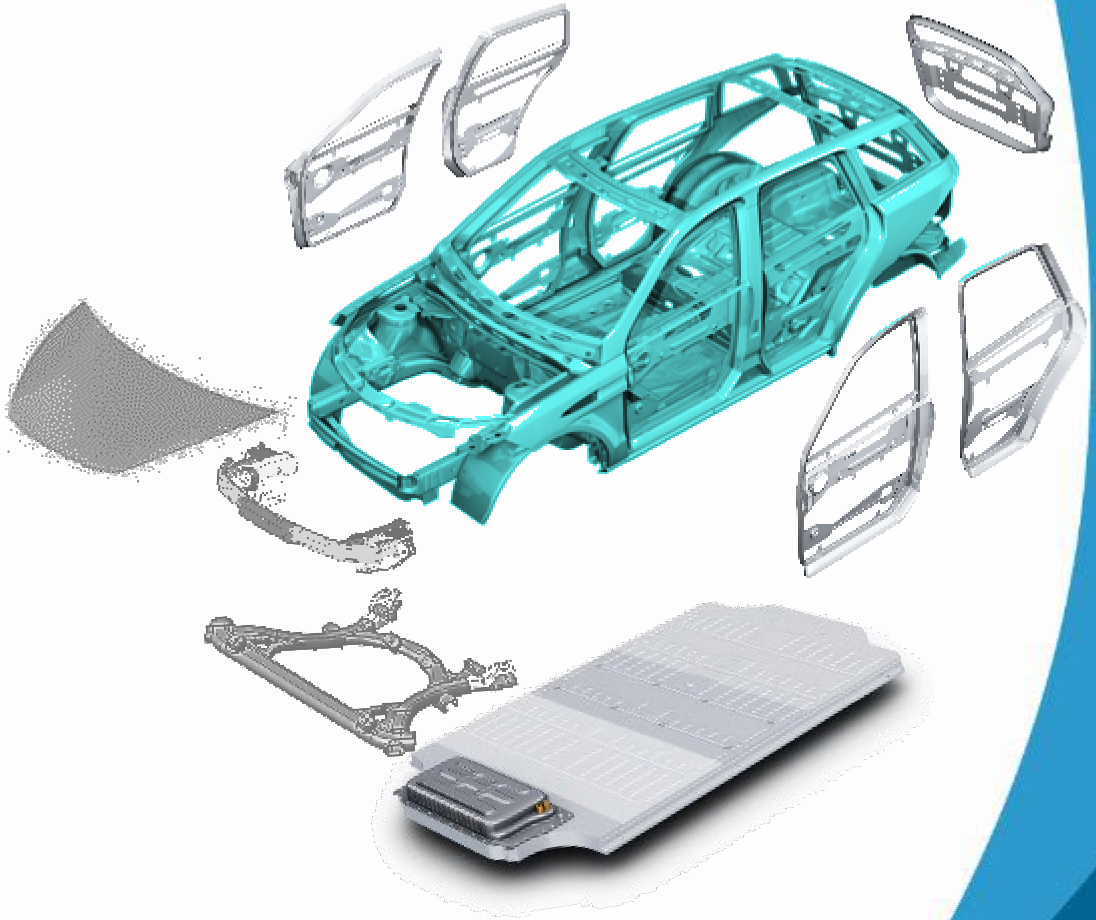
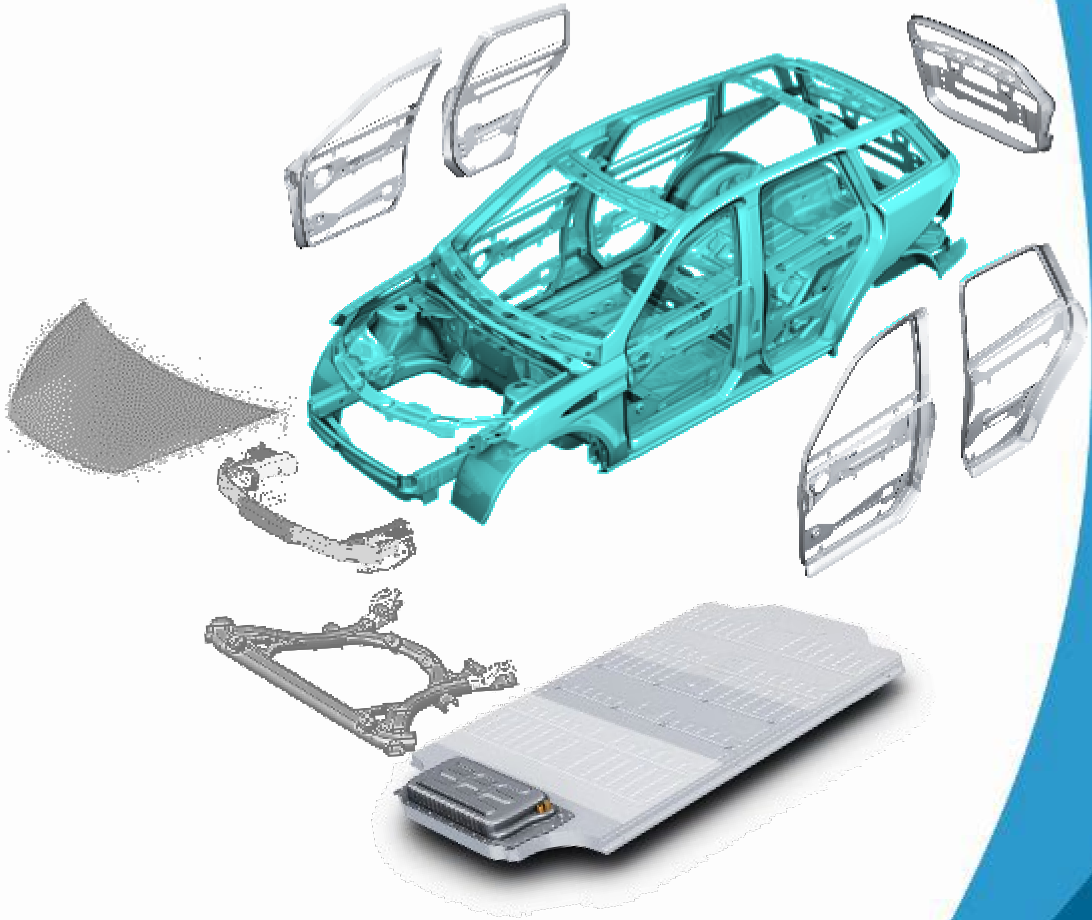
# Body Structure

- **Body Structure Safety & Crashworthiness**
  - Front impact, *examples*:
    - FMVSS 208
    - USNCAP (56 kph) rigid barrier
    - IIHS (64 kph) 40% offset Deformable Barrier
    - IIHS (64 kph) 25% Small Offset Rigid Barrier
    - EuroNCAP (50 kph) MPDB (Mobile Progressive Deformable Barrier) – car to car
    - NHTSA (90 kph) OMDB (Oblique Mobile Deformable Barrier)



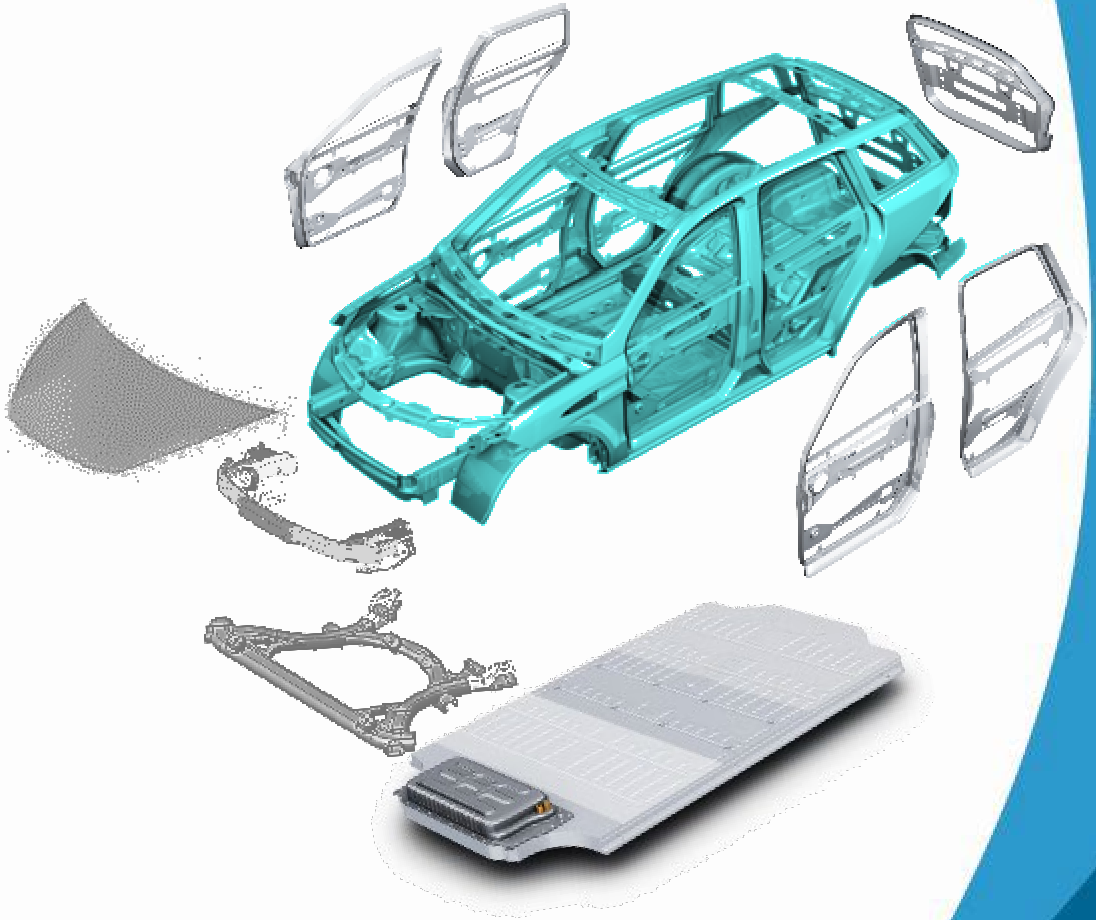
# Body Structure

- **Body Structure Safety & Crashworthiness**
  - Side impact, *examples*:
    - IIHS (60 kph) MDB (Mobile Deformable Barrier)
    - USNCAP (32 kph) Rigid Pole
  - Rear impact, *examples*:
    - FMVSS 305
  - Roof crush, *example*:
    - IIHS Quasi-Static



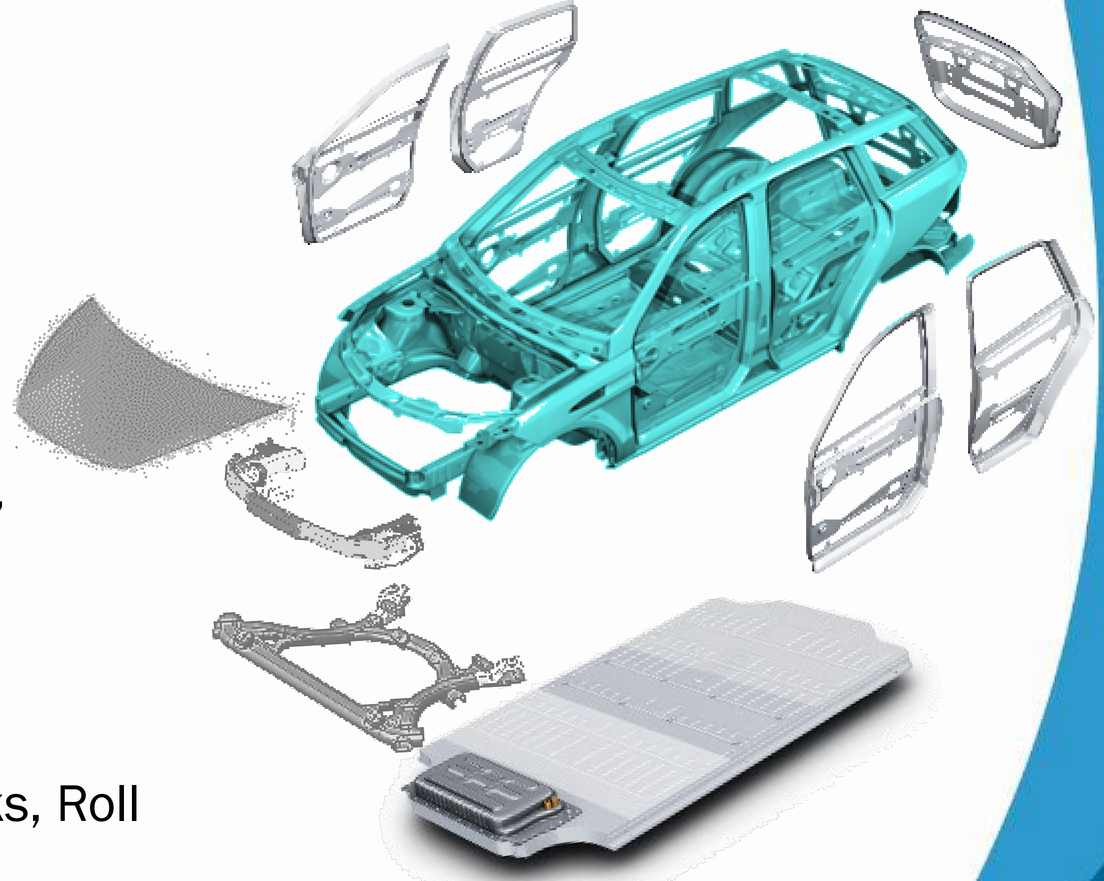
# Body Structure

- Body Structure NVH
  - Enable vehicle primary modes targets
  - Adequate static torsional and bending stiffness to enable vehicle level targets
  - Appropriate local stiffness at all subsystem interfaces to meet durability and isolation targets
  - Appropriate panel resonances to avoid coupling with the acoustic cavity



# Example Grade Families & Technologies - Structures

- **Exposed Panels:**
  - BH
  - Cold stamping
- **Crash Energy Management Structure:**
  - DP, MP, CP, HSLA, PHS, 3rd Gen
  - Cold stamping, Laser welded blanks, Roll forming, Hydroforming, Hot stamping
- **Strength dominant Structural Components:**
  - DP, 3rd Gen, PHS, MS
  - Cold stamping, Hot Stamping, Laser welded blanks, Roll forming, Hydroforming
- **Unexposed Panels:**
  - DP, 3rd Gen, BH
  - Cold stamping, Laser welded blanks, Patch blanks



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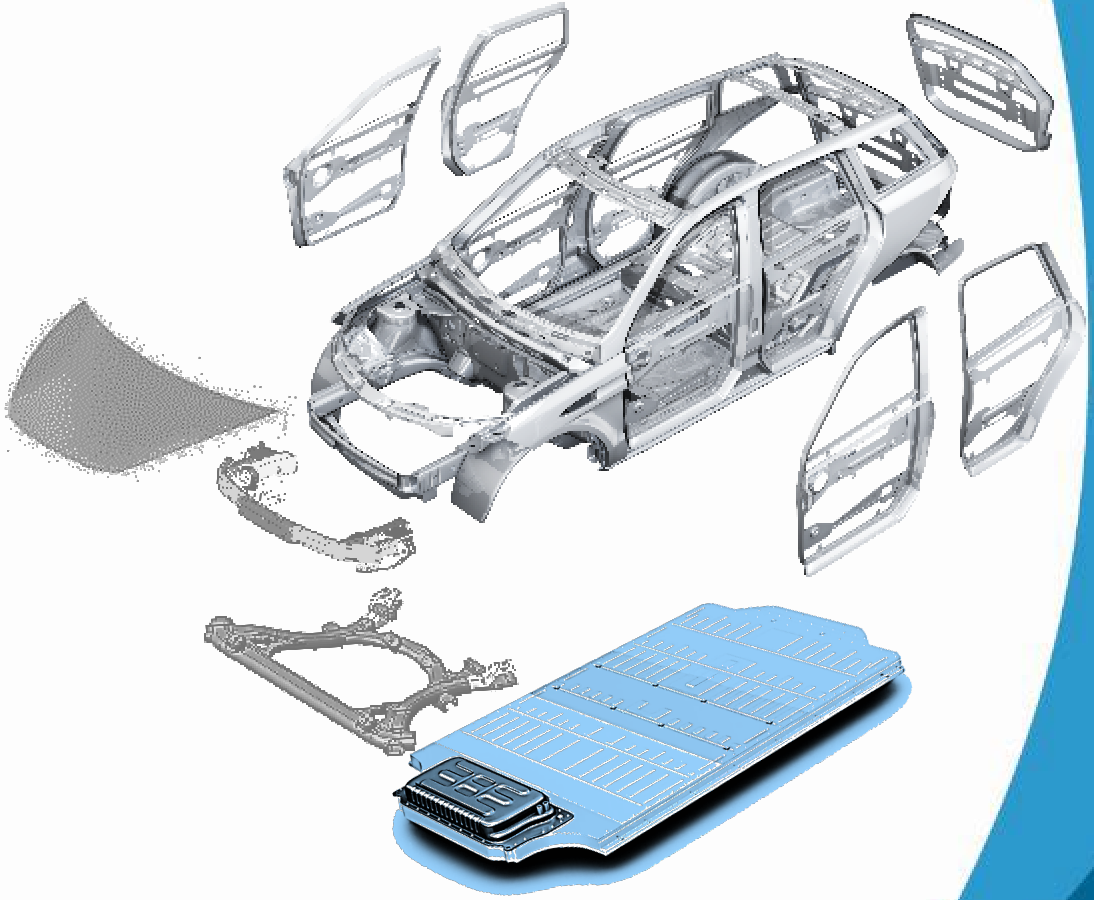
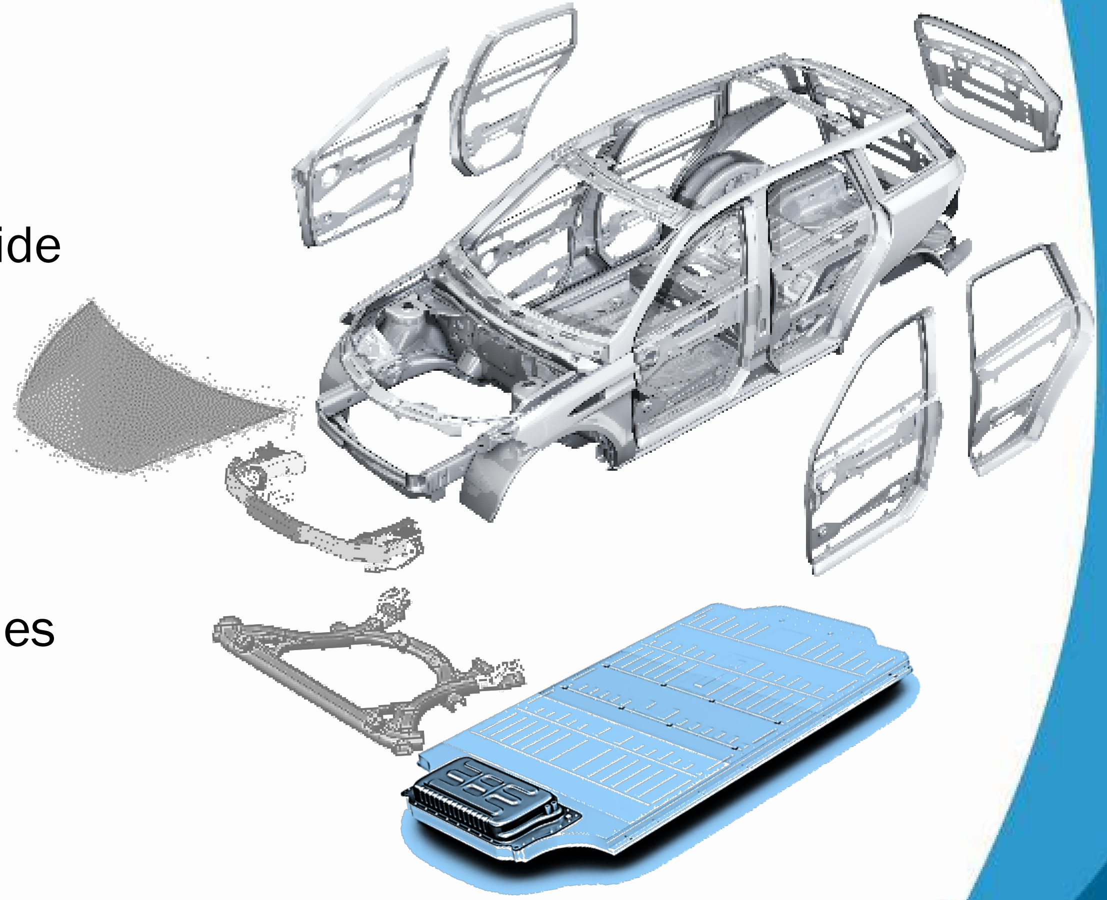
# High Voltage Battery Enclosure Structure

- **Standalone Battery Enclosure Structure**
  - Support, Contain, and Protect Battery Modules
    - Possess adequate stiffness to support the massive battery system under both static and dynamic loading conditions without excessive deformation.
    - Have vibration modes that are sufficiently decoupled from:
      - Vehicle primary bending and torsion modes
      - Floorpan modes
      - Passenger compartment acoustic modes
    - Have sufficient strength to protect the modules from stone and debris impact from below.
    - Possess some level of impact energy management.
    - Adequately sealed to guard against water and dust intrusion and contain battery thermal incidents.



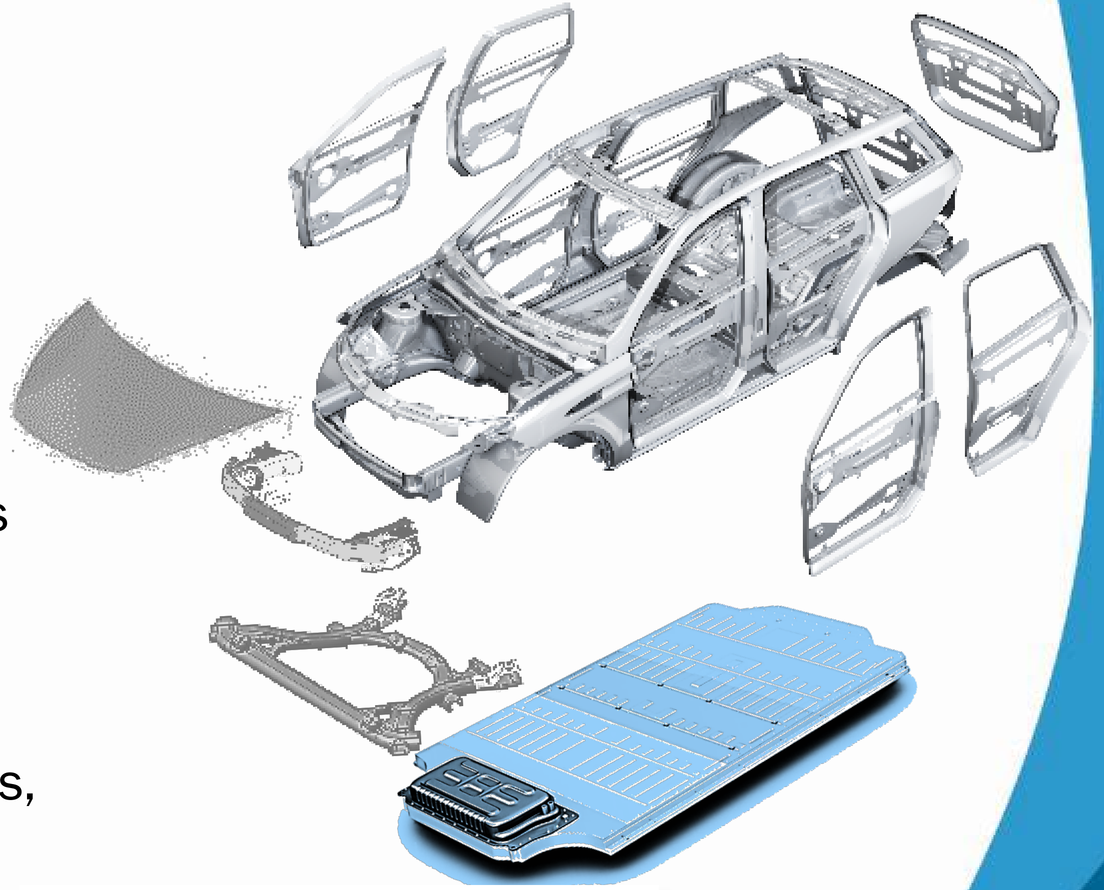
# High Voltage Battery Enclosure Structure

- **Integrated Battery Enclosure Structure**
  - Contribute to:
    - Vehicle crash energy management front/side/side pole/rear
      - Reduce acceleration pulse on modules
      - Prevent encroachment on modules
    - Vehicle stiffness/strength/NVH
      - Offset increase in bending loads
      - Offset reduction in primary vehicle frequencies



# Example Grade Families & Technologies – HV Enclosure

- **Top Cover:**
    - Mild Steel
    - Cold stamping
- **Bottom Cover:**
    - DP, CP, MP, PHS
    - Cold stamping, Laser welded blanks, Patch blanks
- **Structural Components:**
    - PHS, MS, 3rd Gen
    - Cold Stamping, Hot stamping, Laser welded blanks, Roll forming, Hydroforming



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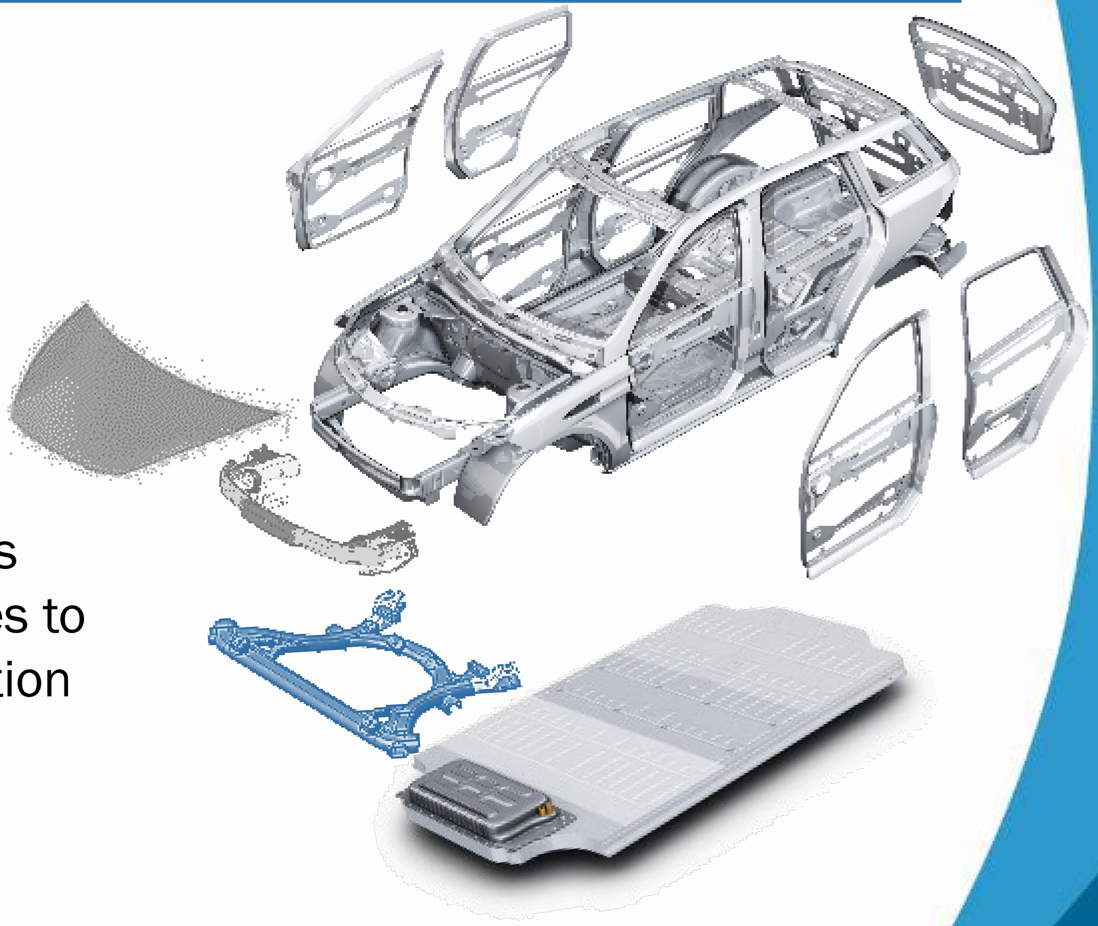
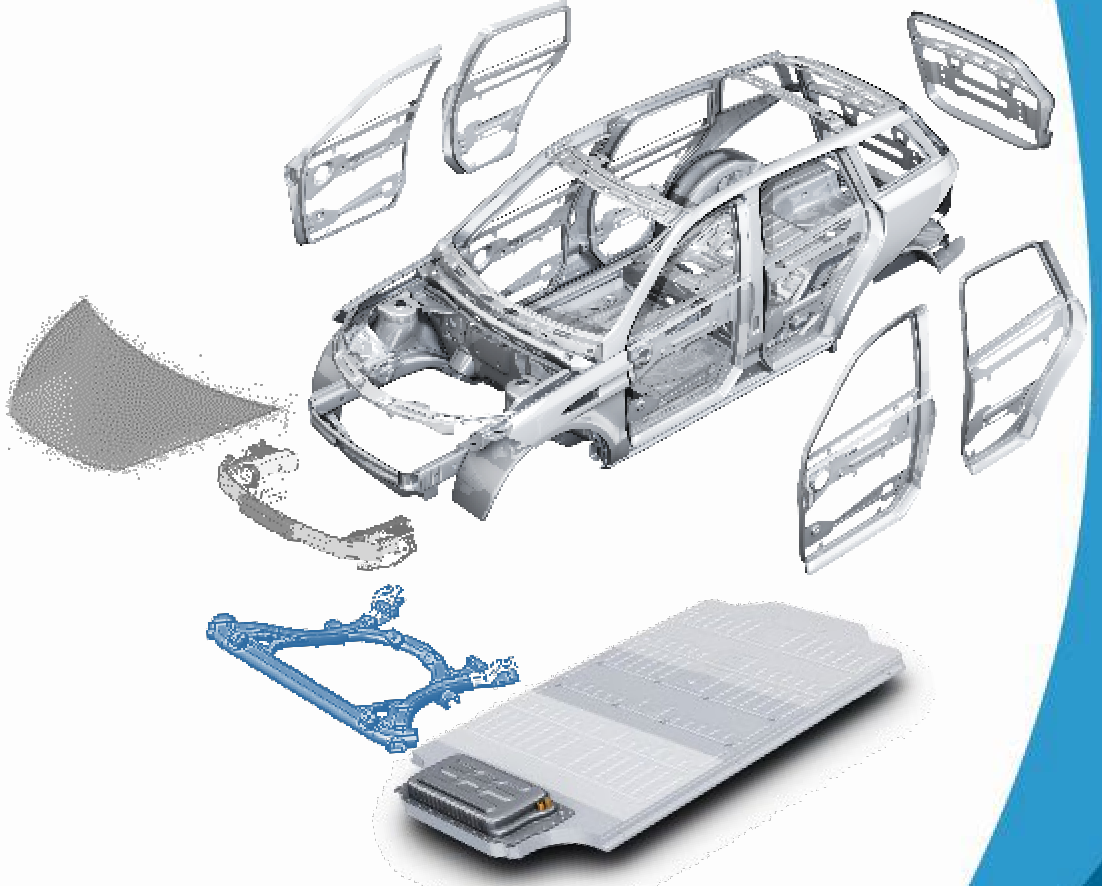
# Chassis Structures

- Front Chassis Subframe
  - Contributes to:
    - Vehicle front crash energy management
      - Example, SORB
    - Motor Compartment Structure Stiffness
      - Example, solidly mounted subframes
  - Supports Powertrain and Front Chassis Subsystems
    - Possess adequate local stiffness at all interfaces to ensure appropriate structural borne noise isolation



# Example Grade Families & Technologies – Chassis Structures

- **Structure:**
  - DP, HSLA, 3rd Gen, PHS
  - Cold stamping, Hot stamping, Laser welded blanks, Hydroforming



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# Summary and Conclusions

- The broad spectrum of steel grades being manufactured in modern steelmaking operations, offers automotive designers the flexibility to optimally balance their program objectives.

- Innovations in steel processing, forming and joining technologies such as laser blanking, tubular and sheet hydroforming, roll-forming, hot stamping, laser welding, etc. will enable:
    - Architectural creativity and freedom to address future integration challenges.
    - Flexible modular architectures to accommodate different configurations, needs and uses;
    - Scalable production volumes.

- Future vehicle electrification will present key development challenges:
    - Crash energy management strategies for both the vehicle occupants and battery modules;
    - Increased durability requirements and component fatigue life targets;
    - Ensure cost-effective design solutions for fleet and mobility service providers;
    - Increased focus on environmental sustainability.

# Thank You / For More Information

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