Bolted-on front crush structure for enhanced platform modularity

Presenters :

Abhishek Das
Staff Engineer, Body Structures

Deepak Theja
Sr. Engineer, Vehicle Safety

Dan Black
Sr. Manager, Service Engineering

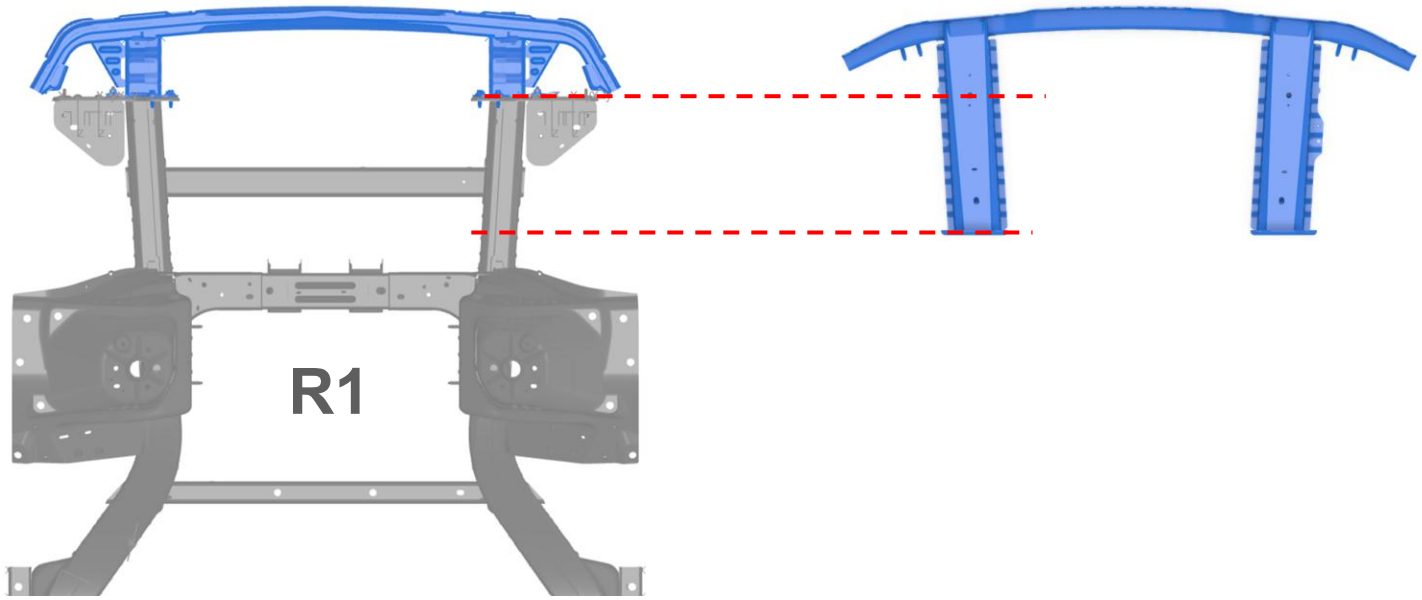
May 20, 2026

Agenda

- Overview
- Design Strategy
- Vehicle Safety
- Vehicle Repairability

Overview

- Elongated bolt-on front crash structure
  - > 2x length compared to current R1
- All steel construction
- RSW primary joining method
- Lightweight construction



Vehicle main structure

Bolted front crash structure

Key Drivers

- Platform commonality
- Repairability
- Volume scalability
  - DFM/DFA
  - Robust quality control

Design strategy

Material Selection

- Manufacturability
- Proven track record

Manufacturing process

- Stamping
- RSW

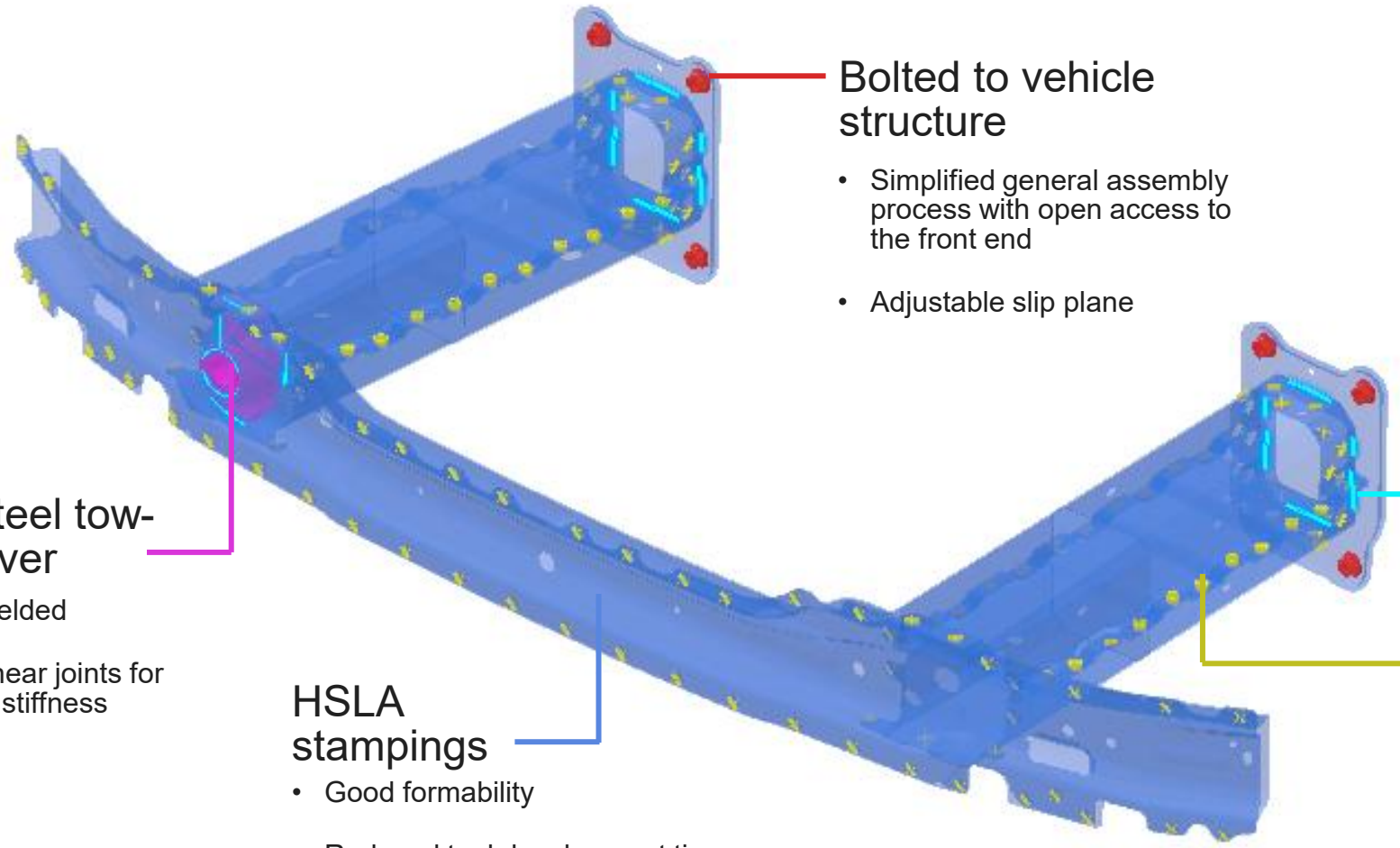
Geometry

- Crash force profile
- Crush mode

Design strategy

Material selection and manufacturing processes

GDIS



Bolted to vehicle structure

- Simplified general assembly process with open access to the front end
- Adjustable slip plane

Forged steel tow-eye receiver

- GMAW welded
- Double shear joints for improved stiffness

HSLA stampings

- Good formability
- Reduced tool development time
- Repeatable crush mode
- Wide global availability

GMAW

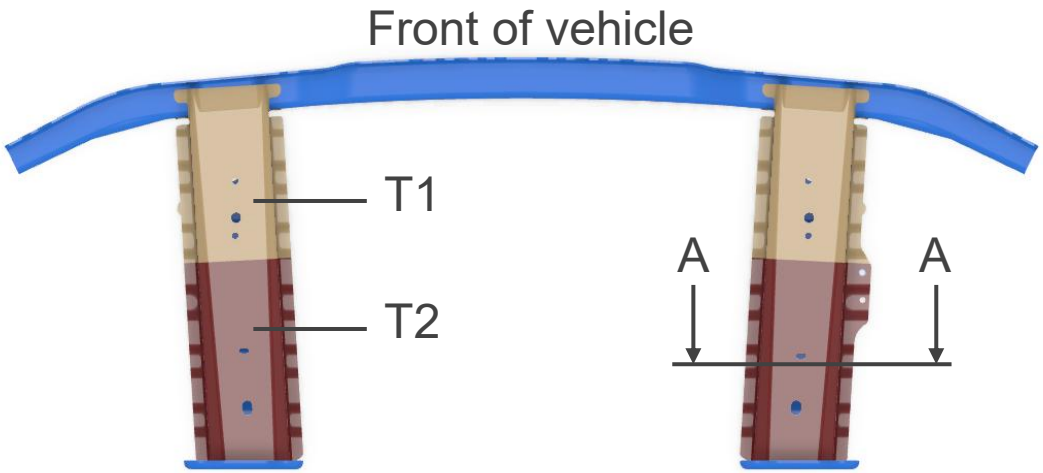
- Strategic locations to maximize strength in restricted spaces

RSW

- Cost effective
- Fast process. Easy volume ramp-up
- Highly repeatable

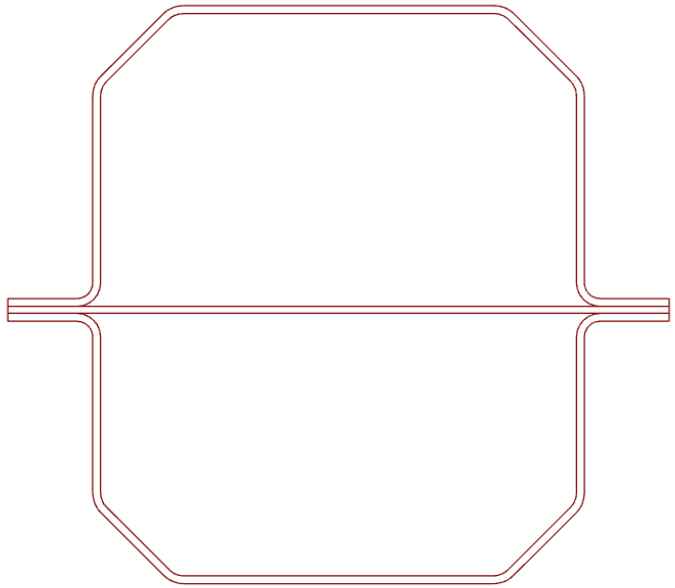
Design strategy

Geometry – **for force profile**



- T2 > T1 (laser welded blank)
- T1 - lower thickness for unbelted occupant
- T2 - higher thickness for increased energy absorption

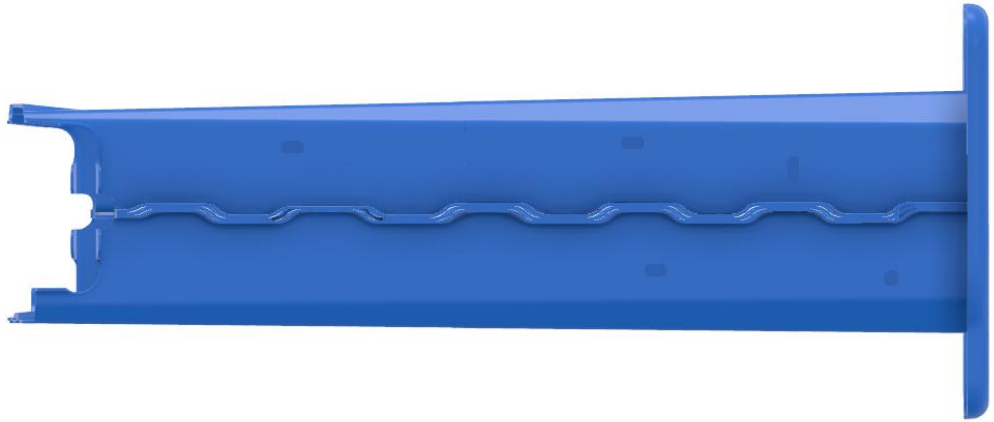
Section A-A



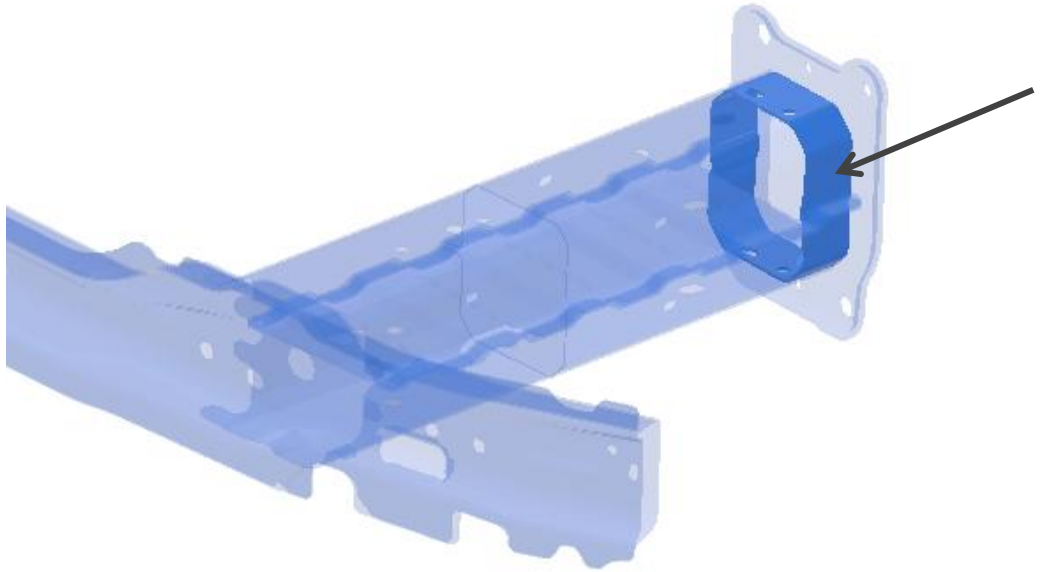
- Octagonal hat section maximizes specific energy absorption
- Weld flange improves loads capacity thus enabling thickness reduction

Design strategy

Geometry – **for crush mode**



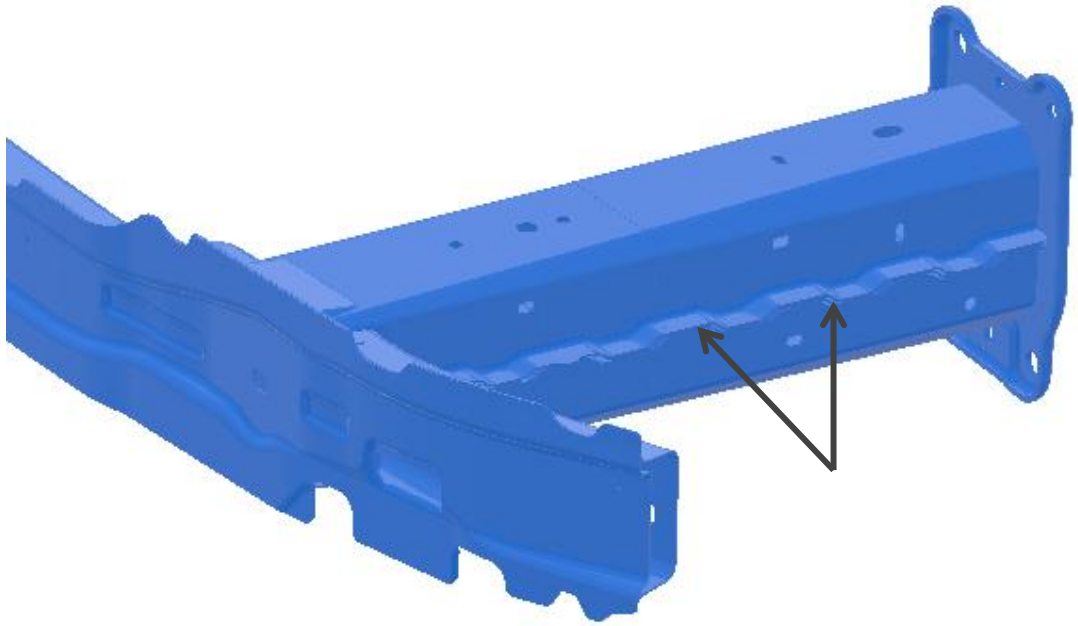
- Crush cans tapered front to back
- Section load capacity increases gradually
- Promotes sequential crush



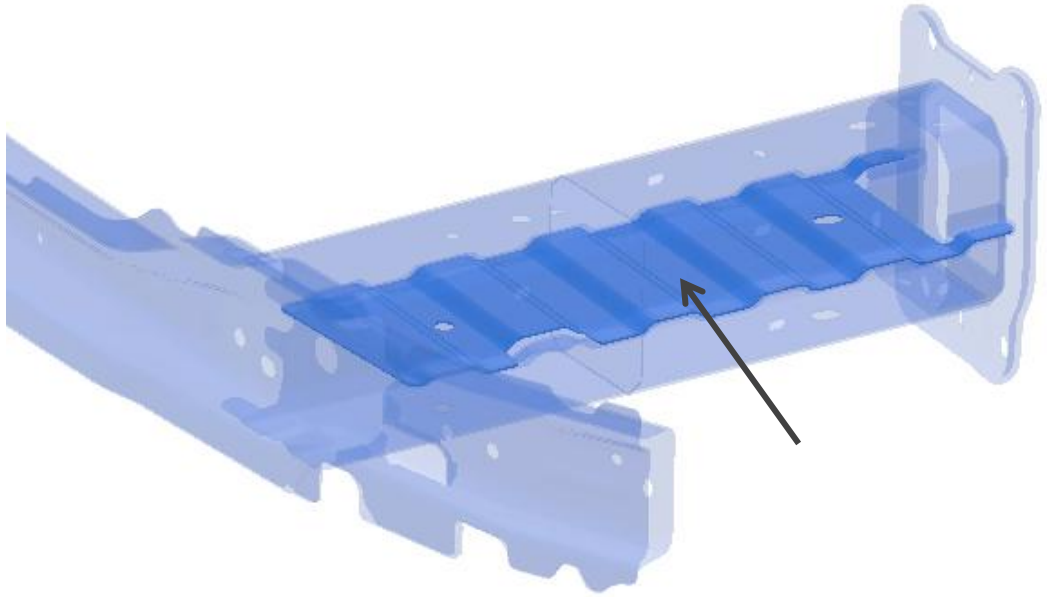
- Sleeve MIG welded to mounting plate
- Crush cans spot welded to the sleeve
- Improves joint stiffness

Design strategy

Geometry – **for crush mode**



- Corrugated weld flange for robust crush initiation
- Initiators are at the neutral plane
- Interlocking geometry promotes combined movement rather than welds peeling in crush



- Mid plate reinforcement with ribs resists lateral buckling
- Works in tension and compression
- Positioned between the upper and lower crush can

Vehicle Safety

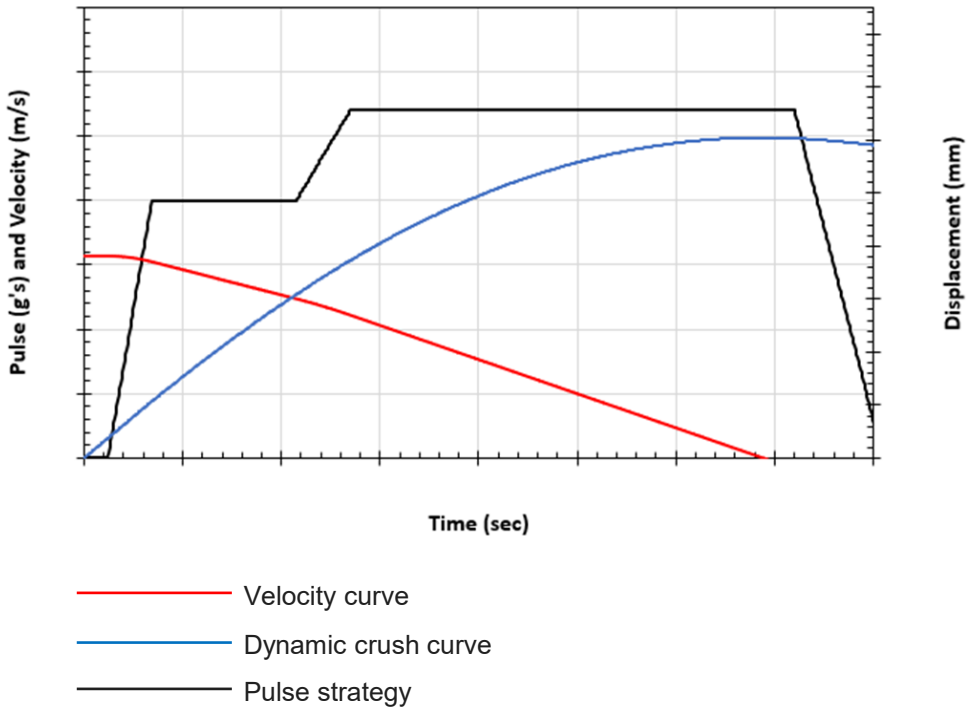
Crush can development cycle

- Safety Pulse strategy
- CAE and Physical test loop of crush can development
- Vehicle Validation

Overview

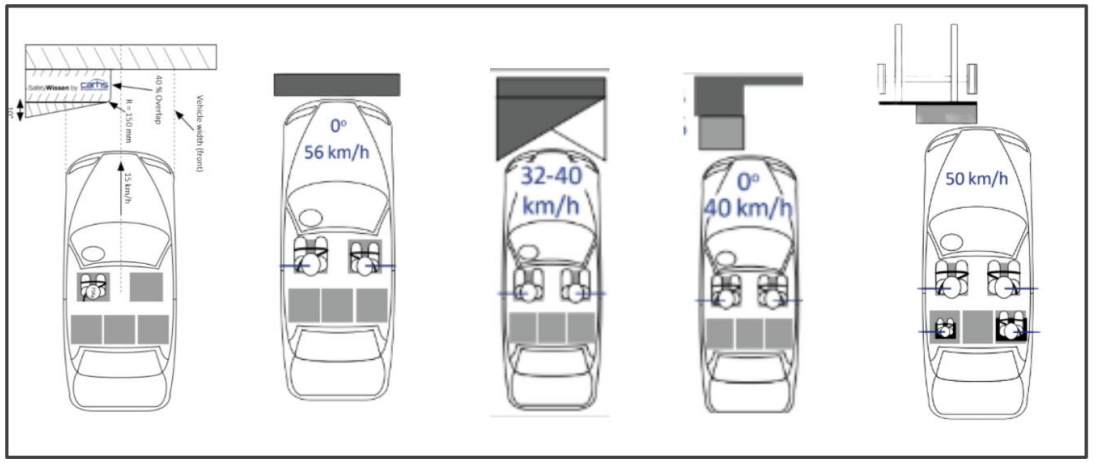
To satisfy injury metric requirements, vehicle safety implemented a staged pulse strategy, which includes:

- **Stage 1 (Softer):** Provides protection for unbelted occupants and manages low-speed crash scenarios
- **Stage 2:** Addresses the management of high-speed crash energy



Crush can design safety considerations:

- The primary energy absorption function is executed by the bolted crush structure
- Ensuring a robust crush mode and maintaining the targeted avg crush force through the length of the crush cans
- Defining joint strength targets for angular and offset modes



Crush Can Development Cycle

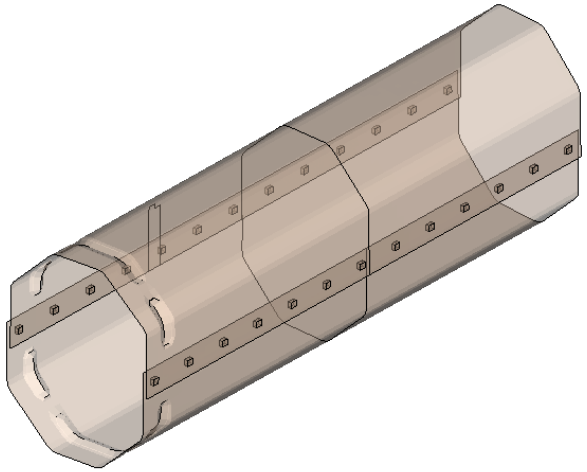
GDIS

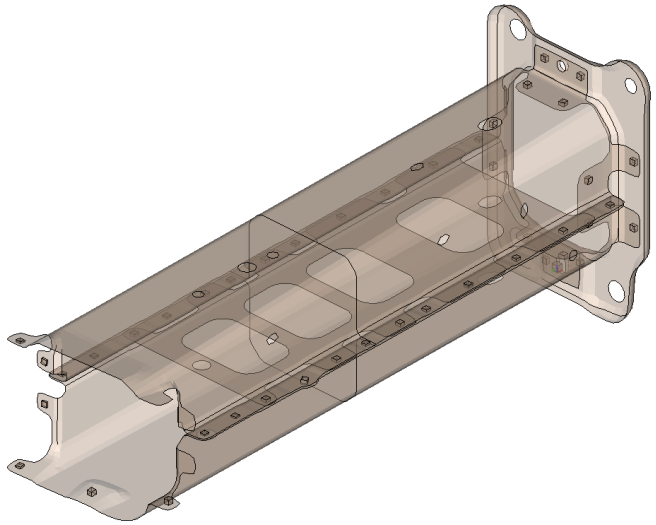
Design Concept

Design Loop 1

Design Loop 2

Vehicle Validation



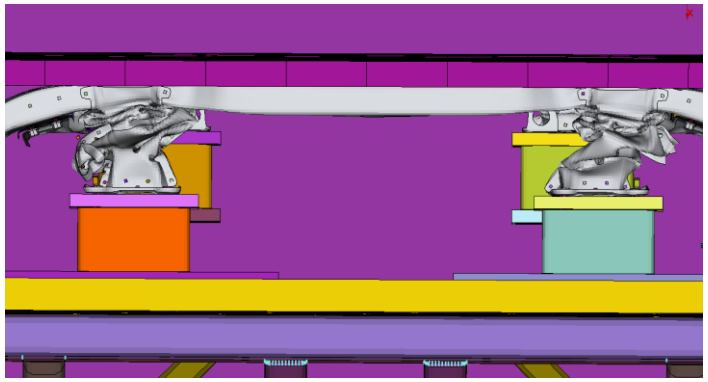


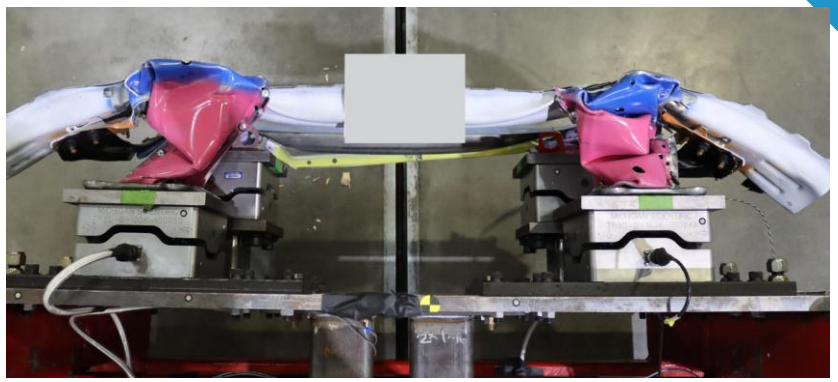
- **Concept:** Geometry was design to achieve maximum crush efficiency. Octagonal section with MIG welded flange was used
- **Construction:** TWB crush can construction to manage 2 step safety pulse strategy
- **Balance:** Rectangular section had to be adapted to balance targets from the cross functional team. Introducing flange also increased the section capacity and enable thickness reduction. Manufacturing process was simplified by using RSW's
- **Crushability:** Crush cans being significantly longer were prone to buckling. It was important to maintain low slenderness ratio - L/r. Mid plate was added to increase the stiffness of the section and keep the walls from flexing. Crush cans were taper to promote a sequential crush.

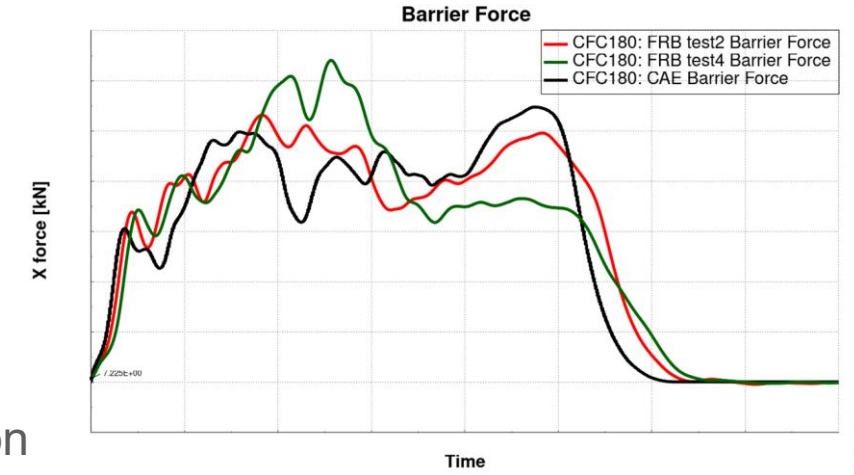
Crush Can Development Cycle

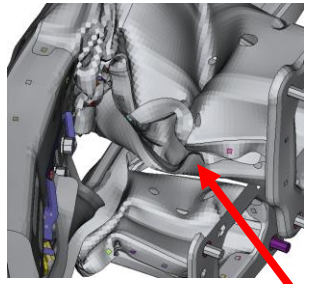
GDIS

- Design Concept
- Design Loop 1
- Design Loop 2
- Vehicle Validation









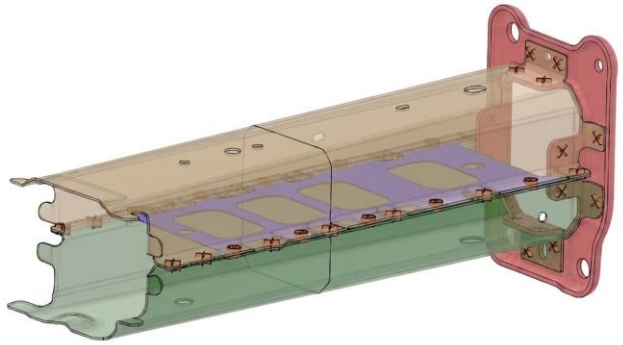
Test Observations

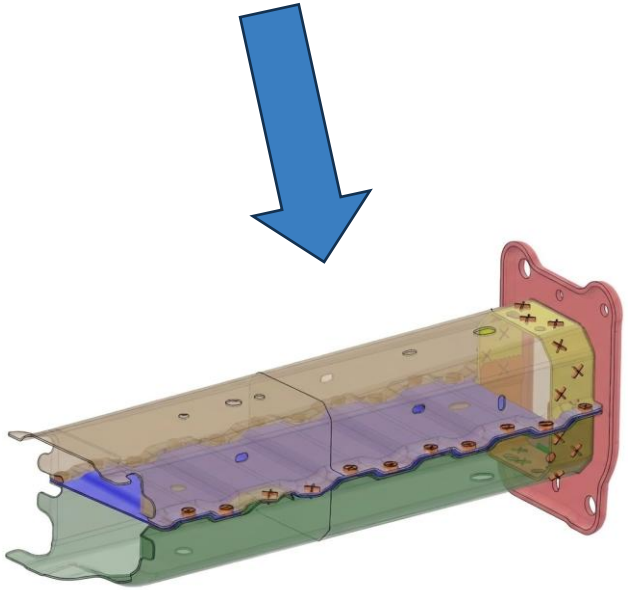
- **Objective:** Achieve robust sequential axial crush
- **CAE Prediction:** Forces and ramp-up to stage 2 matched the desired targets. Variation in crush mode was predicted.
- **Physical Test Results:** Three main shortcomings were observed :
  - **Crush mode** : Excessive buckling. Not repeatable
  - **Excessive weld failure** : At the crush can flanges and mounting plate
  - **Force profile** : Moderately different from prediction. Higher peaks compared to CAE

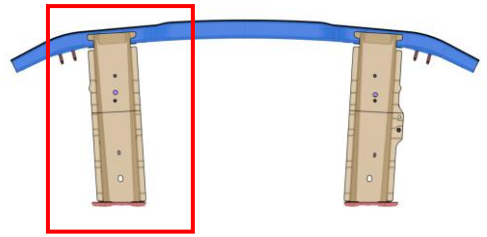
Crush Can Development Cycle

GDIS

- Design Concept
- Design Loop 1
- Design Loop 2
- Vehicle Validation







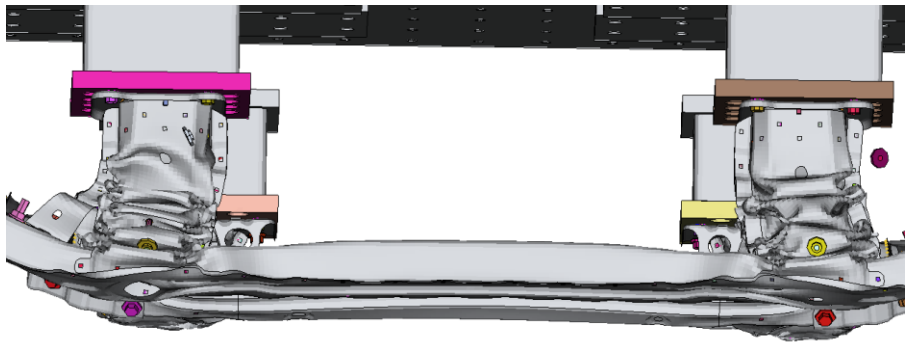
Implemented Modifications:

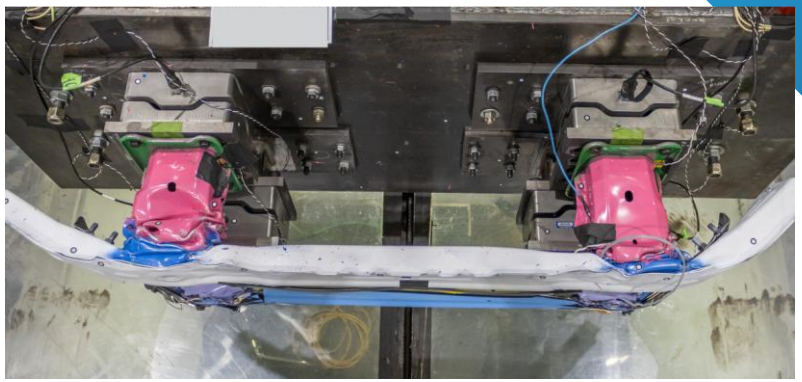
- A sleeve design was added to boost the number of welds and joint strength, resulting in more robust backup and reduced crush instability
- The holes in the mid-plate were removed, and the thickness was increased, which effectively made the section into two small sections and subsequently increased the section moment of inertia
- Steps were integrated to control flange deformation and stabilize the flange opening after weld failure.

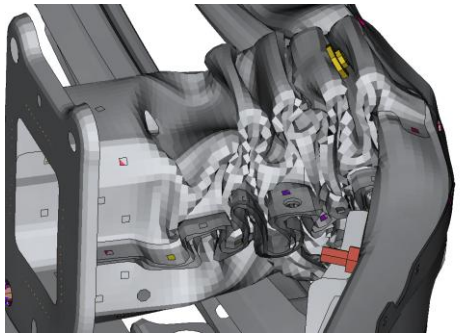
Crush Can Development Cycle

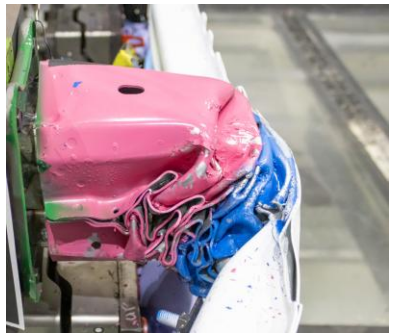
GDIS

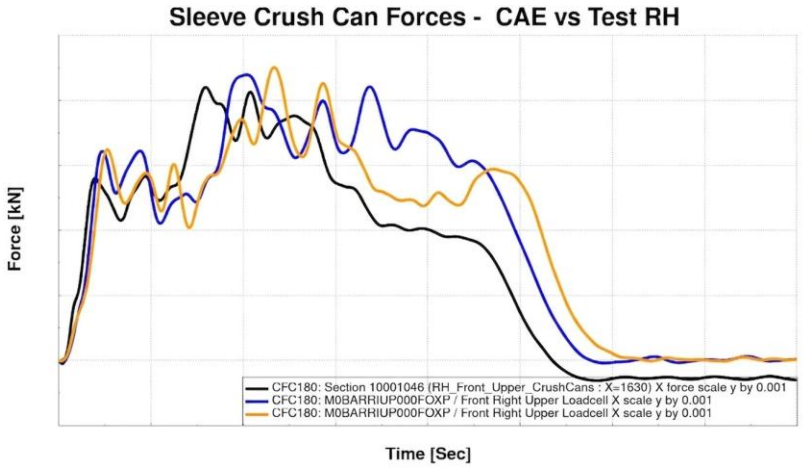
- Design Concept
- Design Loop 1
- Design Loop 2
- Vehicle Validation











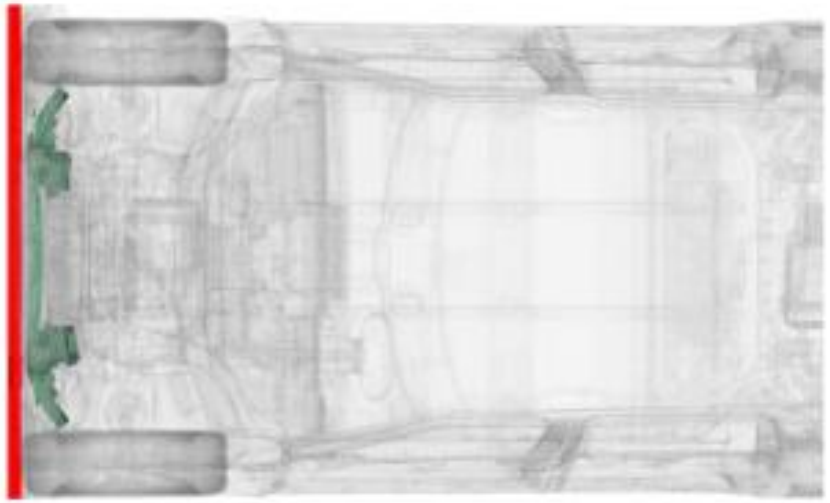
Outcome:

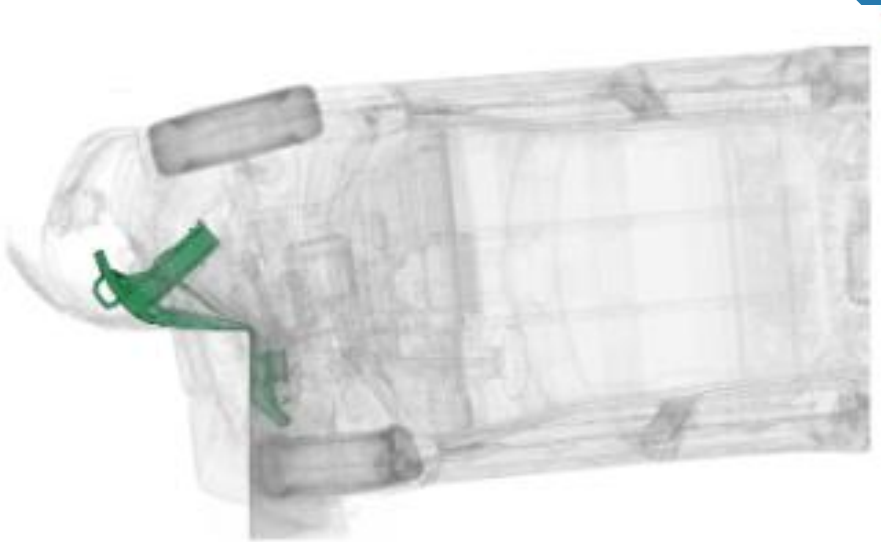
- Observed axial and pleating behavior of the crush can
- Behavior was repeatable over multiple tests
- Significant reduction of flange opening and maintaining the section capacity
- The deformation mode, crush force, and joint strength met internal targets

Crush Can Development Cycle

GDIS

- Design Concept
- Design Loop 1
- Design Loop 2
- Vehicle Validation





Vehicle level results:

- The deformation mode, crush force, and joint strength met the expectations.
- With robust bolt-on performance and achieving the pulse strategy, vehicle level validation showed good performance with the USNCAP and FMVSS test cases.
- IIHS MOT met the targets for pulse and structures intrusion rating.

Vehicle repairability

Reduced repair complexity

- Historical design with limited energy absorption in the bolt-on assembly
- Increased bolt-on great energy absorption at higher loads
- Advanced skillset not needed
- Easy to scale repair operations
- Insurance friendly design

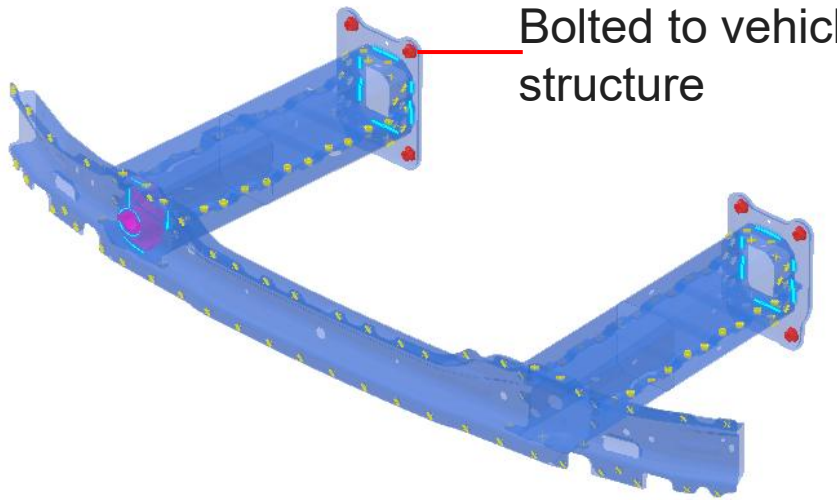
Reduced development

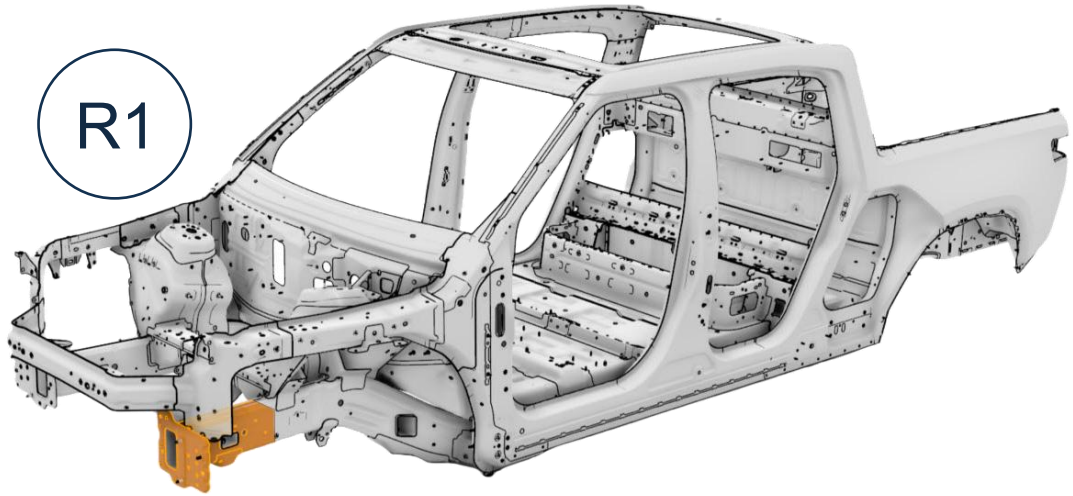
- 1:1 replacement
- Vehicle restored to original design condition
- Separate repair method not needed

Reduced Repair Complexity

Value added bolt-on construction

- Simplified repair process for low-speed instances
- Tooling and operational efficiency
- Technical skill reduction
- Historical optimization
    - Comparison with current R1
    - Hours Saved
- Procedure adoption

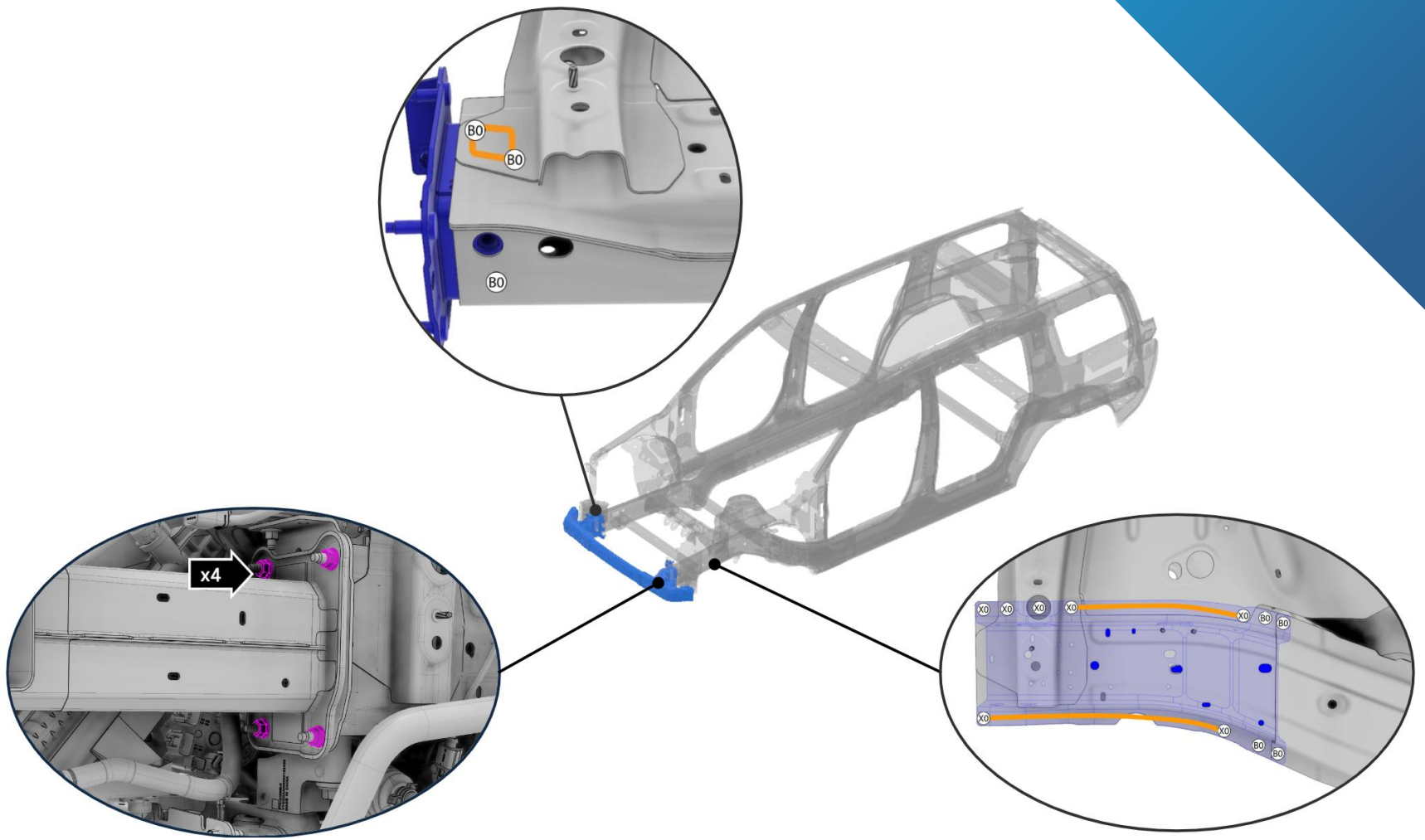




Reduced Repair Concept Development

Advanced concept integration

- Actionable repairability attributes
- Repairability assessments
- Repair conscious joining methods
- Identifying tooling accessibility limitations
- Accounting for joining deviations
    - Controlling heat, post manufacturing



GDIS

THANK YOU