GREAT DESIGNS IN STEEL

# A CATALOG OF DESIGN SOLUTIONS FOR BEV BATTERY ENCLOSURES

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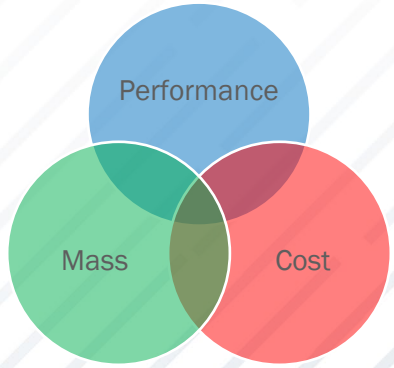
# AGENDA

- Project background, motivation, and objective
- Load cases and targets
- Baseline design concept
- Design options for balancing mass, cost, and performance
- Summary and conclusion

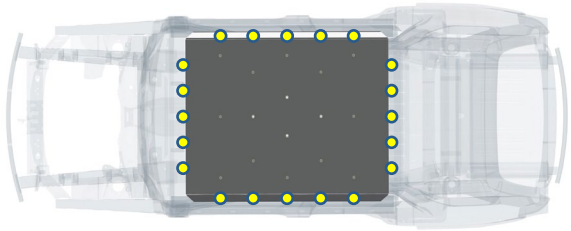
# PROJECT BACKGROUND AND MOTIVATION

- ArcelorMittal has collaborated with many OEMs and Tier 1 suppliers in recent years in developing steel battery enclosure concepts
- One thing quickly became obvious – there are few functional and performance requirements that are consistent between OEMs!
  - Consistent – box must be watertight and must accommodate interior and exterior packaging constraints
  - Variable – load cases, structural performance criteria, cooling strategy, protection shield strategy, attachment strategy, etc.
- In addition, OEMs have different approaches to balancing mass, cost, and performance



# PROJECT BACKGROUND AND MOTIVATION

- However, there are some common themes within the variable items
  - Sill/rocker bolts for BIW attachment are regularly used
    - May also have front/rear or other BIW attachments
  - Side crush and natural frequency load cases are almost always requested
    - Pass/fail criteria can still vary widely



# PROJECT OBJECTIVE

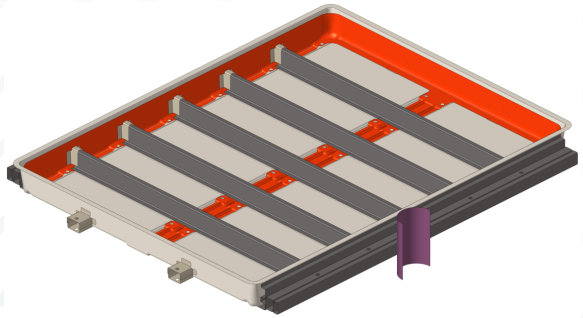
- This objective is to create a steel battery enclosure concept focused on a few key measures
  - Part count reduction and ease of manufacturing and assembly (DFMA)
  - Satisfy the most frequently requested load cases and associated performance targets
  - Provide a catalog of design variations to enable OEMs and Tier 1 suppliers to customize a solution for their specific requirements

# LOAD CASES AND TARGETS

- Based on the regularity of customer requests two primary structural load cases were selected
- Targets for these load cases were established considering commonly specified customer requirements

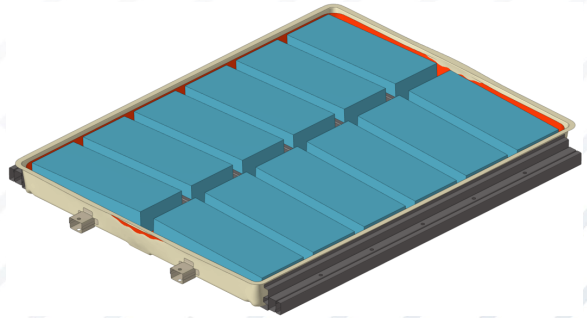
## Side Crush

- Set up per GB-38031 test method
- 200 kN pole force
- *Target – no module contact below 200 kN of pole force*



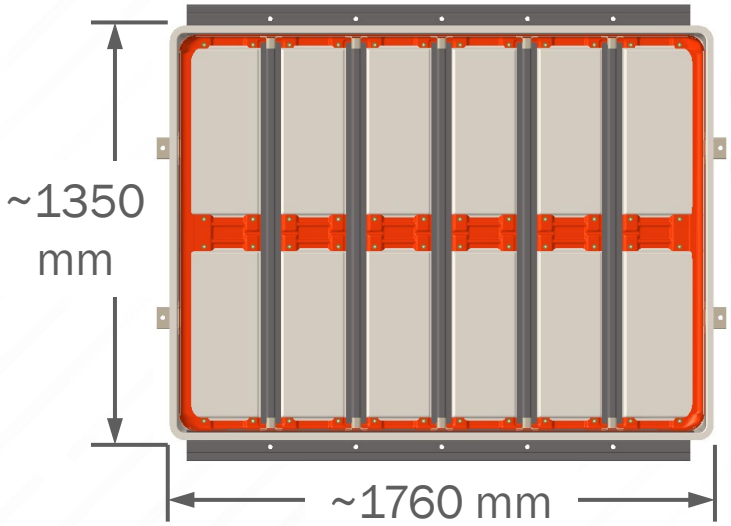
## Natural Frequency

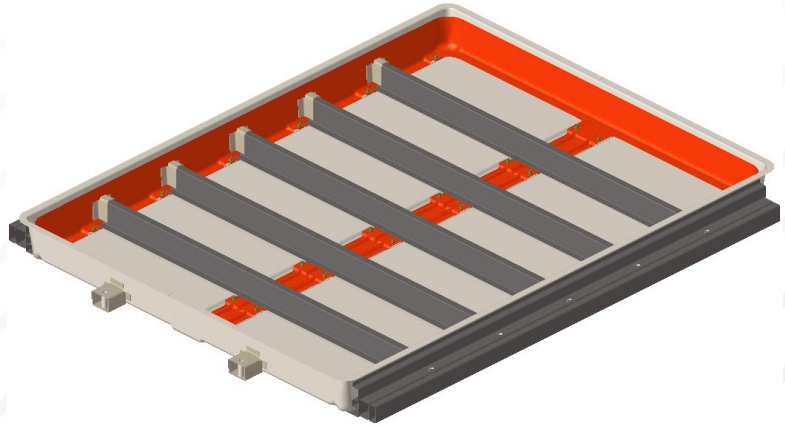
- Constrained at perimeter BIW connections
- Total module mass = 372 kg
  - 12 modules; 31 kg each
- *Target – first structural mode > 30 Hz*



# DESIGN HIGHLIGHTS

- Dimensions typical of battery enclosures for SUV BEVs on the road today
- Single piece stamped tray for improved watertightness
  - Deep drawing steel (DDS) enables aggressive draft angles and radii
- PHS inner frame leads to low part count
  - 9 uniquely tooled parts; 44 parts total*
  - Module attachment features incorporated into the inner frame
- Roll form sections for efficient material utilization
- Primarily assembled using spot welding
  - Less risk of thermal distortion during assembly
- Structural adhesive enables mass reduction while meeting performance targets



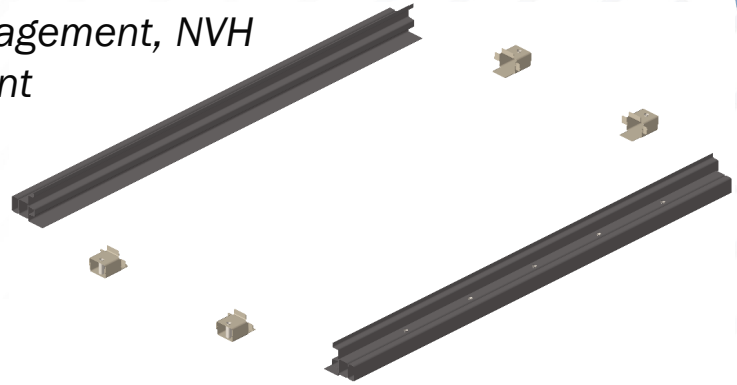



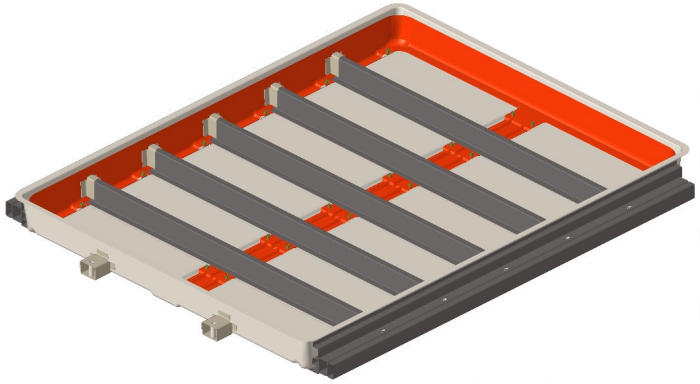
** Part counts are for the structural items shown here. Common, off-the-shelf items like bolts, T-nuts, weld nuts, etc. are not included.*

# DESIGN DETAILS

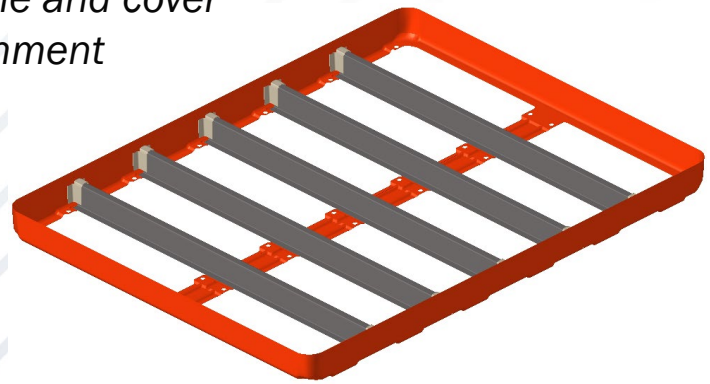
**Stamped tray**
*Eliminate bottom sealing*

**Outer structures**
*Intrusion management, NVH BIW attachment*





**Inner Frame**
*Intrusion management, NVH Module and cover attachment*

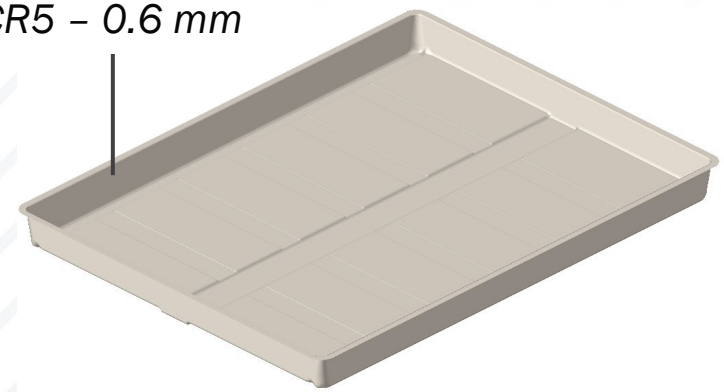


**Cover**
*Sealing*

*The cover is not considered a structural component and has not been included in the cost or performance predictions herein.*

# BILL OF MATERIALS

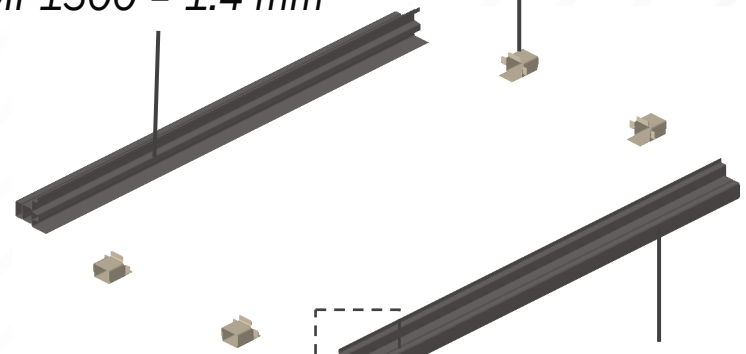
Stamped tray
*CR5 – 0.6 mm*



- CR5
- HSLA420T
- PHS 1500
- MP1500

Frt/Rr BIW Brackets
*HSLA420 – 1.5 mm*

Outer-W (each side)
*MP1500 – 1.4 mm*

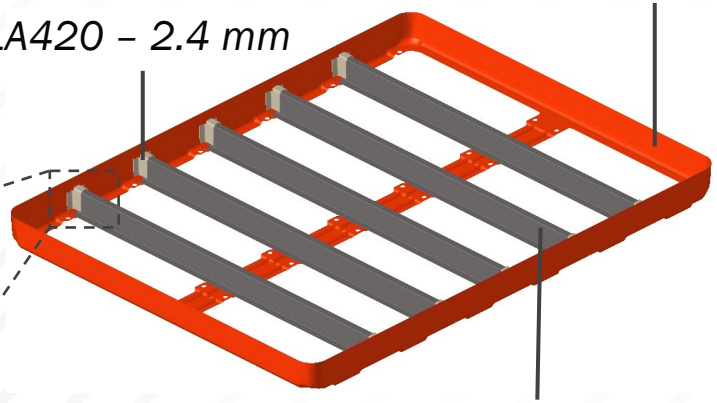


Outer-8 (each side)
*MP1500 – 1.8 mm*

Inner Ring
*PHS 1500 – 1.3 mm*

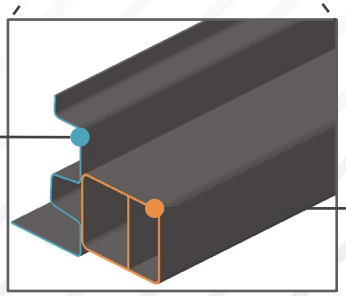
Crossmember Brackets
*HSLA420 – 2.4 mm*

Crossmember Bracket



Crossmember

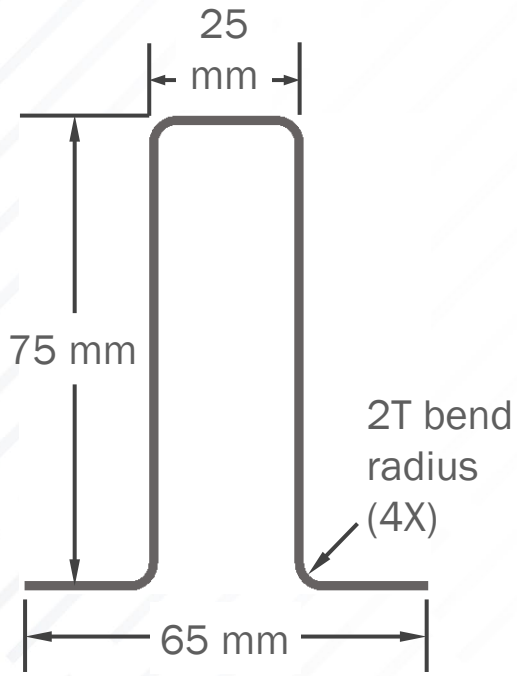
Crossmembers
*MP1500 – 1.4 mm*



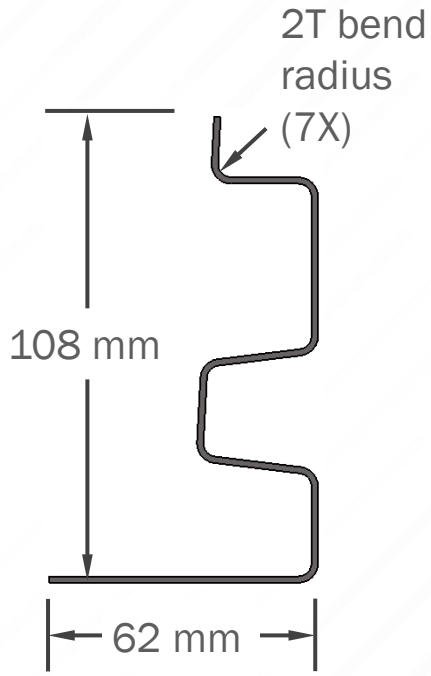
Outer-W
*MP1500*
*1.4 mm*

Outer-8
*MP1500*
*1.8 mm*

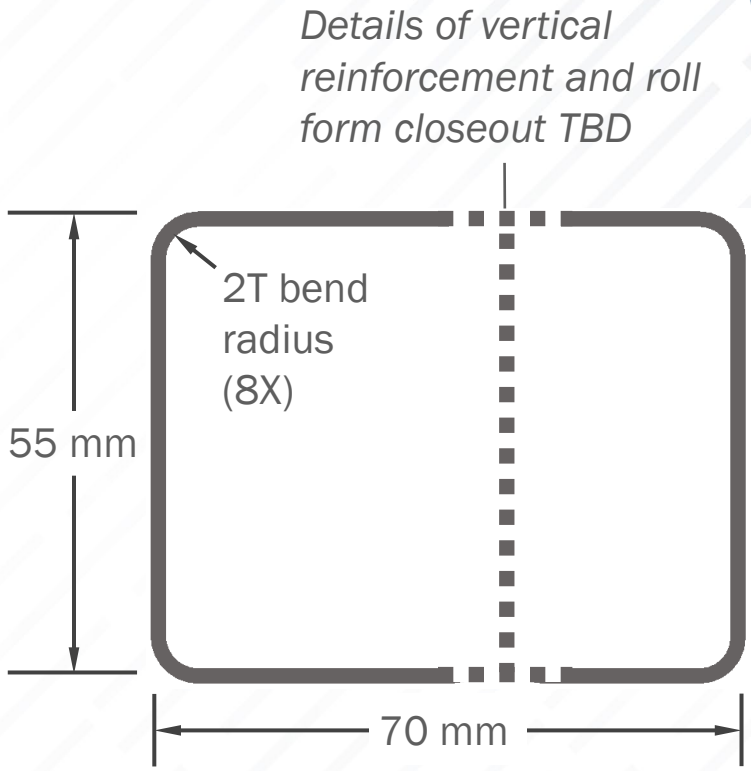
# ROLL FORM SECTIONS




**Crossmember Profile**
*MP1500 – 1.4 mm*



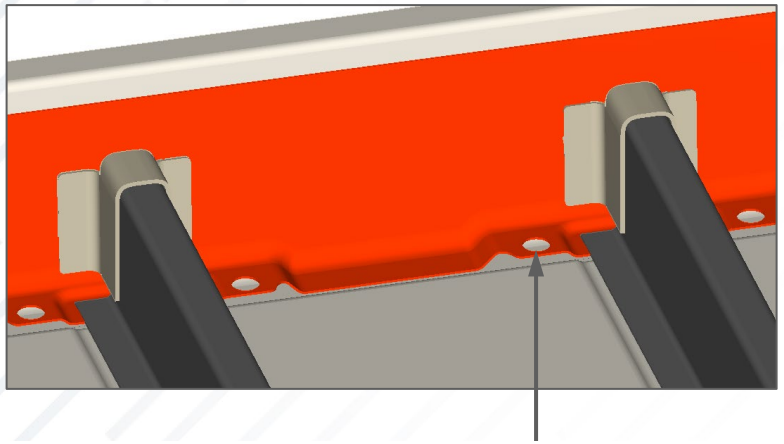

**Outer-W Profile**
*MP1500 – 1.4 mm*



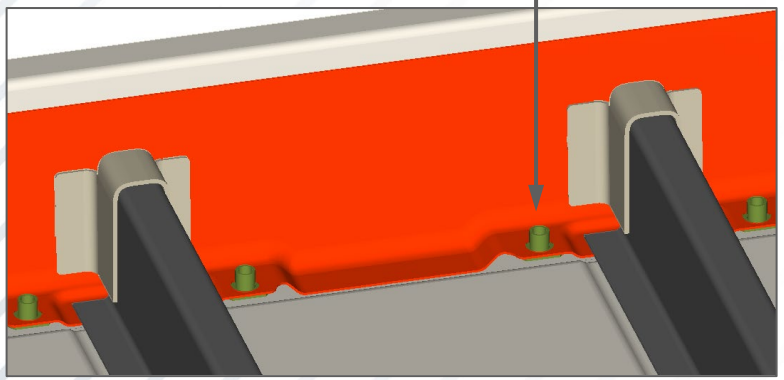

**Outer-8 Profile**
*MP1500 – 1.8 mm*

*MP1500 enables 2T bend radii for the roll form sections.*
*This maximizes roll form flat widths and improves packaging within the enclosure.*

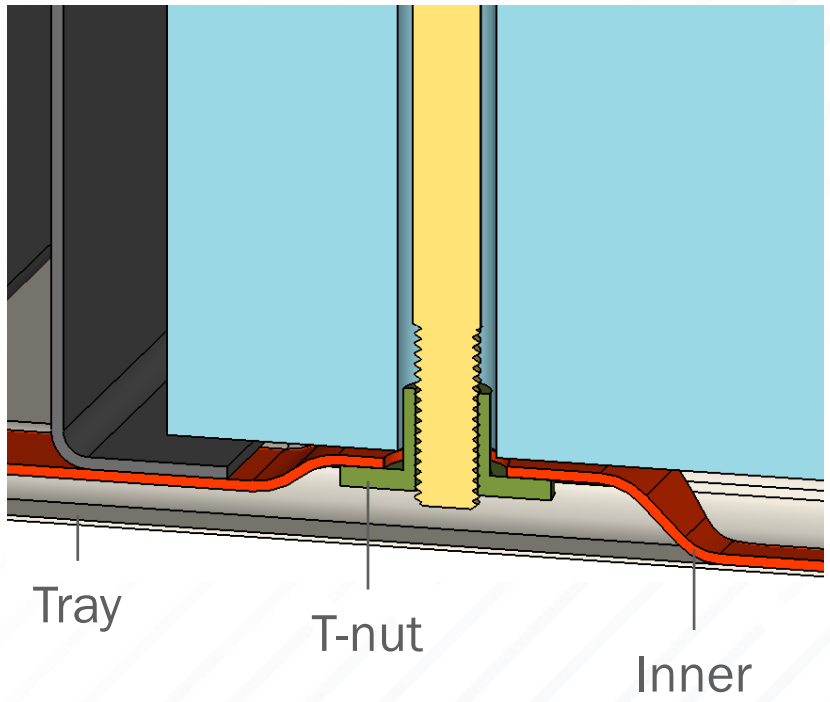
# MODULE ATTACHMENT



***Pierced holes in the inner ring*** to accommodate ***protrusion welded T-nuts*** for module attachment (48X)

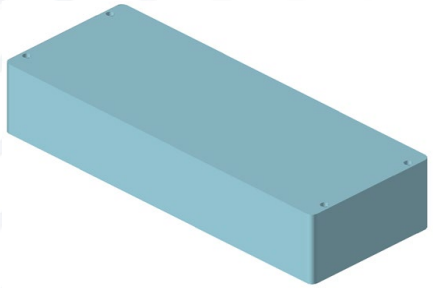


Cross section through module attachment



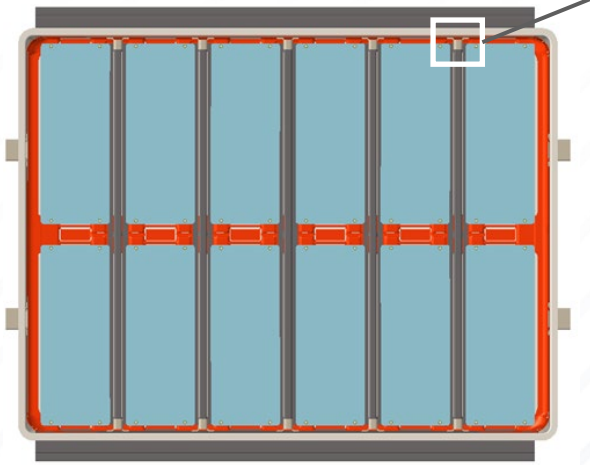

*T-nuts for module attachment are captured between the tray and the inner*

# MODULE CLEARANCES

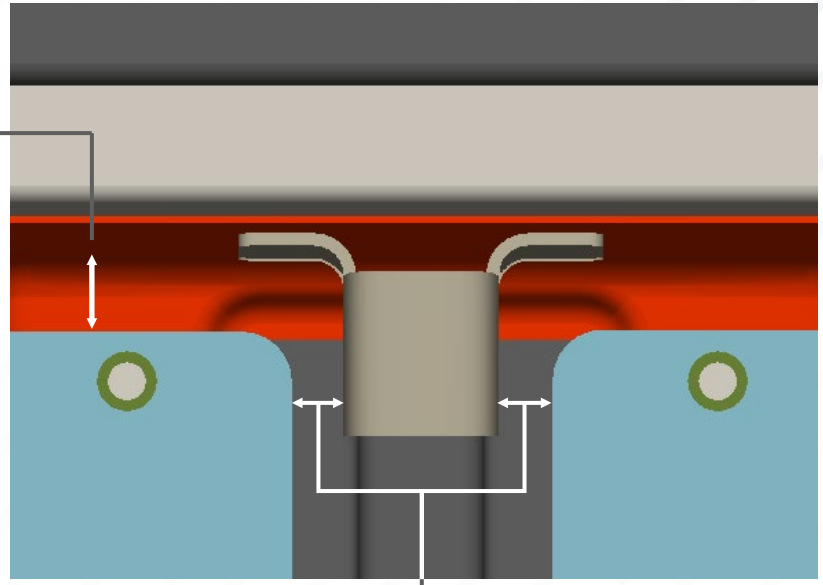


*Module*
(590 x 225 x 109) mm
Mass = 31 kg

*Twelve modules are packaged within the enclosure*
Total module mass = 372 kg



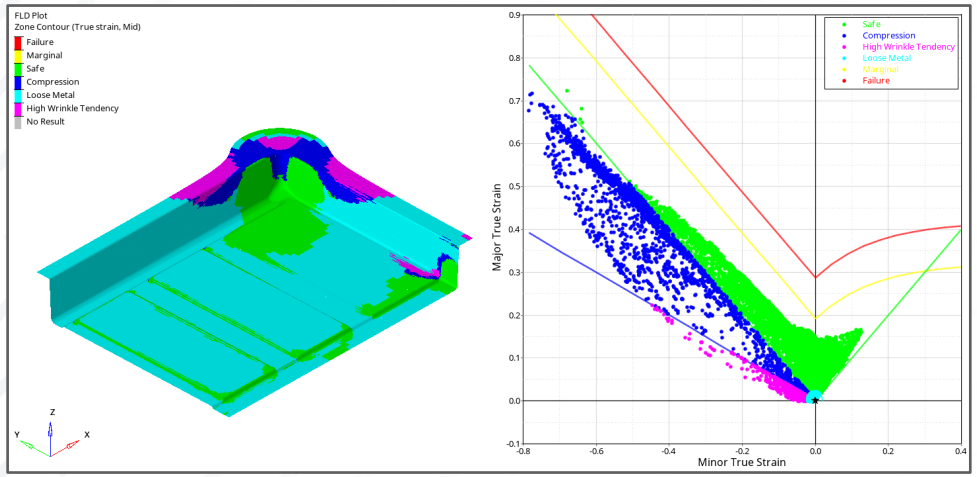
*20 mm intrusion space* between the modules and the enclosure side



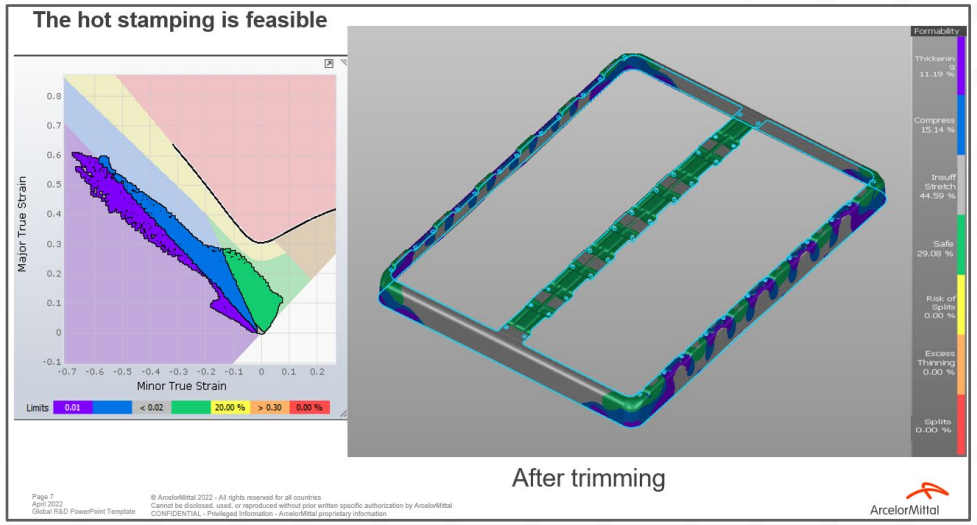
*10 mm clearance* between the modules and the crossmember brackets

# FORMING FEASIBILITY

- Forming feasibility evaluations for the tray and the inner were performed by ArcelorMittal forming experts




*"The tray shows some wrinkling but forming feasibility has been established for 0.6mm CR05. Wrinkling can be eliminated via process development. One-quarter of the tray is shown with symmetry applied".*



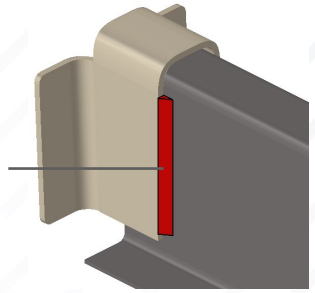

*Tray (cold stamping) and inner (hot stamping) formability have been evaluated by ArcelorMittal forming experts. Both parts are considered forming feasible.*

# WELDING

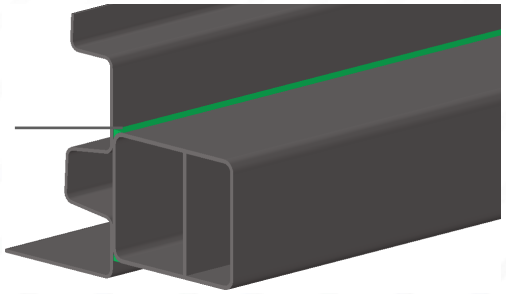
- The battery enclosure is assembled using a combination of spot welding and gas metal arc welding (GMAW)
  - GMAW – total weld length up to 7,500 mm
    - Intermittent stitch welds for attaching outer-8 to outer-W will reduce the total length
  - Spot welding – 528 assembly spot welds as shown in the table
    - Further weld optimization should reduce this count

| Spot weld connections | Type | Qty | Stack up | |
|---|---|---|---|---|
| | | | Grade | Gauge (mm) |
| Crossmember end bracket to inner | 2T | 40 | HSLA420 | 2.4 |
| | | | PHS 1500 | 1.3 |
| Crossmember flange to inner | 2T | 40 | MP1500 | 1.4 |
| | | | PHS 1500 | 1.3 |
| Crossmember flange to tray | 2T | 160 | MP1500 | 1.4 |
| | | | CR05 | 0.6 |
| Inner to tray | 2T | 196 | PHS 1500 | 1.3 |
| | | | CR05 | 0.6 |
| Inner, tray, and outer-W | 3T | 68 | PHS 1500 | 1.3 |
| | | | CR05 | 0.6 |
| | | | MP1500 | 1.4 |
| Inner, tray, and front/rear BIW bracket | 3T | 24 | PHS 1500 | 1.3 |
| | | | CR05 | 0.6 |
| | | | HSLA420 | 1.5 |

Crossmember end bracket to crossmember arc weld

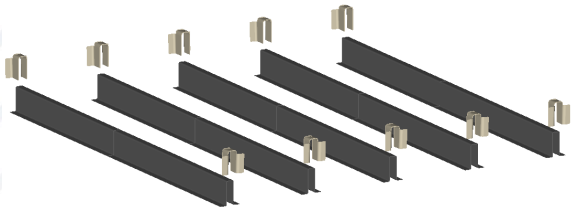


Outer-W to outer-8 arc weld

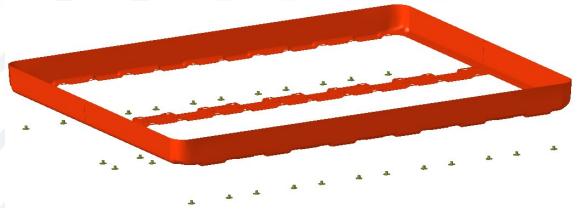


*Weld combinations have been reviewed by ArcelorMittal welding experts. All welds are considered feasible with proper process development.*

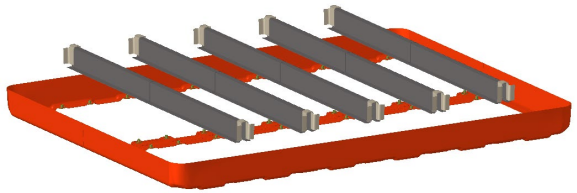
# ASSEMBLY SEQUENCE



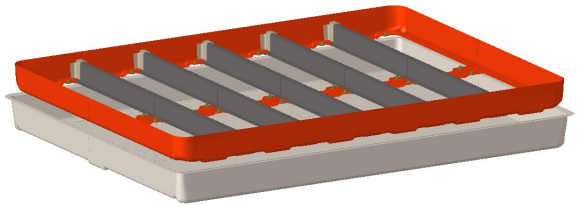
Step #1A - Crossmember end brackets to crossmembers (GMAW)



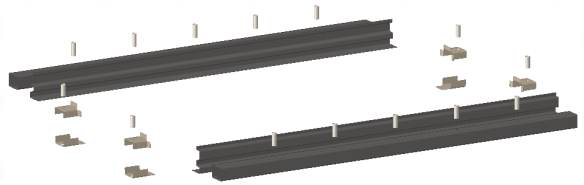
Step #1B – attach T-nuts to inner



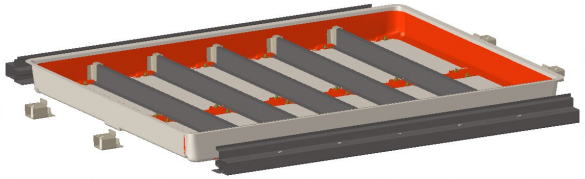
Step #2 – Crossmember sub-assemblies to inner (2T spot welds)



Step #3 – Inner sub-assembly to tray (2T spot welds)

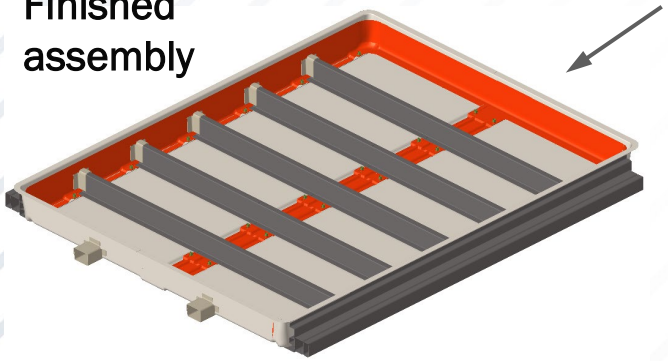


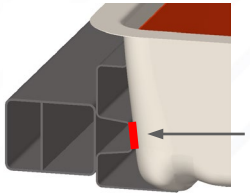
Step #4a – Outer-W to outer-8 with spacers; front/rear BIW brackets with spacers (GMAW)



Step #4b – attach outer sub-assemblies (3T spot welds plus adhesive)

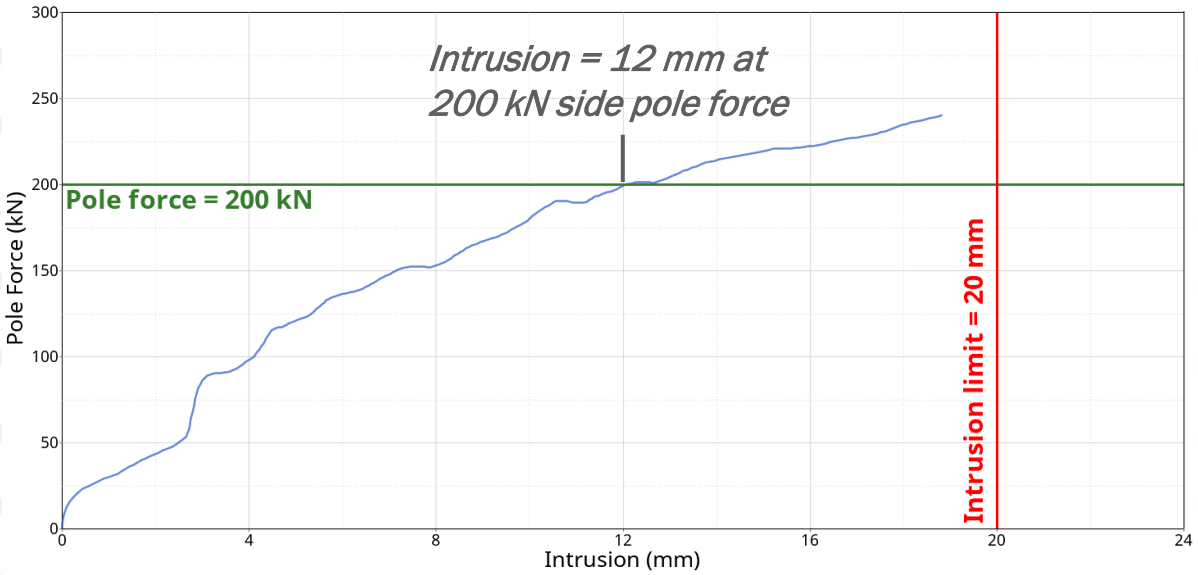
**Finished assembly**

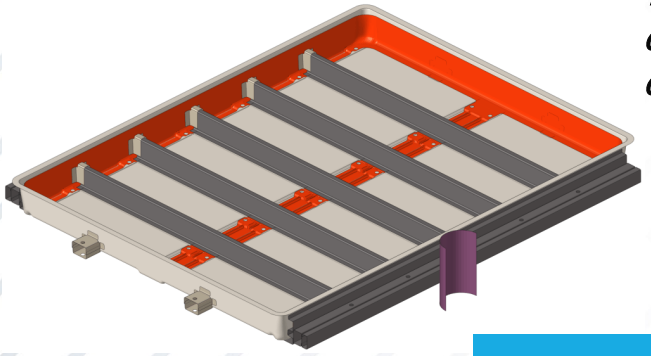




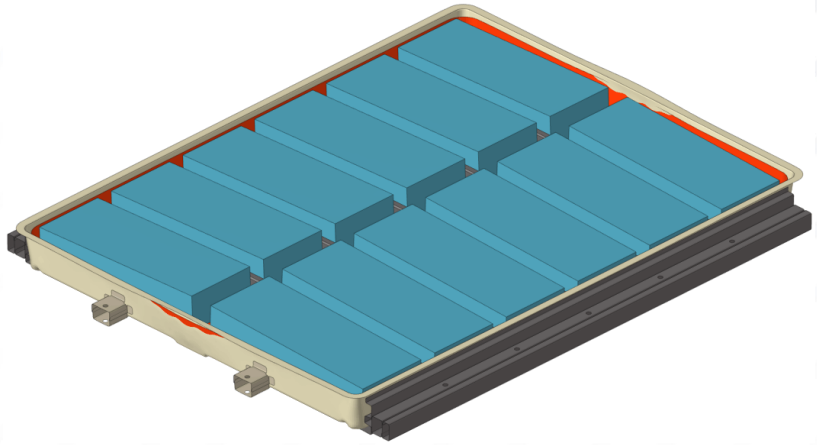
Adhesive between tray and outer-W

# STRUCTURAL PERFORMANCE



*Target – less than 20 mm of intrusion below 200 kN of side pole force*



*First structural mode = 31 Hz (target > 30 Hz)*

- Total module mass = 372 kg (12 modules; 31 kg each)
- *Only perimeter BIW attachments used – 5X along each side rail and two each at the front and rear.*

*Side crush and natural frequency targets are met for the baseline design concept*

# MASS AND COST

- The mass of the steel battery enclosure concept shown here is 63.5 kg
  - This mass includes the tray, inner, crossmembers, outer rails, front/rear brackets, and spacers
  - Does not include the cover, cooling, or fasteners
- ArcelorMittal worked with Intellicosting to generate a cost estimate for the steel battery enclosure
  - Intellicosting is an industry leader in providing detailed forensic cost analysis
  - Their approach combines detailed teardown analysis with Activity-Based Costing, manufacturing knowledge and procurement experience. The Activity-Based Cost methodology analyzes an optimized manufacturing process to ensure the best pricing for the component or sub-system.
- The cost estimate for the steel battery enclosure concept is $323.
  - Manufacturing and assembly of all stamped and roll formed components
  - Installing the T-nuts for module attachment
  - Installing the weld nuts on the tray flange for cover attachment
  - Adhesive as shown in the assembly sequence
  - Assembly e-coating

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# DESIGN OPTIONS

- Options being covered in today's presentation
  - Module cooling
  - Additional BIW attachments
  - Discrete sill brackets
- Options included in the appendix
  - Laser welded blank inner
  - Multi-piece, cold stamped inner
  - Flanged crossmember
  - Reduce number of crossmembers

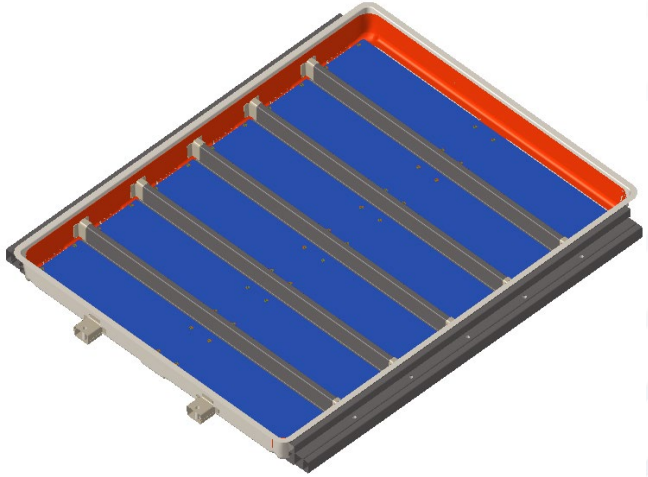
# DESIGN OPTIONS

## MODULE COOLING

- Exterior steel chill plate attached to the bottom of the tray
  - Cooling channels formed via embossments in the lower sheet
  - Coolant is outside of the battery module space
  - Concept is under development
- Interior; either single or multiple chill plates
  - More traditional method for module cooling
  - Requires coolant and plumbing inside the module space

*Exterior steel cooling concept (looking at the bottom of the enclosure)*

*Interior cooling concept*

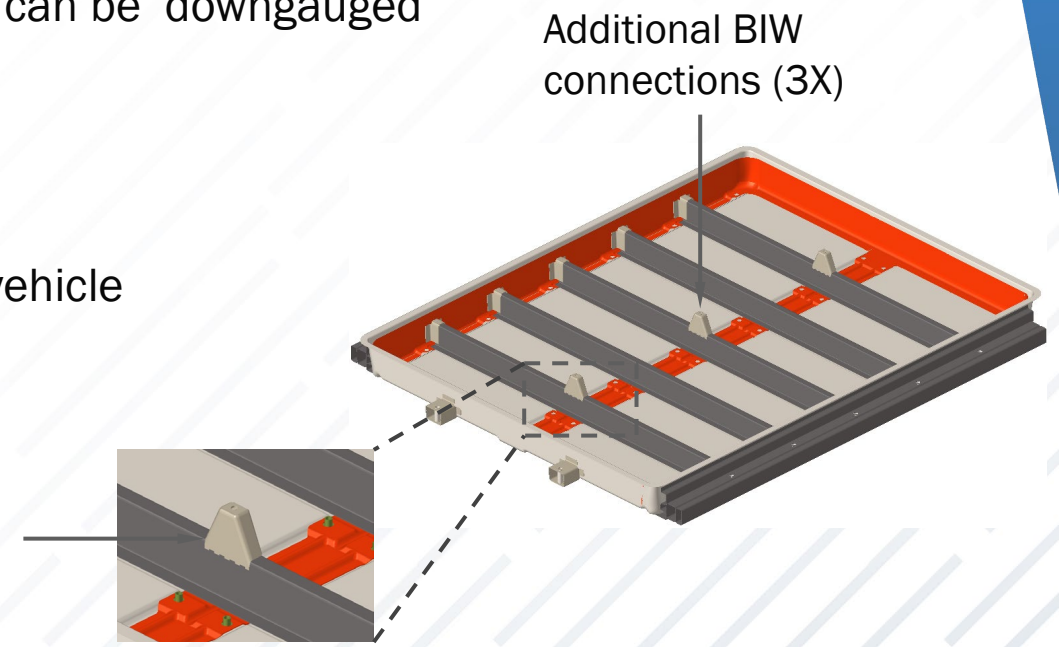


***Concepts only – these have not been fully developed***

# DESIGN OPTIONS

## ADDITIONAL BIW ATTACHMENTS

- Benchmarking shows a number BEVs that attach the battery to the BIW using connections that are central to the pack.
- Pros
  - Simulations show an 11 Hz improvement in the battery pack first structural mode if these connections are added
  - This could lead to mass savings if other components can be  downgauged
- Cons
  - Increases part count
  - Adds to assembly time and complexity
  - Increases complexity of mounting the battery to the vehicle

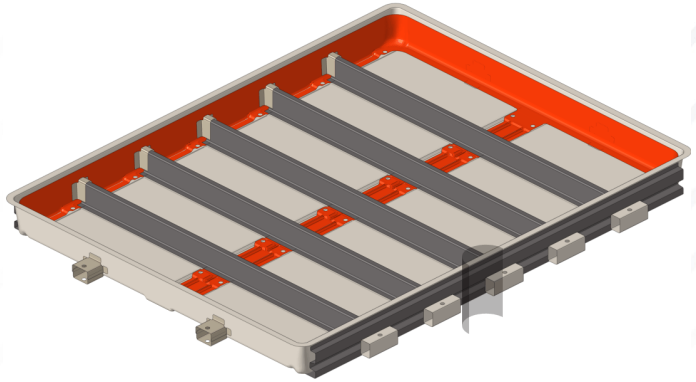


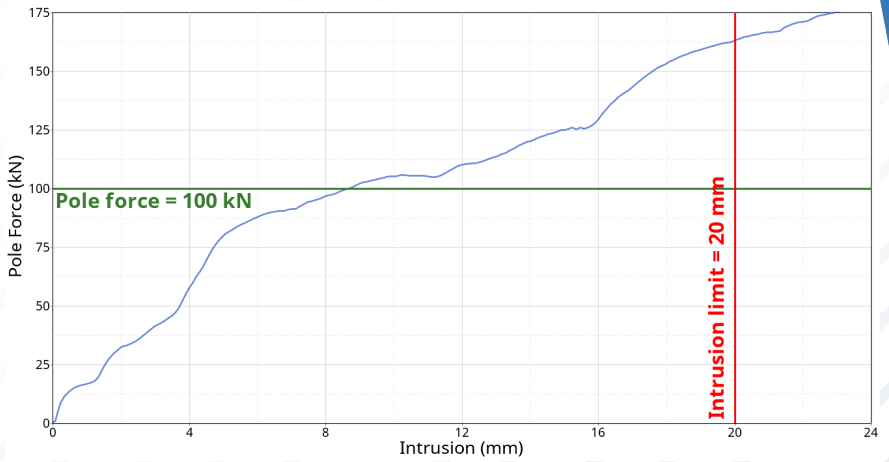
# DESIGN OPTIONS

## DISCRETE SILL BRACKETS

- The outer-8 section can be replaced with discrete BIW attachment brackets if the side crush requirement is lower
- Pros
  - Reduced mass
    - Over 10 kg mass reduction for the concept shown here, assuming a 100 kN side pole requirement
  - Reduced welding
    - Removes ~4,000 mm GMAW
  - Brackets can be designed to achieve modal performance
    - Concept shown here still meets 30 Hz first mode target
- Cons
  - Increased part count
    - Five brackets each side instead of a single roll form

*Side crush performance >200 kN is possible through geometry modifications and/or gauge increases of the baseline concept*





# SUMMARY AND CONCLUSION

- A family of steel battery enclosure solutions has been proposed to address the specific and varied needs of our automotive customers
- The data presented here enables OEMs and suppliers to easily create customized steel battery enclosure solutions to effectively balance
  - Mass
  - Cost
  - Performance

# FOR MORE INFORMATION

Visit our booth at GDIS!

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# GREAT DESIGNS IN STEEL