GREAT DESIGNS IN STEEL

TWENTY YEARS

# COST EFFECTIVE, FLEXIBLE, SCALABLE HV BATTERY ENCLOSURE SOLUTIONS

Juan Armendariz

Katcon

# AGENDA

- **Katcon Overview**
- HV Battery Enclosure
- Design
- Performance
- Summary
- Conclusion

# KATCON AT A GLANCE

## Company Highlights

World leader for emissions control, thermal insulation and lightweight mixed material structures for the transportation industry

Established in 1993, HQ in Monterrey, Mexico

Global expansion in 2009 through the acquisition of Delphi’s exhaust business

In 2017, launched its Advanced Materials division to design, engineer and manufacture composite products

Acquired Wendt Automotive GMBH in 2018 to enter the thermal insulation business

11 manufacturing sites and 5 tech centers, in 8 countries

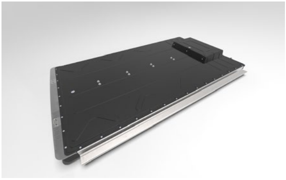
+1,500 employees representing  over 20 nationalities

Family-owned, part of diversified group with experience in manufacturing, real estate, and food & beverage

## Business divisions

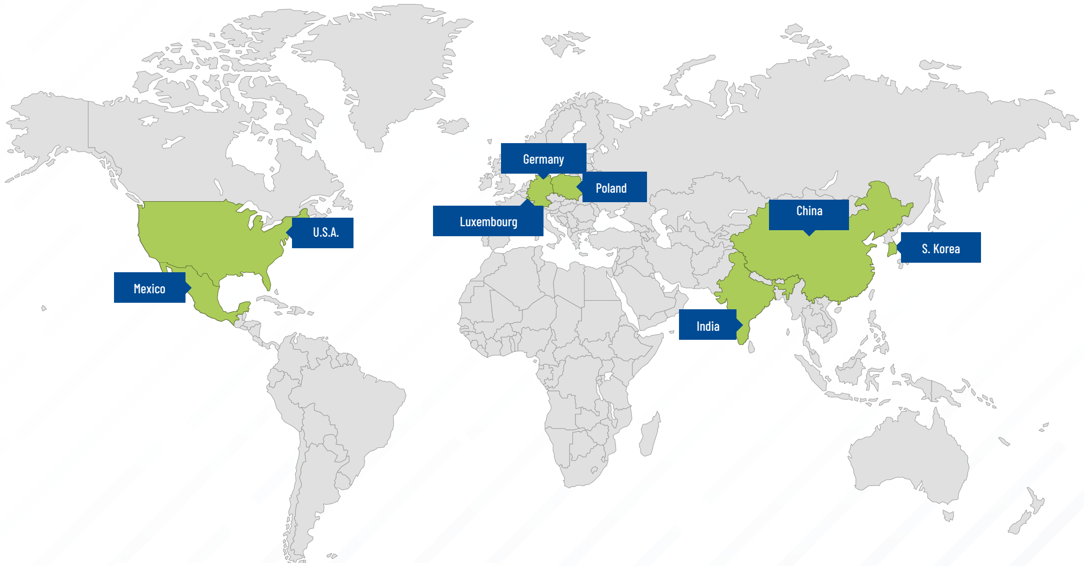
Emissions control

Thermal Insulation



Advanced Materials

## Global design, engineering, and manufacturing platform

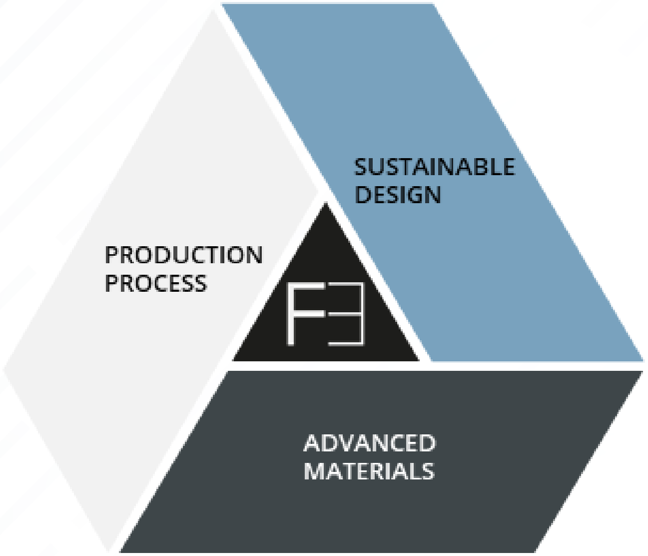



KATCON

# FORWARD ENGINEERING

## YOUR PARTNER FOR AUTOMOTIVE. COMPOSITE. SOLUTIONS.

FORWARD ENGINEERING




Industry Leading Design & Engineering Partner for Sustainable Products and Economical Lightweight Solutions

- “Material & Production Based Engineering” – From concept to series production
- Accelerate product development by asking and answering the right questions at the right time
- Increase confidence in performance-, cost- and CO2 forecasts
- Reduce validation costs & time with target-oriented CAE-analysis
- Enable well-founded decisions & empower our customer with unique material and technology know-how
- Offer independent & flexible service in a strong composite network in Germany and globally

# DRIVING SUCCESS THROUGH COLLABORATION

Combining the Global Tier 1 strength and resources of KATCON with Forward Engineering's industry leading mixed material design expertise, the team engaged industry leading material and technology suppliers in this collaborative program to employ the latest proven cost-effective material and process technologies in the development of KATCON's new battery enclosure solution sets

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# RECHARGEABLE ENERGY STORAGE SYSTEM

### State-of-the-art design

- Tailored for weight optimization
- Improved thermal management
- CAE validated with production relevant geometries and OEM load cases
- 20-30% lighter than steel

### Cost-effective

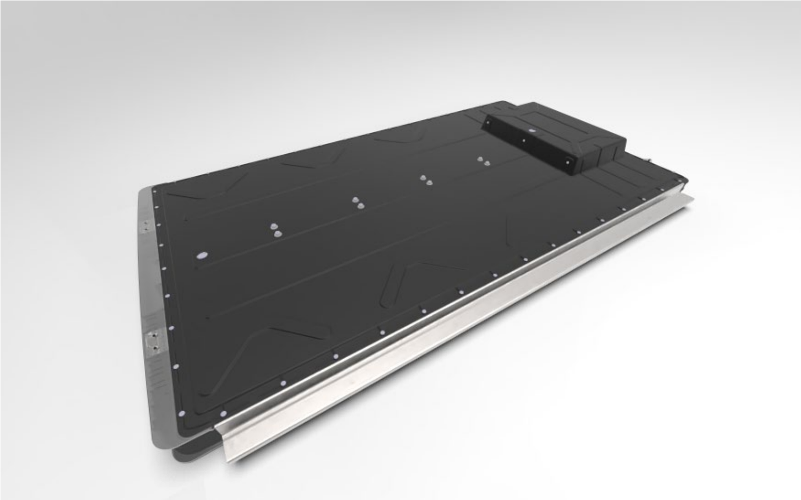
- Cost was critical to select the appropriate material for each component
- Reduced capex investment by intelligent mix of materials and manufacturing technologies
- Competitive cost vs steel intensive

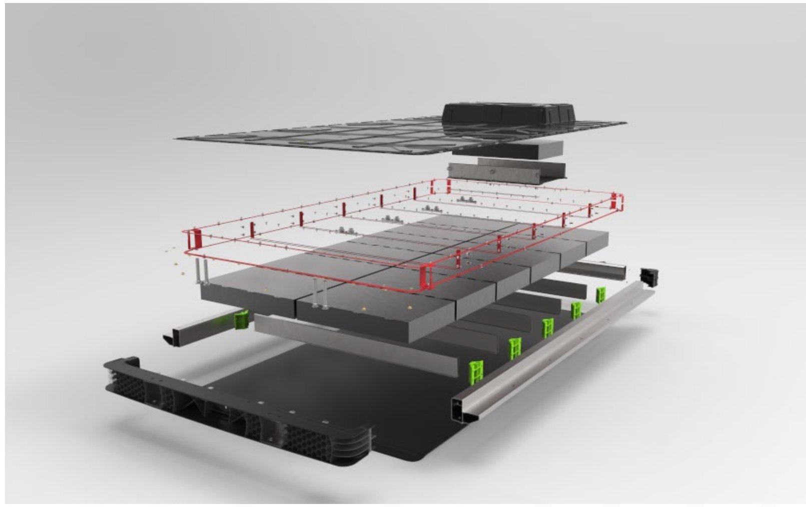
### Flexible

- Modular design simplifies adaption to multiple products
- Composite nodes balance part integration with flexibility
- Hybrid joints support flexibility while ensuring seal integrity

### Scalable

- Forming processes and geometry allows for low and high-volume applications





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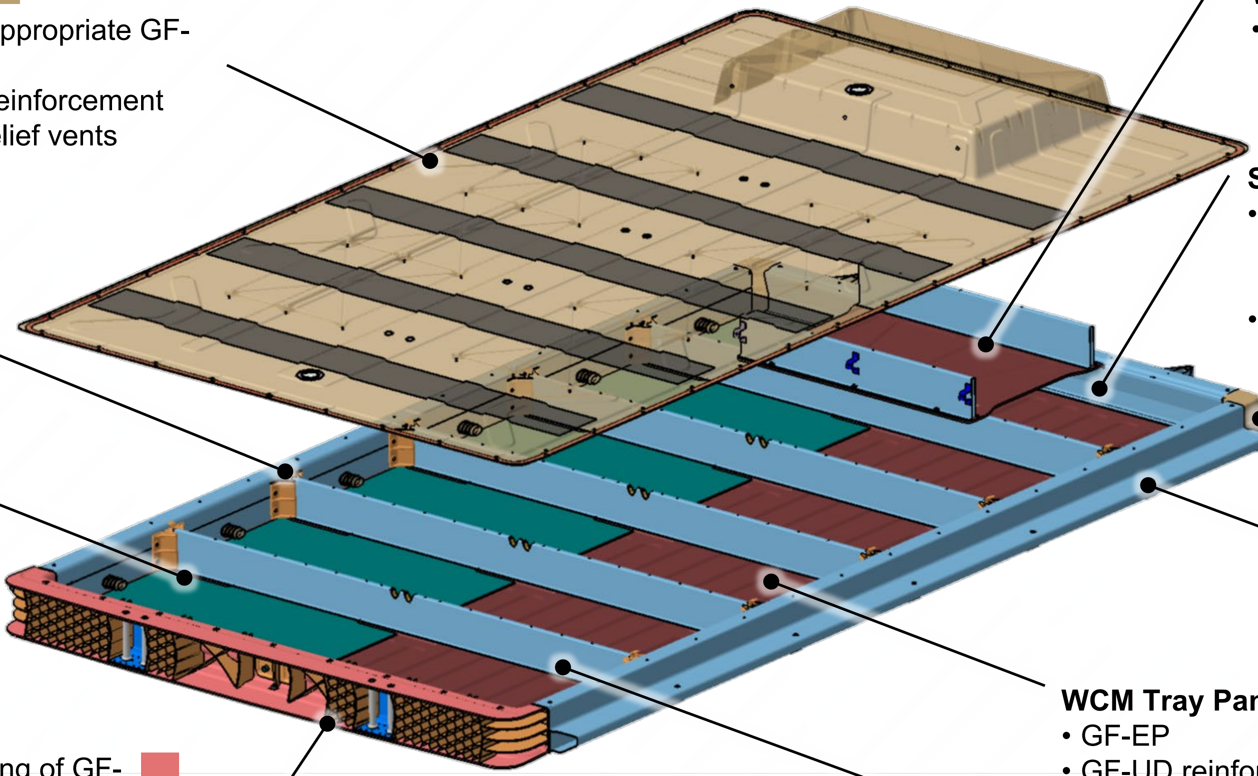
# DESIGN OVERVIEW | RIGHT MATERIAL AT THE RIGHT PLACE

**SMC Cover Panel**
- Thermal runaway/FST appropriate GF-UP-SMC
- One shot incl. GF-UD Reinforcement
- Steel inserts for press relief vents

**LFT Crossmember Bracing**
- Injection molded LGF-PA6

**Cooling Plate**
- Aluminum
- made of FSW sections / rollbonded sheets

**GFRTP Front Header**
- One shot Injection-overmolding of GF-PA6-Organosheet
- Local GF-PA6-UD reinforcement
- High integration potential of features
- Overmolding of energy absorbers & ribs
- Steel inserts for structural connections



**WCM Upper Frame**
- GF-EP

**Steel Rear Lateral Beam**
- UHSS DP DP780 (optional DP980) 1-shell roll-forming profile
- UHSS Welded Brackets for BiW connection

**SMC RR Nodes**
- High strength GF-UP

**Steel Longitudinal Beam**
- UHSS DP1180 1-shell roll-forming profile

**WCM Tray Panel**
- GF-EP
- GF-UD reinforcement

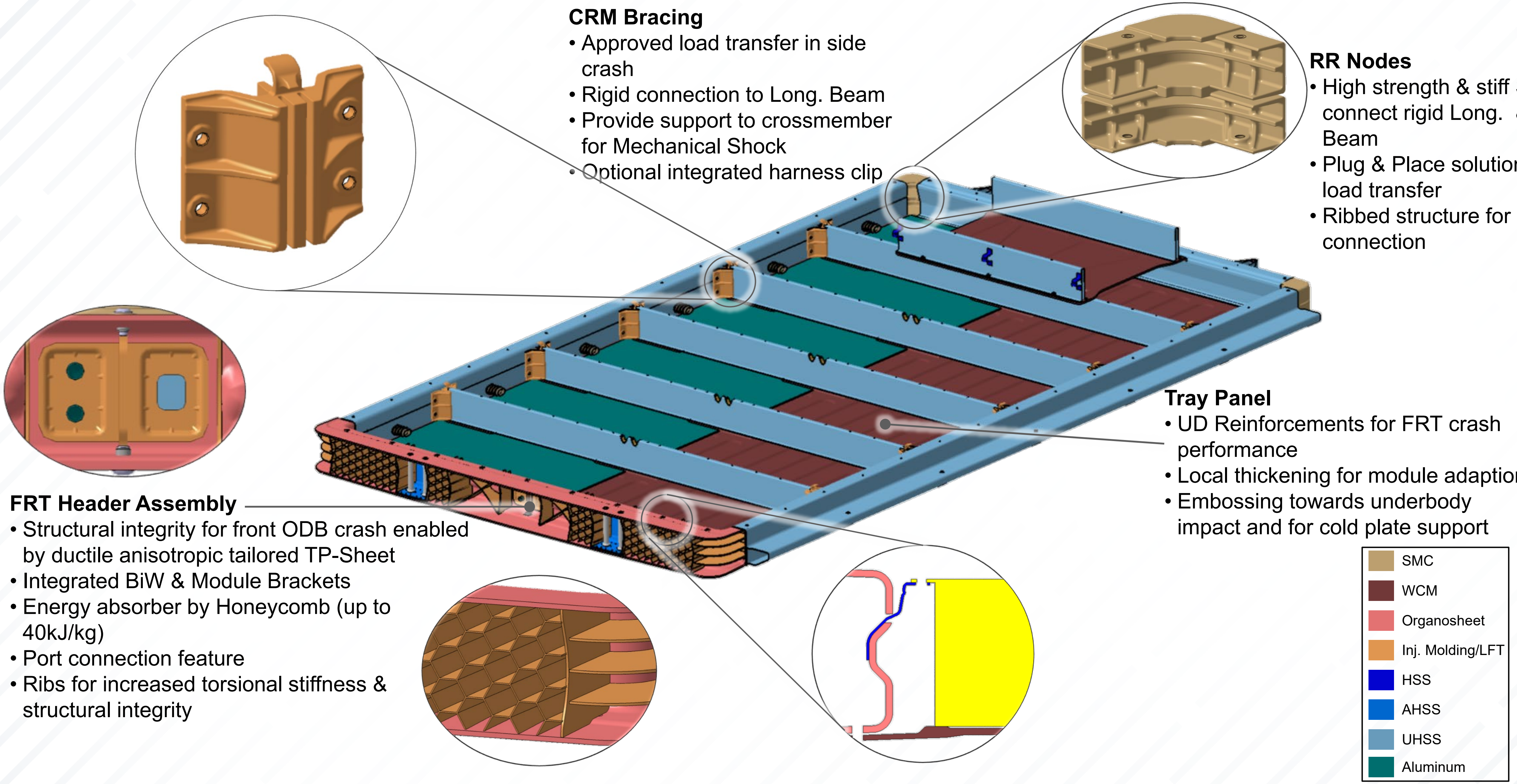
**Steel Crossmember**
- UHSS DP980 1-shell roll-forming profile

SMC
WCM
Organosheet
Inj. Molding/LFT
HSS
AHSS
UHSS
Aluminum

# DESIGN FEATURES | LWR CASE (1/2)

**CRM Bracing**
- Approved load transfer in side crash
- Rigid connection to Long. Beam
- Provide support to crossmember for Mechanical Shock
- Optional integrated harness clip

**RR Nodes**
- High strength & stiff SMC node to connect rigid Long. & Lateral Beam
- Plug & Place solution for simple load transfer
- Ribbed structure for stiffening connection




**Tray Panel**
- UD Reinforcements for FRT crash performance
- Local thickening for module adaption
- Embossing towards underbody impact and for cold plate support

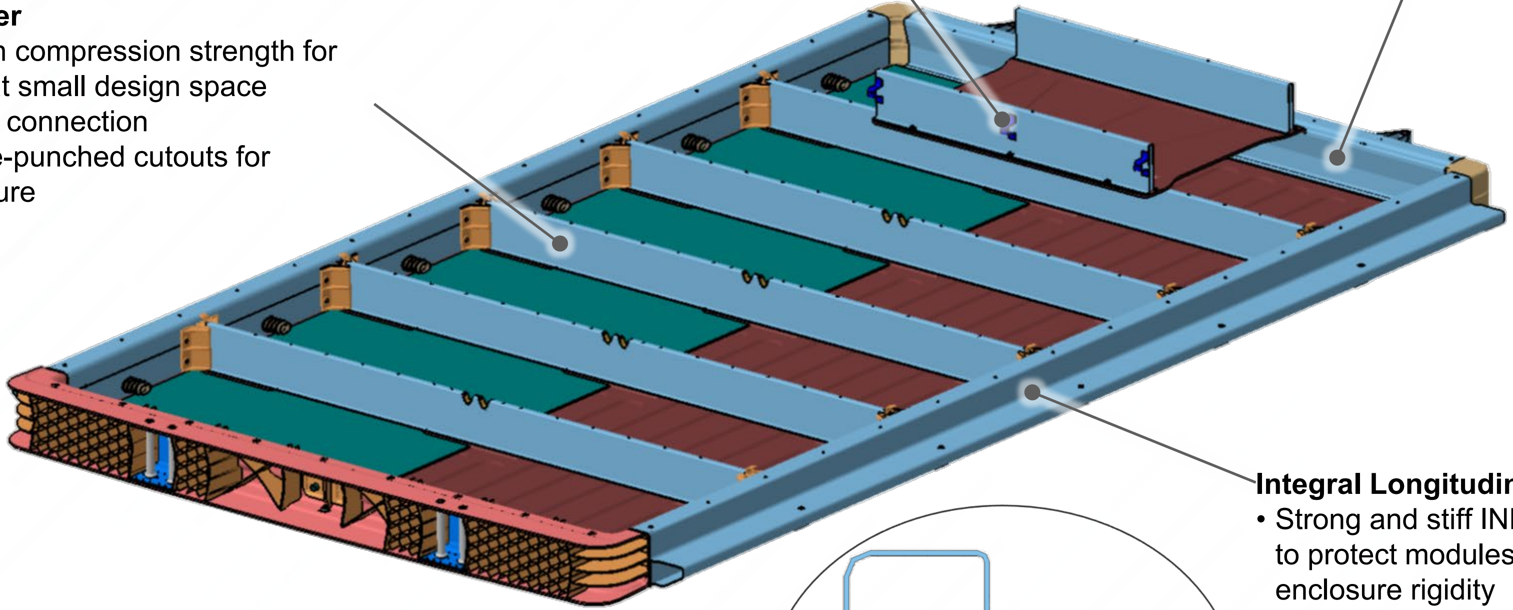
**FRT Header Assembly**
- Structural integrity for front ODB crash enabled by ductile anisotropic tailored TP-Sheet
- Integrated BiW & Module Brackets
- Energy absorber by Honeycomb (up to 40kJ/kg)
- Port connection feature
- Ribs for increased torsional stiffness & structural integrity

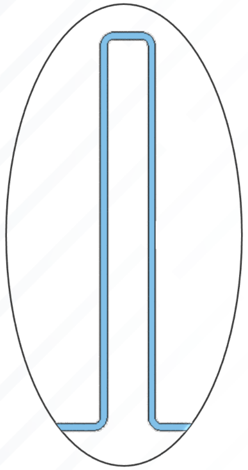
# DESIGN FEATURES | LWR CASE (2/2)

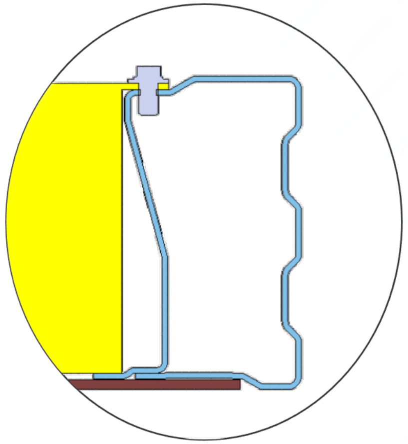
**Steel Crossmember Brackets**
- Stiffening Cover Panel

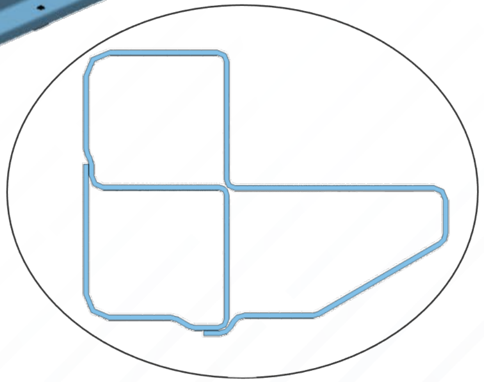
**RR Lateral Beam**
- Integrated module & UPR Frame attachment
- Swaging area for RR Nodes adaption

**Crossmember**
- Provide high compression strength for side crash at small design space
- Stiff module connection
- Optional pre-punched cutouts for harness fixture









**Integral Longitudinal Beam**
- Strong and stiff INR profile section to protect modules and ensure enclosure rigidity
- OTR profile section tailored for side impact energy absorption and BiW-attachment
- Reduced part count and assembly effort

- SMC
- WCM
- Organosheet
- Inj. Molding/LFT
- HSS
- AHSS
- UHSS
- Aluminum

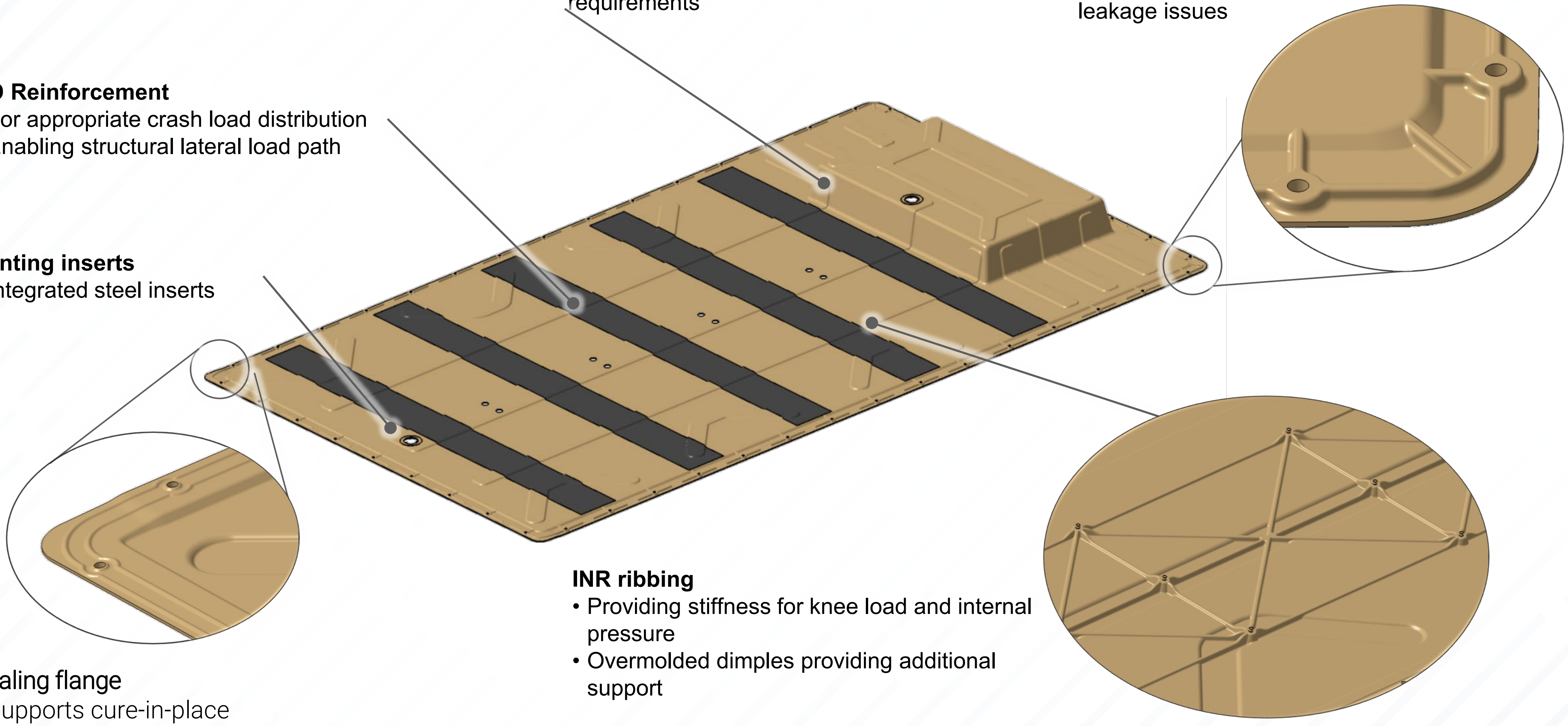
# DESIGN FEATURES | COVER PANEL

**Flange reinforcement**
- Enabling stiff & strong cover mounting areas
- Stiff corners addressing leakage issues

**Local embossing**
- Targeting stiffness requirements

**UD Reinforcement**
- For appropriate crash load distribution
- Enabling structural lateral load path

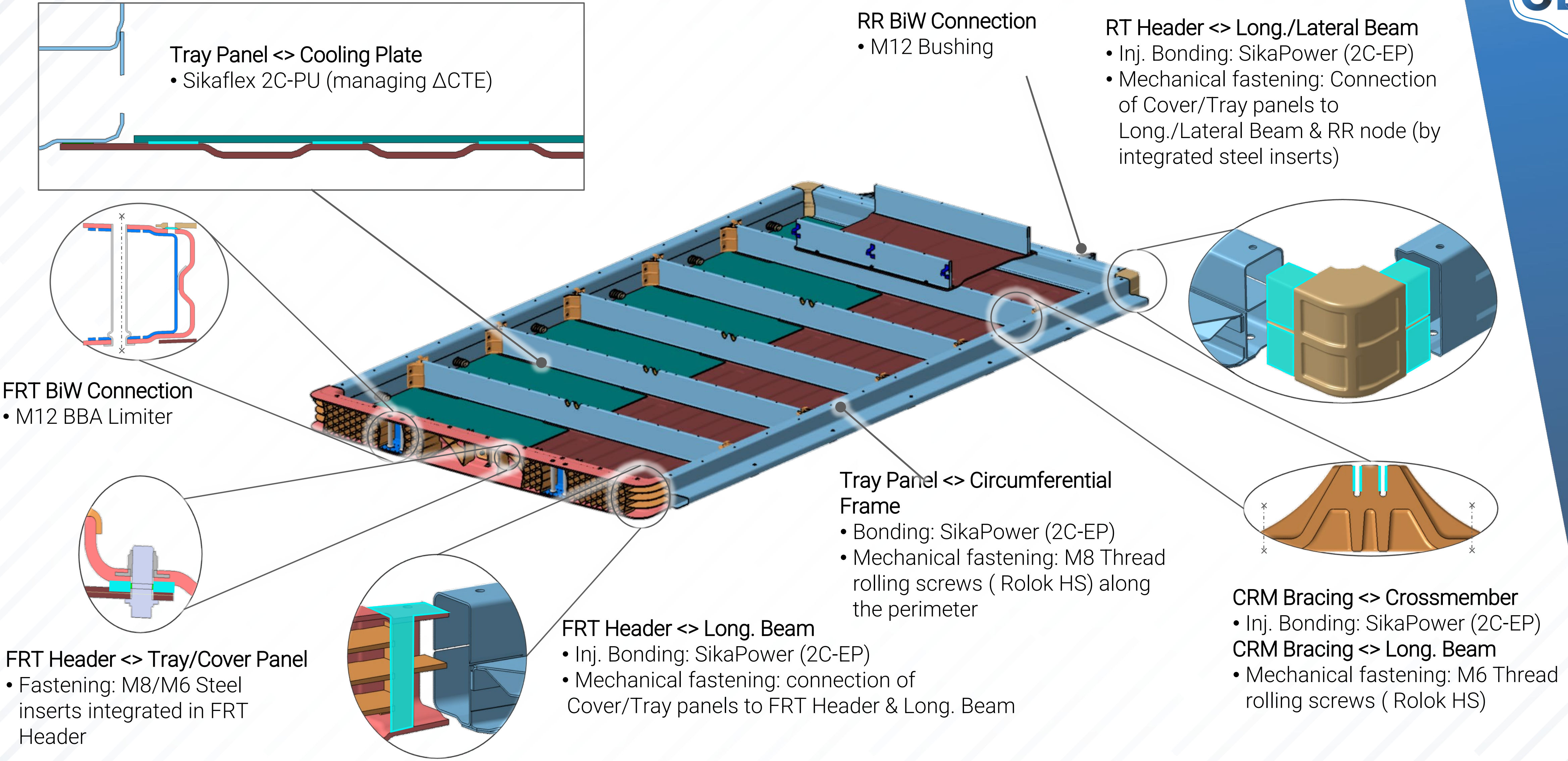
**Venting inserts**
- Integrated steel inserts



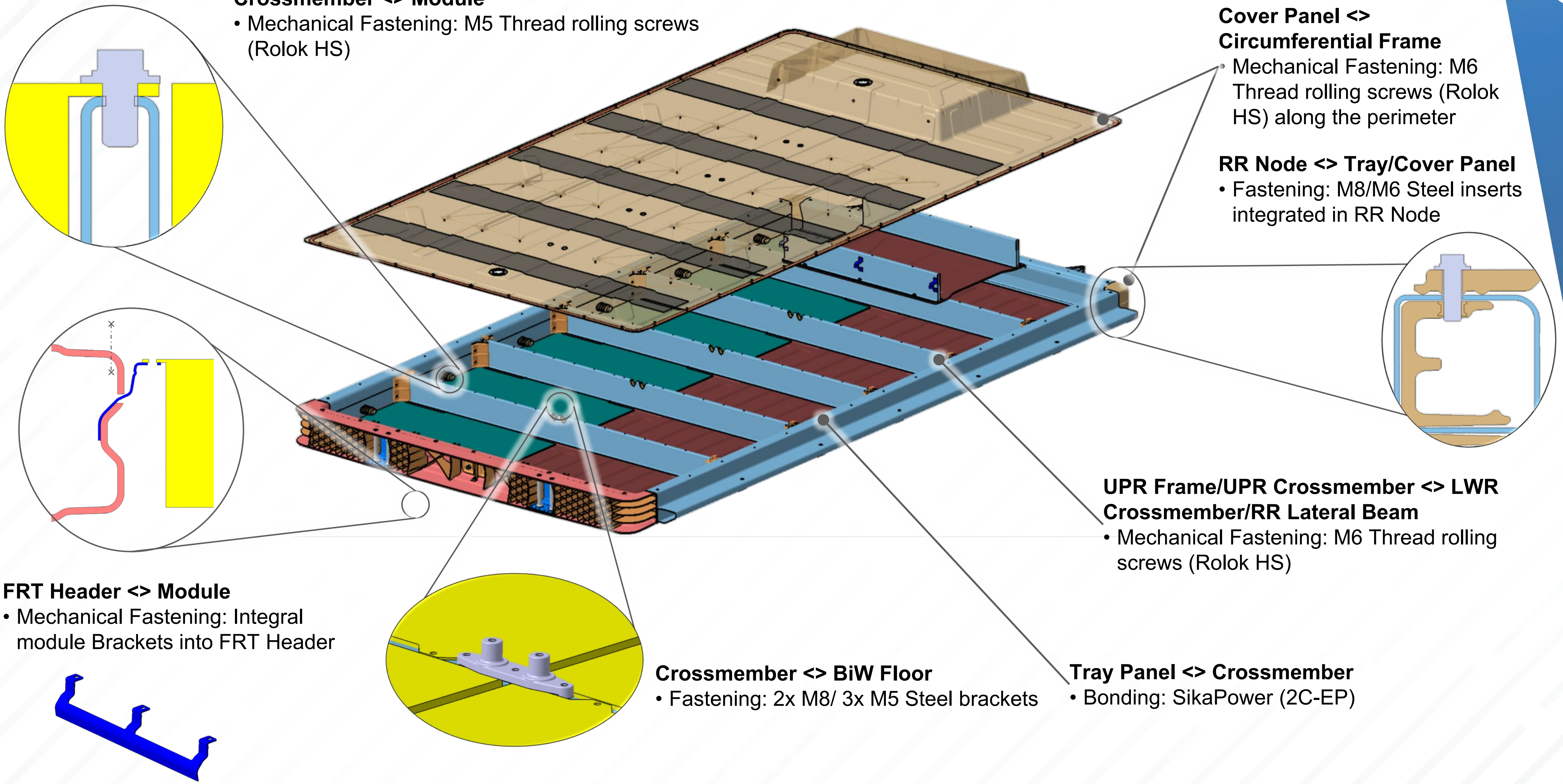
**INR ribbing**
- Providing stiffness for knee load and internal pressure
- Overmolded dimples providing additional support

Sealing flange
- Supports cure-in-place gasket solution

# JOINING TECHNOLOGIES (1/2)



# JOINING TECHNOLOGIES (2/2)



**Crossmember <> Module**
- Mechanical Fastening: M5 Thread rolling screws (Rolok HS)

**Cover Panel <> Circumferential Frame**
- Mechanical Fastening: M6 Thread rolling screws (Rolok HS) along the perimeter

**RR Node <> Tray/Cover Panel**
- Fastening: M8/M6 Steel inserts integrated in RR Node

**UPR Frame/UPR Crossmember <> LWR Crossmember/RR Lateral Beam**
- Mechanical Fastening: M6 Thread rolling screws (Rolok HS)

**FRT Header <> Module**
- Mechanical Fastening: Integral module Brackets into FRT Header

**Crossmember <> BiW Floor**
- Fastening: 2x M8/ 3x M5 Steel brackets

**Tray Panel <> Crossmember**
- Bonding: SikaPower (2C-EP)

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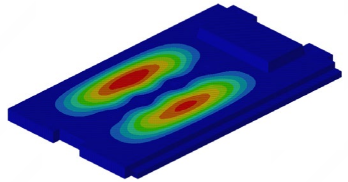
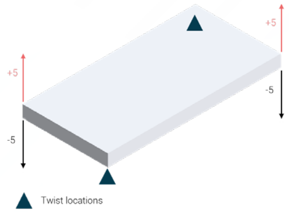
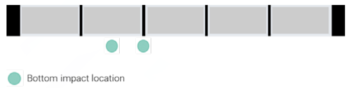
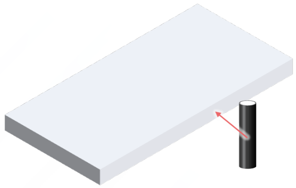
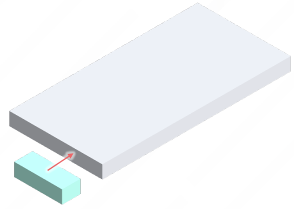
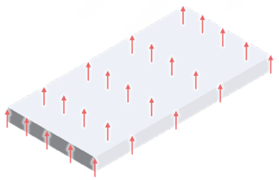
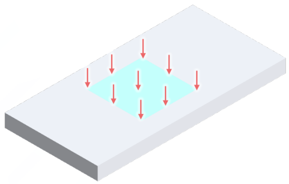
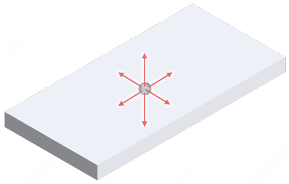
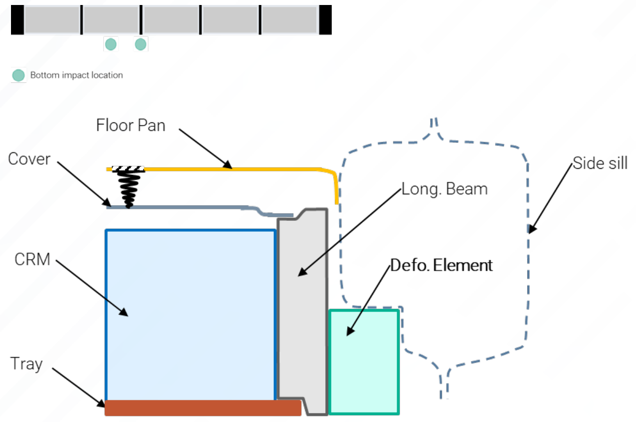
# SUMMARY OF LOAD CASES

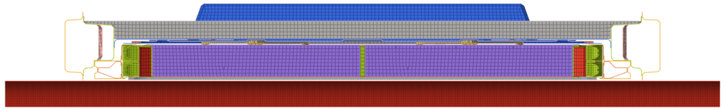
| REQUIREMENT | SETUP | LOAD | TARGET | |
|---|---|---|---|---|
| Modal Analysis |  | Eigen Frequency | 1st Mode >70Hz | ✓ |
| Twist Analysis |  | ±5 of vertical displacements | ▪ No permanent deformation<br>▪ No damage to modules/attachments | ✓ |
| Underbody Impact |  | 2m/s drop on a 150mm DIA over pack width | ▪ No plastic deformation<br>▪ No intrusion into modules | ✓ |
| Side pole Crush |  | 300kN | Intrusion inner wall <Δy (No damage to modules) | ✓ |

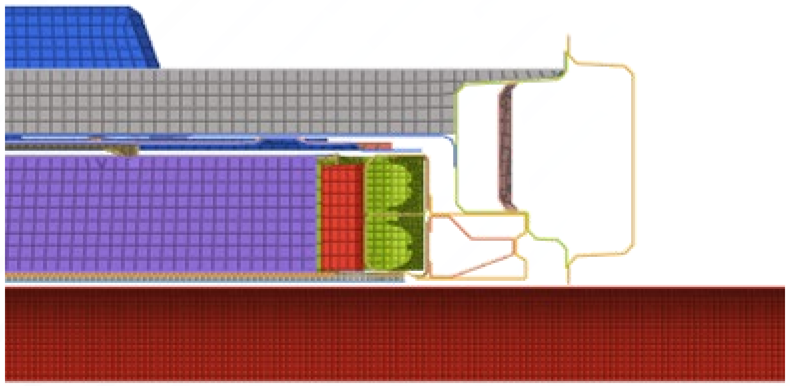
# SUMMARY OF LOAD CASES

| REQUIREMENT | SETUP | LOAD | TARGET | |
|---|---|---|---|---|
| FRT ODB Crush |  | 200kN | Intrusion inner wall <Δx (No damage to modules) | ✓ |
| Internal Pressure |  | 70kPa | Enclosure assembly withstand | ✓ |
| Knee Load |  | 500N over 100mmx100mm (on cover) | ▪ No plastic deformation<br>▪ No intrusion into modules | ✓ |
| Mechanical Shock |  | ax ≤ 25g; ay ≤ 25g; az ≤ 25g | ▪ No break<br>▪ Enclosure remains retained to vehicle | ✓ |

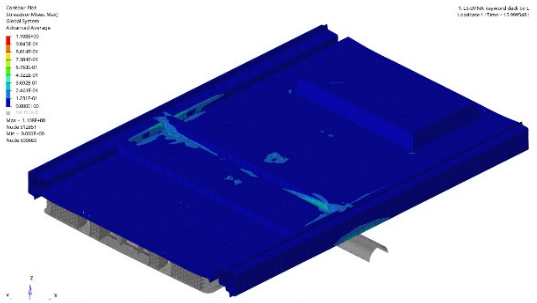
# PERFORMANCE| UNDERBODY IMPACT

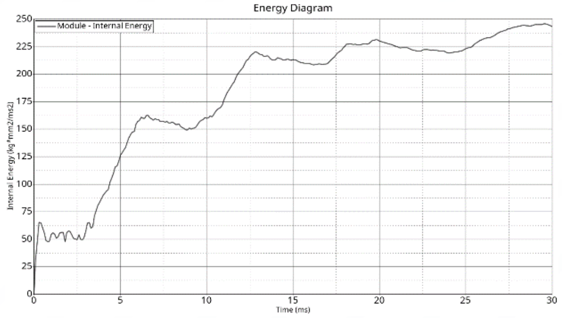




| LOAD | UNDERBODY IMPACT |
| --- | --- |
| Simulation Method | Nonlinear dynamic |
| Requirement | ▪ 2m/s drop on a 150mm DIA over pack width<br>! No plastic deformation<br>! No intrusion into modules |

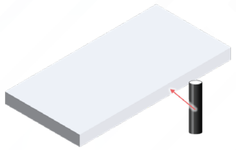




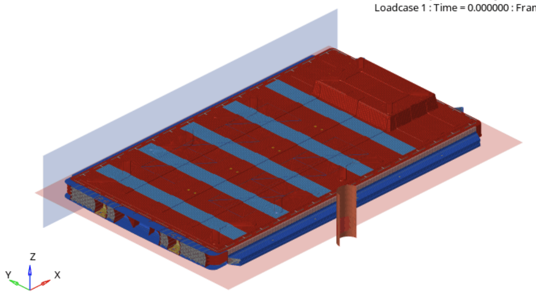

- Results
  - Concept study with bushings to BiW, double-shell tray and detachable energy absorber allows reduction of module intrusion for ca. 90% (double layer Tray Panel) compared to baseline model
  - No plastic deformation of relevant body structure

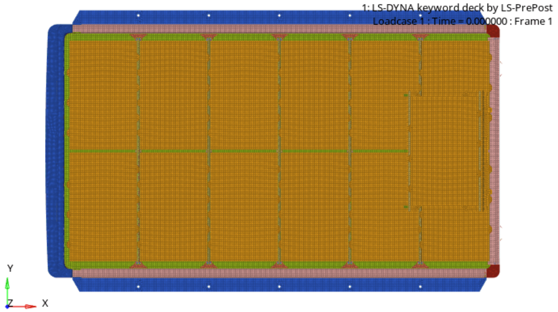
- Conclusion
  - ✓ Indicative potential for holistic absorption mechanism
  - Further boundary conditions for model refinement recommended (sill structure, floor structure)
  - Design space for tray structure to be confirmed

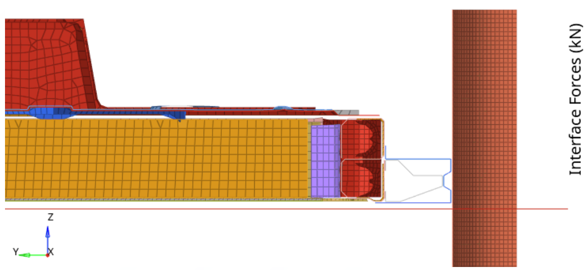
# RESULTS | SIDE POLE CRUSH

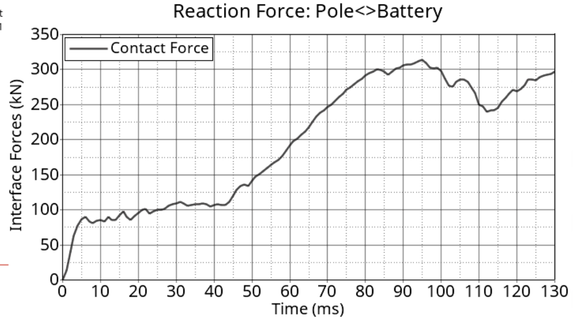


| LOAD | SIDE POLE CRUSH |
| --- | --- |
| Simulation Method | Nonlinear dynamic |
| Requirement | ▪ Resistance to 300kN pole<br>! Intrusion inner wall <Δy (No damage to modules) |



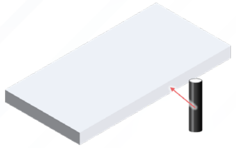



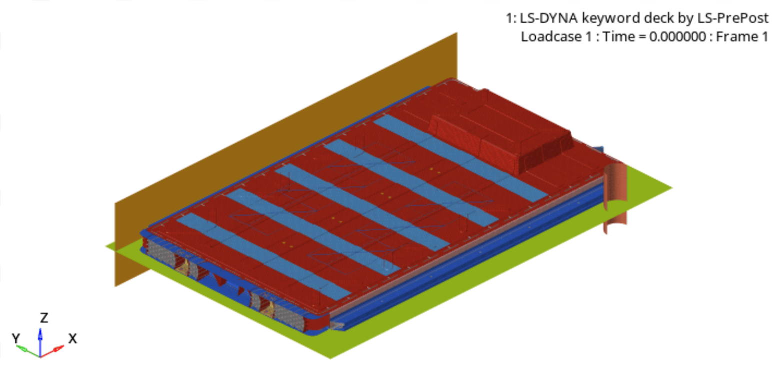



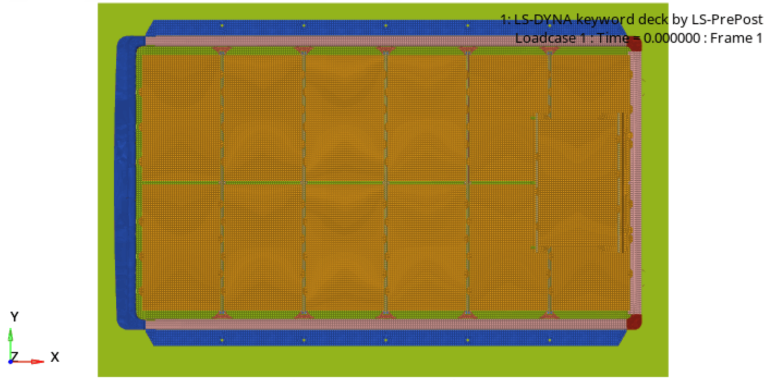

- Results
  - Reaction force before module intrusion > 300kN
  - Inner structure of longitudinal beam remains intact
  - CRM Bracings enable controlled beam deformation and proper energy absorption
  - More challenging setup of pole in between crossmember than direct on crossmember
  - Load case fulfilled in both scenarios, on crossmember, as well as in between crossmember
- Conclusion
  - ✓ Attractive structural response of multi material assembly
  - ✓ Longitudinal beam shows sufficient bending strength and triggering works together with Defo. Elements
  - ✓ Roll-formed steel profiles enable tailored design for energy absorption

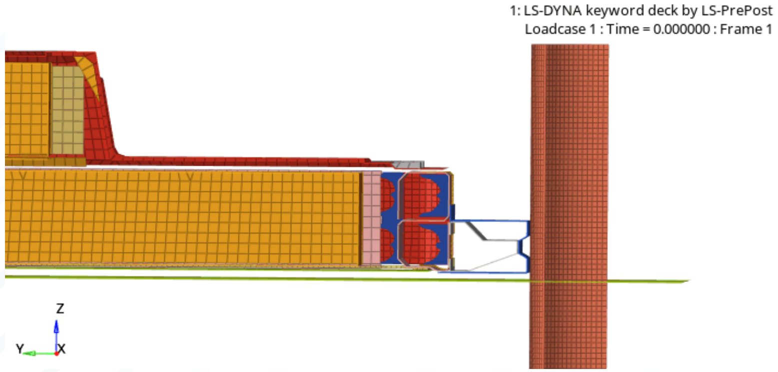
# RESULTS | SIDE POLE CRUSH – REAR AREA

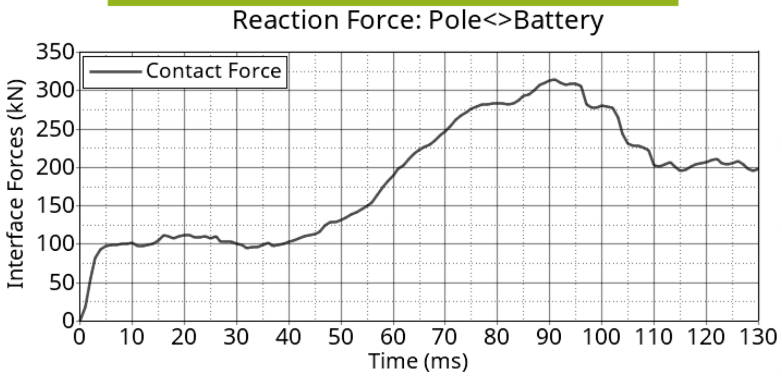


| LOAD | SIDE POLE CRUSH |
|---|---|
| Simulation Method | Nonlinear dynamic |
| Requirement | ▪ Resistance to 300kN pole<br>! Intrusion inner wall <Δy (No damage to modules) |



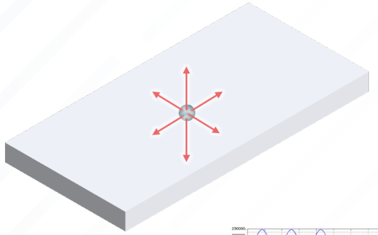



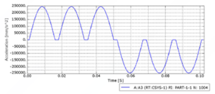



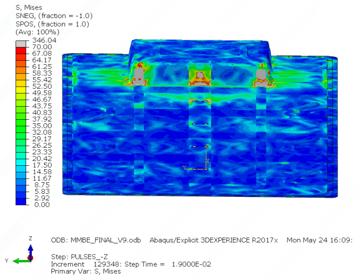

- Results
  - Reaction force before module intrusion > 300kN
  - Bending strong longitudinal beam in cooperation with ribbed GF-SMC node create strong back-structure for defo-element
  - Locally reinforced cover and tray help to reduce pole intrusion further
- Conclusion
  - Boundary conditions preventing rotation of battery enclosure (acc. to yawing of vehicle) enable targeted reaction force
  - GF-SMC-node can be designed to resist high side (and rear) impact loads
  - Proper (local) bracing by cover and tray is effective to support longitudinal beam and GF-SMC-node
  - Applied technologies allow tailorable weight and performance

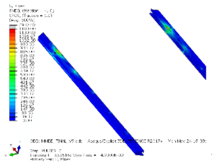
# RESULTS | MECHANICAL SHOCK

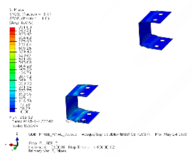


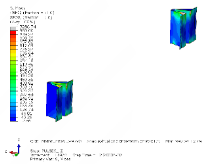


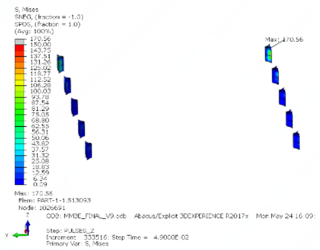
| LOAD | MECHANICAL SHOCK |
|---|---|
| Simulation Method | Nonlinear dynamic |
| Requirement | ▪ $a_x \leq 25g$; $a_y \leq 25g$; $a_z \leq 25g$<br>▪ No break<br>▪ Enclosure remains retained to vehicle |

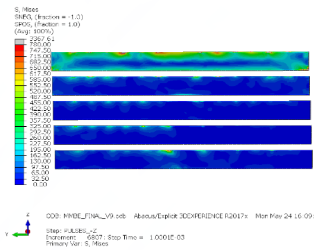


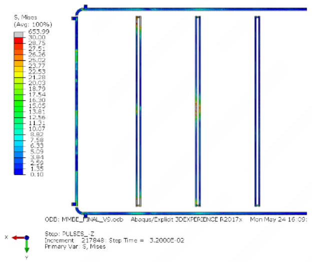












- Results
  - (Locally) high but controllable stresses in enclosure structure
  - Mezzanine and periphery is most loaded area
  - Module bolting generate high loads in crossmember
  - Body attachments show high local stresses → with selected alloys some local plastic deformation but mainly just elastic deformation has to be expected
- Conclusion
  - ✓ With suggested crossmember alloy module mounting can be considered as strong enough
  - ✓ Crossmember attachment (brackets and adhesive joining to tray) turns out to be robust
    - Local stresses in GF-SMC cover around bolting areas to be captured by local ribbing / thickness increase

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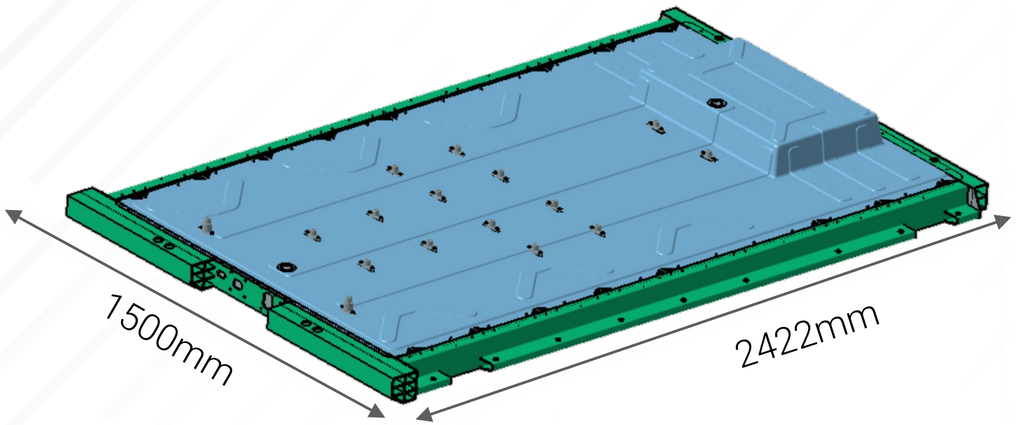
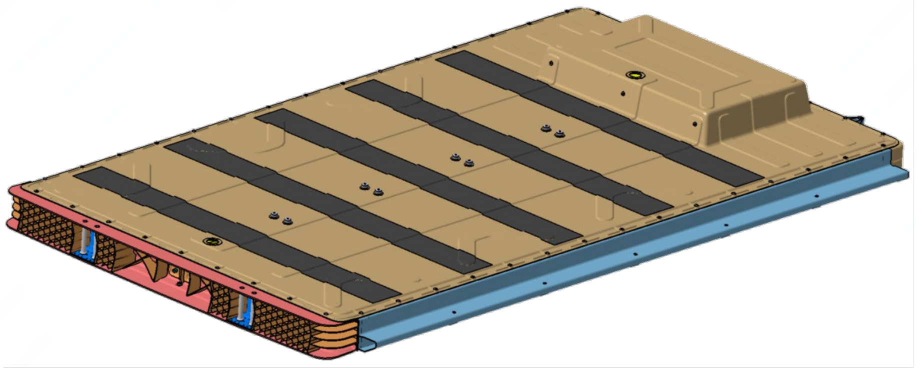
# COST & MASS BENCHMARK

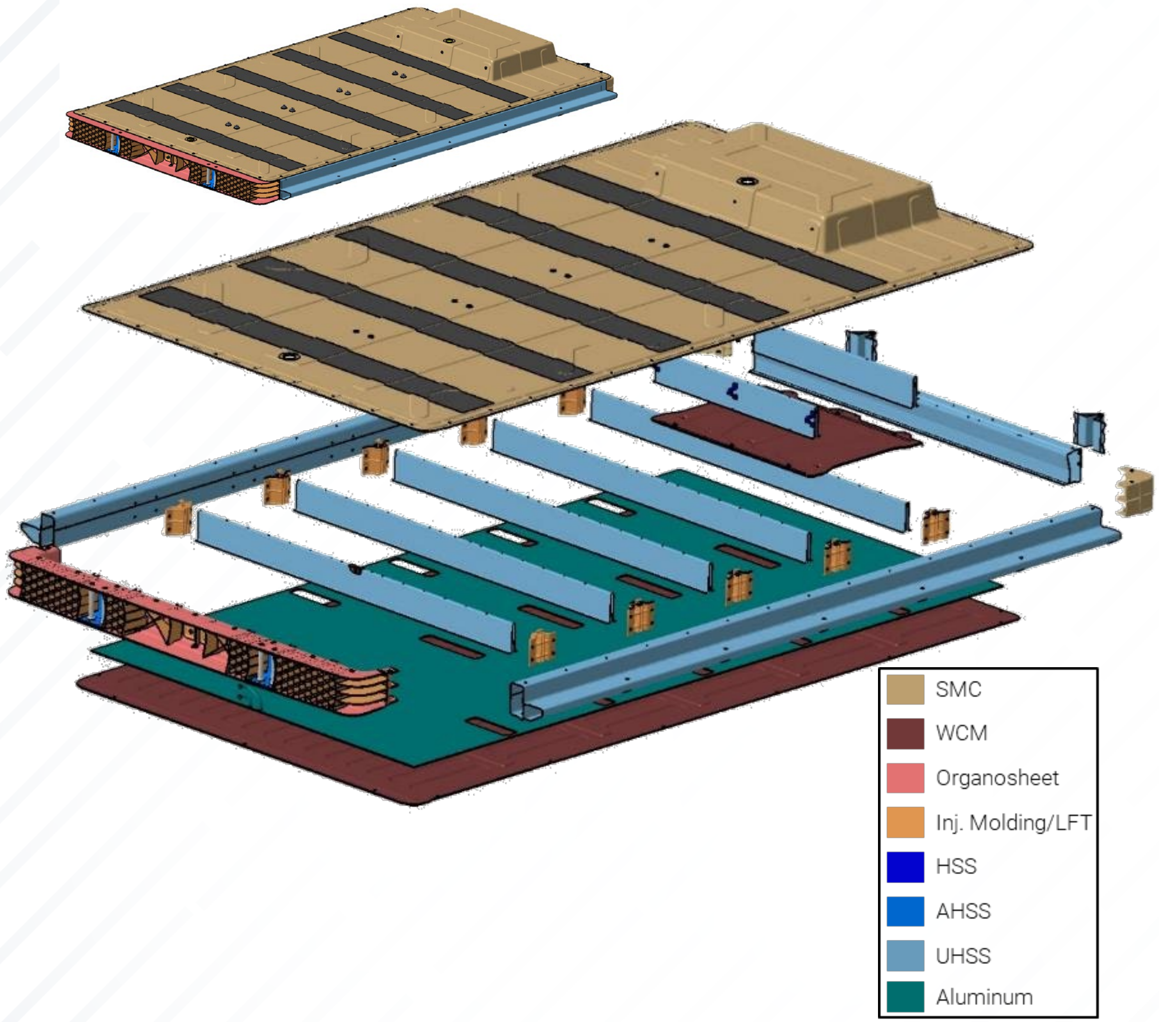


Aluminum Intensive Reference

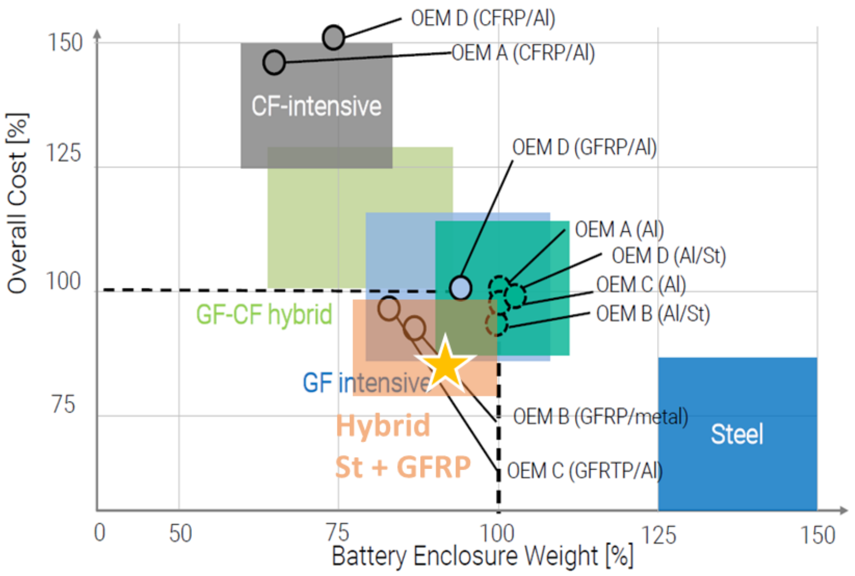
| KATCON Multi Material Battery Enclosure | |
|---|---|
| Weight Overall | Mass Savings = 40 kg |
| Weight Enclosure | Enclosure Mass Savings = 26% |
| Est. Part Price | Cost Savings = 16% to 14% |
| Tooling & Assembly Fixtures | Cost Savings = 12% |

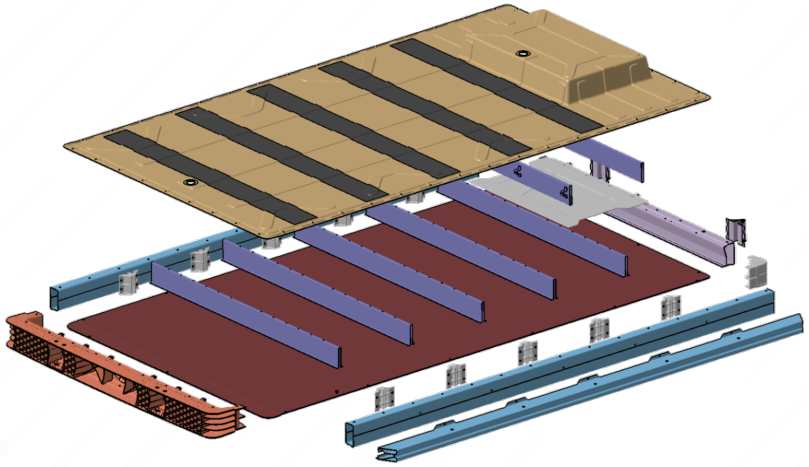
# KATCON MMBE VALUE PROPOSITION



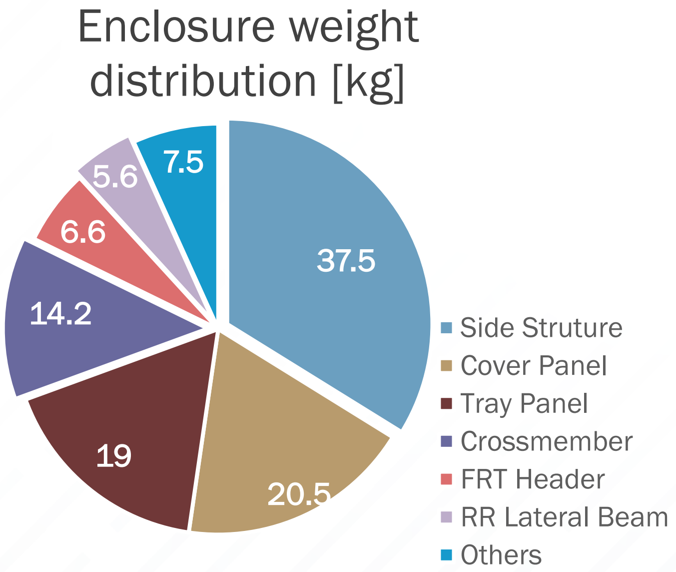

- COST EFFECTIVE
  - Material cost is critical driver for structures - Mixed material design efficiently utilizes each materials strengths
  - Low pressure forming processes drives down capital costs
  - Innovative application of proven series production technologies
- FLEXIBLE
  - Modular design simplifies adaption to multiple products
  - Composite nodes balance part integration with flexibility
  - Hybrid joints support flexibility while ensuring seal integrity
  - Modular design protects for emerging CO2/LCA/EoL targets
- SCALABLE
  - Forming processes and geometry simplifies low and high-volume demand response
- BENCHMARK PERFORMANCE
  - Mass is competitive with aluminum intensive enclosures
  - CAE Validated Performance (crash, shock, int pressure & knee load)

# WEIGHT PERFORMANCE



- Total MMBE (excl. modules)= 111kg
- 20-30% lighter than steel intensive (1)
- 10% lighter than aluminum intensive (1)
- Cost comparable with steel (1)
- 56% Steel & 44% Composite materials
- Weights distribution:
  - LWR Case= 85.7kg
  - Cover Assembly= 20.5kg
  - Frame Assembly= 4.4kg



# CONCLUSION

- Starting with a clean sheet and the most challenging global OEM and regulatory requirements the KATCON led team has developed a cost effective, flexible, scalable high voltage battery enclosure solution to meet the highly volatile markets requirements

- The KATCON led team of global industry leaders is ready to develop a battery enclosure solution specific to your application requirements

- KATCON has the resources and facilities necessary to accelerate the design, development, prototyping, validation and global production scale up of battery enclosure solutions specific to your applications

KATCON
ADVANCED MATERIALS

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20 YEARS GDIS