STEEL E-MOTIVE

IN PARTNERSHIP WITH

WorldAutoSteel RICARDO

Steel Vehicle Structures for Autonomous MaaS

George Coates, WorldAutoSteel

Neil McGregor, Ricardo

May 18, 2022 | Great Designs in Steel

CONTENTS

STEEL E-MOTIVE

IN PARTNERSHIP WITH

WorldAutoSteel

RICARDO

www.steelemotive.world

ANSTEEL
ArcelorMittal
BAOWU
CSC
ERDEMIR
河钢集团 HBIS GROUP
HYUNDAI STEEL
JFE
JSW
KOBELCO
NIPPON STEEL
NUCOR
posco
Severstal
TATA STEEL
Ternium
voestalpine ONE STEP AHEAD.
USIMINAS
U. S. Steel

OBJECTIVES – STEEL E-MOTIVE PROJECT

Objective Steel E-Motive Project

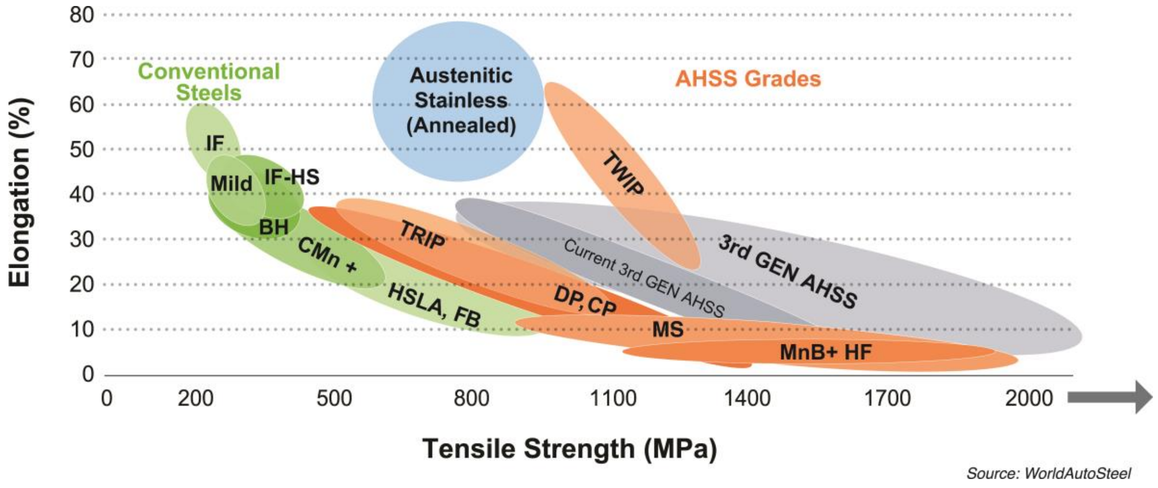
Connecting the steel industry with OEM's and future mobility service providers

- To showcase the ***steel body structure*** modules of the autonomous battery electric vehicle
- To position steel as the ***leading material*** of choice for future vehicle architectures specifically demonstrating strength, durability, emissions and affordability
- To focus on ***future of mobility***
- To focus on ***environmental impact***

The automotive sector is undergoing the most rapid change in 40 years.

This project will demonstrate the benefits of steel, linking the properties of the material to the required architectures & attributes for Mobility As A Service (MaaS) vehicles.

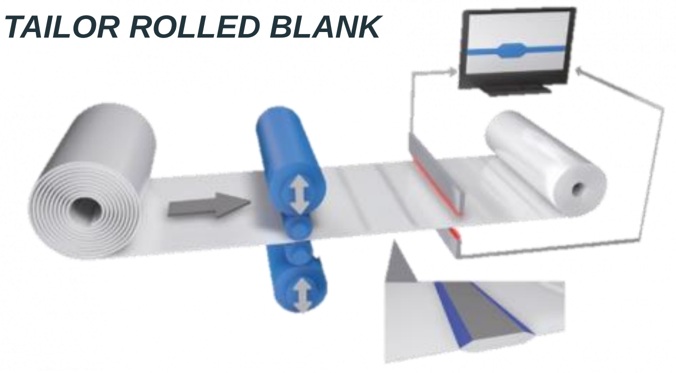
COMPREHENSIVE STEEL GRADE AND PROCESS PORTFOLIO



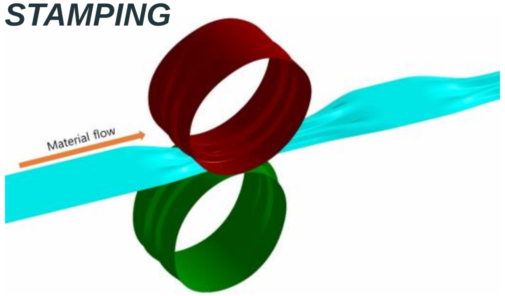
Example Steel Grades for Steel E-Motive

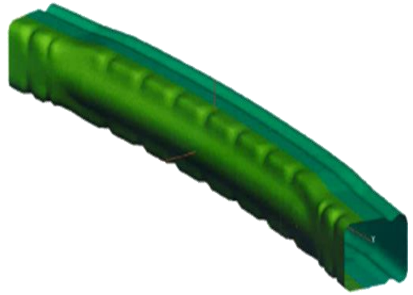
- Complex Phase
- Dual Phase, High Formability
- Quench and Partitioned
- Ferrite-Bainite
- Manganese-Boron

TAILOR ROLLED BLANK



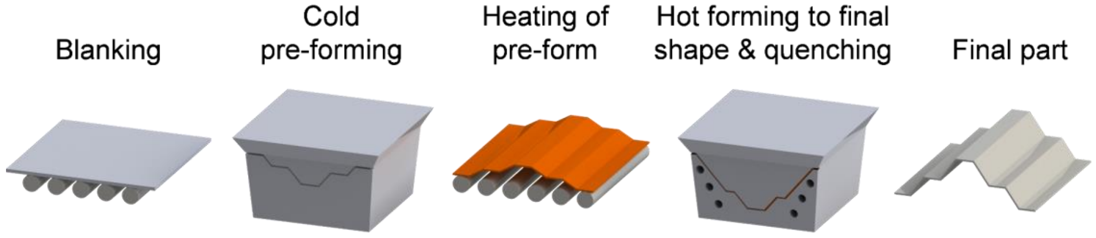
ROLL STAMPING





MULTI-WALLED HYDROFORMED TUBES

HOT STAMPING (HYBRID)



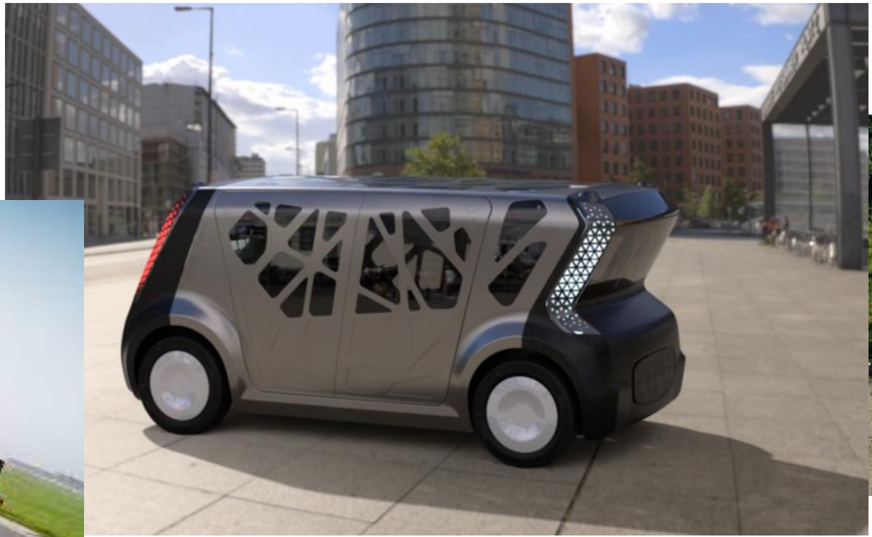
CONTENTS

Steel E-Motive Vehicle Program

Neil McGregor
Chief Engineer Steel E-Motive

STEEL E-MOTIVE: A GAME CHANGING, WORLD FIRST?

STEEL E-MOTIVE ?



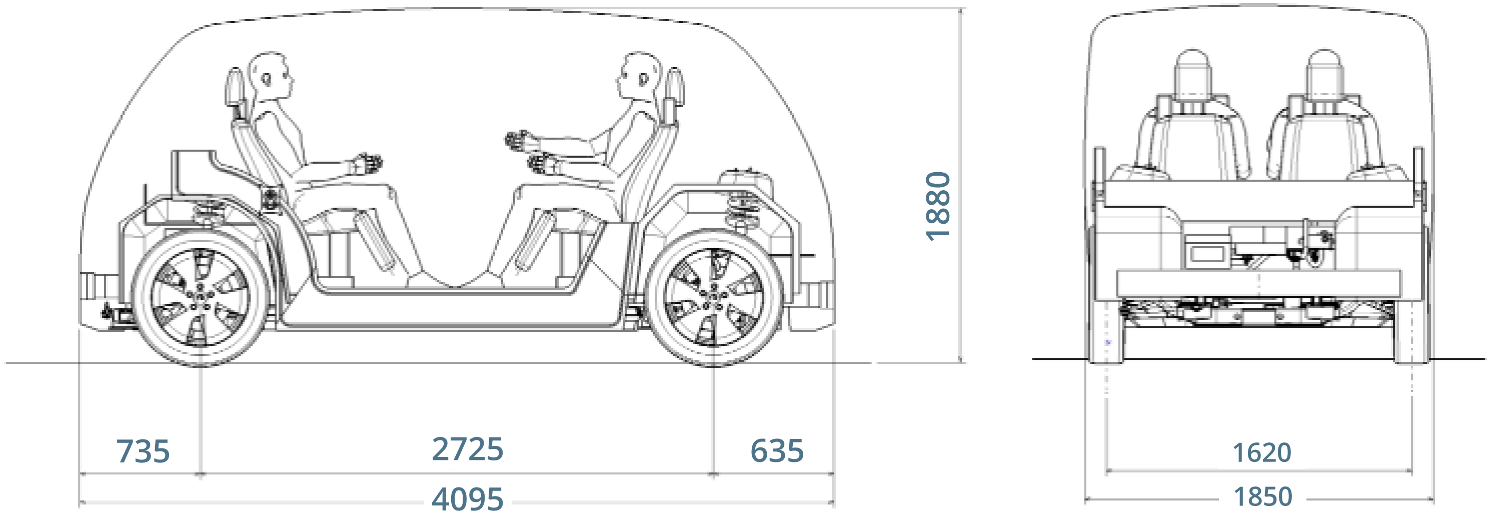
- Level 5 autonomous, battery electric propulsion ✓
- Operates in mixed mode traffic. Limited infrastructure requirements (conventional road network) ✓
- Meets global crash worthiness standards ✓
- Clean sheet, ground up engineered ✓
- Conventional, high volume vehicle manufacture methods ✓

- Limited benchmarks/comparison (Steel E-motive is the benchmark!)
- Target setting is difficult

STEEL E-MOTIVE: 2 VEHICLES BASED ON A SINGLE MODULAR PLATFORM, COVERING URBAN AND INTER-URBAN JOURNEY REQUIREMENTS

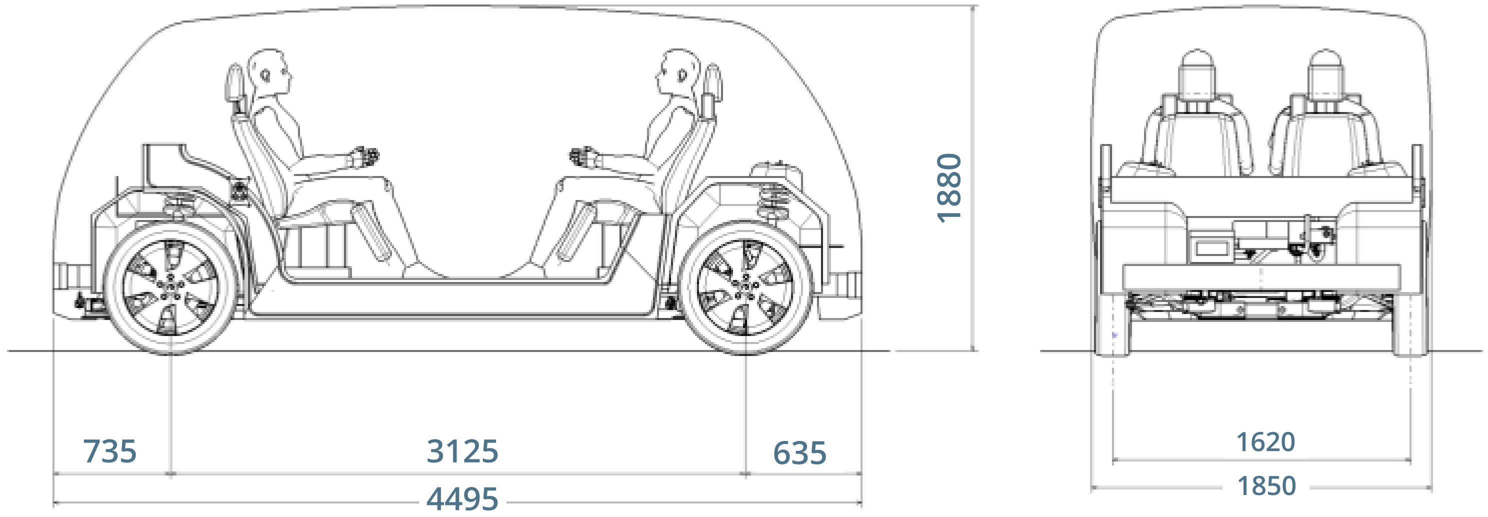
SEM1: Short Wheelbase Urban Version

- Single, front wheel electric drive
- Compact design and vehicle footprint
- Comparable to European B/C segment size



SEM2: Long Wheelbase Extra Urban Version

- Front and rear wheel electric drive
- Extended wheelbase. Maximise SEM1 carry-over



STEEL E-MOTIVE ADDRESSES THE KEY EXPECTED USER AND FLEET OPERATOR REQUIREMENTS FOR AUTONOMOUS RIDE HAILING VEHICLE

Creating a desirable, comfortable and convenient journey experience

PASSENGER COMFORT & CONVENIENCE

Protection of occupants and road users in all eventualities

SAFETY

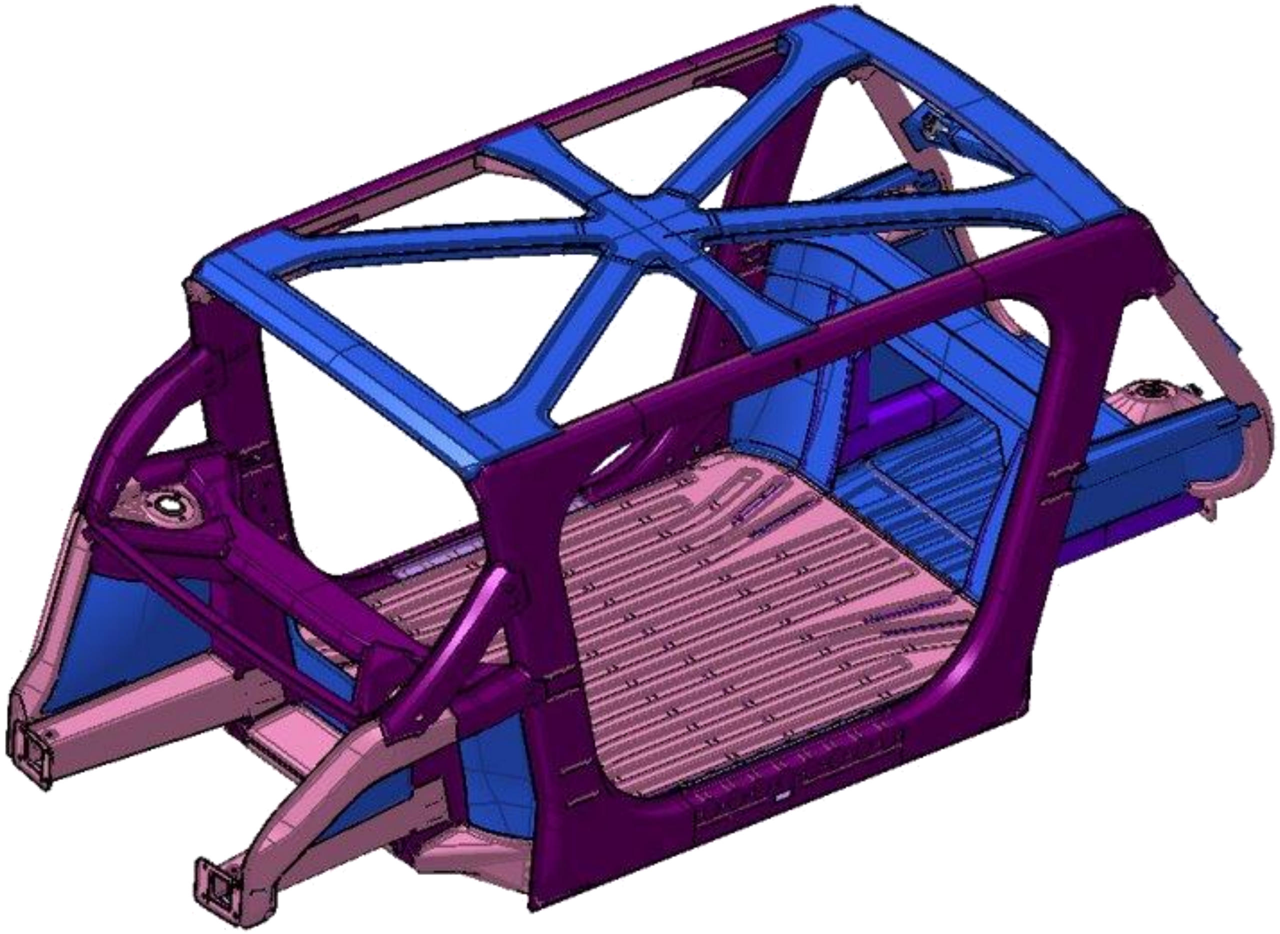
Ensuring competitive pricing for passengers and profitability for fleet operators

TOTAL COST OF OWNERSHIP

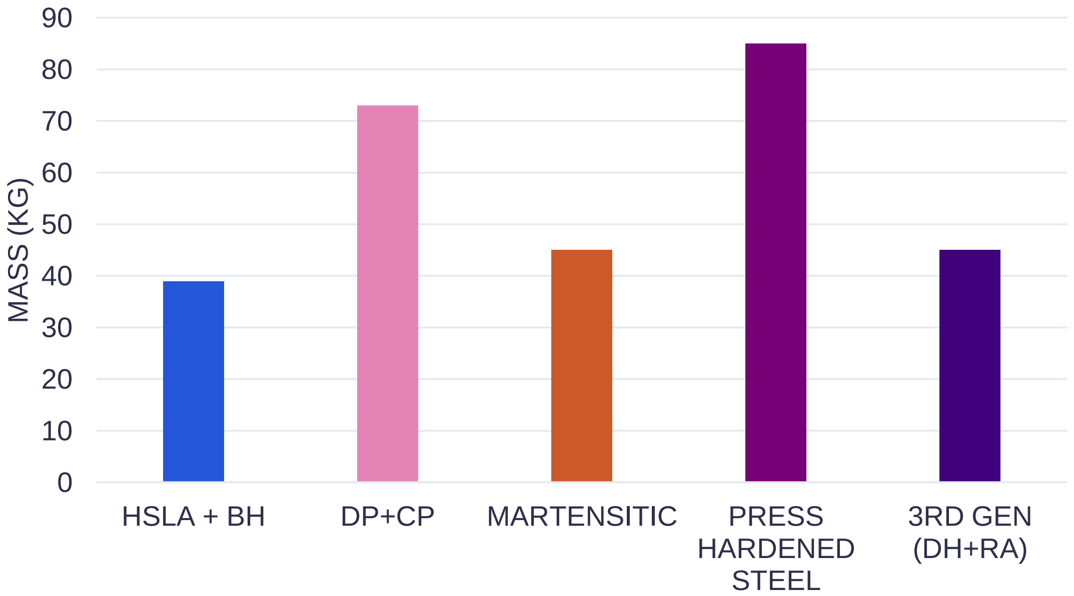
Addressing global sustainability challenges

ENVIRONMENT & SUSTAINABILITY

STEEL E-MOTIVE BIW (PRELIMINARY GRADE SELECTION). GREAT STEELS IN DESIGN!



- Right steel grade in the right place
- Significant proportion of >1500MPa grades, primarily for occupant and battery intrusion zones
- Mixture of stamped, roll formed, roll stamped, press hardened steel and hydroformed parts
- Spotweld, laser weld and structural adhesive



AT THE CORE OF THE STEEL E-MOTIVE CONCEPT IS AN INNOVATIVE BATTERY DESIGN, ENABLING REDUCED COST AND WEIGHT WITHOUT COMPROMISING SAFETY

- Battery modules and cooling plates mounted to steel carrier frame (off-line)
- Carrier frame mounted to body structure (general assembly)
- BIW floor acts as top cover and provides sealing
- AHSS bottom cover plate provides impact protection
- Cost and weight saving. Improved NVH. No compromise to safety. Improved package, enables lower floor height and flat floor

PASSENGER COMFORT AND CONVENIENCE: DESPITE IT'S COMPACT SIZE STEEL E-MOTIVE HAS A SPACIOUS INTERIOR WITH CONVENIENT ACCESSIBILITY FOR ALL USERS

One-box architecture providing an open, spacious interior and occupant positioning. B pillar in door enabling a more open cabin environment

Glazed panel roof, enhancing airiness spacious feeling

Rear facing front occupants for enhanced journey experience

Flat floor and competitive step in height. Enabled by efficient steel sections and integrated battery frame design

Unique scissor doors, enabling >1.0m aperture for enhanced occupant ingress/egress. The pillar mounted scissor hinge mechanism is lower cost & weight and easier to integrate than a sliding door, solution where the tracks and rails can impinge the rockers and cantrail

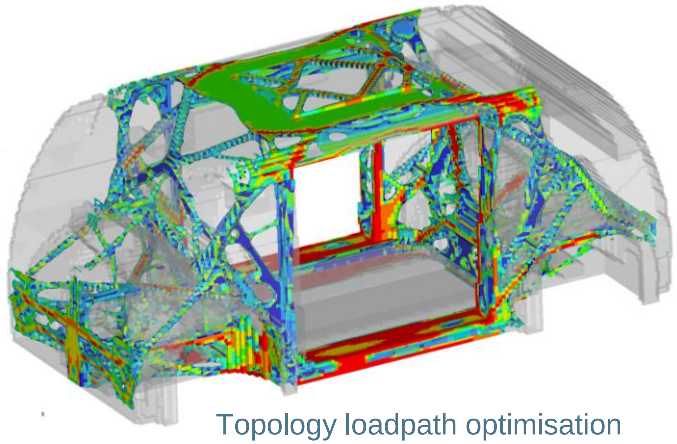
Front and rear wheel steer. Tighter turning circle enables the vehicle to operate and access more enclosed locations

PASSENGER COMFORT AND CONVENIENCE: WE'VE ACHIEVED COMPETITIVE BODY STIFFNESS WITH AN OPEN ONE BOX BODY STRUCTURE WITHOUT B PILLAR

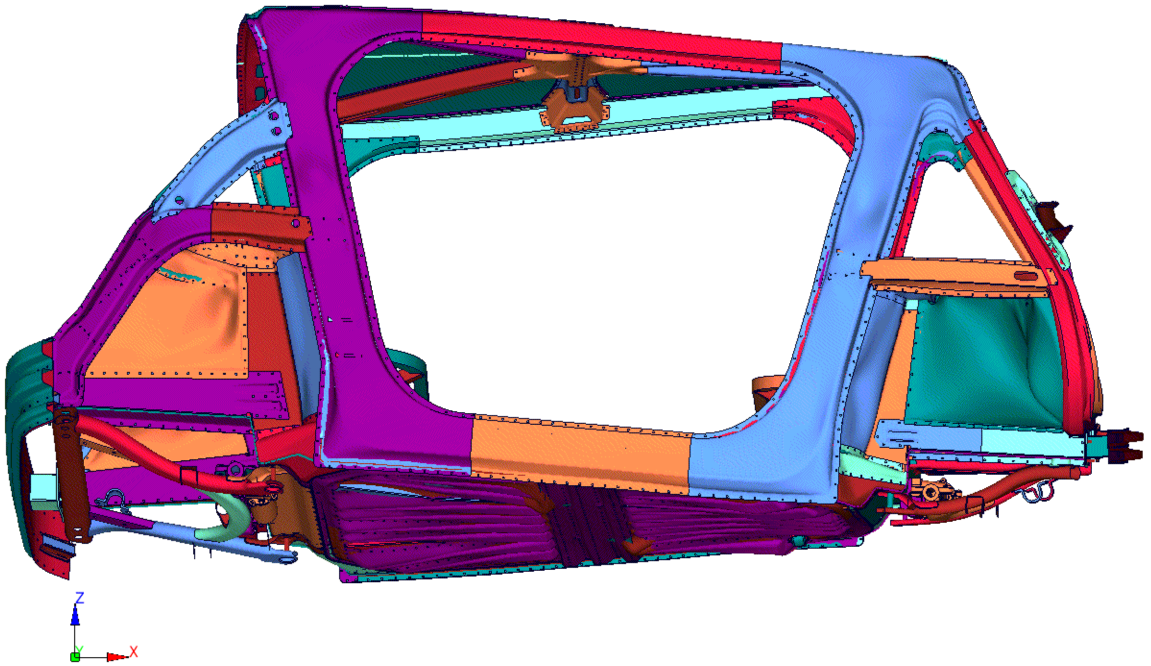
Approach for achieving body stiffness:

- Topology loadpath optimisation
- Appropriate section size, profiles, part integration and flange and joint design
- Strut towers integrated with key body members such A pillars, vertical dash brace
- Contribution from structural battery frame and battery cover closing, roof structure trusses
- Rigidly connected front and rear subframes
- Optimised joining and structural adhesives
- Inherent high modulus of steel!

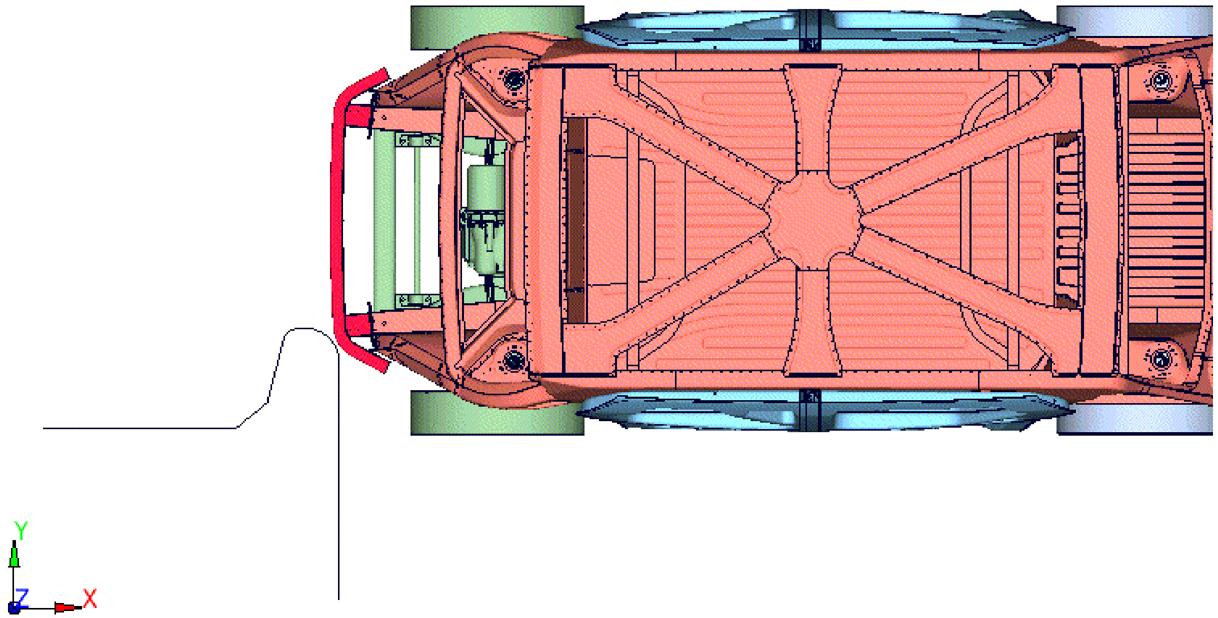
- Static torsional stiffness 38,000Nm/deg
- Global trimmed BIW modes >28Hz
- Local attachment static & dynamic stiffness 10x bushing stiffness



Topology loadpath optimisation



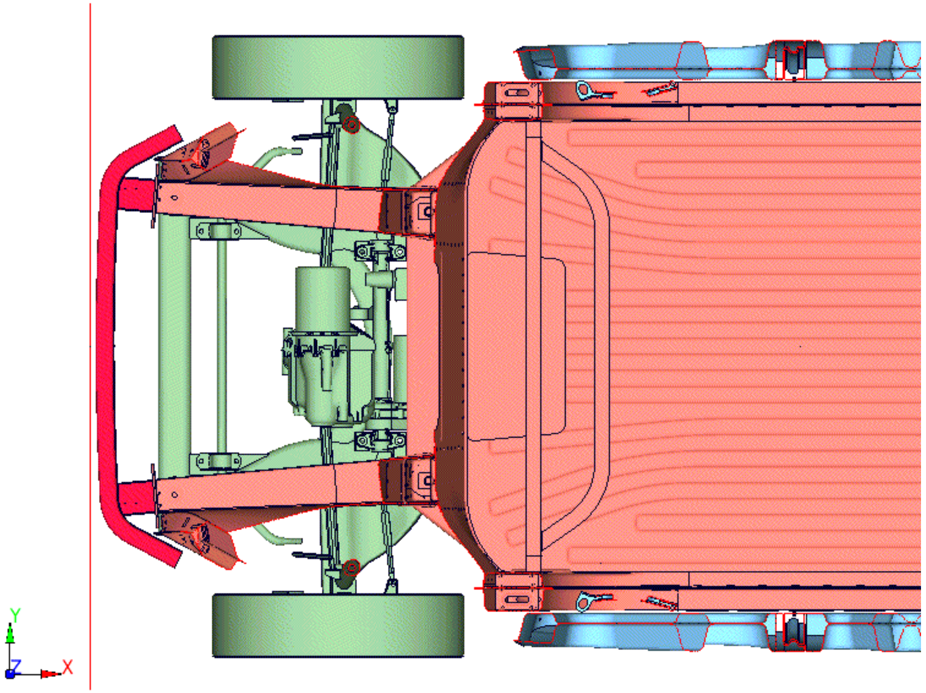
SAFETY :FRONT CRASH PERFORMANCE. IIHS "GOOD" RATING ACHIEVED IN 64kph 25% SMALL OVERLAP

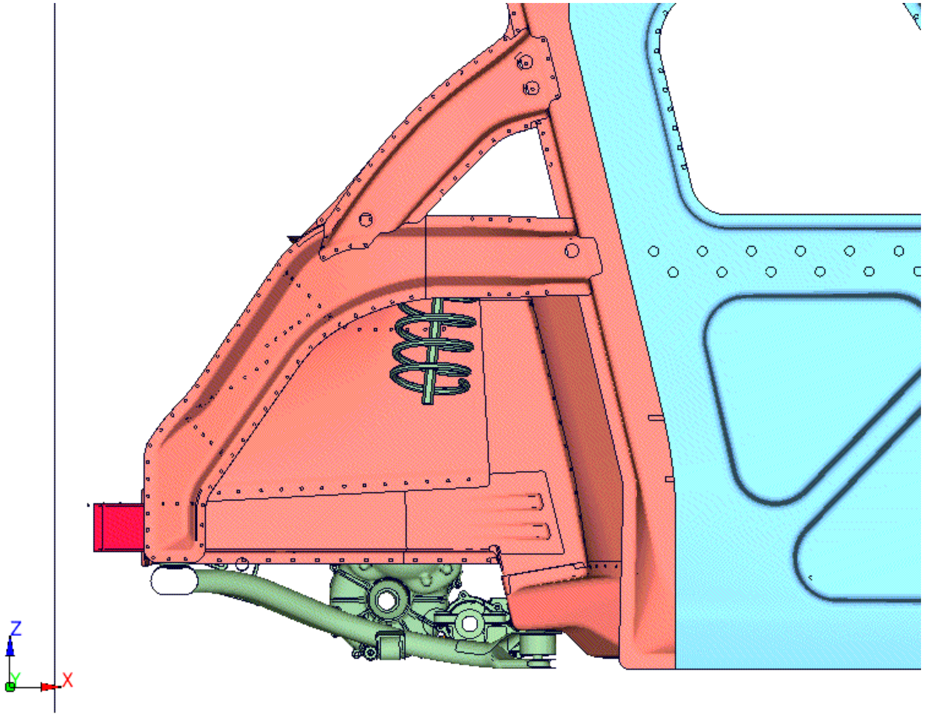


IIHS 64kph 25% small overlap crash simulation

- IIHS "good" rating achieved (based on predicted intrusions)
- Our strategy for IIHS Small Overlap test was to achieve a "glance off" the barrier
- Glance off results in some continued onward vehicle velocity after the impact. This results in reduced crush energy, lower vehicle pulse and intrusions = enhanced occupant protection
- Significant challenge to achieve a glance-off with short front overhang vehicle
- Front suspension engineered to detach on impact. This is important for achieving glance off

SAFETY: FRONT CRASH PERFORMANCE, USNCAP 56kph Rigid Barrier





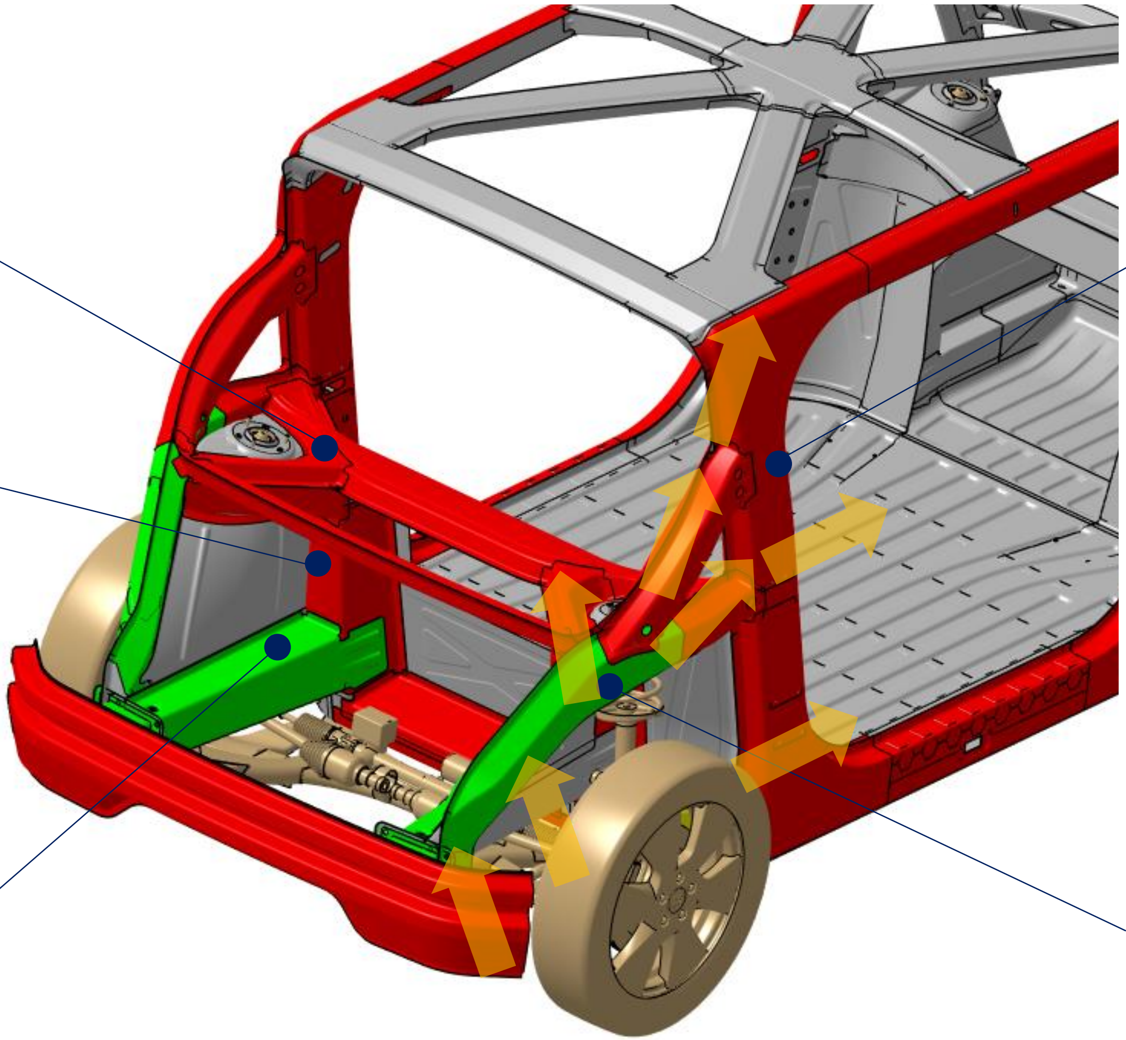
- Compact sized vehicles with short front overhang also pose challenges for crush energy management
- Uniform, progressive collapse of mid rail. Front subframe and shotgun/SORB beam engineered to fold and collapse in FFB
- Vehicle crash pulse <30g & very low intrusions

SAFETY – FRONT CRASH STRUCTURE ENGINEERED TO BALANCE THE REQUIREMENTS OF 56KPH USNCAP FFB, IIHS ODB, IIHS SORB AND EURONCAP MPDB LOADCASES

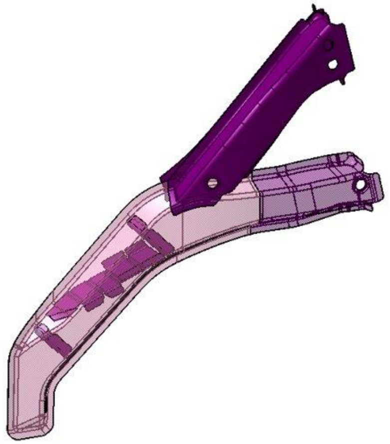
PHS Front strut brace protects occupants and supports SORB load barrier reaction

PHS vertical dash brace and #1 bar reacts crush loads and minimises intrusion to battery and cockpit

Longitudinal TWB Dual Phase mid rail, tuned for FFB crush performance. Plan view angle optimised for Small Overlap Barrier engagement



UHSS (2GPa) PHS occupant protection zone

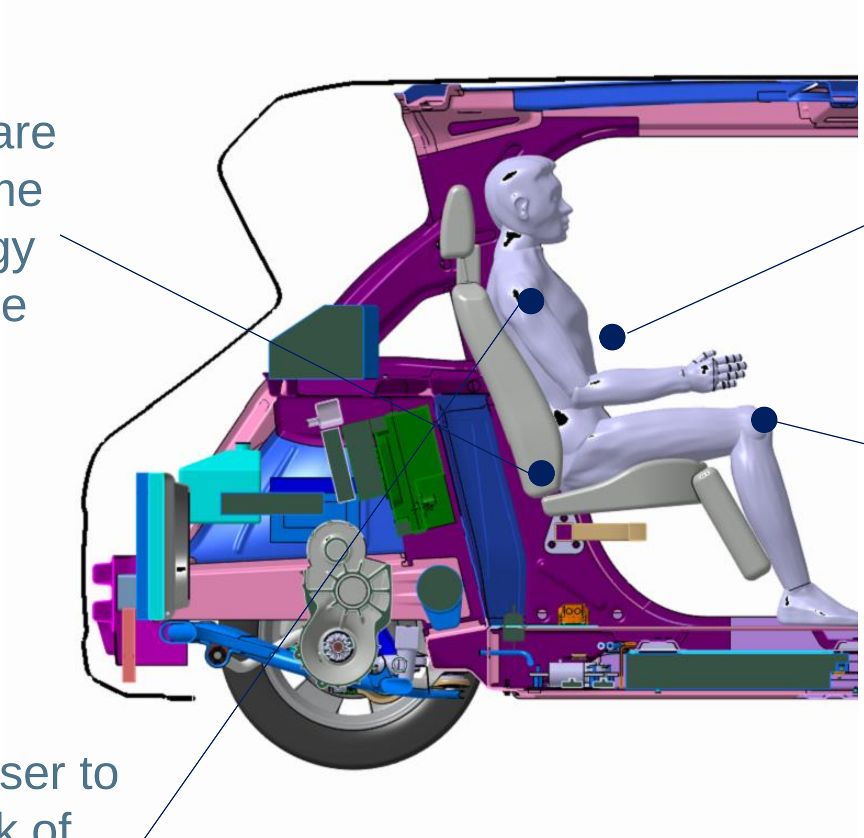


Tailor Welded PHS SORB beam. Engineered to crush in Frontal Rigid Barrier and provide lateral load reaction to the Small Overlap Barrier

Note: components have been removed from this image for clarity. Design shown is development, not final design

SAFETY – DIFFERENT APPROACH AND CONSIDERATIONS ARE REQUIRED FOR THE PROTECTION OF REAR FACING FRONT OCCUPANTS. WE ARE EFFECTIVELY DEALING WITH A HIGH SPEED REAR IMPACT EVENT

Occupant deceleration loads are primarily through the seat frame and mounting structure. Energy management and design of the seat structure and headrest is more critical



Seat belt loads on front occupant are generally lower than forward facing. No frontal airbag

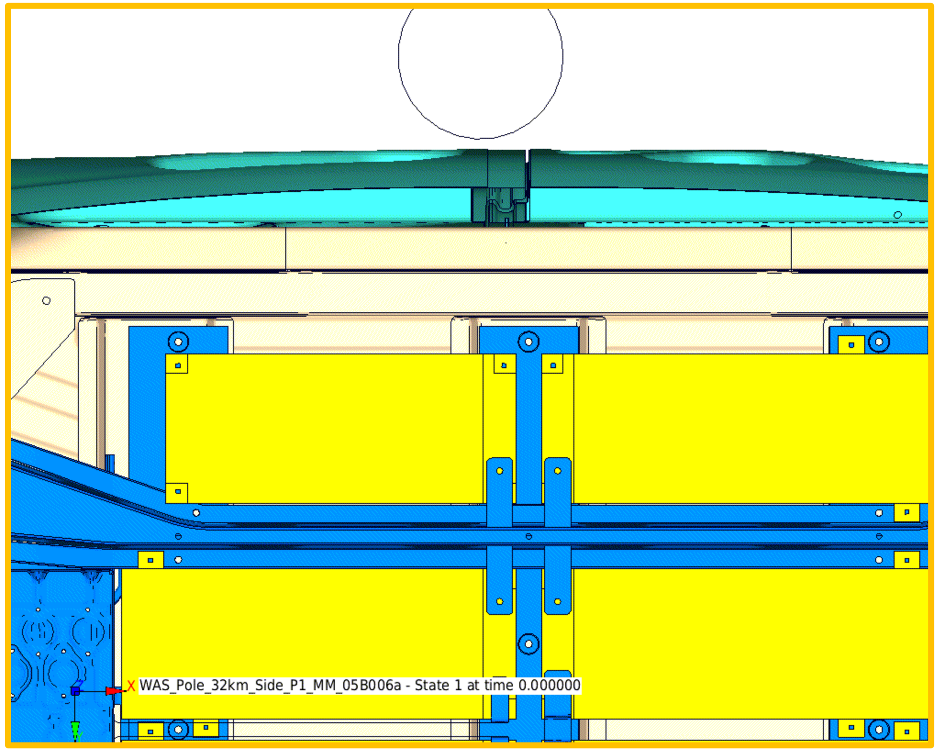
Front occupant legs, feet, arms less risk of injury from intrusion (no dash, steering wheel)

Occupant head and torso is closer to the front crash zone. Higher risk of intrusion injury. Intrusion targets have been adjusted to account for this. UHSS protection zone around front occupant

For ride hailing MaaS vehicle, we need to account for greater degree of changing occupant size. We may require smart sensors and actuators to ensure occupants are appropriately seated and restrained

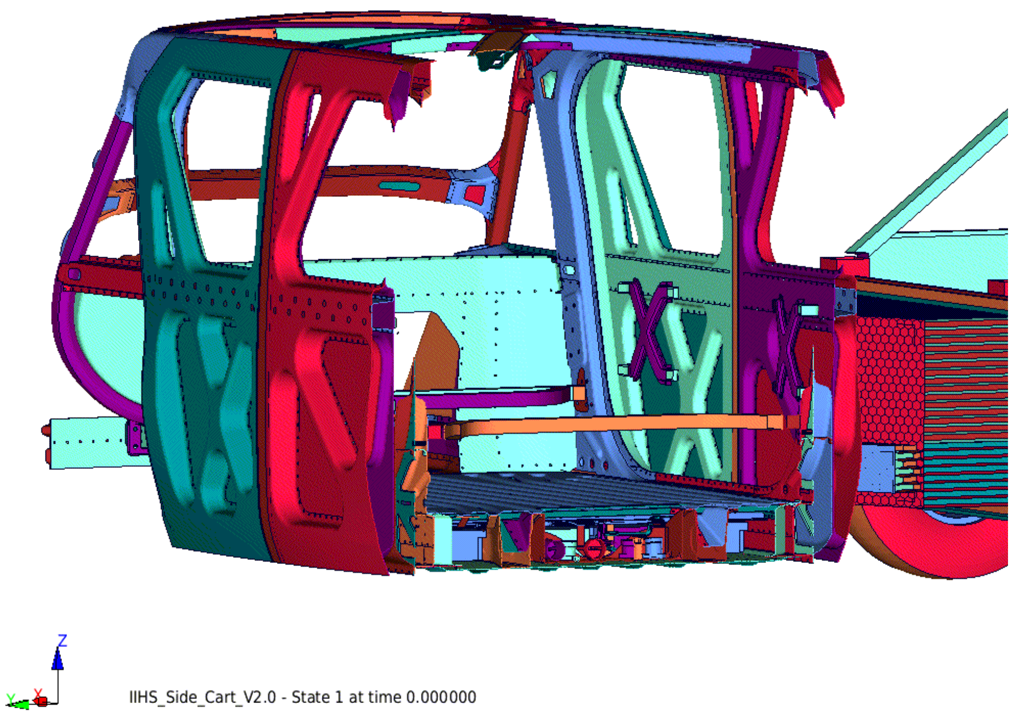
SAFETY – STEEL E-MOTIVE DESIGN DEMONSTRATES VERY GOOD SIDE CRASHWORTHINESS. GOOD LEVELS OF OCCUPANT AND BATTERY PROTECTION

USNCAP 32kph side pole (battery protection)



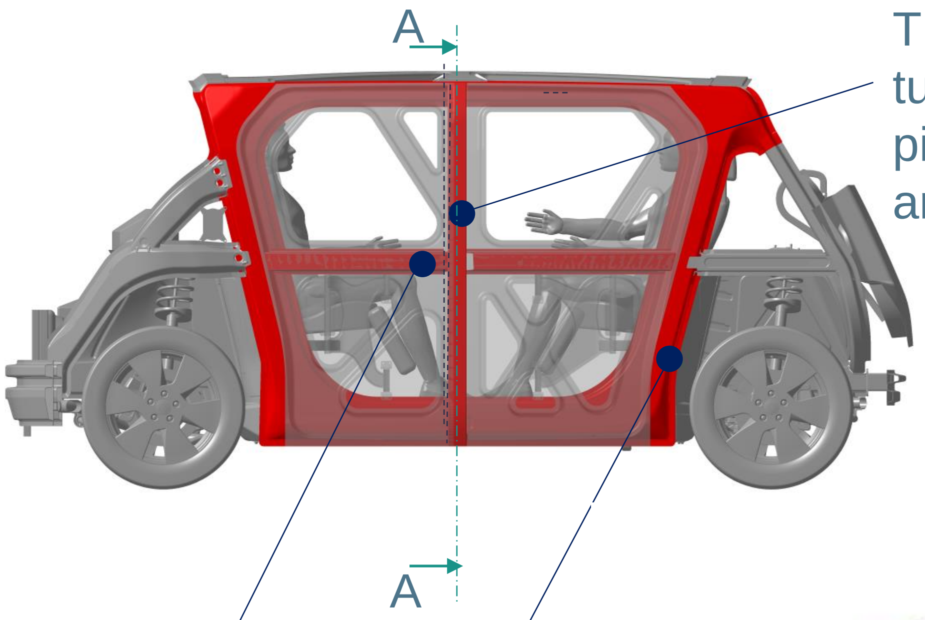
- In addition to the occupant protection test, additional side pole loadcases to ensure battery protection
- >30mm clearance to battery maintained

IIHS 60kph side barrier II (occupant protection)

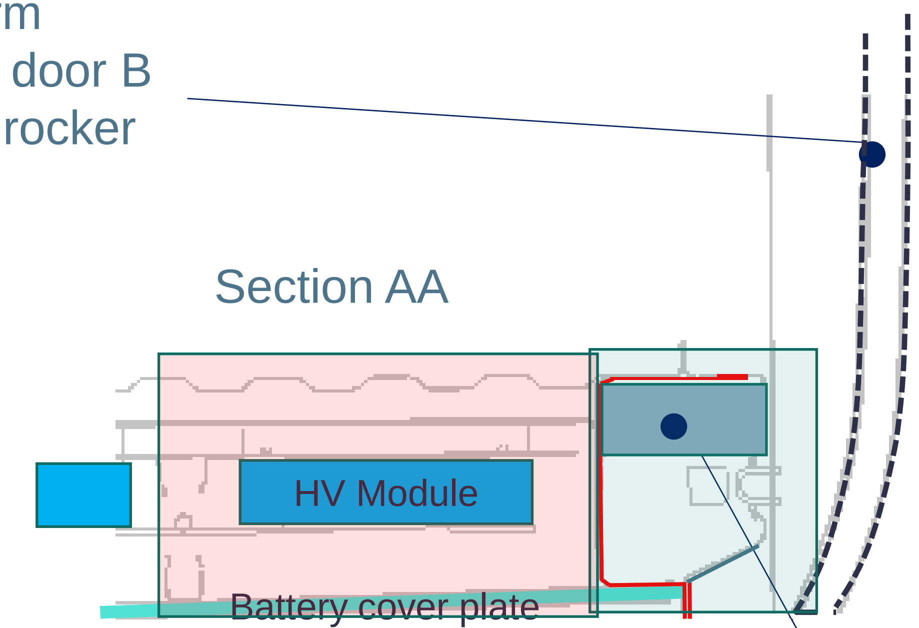


- IIHS “good” rating (based on predicted intrusions)

SAFETY – SIDE CRASH STRUCTURE CONSISTS OF ABSORPTION AND INTRUSION PREVENTION ZONES, COMPENSATING FOR LARGE BODY APERTURE

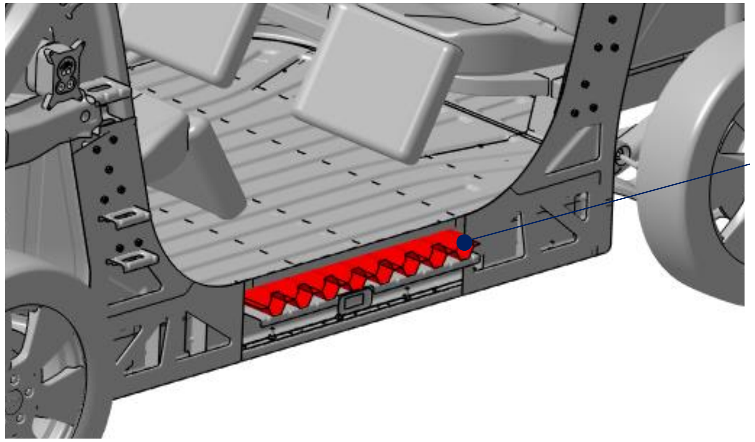


TRIP690 hydroform tubes interlocking door B pillars (wrap over rocker and cantrail)



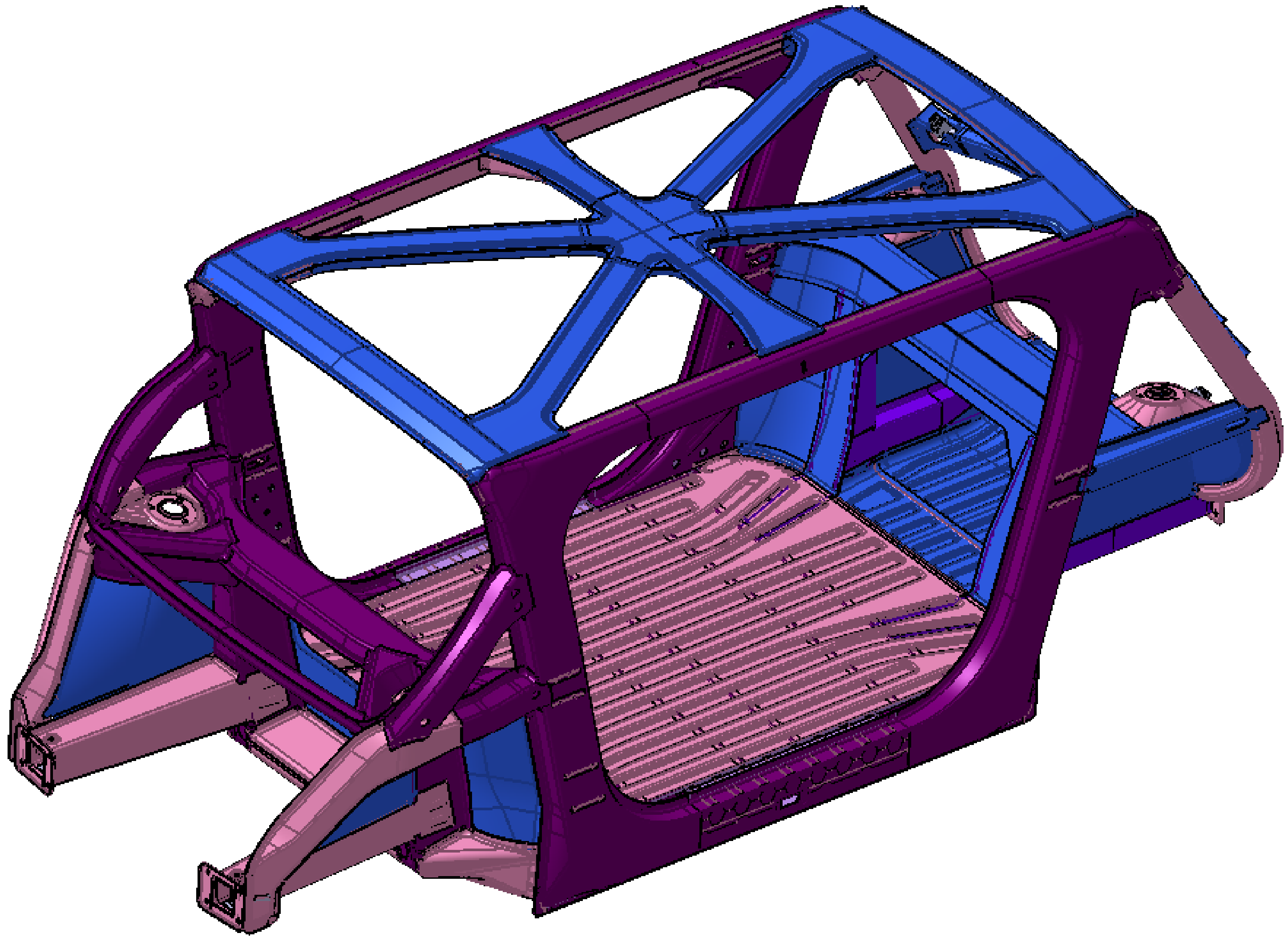
Roll stamped martensitic door waistrail beams

One piece TWB, Press Hardened Steel door ring outer. A and C pillars in line with occupants providing good side impact protection



Side impact crush “hex” beam. 2 piece roll formed DP590

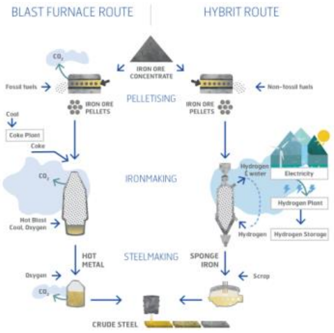
TOTAL COST OF OWNERSHIP: VEHICLE AND BODY IS DESIGNED FOR CONVENTIONAL FABRICATION AND ASSEMBLY PROCESSES



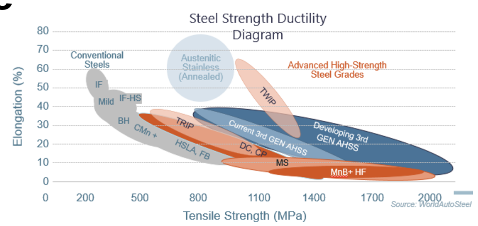
- Steel body design optimised to maximise material utilisation, minimise scrap rate
- Full formability analysis for critical/challenging panels
- Suitable for >250,000 units/year
- Conventional press, fabrication and joining tools
- Compatible with existing global automotive manufacture facilities

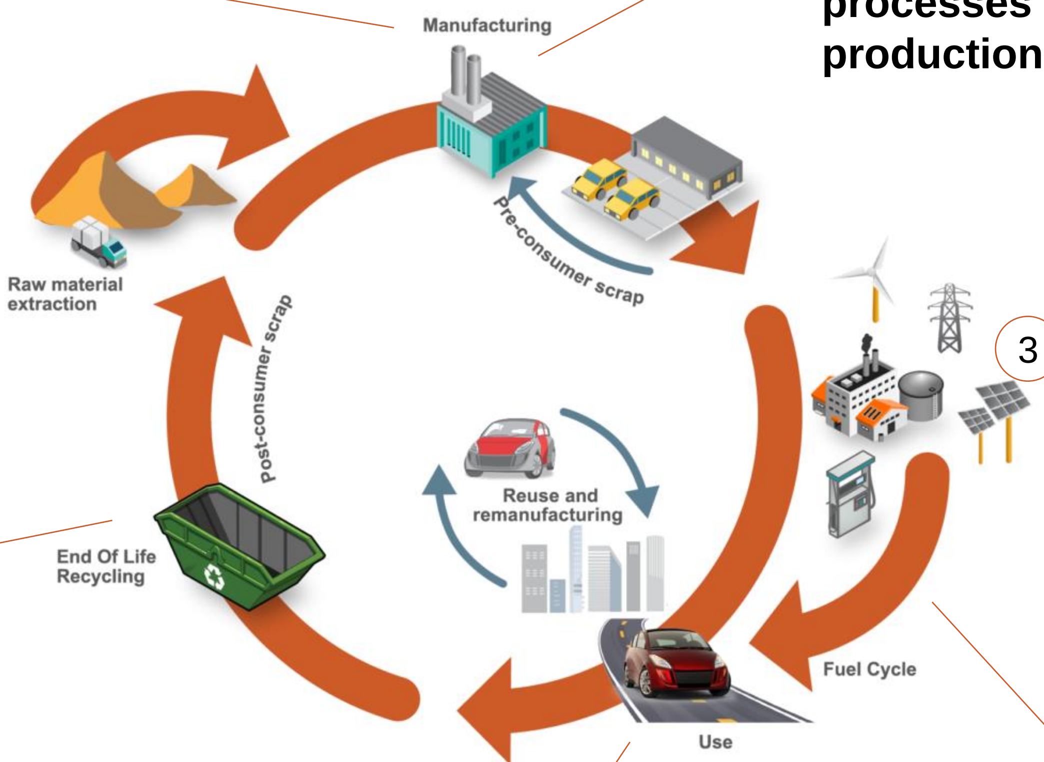
ENVIRONMENT & SUSTAINABILITY: COMPREHENSIVE LIFE CYCLE ASSESSMENT AND OPTIMISATION

1 **Decarbonise steel production (e.g. hydrogen Electric Arc Furnace)**

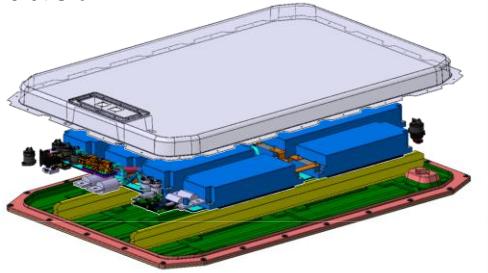


2 **Optimise vehicle design, material utilisation and fabrication processes to minimise production emissions**

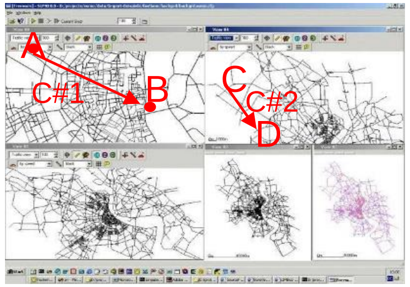




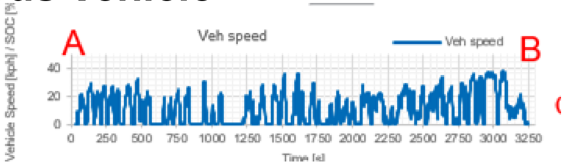
3 **HV battery production emission study and > 2030 forecast**



6 **Maximise Re-use, Re-manufacture, Recycling. End of life methodology**



5 **Real world drive cycle and drive cycle smoothing with autonomous vehicle control**



4 **Decarbonise electricity grid supply for xEV. Global variations & >2030 forecast (production and vehicle use)**

Image source: SSAB, ArcelorMittal

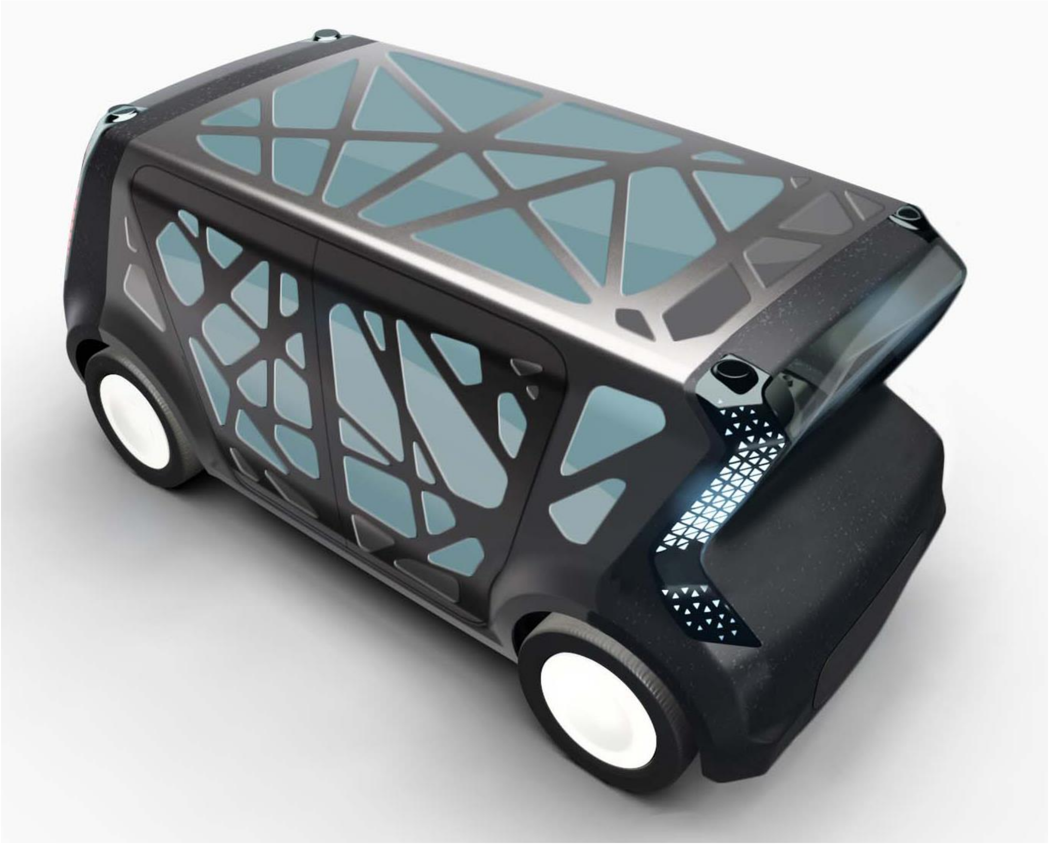
STEEL E-MOTIVE – KEY OUTCOMES

- Steel E-Motive project is delivering an exciting, futuristic vehicle, optimised from the ground up for autonomous Mobility as a Service application

- We have addressed the key challenges through careful design, application of simulation tools and efficient use of the latest Advanced High Strength Steels and processes:
  - safety
  - occupant comfort and accessibility
  - cost effectiveness
  - environmental & sustainability

- Steel E-Motive concept is suitable for global production in conventional automotive manufacturing facilities

- Follow us on our journey https://steelemotive.world/



STEEL E-MOTIVE
IN PARTNERSHIP WITH
WorldAutoSteel
RICARDO

Thank you.

Neil McGregor
Chief Engineer, Steel E-Motive
Ricardo
E: neil.mcgregor@ricardo.com | ricardo.com

George Coates
Technical Director
WorldAutoSteel & Steel E-Motive
E: georgecoates@thephxway.com
worldautosteel.org | steelemotive.world