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Smarter Safer Cleaner

Co-operative Research Centre for Advanced Automotive Technology

Project C2-23

Lightweight Modular Vehicle Platform

Design Challenges and Solutions

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Outline

- Design Principles
  - Lightweighting Approaches
  - LMVP Key Design Principles
  - Starting Point and Key Design Targets
- LMVP Conceptual Design Overview v1.0
  - Initial Concept Proposal
  - Initial Structural Assessment
  - Current Progress and Where to From Here?

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Design Principles and Targets

Lightweighting Approaches

Typically three approaches:

1. **Downsizing**
   - ❖ Reduction in vehicle size, storage space, no. of occupants etc.
   - ❖ Component size reductions – engine downsizing

   CURRENT APPROACHES

   - Can limit practicality
   - Can reduce performance / comfort
   - Weight savings are limited
   - Rely on existing design architecture

2. **Material substitution**
   - ❖ Replace with lower density materials
   - ❖ Often manufacturing constraints apply

   CURRENT APPROACHES

   - Often results in cost increase
   - Current infrastructure is relied upon
   - Conventional manufacturing techniques are relied upon
   - Weight savings are limited
   - Rely on existing design architecture

3. **Optimising vehicle structure**
   - ❖ Re-design with new materials / manufacturing processes
   - ❖ Novel integration of components / sub-assembly / modules

   NEW OPPORTUNITY

   - Requires a clean-sheet approach if performed at vehicle level
   - Resource intensive for current Auto Companies
   - Major infrastructure changes
   - Potential for large weight savings
   - Potential for large cost reductions

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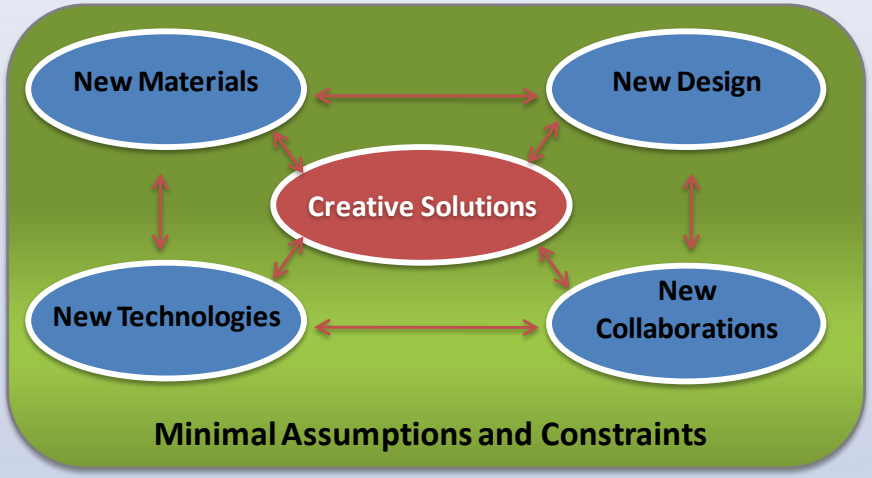
LMV - Basic Design Principles

- Lightweight
  - Lightweight Quality – no compromise to safety or structural performance
- Flexible in design and manufacturing
  - Ability to suit multiple platform variants and powertrain/fuel storage sources
  - Ease of manufacture and assembly using a distributed manufacturing model
  - Market flexibility – interior / exterior packages added to suit variety of markets
- Low cost
  - Body structure cost is comparable to current vehicles (BIW)
  - Cost is relatively insensitive to production volumes
  - Low cost tooling / infrastructure requirements for plant setup
  - Scalable suit entry level to premium markets



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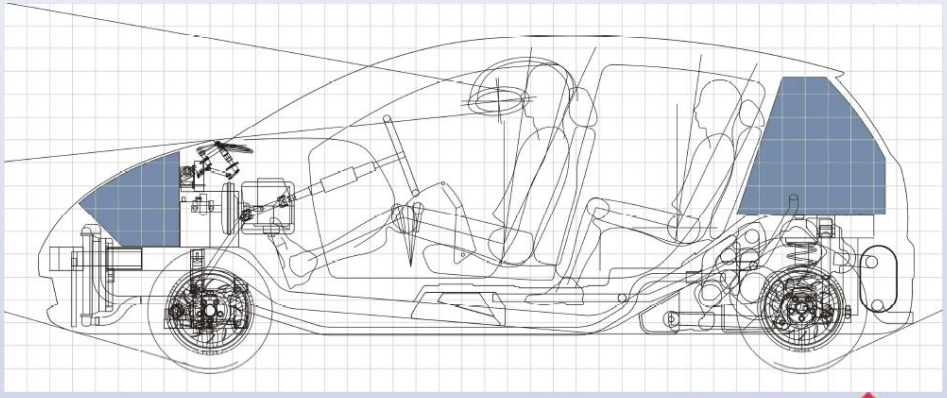
Starting point for the concept

- Vehicle Layout - Duoleta Package
  - Small to medium sized vehicle – 3825 L x 1648 W x 1476 H
  - Front Track and Wheelbase
  - Conform to Exterior Style – aerodynamics (C_d < 0.25)
  - Secure luggage compartment in front and rear storage (variant dependent)
- Rear mounted engine – Rear drive
  - CAD packaged Mitsubishi 1.0L Petrol Engine
  - Ability to suit multiple powertrain types and fuel storage sources – rear engine cradle package
- New Design Model - Function before Form (non-traditional approach – Model T^2)
  - Ability to produce multiple vehicle variants from modular vehicle structure (sedan, hatch, wagon, utility/pickup, convertible)
  - Ability to suit multiple market segments – entry-level to premium market



Design Targets

Vehicle Attribute / Metric		Target
Mass	Vehicle Kerb Weight	700 kg (heaviest vehicle variant)
	Body Structure Weight	105 – 140 kg (15-20% of kerb weight)
Structural Performance	Static Torsional Stiffness	≥19 kNm/deg (with roof) or ≥11 kNm/deg (no roof i.e convertible)
	Static Bending Stiffness	≥17 kN/mm (with roof) or ≥8 kN/mm (no roof i.e convertible)
	Lightweight Quality Factor	≤ 2.0 (with roof) or ≤ 3.4 (no roof)
Crash Performance	EURO NCAP / AUS NCAP / US NCAP	Competitive with current stringent crash regulations - 4 or 5 star equivalent
Affordability	Body Structure Cost	$1,500 Competitive with current body structures
Flexibility	Configurable Vehicle Platform	Ability to easily interchange /scale modules to suit different vehicle variants and powertrain sources
	Market Flexibility	Ability to suit various markets – styling flexibility, upgradeable, customisable
	Flexible Manufacturing Process	Low cost and flexible tooling configuration, scalable production volumes (15,000 – 100,000), minimal infrastructure
Environmental Sustainability	Life Cycle Impact	Minimal environmental burden throughout entire product - Life Reference to ULSAB and SLC LCA

Targets set through benchmarking

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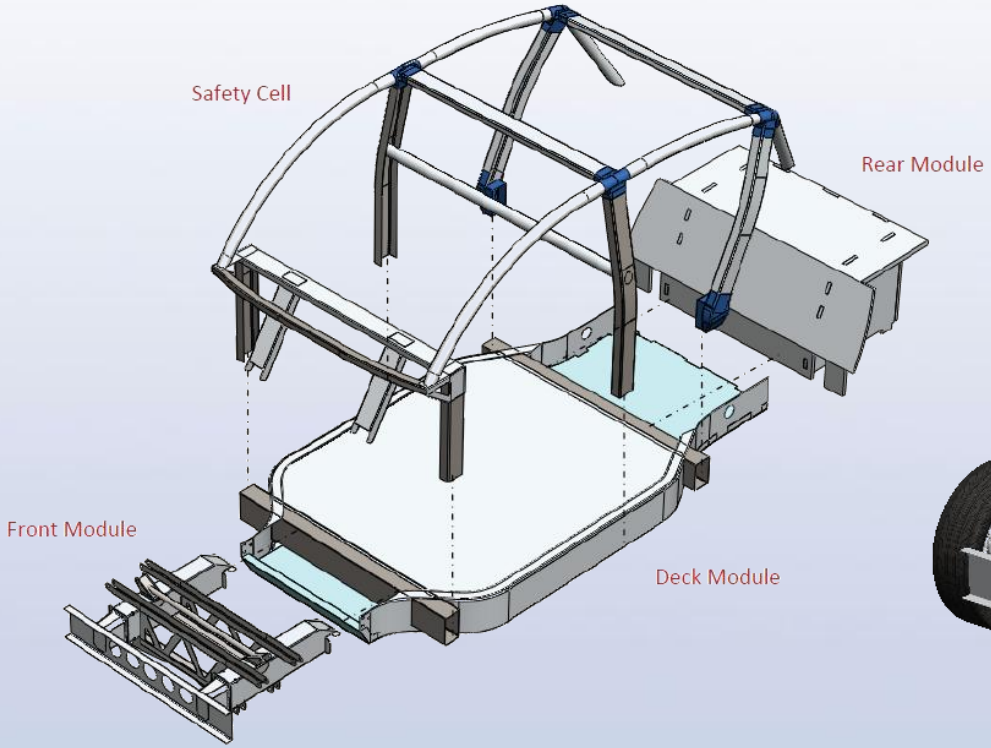
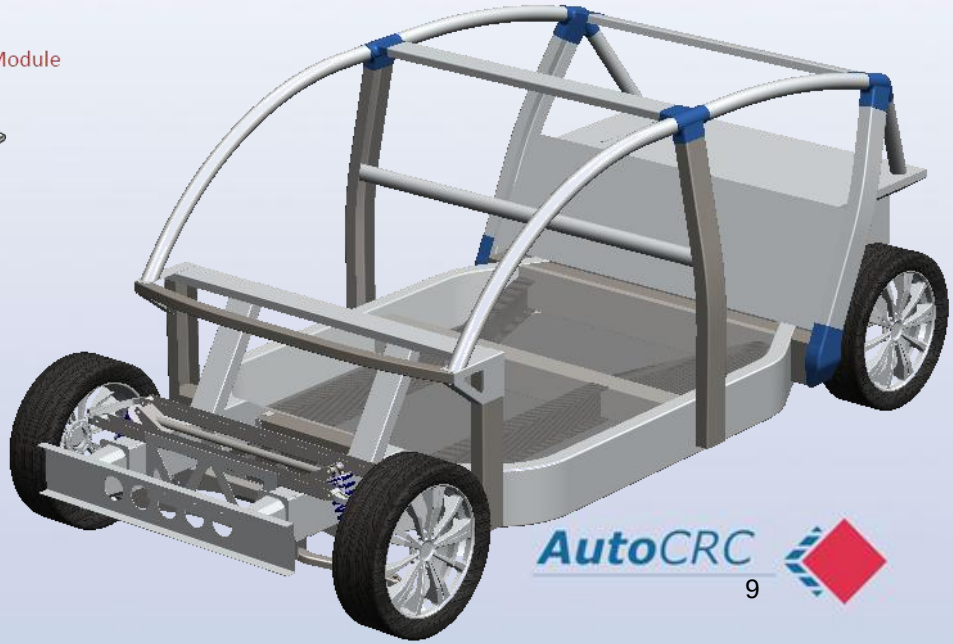
Concept Design Overview v1.0

Concept Overview

- Each module optimised for specific functional and structural objectives
- Architecture defines strategies to manage objectives
- Simplistic geometry provides flexibility and low cost manufacturing methods
- Material is engineered and optimised to meet all structural, cost, LCA, and manufacturing requirements





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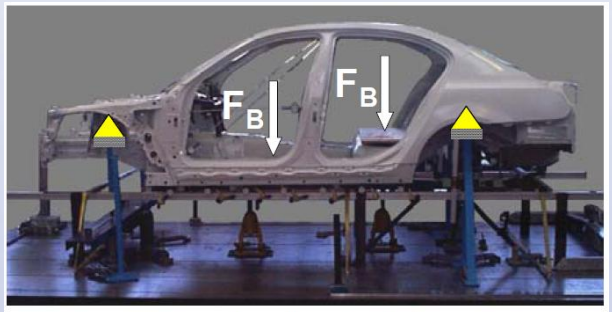
Deck Module

- Functional Design Objectives:
  - Form the basis of the vehicle structure to which additional modules can be attached and as a result reduce the need for complex assembly fixtures
  - Accommodate suitable packaging space for fuel/energy storage
  - Module to be common to all vehicle variants
  - Scalable and modular – allow parametric scaling to suit varying vehicle size
  - Lightweight, competitive cost with traditional methods
- Structural Requirements:
  - Act as primary fixture for accommodating road load inputs
  - Provide significant contribution to total vehicle torsional and bending stiffness
  - Contribute to protection of occupants / fuel source in impact

torsional test

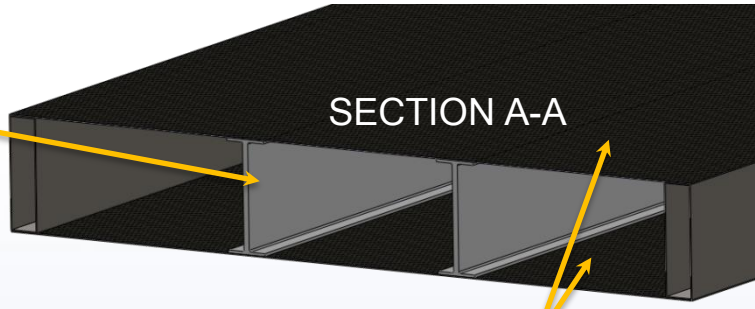


bending test

Deck Module

Optimised Composite Sandwich Floor Structure

Pultruded GFRP I-Beam sections reinforce sandwich structure

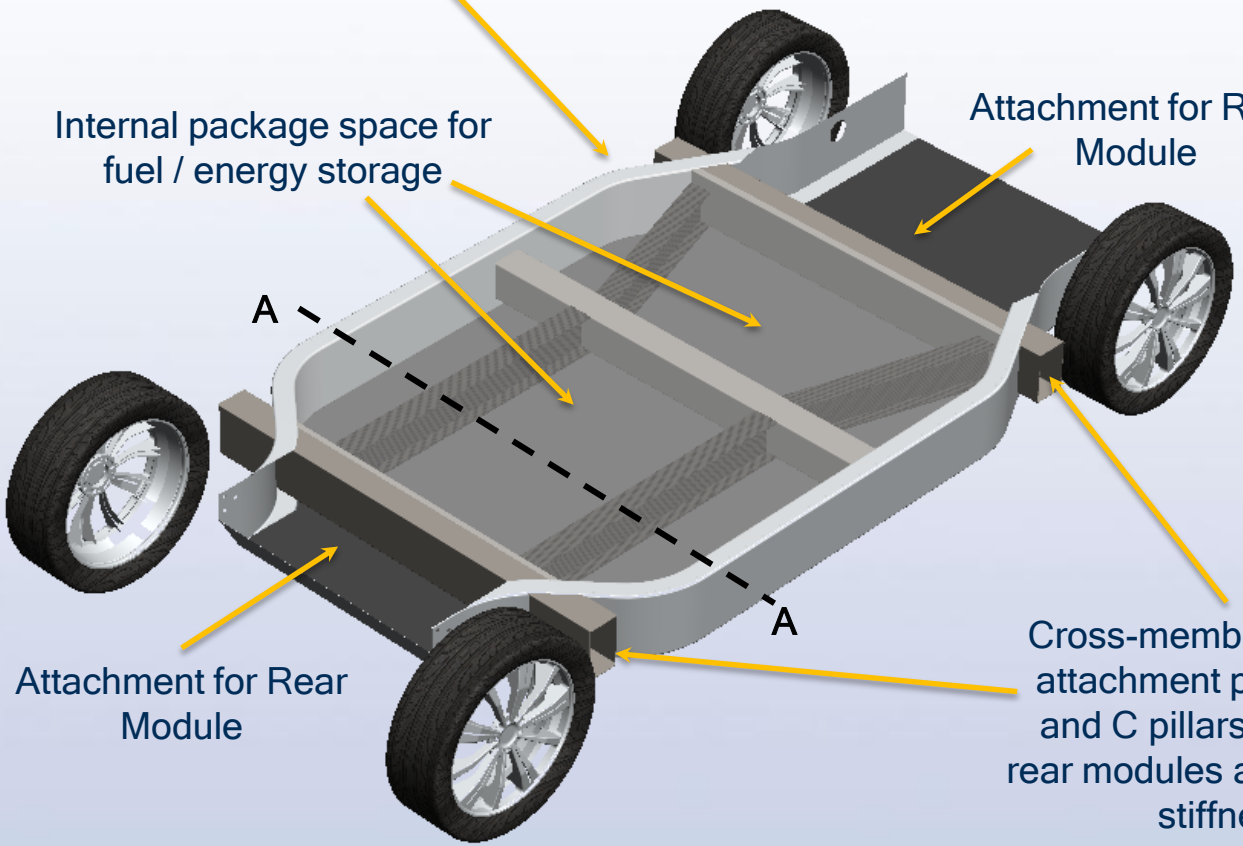


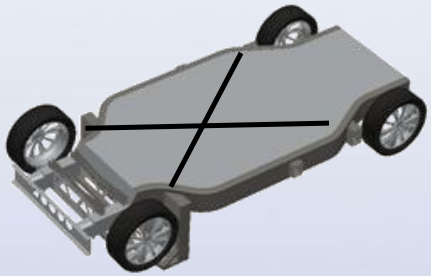
AHSS/ UHSS Chassis Rails – maximum section height to increase bending stiffness

Internal package space for fuel / energy storage

Attachment for Rear Module

Composite Face Sheets engineered to provide improvements to torsional stiffness and NVH



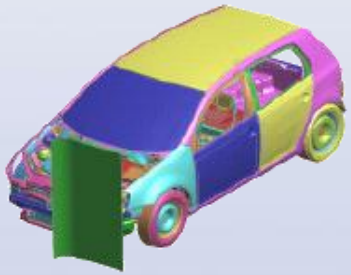


Attachment for Rear Module

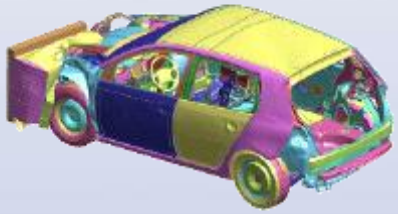
Cross-members provide attachment points for A and C pillars, front and rear modules and increase stiffness

Front Module

- Design objectives
  - Protect occupant during frontal impact
  - Provide attachment for front suspension sub-system
  - Provide suitable area for storage
  - Package space for headlights, radiators and other vehicle ancillaries
  - Module to be common to all vehicle variants
  - Lightweight
  - Ease of assembly / disassembly from deck module
- Structural Requirements
  - Optimised for energy absorption in frontal and offset frontal crash
  - Minimise or deflect intrusion into vehicle safety cell
  - Provide suitable local bending and torsional stiffness



AZT Insurance Frontal Test

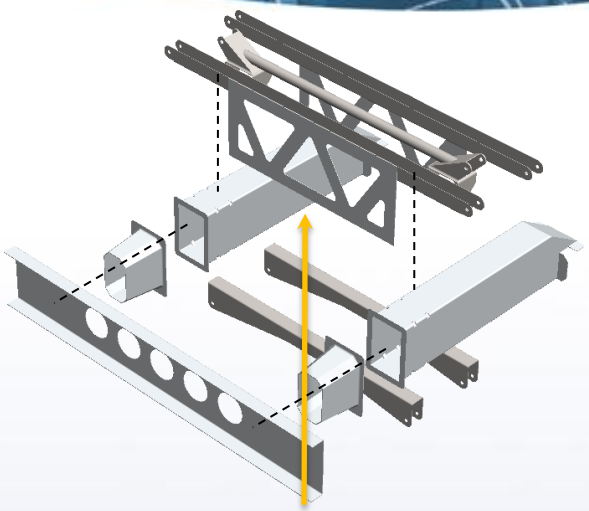


EuroNCAP Front Impact

Front Module

Low Speed Crash Cones

Crash Rails – optimised for energy absorption to ideal crash pulse. Mounting points for suspension module

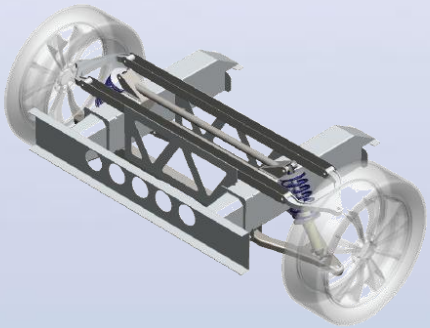


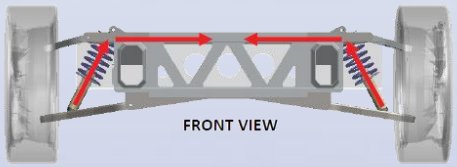
Simplified front suspension assembly

Roll formed bumper beam

Roll formed suspension cross-members provide flexibility in hard point attachment

Shear plates improve torsional stiffness – improved vehicle handling

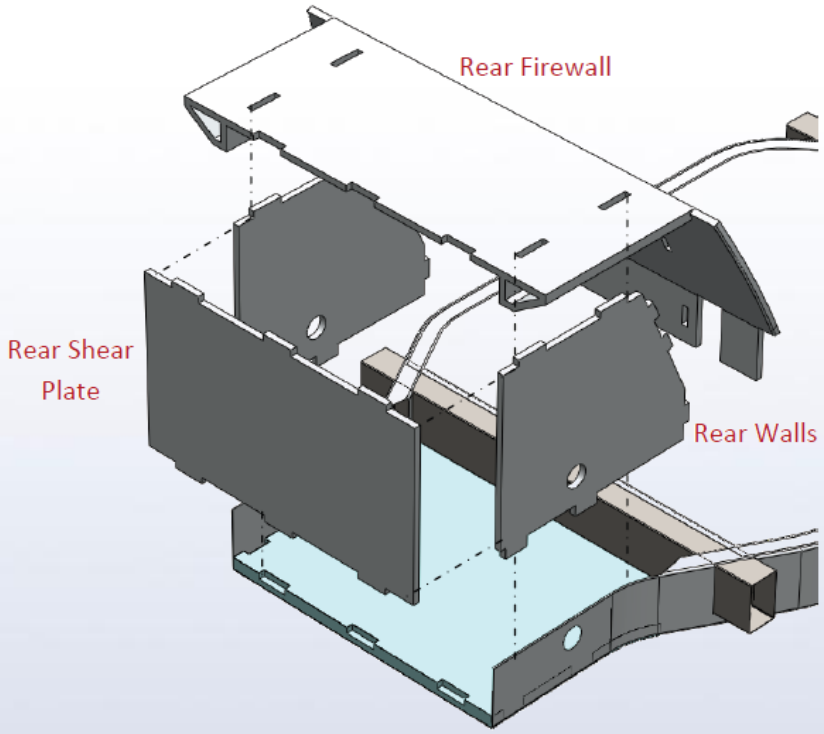




Double wishbone suspension simplifies body structure requirements – reducing mass

Rear Module

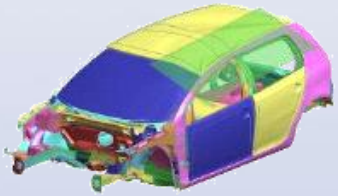
- Design objectives
  - Accept powertrain sub-assembly
  - Accommodate package space for cargo storage
  - Accommodate attachment of rear suspension sub-assembly
  - Module common to all vehicle variants
  - Lightweight
  - Ease of assembly / disassembly to deck module
- Structural Requirements
  - Optimised for energy absorption and control intrusion given rear engine package
  - Provide suitable local bending and torsional stiffness when suspension



Safety Cell

- Design Objectives:
  - Accommodate occupants
  - Protect occupants in the event of a crash
  - Scalable and modular – allow multiple vehicle variants with minimal change
  - Lightweight
  - To be easily attached / detached from deck module
- Structural Requirements:
  - Suitable Stiffness to minimise intrusion during a crash events
  - Distribute crash loads throughout structure – balancing intrusion / energy absorbtion
  - Contribute to global torsional and bending stiffness of vehicle structure

EuroNCAP Side Impact



FMVSS 216 Roof Crush

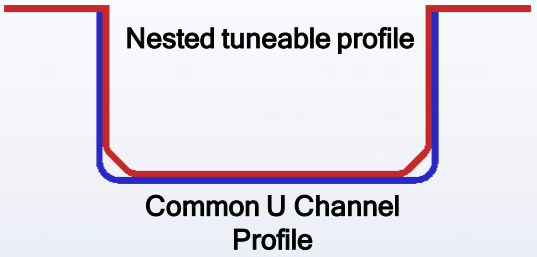
EuroNCAP Pole Impact

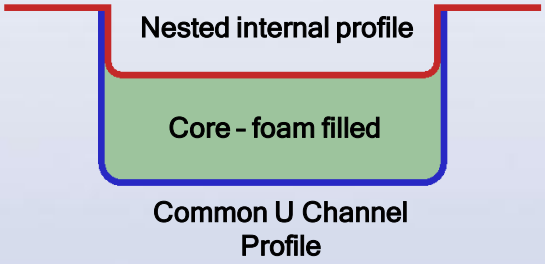
Safety Cell

To achieve modularity:

- Use a common roll formed profile to provide initial structural package
  - Allow application of other technologies to provide additional stiffness / strength where required within the roll formed profile package
    - Application of nested roll formed profiles in areas where improved stiffness / strength is required
    - Foam filled closed members
    - Composite inlays
  - Reduce complicated and expensive tooling costs
  - Modularity is achieved at a part level within the safety cell
- Simple geometry and constant cross-section allow adjustability - modularity

Tuneable and scalable to various vehicle types and crash requirements

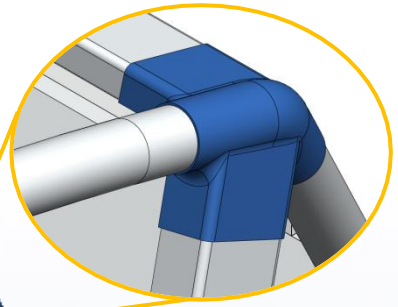




Safety Cell

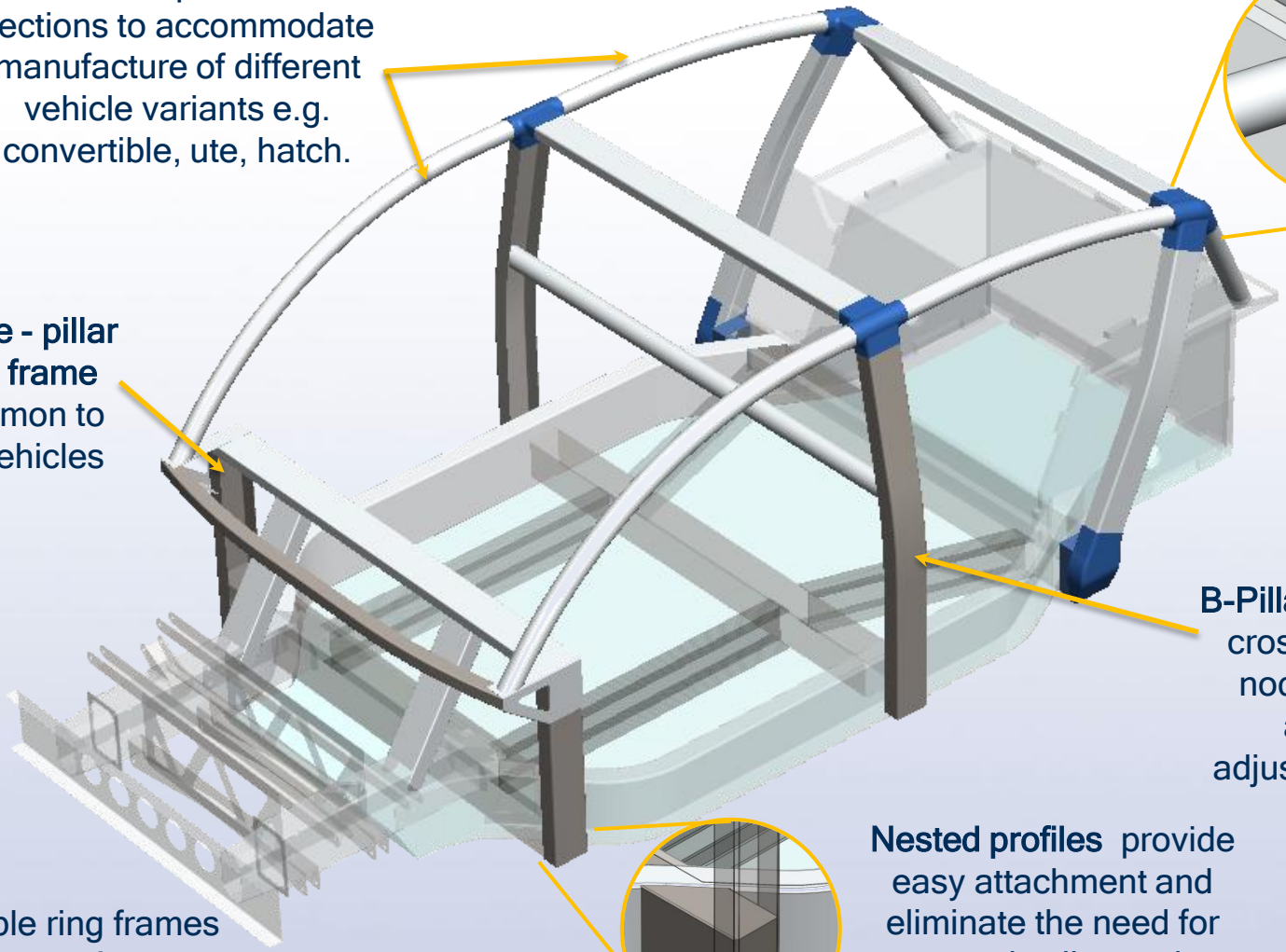
Light alloy tubular roof rails and roll formed roof cross members

Roof Rail split into two sections to accommodate manufacture of different vehicle variants e.g. convertible, ute, hatch.



Cast connection nodes

Hinge - pillar ring frame common to all vehicles



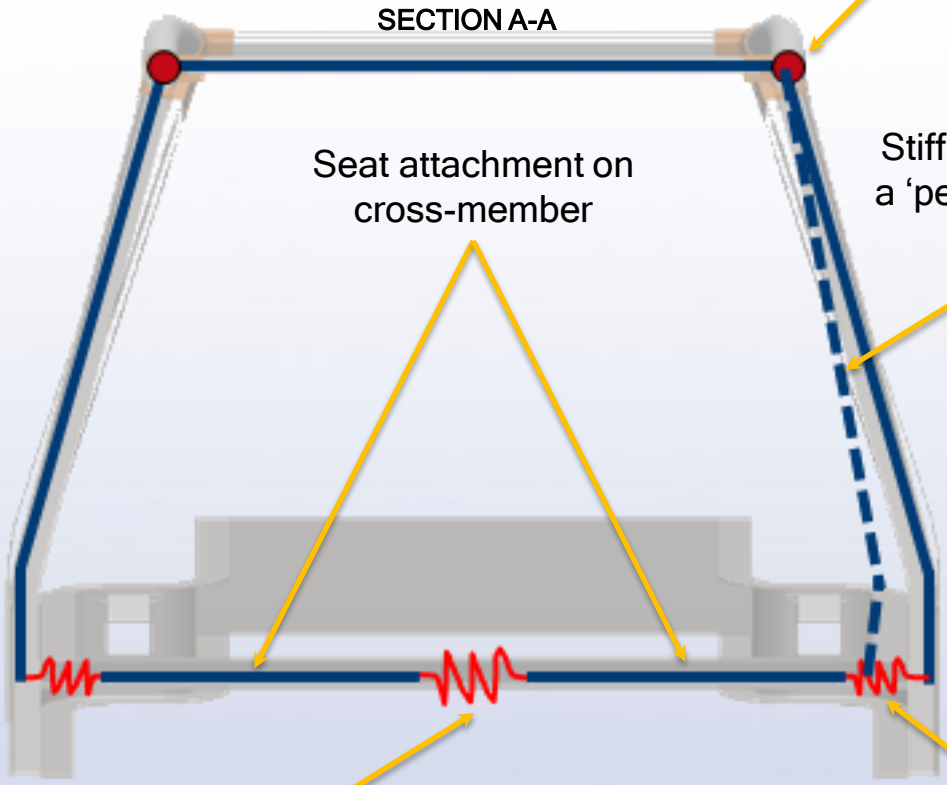
B-Pillar ring frame common cross section at roof rail nodes and chassis rail allow parametric adjustment of longitudinal placement

Nested profiles provide easy attachment and eliminate the need for complex jigs and flanging

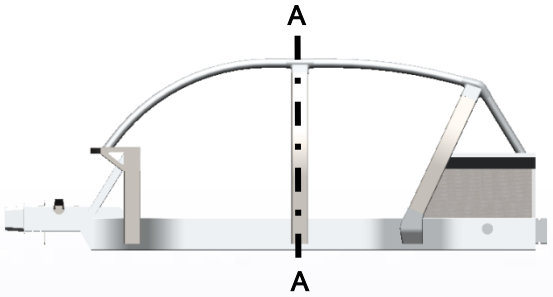
Simple ring frames and roof rails achieve modularity

Safety Cell

Side Impact Design Strategy



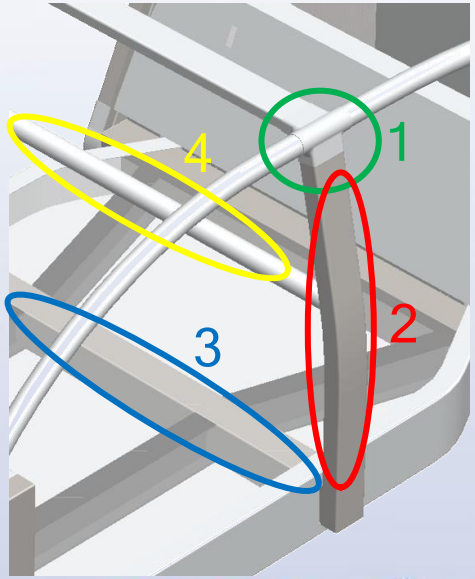
Cast node acts as roof joint during side impact - tuneable



Seat attachment on cross-member

Stiff B-Pillar collapses in a 'pendulum' type motion

Four Tuneable Elements

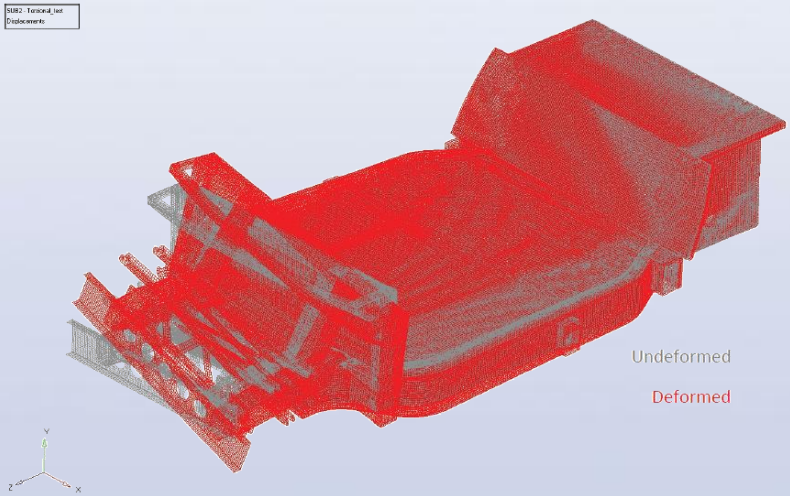


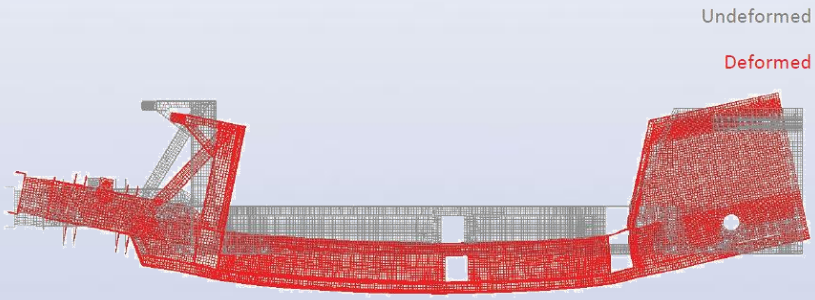
Occupant is moved by the seat with the crash zone and secondary energy absorption occurs by a central crushable element - tuneable

Outer crumple zones crush first reducing the initial crash pulse - tuneable

Initial Structural Analysis

Vehicle Attribute / Metric		Target	Initial Concept Specs
Mass	Body Structure Weight	105 – 140 kg (15-20% of kerb weight)	148.3 kg
Structural Performance	Static Torsional Stiffness	≥ 11 kNm/deg (no roof)	11.3 kNm/deg (lower structure only – no roof)
	Static Bending Stiffness	≥ 8 kN/mm (no roof)	6.50 kN/mm (lower structure only – no roof)
	Lightweight Quality Factor	≤ 3.4 (no roof)	3.5 (no roof)





Conclusion

- LMVP Concept v1.0
  - Vehicle architecture and descriptive strategies to manage functional and structural requirements developed
  - Design refinement and optimisation
  - Material engineering and manufacturing process development

- The LMVP project aims to propose a new vision for the next generation vehicle structure by taking a clean-sheet approach
  - Elimination of current assumptions and constraints
  - New design approach – function before form
  - New materials and manufacturing processes
  - On track to meeting aggressive design targets

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Thank You

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