THE LIGHTWEIGHT MODULAR VEHICLE PLATFORM (LMVP) PROJECT

LIGHTWEIGHT DESIGN CHALLENGES

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Outline

- The Lightweight Modular Vehicle Project (LMVP)
  - What? Who?
  - Lightweight, Flexible and Low Cost Body Structure
- Background - Current Automotive Trends and Limitations
  - Rationale for Lightweight Vehicles
  - Mass Reduction Strategies
  - Need for Revolution not Evolution
- LMVP Overview
  - Basic Design Principles
  - Starting Point and Design Targets
  - Initial Concept
  - Initial Structural Assessment
  - Current Progress and Where to From Here?

Lightweight Modular Vehicle Platform Project

AutoCRC Smarter Safer Cleaner

DEAKIN UNIVERSITY

SWINBURNE UNIVERSITY OF TECHNOLOGY

VPAC VICTORIAN PARTNERSHIP FOR ADVANCED COMPUTING

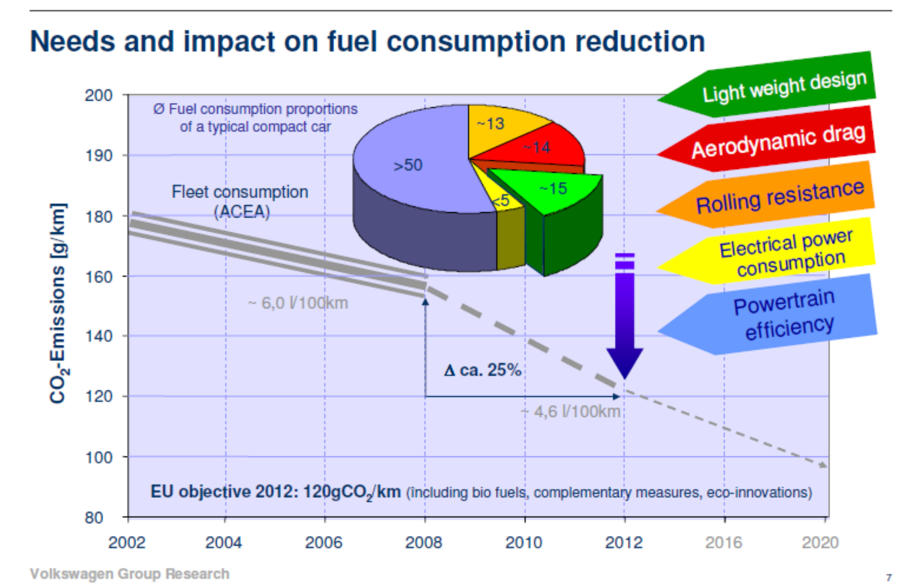
RMIT UNIVERSITY

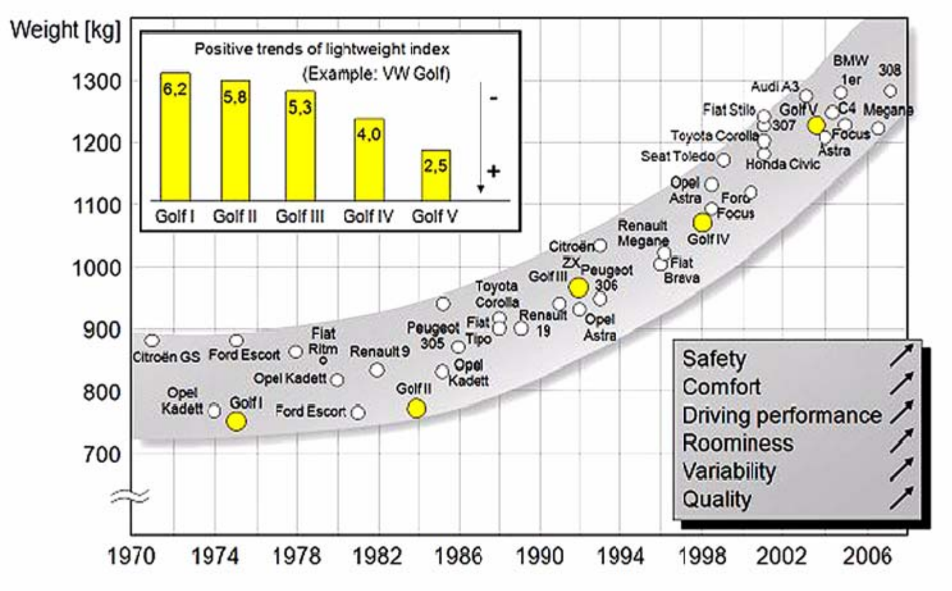
ANU THE AUSTRALIAN NATIONAL UNIVERSITY

- What's the aim?
  - Develop a **lightweight**, **modular** vehicle platform to provide the structural basis for a large range of vehicles in markets around the world
  - Propose an alternative vision for the auto industry
  - Further develop research in lightweight vehicle structures
- Who's involved?
  - Funded by the Cooperative Research Centre for Advanced Automotive Technology (AutoCRC) as part of the Visionary Projects
  - Five Australian Research Partners
- What are the outputs?
  - Conceptual design and feasibility assessment of vehicle body structure
  - Technology development plan supported by ongoing research

![AutoCRC Technical Conference 2011]

Rationale for Lightweight Vehicles





Consumers and governments impose harsher targets for auto designers

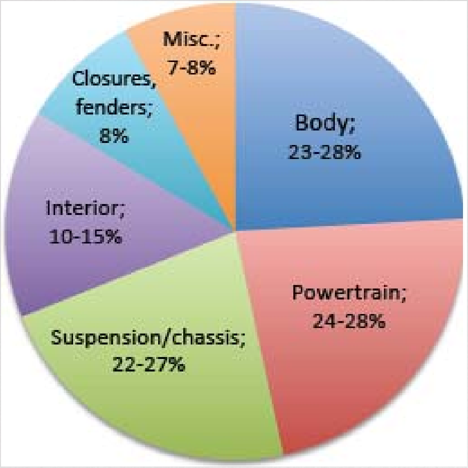
- Improved safety, comfort, performance, quality ↑ **Vehicle Mass**
- Reduced fuel consumption, emissions, sustainability ↓ **Vehicle Mass**

Image Sources: Sahr, C. et al. Pathways for a sustainable Automotive Furture in Europe. Lightweight Vehicle Structure Conference Proceedings. 2009. Germany

Body Structure Mass

Reduction in vehicle structure mass can:

- Lead to significant secondary weight savings – Powertrain, Chassis etc.
- Lower emissions (ICE,Hybrid) or improve range (Electric, Hybrid) or introduce non-conventional powertrain sources (compressed air, CNG)
- Be critical in meeting future emission regulations
- Improves driving performance



Vehicle Mass Breakdown

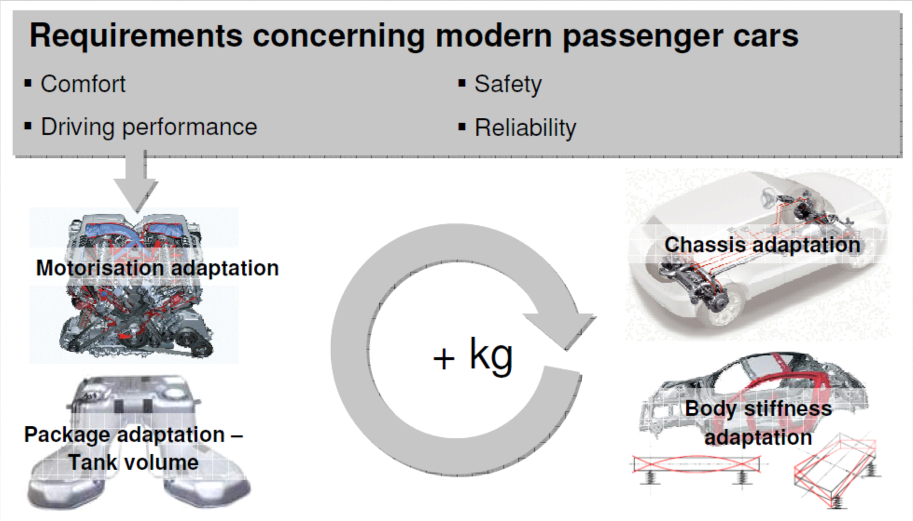


Image Source: Sahr, C. et al. Pathways for a sustainable Automotive Furture in Europe. Lightweight Vehicle Structure Conference Proceedings. 2009. Germany

Typical Mass Reduction Strategies

Typically three approaches:

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

   - Can limit practicality
   - Can reduce performance / comfort
   - Weight savings are limited
   - Rely on existing design architecture
   - Not really lightweighting

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

   - 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

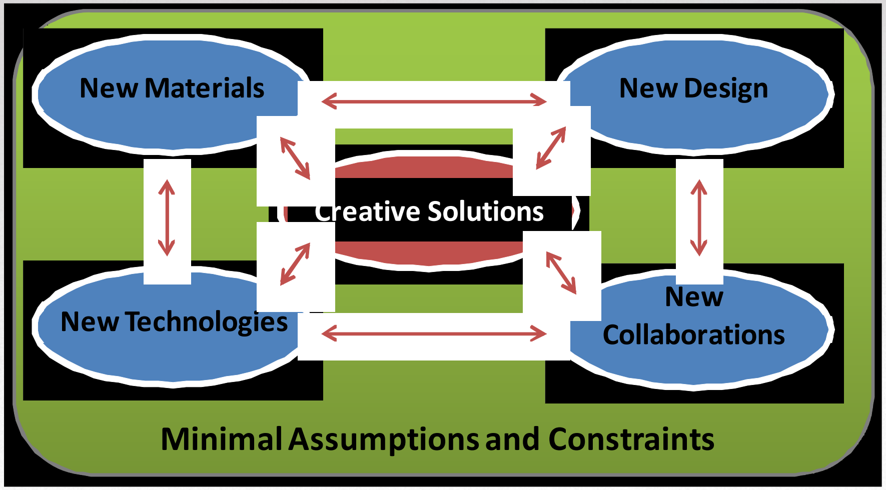
3. **Mass Optimisation – vehicle level**
   - ❖ New design approaches enable new materials, new manufacturing processes

   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**
   - **Potential for increased product flexibility**

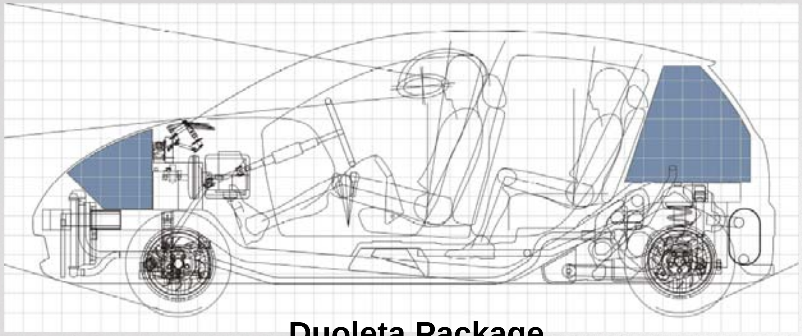
LMVP - Basic Design Principles

- 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 to suit entry level to premium markets



Starting Point

- Vehicle Layout - Duoleta Package
  - Small to medium sized vehicle – 3825 L x 1648 W x 1476 H
  - Front Track and Wheelbase - initial vehicle package
  - 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
  - Optimise for mass reductions



Duoleta Package

Model T^2

Data courtesy of: Duoleta Lightweight Vehicle - Technical Report. 2006, CSIRO. University of South Australia. AutoCRC.

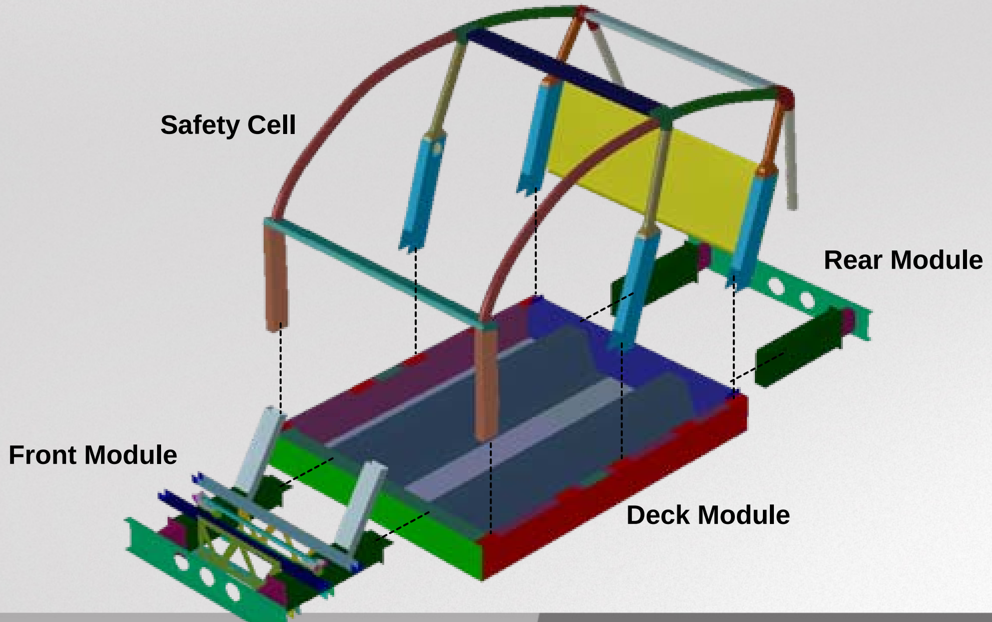
Body Structure Design Targets

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
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

Concept Overview

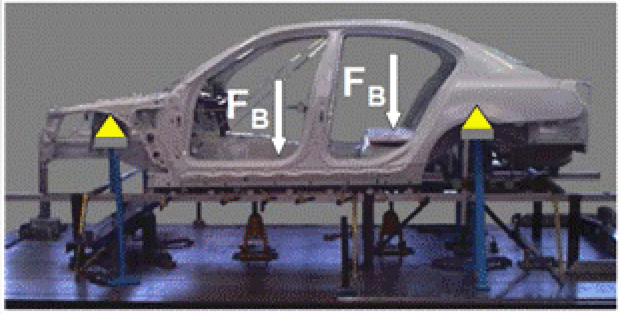
- Body structure is decomposed into functional modules
- Each module optimised for specific functional and structural objectives
- Architecture defines strategies to manage objectives
- Simplistic geometry provides flexibility and low cost manufacturing methods
- Material is engineered and optimised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



Deck Module

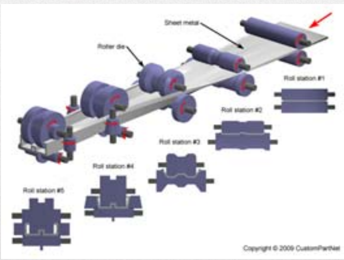
- Functional Design Objectives:
  - Form the basis of the vehicle structure to which additional modules can be attached and as a result reduce the need for complex assembly fixtures
  - Accommodate suitable packaging space for fuel/energy storage
  - Common module to all vehicle variants
  - Scalable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

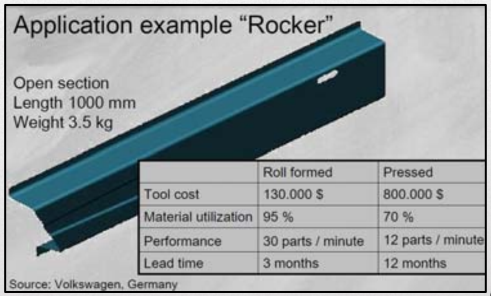
torsional test



bending test

Deck Module





Application example "Rocker"

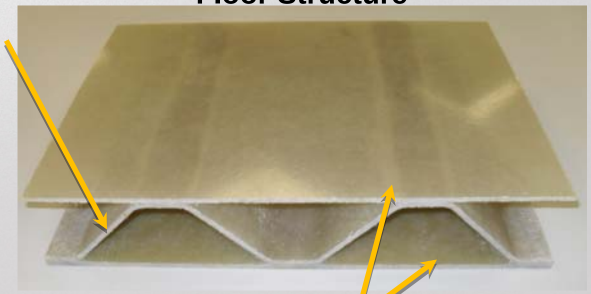
Open section
Length 1000 mm
Weight 3.5 kg

	Roll formed	Pressed
Tool cost	130.000 $	800.000 $
Material utilization	95 %	70 %
Performance	30 parts / minute	12 parts / minute
Lead time	3 months	12 months

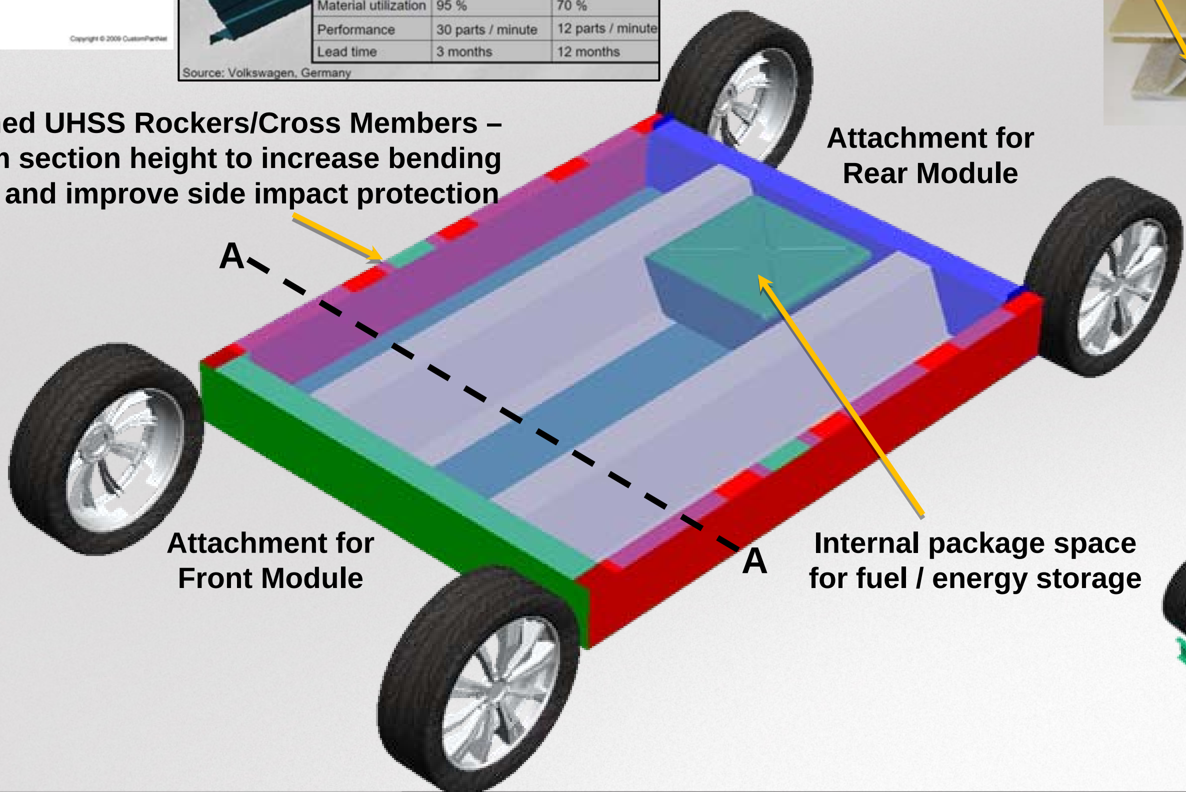
Source: Volkswagen, Germany

Internal Corrugations are easy to manufacture and increase specific bending stiffness

Hybridised Composite Corrugated Floor Structure



Roll formed UHSS Rockers/Cross Members – maximum section height to increase bending stiffness and improve side impact protection

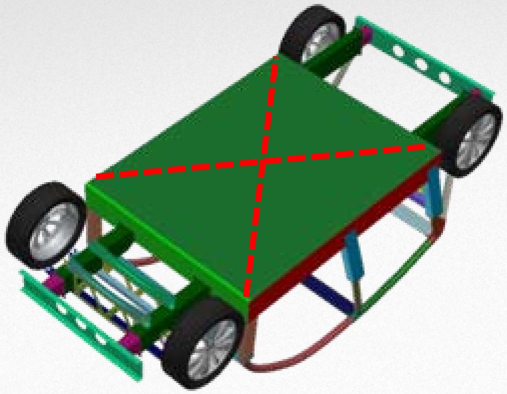


Attachment for Rear Module

Hybrid composite face sheets engineered for torsional stiffness, weight and cost

Attachment for Front Module

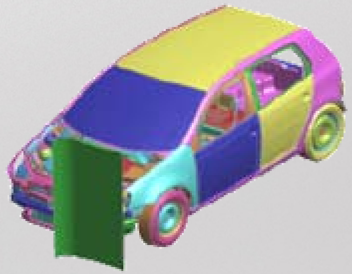
Internal package space for fuel / energy storage



Roll forming image: Weber, H., Roll Forming of Advanced High-Strength Steels, in Great Design in Steel Seminar. 2004.

Front Module

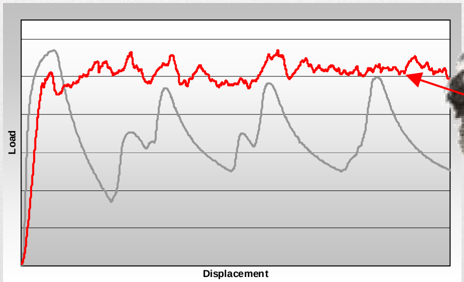
- Functional Design objectives
  - Protect occupant during frontal impact
  - Provide attachment for front suspension sub-system
  - Package space for headlights, radiators, cargo storage and other vehicle ancillaries
  - Scalable – to suit varying vehicle size
  - Common module to all vehicle variants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

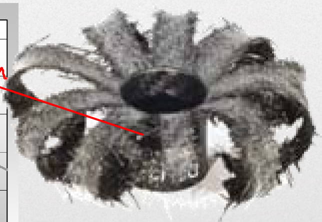


AZT Insurance Frontal Test

EuroNCAP Front Impact

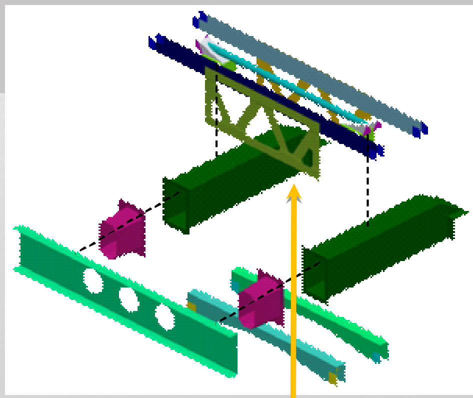
Front Module





Shear plates improve localised torsional stiffness – improved vehicle handling

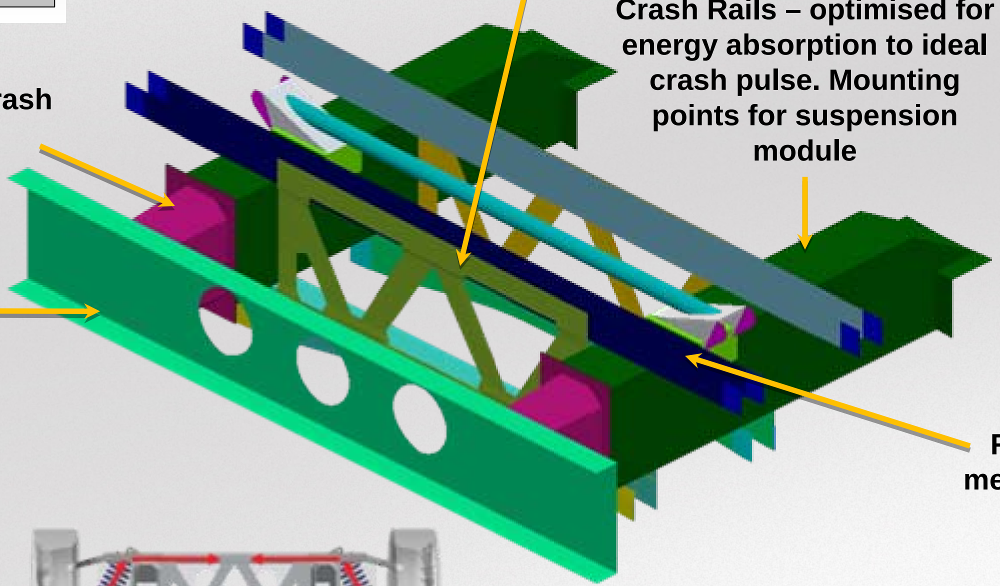
Crash Rails – optimised for energy absorption to ideal crash pulse. Mounting points for suspension module



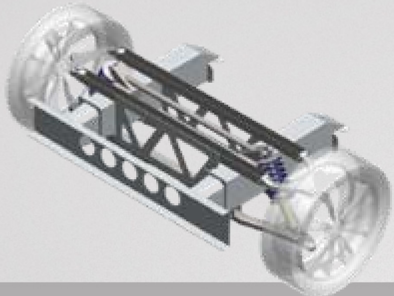
Simple, lightweight and scalable front suspension module attaches easily

Low Speed Crash Absorber

Roll formed UHSS bumper beam



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



Double wishbone suspension simplifies load path and body structure requirements – reducing mass

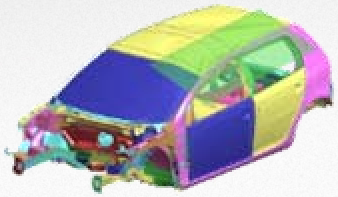
Carbon Fibre Tube Crush data courtesy of Dr. Michael Silcock.

Safety Cell

- Functional Design Objectives:
  - Accommodate occupants
  - Protect occupants in the event of a crash
  - Scalable and modular – allow multiple variant configurations with minimal change
  - Lightweight and cost competitive
  - To be easily attached / detached from deck module
- Structural Requirements:
  - Suitable stiffness to manage intrusion during crash events
  - Distribute crash loads throughout structure – balance intrusion / energy absorption
  - Contribute to global torsional and bending stiffness of vehicle structure

EuroNCAP Side Impact

EuroNCAP Pole Impact



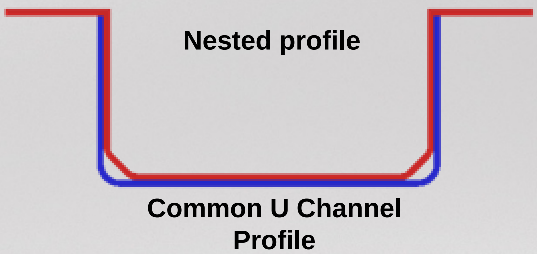
FMVSS 216 Roof Crush

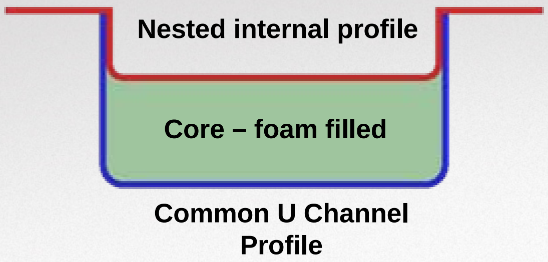
Safety Cell

To achieve modularity:

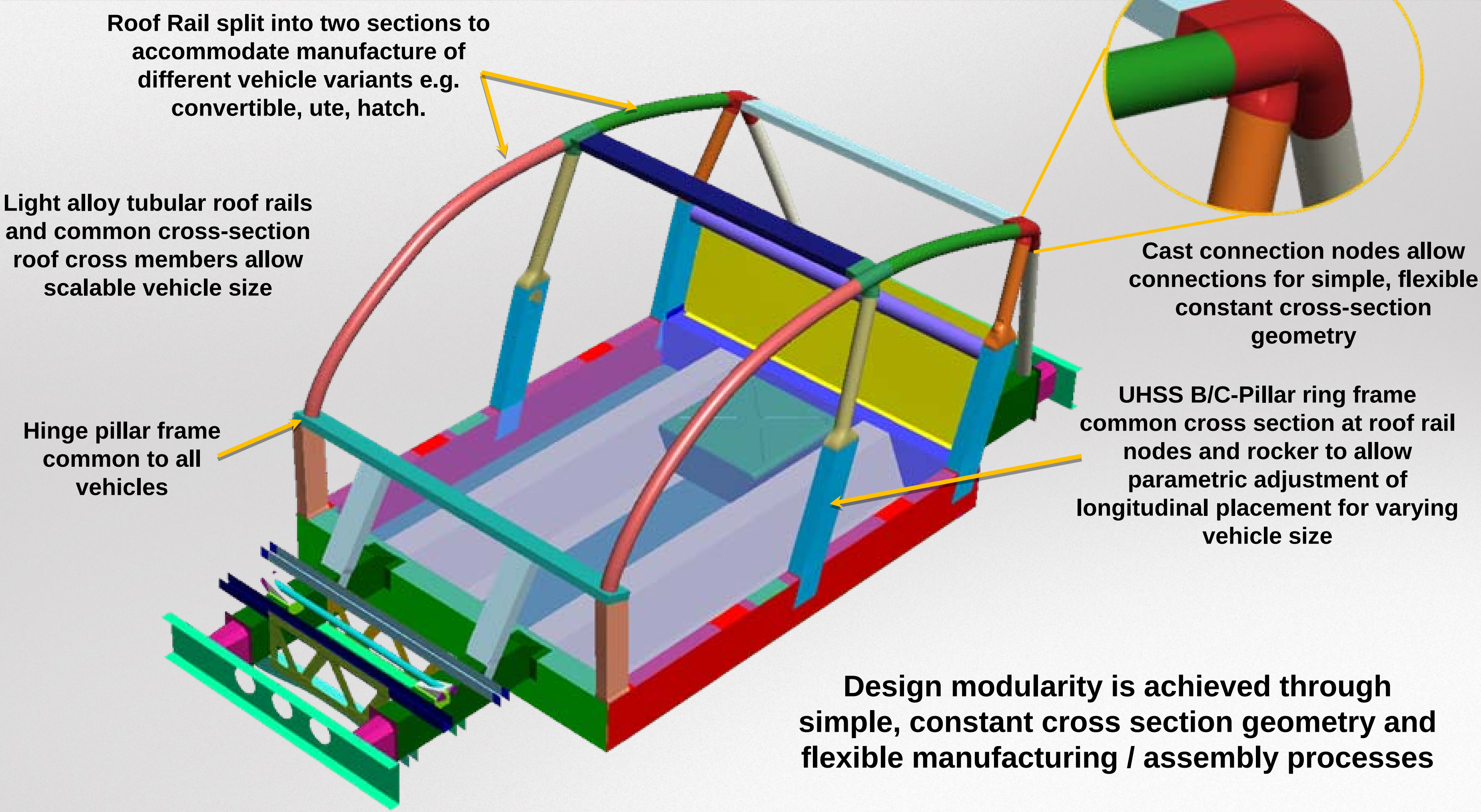
- Common roll formed profile to provide initial structure
  - Allow application of other technologies to provide additional stiffness / strength where required
    - Application of nested roll formed profiles in areas where improved stiffness / strength is required
    - Foam filled closed members
    - 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





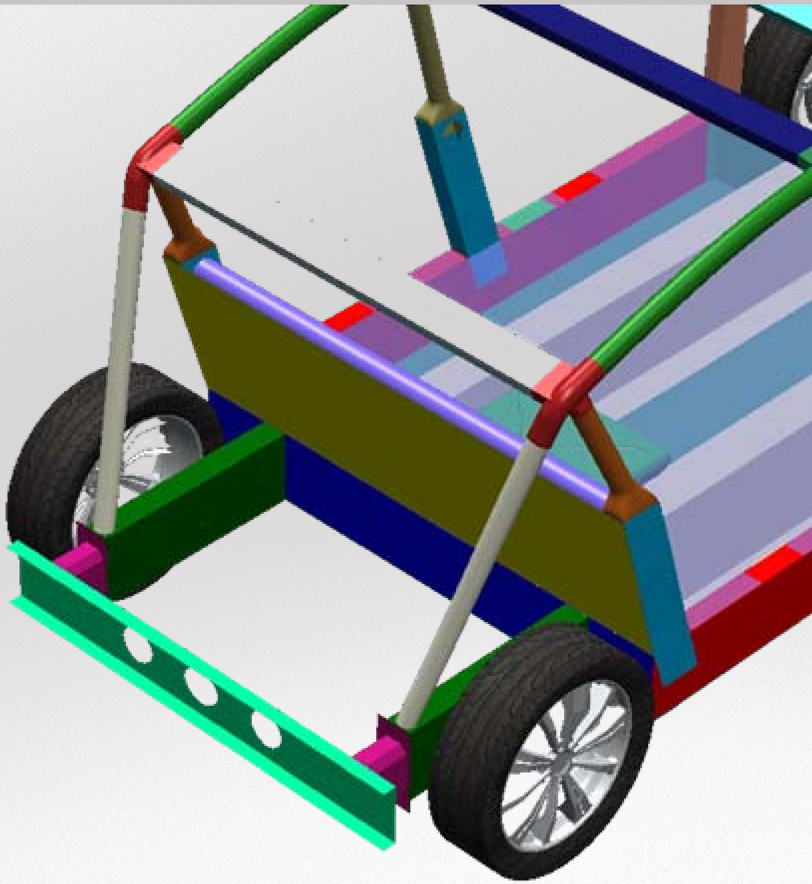
Safety Cell



Design modularity is achieved through simple, constant cross section geometry and flexible manufacturing / assembly processes

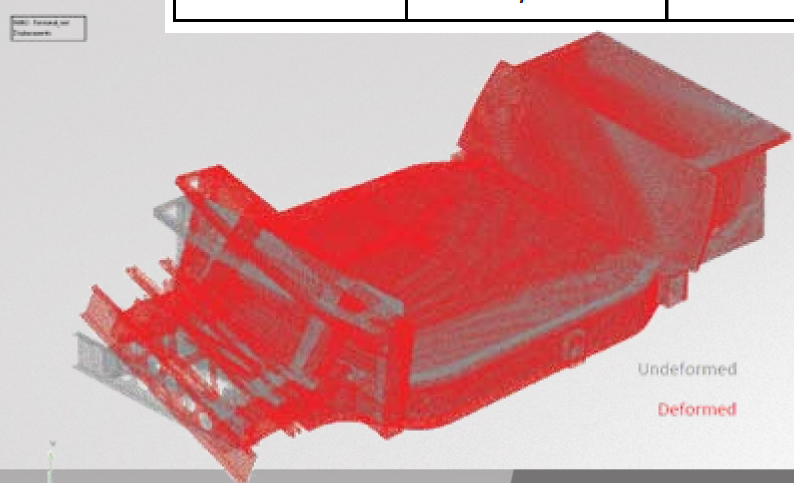
Rear Module

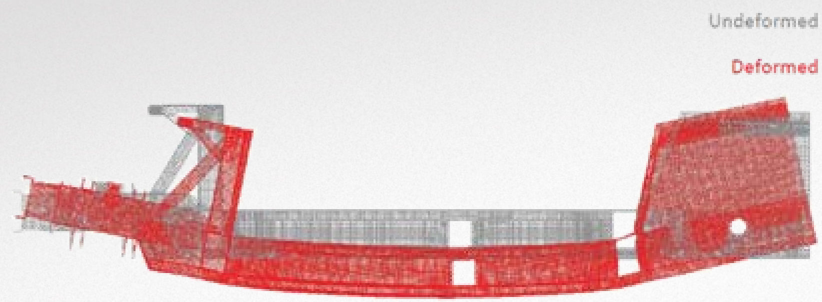
- Functional Design objectives
  - Accept powertrain sub-assembly
  - Accommodate attachment of rear suspension sub-assembly
  - Module common to all vehicle variants
  - Lightweight and cost competitive
  - Ease of assembly / disassembly to deck module
- Structural Requirements
  - Optimised for energy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



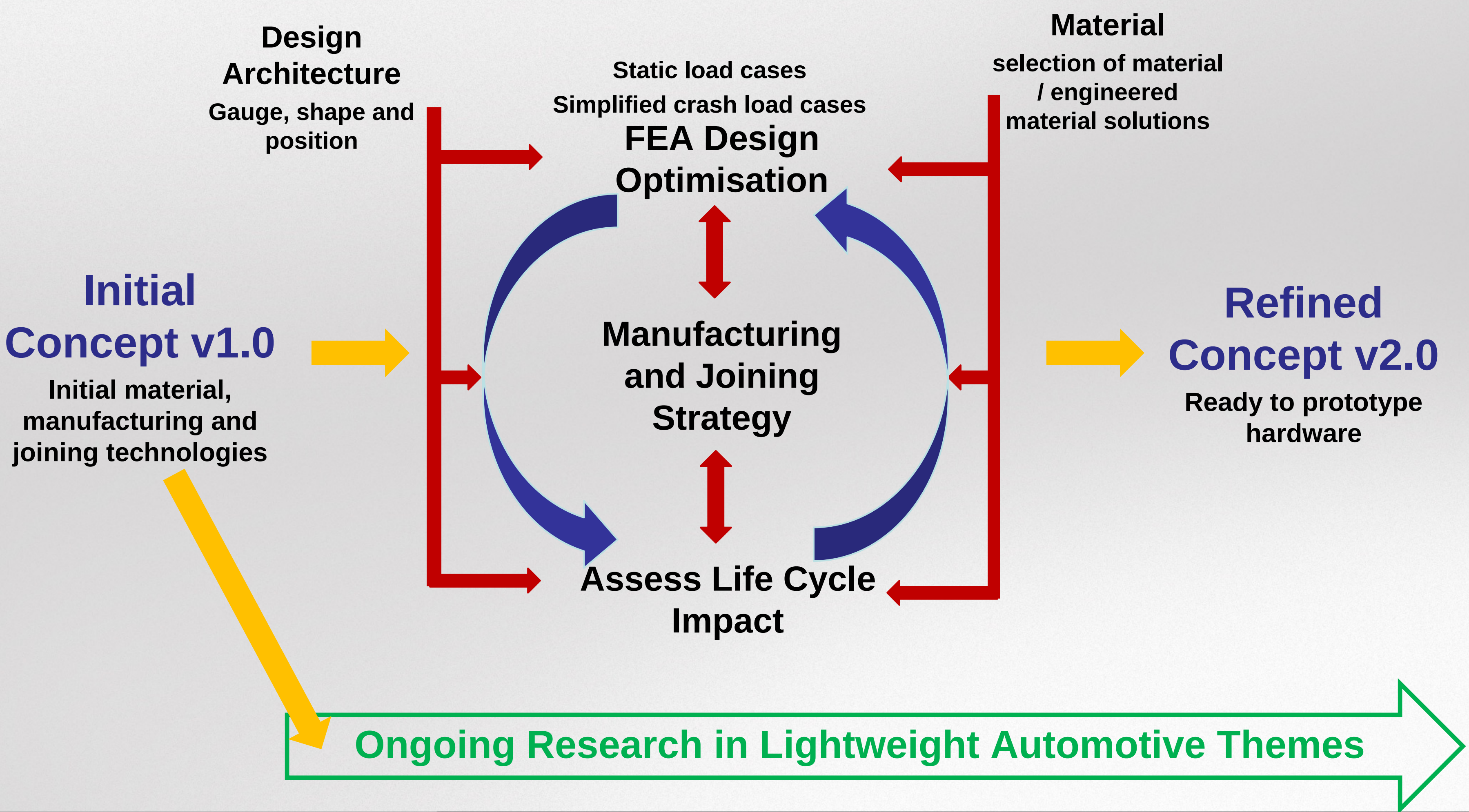
Initial Structural Analysis

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)



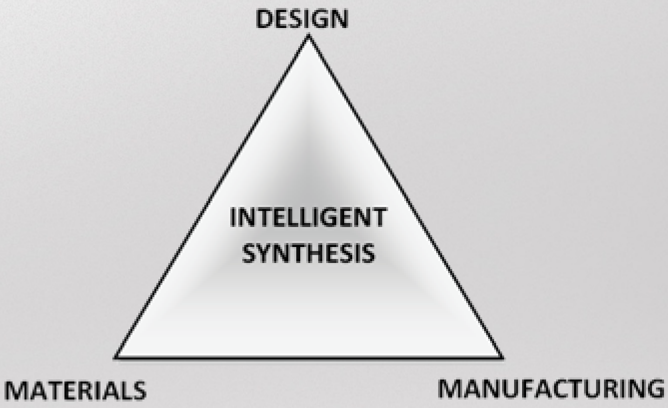


Next Steps


Design Architecture
Gauge, shape and position
Static load cases
Simplified crash load cases
FEA Design Optimisation
Material
selection of material / engineered material solutions
Initial Concept v1.0
Initial material, manufacturing and joining technologies
Manufacturing and Joining Strategy
Refined Concept v2.0
Ready to prototype hardware
Assess Life Cycle Impact
Ongoing Research in Lightweight Automotive Themes

Conclusion

- To significantly reduce weight requires significant change in the design, materials and manufacturing processes
  - Clean sheet approach
  - Simultaneous assessment
- 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
    - Manufacturing driven design decisions
  - Initial concept and FE assessment - on track to meeting aggressive structural and mass targets



Thank You

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