WILLIAMS | ADVANCED ENGINEERING

PLATFORM APPROACH TO LIGHTWEIGHTING & ELECTRIFICATION

Welsh Automotive Forum - Autolink Event

19th June 2019

Tony Martindale, Head of Mechanical Engineering

WILLIAMS ADVANCED ENGINEERING **PROFILE**

ABOUT US

- Williams founded in 1977
- Public Limited Company
- 1000 Williams Group Employees (325 at Williams Advanced Engineering)
- 114 F1 race victories and 16 World Championships
- Williams Advanced Engineering formed in 2010
- World class design, manufacturing and testing facilities

CORE COMPETENCIES

- Aerodynamics and Thermodynamics
- Lightweighting
- Electrification
- Vehicle Integration
- Precision manufacturing and assembly
- Design and development
- Data capture and analysis
- Testing and simulation

FACILITIES

- Two wind tunnels (50% - 100% scale)
- Low-volume composite manufacturing
- Latest suite of CAD / CAM / CAE tools
- Prototype build and test
- Precision machine shop
- Comprehensive rig testing
- On-site vehicle simulators
- Battery build and test
- CMM quality assurance
- Multiple build areas with extensive sub assembly facilities

WAE AWARDS

- MIA Business of the Year 2012
- Oxford Brookes Innovation Award 2013
- British Renewable Energy Pioneer 2014
- Race Tech Most Innovative New Motorsport Product Award 2015
- Royal Automobile Club Simms Medal 2015
- The IET Horizontal Innovation Award 2016
- British Engineering Excellence Award for Consultancy of the Year 2016
- MIA Business Excellence Award for Technology and Innovation 2017
- ISO 9001:2015 awarded July 2017
- Queen's Award April 2018

HISTORY OF WILLIAMS **ELECTRIFICATION**

2009
Originated in F1 during the development of the Williams F1 KERS system. Designed in-house by Williams.

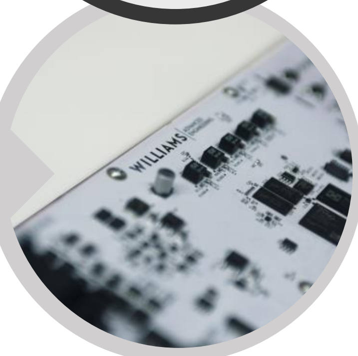
2011
F1-derived battery technology implemented into the Jaguar C-X75 hybrid road car.

2014
Further developed version of battery technology produced for Formula E. Supplied all teams Seasons 1-4.

2016
Multiple demonstrator vehicles for leading OEMs created with Williams Advanced Engineering battery systems.

2017
Initiation of numerous automotive production battery and electrification projects.

2018
Williams Advanced Engineering commit to next generation BMS for production programmes.



Williams Advanced Engineering has a demonstrable track record of delivering high-performance propulsion systems for ambitious engineering programmes.

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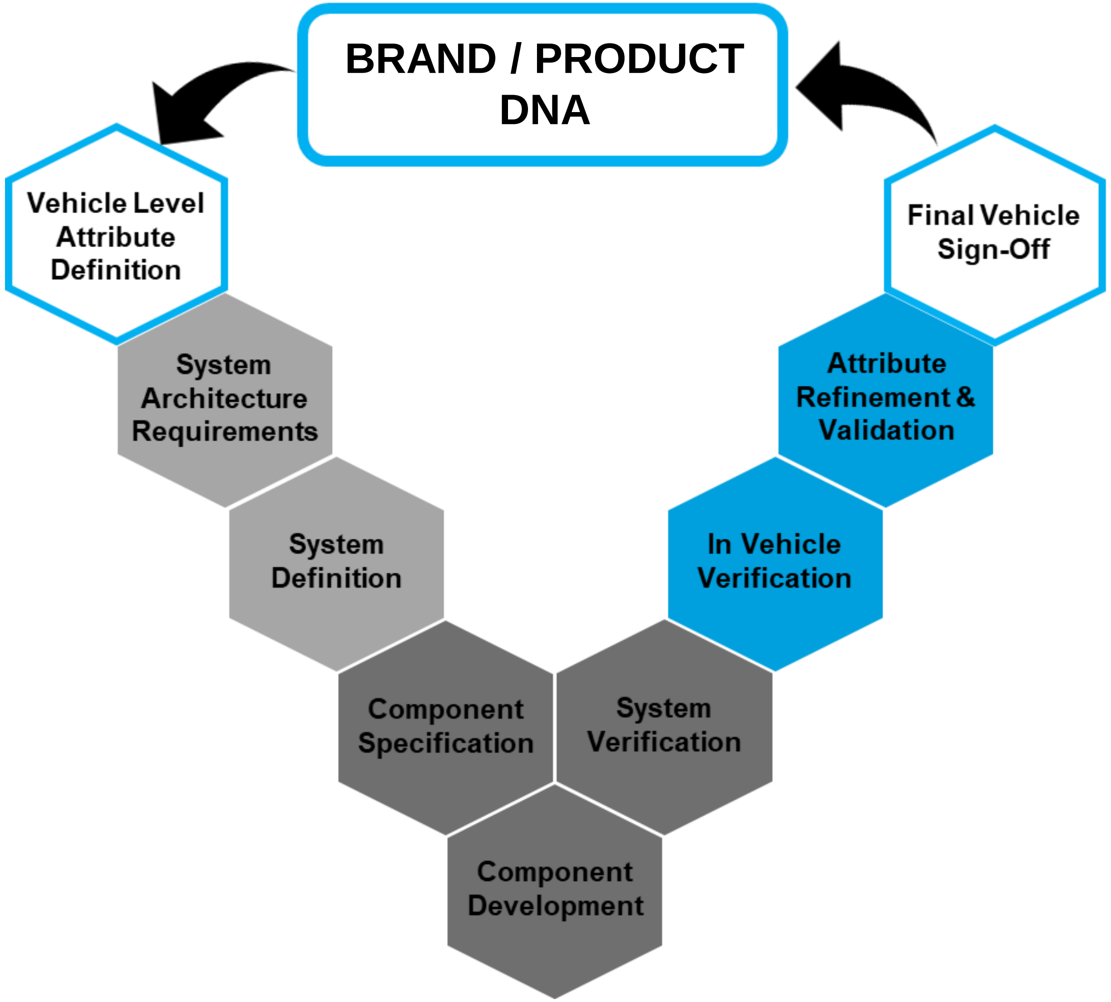
WHY THE NEED?

CUSTOMER LEVEL ATTRIBUTE REQUIREMENTS

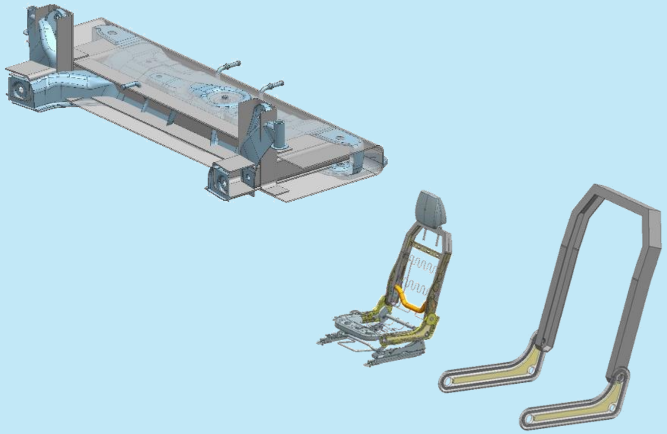
- Increased demand for Electric Vehicles operating in a balanced set of requirements, comparable or better than traditional ICE vehicles.
- Challenges of balancing what matters to the end user:
  - Performance
  - Range
  - Cost
- Current lack of in-depth understanding of electric vehicle technology, leads to inability to maximise performance.
- System Integration approach required to maximise the performance

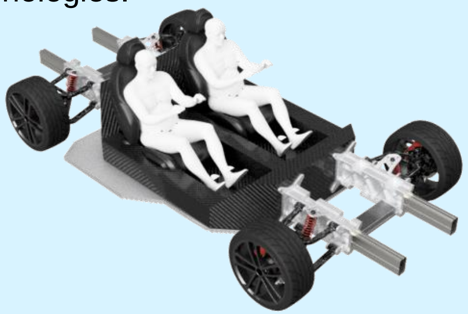


WILLIAMS ROADMAP

NEXT GENERATION LIGHTWEIGHTING

Now	Near-Future	Next
Existing & Williams Technologies: • Integrated EV Platform (FW-EVX). • 223™ and RACETRAK™ composite technologies. • Structural compression over-moulding. • Battery design and integration.	**New Component Applications:** • Application of Williams technologies to components such as subframes, battery housings and seats. • Transition from TRL3 to TRL7 in 2019	**Next-Gen Platform:** • Application of 223™ and RACETRAK™ combined with SMC compression over-moulding to create FW-EVX^2 platform. • Integrated flexible performance platform designed for higher volume production compared to FW-EVX. • Development of simulation tools to support optimisation of new technologies.





EVX

KEY FEATURES

Composite / hybrid chassis

Innovative cell / module enclosure

Structural integration of module case

Battery cooling system via sills

Energy absorbing sill

Integration of battery cooling

Wireless module control to BMS link

Composite wishbones

POWERTRAIN

Twin motor rear drive

(Yasa P400, through Xtrac P1227) enabling torque vectoring

Single motor front drive

(Yasa P400, through Xtrac Differential)

Power availability up to a maximum of 480kW

On board AC charging

LIGHTWEIGHT EV PLATFORM

PLATFORM WEIGHT

Cells	340kg
Mechanical Powertrain	150kg
Power Electronics / Charging	35kg
Modules / Busbars	100kg
Cooling System	70kg
Chassis / Suspension	180kg
Wheels	80kg
TOTAL	**955kg**

WHEELBASE & MODULARITY

Nominal wheelbase 2800mm

Wheelbase designed to be modular with battery module width being 136mm

VEHICLE & RANGE

Flexible vehicle architecture platform

Vehicle mass. 1750kg

Vehicle Cda 0.27

Standard energy: 80kWh

Calculated NEDC range: 343 miles

BATTERY & MODULES

Structural exoskeleton with lightweight frames

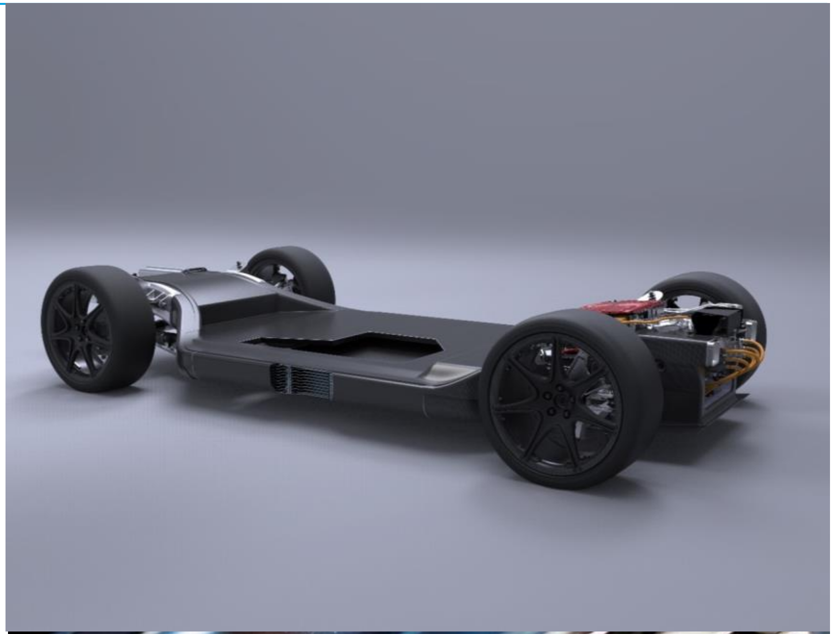
10 pouch cells per module

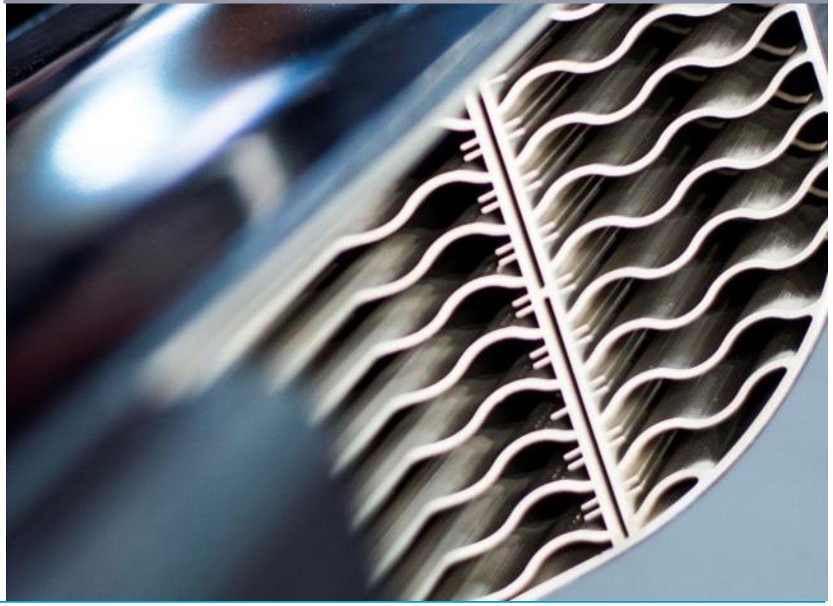
38 modules. Standard wheelbase

Arranged in rows of 3 across the vehicle

2.1 kWh per module

800V system





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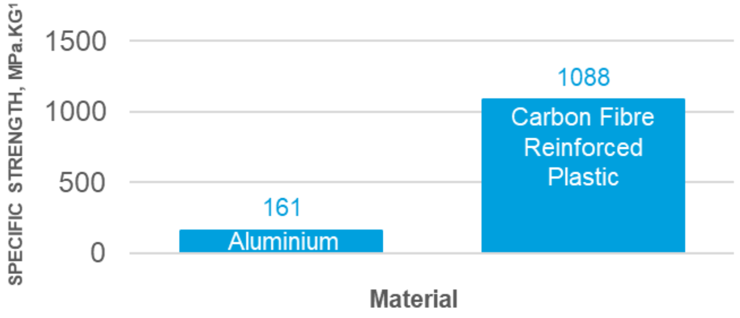
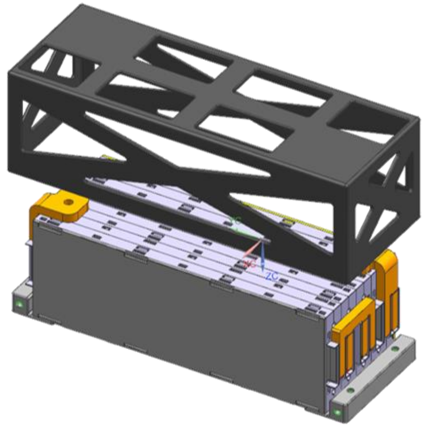
BATTERY ENCLOSURE

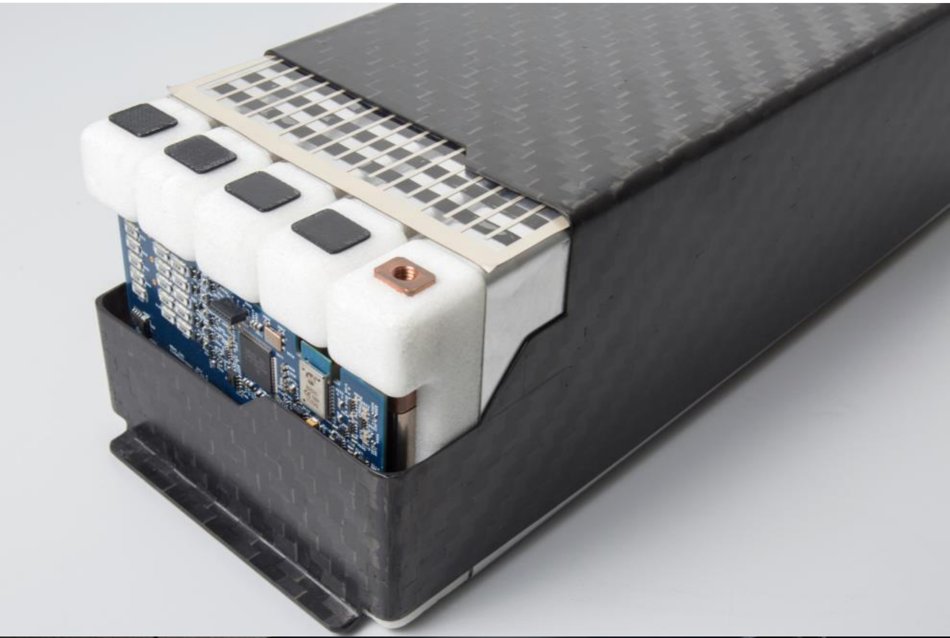
WAE 223 FULCRUM TECHNOLOGY

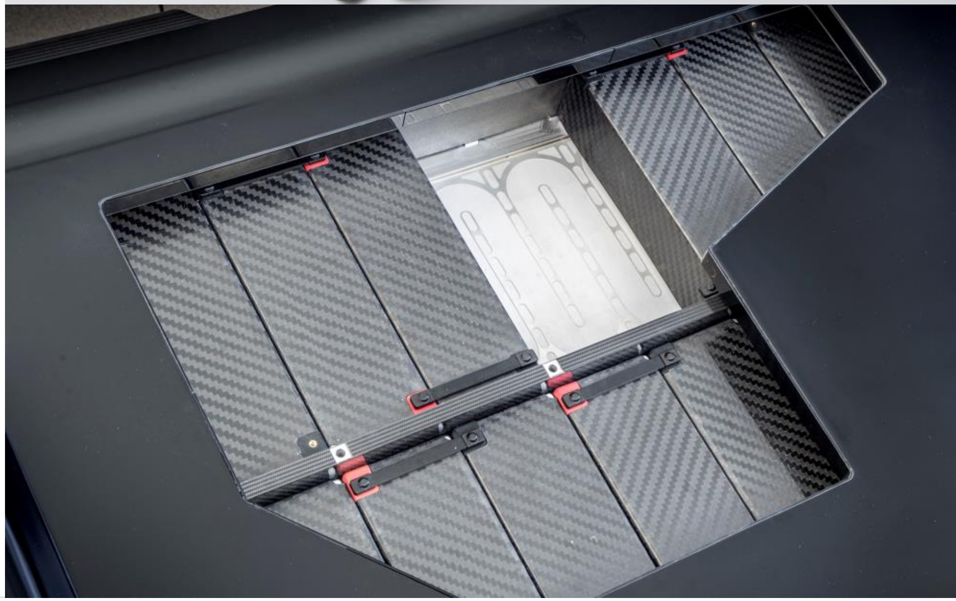
2D TO 3D BY ENGINEERED COMPOSITE FULCRUM TECHNOLOGY

- Creation of a 3D structure from a singe 2D composite preform
- ‘Open’ architecture pioneers novel manufacturing operation
- Technology being applied to body structures and battery cases
- Low marginal cost, high production rate: circa 400kg.hr-1 fibre deposition
- Low press tooling cost
- Simultaneous in-process bonding of primary and secondary structures
- Multi-material compatible
- Patent pending









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CONTROL SYSTEMS

WILLIAMS VEHICLE CONTROL MODULE GEN 2

ENGINEERED FOR LOW VOLUME AUTOMOTIVE APPLICATIONS

A custom Vehicle Control Module
developed with motorsport in mind. A combination of the dual ARM Cortex-A9 and the programmable FPGA, ensure it can be configured for process intensive tasks. With a maximum of 6 CAN bus, it ideally suited for use in the control of EV powertrain and vehicle systems.

Processor Core
Xilinx Zynq 7020 System on Chip
- Dual ARM Cortex-A9
- FPGA – 85k Cells

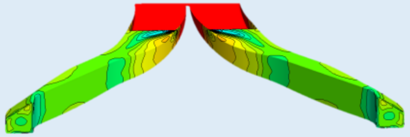
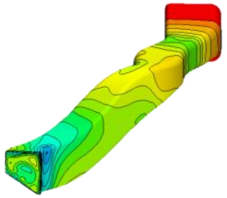
128Mb (16MB) Flash Memory
16GB Logging Memory
4Gb DDR3 SDRAM
Inputs
- 37 x Analogue i/p (0-5v, 1kHz)
- 4 x Analogue i/p (0-5v, 400kHz)
- 8 x Analogue i/p (0-5v,0-12v or 1k/5v pull-up, 1kHz)
- 8 x NTC1000 Temperature Inputs
- 8 x Digital Inputs (12v)
- 1 x 12V Digital Wake-Up Pin
- 8 x Digital Inputs (3.3v)

Outputs
- 2 x 5v Sensor Supplies
- 4 x Half Bridge Outputs (12v, 5A)
- 3 x High Side Drive Outputs (12v#1, 3A)
- 8 x High Side Drive Solenoid Outputs i/p (12v, 2.5A)
- 6 x Low Side Drive (3A)
- 5 x High Side Drive Outputs (3.3v)

Communications
- 4 x CAN 2.0B
- 1 x 100Mb Ethernet
- 1 x RS232
- 4 x LIN (Future Expansion)
- 2 x CAN 2.0B (Future Expansion)

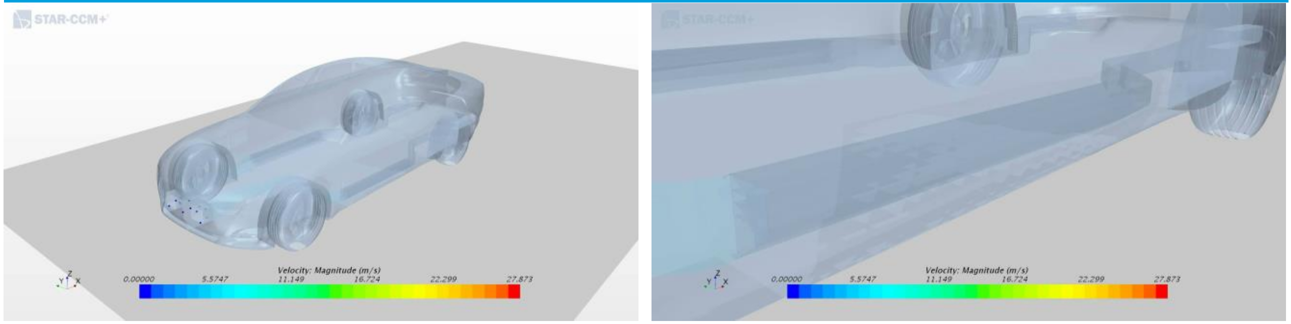
OPTIMISED THERMAL SOLUTIONS

SIMULATION RESULTS

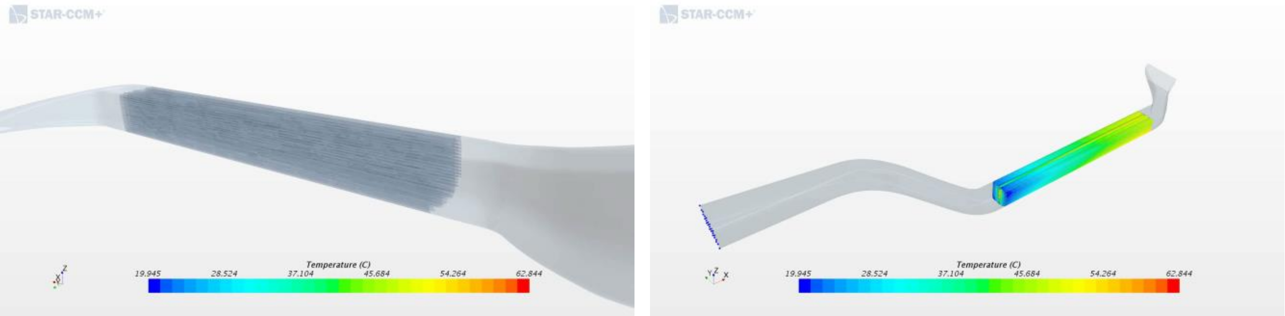
APPROACH	RESULTS	LAYOUT
Central Duct	Dp~36Pa @3m/s	
External Duct	Dp~110Pa @3m/s	

- Pressure drop is lower for the central duct layout.
- Due to battery packaging requirements, external duct approach chosen

VELOCITY



TEMPERATURE



Modelled airflow through vehicle shows positive thermal results with minimal aerodynamic drag impact – Highly dependent on overall vehicle design

CRASH ROBUSTNESS

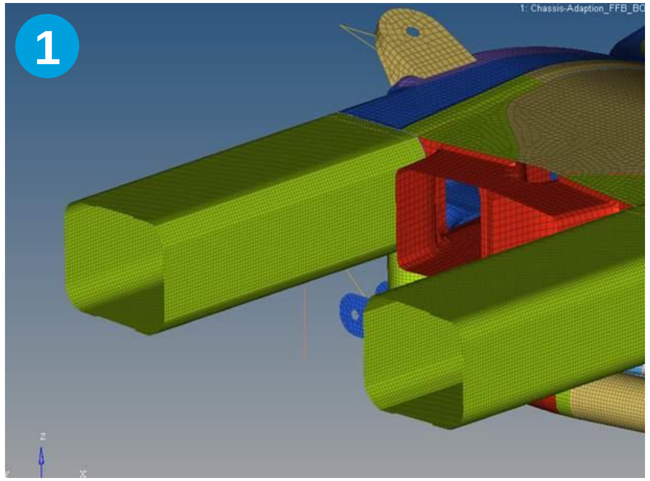
FRONT & SIDEPOLE CRASH RESULTS

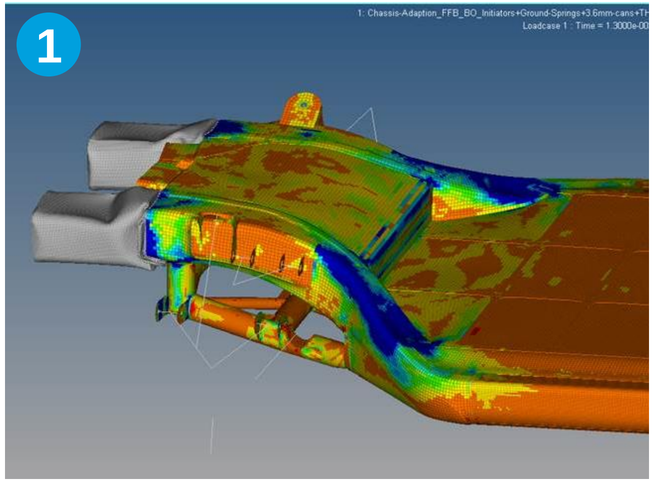
1 FRONTAL IMPACT (FFB) - 56 KPH

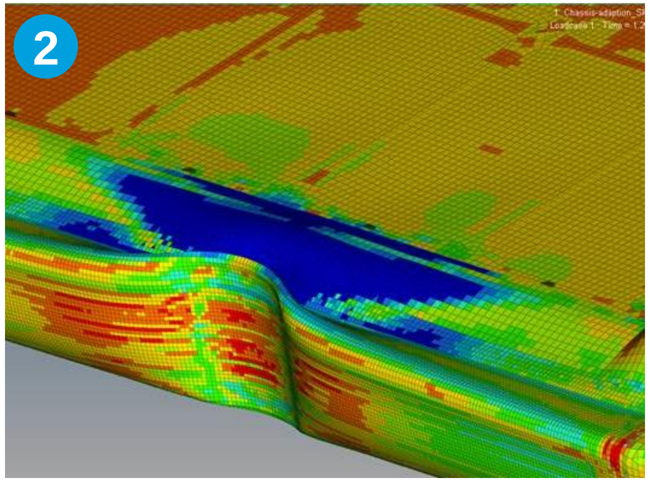
- Crush cans are 3.6 mm thick.
- Energy absorbed is 59 % of total impact.

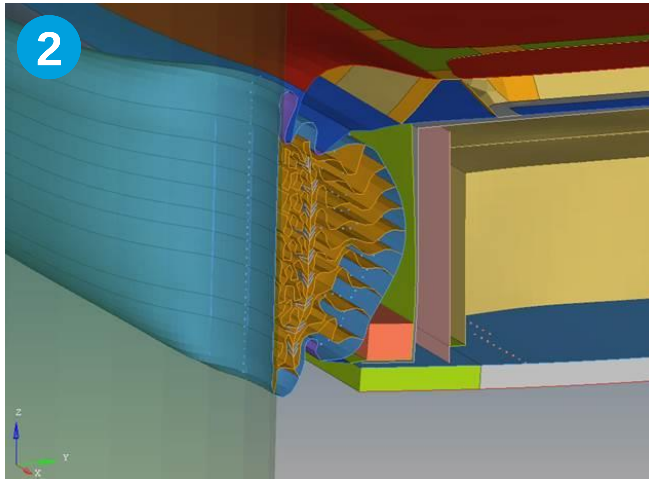
2 SIDE POLE IMPACT - 32 KPH

- The sill structure collapses in a progressive manner.
- The battery structure remains undamaged.









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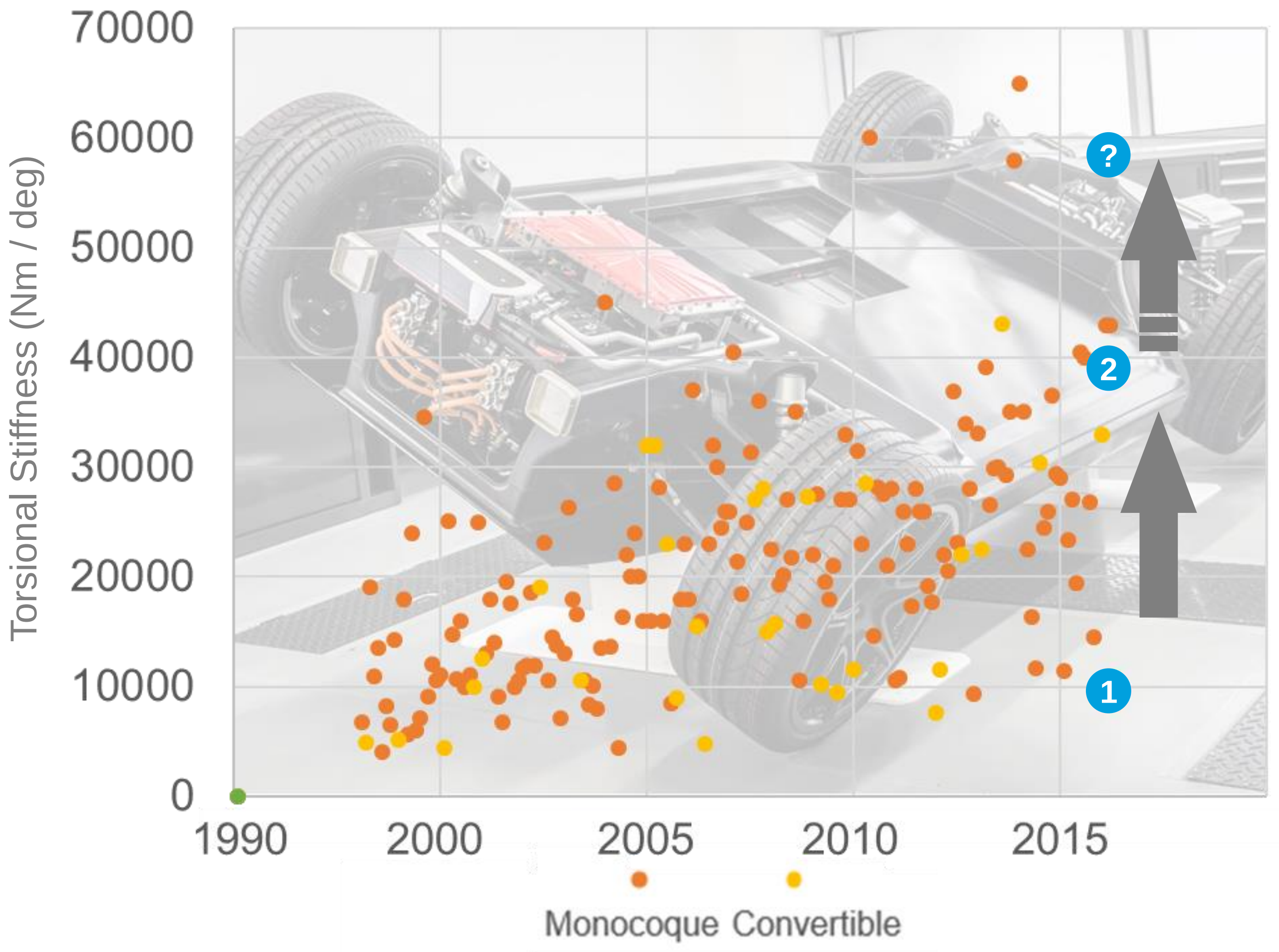
BODY INTERFACING

TORSIONAL STIFFNESS



1	FW-EVX – w/o Battery	9800 Nm /deg
2	FW-EVX – w/ Battery	38600 Nm /deg
?	FW-EVX – w/ Battery (+ Body)	50000+ Nm /deg

- **FW-EVX achieves very competitive torsional stiffness, even without body**
- **Battery is a key structural component**
- **Opportunities to balance cost, mass and performance**

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THE FUTURE DIRECTION

FW-EVX2

PLATFORM SCALABILITY

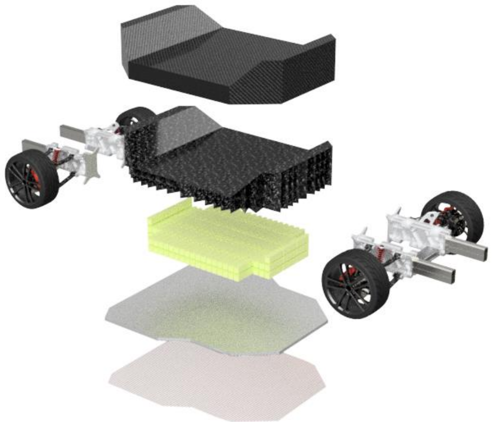
Multiple Options for Scalability:

- New performance platform that can be scaled across multiple vehicles.
    - Extended Wheel Base
    - 4-Seater
    - SUV
- Flexible manufacturing process for customer package requirements such as H-point and seating configurations.

INNOVATIVE MANUFACTURING

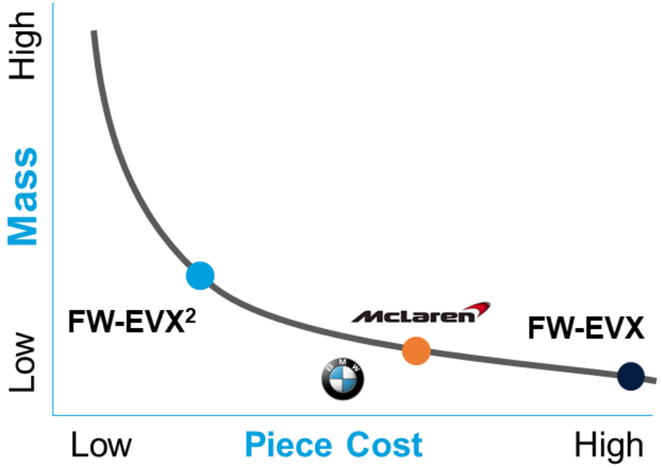
Short fibre compression over moulding

- Structural reinforcement of outer shell.
- Housing for modules.
- Includes over moulded inserts for mounting points.
- Utilising recycled chopped fibres



COST COMPETITIVENESS

Objective for FW-EVX^2 to be **leader for piece cost** and **competitive for weight** compared to benchmark technologies in the performance space.



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CONCLUSIONS

SYSTEM INTEGRATION KEY TO DELIVERING CUSTOMER LEVEL ATTRIBUTES

- Increased demand for Electric Vehicles operating in a balanced set of requirements, comparable or better than traditional ICE vehicles.
- Challenges of balancing what matters to the end user:
    - Performance, Range & Cost
- Williams Advanced Engineering approach is to maximise system integration to deliver the overall vehicle attribute characteristics
- Lightweighting, Aero / Thermal solutions key to maximising Energy Management in an Electrified Vehicle
- Future opportunities exist for further exploitation in:
    - Platform Scalability
    - Innovative Manufacturing
    - Cost Competitiveness in Performance domain

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THANK YOU

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