Formula E Race Car Engineering

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WHAT IS FORMULA E?

- Pinnacle of full electric circuit motorsport since 2014
- Single day race events
- Entire business model and ‘ecosystem’ is intended to capture new market of fans
- Engaging at street level in many major cities across the world to bring motorsport to urban areas
    - Without the noise (and other) pollution issues associate with traditional engines.
- Fan engagement has been part of the race story since inception with various interactive elements affecting the sporting outcome.

WHAT IS FORMULA E?

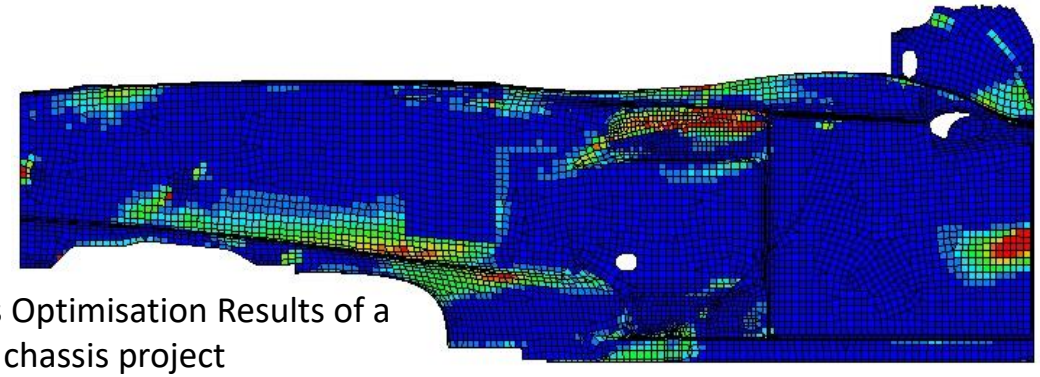
- The cars are primarily common hardware –
  - Chassis, running gear, battery, front powertrain, tyres – everything visible externally.
- Technical challenge focussed on the rear powertrain and how it is integrated and utilised successfully
- Tracks typically exclusive for Formula E
  - Lead to events being more unpredictable and ‘raw’ – despite significant investment in simulation
- One day event format
  - Smooth operation cars is key to maximising ‘seat time’

WHY ARE MAHINDRA IN FORMULA E?

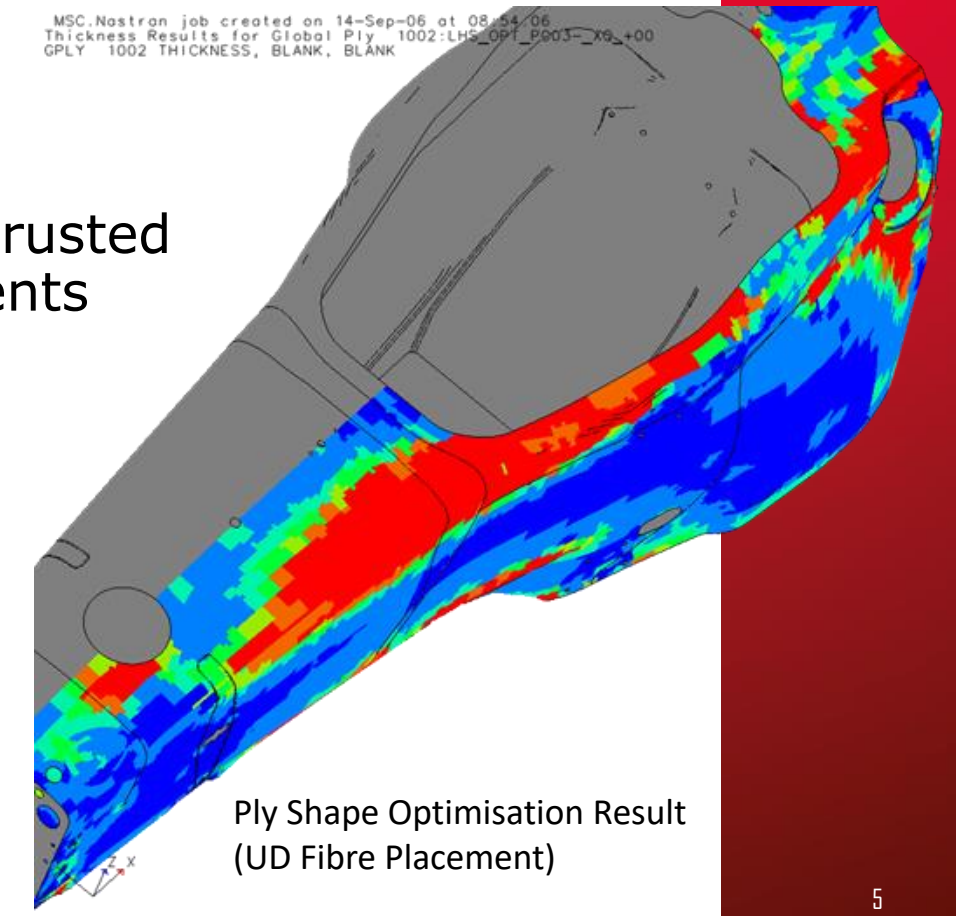
- Formula E has strong 'race to road' justification & benefits
- Mechanical simplicity of the cars shifts the focus of IP retention to software and strategies relevant to many different platforms
- This incentivises many manufacturers into the sport
- Mahindra is the only founding Formula E team with full manufacturer ownership
    - Redefining what it means for a manufacturer to be "playing the long game" – and are very proud of this stability.

WHY USE GRM?

- Familiarity with Formula E regulations and requirements
- Experience developing composite structures and delivering within MotorSport timescales
- Optimisation methods developed over 20 years
- Due to the cyclic development nature, utilising a trusted external resource is more cost effective and prevents dormant internal resource



Thickness Optimisation Results of a legacy F1 chassis project

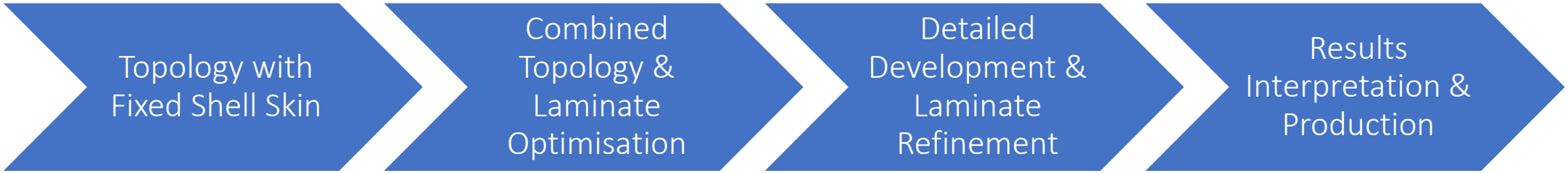


Ply Shape Optimisation Result (UD Fibre Placement)

DEVELOPMENT WORKFLOW

CAE process developed concurrently with design maturation

Optimisation & simulation results guide design layout and details



Early phase considering available package and initial estimates of outer laminate geometry

Main outer geometry confirmed, allowing combined laminate optimisation and internal reinforcement development

Verification & minor revision of laminate definition following confirmation of geometry detail

Generation & export of laminate schedule for manufacture including:

- Visual ply book
- Total thickness information
- Ply schedule

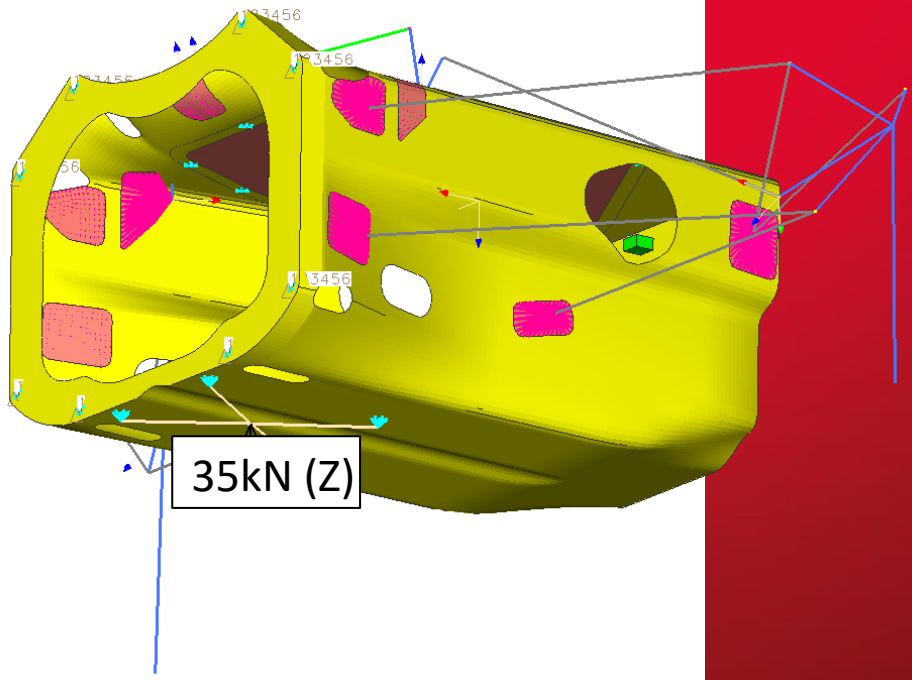
LOADING SCENARIOS

3 sets were utilised –

FIA Signoffs – these typically define the total laminate stack requirements in strength terms, sometimes also stiffness.

Strength in Track Loadcases – typically defined by durability requirements through part life and for real-world occurrences such as hitting walls.

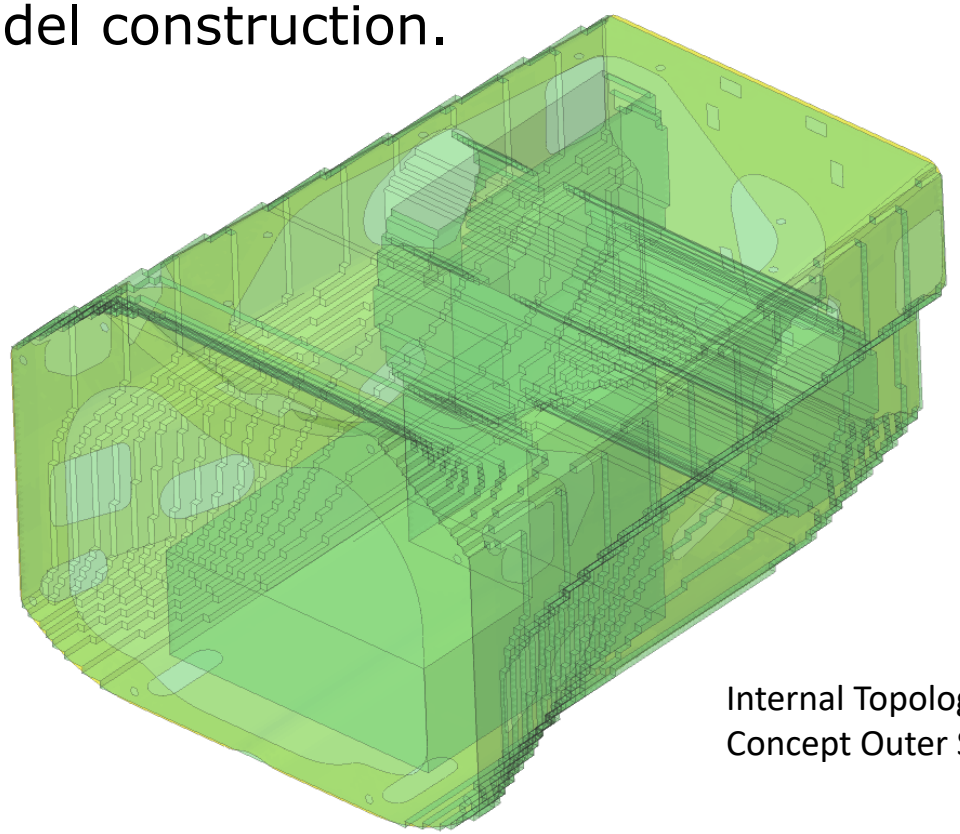
Specific Unit Loadcases – primarily target drivers for Vehicle Dynamics.



CONCEPT MODEL FORMAT

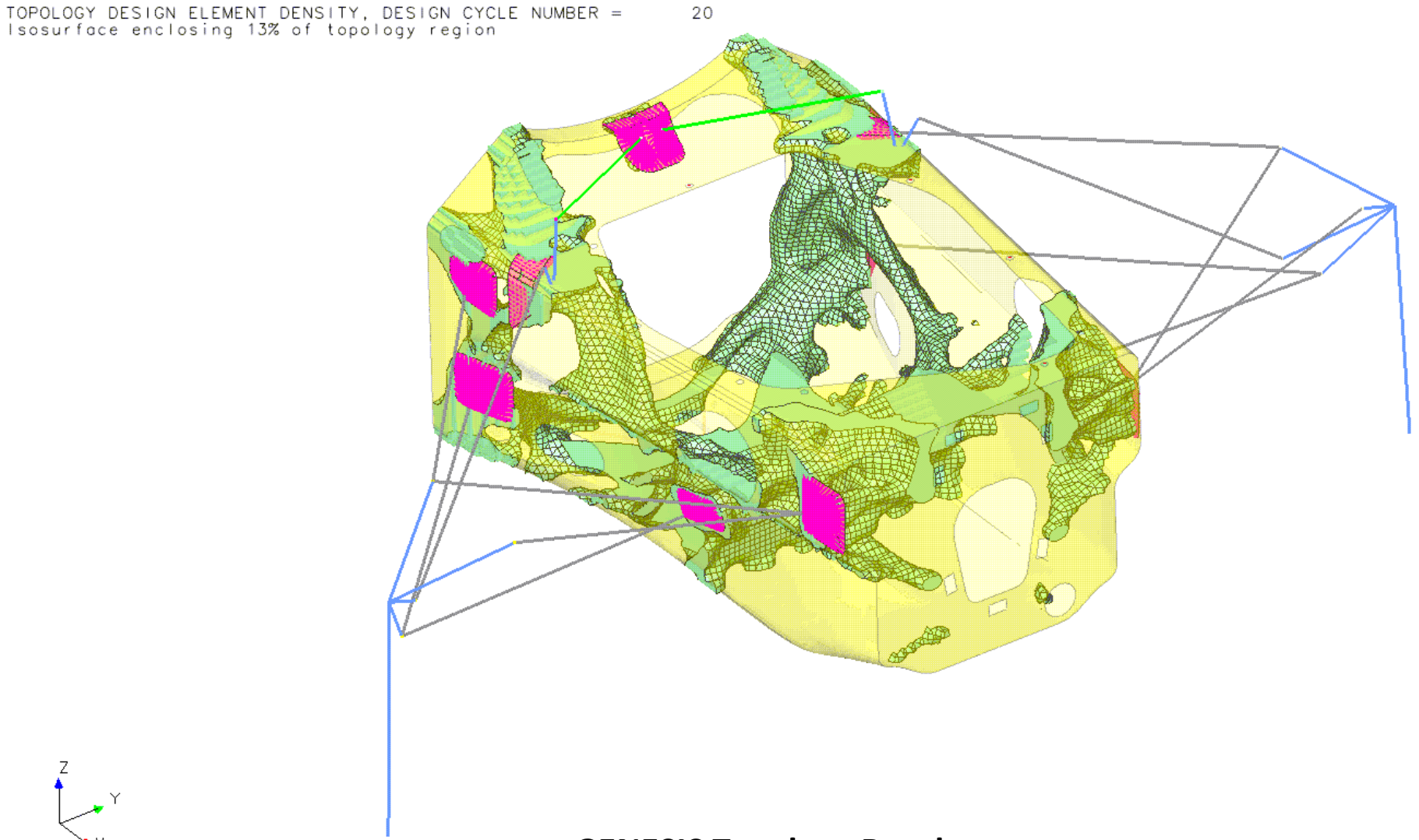
Utilised mutually agreed ‘go / no-go’ zones for package volume.

Hexahedral and quadrilateral Solid-Shell hybrid model was required to capture the requirement for shape and laminate optimisations within the same model construction.



Internal Topology Package & Concept Outer Surfaces

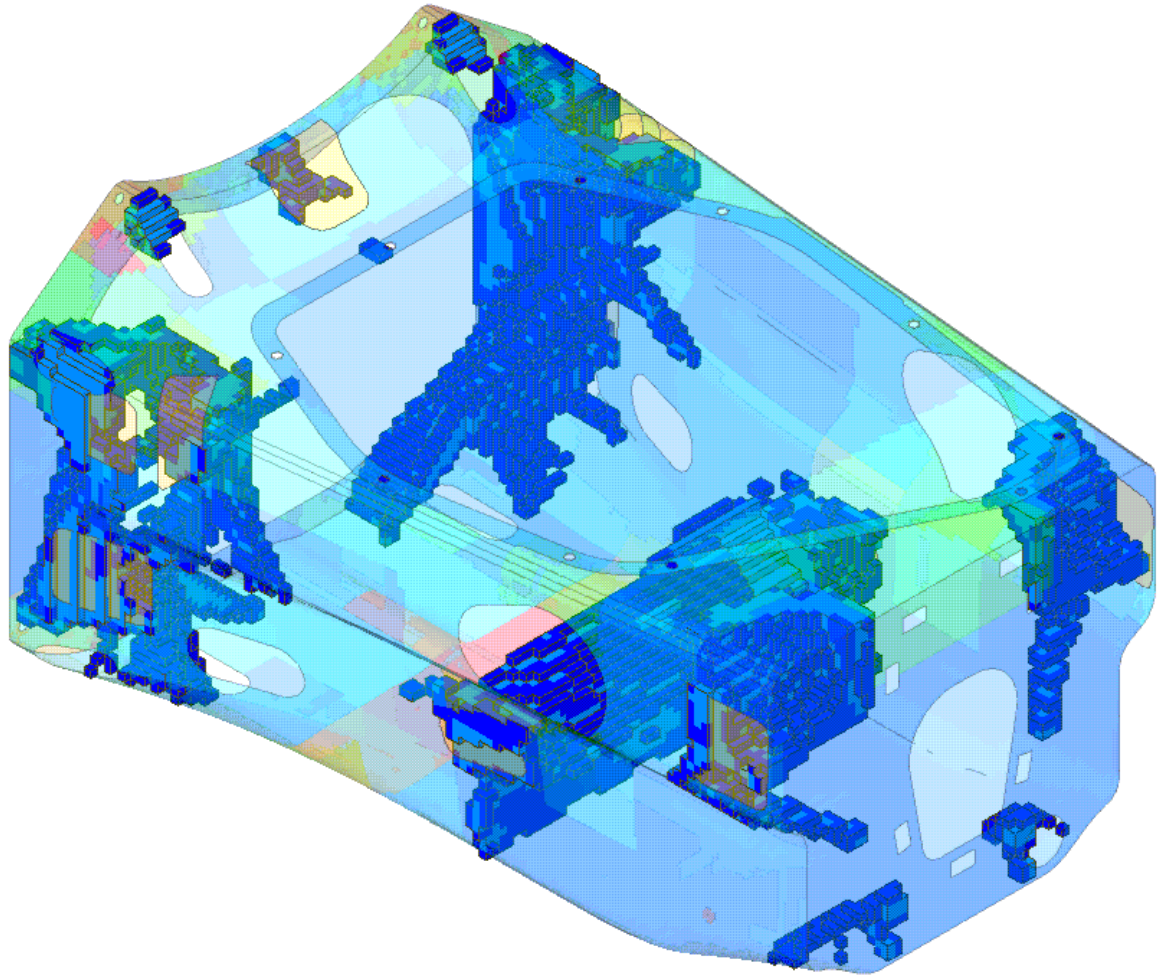
INTERNAL TOPOLOGY PHASE 1 RESULTS



GENESIS Topology Results

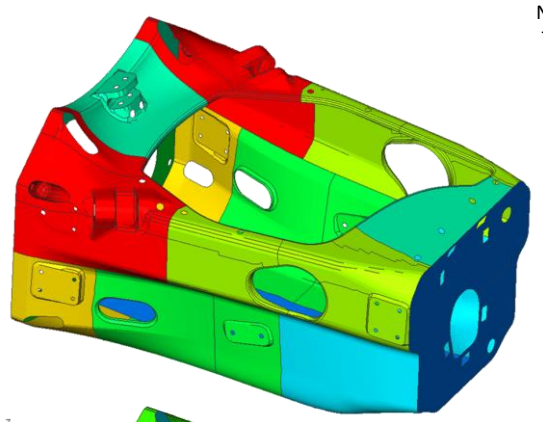
mahindra

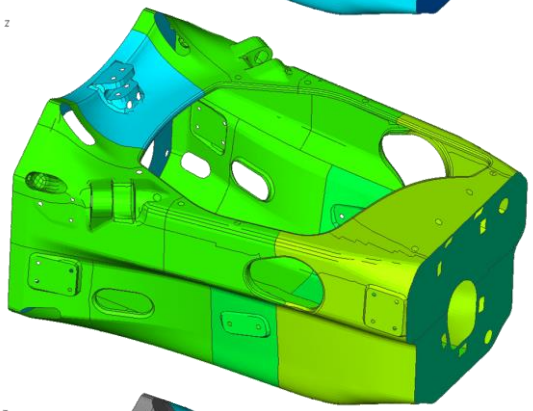
LAMINATE AND TOPOLOGY RESULTS SET

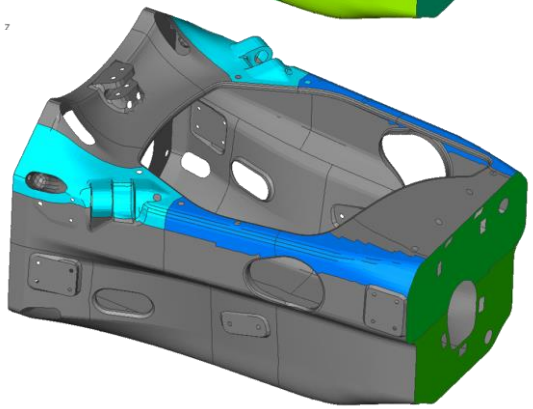


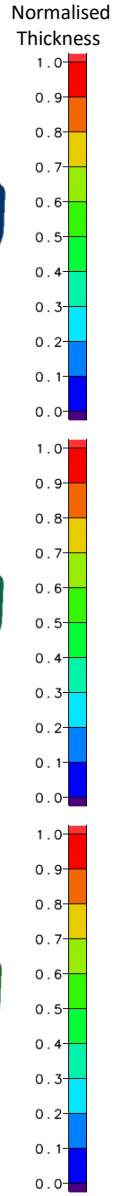
GENESIS Combined Topology & Laminate Results

LAMINATE PLY-BY-PLY ORIENTATION BREAKDOWN





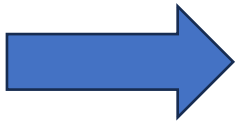


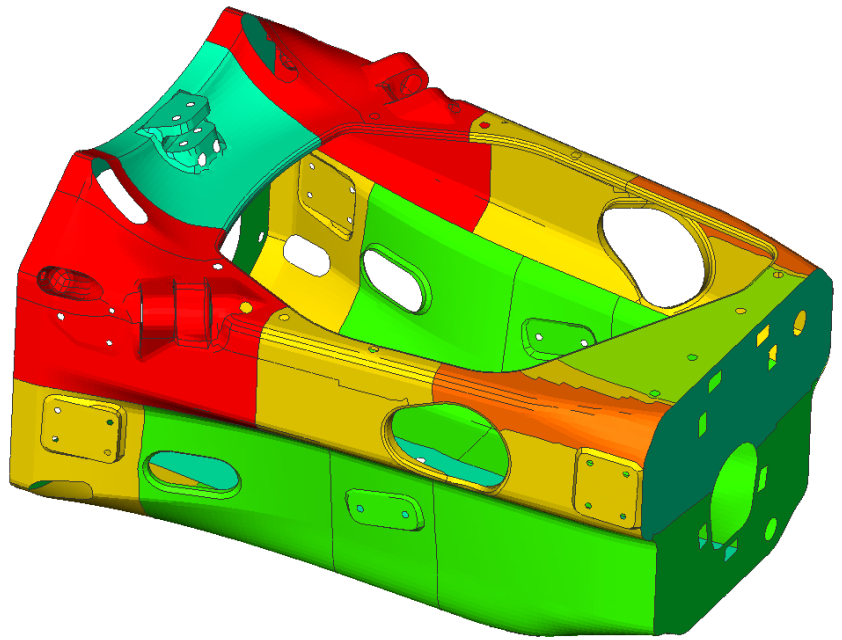


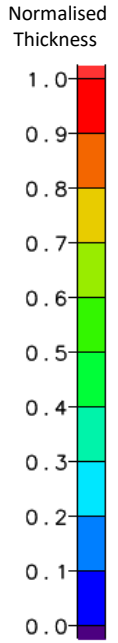
0° Cloth

45° Cloth

UD Fibre Placement







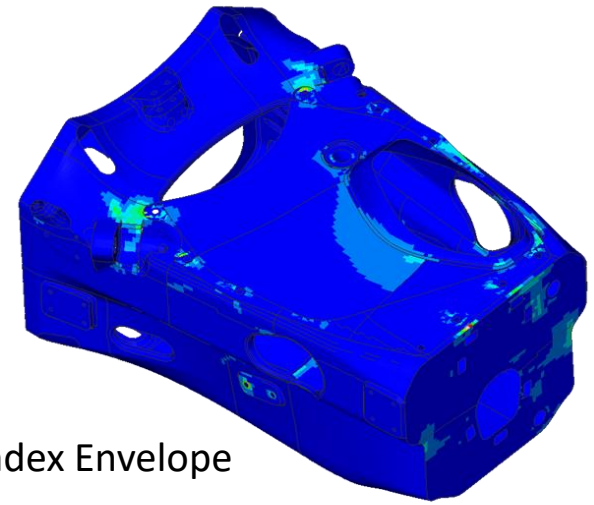
Total Thickness

RESULTS INTERPRETATION & PRODUCTION

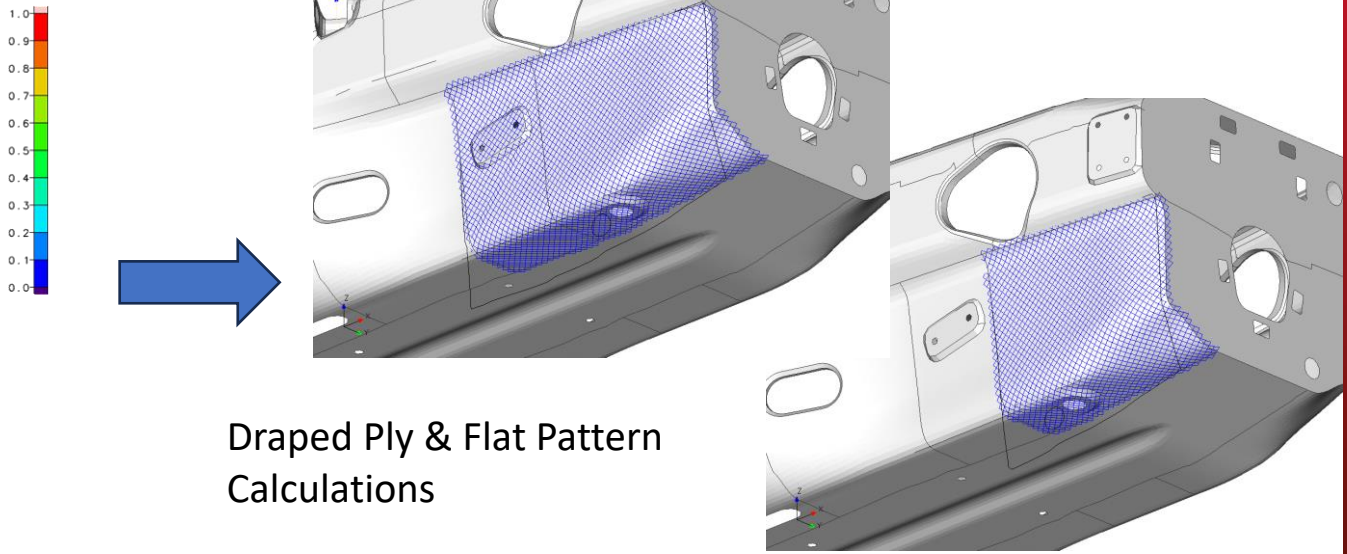
Checking that the required constraints on strength and stiffness are adhered to, in addition to general visibility of strains and stresses in critical areas – i.e. 'taking a look' at the results – is married to a process of visualising the laminate on one large text file.

This text file shows in precise detail how many plies are where, and what orientation they are, in ply stack order.

This in combination with an automated Laminate Book being produced by OptiAssist is very powerful for communication with downstream engineering and production processes.



Failure Index Envelope



Draped Ply & Flat Pattern Calculations

SUMMARY & CONCLUSIONS

- The Series:
  - Formula E is a unique motorsport proposition, where many significant manufacturers operate in a relatively strict hardware limitation, but with freedom in a key area for differentiation of their end product.
  - Included in this balancing act of cost / benefit / IP – we have the need to ensure we spend in the right ways.
  - Formula E is still a developing sport with exciting opportunities.
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THANK YOU....