Work Package 2 – Thermal Management System

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Agenda

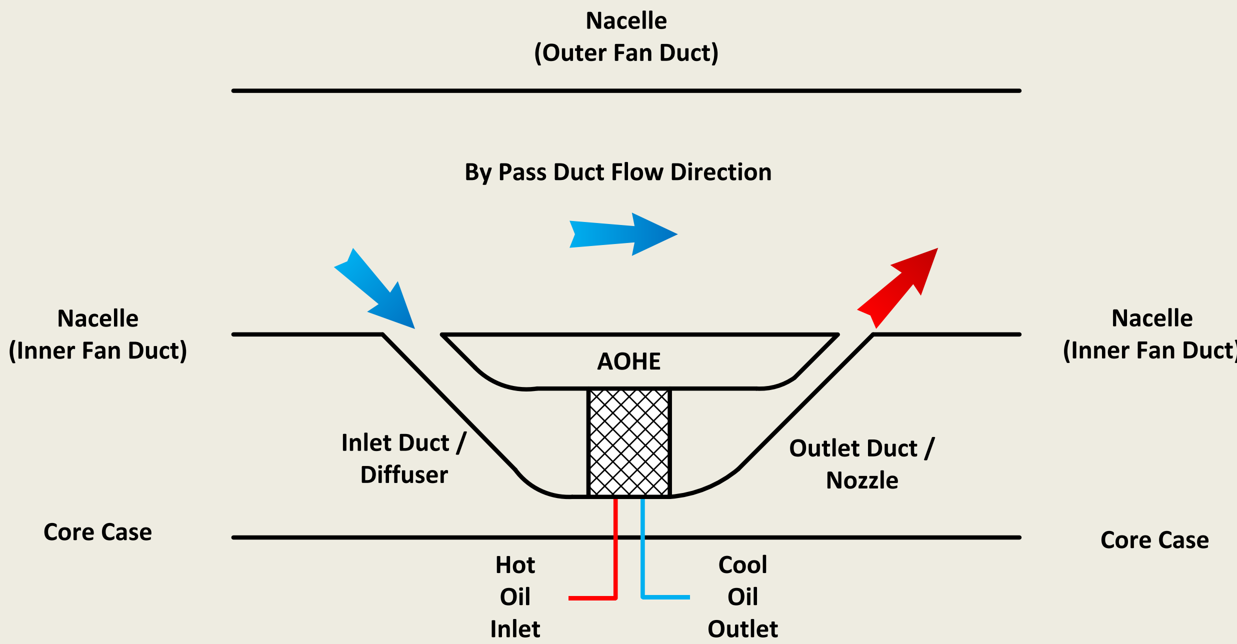
- Thermal Management System Scope and Work Package Objectives
- Design Process
- Optimisation
- Duct Manufacture

Thermal Management System Scope

- The thermal management system (TMS) rejects excess heat from the electrical generator oil systems into the secondary flow stream.
- Heat load requirements for both the permanent magnet generator (PMG) and the variable frequency generator (VFG) formed the specification.
- The components constituting the TMS reside within the booster zone.
- The TMS is composed of the following components;
  - Inlet Duct
  - Outlet Duct
  - Air-Oil Heat Exchanger (AOHE)
  - Mounting Brackets
- The AOHE assembly includes oil by-pass valves to prevent over cooling and over pressure of the system.

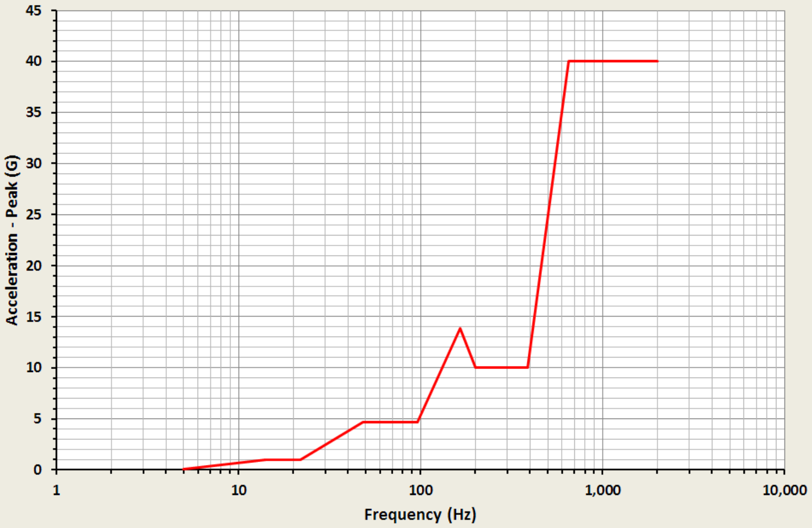
Work Package Objectives

- Optimise TMS packaging by increasing aero-thermal performance.
- Reduce TMS duct manufacturing costs and lead times.



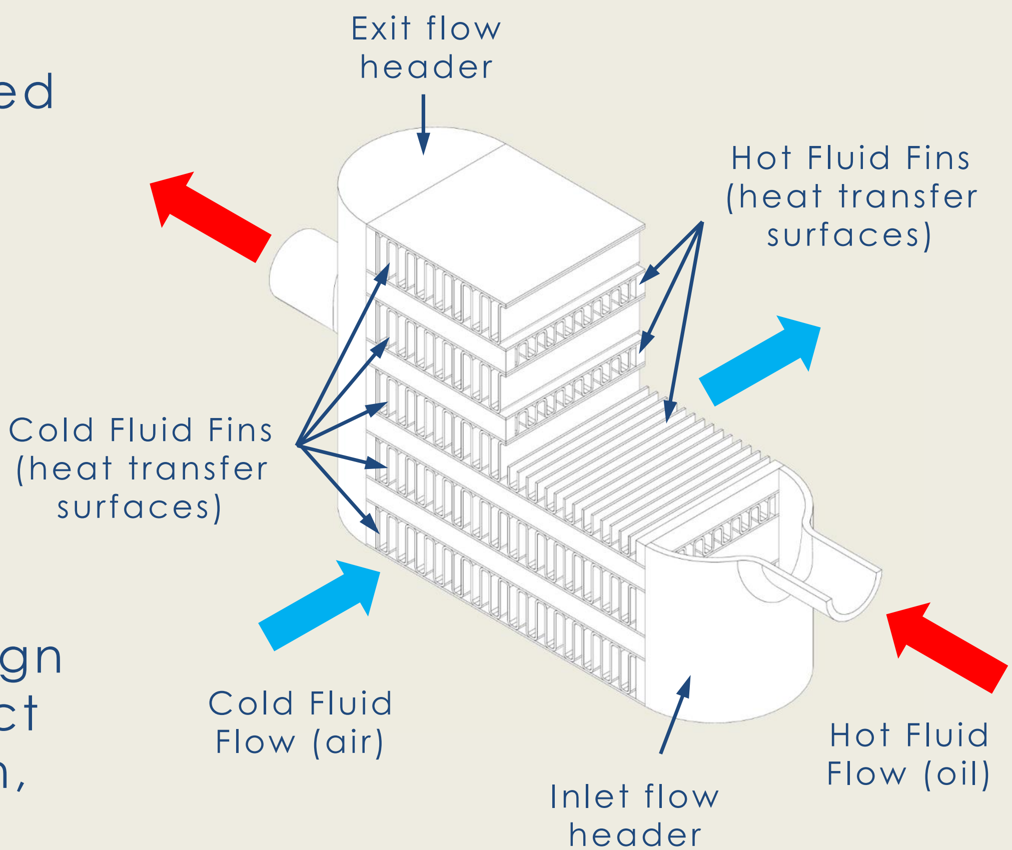
Design Challenges

- Meggitt has introduced it's system engineering capabilities to the integration of TMS.
- Reduction in available space envelope. Typical nacelle mounted ducted AOHE's are far larger.
- Harsh vibration environment.
- Reducing impact of air side total pressure loss to minimise degradation of specific fuel consumption (SFC).
- Adapting design philosophy to best utilise new manufacturing techniques.



AOHE Design Methodology

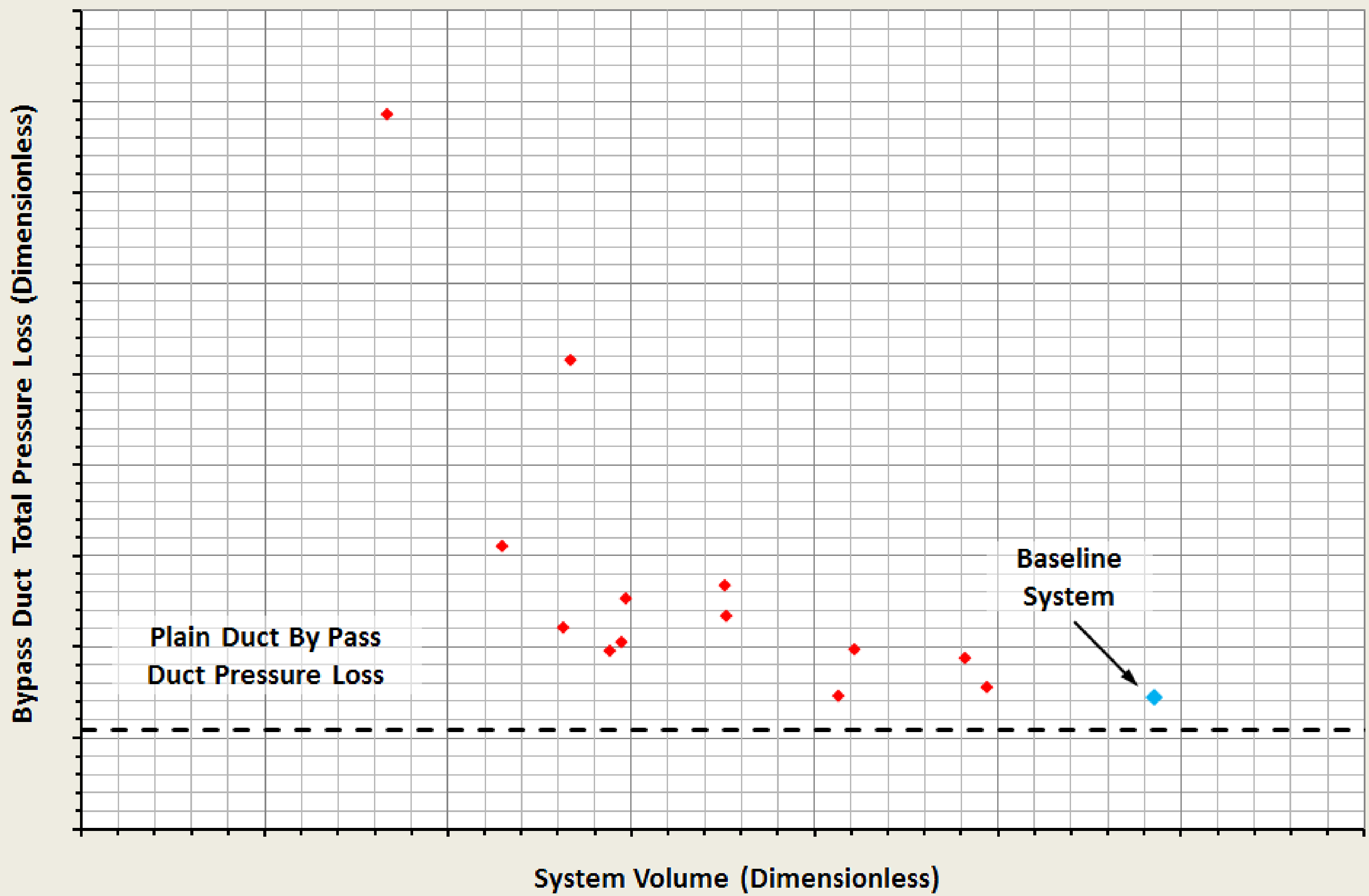
- For the NIPSE project, a plate and fin style heat exchanger was considered the optimal design balancing performance with size & weight.
- For the project, existing technology has been deployed.
- The heat exchanger design process is a balancing act between heat dissipation, size and pressure loss.



Concept Generation

- The design team sketched out over 12 different conceptual designs.
- Each design was analysed using Computational Fluid Dynamics (CFD) to understand the aero-thermal performance.
  - ANSYS Fluent was used with Meggitt generated code to replicate the complex thermal performance and distribution within the plate and fin architecture of the AOHE.
- An internal design review was held to down select designs for optimisation and wind tunnel testing.
- The down selection criteria included;
  - Performance
  - Potential
  - Installation
  - Manufacture
- Meggitt is currently exploring options to secure IP gained during this exercise.

Concept Generation



Wind Tunnel Testing

- In January 2017, wind tunnel testing was conducted on a preliminary prototype.
- The results were used to validate the analytical models developed by Meggitt to predict the aerothermal performance of the system.
- From the concept down selection, 5 concepts were forwarded for further wind tunnel testing.
- The purpose of the testing was to;
  - Validate the concept down selection process
  - Validate the refined analytical models

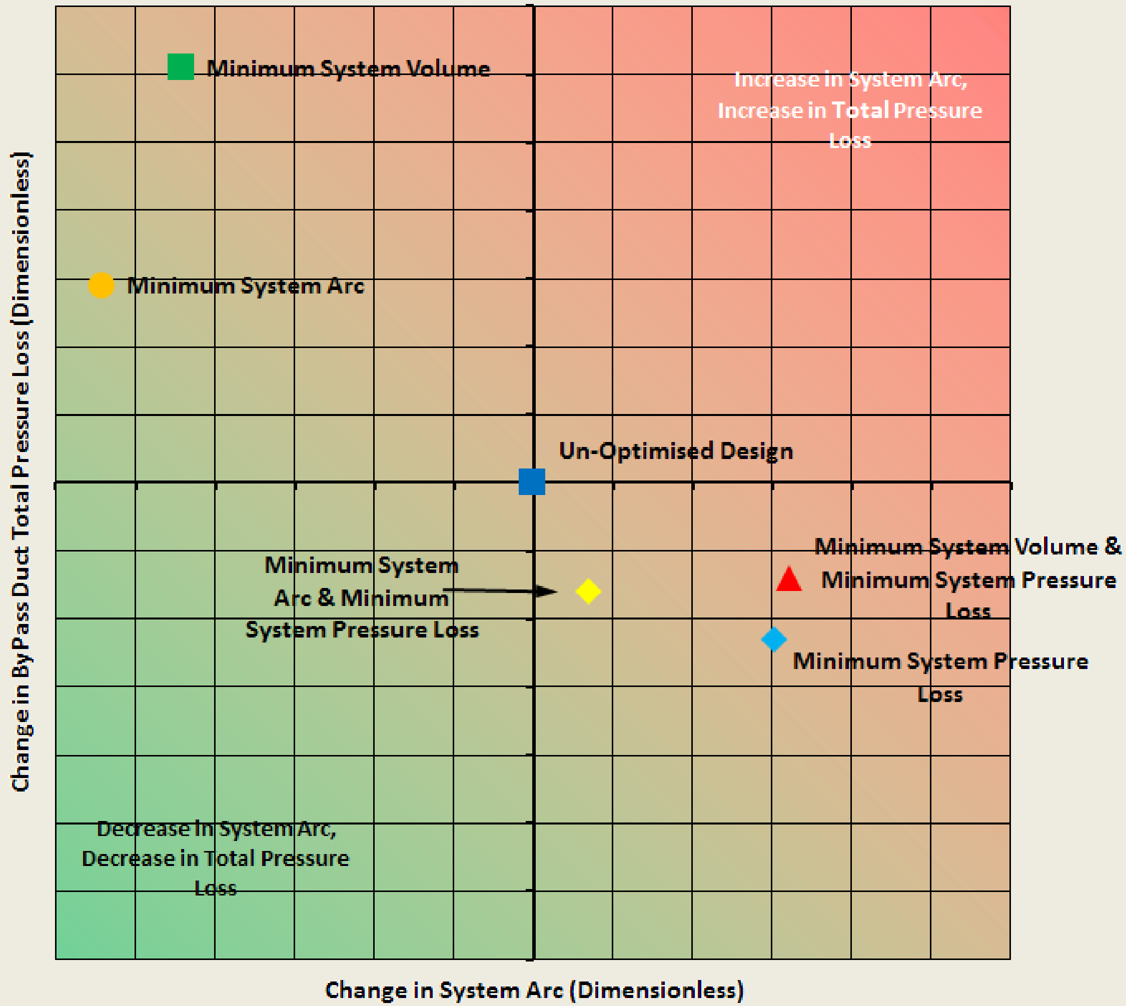
Aero-Thermal Optimisation

- The geometry and AOHE fin selection were aero-thermally optimised using CFD.
  - ANSYS Fluent (CFD)
  - ANSYS DesignXplorer (optimisation).
- To understand the design space, several design of experiments (DoE) were setup covering over 700 design points.
  - 7 Geometry Parameters
  - 192 Fin Combinations
- From the DoE, a response surface was generated to predict the total heat dissipation and total system pressure loss.
- The accuracy of the response surface was verified by generating a series of randomised designs back through the CFD and comparing the results with the response surface predictions. The results were found to be within pre-defined accuracy thresholds.

Aero-Thermal Optimisation

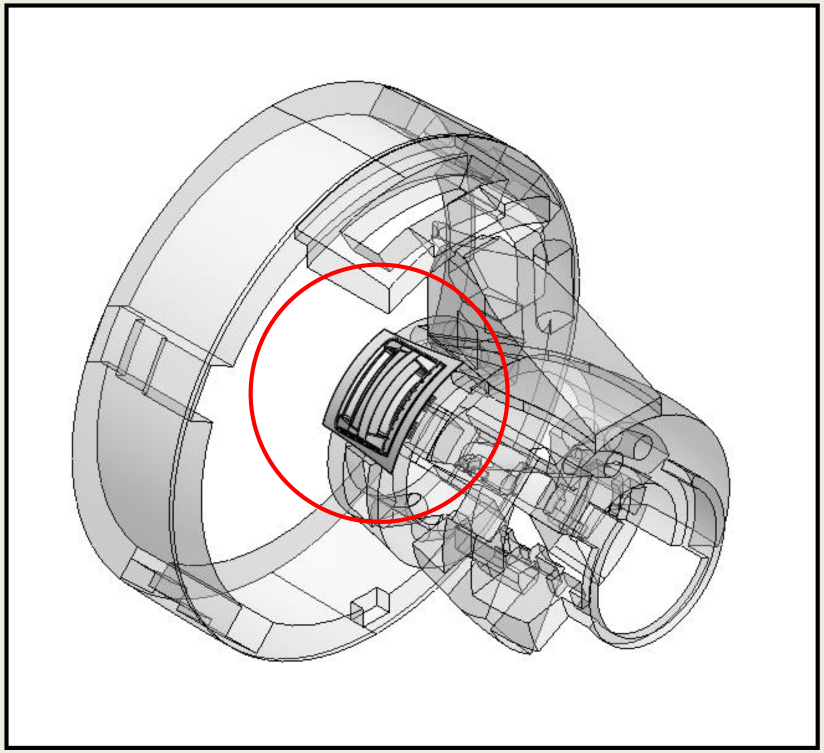
- With the response surface, a Multi-Objective Generic Algorithm (MOGA) was used to find optimal designs covering 5 separate objectives;
  - Minimum system pressure loss
  - Minimum system volume
  - Minimum system volume & minimum system pressure loss
  - Minimum system arc
  - Minimum system arc & minimum system pressure loss
- The required heat dissipation was set to achieve the NIPSE specification requirements.
- The resultant designs were then verified by CFD analysis.
- The results of the optimisation are shown on the next slide.

Aero-Thermal Optimisation



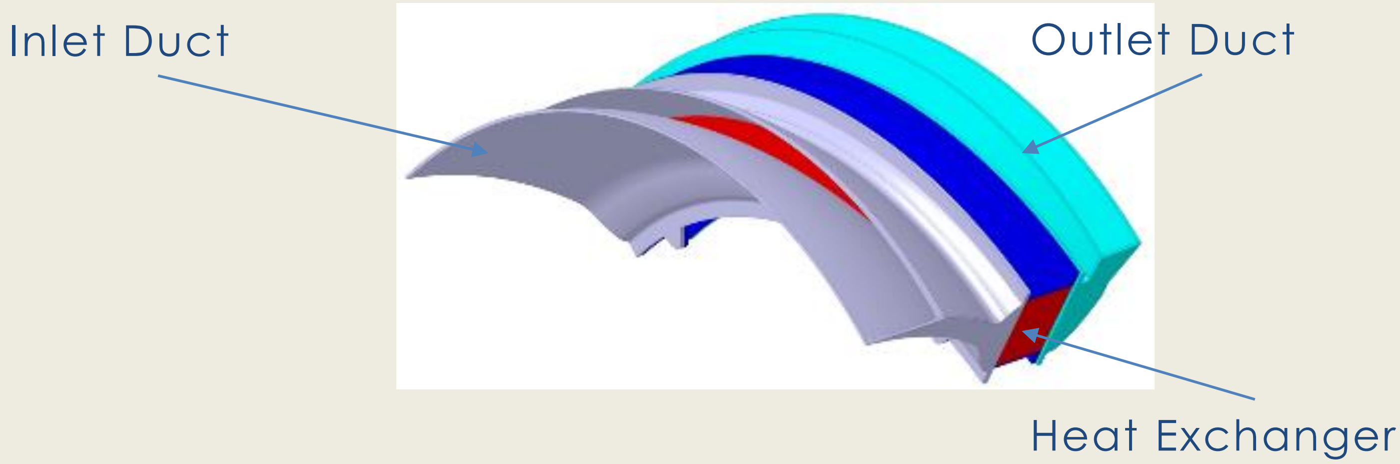
Design Optimisation

- In parallel to the optimisation study, the mechanical design was developed.
- Working with the composites team, a concept was realised which embodied the pre-defined aerodynamic surfaces.



Composite Duct Baseline Design

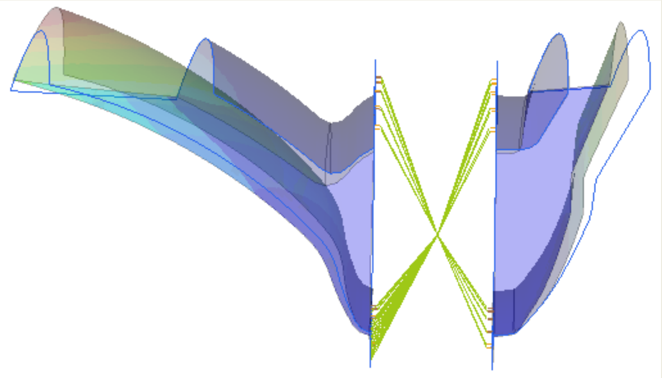
- Baseline design is a typical ducted system layout:
  - Comprising of to independent composite structures mechanically fastener to the Heat Exchanger

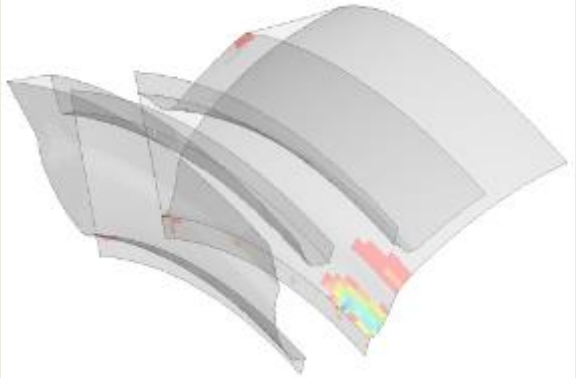


  - Baseline Structure consisting of a monolithic Carbon-fibre BMI (Bis-Maleimide resin) structure
    - Manually assembly process including
      - Hand laid pre-preg assembly
      - Multiple debulks and single cure

Composite Duct Baseline Analysis

- The Baseline design ducts were considered against a nominal loading environment to establish a structural baseline
  - Typical deflections
  - Critical stress areas

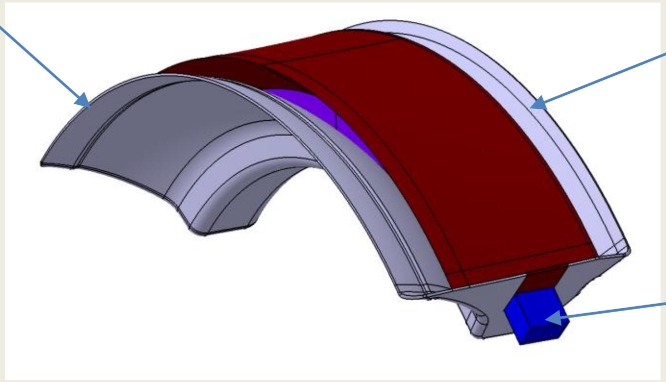




- The baseline design was considered for production sealing for both aerodynamic and fire retention requirements.

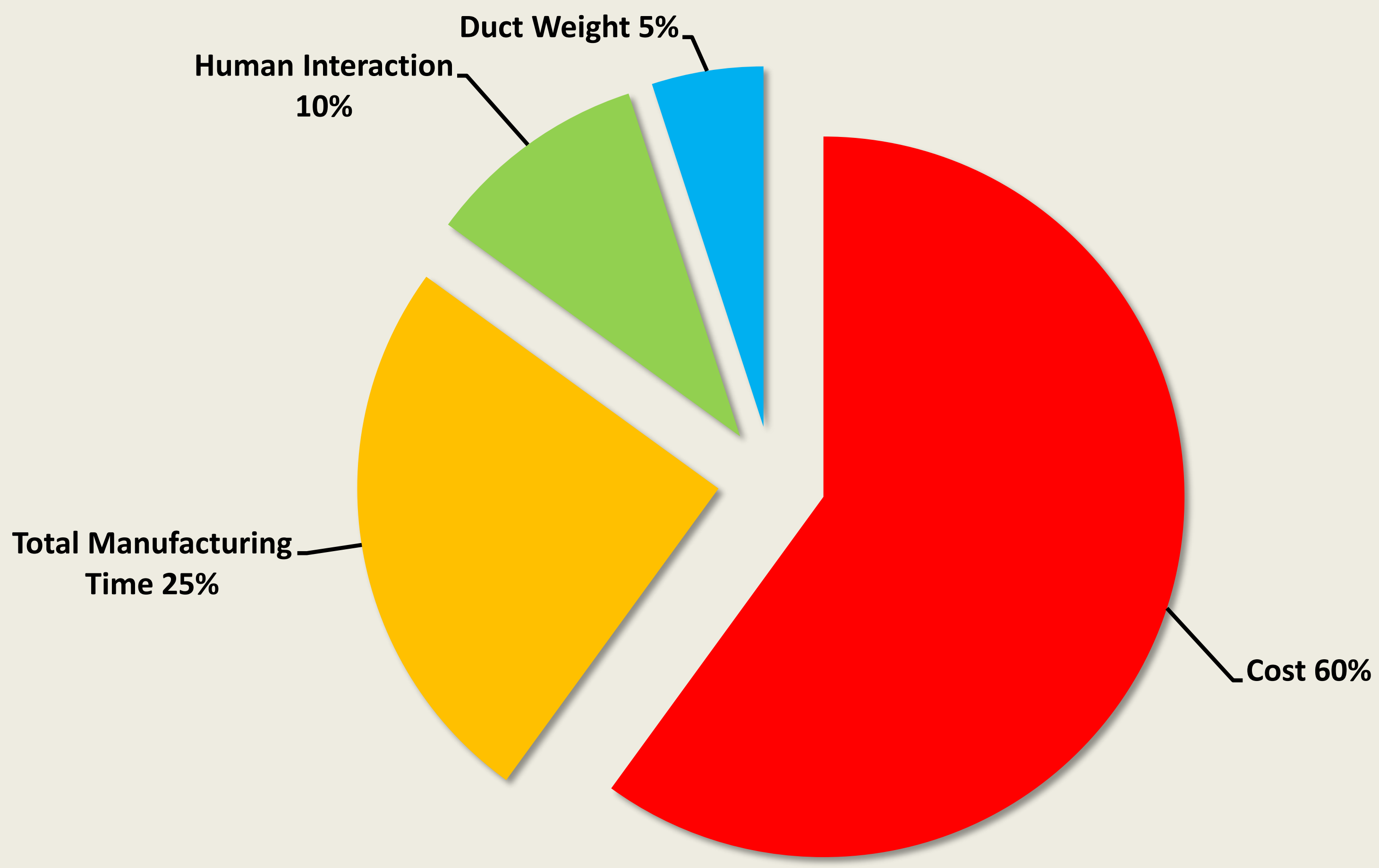
Composite Duct Re-Design for Manufacture

- The system configuration development provides opportunity to reduce composite contribution to system costs.



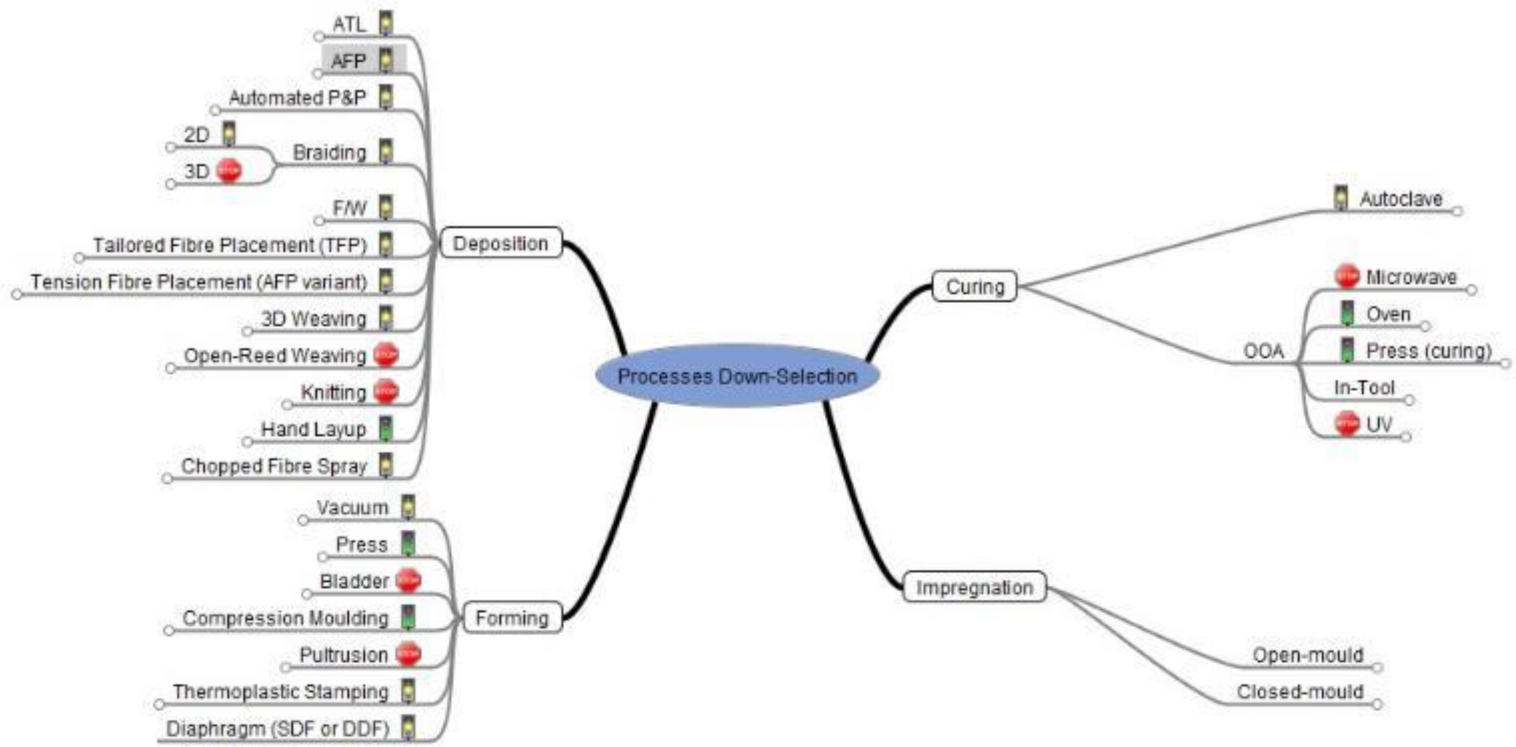
- Revised system design allows
  - The utilisation of materials suitable to local operating temperatures
  - Composite structure supports multiple manufacturing methods

Manufacturing Process Trade Study



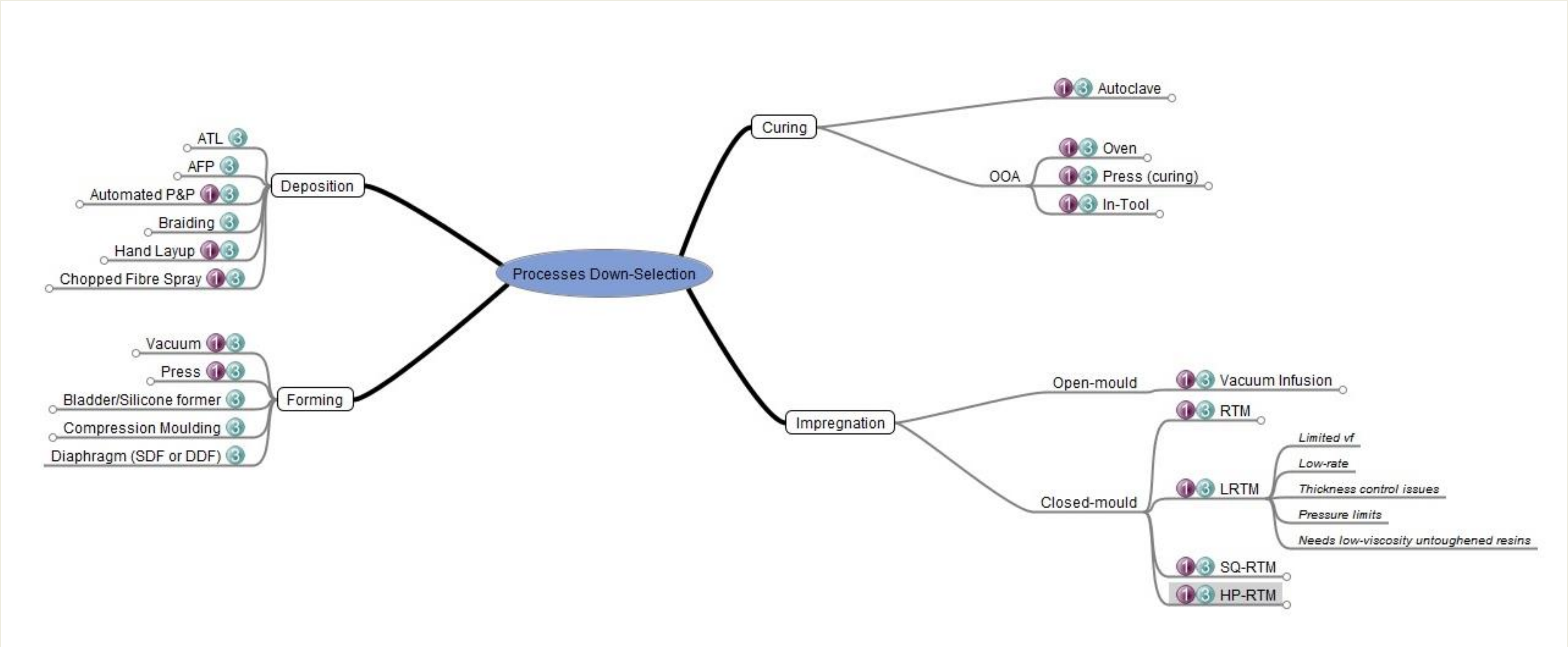
Manufacturing Process Trade Study

- Trade Study Process Mind Map



Manufacturing Process Trade Study

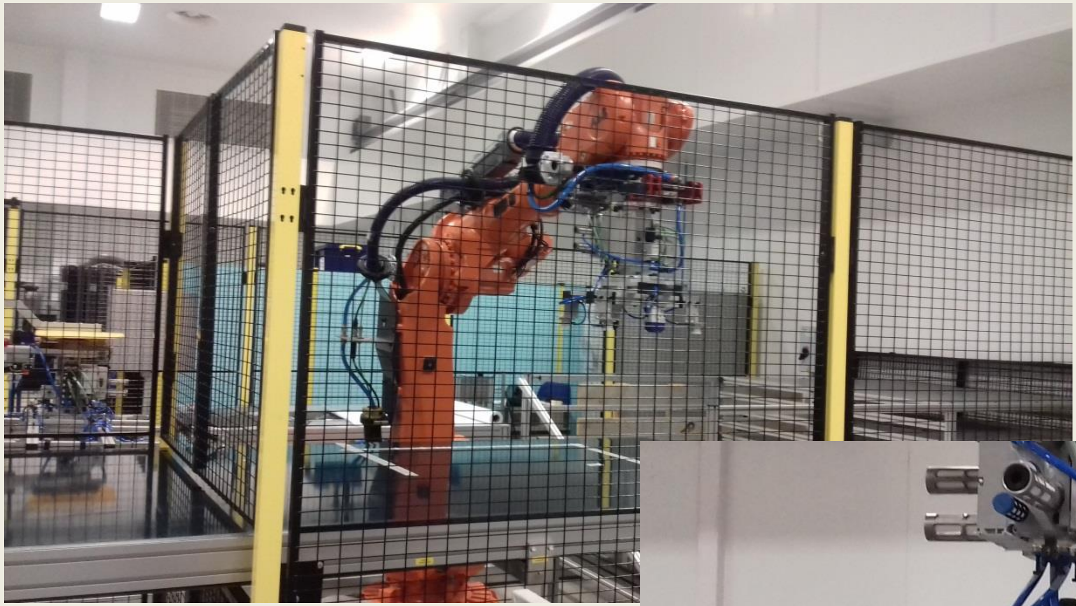
- Trade Study Process Mind Map

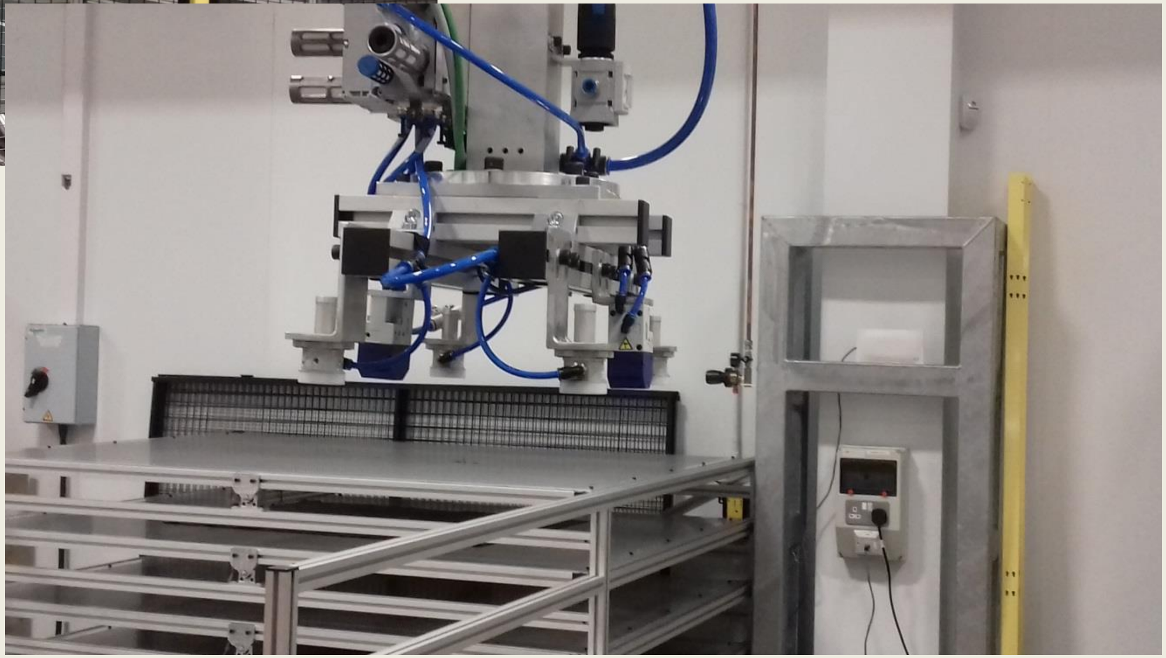


Manufacturing Process Down Selection

- Trade Study output for Inner & Outer Composite Component
  - Material Options
    - Carbon-fibre / High temperature epoxy
    - Carbon-Fibre / Bis-Maleimide
    - Carbon-fibre / Cyanate Ester
    - Bulk Moulding Compound / Bis-Maleimide
  - Process Automation
    - CNC ply cutting
    - Robotic Pick and Place
  - Tooling / Support Processes
    - Metallic tooling
    - Preform operations

Duct Manufacturing Trials





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