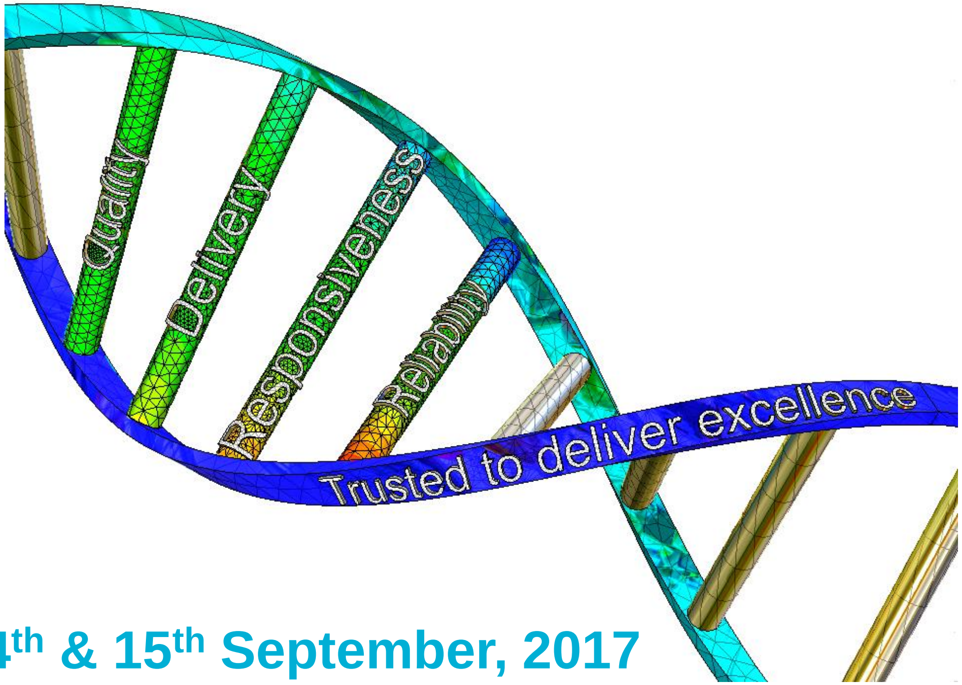
CAE Geometry Handling & Meshing for FE Analysis



Ed Green
Specialist – FE Analysis
Rolls-Royce plc

ITI CAE Geometry Workshop – 14th & 15th September, 2017

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CAE Geometry Handling & Meshing for FE Analysis

- **Introduction**
- **Simulation Requirements**
- **Geometry & Meshing Requirements**
- **Status & near term improvements**
- **Drivers for Further Improvements**
- **Conclusions**

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Our businesses

Civil Aerospace

Defence Aerospace

Power Systems

Marine

Nuclear

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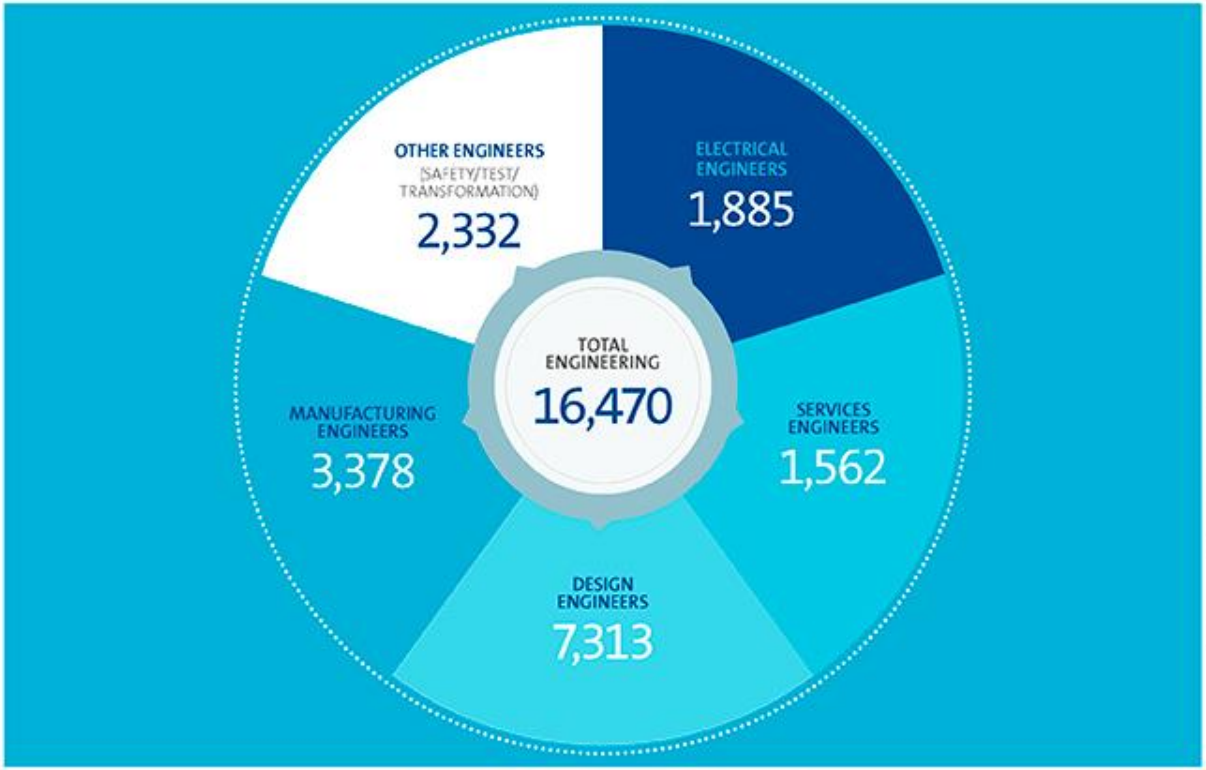
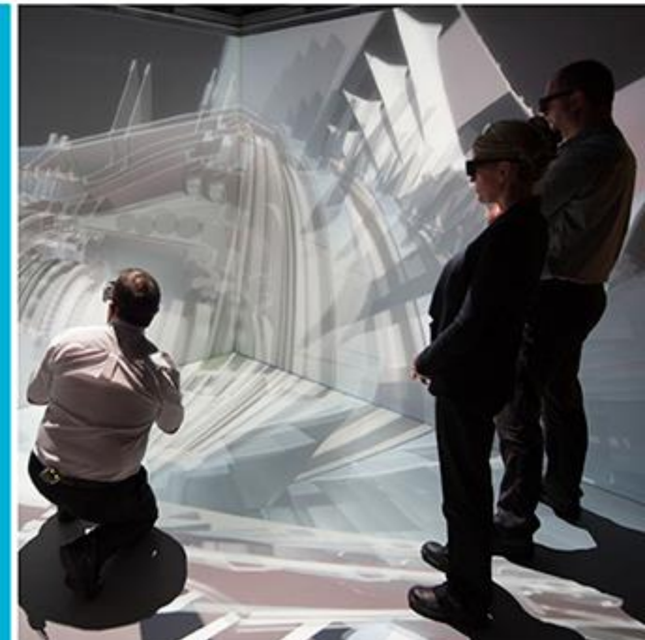
Engineering excellence



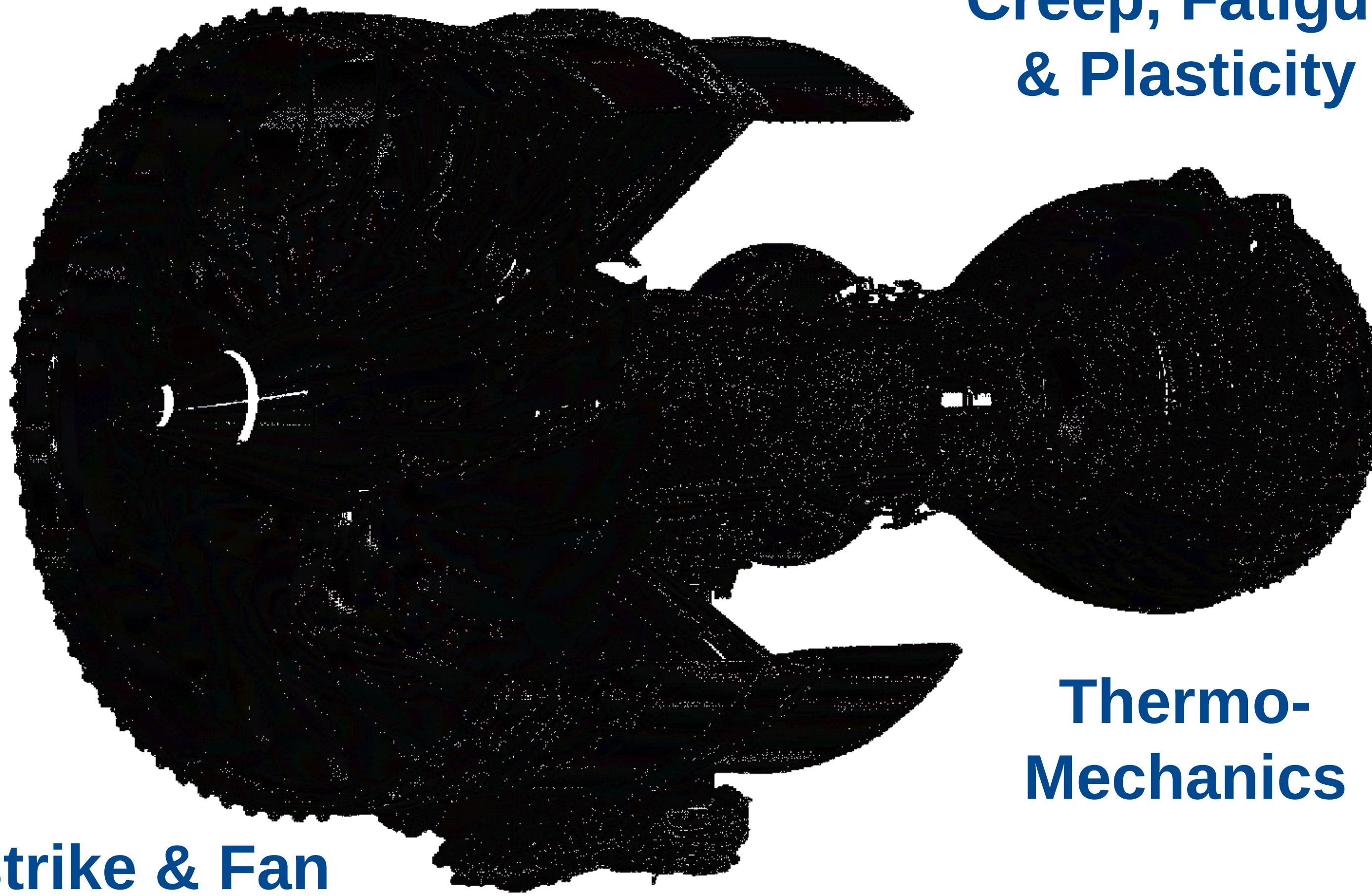


Research and development	University technology centres	Advanced manufacturing centres
£1.3bn	31	7

'Vision 20'
Our approach to technology and product development over a 20-year cycle

2016 financial data

The Engineering Challenge



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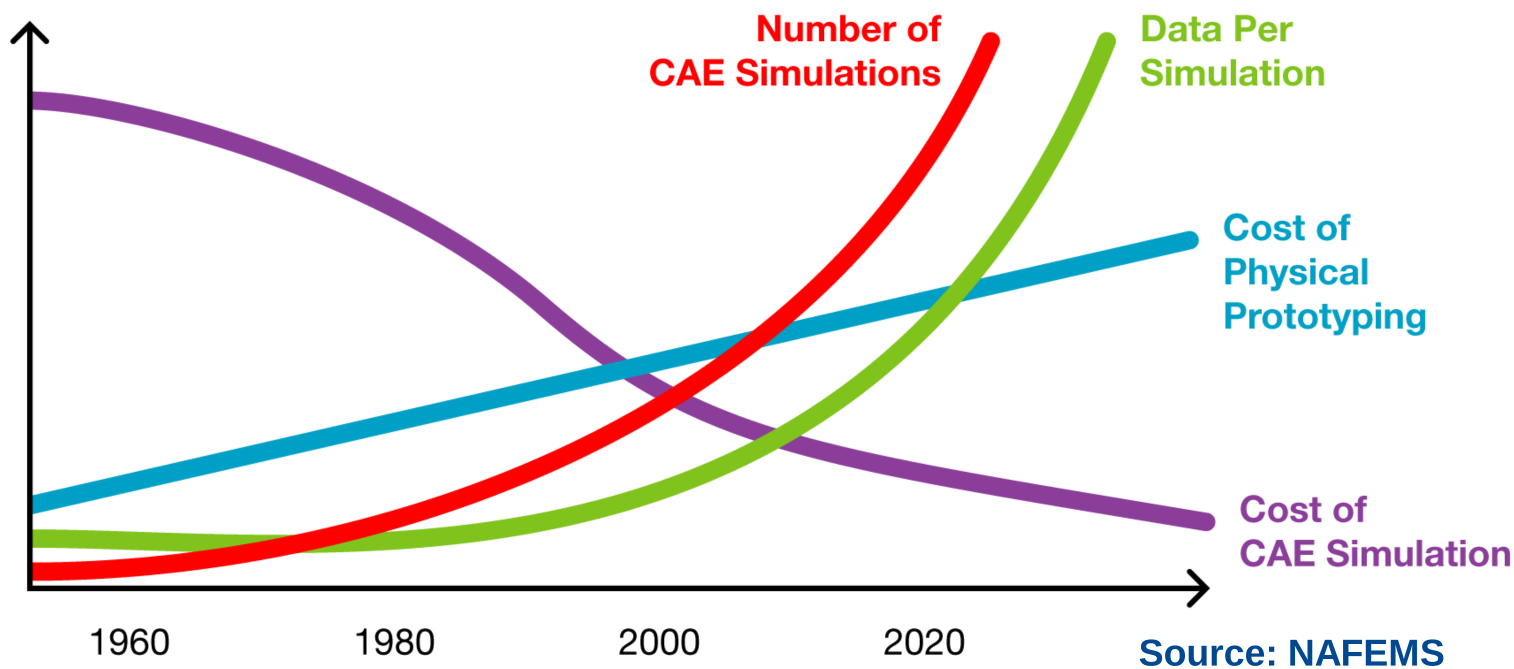
The Simulation Challenge

Increasing Number of Simulations
Increasing Complexity of Simulations
More Data per Simulation

10 000's of models per year
1 000 000's of FEA runs per year
Pb of Simulation Data per year



Source: NAFEMS

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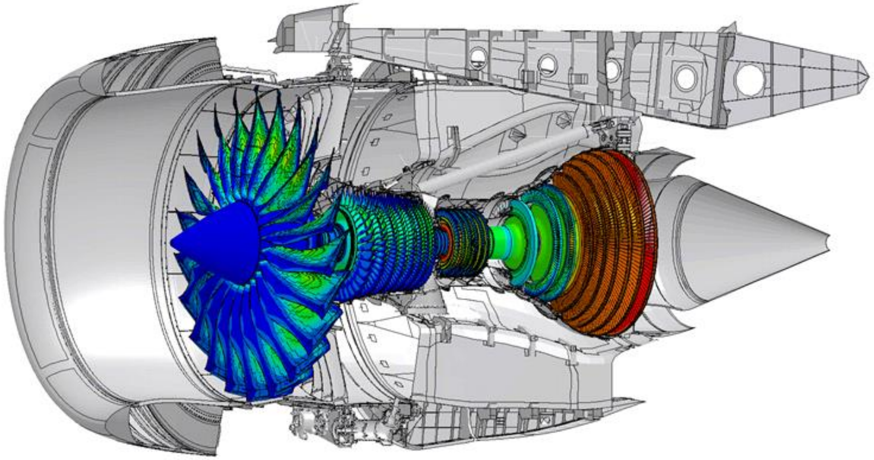
The Need for High Fidelity Modelling

Gas turbines engines are highly integrated and optimised systems, with most major components and modules performing multiple functions

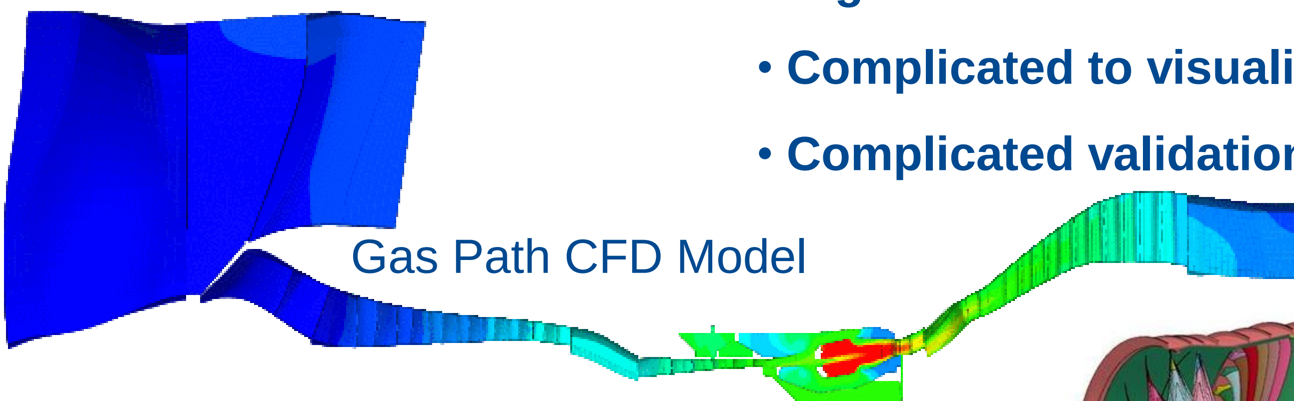


Interactions between all of the engine systems drives the need to build fully integrated, engine level, multi-physics models to properly understand engine behaviour

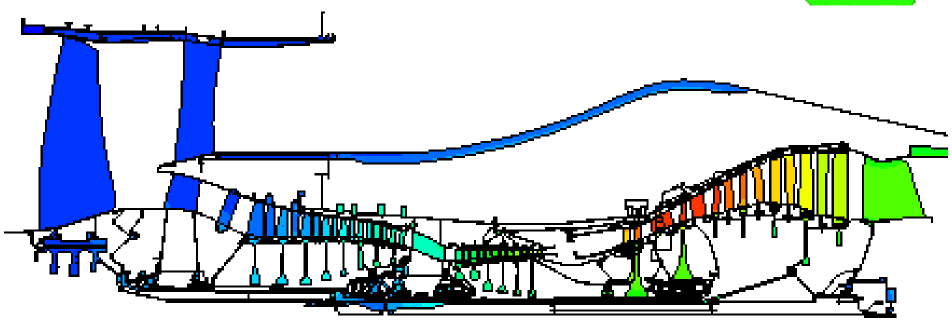
Powerplant Level Simulation

Challenges:

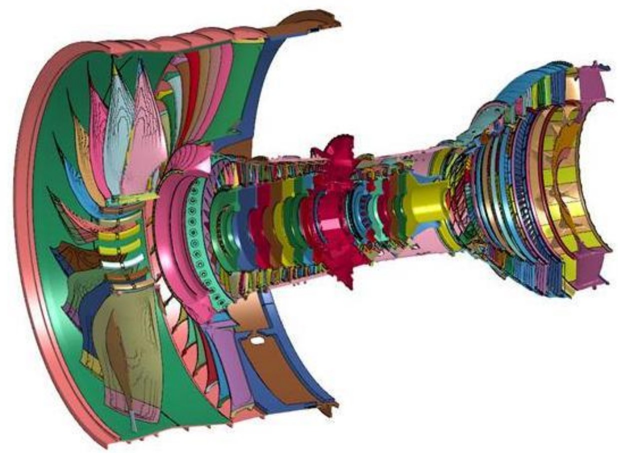
- **Complicated & time consuming to build**
- **Rapid response needed to design changes**
- **Implicit FEA solve increasingly difficult**
- **High volume of data exchange**
- **Complicated to visualise & interpret**
- **Complicated validation requirements**



Gas Path CFD Model



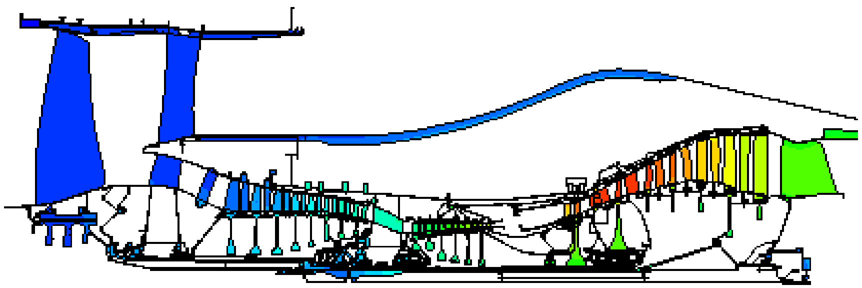
Whole Engine Thermo-mechanical model

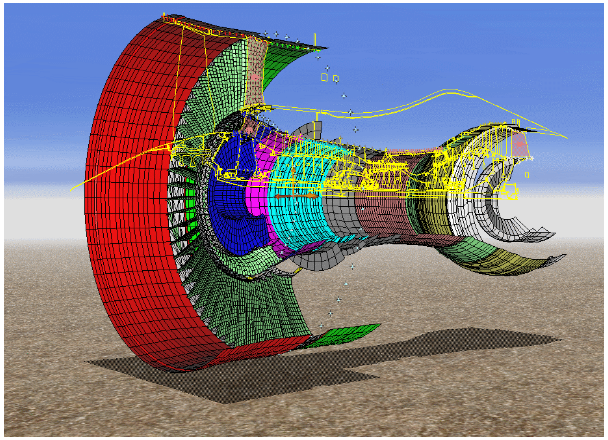


Fan Blade-Off Model

Mechanical Simulation: Improvements needed in 3 Dimensions

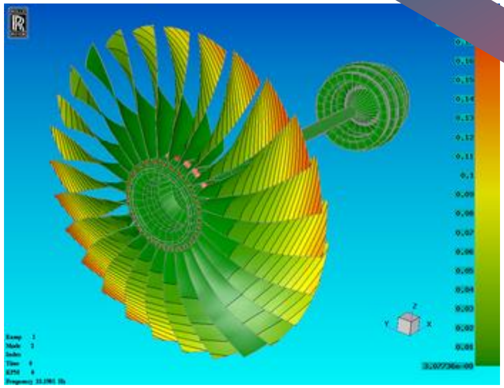
Simulation Ranging over Component, Sub-System & Whole Engine Levels





Multi-Disciplinary Simulation

Simulation Earlier, and Later, in the Design Process (Variable Fidelity)



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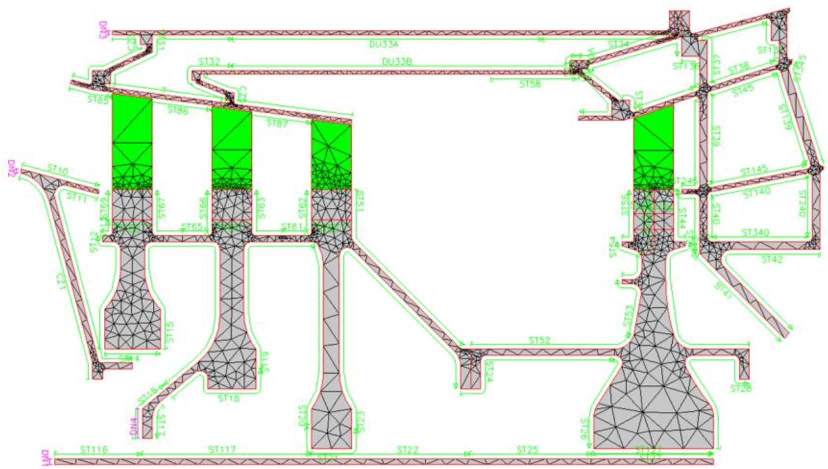
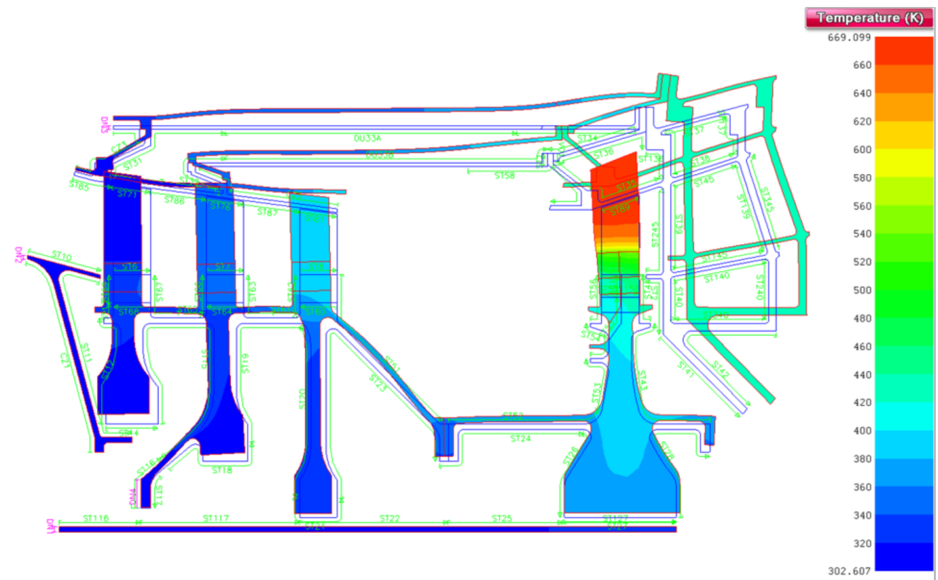
Simulation Example
– 2D Thermal & Thermo-Mechanical Benchmark



- **2D Axisymmetric model**
- **Transient analysis**
- **Coupled thermal & mechanical analysis**

- **Simplified geometry but with representative boundary conditions**
- **2D & 3D versions available**



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Geometry & Meshing – High-Level requirements

- Requirement for fast geometry preparation & meshing to meet the need to influence the design process

- Requirement for large model size: ~ 1bn Elements

- Experience is with high order elements

- Due to the nature of models, hexahedral elements (Hex20's) are most effective & efficient in providing accurate results

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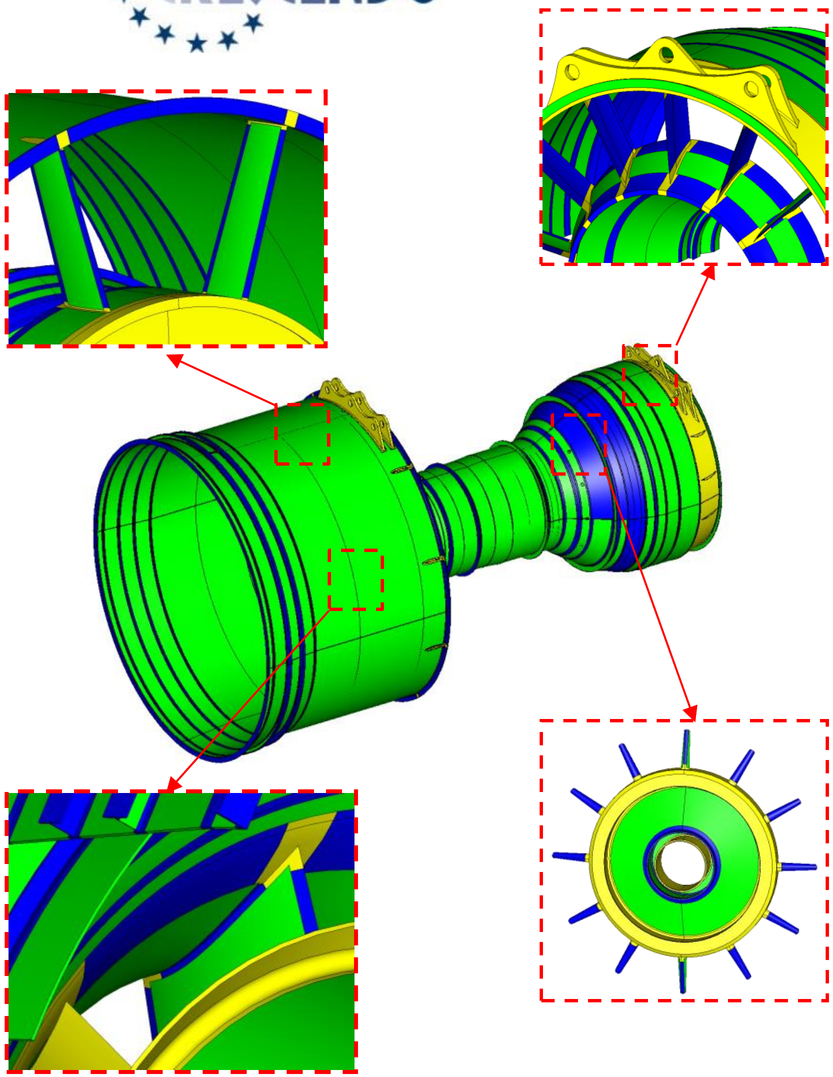
Geometry & Meshing

- **Shell Meshing**
  - **Focus on automation**
- **Tet Meshing**
  - **Improvements in mesh adaption**
  - **Improved meshing robustness**
  - **Focus on mesh quality**
- **Mixed dimensional Meshing**
  - **Thin / slender / complex partitioning for shell, swept, solid meshing giving high fidelity results with reduced model size**

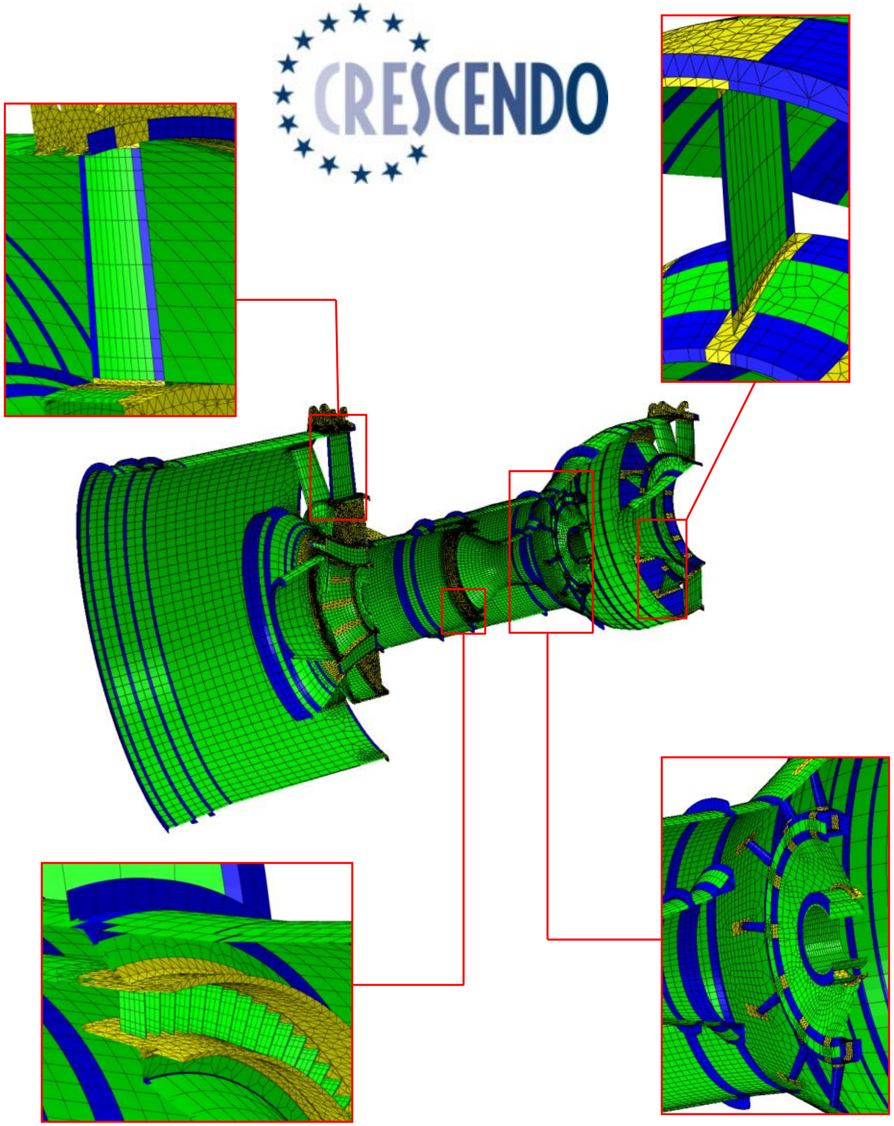


Geometry & Meshing

- **Hex Meshing**
  - **Automate as much of the process as possible**
  - **Semi-automated meshing of large, complex 3D structures when conventional techniques fail**
  - **Expert system, data analytics, rule based approach to meshing**
  - **Leading to –**

    Automated Hex Meshing

- **High Performance Computing**
  - **Improved parallelisation of the meshing process**



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Drivers for Geometry & Meshing Improvements

Faster simulation model build and re-build after design iterations

- **Faster acquisition & conversion of design geometry to analysis geometry**
- **Meshing directly from CAD**
- **Ideally, we need to mesh manufacturing geometry (minimal de-featuring, automatic were needed)**
- **We need to use geometric information to speed-up application & re-application of boundary conditions (Use of concepts like Geometric Reasoning* & Simulation Intent*)**

* Terms defined by Queen's University Belfast & ITI-Global

Drivers for Geometry & Meshing Improvements

- **Parallelisation**
  - Ability needed to mesh very large assemblies in parallel using HPC systems
  - Integration of model build, meshing, solve an visualisation in one system for processing on HPC
- **CFD / FEA (Multiphysics) Integration**
  - Ability to identify and mesh solid & fluid domains
  - Mapping capability to pass data between domains as accurately & efficiently as possible
- **Simulation Verification**
  - Demonstrating the credibility and maturity of simulation models is increasingly important
  - Better measures of mesh quality needed to feed into verification of simulations

Drivers for Geometry & Meshing Improvements

- **Uncertainty Quantification**
  - CMM or laser scan measurements generate surface definitions of components
  - The ability to either morph meshes, or rapidly re-mesh, to these measured surfaces is needed
  - This needs to be fast & accurate to cope with the large samples needed to provide significantly significant samples
- **Hot Running to Cold Static Corrections**
  - Aerodynamic shapes need to be correct at operating conditions
  - This requires the ability to back calculate the manufacturing shape from a simulated operating condition.
  - Displacements from the simulation need to be used to create the manufacturing CAD geometry

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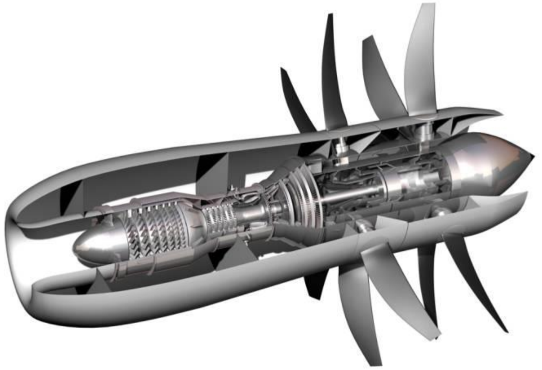
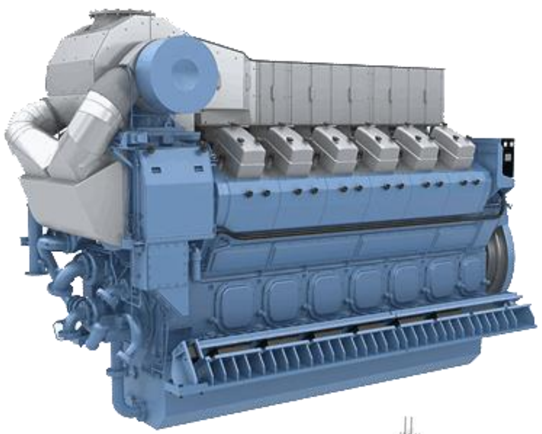
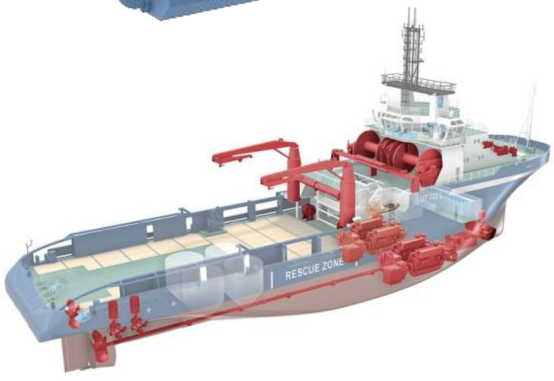
In Conclusion……

- We face significant business challenges which drive the need for more effective Simulation
- The scale and complexity of Simulation is increasing rapidly
    - Larger models
    - Including multi-physics
    - Earlier in the design process
- Fast, accurate CAE Geometry generation & meshing of very large models is essential in achieving this
- Major improvements in geometry & meshing needed to allow engineers to make productive use of Simulation
- Requirements change, so we need to remain flexible and agile!







" Take the best that exists and make it better…

If it doesn't exist,

create it."

Sir Henry Royce