Computational Science and Engineering Grand Challenges in Rolls-Royce

Leigh Lapworth

Networkshop42,

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Rolls-Royce

Rolls-Royce – 5 key sectors

Civil Aerospace

Defence Aerospace

Energy & Nuclear

Marine

Power Systems

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Trent XWB

The most efficient engine flying in the world today

The Trent XWB is 10% more fuel efficient than the engines it is designed to replace This will save airlines operating the A350 around US $2.5M per aircraft per year in fuel costs.

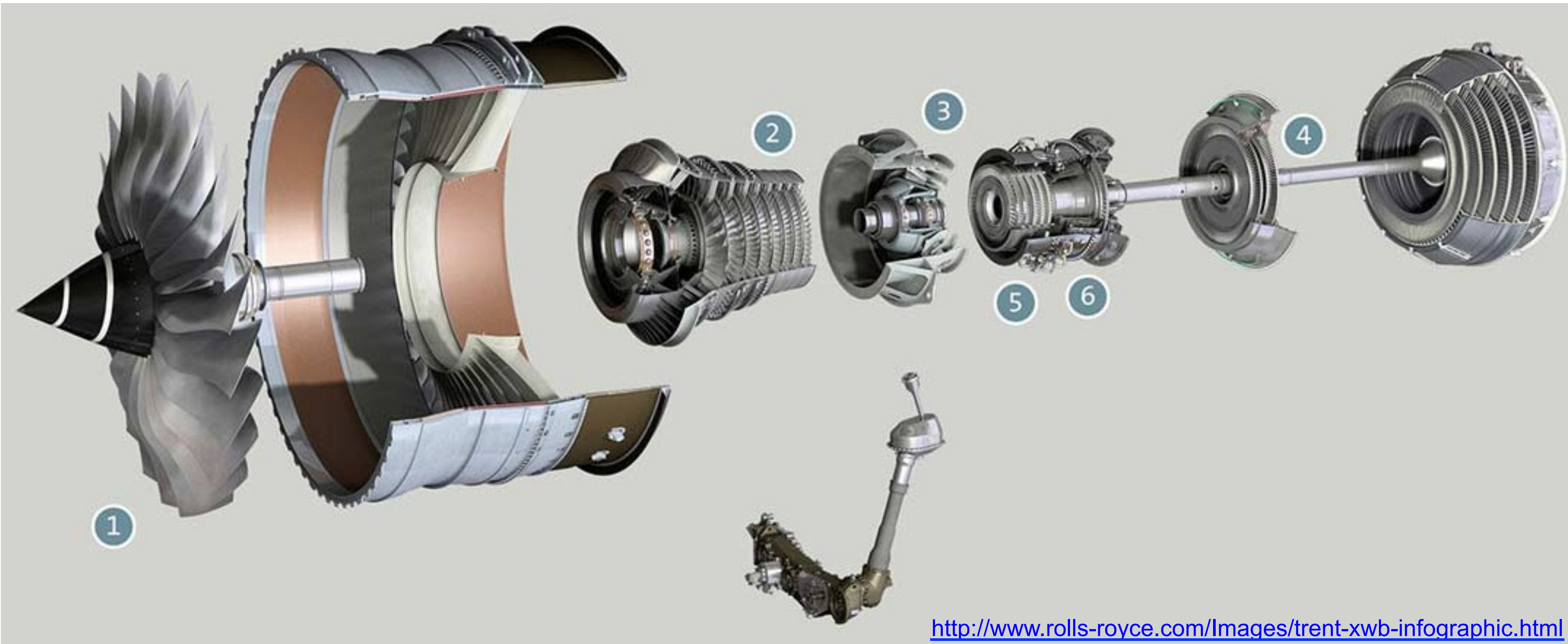
http://www.rolls-royce.com/Images/trent-xwb-infographic.html

Trent XWB – Scope of simulation

1. Ultra efficient swept fan (CFD, FEA & impact)

2. Advanced compressor aerodynamics (CFD)

3. Improved sealing air requirements (CFD & FEA)

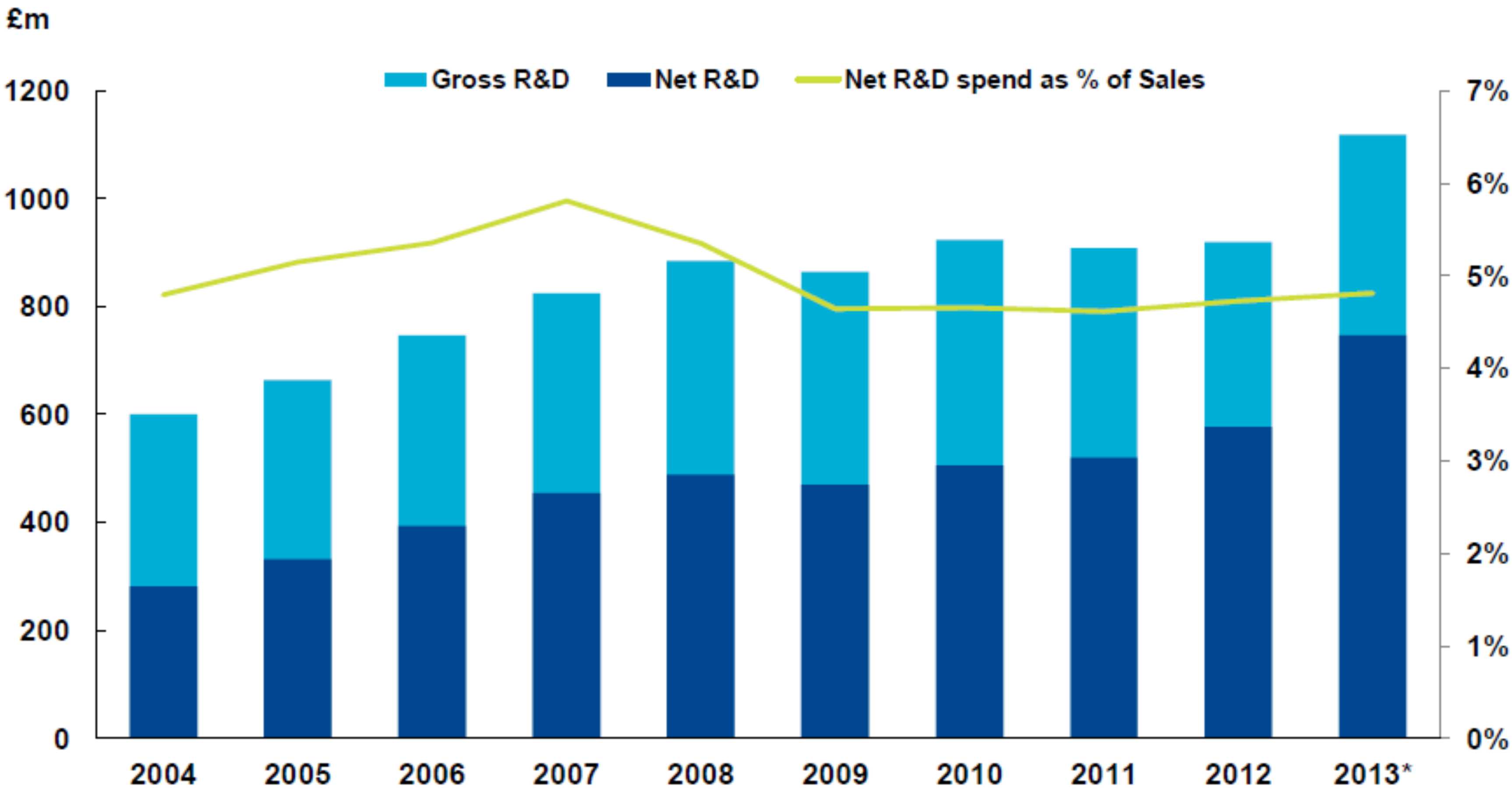


4. Improved efficiency 2-stage IP turbine (CFD)

5. Intelligent air system management

6. Single skin combustion casing (FEA)

Investment in R&D



http://www.rolls-royce.com/Images/2013_Full_Year_Appendices_Data_Pack_tcm92-54901.pdf

* Includes Tognum R&D of £165m

University Technology Centres

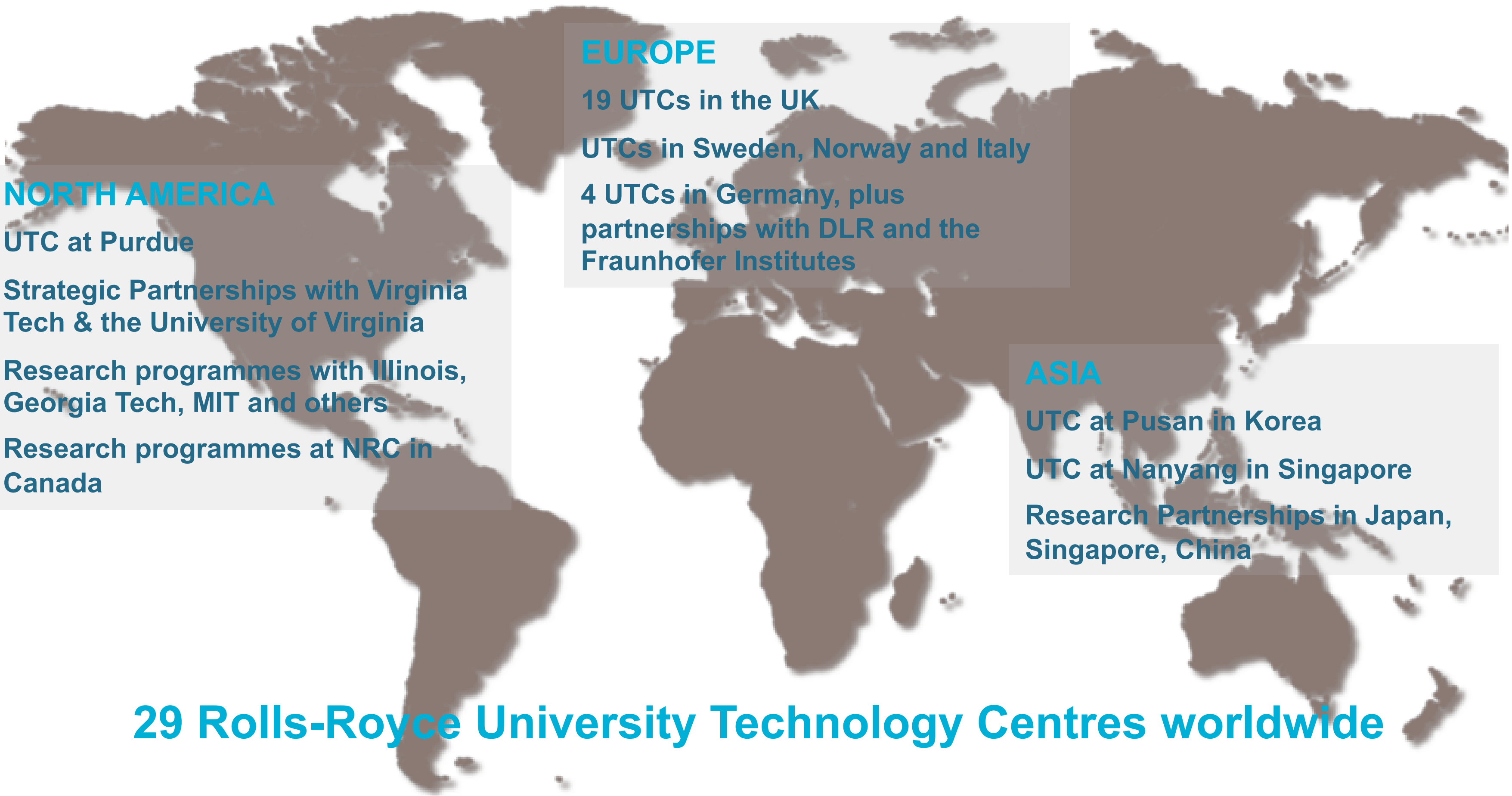
History

- In the late 1980s, Rolls-Royce adopted policy of focusing academic research with selected university partners
- First formal UTC collaborations signed in 1990
- UTCs now in UK, Germany, USA, Norway, Sweden, Italy, S.Korea, Singapore

Philosophy

- Each UTC addresses a key technology
- Collectively they tackle a wide range of cross sector challenges – from combustion and aerodynamics to noise and manufacturing
- Consistent strategy of developing long-term relationships with selected universities

Rolls-Royce University Technology Centres
An increasingly global network



EUROPE

19 UTCs in the UK

UTCs in Sweden, Norway and Italy

4 UTCs in Germany, plus partnerships with DLR and the Fraunhofer Institutes

NORTH AMERICA

UTC at Purdue

Strategic Partnerships with Virginia Tech & the University of Virginia

Research programmes with Illinois, Georgia Tech, MIT and others

Research programmes at NRC in Canada

ASIA

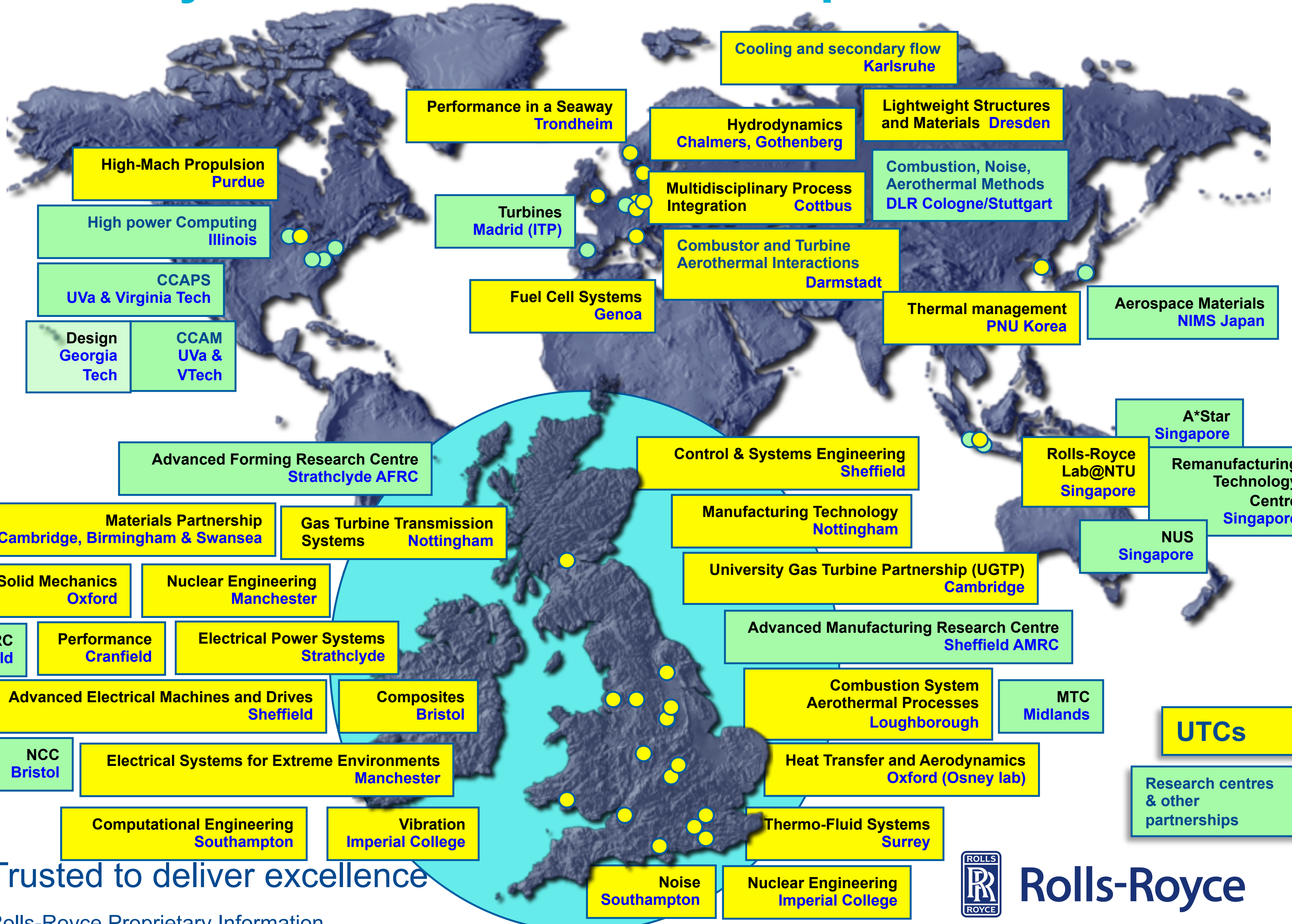
UTC at Pusan in Korea

UTC at Nanyang in Singapore

Research Partnerships in Japan, Singapore, China

29 Rolls-Royce University Technology Centres worldwide

Rolls-Royce Academic Partnerships include:



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Rolls-Royce Proprietary Information

Rolls-Royce

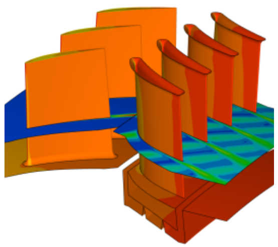
Global Network of Manufacturing Research Centres

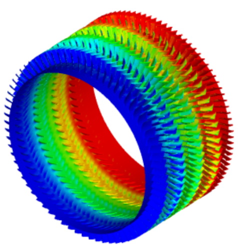
A Global Network of Advanced Manufacturing Research Centres

Design Systems Engineering

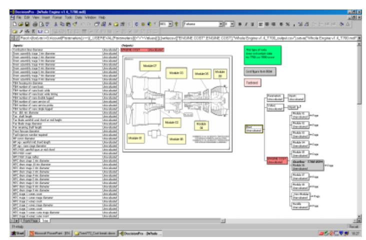
Rolls-Royce uses a wide variety of analysis techniques for design verification from whole engine to component

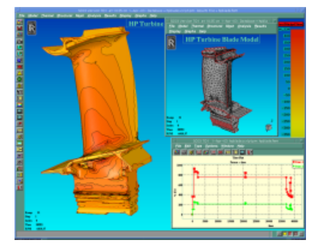
Computational fluid dynamics is used to understand the aerodynamics of engines in order to maximise performance.





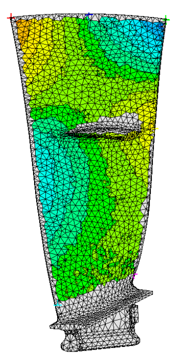
Cost modelling is used to identify cost drivers and maximise value



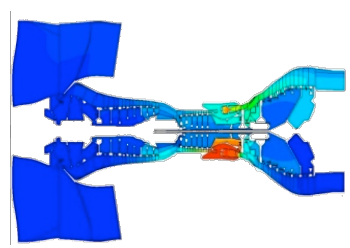


Finite element structural analysis is used for vibration, lifing and thermal analysis, both linear and non-linear at component and sub-system level.

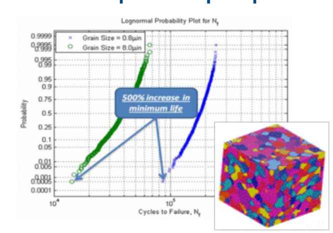
Combined CFD and Structural analysis is used to study forced vibration on turbomachinery



Multi-disciplinary Whole Engine Design Systems predict the behaviour of the integrated product



Materials designed for required properties



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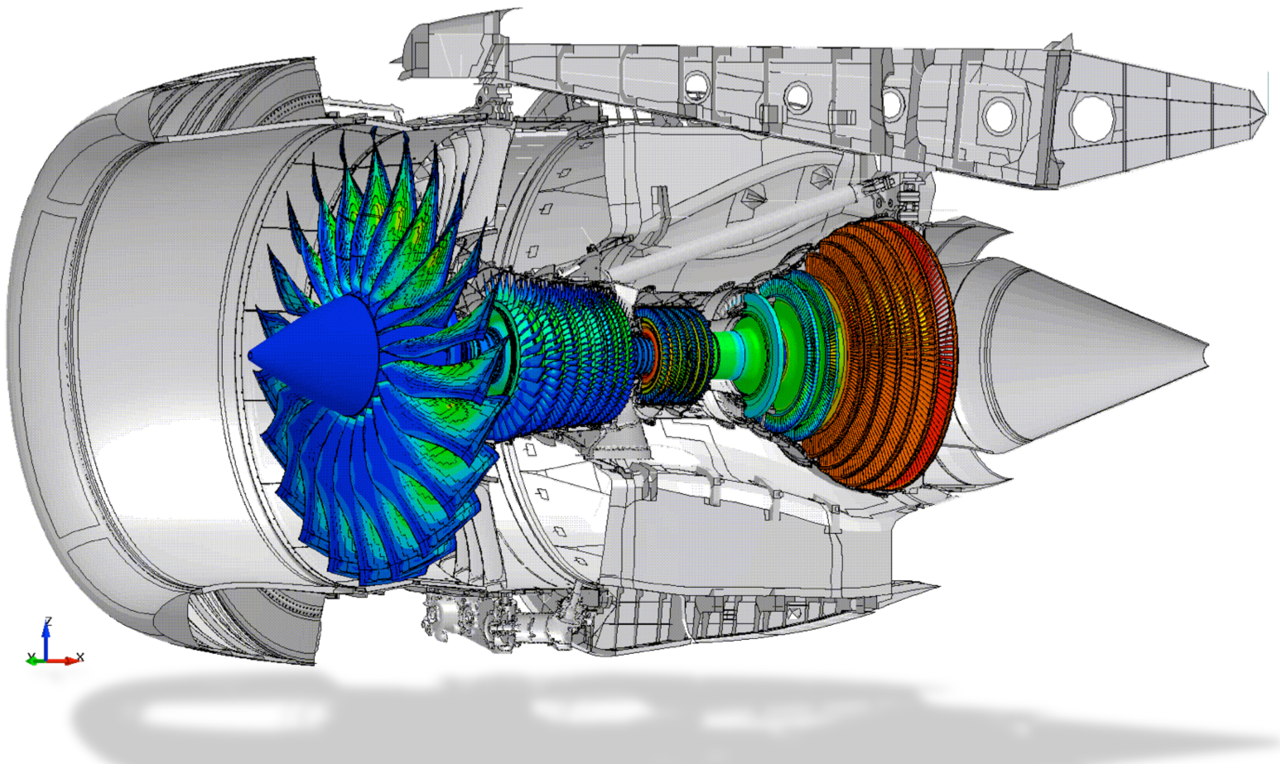
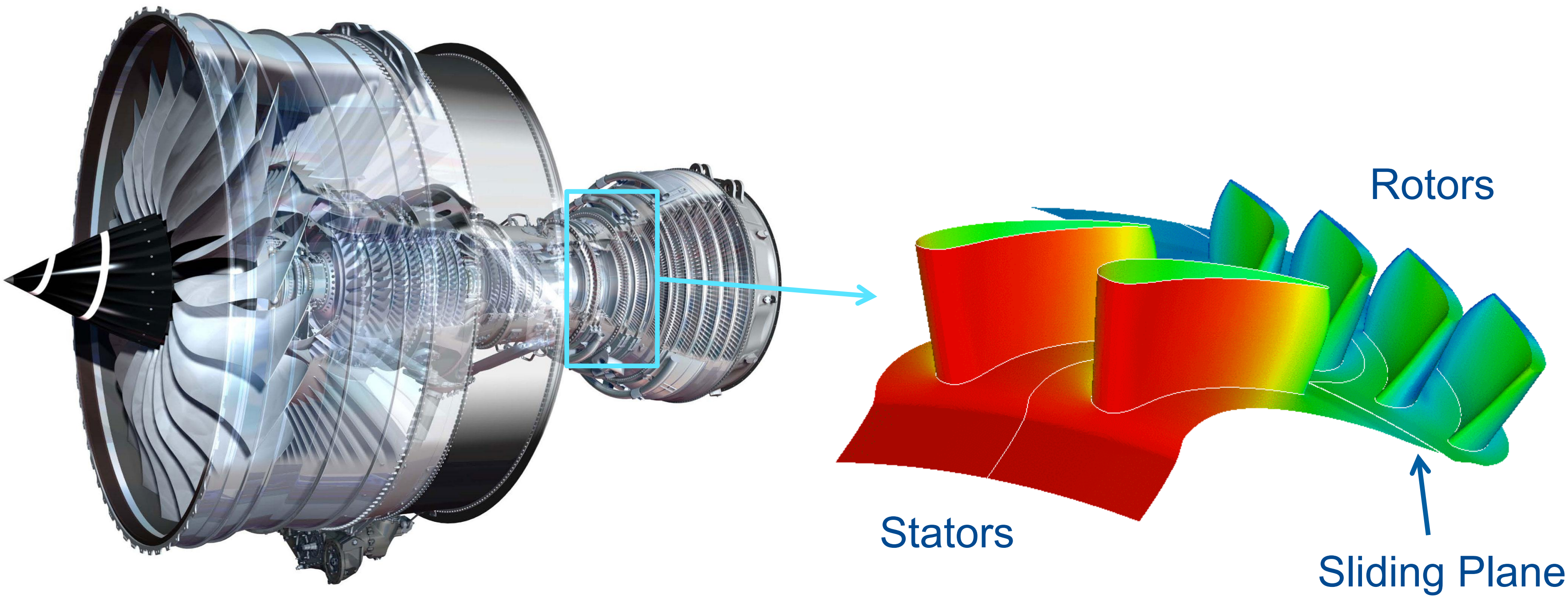
Our Vision



High fidelity virtual engine simulation and design

- > 1 trillion degrees of freedom (DOF)
- > 1 billion core hours per calculation (Whole of ARCHER for 20 months)

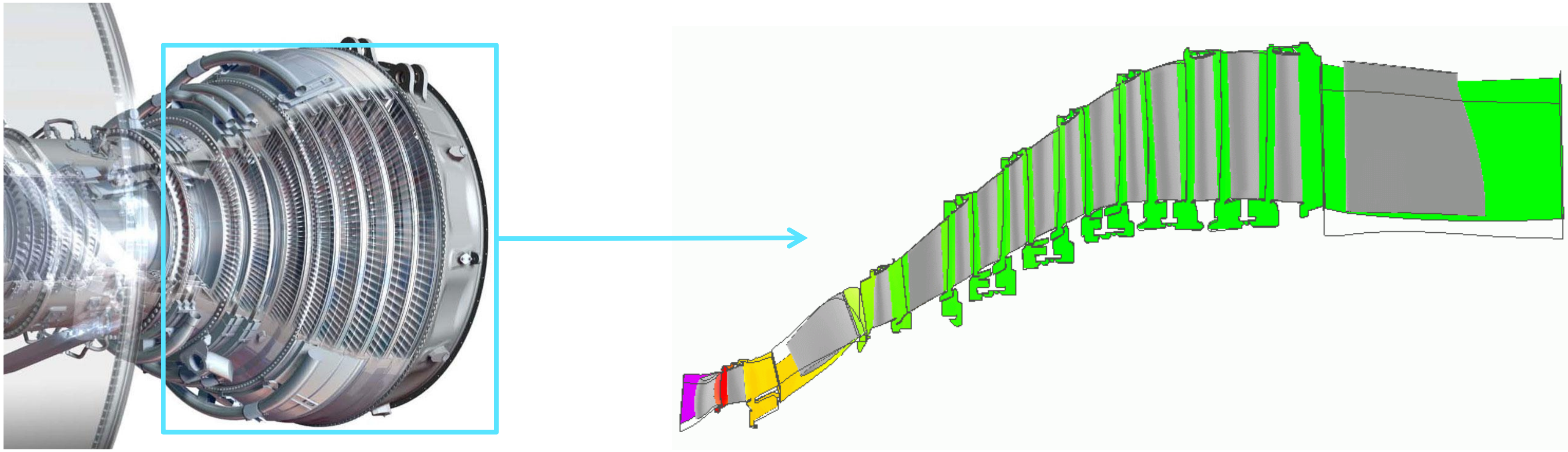
The challenge of turbomachinery



The challenge

- Adjacent rows of rotating and stationary aerofoils
- Computationally, we put a *sliding plane* between them
- Each update to the rotor position changes the SP connectivity

Steady state modelling



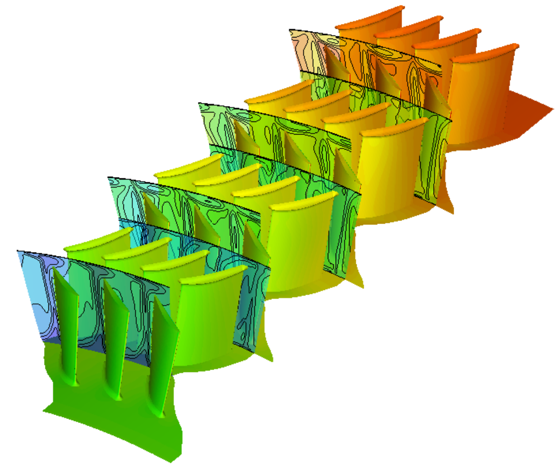
Making design tractable

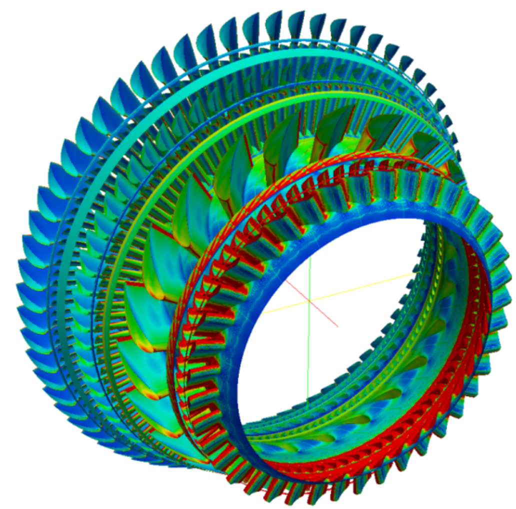
- Circumferentially average sliding plane → steady state model (no dynamic topology)
- Single passage per row (small number of passages in the model)
- 10-100M degrees of freedom

Unsteady modelling

The cliff edges

- Large number of passages
- Single shaft has simple periodicity
- O(10^9) DOF but single revolution
- Multi-shaft periodicity is lowest common multiple
- O(10^{10}) DOF and multiple revolutions
- Above is all for RANS - LES, DNS to come

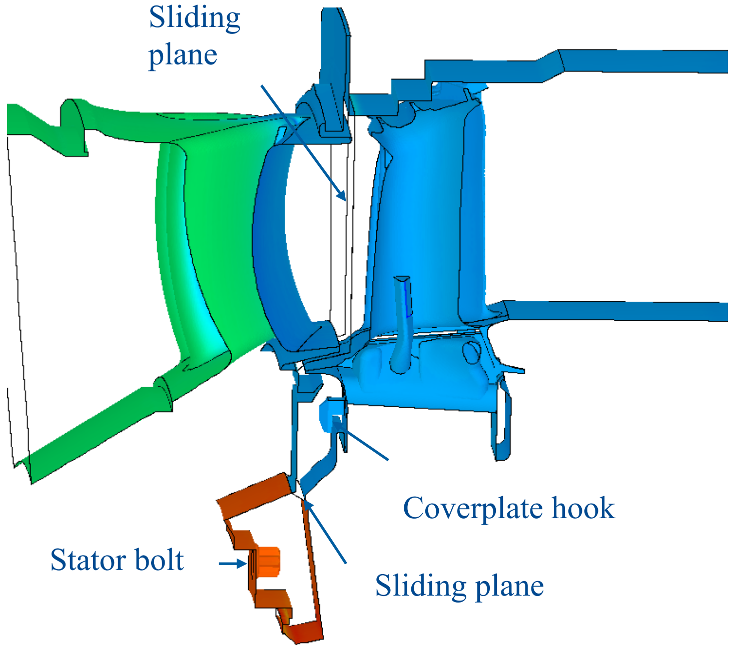




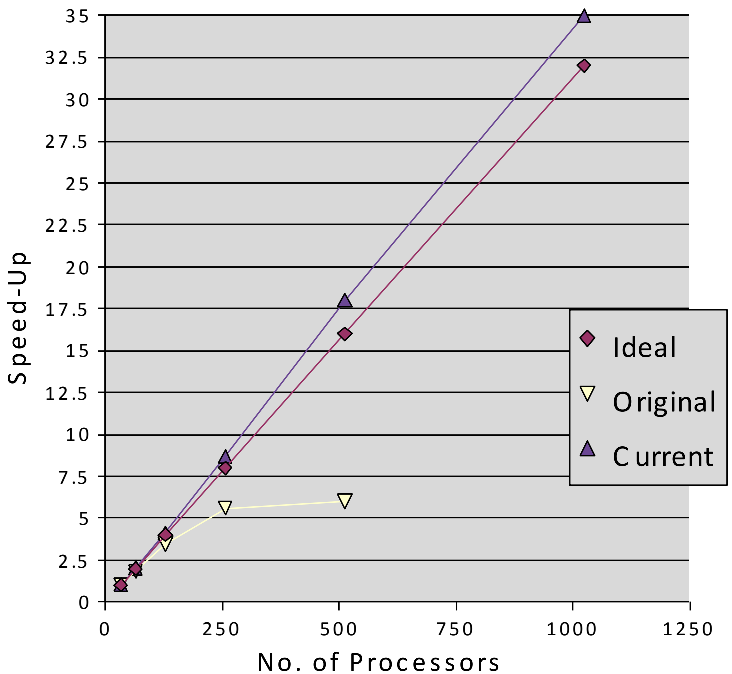
The benefits

- Greater physical accuracy → better products with higher confidence in design
- Design for operability

The scalability problem



HPT Stage: 8 vanes, 14 blades, 9 bolts. 72° sector,
19 Million nodes - 24 hours on 256 processors



(Hills ,Aeronautical Journal, 2007)

The computer science challenge

- Codes don't always go faster on bigger computers

Our approach

Fundamental Physical Research

- Continue to utilise national and regional HPC via our UTCs

Computational Science and Engineering Research

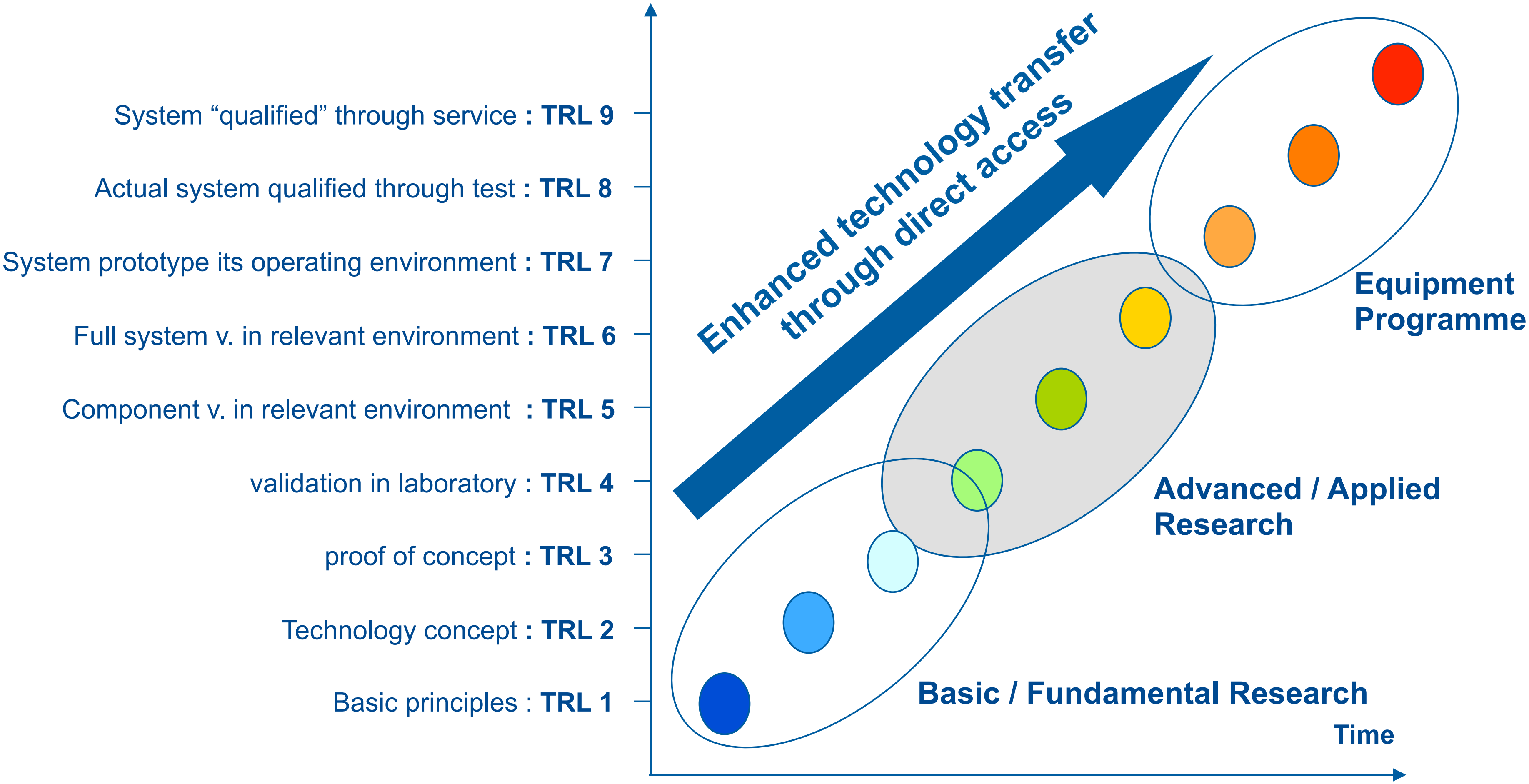
- Develop new CSE network working with CS specialists at the national and regional centres
- Access to national HPC for scalability work and capability demonstration

Networking

- Aim to engage Rolls-Royce directly with the network of HPC and CSE centres
- Fill the *TRL 5 valley*.

Technology Transfer

Direct network access requires appropriate controls, e.g. secure access, data security, export controls etc.



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Rolls-Royce

HPC partnerships

National centres

- Hartree and EPCC (EPSRC) in UK
- NCSA in US, iHPC in Singapore

Regional centres

- HPC Midlands (Loughborough)
- Discussions with other regional HPC centres

Local offload

- ASRC in UK (Bristol)
- CPU247 in Germany (Berlin)
- NCSA in US (Illinois)

Building a network

HPC Midlands (Loughborough)

- Secure access and data storage approved by RR
- 17 miles from Derby
- Loughborough is also a UTC

Direct Connectivity

- Application to Janet Reach to establish direct connection
- RR connection security to be approved by RR

Follow-on

- The above is a pilot and will provide the template for direct access to other centres

Summary

Grand challenges

- The next level of physical complexity in our design tools introduces *cliff edges* in our simulation roadmaps
- Preparing ourselves and our codes for the world of the virtual engine is an immense task – we cannot do this alone

The network solution

- Build on our long track record of working with universities
- Direct collaboration using the national infrastructure
- New research opportunities and more immediate research impact.