HPC in RR: Enabling Simulation Based Design Engineering

Reliability, integrity, innovation

Dr Yoon Ho

Design Systems Engineering

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Product Portfolio

Vcom 15425

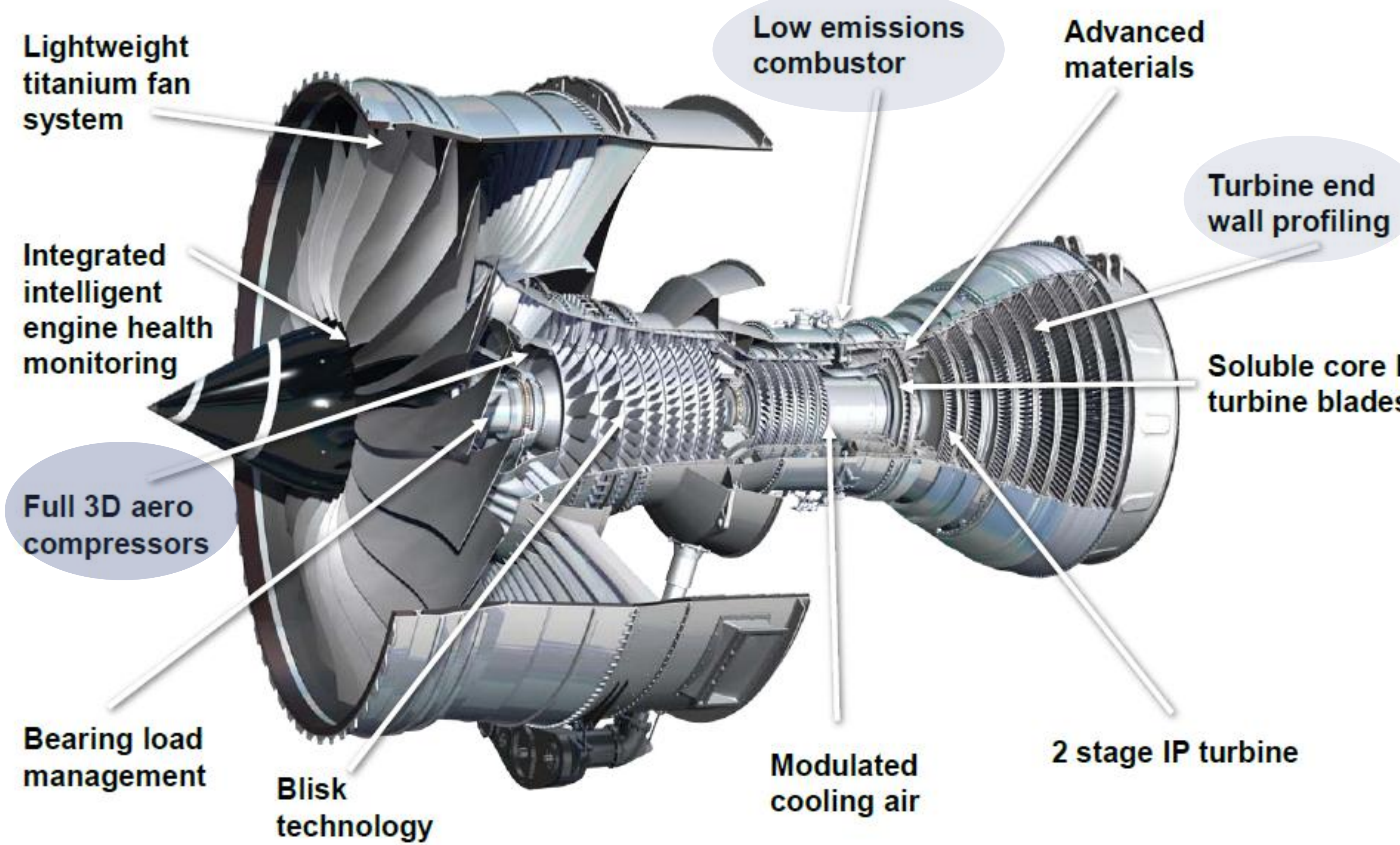
Trent XWB

- World’s most efficient aero engine
- Designed exclusively for the Airbus A350 XWB
- The sixth member of the market-leading Trent family
- Every 28 seconds, somewhere in world a Trent powered aircraft takes-off
- Certified for 84,000 lbf of thrust
- To date more than 1,300 Trent XWB engines have been sold to 35 customers across 25 countries and three airlines alliances, making it the fastest selling widebody engine ever!


Trent XWB – facts

- The 3m diameter hollow, titanium fan set consists of 22 blades, rotating at 2,700rpm and sucks in up to 1.3 tonnes of air every second at take off!
- The tip of each blade travels at 950mph, faster than a speeding bullet
- At take-off each fan blade carries a load of 90 tons which is equivalent to 9 London buses hanging from the tip of each blade
- At take-off each of the 68 high pressure turbine blades generate around 900 horsepower, equivalent to a formula One racing car!

Trent XWB – Advanced Technology

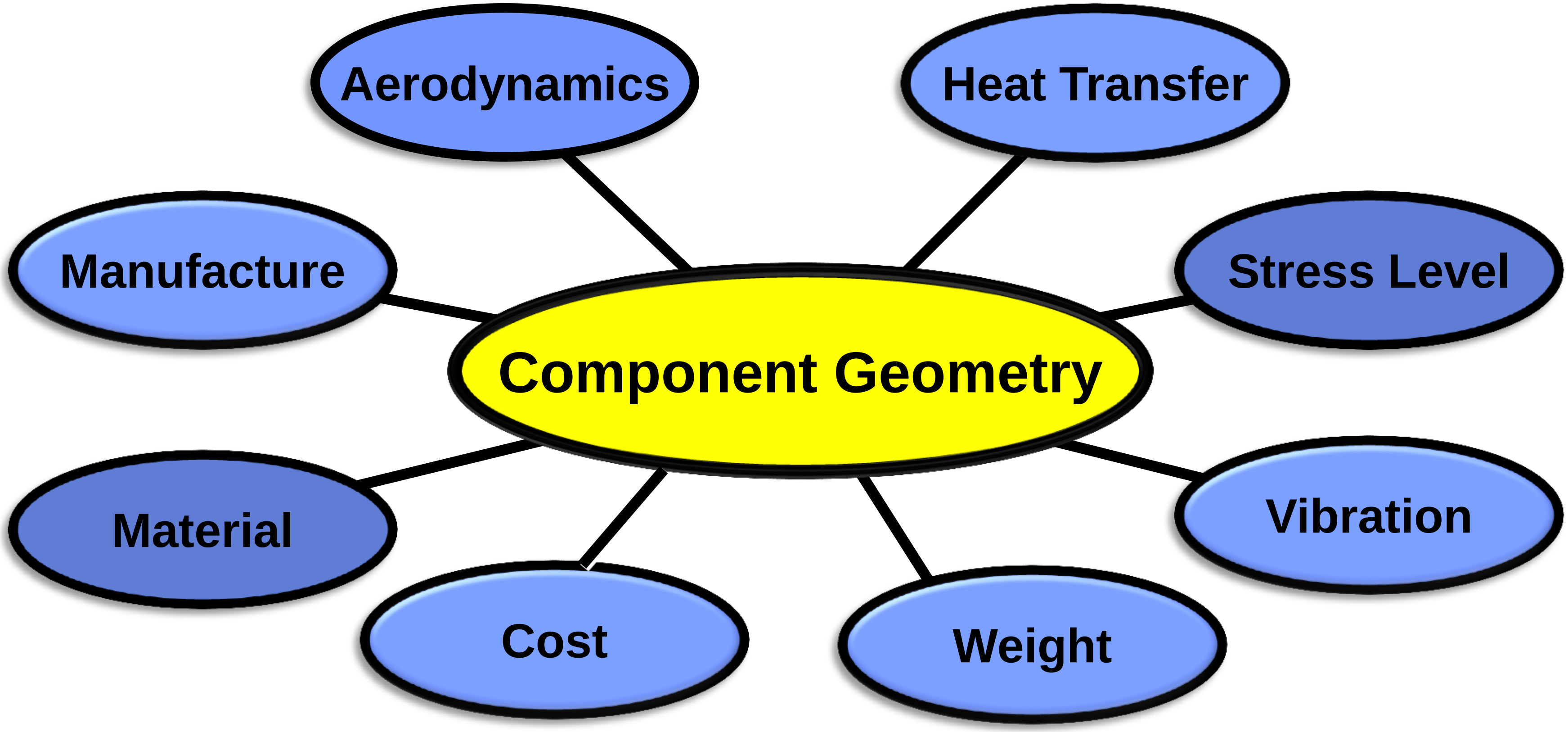


- **High-performance computing (HPC) is the use of parallel processing for running advanced application programs efficiently, reliably and quickly**
  - ***Hardware***
  - ***Software***
  - ***Workflows (process)***
  - ***People (skills)***

HPC … Not just big computers

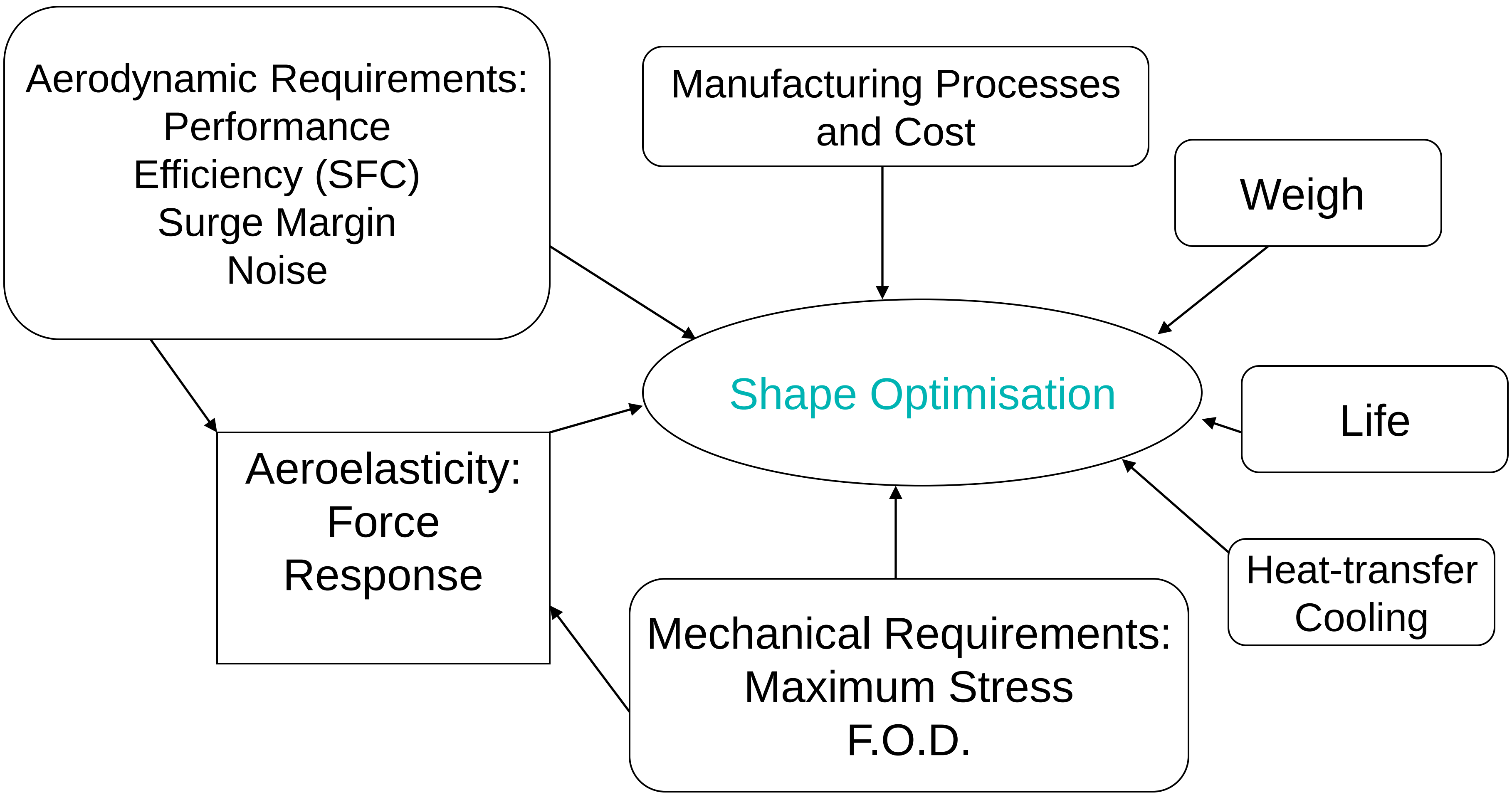
Design process

Design considerations



Shape Optimisation

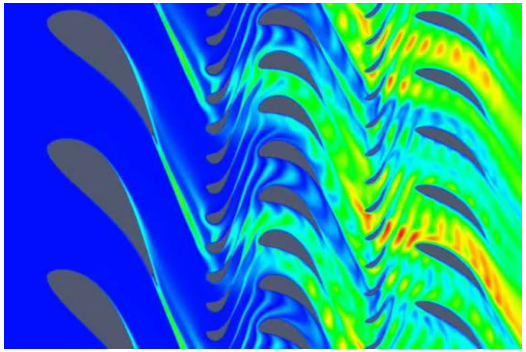
(Reduction of Design Time- Whole Engine Modelling)

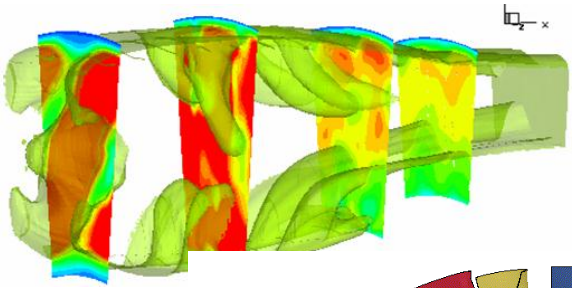


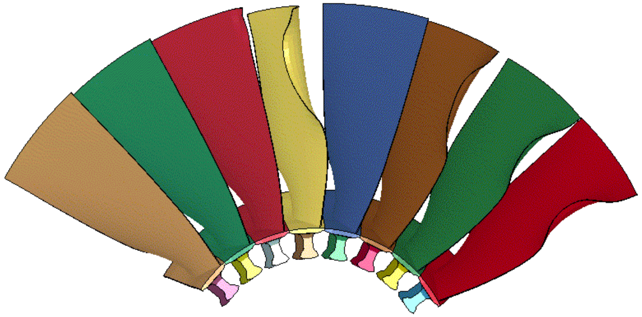
CFD and FEA

The use of simulations in RR

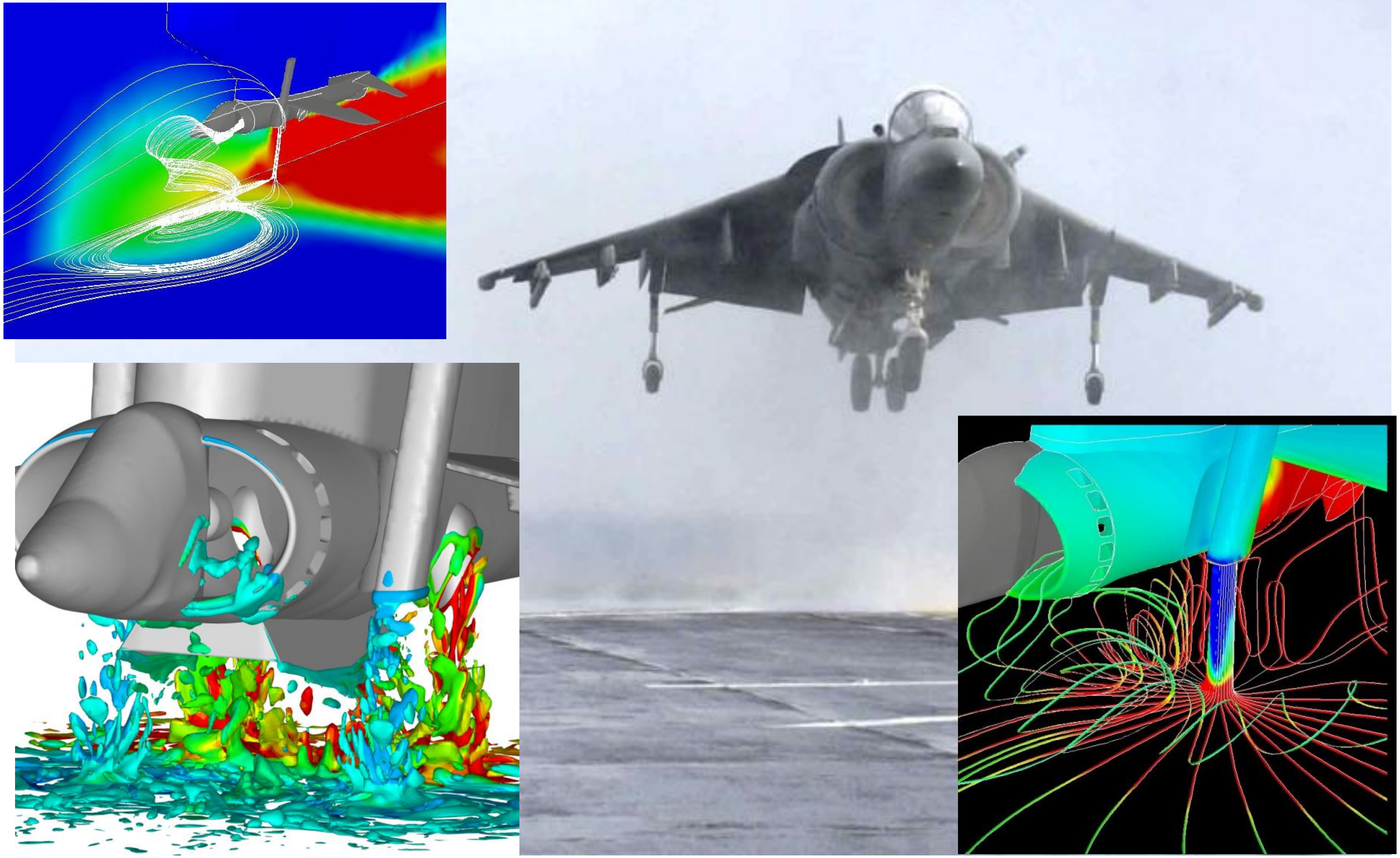
- **Aeromechanics**
  - ➢ ***Stall, Flutter, Forced response***
- **Fluid Mechanics**
  - ➢ ***Unsteady turbo-machinery***
  - ➢ ***Combustion***
- **Thermo-Mechanical**
  - ➢ ***Transient thermal analysis***
  - ➢ ***Lifing***
- **Extreme Events**
  - ➢ ***Fan blade off***
  - ➢ ***Bird strike***
  - ➢ ***Ice ingestion***



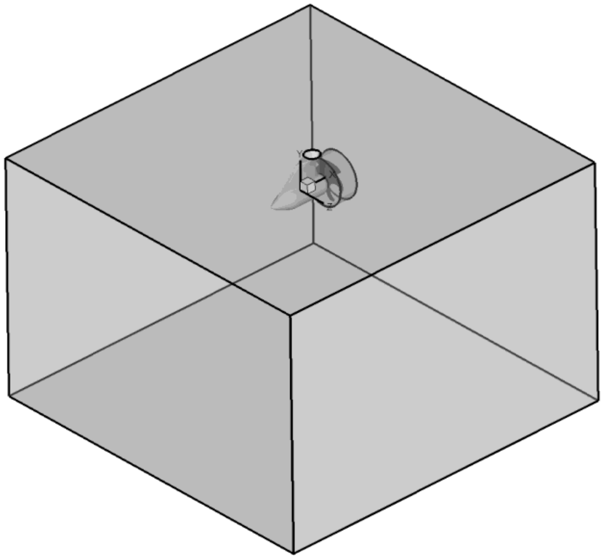


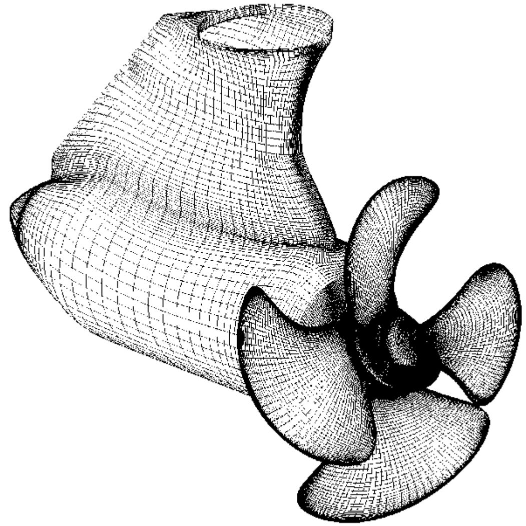


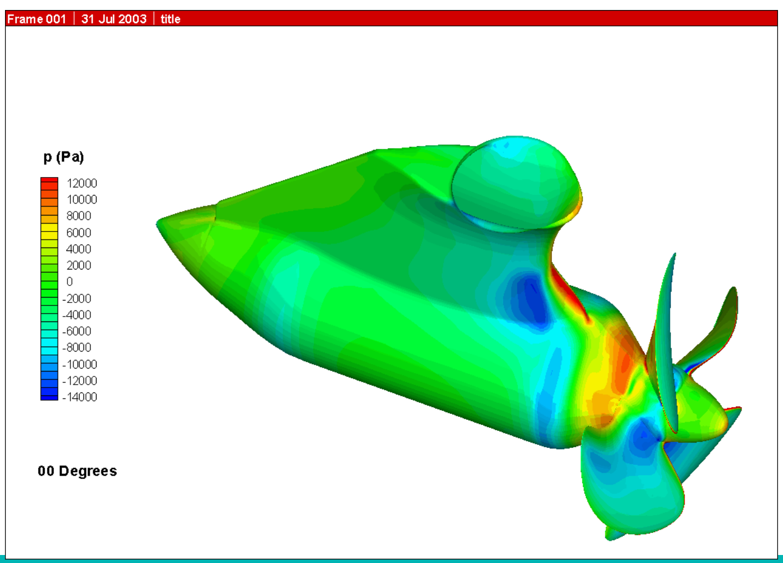
LES - Hot gas ingestion modelling

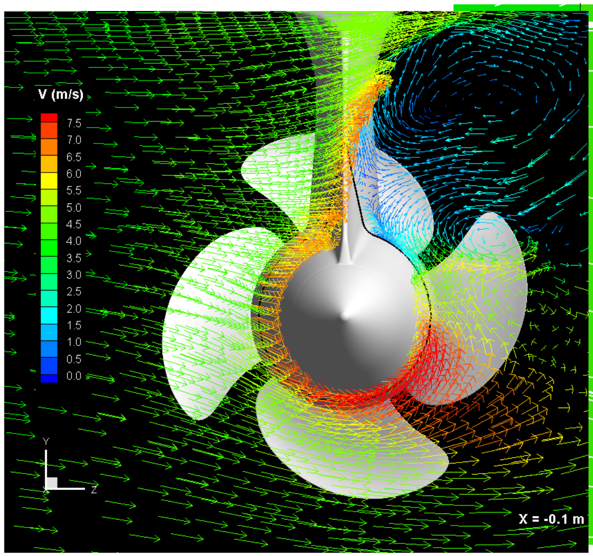


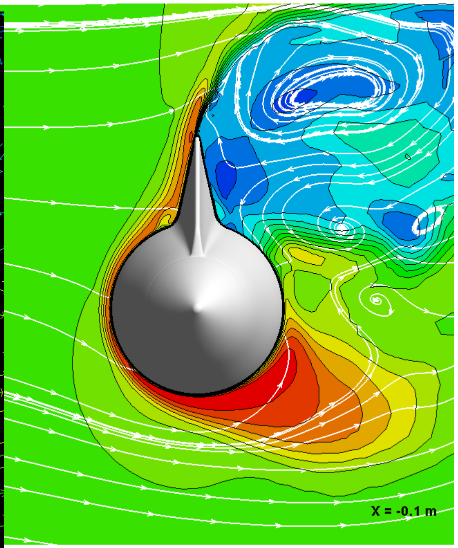
Quasi-steady Calculation of Pod Unit





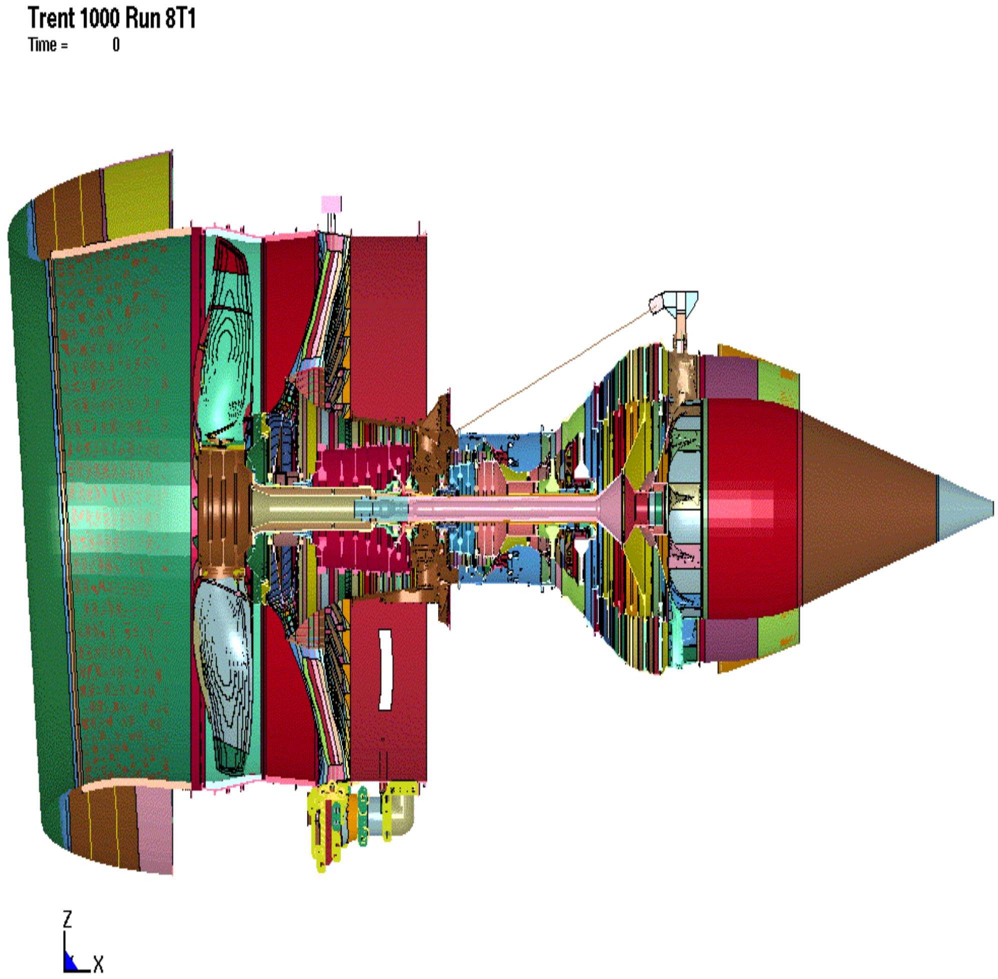






LS-Dyna WEM

- Majority of engine 3D detailed solid models
- Non-linear material properties included
- Contact allowed between components
- Physical model leads to far fewer assumptions than traditional WEM
- First few engine revolutions following FBO analysed



What Has HPC Allowed Us To Do?

- Reduce numerical errors – larger mesh
- Capture component interactions
- Reduce sub-modelling – improved BCs
- Mesh solid geometry not shells
  - trade analyst time for compute time
- Analyse more complex missions
- Analysis delivering in project timescales
  - calculations become relevant to design
- Optimisation beginning to become viable

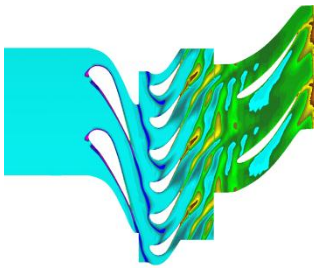
Other potential applications of HPC

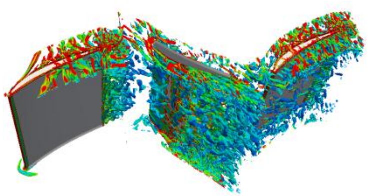
- **Materials modelling (molecular modelling of micro-structures, predictions of materials properties,…)**
- **Manufacturing process modelling (casting, forming, machining, optimisation of machining paths,…etc)**
  - **Materials UTP**
  - **PRISM2- Partnership for Research in the Simulation of Manufacturing and Materials**
- **Modelling sea states & ship performance**
- **Modelling tidal generation arrays in real geography**
- **Combined CFD/thermal/mechanical analysis of nuclear steam generation plant**
- **Modelling of RR organisation to optimise processes and organisational efficiency**

Future modelling challenges

Future State – Design and Analysis Options

Higher Fidelity Discipline Modeling

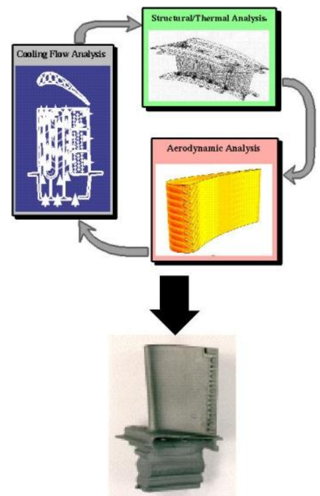




increase accuracy

Improve Understanding

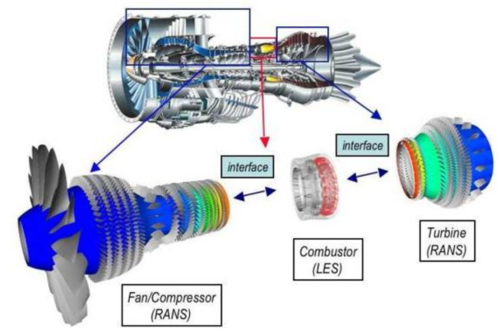
Multi-Disciplinary Design & Optimization



screen domain design space

Produce Best Design

Virtual Product Modeling

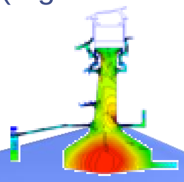


reduce product tests

Reduce Cost, Risk & Time

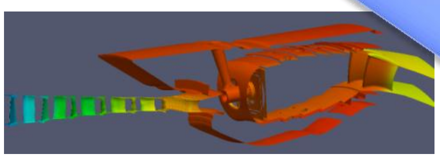
Vision - Virtual Product Systems

Component Level
(e.g. HP Turbine Disc)



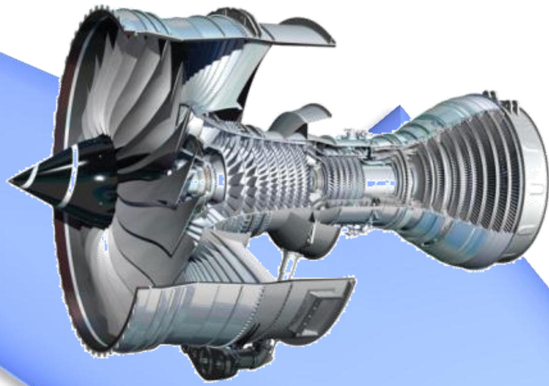
Sub-system Level
(e.g. Integrated HP Spool)

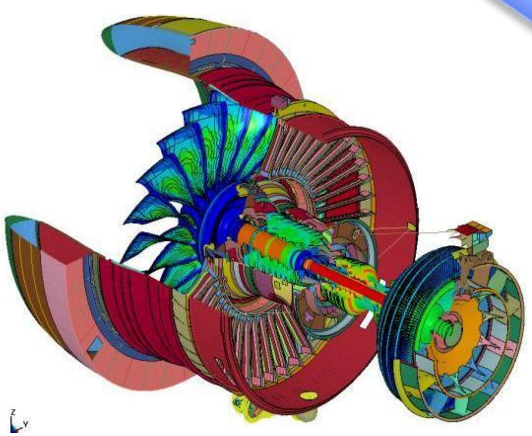
•Multi-component
•Multi-physics
•Multi-fidelity
•Optimised sub-systems
•Improved Product Performance
•Reduced Environmental Impact



Full Virtual Engine

•Virtual Product Systems
•Optimised & Robust Systems
•Step change in:
  • Through life operational & environmental performance
  • Number & range of complex product systems



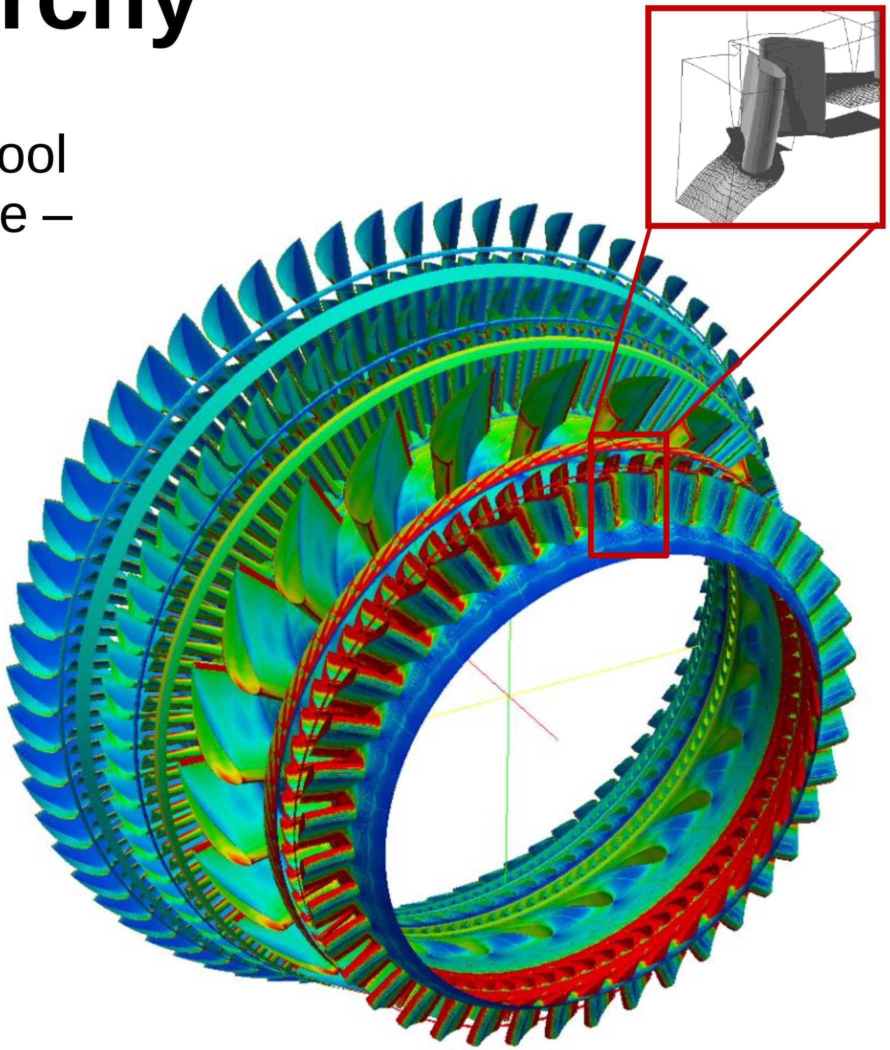


Rolls-Royce

Future challenges: compute

Test Problem Hierarchy

Aero-thermal and mechanical multi-spool CFD of the fully featured High Pressure – Intermediate Pressure turbine.



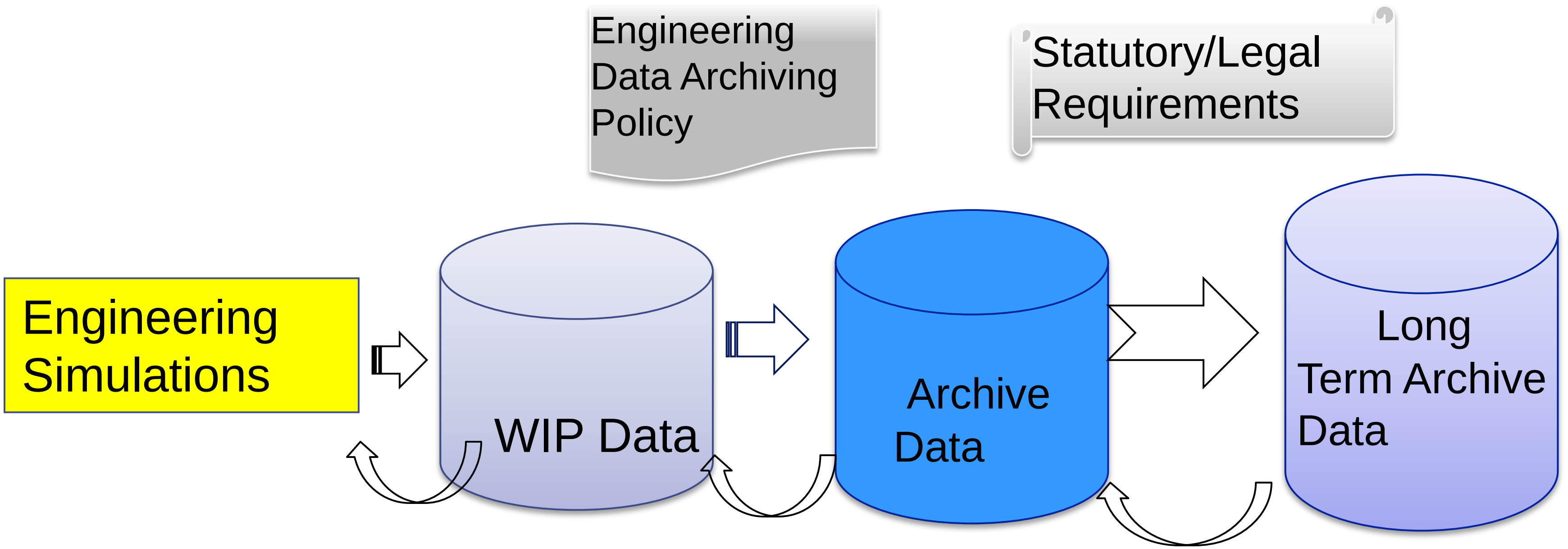
HPC Estimates

- Assumptions and targets
  - 2 week turn-around time
- Cost and speed benchmark
  - Intel(R) Xeon(R) CPU X5650 @ 2.67GHz

- HPC estimates and cost per calculation:
  - Problem #1: Traverse-HP — 1,700 cores
  - Problem #2: IP1 or IP2 — 2,000-4,000 cores
  - Problem #3: Traverse-HP-IP1 — 20,000 cores
  - Problem #4: Traverse-HP-IP — 36,000 cores
- Beyond these:
  - Stall prediction — 20,000 cores
  - Hi-Fidelity VE (thermo-mech) — 100,000 cores

Future challenges: Data Volume

Simulation Data Flows :



Storage sizes:	100s TB	10s PB	EB (?)
Storage durations:	Weeks/Months	Years	Decades

Summary

- **HPC underpins simulation based design process**
- **Multi physics, multi-components simulations are done as a matter of routine within our design cycles**
- **Looking to the future, we want to move towards Virtual Product Systems**
- **Challenges in both compute and data volume:**
  - Recognise that business pressures and incremental approach will not bridge the gap.
  - Potential for business impact is very high, but...
  - Risks are also high
    - Scalability of the solver
    - Reliability of the pre-processor
  - Cost of HPC would be prohibitive, storage would be huge!