Future Challenges in Gas Turbine Technology

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Content

- **Rolls-Royce**
- **Propulsion System developments**
- **Summary**

Background on Rolls-Royce

Power Systems for air, land and sea

Civil Aerospace

Defence Aerospace

Power Systems

Marine

Rolls-Royce

A leading position in the Civil market

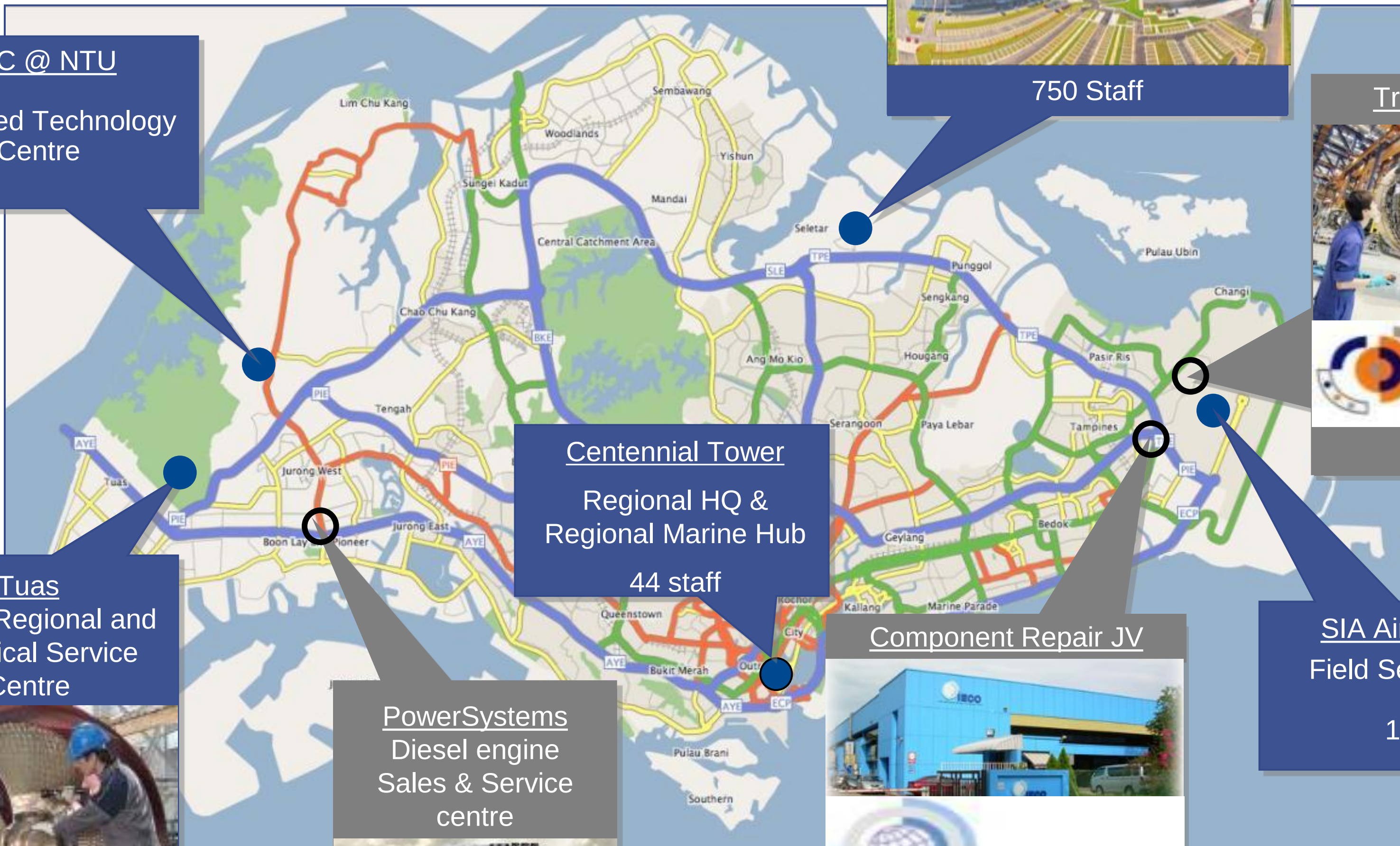



- **13,000 engine installed in over 30 aircraft types**
- **380 airline and leasing customers**
- **Over 30 million flying hours accumulated (2013)**
- **TotalCare™ and CorporateCare™ are market leading service programmes**

A leading position in the Defence market

- **16,000 engines installed in 24 aircraft types & 7,000 helicopter engines in operation**
- **160 global military customers in 103 nations**
- **MissionCare™ offers similar services as in the commercial world**

Presence in Singapore



Rolls-Royce Seletar Campus

750 Staff

ATC @ NTU

Advanced Technology Centre

Trent MRO JV

SAESL

970 Staff

Centennial Tower

Regional HQ & Regional Marine Hub

44 staff

Tuas

Marine Regional and Technical Service Centre

90 staff

PowerSystems

Diesel engine Sales & Service centre

400 staff

Component Repair JV

IECO

221 Staff

SIA Airline House

Field Service Office

10 Staff

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Rolls-Royce proprietary information

Seletar Campus

- Over 750 staff
- 65,000 sqm facilities on 154,000 sqm site
- S$700m investment

HUB

- Advanced Technology Centre
- Regional Training Centre
- Energy Asia HQ
- Corporate Shared Services
- 400 staff capacity
- 1st occupancy in 2011

Wide Chord Fan Blade manufacturing facility

- 7600 Trent fan blade capacity
- 26,500m^2 production floor
- Multiple Trent engine fan blade capability
  - Trent 900, 1000, XWB
- 1st production fan blades in 2013

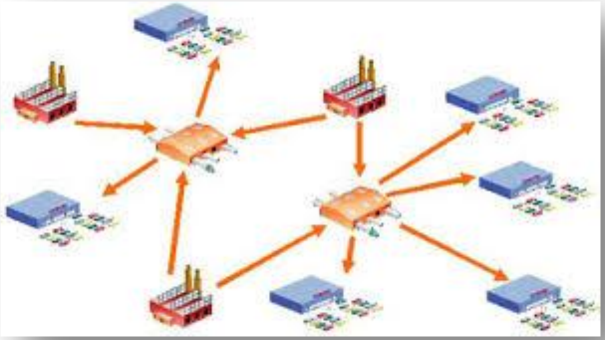
Trent Aero Engine Assembly & Test facility

- 250 Trent engine build capacity
- 19,500m^2 assembly hall & 7,000m^2 Test Bed
- Multiple Trent engine capacity
  - Trent 900 & 1000
- Test capacity: 140” fan diameter
- 1st production engine in 2012

Rolls-Royce proprietary information

Customer Requirements

Challenges to consider …



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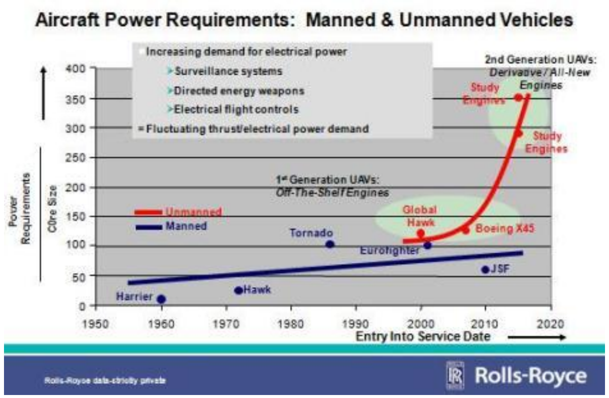
Requirements

Propulsion System manufactures face continuous demands from both airframer. system integrators and both civil / military operators to –

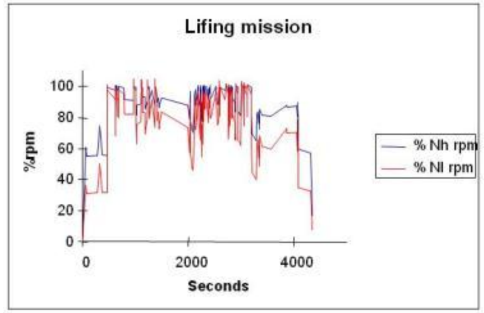
1. provide **much more electrical power** for (mission) equipment, sensors and systems;
2. retain their investment into engines **affordable over the asset life-cycle**;
3. make engines **easier to maintain, repair and upgrade**;
4. address the **environmental impact**, incl. becoming even more fuel efficient

and in any case: **more thrust or power**.

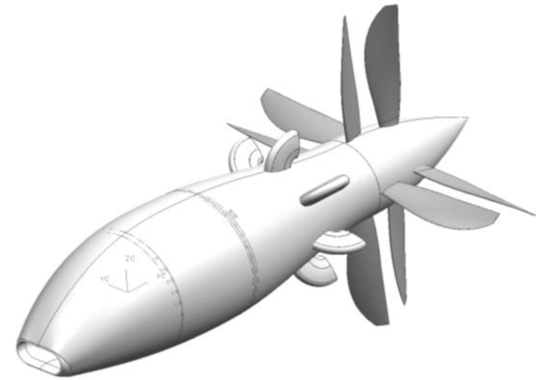
Propulsion Systems - Requirements



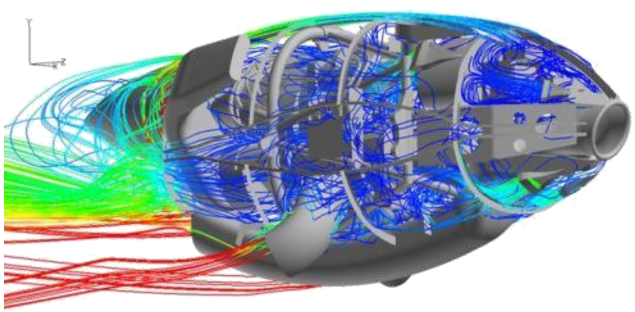
Increased electrical off-take



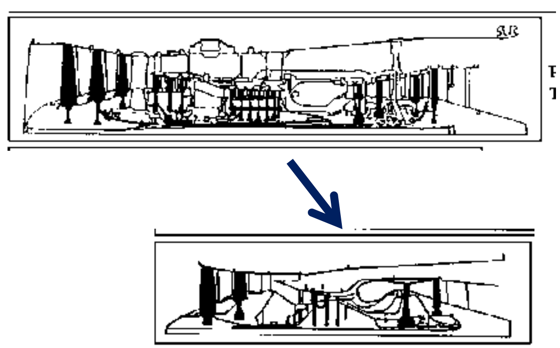
Health Management (EHM), Repairability



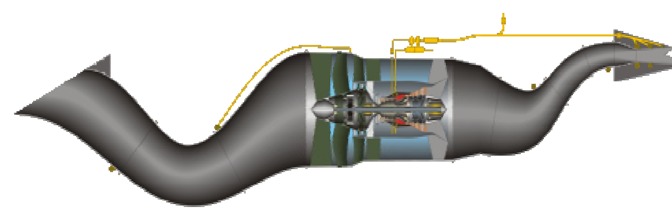
Higher Efficiency



Thermal Management



More compact, lighter and efficient Gas Turbines



Higher Surviveability

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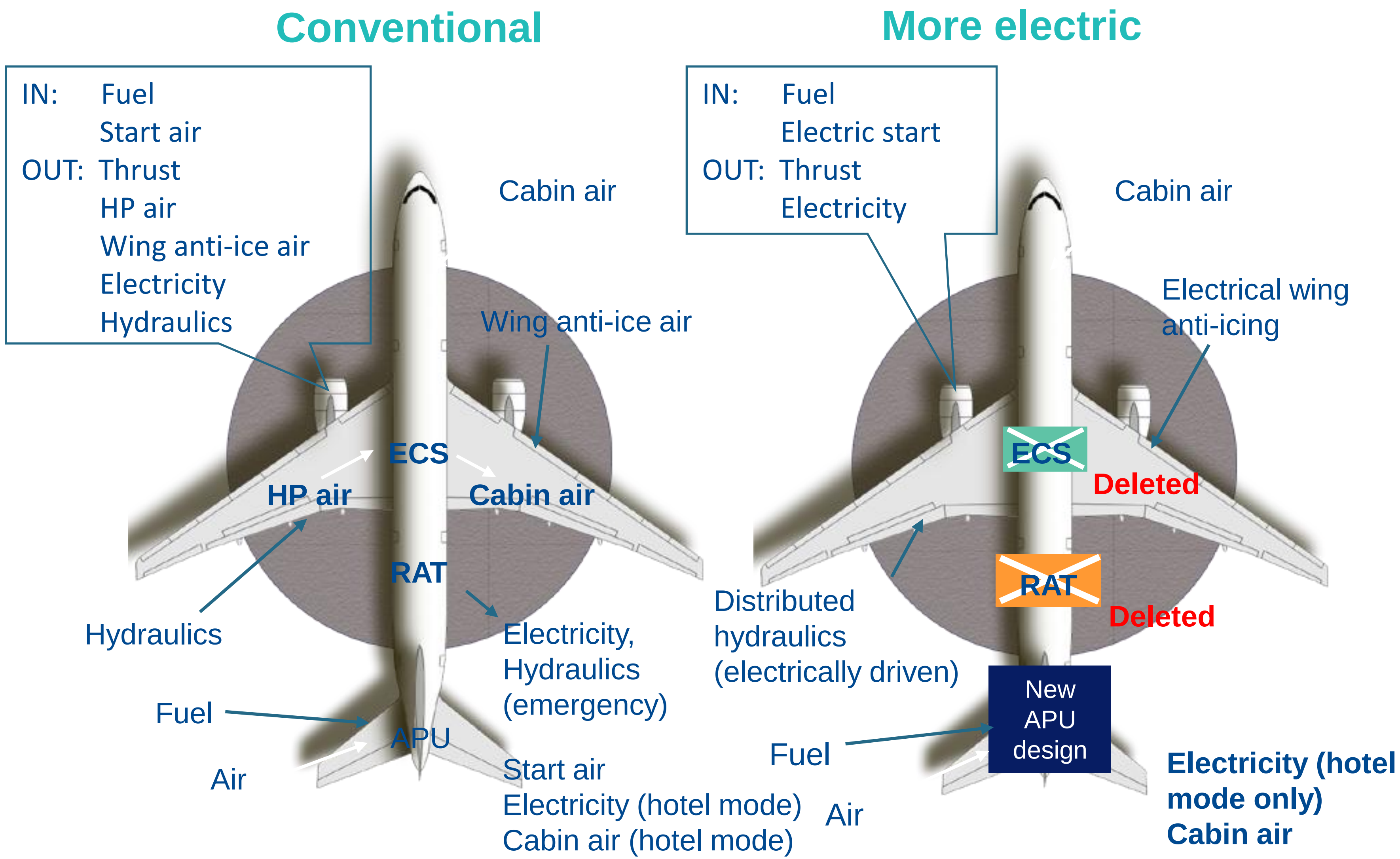
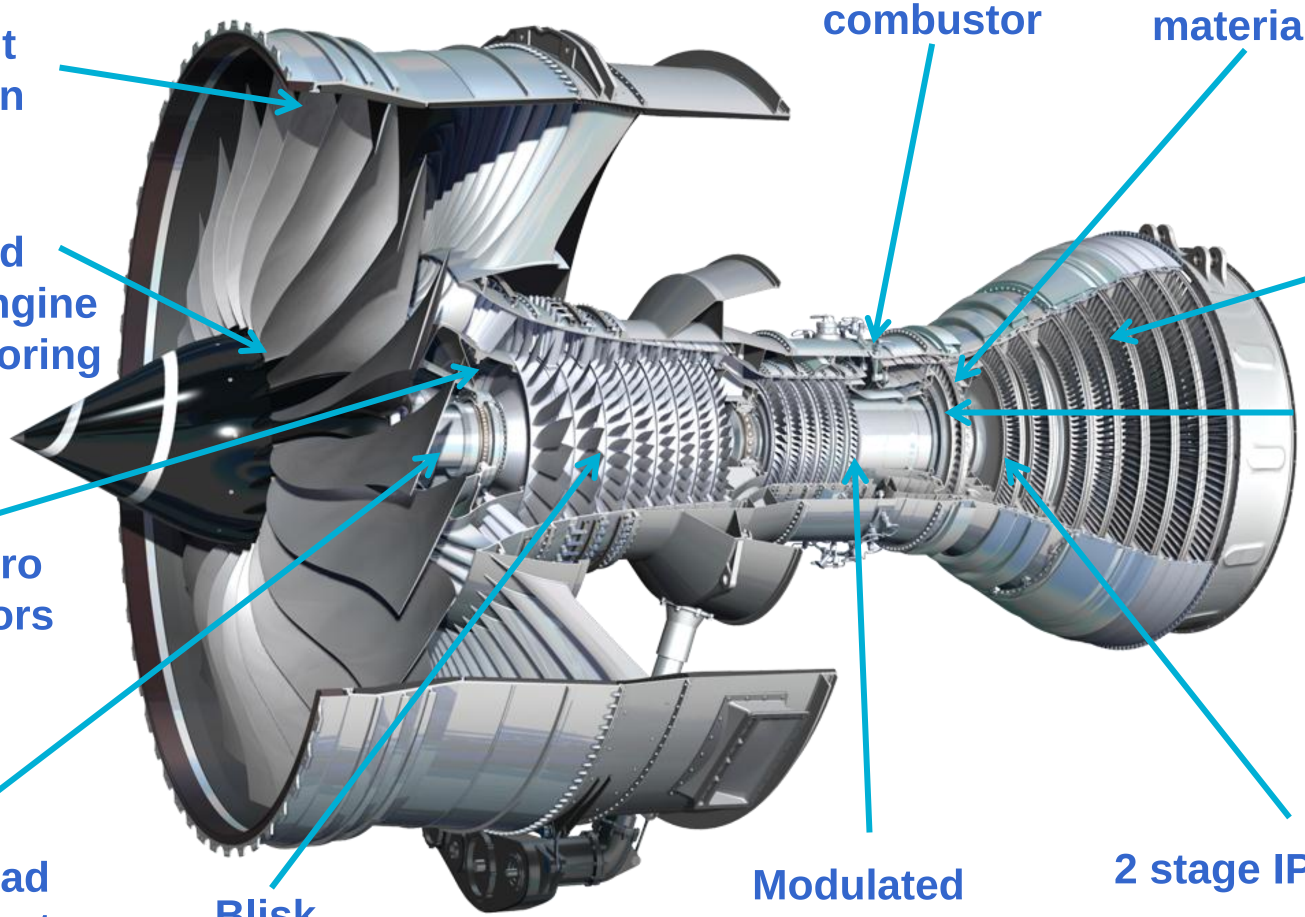
Technology Developments for Gas Turbines

The more electric engine



Trent XWB – adv. technology for A350



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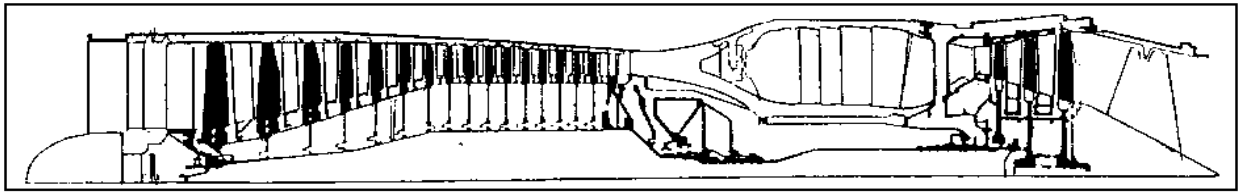
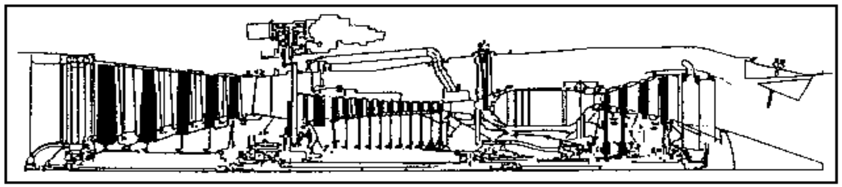
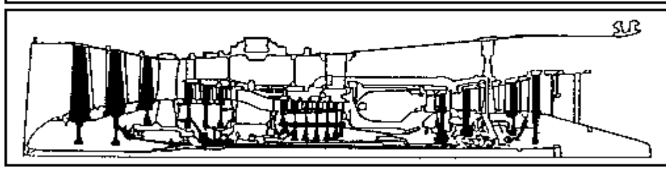
Lighter, more compact, higher efficiency



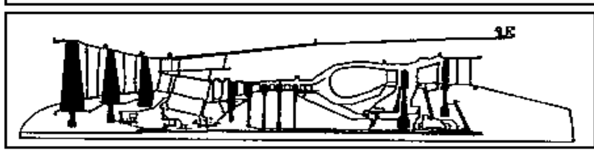
Avon 20
T/W (Thrust to Weight) = 4:1



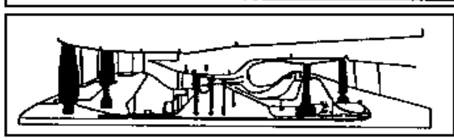
Spey 202
T/W = 5:1



RB199
T/W = 7:1



'Current Technology'
EJ200
T/W = 9:1



'Next Generation '
T/W = 15:1

Engine scaled to the same thrust level

Development of Rolls-Royce engines

- **Higher stage loading (adv. 3D aerodynamics, shaped aerofoils)**
- **Compact, high pressure ratio core**
- **New materials (lighter, higher temperature ability)**
- **Composites, Blisk/Bling technology, vaneless Turbines, variable optimised cycle**

There is still opportunity for new technologies

Alternative Fuels

Suitability

energy density
fuel specification

+

Sustainability

CO_2 benefit
Food / water

+

Industrialisation

mass production
global distribution

Evaluation of several Fischer-Tropsch synthesized fuels is on-going

Bio-Fuels yield a long-term potential

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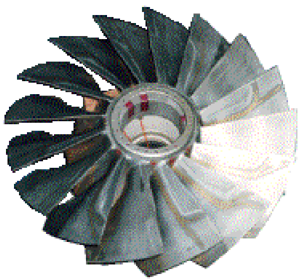
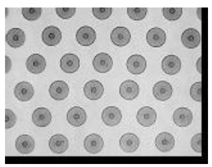
Progress in Gas Turbine Technology

Materials



Improved hollow Blisks



Metal Matrix Composite Blisks

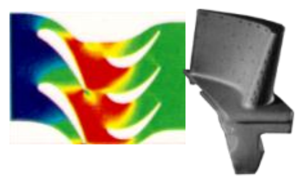
Ceramic Metal Composites (CMC)

High temperature resistant alloys

Air bearings, Magnetic bearings

Architecture and Aerodynamics

Improved 3D aerodynamics



Vaneless counter-rotating Turbines

Variable Cycles

Unit Costs

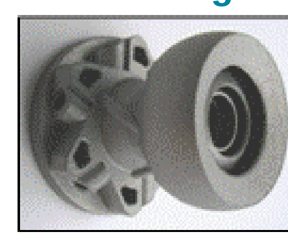
Innovative cost efficient manufacturing

Precision-Casting

Laser drilling

5-axis CNC machining

Laser cladding



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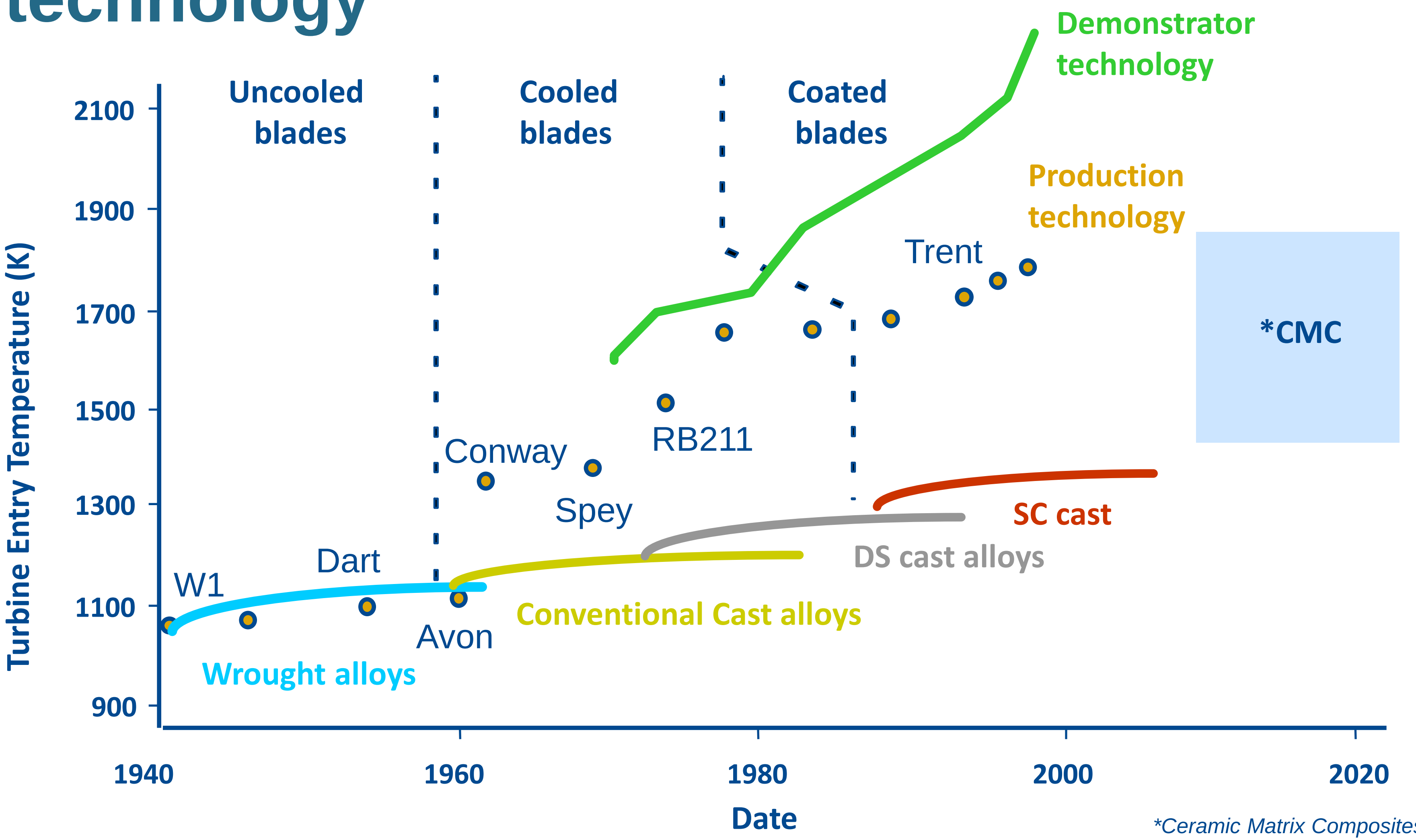
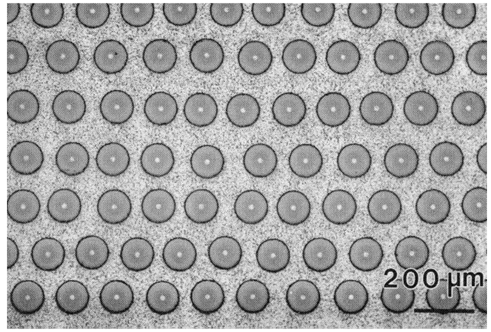
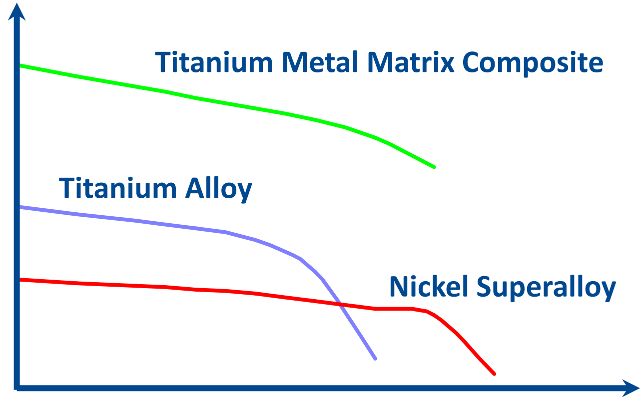
Progress in turbine materials and technology



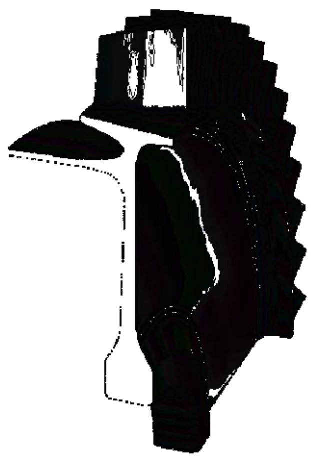
*Ceramic Matrix Composites

Metal Matrix Composites





Conventionally bladed Disk



Blisk – up to 30% weight reduction

Bling – Ti MMC
– more than 30% weight reduction

Weight reduction for Compressor modules

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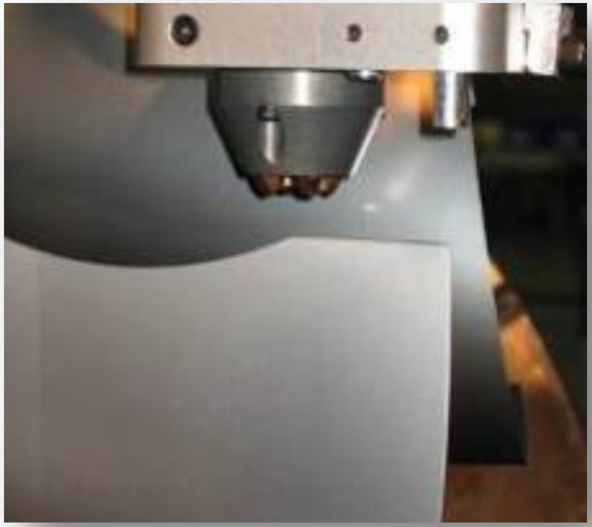
Blisk Repair

- Repair processes are inevitable pre-conditions for economically viable use of BLISK components
- Blending of damaged areas remains the preferred solution, until the repair becomes no longer viable
- Rolls-Royce has developed a Laser-cladding process using Titanium powder to repair damaged areas

Damaged material removed

Laser in Position



New material deposited

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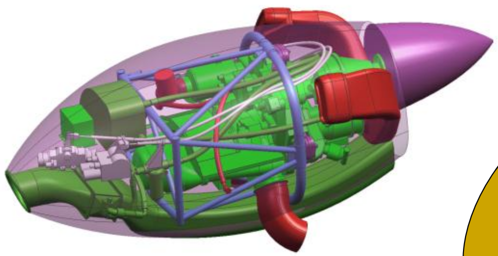
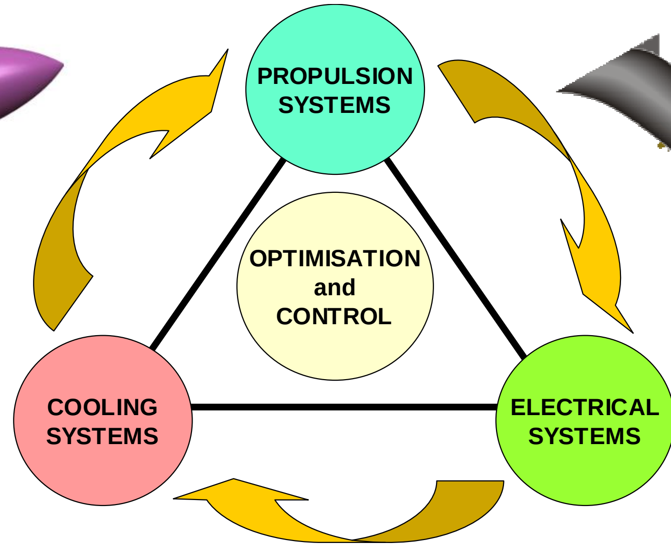
Aero-Mechanically Optimised Blisk (AMOB)

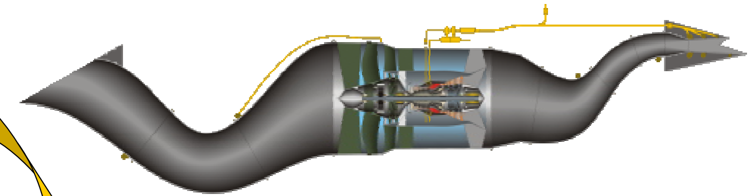
- Replacement of the existing blade core with a visco-elastic dampener.
- V-E material absorbs the energy from stresses, this reduces the amplitude of a given same exitation.
- The high damping capability – >90% in higher vibration modes – allows thinner and hence lighter aerofoils

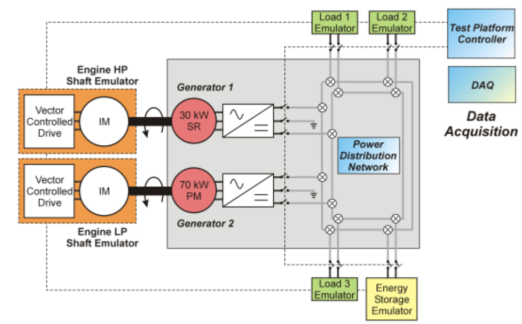
Integrated Power Systems

- Intelligent combination of propulsion, thermal management and electrical power generation





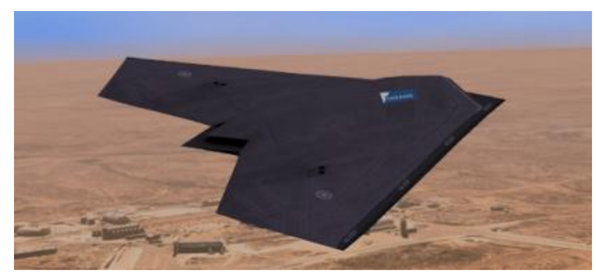




Mantis UAS Demonstrator

- UAS demonstrators already used for trials

Taranis UCAS Demonstrator



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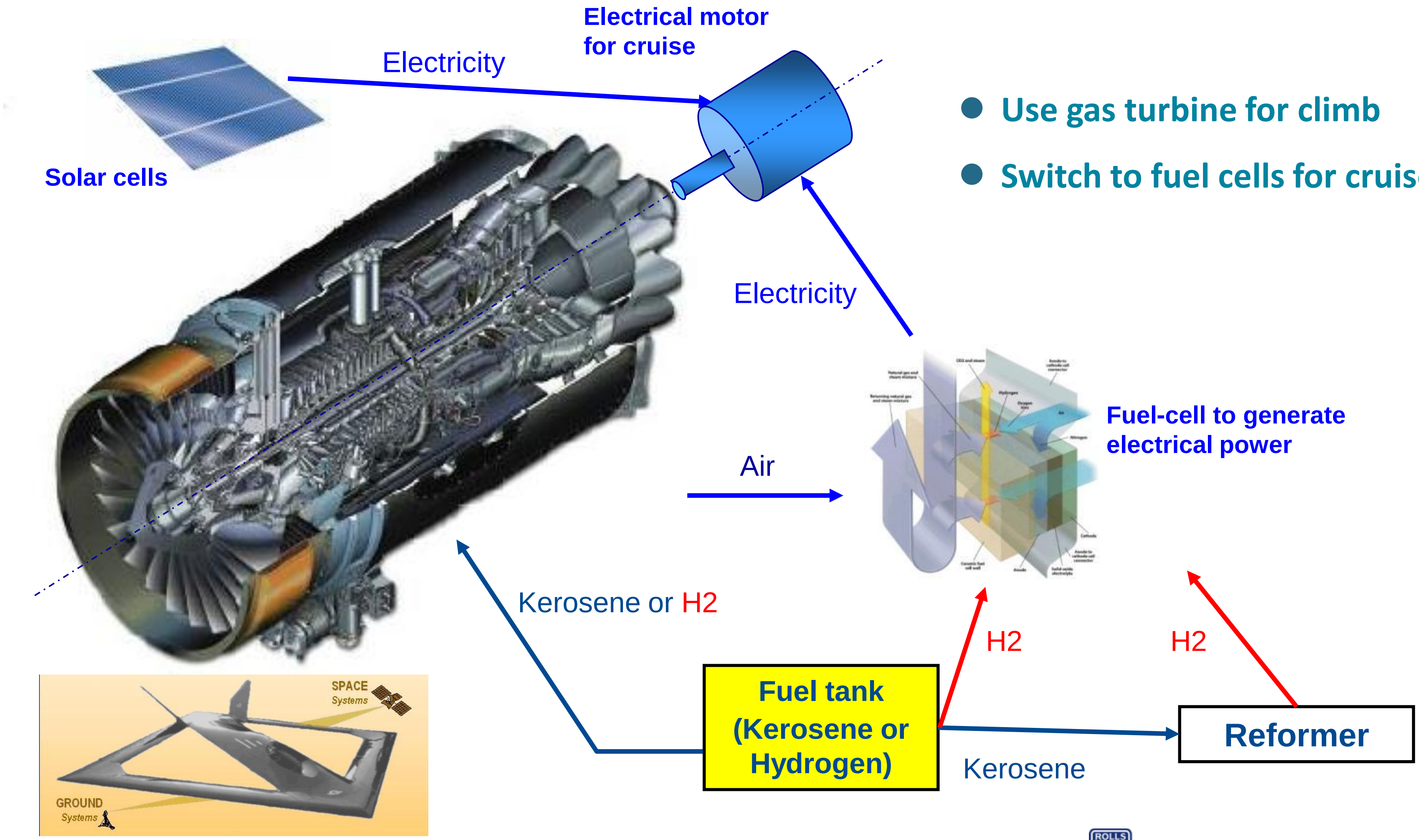
HALE hybrid-electric gas turbine

- **Use gas turbine for climb**
- **Switch to fuel cells for cruise**



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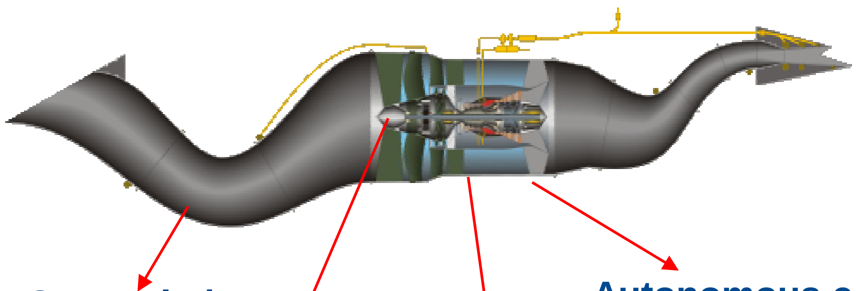
Unnamed Combat Air System (UCAS)

'Intelligent, stealth and more electric'

Obscured vanes

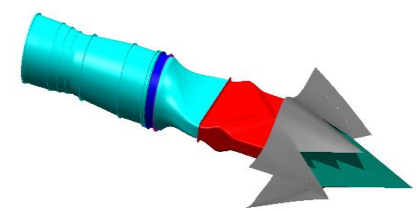


Concealed Installation

vortex-tolerant Compressor

Variable cycle technology

Autonomous control system with Engine Health Monitoring



Key requirements

- Compact gas turbine
- Innovative Integration – shaped ducts, RAM, improved cooling
- Intelligent controls

Future Technologies

- Advanced gel fuels (storage at higher temperatures w/o coking)
- Thermo-electrical power generation (reduced IFR signature and higher electrical offtake)

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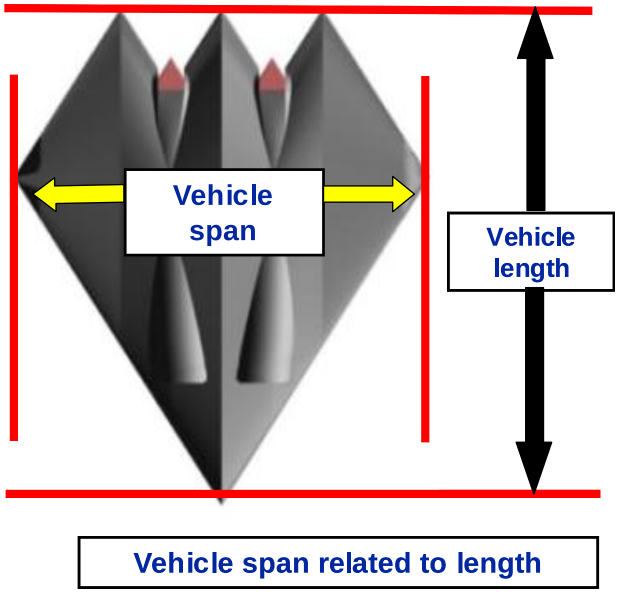
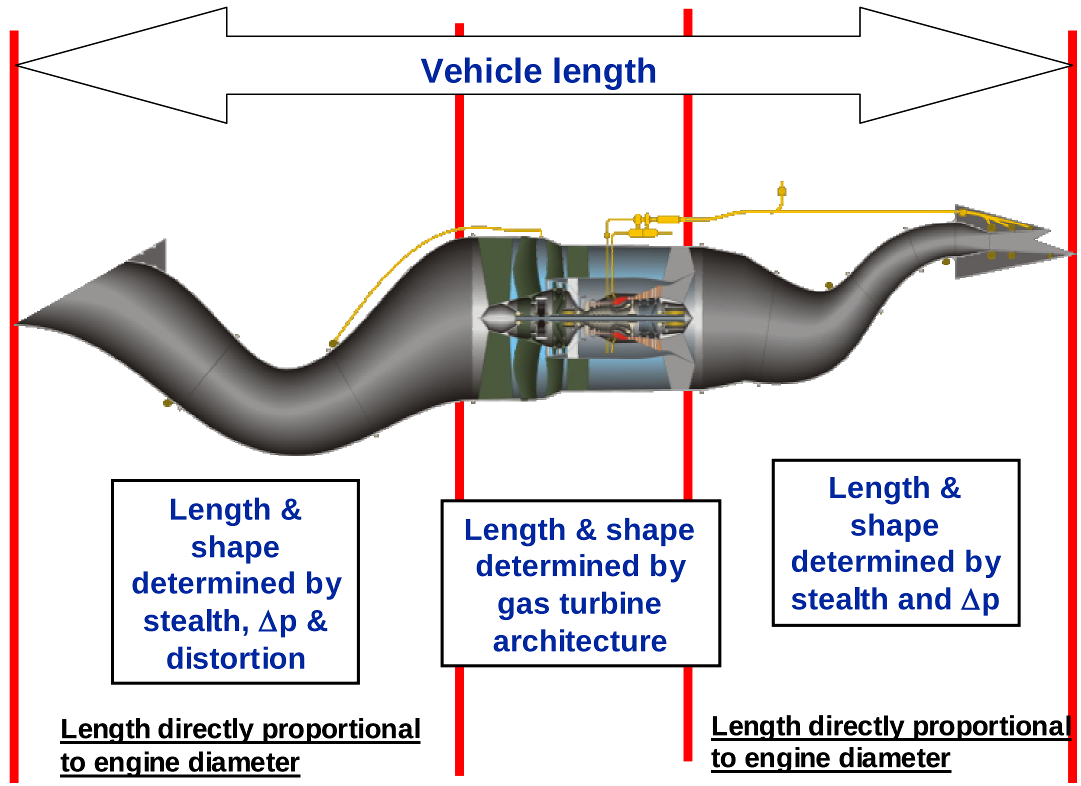
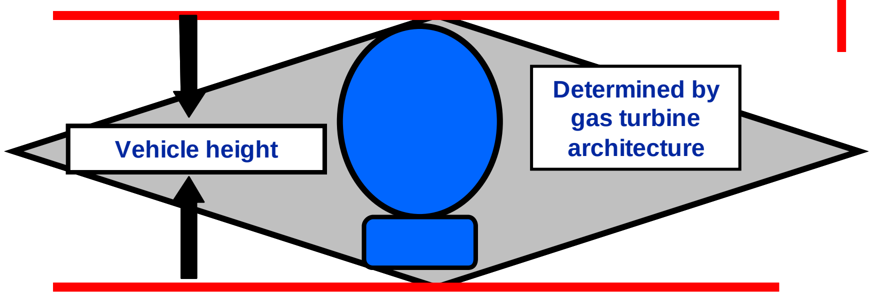
Propulsion influences UCAS shape







All 3 dimensions of the UCAS (length, height und span) are directly influenced by the powerplant

Comprehensive Maintenance Services

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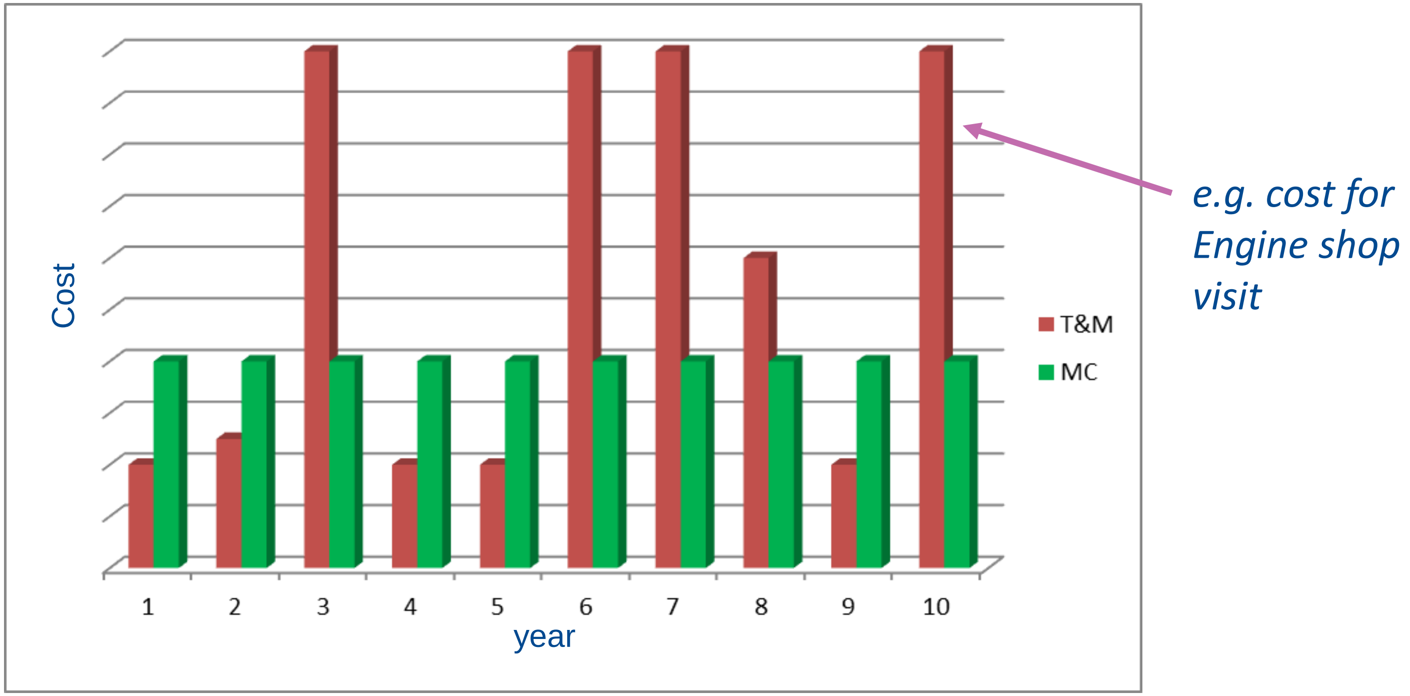
MissionCare™ vs Time & Material

Compared to Time&Material arrangements, MissionCare™ offers customers:

- **budgeting predictability over a long period**
- **greater value**

Exemplary comparision of cost profiles over 10 years – simplified to outline the difference:



Summary

Conclusion

- **Aircraft will continue to rely upon Gas Turbines – unbeatable power density**
- **There is still potential to achieve further Gas Turbine Technology improvements – however, the cost are increasing**
  - **Thrust efficiency (e.g. Ultra high bypass ratio / Geared Fan and Open Rotor)**
- **Next to the Gas Turbine, the entire platform should be optimised**
  - **Integrated Power Systems – intelligent and more autonomous**
  - **Heat exchanger and Thermal management**
  - **Stealth and Cruise at high Mach numbers**
- **Further consolidation of the engine OEM landscape is in-evitable – to bundle and focus resources and activities**

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trusted to deliver excellence