How the More Electric Aircraft is influencing a More Electric Engine and More!

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Colin Smith CBE FRS

• Joined Rolls-Royce in 1974 as an undergraduate apprentice

• Chief Engineer of Small Engines in Bristol

• Chief Engineer for the Trent 500 and Trent 700 Engine projects

• Director of Research and Technology in 2001

• Director of Engineering and Technology in 2005

Unlike Sir Henry Royce, not an Electrical Engineer by background!
A brief history of Rolls-Royce

1884 FH Royce & Co
1899 Royce Ltd
1904 Rolls meets Royce
1906 Rolls-Royce Ltd
1931 'R' Engine wins Schneider Trophy
1940 Merlin helps win Battle of Britain
1940s Rolls-Royce begins Gas Turbine Development
1953 Dart & Avon enter Civil Market
1966 Bristol Aero Engines acquired
1969 1st run of RB211
1970 1st run of Trent
1990 TrentXWB Certification
1995 Allison acquired
1999 Vickers acquired
2000 BMW Aero Engs acquired
2013 TrentXWB Certification
Rolls-Royce products today

Civil Aerospace
Our engines keep up 400,000 people in the air at any one time

Defence Aerospace
160 armed forces around the world depend on our engines

Marine
30,000 commercial and naval vessels use our marine equipment

Power Systems
Develop, produce and service energy markets under the MTU and Bergen engine brands

Nuclear
Design authority for the Royal Navy’s naval nuclear plant
The move to a More Electric Engine

- Over the last 100 years transportation has become increasingly electrified

- Increased sharply over the last decade with the Boeing 787 ‘More Electric Aircraft’

- As we look to the future this trend will only increase…

- … and the Engineering challenges are great!
The Electric Revolution In Marine Propulsion

‘Electric’ Warships of WWII

- Launched in 1918; the USS Mexico was claimed to be the world’s first Electric Warship
- Used 20% less fuel than its two sister ships which had conventional direct drive turbine.
- The design used in the Tennessee class battleships

Rim Driven Tunnel Thruster

- Thrusters of this type are installed on all type of vessels
- They are used for harbour manoeuvring and ship positioning during operations at sea
- Rolls-Royce produce ~500 thrusters per year
The move to a More Electric Engine

Contents

The Present –
Key driving factor
Why the More Electric Aircraft has changed the gas turbine

The Future –
Key Driver
How the all Electric Aircraft will impact the propulsion system
The move to a More Electric Engine
Present - Key driver

Aerospace Industry Challenges

Overall ACARE* Environmental Targets for 2020

Targets are for new aircraft and whole industry relative to 2000

- Reduce perceived external noise by 50%
- Reduce fuel consumption and CO₂ emissions by 50%
- Reduce NOₓ emissions by 80%

The ACARE targets represent a doubling of the historical rate of improvement...

* Advisory Council for Aerospace Research in Europe
How the More Electric Aircraft has changed the Gas Turbine

**Conventional**

**IN:** Fuel  
Start air  
HP air  
Wing anti-ice air  
Electricity  
Hydraulics  

**OUT:** Thrust  
HP air  
Wing anti-ice air  
Electricity  
Hydraulics

**More Electric**

**IN:** Fuel  
Electric start  
Electricity  

**OUT:** Thrust  
Electricity

**Options**

- Increased complexity of system control including Engine  
- cabin air  
- Electrical wing anti-icing  
- New APU design  
- Bleed Deleted  
- Electric start Electricity (hotel mode only)  
- Cabin air

**Rolls-Royce**
How the More Electric Aircraft has changed the Gas Turbine

Progression of Aircraft Electrical Power Requirements

Power Requirements [kW]

- 1980: Conventional B767
- 1990: F4 - 60kW
- 2000: F14
- 2010: A380
- 2020: B787
- 2030: Hybrid / All Electric Aircraft

Rolls-Royce
Power Optimised Aircraft Project

- 43 European aerospace partners

**The objectives were:**
- To test candidate technologies
- To find out what are the critical design issues associated with installing these technologies.
- The engine test was to prove the capability of these technologies it was not a product demonstrator

**SEED**
(Small Electric Engine Demonstrator)

- Single Spool Core Demonstrator Engine on Build Stand
- The first in-house Rolls-Royce engine with embedded electric start
The move to a More Electric Engine
Trent 1000 – Tailored for the More Electric Aircraft

The Trent 1000 has been tailored for the Boeing 787 Dreamliner™
Built on the success of the Trent family, the Trent 1000 offers airline operators a unique combination.

- Trent family experience
- Advanced technology
- Smart design

Rolls-Royce
The move to a More Electric Engine Intermediate Pressure Power Off-Take

Unique to 3-shaft architecture
- Fuel savings on short range
- Best Compressor Operability
- Lower idle thrust
- Lower noise

Challenges surrounding Electrical to Mechanical stiffness
- Sustained Torsional oscillation
- Increased integration of systems
The move to a More Electric Engine
Key technology components

- Novel Starter Generator
- Electrical Accessories
- Electric Actuators
- Advanced Bearings
- Potential to remove the Accessory Gearbox
- Can be Bled or Bleedless engine
The move to a More Electric Engine
The main challenges

Technology
- x1 order of magnitude for Thermal Integration
- X2 order of magnitude for Power Electronics
- X3 order of magnitude for Technology

Risk
- Customer has zero tolerance to programme delay
The move to the More Electric Engine & more! Future Key driver – New ACARE Targets for 2050

Targets are for new aircraft and whole industry relative to 2000

- Reduce perceived external noise by 65%
- Reduce fuel consumption and CO₂ emissions by 75%
- Reduce NOₓ emissions by 90%

Potential targets
- Aircraft movements are emission-free when taxiing.
- Air vehicles are designed and manufactured to be recyclable.
- Europe is established as a centre of excellence on sustainable alternative fuels
The move to the More Electric Engine & more! The S-Curve of Technology Cycles

Aircraft Engines

Innovation:
- Evolutionary
- Disruptive

What’s Next?

Brayton Turbofan

Brayton Turbojet

Otto cycle IC

Lot of cash, little improvement

Capability or Value

Time or Investment $
The move to the More Electric Engine & more! Fully Distributed Propulsion

Distributed Electrical Aerospace Propulsion (DEAP) project

• Technology Strategy Board and Industry funded project (value £1.07M);
• Partners are Airbus Innovation, Rolls-Royce and University of Cranfield;
• Started in early 2013 and runs until 2015;
• Key innovative technologies:
  • Improved fuel economy
  • Reduced exhaust gas and noise emissions
  • Distributed Propulsion (DP) system architecture
  • Boundary Layer Ingestion (BLI)
The move to the More Electric Engine & more!
Fully Distributed Propulsion Concept Layout
The move to the More Electric Engine & more!
Fully Distributed Propulsion Concept Layout
The move to the More Electric Engine & more!
The main challenges

Superconducting electric machines

Very high power dense advanced Power Electronics

Cryogenic cooling
The move to the More Electric Engine & more! Challenges - Advanced Power Electronics

- **N-Technology Stream** *(Now Generation)*
  - Silicon based technology developed from automotive experience;

- **N+1 Technology Stream** *(Next Generation)*
  - New generation Integrated Silicon Carbide or Gallium Nitride Devices
  - Ultra Efficient (>99%)

- **N+2 Technology Stream** *(Generation after next)*
  - A suite of technology streams will be developed by our network of University Technology Centres ready for later technology insertion
The move to the More Electric Engine & more! Challenges - Cryogenic Cooling

Cryogenic Cooling for Distributed Propulsion

Projected Development of Aerospace Cryocoolers

Aerospace Cryocooler Specific Mass (kg/kW Input Power)

- Actual
- Estimated

NASA/DEAP project 2035 Target – 3 kg/kW

In Summary

• Rolls-Royce is well positioned to understand how a shift to a More Electric Aircraft will impact its product offering

• However, the full electrically powered MEA is some way off and

• To get there many technical challenges such as increased control and integration of systems will be required

• Electrical technology is increasingly important across all our business sectors

• Already exploiting the benefits in Marine where weight and space are less important

• Need to learn from other industries eg Automotive

• RR looking forward to the next 100 years

Thank you for your time & attention
Questions

“Invent once, re-use many times.”