Challenges of Advanced Propulsion Systems Development for Future Civil Air Transport

Large civil aircraft engines for the future
Evolution and revolution

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Trusted to deliver excellence
Rolls-Royce product sectors

**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**
Reciprocating engines for propulsion and distributed energy systems

**Nuclear**
Design authority for the Royal Navy's naval nuclear plant
Modern Day Example – Trent XWB

- Rolls-Royce’s latest engine
  - Certified: February 7, 2013
  - First flight: June 14, 2013
  - Delivery to first customer Q4 2014

World’s Quietest and Most Efficient Engine
Meeting the Challenges with Modern Technology

Inlet mass flow 1200kg/s

HP compressor inlet pressure 11 bar
Temperature 350°C

HP compressor outlet pressure 50 bar
Temperature 700°C

Turbine entry temperature 1700°C

IP turbine outlet temperature 900°C

Thrust 40 tons

Combustion chamber 7lb/sec of fuel
Product evolution

Trent XWB

World’s most efficient engine

Advance

<table>
<thead>
<tr>
<th>Technology EIS Readiness</th>
<th>2020+</th>
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<tbody>
<tr>
<td>Bypass Ratio</td>
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Rolls-Royce
Product evolution

Trent XWB

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Key Technologies

- Lightweight CTi Fan System & Externals
- Additive Layer Manufacturing
- Controls, EHM & Systems Integration
- Advanced Manufacturing Research Centres
- Advance Core Architecture
- Lean Burn Combustor
- Virtual Engine (High Performance Computing)
- Aerothermal Excellence
- VHBR Enablers

Key Benefits
- Fuel Burn
- Environment
- Maintenance
- Lifecycle Cost
Product evolution

Trent XWB

World’s most efficient engine

- Integrated Propulsion System
- Lightweight LPT System
- Hollow Ti Fan System
- 3 Stage Turbine Core

Advance

- Integrated Propulsion System
- Lightweight LPT System
- CTi Fan System
- Advance Core

UltraFan™

- Integrated Slim Line Nacelle (No Thrust Reverser)
- Geared Multi Stage IPT System
- Variable Pitch CTi Fan System
- Advance Core
Product evolution

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World’s most efficient engine
Recent Advanced Propulsion System Studies

NASA N+2 Environmentally Responsible Aviation (ERA) Project

Northrop Grumman
Boeing
Lockheed Martin

The S-Curve of Technology Cycles

Aircraft Engines

Innovation:
- Evolutionary
- Disruptive

What's Next?
Lot of cash, little improvement
Multiple Rapid Incremental Component & System Improvements

Capability or Value

Time or Investment $

Brayton Turbofan
Brayton Turbojet
Otto cycle IC

Major Tech Obstacles Overcome

NASA “N3-X” Distributed Turbo-Electric Propulsion System

Rolls-Royce
Future Concepts – Greener Aircraft

NASA N+2 Environmentally Responsible Aviation (ERA) Project
Advanced Vehicle Concept Studies

All are still very much at the concept stage working on Vision 20 EIS

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<th>NASA N+2 Goal</th>
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<tr>
<td>-50% Fuel Burn</td>
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<tr>
<td>-42 dB</td>
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<td>-75% NOx</td>
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Lockheed Martin
Northrop Grumman
Boeing

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More-Electrical Aircraft Architecture

Generate, Distribute, and Consume energy in an effective and efficient manner

- Hybrid AC and DC Primary Distribution Systems
- Remote Power Distribution System
- Power Conversion
- Variable Frequency Generation
- Liquid cooling of Conversion and Motor Controllers
- Aft E/E Bay
- Forward E/E Bay
- APU Starter / Generator System
- Current Return Network
- Electric Engine Start
- Adjustable Speed Motors and Motor Controllers
- Electric Wing Ice Protection
- Conventional Ground Power Sources
- Elimination of Pneumatic Bleed System
Distributed Electrical Aerospace Propulsion (DEAP)

- UK Technology Strategy Board and Industry funded project

- Partners: Airbus Innovation Works, Rolls-Royce and University of Cranfield;

- Key innovative technologies for
  - improved fuel economy
  - reduced exhaust emission
  - reduced noise emissions

- Distributed Electrical Propulsion (DP)
- Boundary Layer Ingestion (BLI);
Future IPS Concepts – Fully Distributed

“E-Thrust” - Electrical Distributed Propulsion System

- Single Advanced Gas Turbine
- Electrically-Powered Fans
- Energy Storage

Benefits*

- Emissions:
  - CO2: -75%
  - NOx: -90%
- Noise: -65%

*Compared to year 2000 standards
Better Power for a Changing World