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

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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

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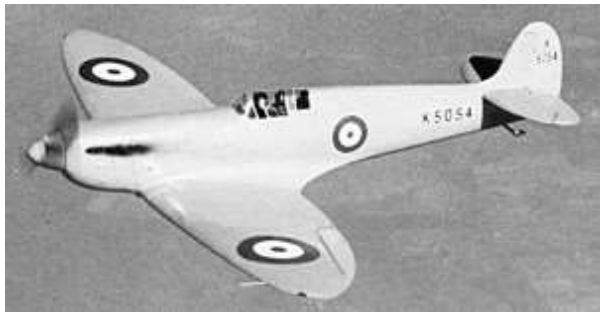
Notable Propulsion-Enabled “Firsts”



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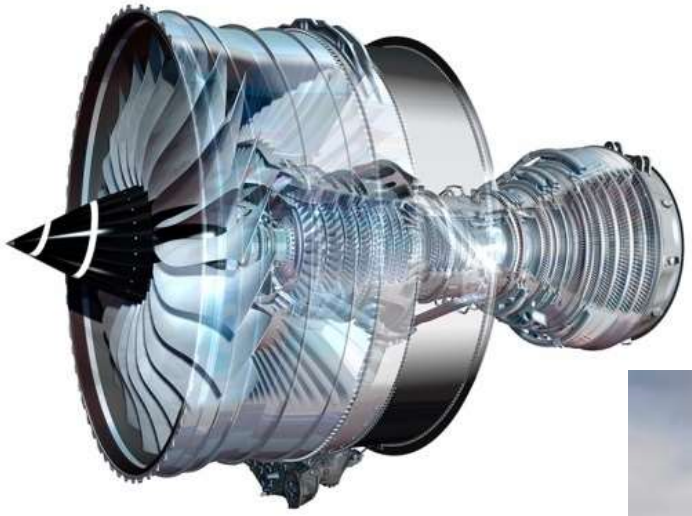
Modern Day Example – Trent XWB



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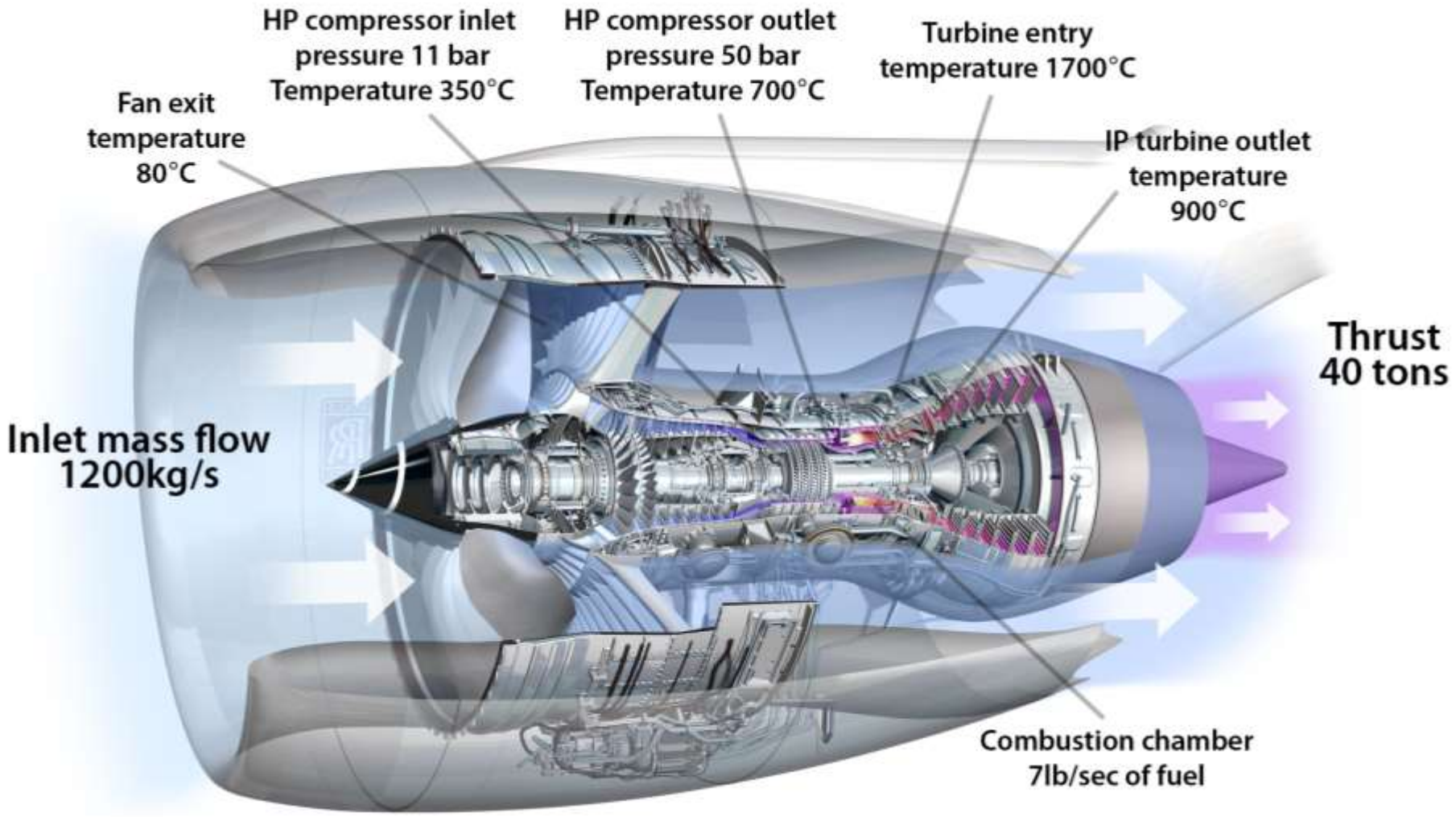
- **Rolls-Royce's latest engine**
  - **Certified: February 7, 2013**
  - **First flight: June 14, 2013**
  - **Delivery to first customer Q4 2014**

Airbus A350

World's Quietest and Most Efficient Engine

Rolls-Royce

Meeting the Challenges with Modern Technology



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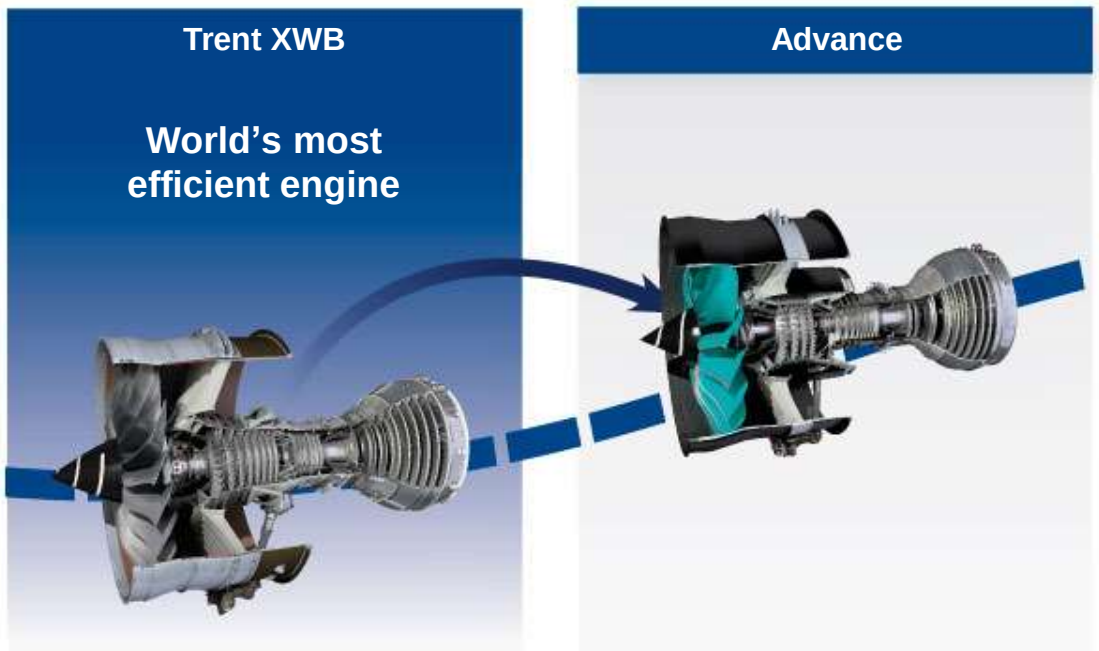
Product evolution



Technology EIS Readiness	2020+
Bypass Ratio	11+
Overall Pressure Ratio	60+
Efficiency relative to Trent 700	20%+

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Product evolution

Technology EIS Readiness	2020+	2025+
Bypass Ratio	11+	15+
Overall Pressure Ratio	60+	70+
Efficiency relative to Trent 700	20%+	25%+

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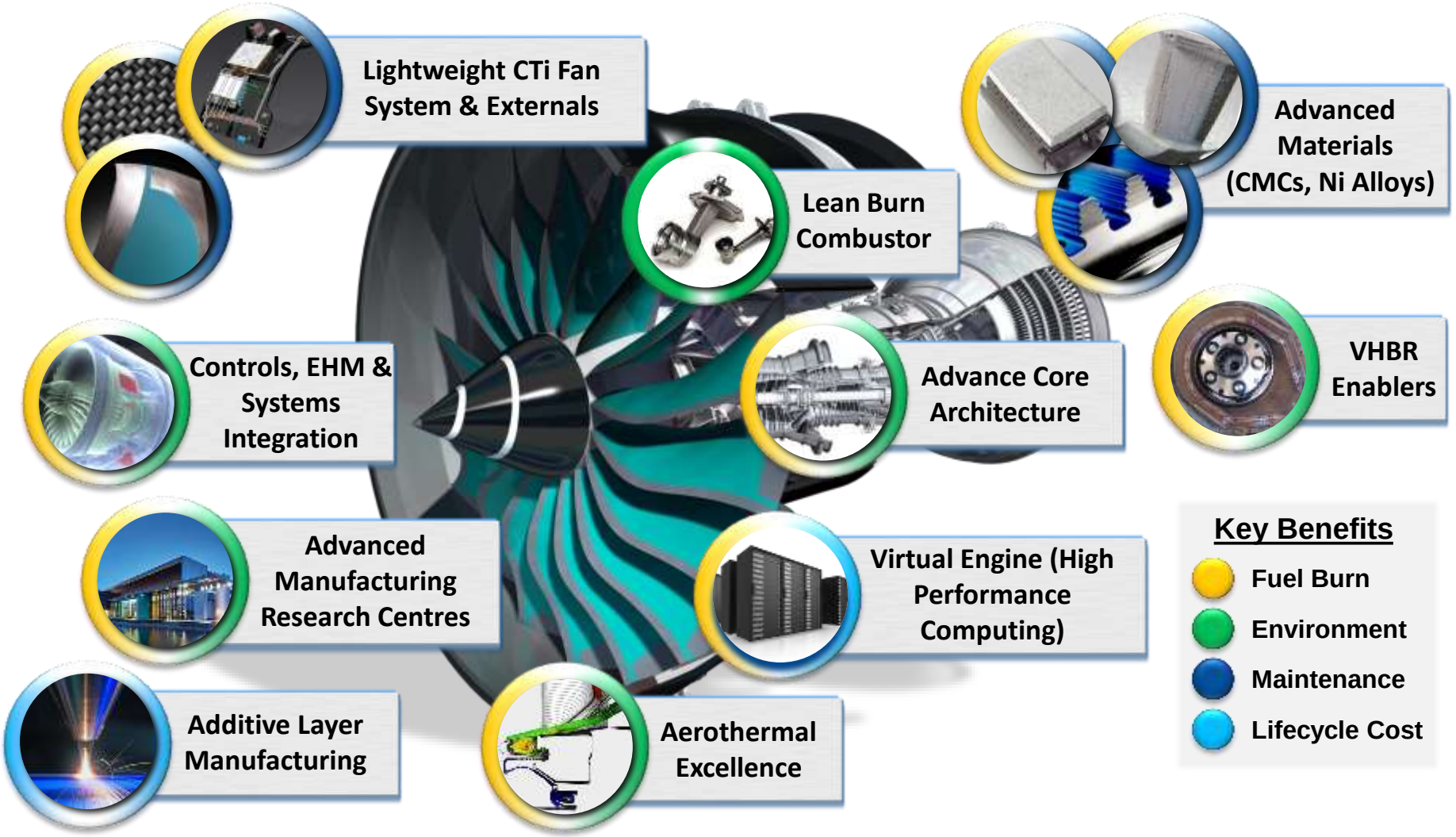
Key Technologies



Rolls-Royce proprietary information

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Product evolution

Trent XWB	Advance	UltraFan™
Integrated Propulsion System	Integrated Propulsion System	Integrated Slim Line Nacelle (No Thrust Reverser)
Lightweight LPT System	Lightweight LPT System	Geared Multi Stage IPT System
Hollow Ti Fan System	CTi Fan System	Variable Pitch CTi Fan System
3 Stage Turbine Core	Advance Core	Advance Core

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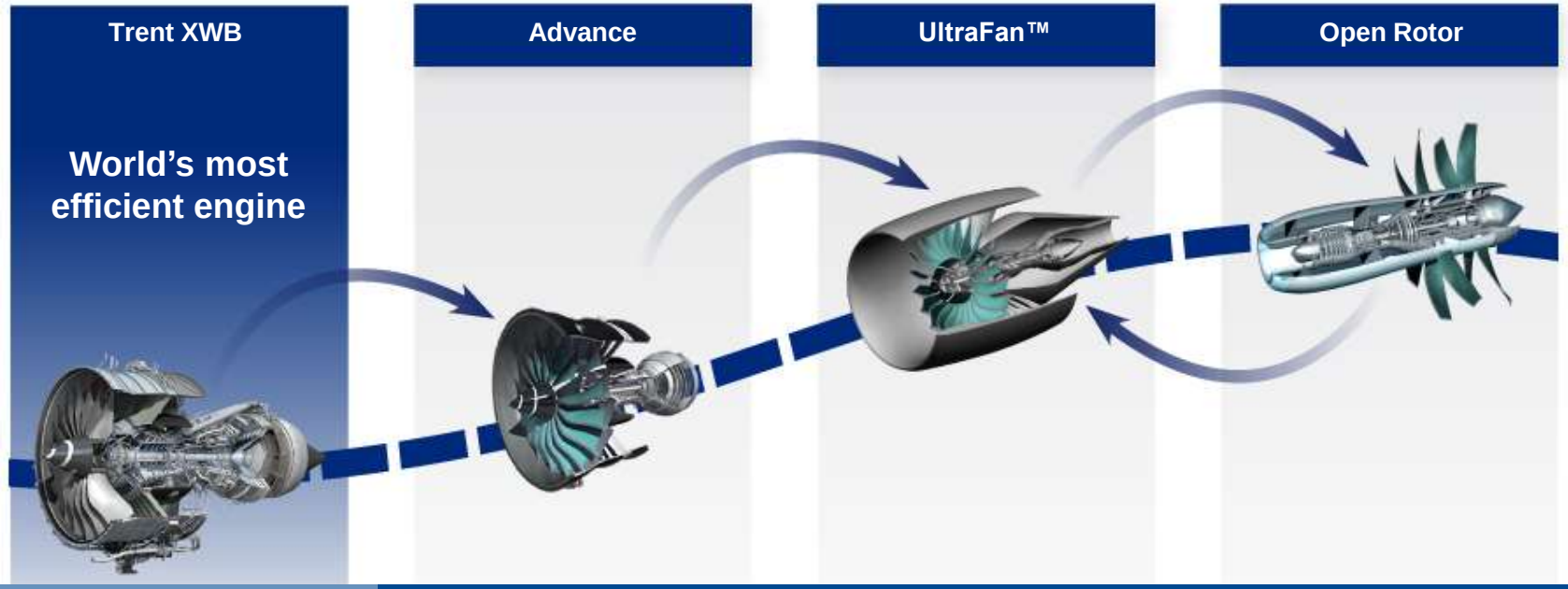
Product evolution



Technology EIS Readiness	2020+	2025+	Airframe Dependant
Bypass Ratio	11:1+	15:1+	50:1+
Overall Pressure Ratio	60:1+	70:1+	70:1+
Eff relative to Trent 700	20%+	25%+	30%+

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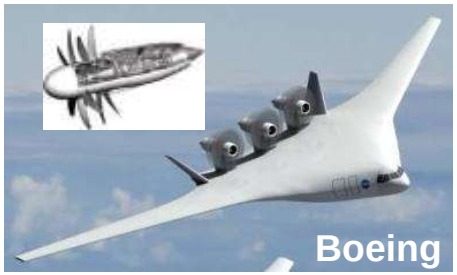
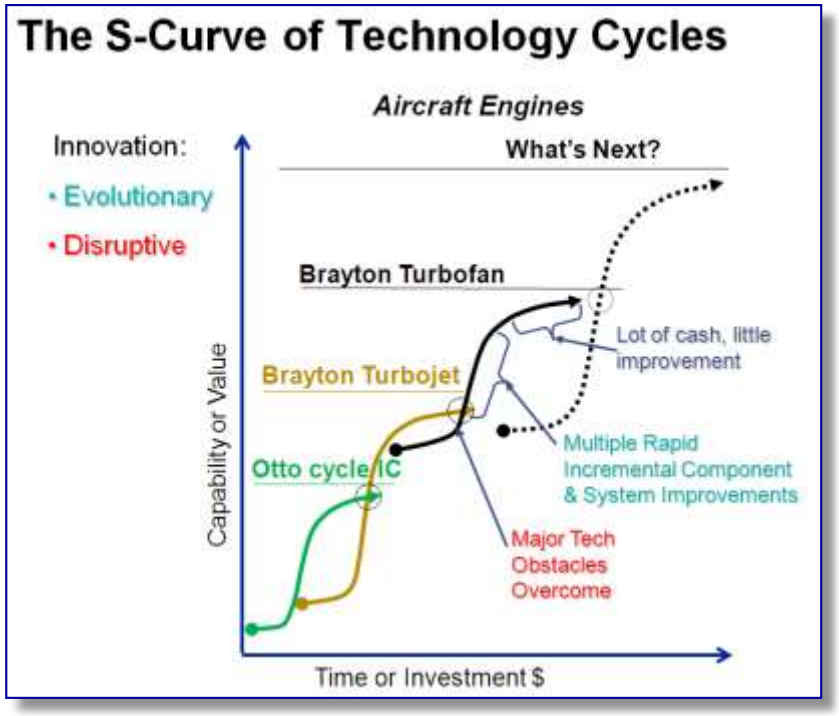
Recent Advanced Propulsion System Studies

NASA N+2 Environmentally Responsible Aviation (ERA) Project





NASA "N3-X" Distributed Turbo-Electric Propulsion System

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Future Concepts – Greener Aircraft

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

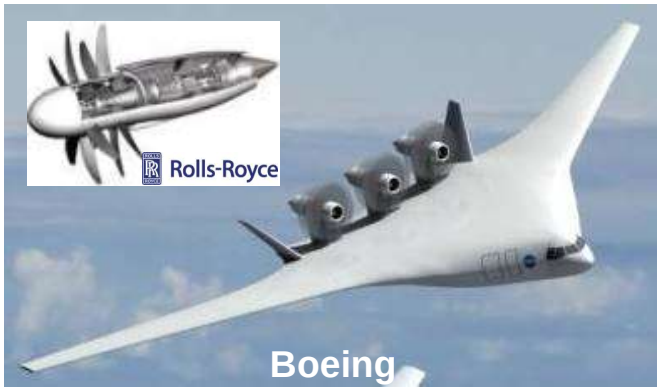
Fuelburn ■ Noise ■ Emissions ■

Fuelburn ■ Noise ■ Emissions ■

NASA N+2 Goal
-50% Fuel Burn
-42 dB
-75% NO_X

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

Fuelburn ■
Noise ■
Emissions ■



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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

Power Conversion

Variable Frequency Generation

Remote Power Distribution System

Liquid cooling of Conversion and Motor Controllers

Forward E/E Bay

APU Starter / Generator System

Aft E/E Bay

Conventional Ground Power Sources

Electric Engine Start

Current Return Network

Adjustable Speed Motors and Motor Controllers

Electric Wing Ice Protection

Elimination of Pneumatic Bleed System

BOEING

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);

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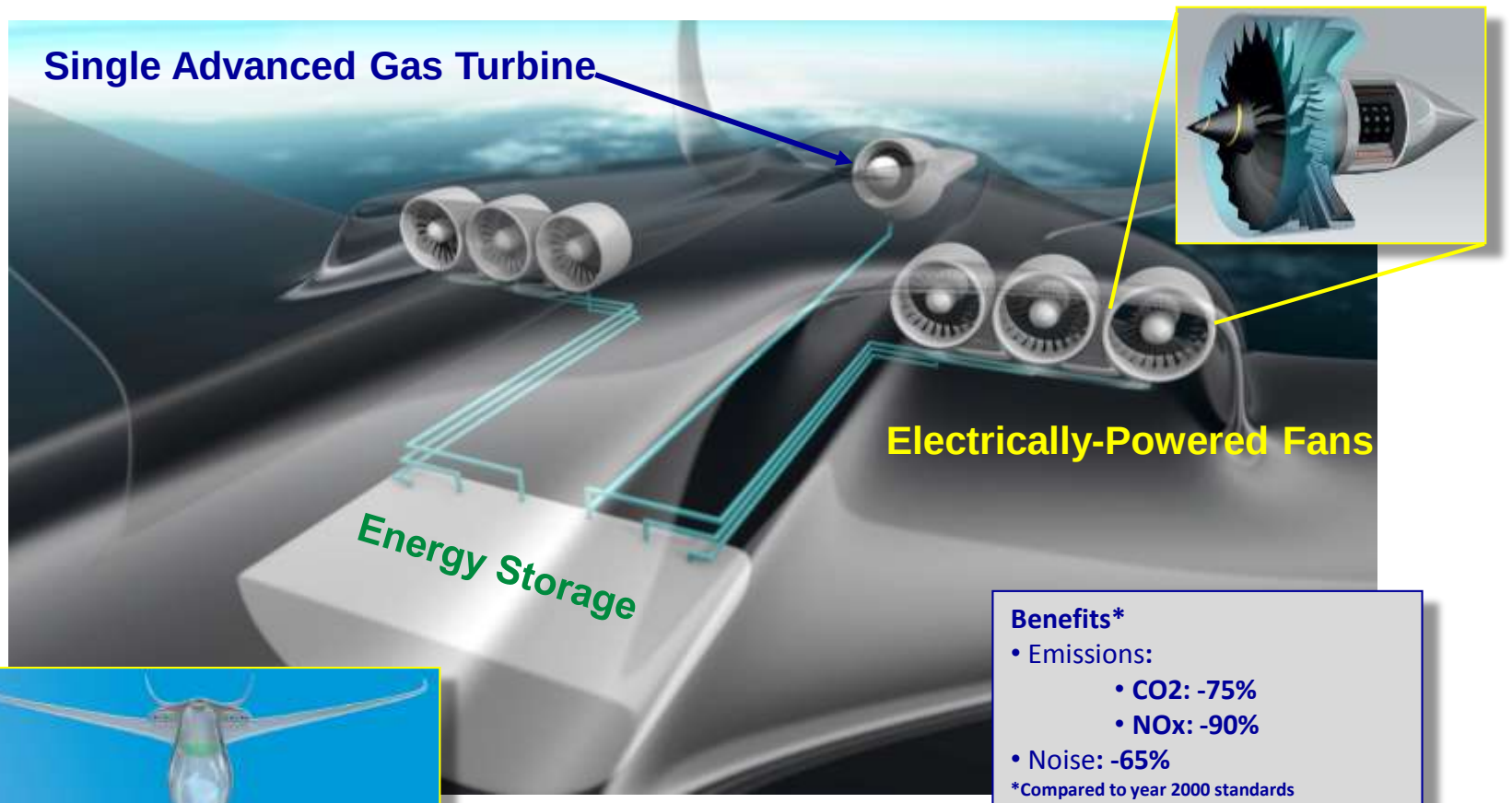
Future IPS Concepts – Fully Distributed

"E-Thrust" - Electrical Distributed Propulsion System



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

***Compared to year 2000 standards**

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Better Power for a Changing World