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**Environmentally friendly aero-engines for
the 21st century**

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Rolls-Royce Deutschland**

CEAS Berlin, 12th September 2007

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 - LuFo E3E (Engine 3E: **E**nvironment, **E**fficiency, **E**conomy)
 - EU VITAL (En**V**ironmen**T**ally Friendly Aero Engines)
 - UK EFE (**E**nvironmentally **F**riendly **E**ngine)
- Future programmes
- Conclusions

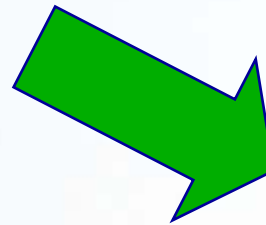
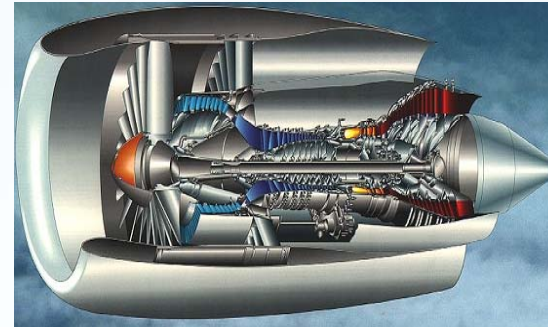


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Engine ACARE* environmental targets for 2020

ACARE 2020 OBJECTIVES (reference : 2000 aircraft)

- Reduce perceived noise by half (10 EPNdB)
- Reduce NOx by 80%
- Reduce CO2 by 50%
- Acceptable cost



ACARE 2020 OBJECTIVES Engine Contribution

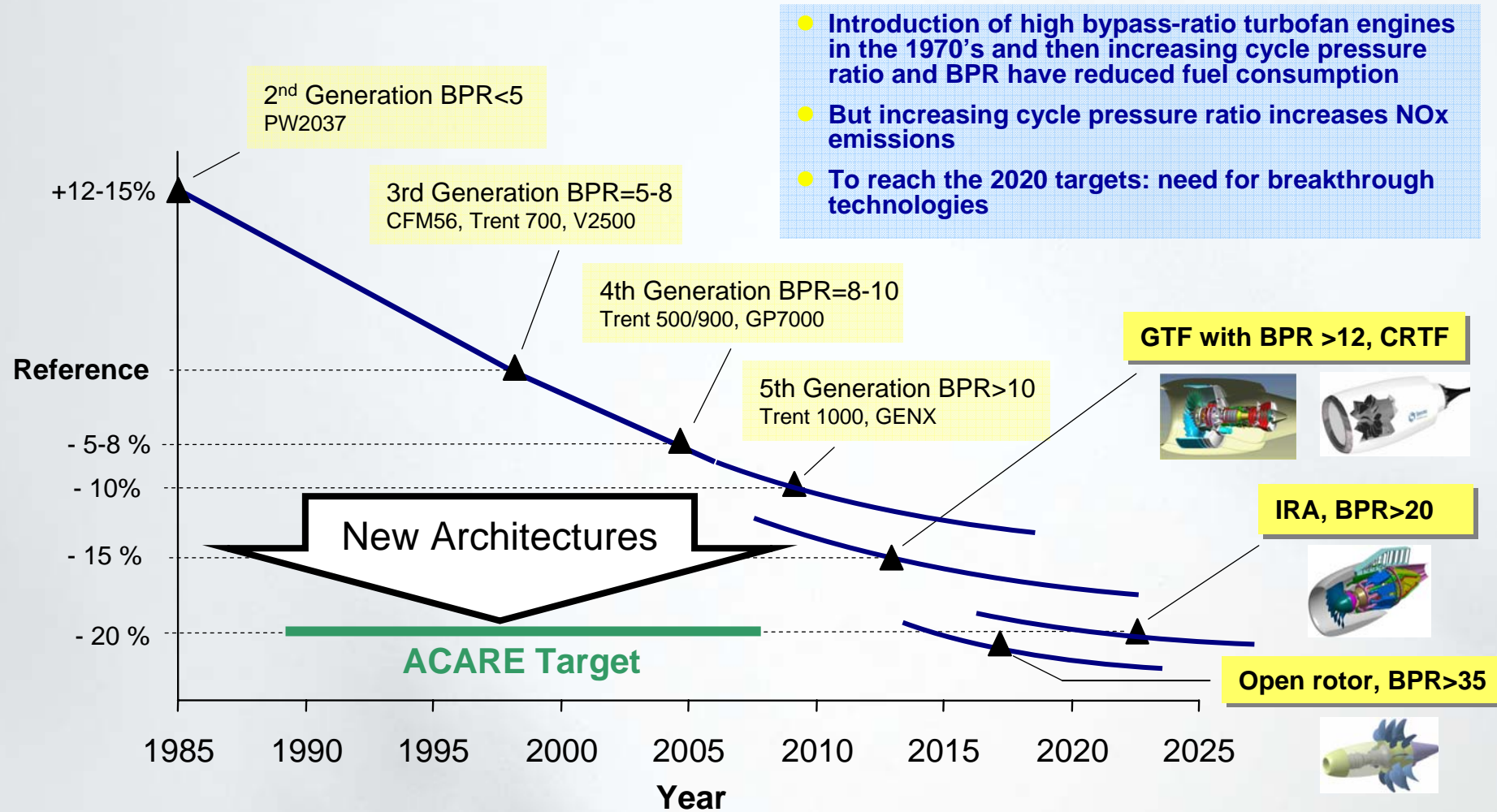
- Reduce noise by 6 EPNdB at each certification point
- Reduce NOx by 80%
- Reduce CO2 by 20%
- Acceptable cost

* Advisory Council for Aerospace Research in Europe

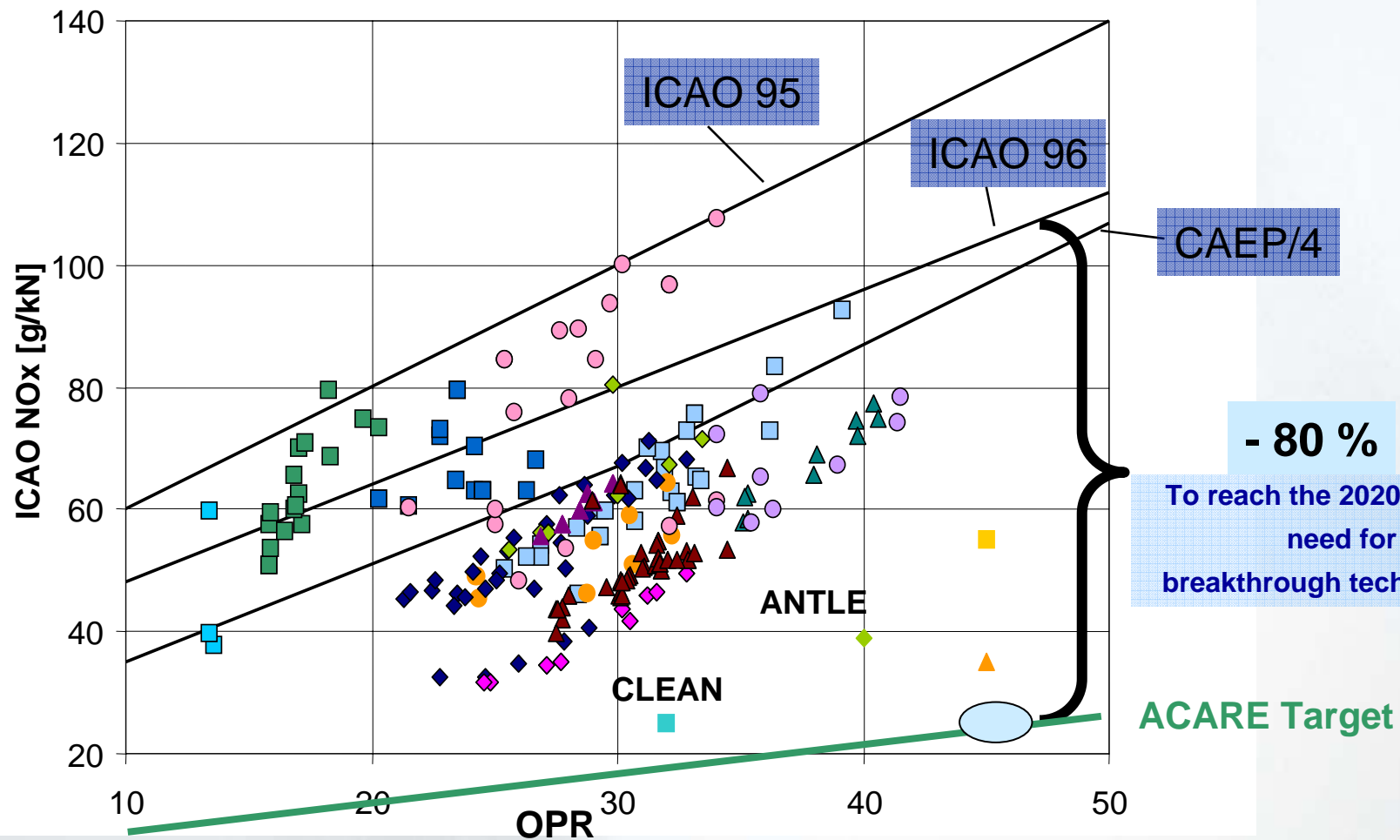


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Impact of Bypass-Ratio on Fuel Consumption / CO2

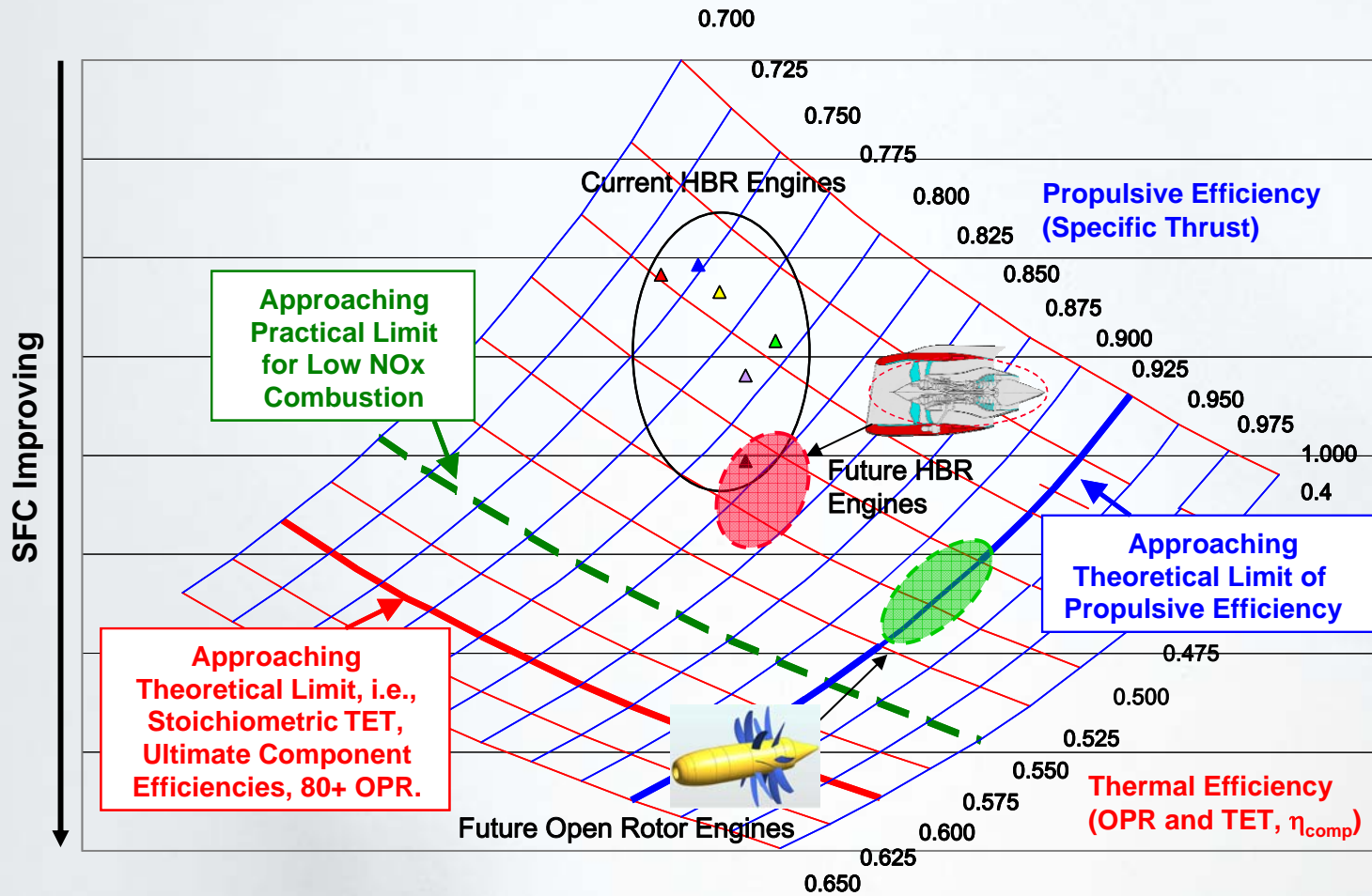


Impact of Overall Pressure Ratio (OPR) on NOx



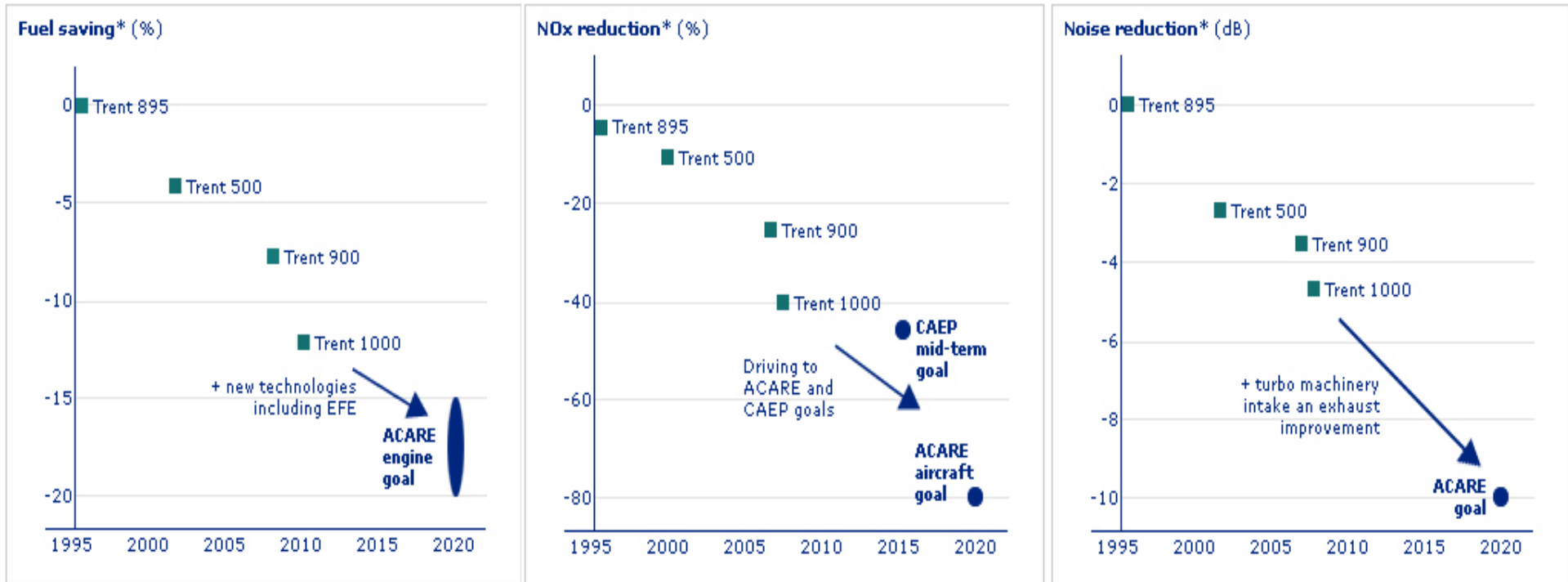
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Cycles to meet ACARE targets



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Progress towards reaching the ACARE goals



*SFC: fuel consumption normalised for engine power

*Normalised to CAEP standards for engine power

*Corrected for aircraft weight

The ACARE NO_x target is interpreted with reference to total NOX emissions produced over the flight. Improvements in engine emissions technology are expected to deliver three quarters of the 80% target, with the balance coming from reductions in overall fuel burn as a result of improved efficiencies in engine, airframe and operations.

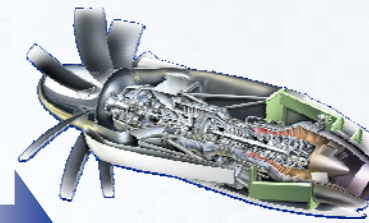


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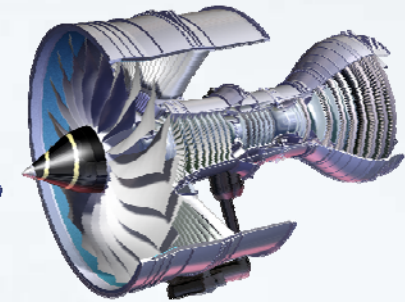
Rolls-Royce technology 'Vision'

● Vision5 – Near term

- Latest 'on-the-shelf' technologies applied to existing architectures
- Near term upgrade and improvement programmes



TP 400



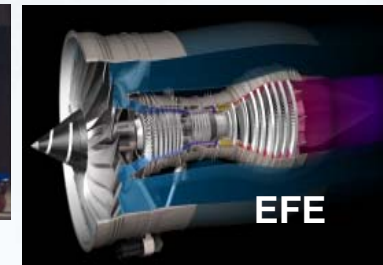
Trent 1000

● Vision10 – Next generation

- Leading edge, technology validation.
- Technologies currently at demonstration stage



Engine 3 E
Demonstrator



EFE

● Vision20 – Future generation

- Includes technologies that are currently emerging or as yet unproven
- Advanced environmental and efficiency targets for aircraft, engines and systems.

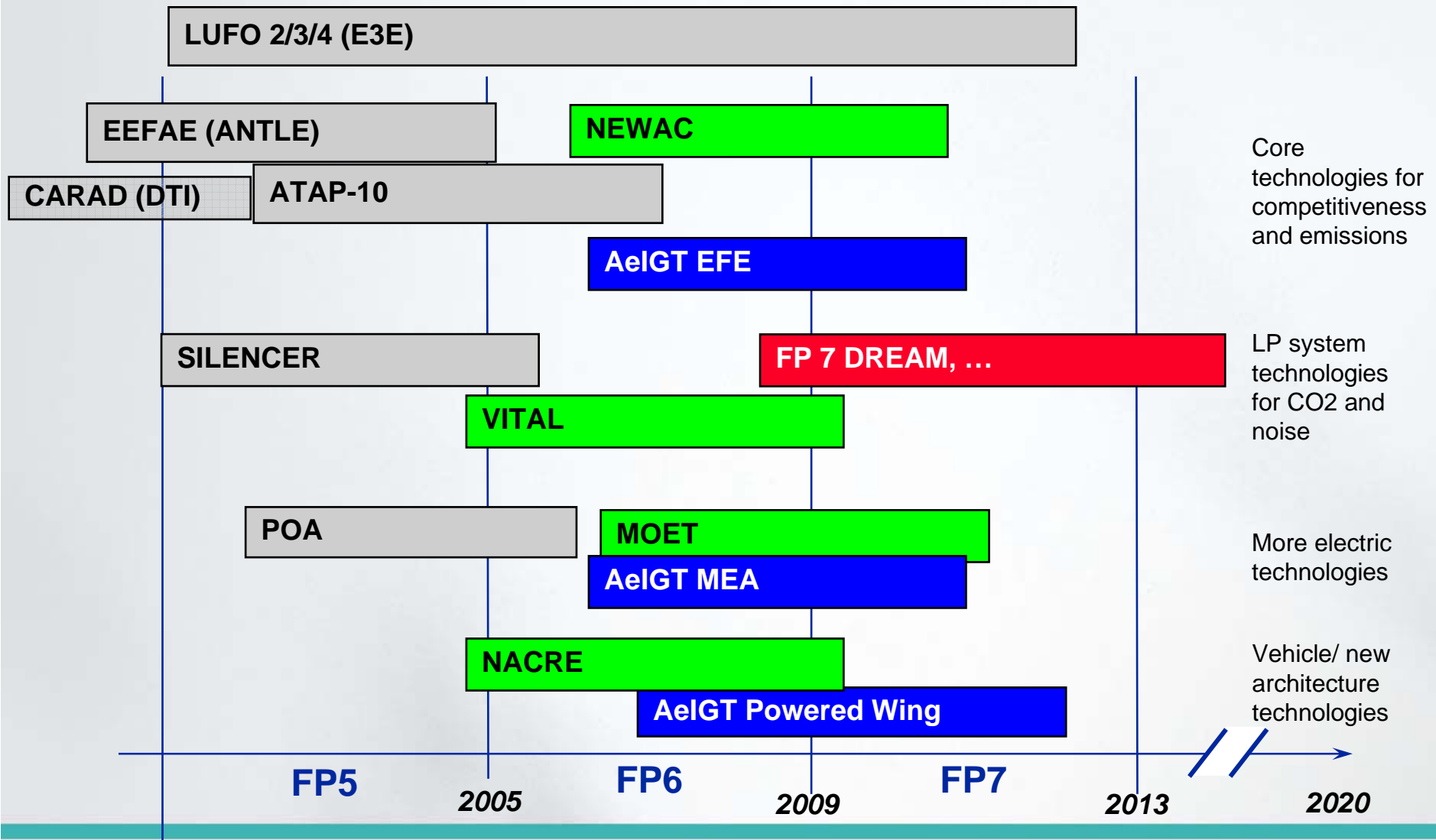
The ACARE Goals*

- Half current perceived average noise levels
- Reduce CO₂ by 50% per passenger km
- 80% cut in NOx



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Environmental technology programmes



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EEFAE - ANTLE – Vision10 technology

- **EEFAE Programme**

- 2 vehicles (ANTLE & CLEAN)
- 19 partners
- €101M EU FP5 Programme

- **ANTLE**

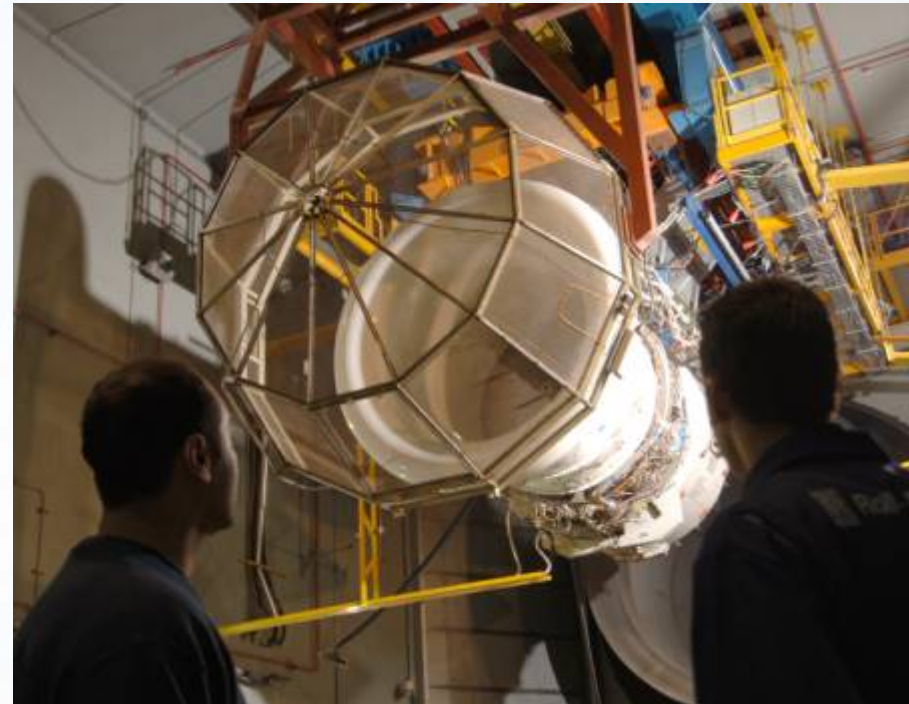
- “**A**ffordable **N**ear **T**erm **L**ow **E**missions”
- Target 12% reduction in CO2 emissions and 60% reduction in NOx by 2008
- Engine assembly complete January 2005
- First start of engine 9th March 2005
- Test programme completed May 2005
- Supported by EU, DTI & Spanish Govt.



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Test campaign highlights

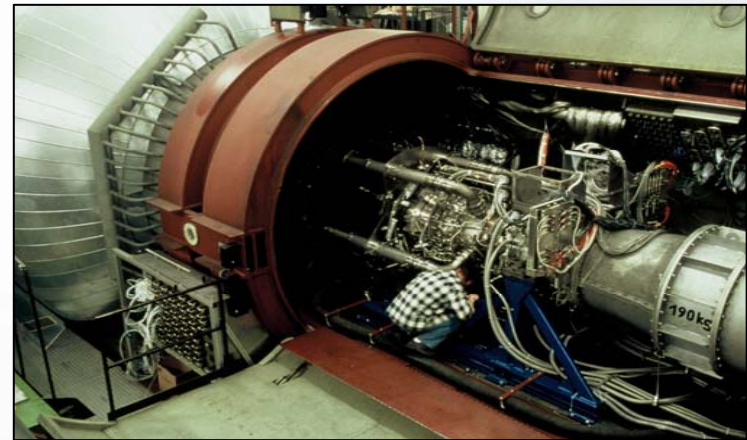
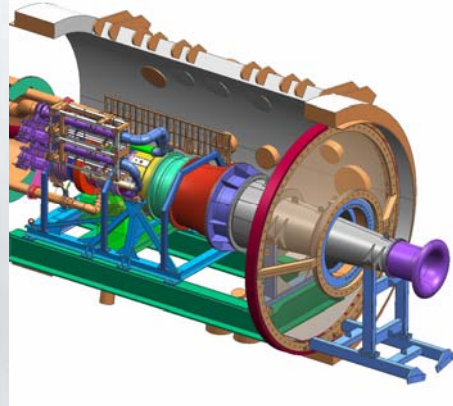
- Circa 30 Hours total running conducted
- HP & LP Rotating Strain Gauge Experiments
- Performance Experiments
- Combustion
 - Staging laws
 - Emissions / Rumble Mapping
- Distributed / Versatile Control system demonstrated
- Electric Oil System demonstrated
- In-cell noise tests



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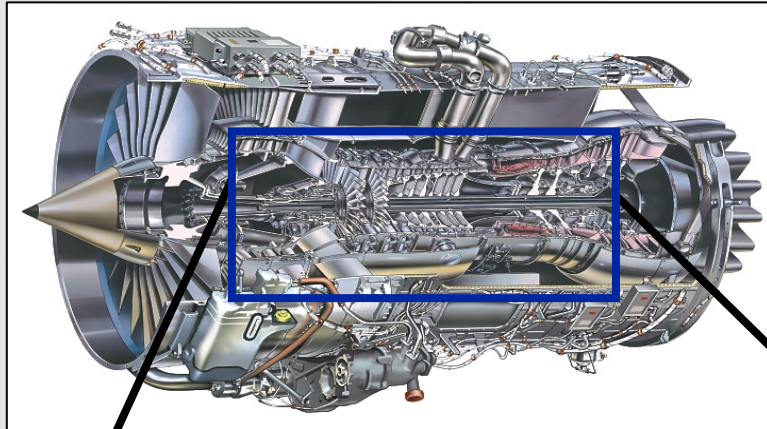
Engine 3E

- E3E is the aero engine part of the German Aeronautics Research Programme funded by the Ministry of Economics and Land Brandenburg
- The Rolls-Royce Deutschland programme consists of 5 major work packages: HPC (funded by Land Brandenburg), Combustor, HPT, Integration and Validation (all funded by German Ministry of Economics)
- Core 3/2 is the technology demonstrator within the programme



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LuFo E3E – Vision10 technology

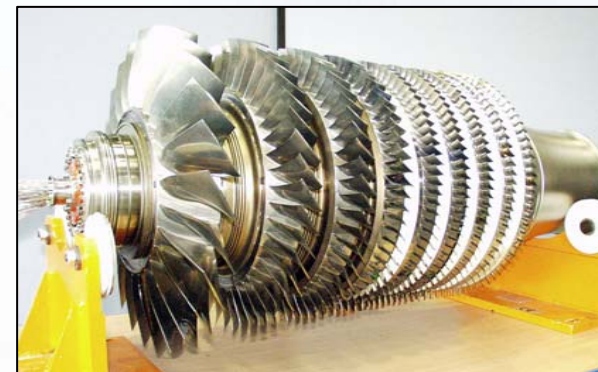


**BR715
(1998)**

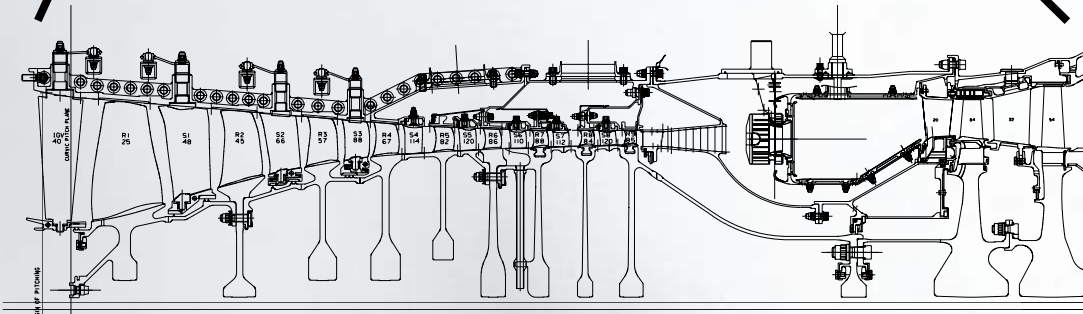


**Cooled 3D turbine
blade featuring
contoured
endwalls**

Fuel burn reduction (CO₂) 5-8%
NO_x reduction 25-30%
Cost reduction >40%



**High Pressure Compressor
Rig Test funded by Land
Brandenburg**

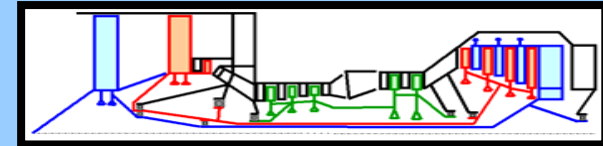
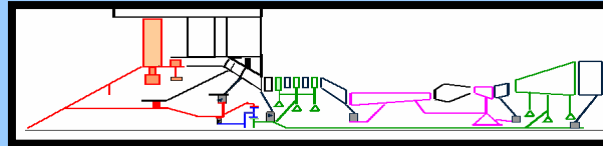
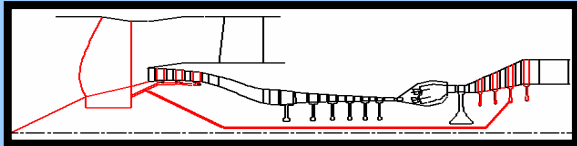


LUFO Engine 3E Core Engine (Test 2008)



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VITAL: the expected results



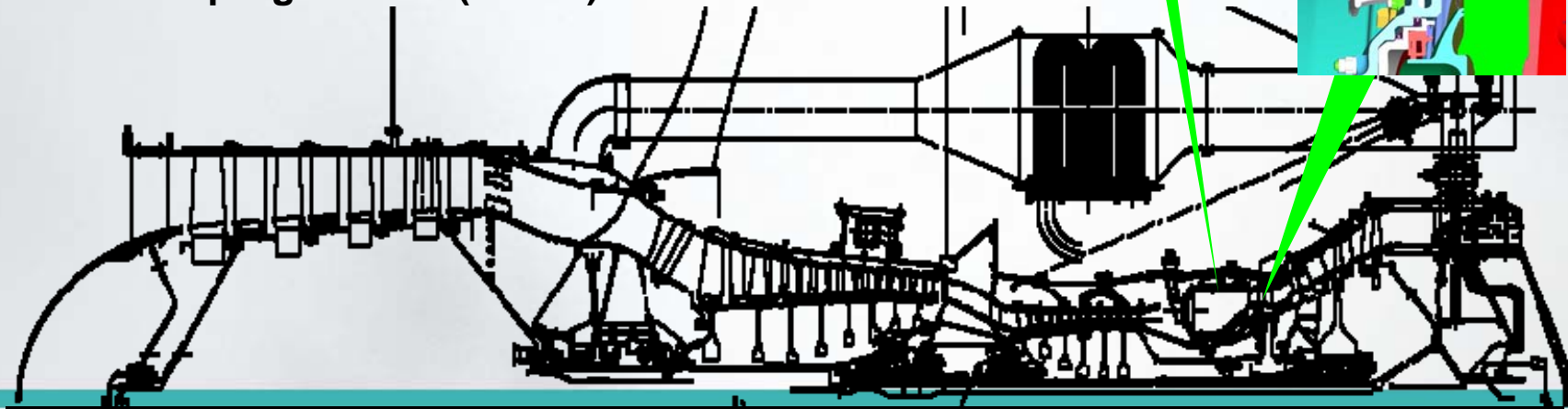
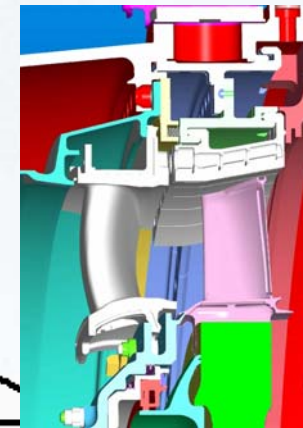
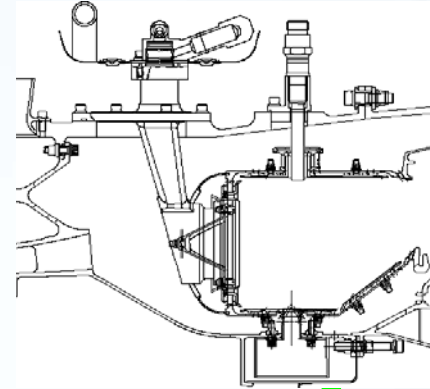
	SP2	SP3	SP4	SP5	SP6	SP7	SP 8
VITAL Subprojects Exploitable Outcomes	FAN	Booster	Structures	Shaft	Low Pressure Turbine	Installation	Architecture (Cycle Effect)
Noise Cumulative Margin	+ 6 EPNdB	Enabler	Enabler	Enabler	+ 2 EPNdB	+1 EPNdB	+ 9 to +12 EPNdB
Engine Efficiency	+ 1 %	+ 0 %	+ 0 %	Enabler	+ 0 %	+ 0 %	+ 6 %
Power Plant System weight	- 7%	- 1%	- 4%	Enabler	- 6%	- 5%	+ 25%
Whole engine Significance	15-18 EPNdB cumulative Noise reduction		BPR increase at almost Constant PPS weight		7% improvement in Propulsion efficiency		



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EFE – Environmentally Friendly Engine

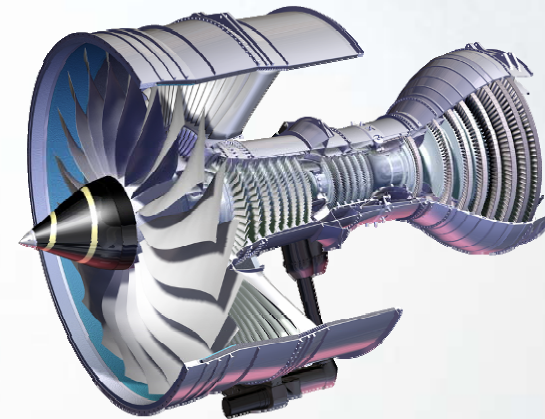
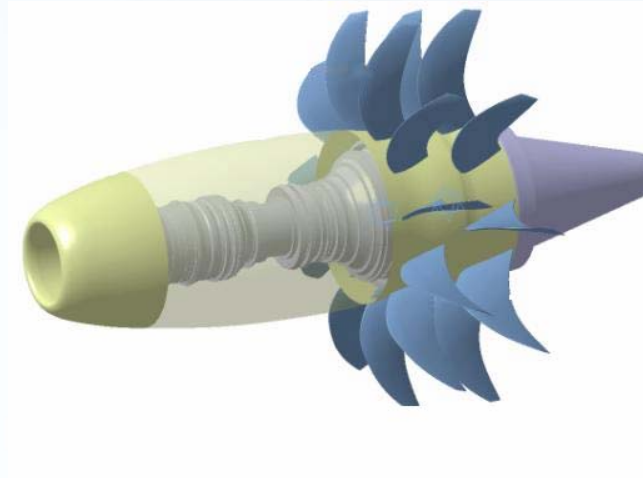
- **EFE**
 - £95M gross, 5 years (2006-2010)
 - Trent family donor hardware
 - Six builds, First run 2008
- **Focused technology validation:**
 - HP turbine (materials, cooling, aero)
 - Lean-burn combustion
- **Part of an integrated set of environmental technology programmes**
 - Compressor and LP system technology validated in European Union programmes (FP6+7)



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Clean Sky Potential RR contribution

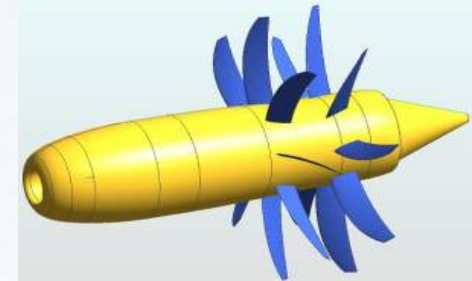
- 2 RR-led demonstrator programmes on comparable scale to ANTLE
- Scope for both radical and more conventional architectures



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Challenges of open rotor concepts

- Noise and vibration
 - Reliability, maintenance cost
 - Weight
 - Aircraft integration, certification
 - Different operating cost vs. design flexibility characteristic drives fleet re-structuring
 - Speed still essential for flexibility and cash operating cost
- and
- Perception



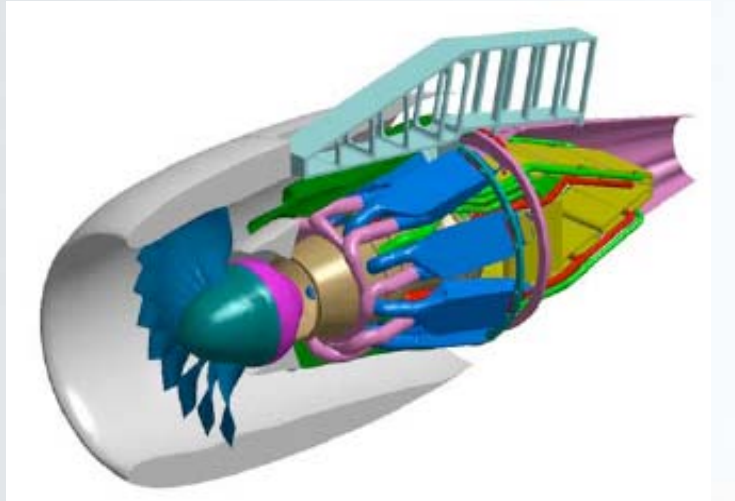
The potential fuel burn benefits of open rotor concepts are compelling in the light of the climate change debate

Rolls-Royce is committed to invest in open rotor technology to address the challenges and realise the benefits



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Engine Improvements for 2015 and beyond



Intercooling



Open Rotors

- Enclosed, high-bypass turbofans have brought increased efficiency and greatly reduced noise
- Open rotors with modern aerodynamic design offer potential for significant fuel savings
- Further optimisation work required to match fuel burn benefit with potential noise penalties compared to equivalent technology turbofans



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Conclusions

- Major demonstrator programmes launched in 2000/2001 are now delivering engine tests validating technologies for improved emissions, noise and more electric engine
- Pull-through of these technologies into product is beginning
- E3E and EFE will validate combustion and turbine technologies to close ~50% of the remaining CO₂ & NOx challenges
- Further programmes (e. g. Clean Sky) will be required to fully meet ACARE challenge
- Maximum fuel burn reduction and maximum noise reduction not achievable with one concept. Trade driven by customer and influenced by parameters like fuel price, landing fees, regulations.
- Climate change has replaced noise as top environmental concern in air traffic
- Rolls-Royce is determined to play positive role as outlined in our 2007 environmental report “Powering a better world”



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Thank you for your attention.



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Fan/IGV interaction

Noise optimised VHBR fans

Lightweight Containment case

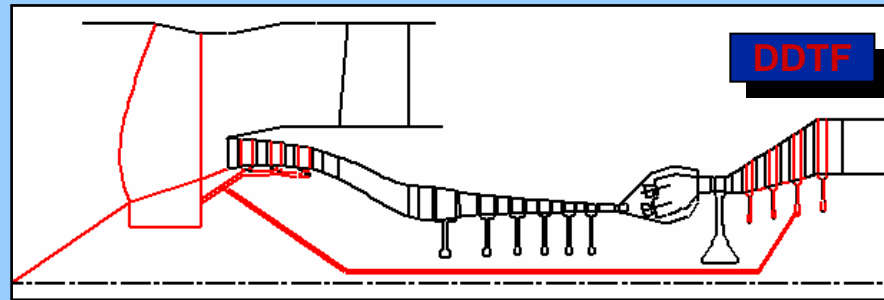
Lightweight structures

High Torque shaft

Low noise Turbine

Lightweight Turbine

Lightweight Nacelle

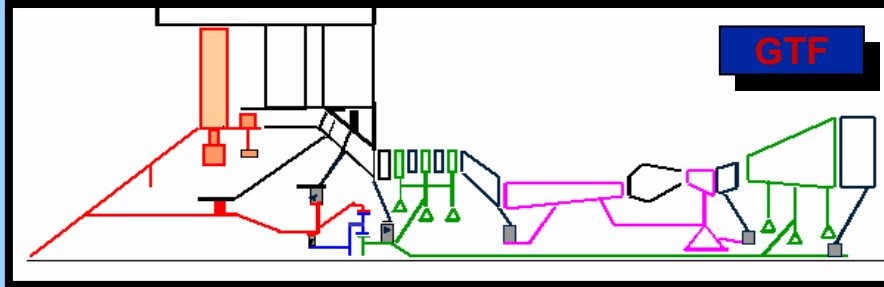


DDTF fan

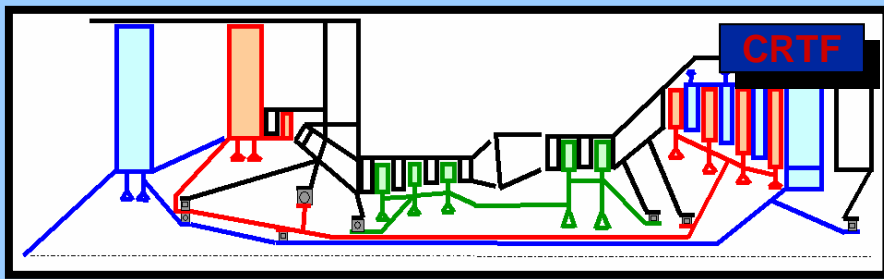
Low Speed booster

Variable Nozzle

Low noise OGV



High Speed booster



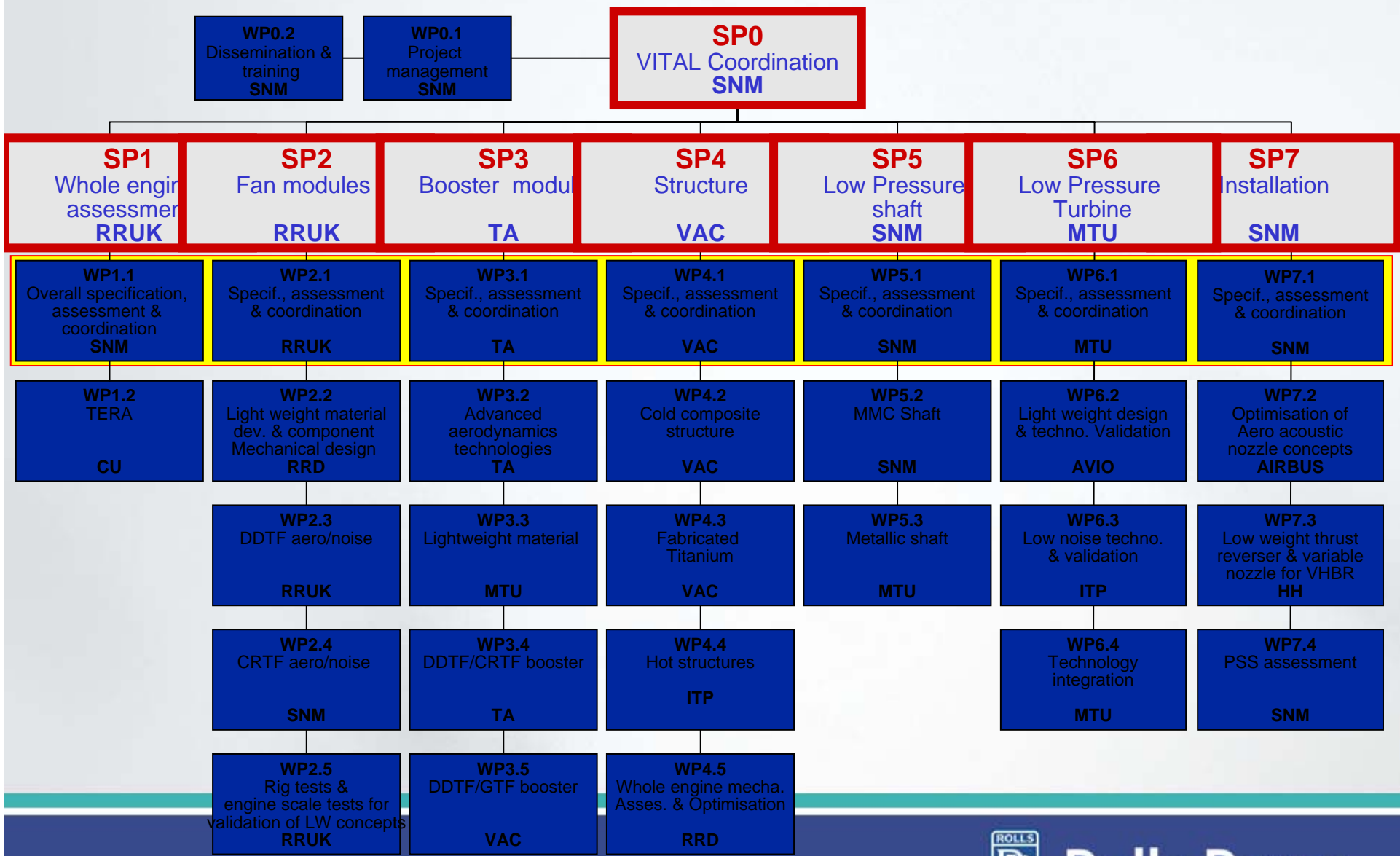
CRTF fan

Low Speed booster

CR Turbine study

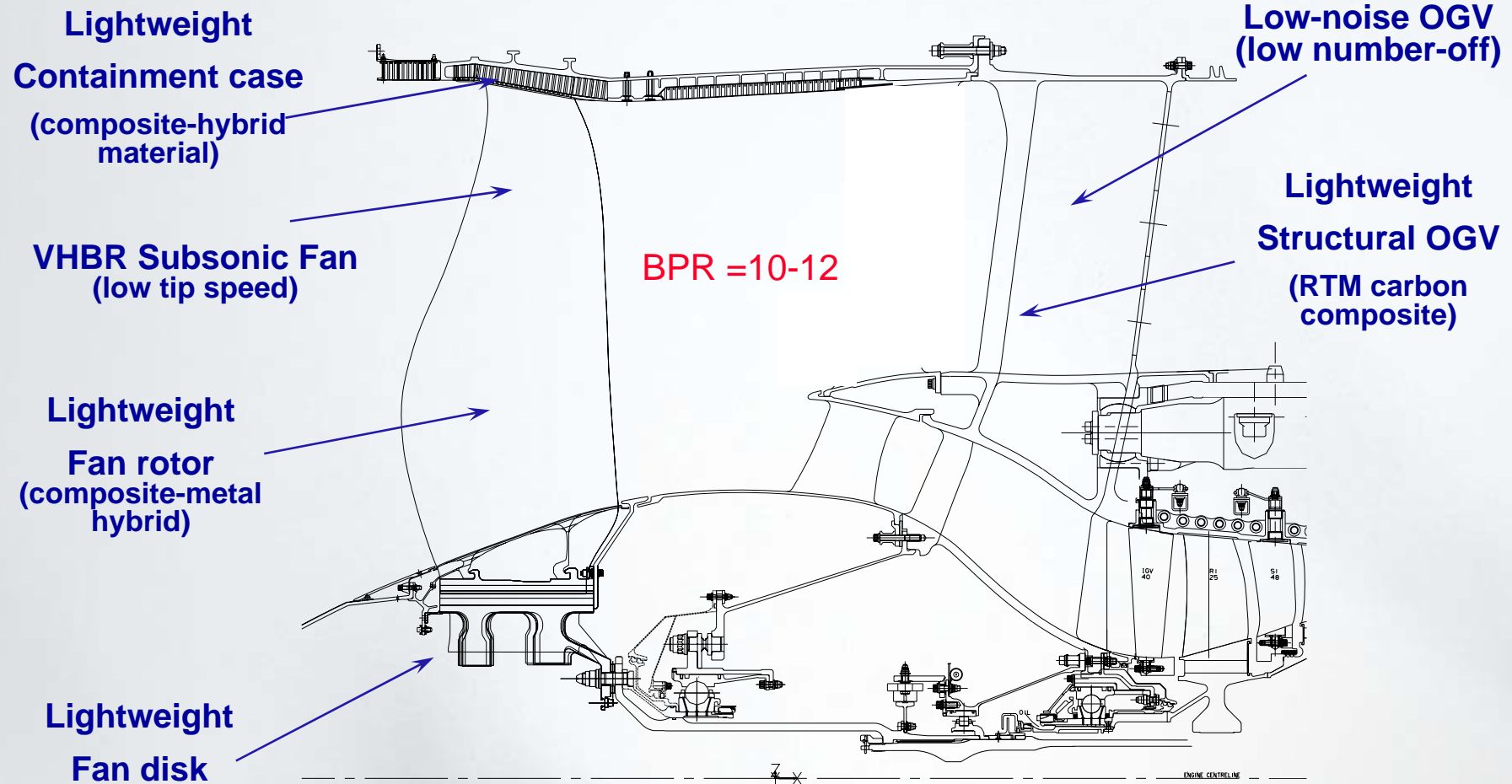
Applicable to all 3 VITAL engine concepts

Specific to a VITAL engine concept



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VITAL : Conventional High BPR fan



Targets: Noise -6EPNdB, Weight = -25%, Effy = +2%
(relative to yr 2000 production e.g. BR715)



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