dream

Validation of radical engine architecture systems

the **alternative** solution
for a cleaner future

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SEVENTH FRAMEWORK PROGRAMME

dream

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the **alternative** solution
for a cleaner future

Our mission

“To develop and validate technologies aimed at significantly reducing the engine specific fuel consumption and reducing the CO_2 while achieving acceptable noise levels”

SEVENTH FRAMEWORK PROGRAMME

The environmental challenge

"It is very likely that human activities are causing global warming"

International Panel on Climate Change

(*continued*)

valiDation of Radical Engine Architecture systeMs (DREAM)

The DREAM project is the response of the engine community to commercial and environmental pressures that have come about mainly as a result of two main factors:-

- The political pressure to reduce CO_2 has increased considerably since the publication of the ACARE goals.
- Future availability and cost of Jet A1 fuel. Recent fuel prices have oscillated significantly, but the future trend is likely to be upwards.

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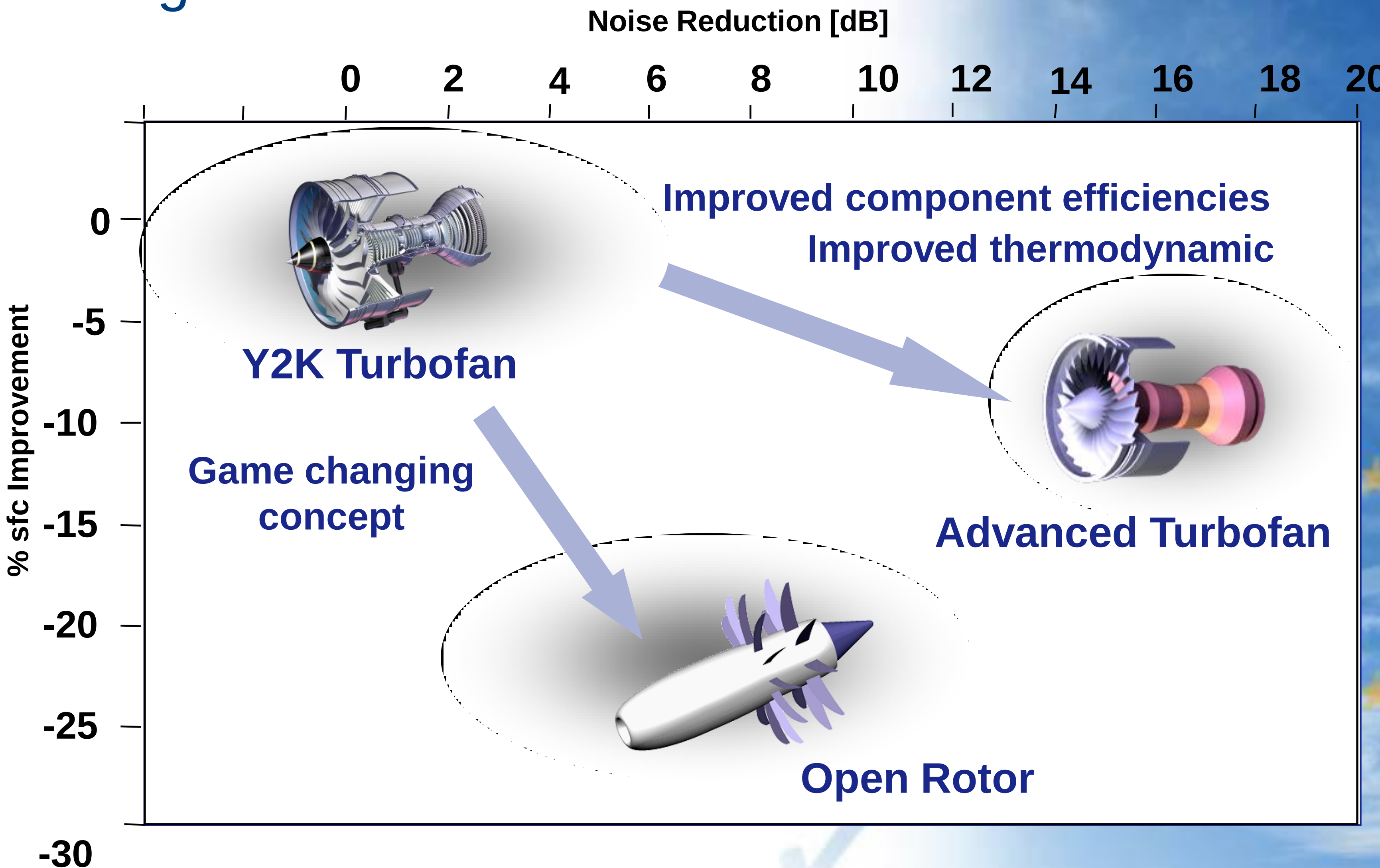
Background



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Background

1980s - significant pressure to achieve substantial reductions in Specific Fuel Consumption driven by the escalating cost of fuel.

It was known that conventional propeller engines can offer significant fuel burn advantages over a turbofan engine at lower Mach numbers (M < 0.6).

The drive was to use modern methods to design an efficient open rotor propeller to maintain its efficiency at the much higher cruise Mach numbers typical of the latest short-range aircraft (M = 0.78 to 0.8).

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Background

Aero-engine manufacturers looked at the development of advanced open rotor propellers.

Features included: swept blades for higher speeds, higher blade numbers, blades with lower thickness/chord ratios, higher hub/tip ratios and a second row of counter-rotating blades to eliminate net swirl.

Open rotor engines that were developed:-

The General Electric GE-36 (the UDF™ with direct drive contra rotating propellers)

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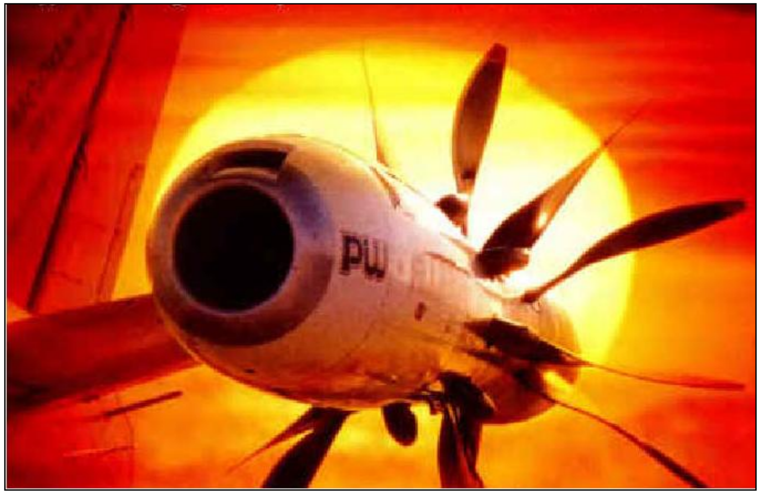
Background



The P&W/Alison 578-DX (the Propfan™ engine with a reduction gearbox driving the propellers)

The Progress-D27 (a forward counter-rotating open rotor engine made for the Antonov-70).

All were able to deliver high Mach speeds (0.72 to 0.8) and reduced SFC, although noise levels were well in excess of those achieved by existing turbofan engines.

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Background

The drop in oil prices in the 1980s and little focus on CO_2 and its impact on climate change resulted in less interest from the airlines, and further development of the concept was stopped. Consequently no large commercial passenger aircraft incorporating contra-rotating open rotor engines have been produced.

In 2000, an increased focus on climate change resulted in the creation of the ACARE 2020 goals:

- **Reduce fuel consumption and CO_2 emissions by 50% (20% for the engine alone)**
- **Reduce perceived external noise by 50%**
- **Reduce NOx by 80%**

In addition, fuel prices continue to oscillate, but the trend is likely to be upwards over the coming years.

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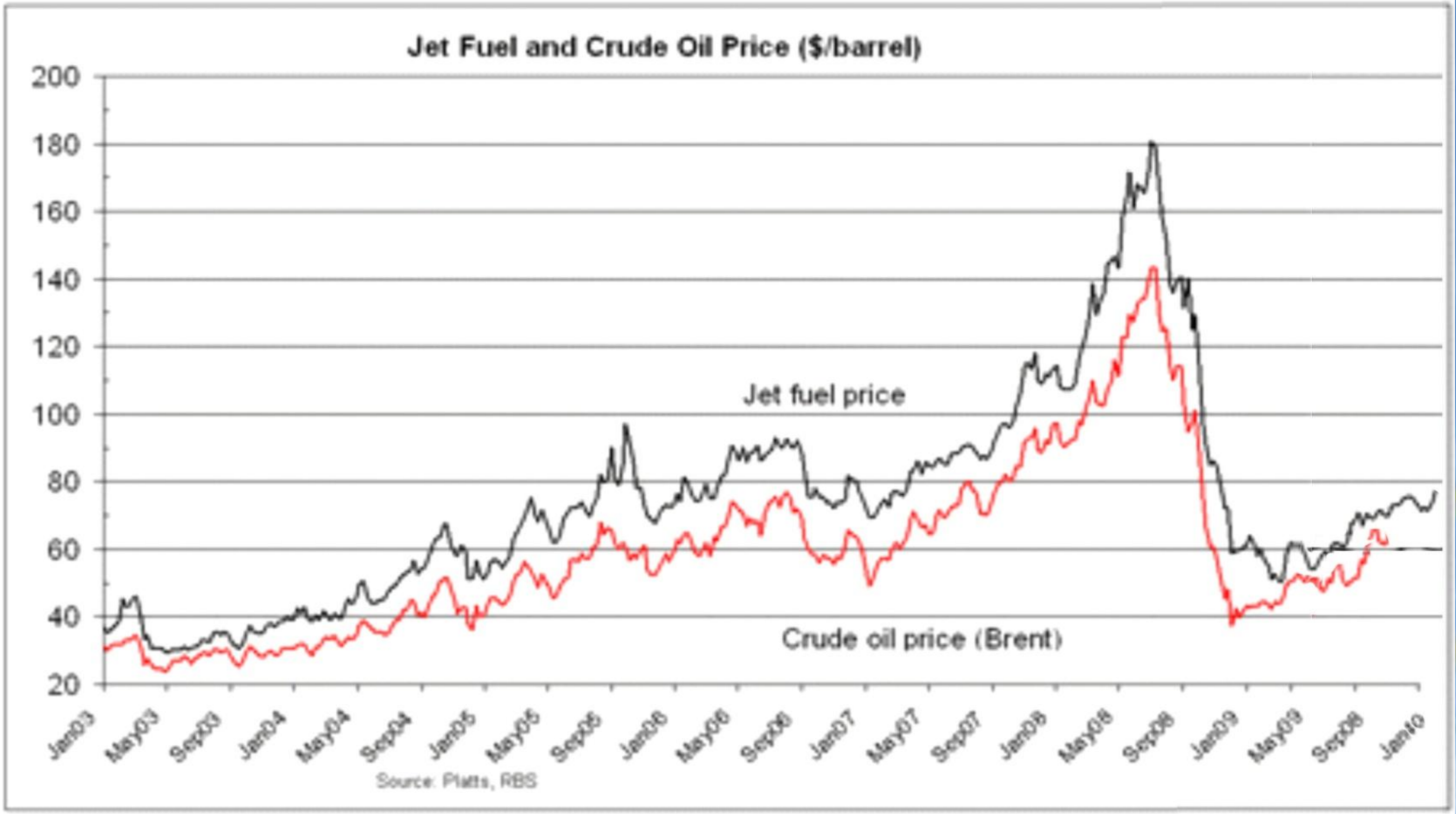
Background

Jet Fuel Price Trend



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Background

To support achievement of these objectives, DREAM is studying a range of novel designs for both contra-rotating open rotors and turbofans by:

- Exploiting progress made since 1990 in 3D fluid dynamics methods in steady and unsteady conditions to increase the aerodynamic efficiency while reducing noise levels
- Performing tests on contra-rotating rigs to measure aerodynamics and noise that will feed the simulation models
- Developing novel engine systems on top of the NEWAC and VITAL technologies including active and passive vibration control, engine structures with additional functionally and active solutions for turbines such as smart active clearance control and active boundary layer control
- Validating the use of alternative fuels in these aero engines and demonstrating green house gas emission reduction.

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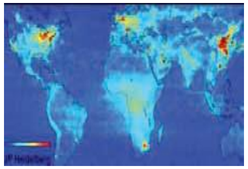
Objectives

The DREAM objectives are for the engine and pylon in isolation

- CO_2 - 9 % over and above VITAL/EEFAE TRL4/5 (7 % better than ACARE or 27 % better than Year 2000 engine)



- Noise - 3 dB per operation point (~ –9dB cumulated on 3 cert points) versus the Year 2000 engine references at TRL4 with improved methods, materials and techniques developed on past and existing noise programmes

- NOx – no specific objective but will be reduced accordingly with engine specific fuel burn reduction

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Project Size and Duration

Framework 7 Call 1 Level 2 Project

Gross project budget	€40.2m
Funding	€25.0m
Start Date	February 2008
Duration	36 Months

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Project Organisation

- 44 partners from 13 countries
- Expertise and capability from within the EU, Switzerland, Russia and Turkey.
- The variety of organisations involved in the project including larger OEMs, SMEs, Universities and Research establishments

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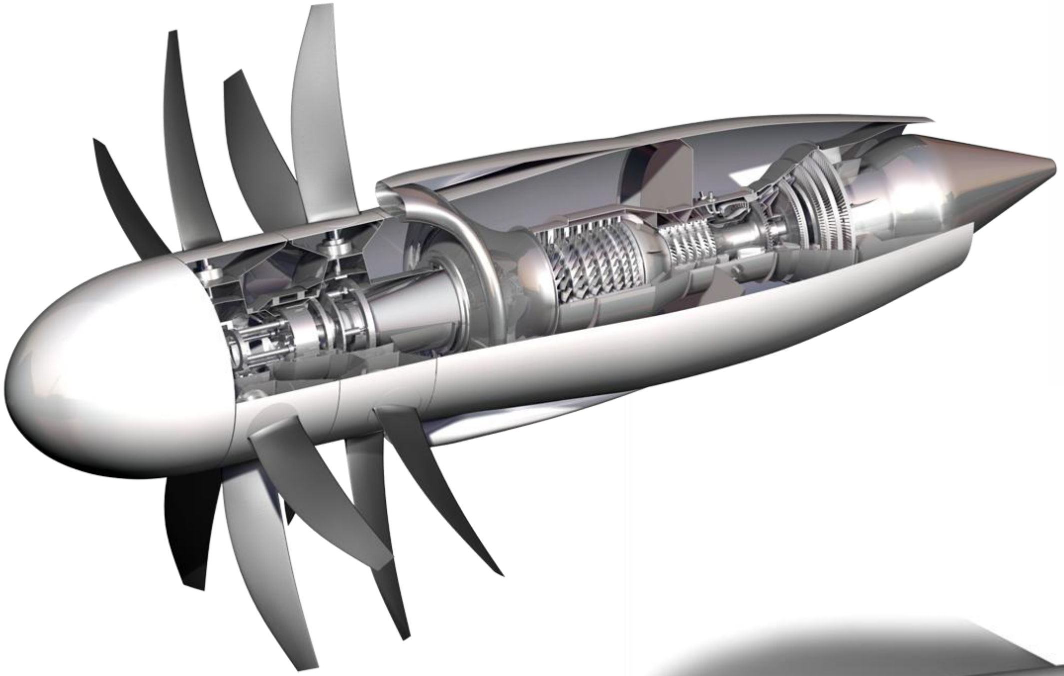
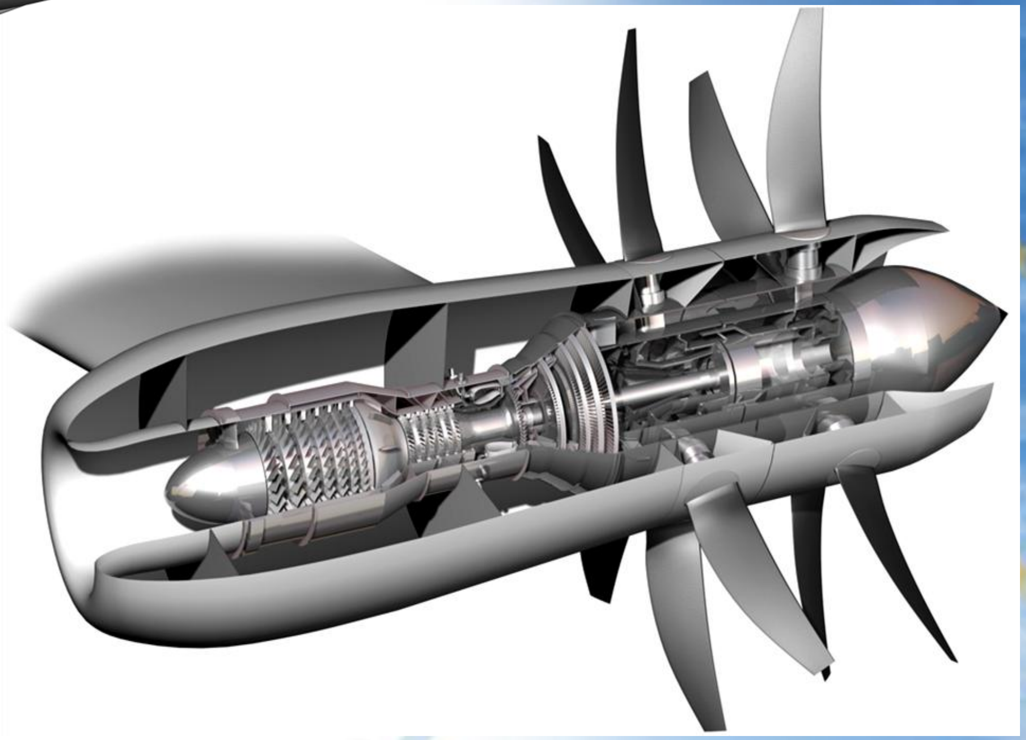
Alternate Open Rotor configurations





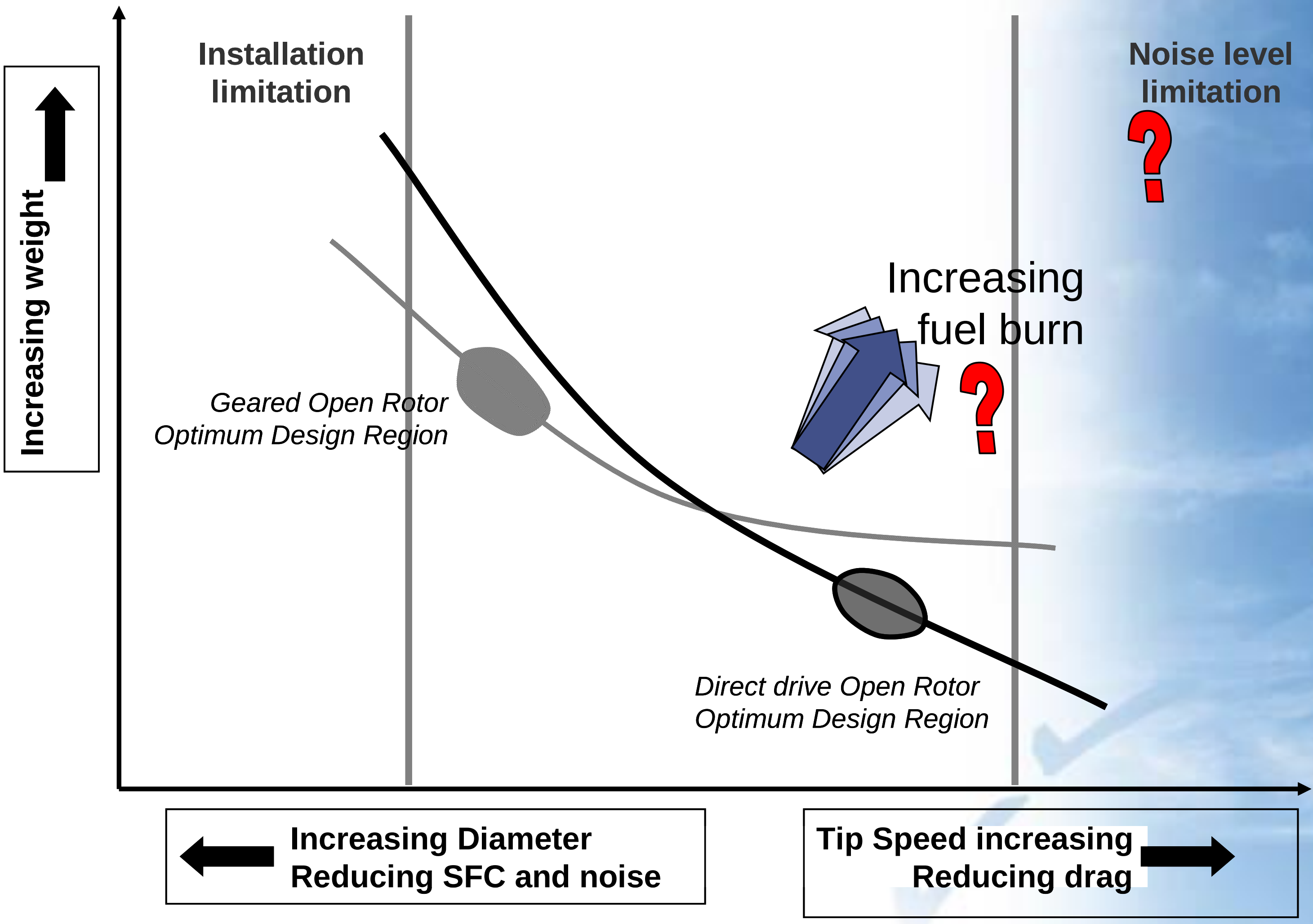
DREAM: What Open Rotor Drive System?

There are two drive mechanisms that will be assessed in DREAM: the Geared Open Rotor and the Direct Drive Open Rotor. Both of these systems have potential advantages and disadvantages in relation to noise and installation issues:-

Geared Open Rotor - greater control of tip speed whilst using more conventional and proven turbine technology. Complex and potentially heavy gearbox positioned in the hot flow-path.

The Direct Drive Open Rotor – Potentially lighter. There is no gearbox in the hot flow-path or a heat exchange system to integrate, but complex contra-rotating stator-less turbine compared to conventional LP turbine

DREAM:
What Open Rotor Drive System? (cont')



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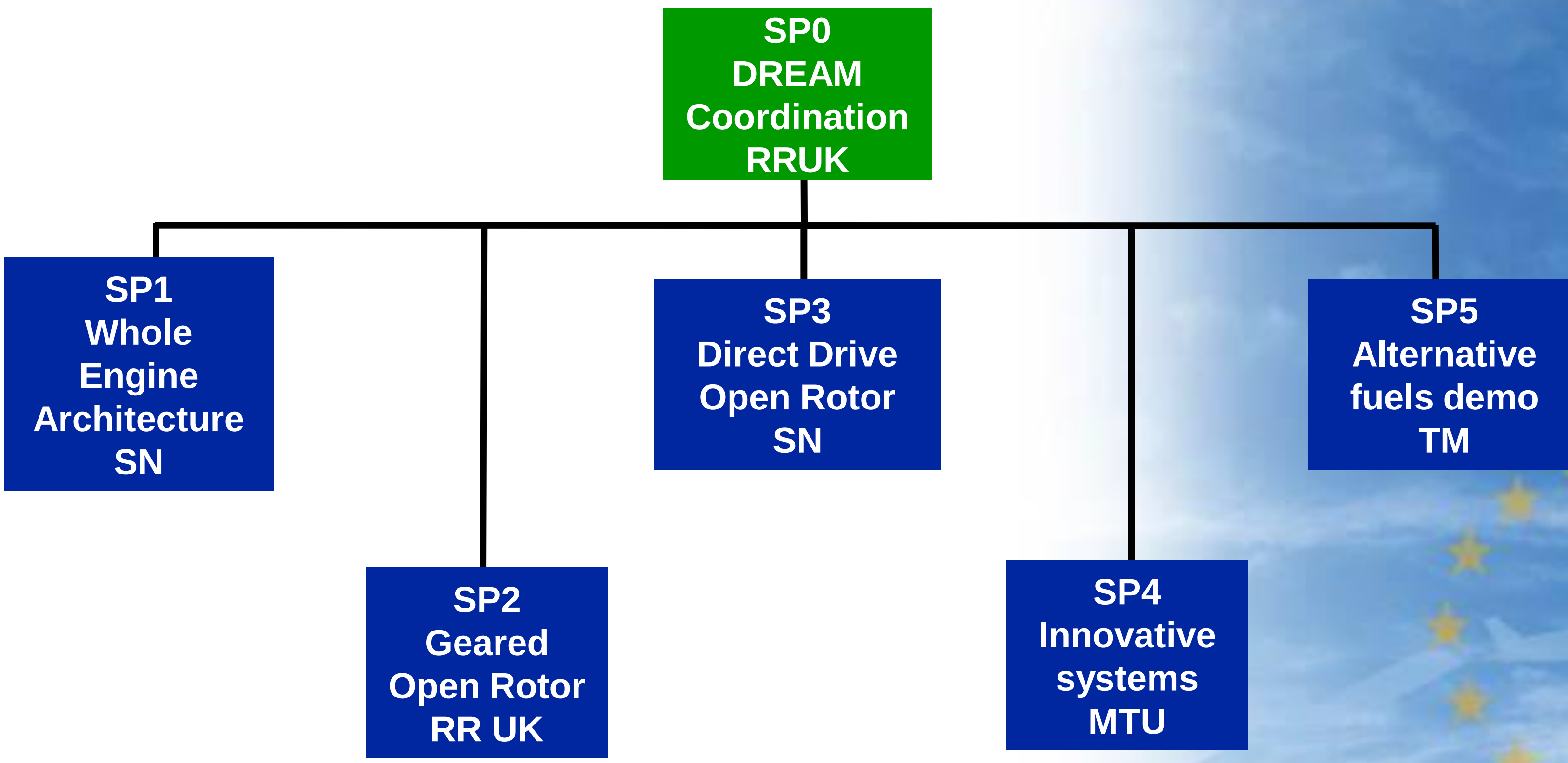
DREAM Project Structure



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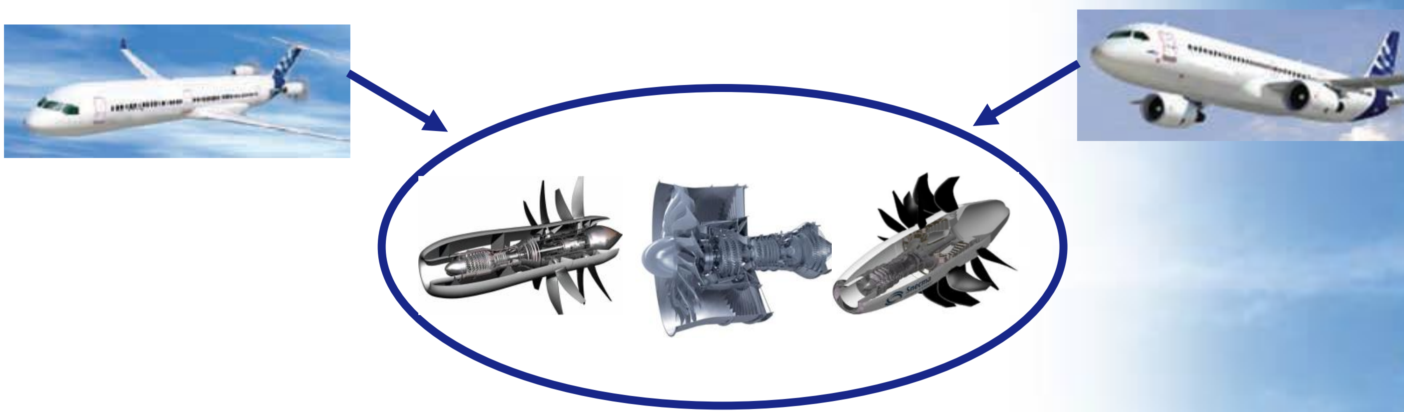
SP1

Whole Engine Architecture

The technical objectives of SP1 are to:

- Define the aircraft specifications that set the DREAM engine requirements both for open rotors architectures and advanced conventional turbofan technologies



- Compare, assess and rank the systems investigated within DREAM by their technological potential whilst achieving environmental goals
- Provide requirements and objectives of each different DREAM engine technology

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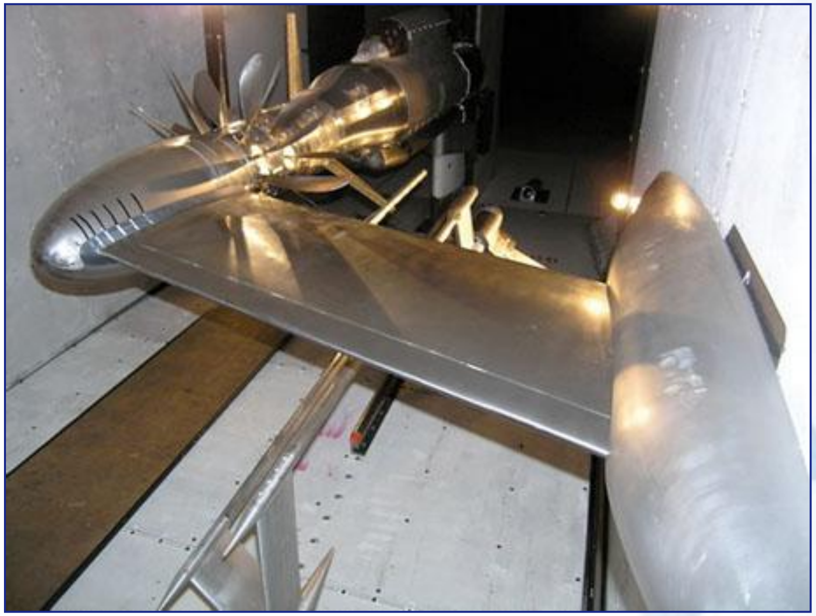
SP2
Geared Opened Rotor

This Sub-Project will develop a Geared Open Rotor and is formed in six work-packages

WP2.2 & 2.3 Installed and uninstalled aero/acoustic rig testing

- Test data from Rig 145 Geared Open Rotor running at DREAM partner ARA has enabled high speed noise and performance data to be obtained both with and without installation features.



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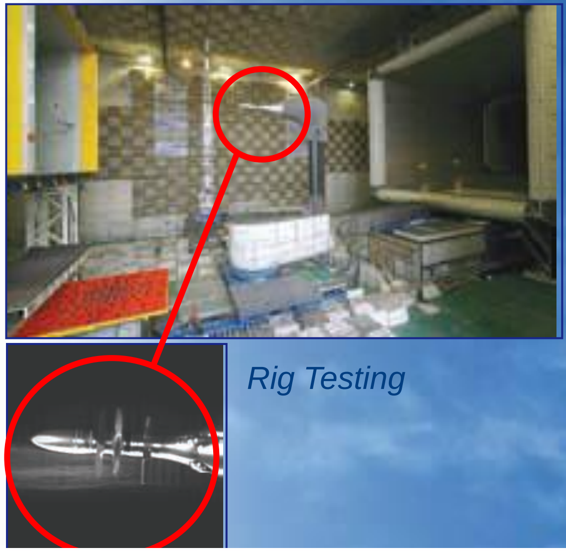
SP2
Geared Opened Rotor

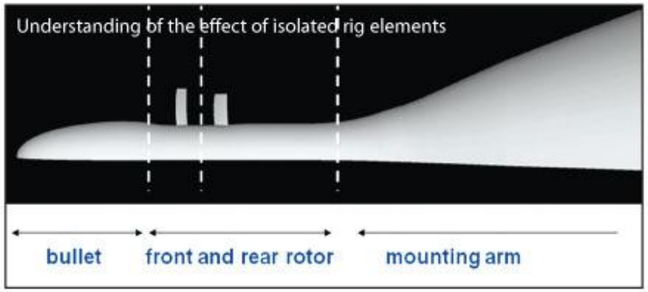
WP2.2 & WP2.3 Installed and uninstalled aero/acoustic rig testing

Test data from Rig 145 Geared Open Rotor running at DREAM partner DNW has enabled low speed noise and performance data to be obtained both with and without installation features.

• Acquisition of quality data to understand key aero-mechanical parameters to validate CFD and CAA prediction capabilities permit the creation of enhanced blade designs for follow on tests within DREAM.



Rig Testing



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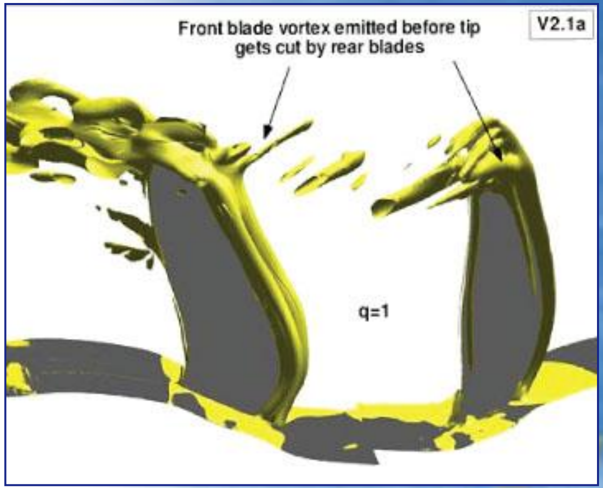
SP3

Direct Drive Open Rotor

SP3 will develop a Direct Drive Open Rotor.
The partners will investigate the critical components of the concepts.

WP3.2 will perform Open Rotor propeller blades detailed design and evaluation, and in particular:

- Definition of mock blades for aero and acoustic tests
- Installation effects and design a mock pylon for installed tests
- Aero-acoustic advanced concepts for open rotor with aero-acoustic and mechanical assessment
- Impact of smart blade concepts on blade design and performances



Chorochonic computations (ONERA)

(continued)

SP3

Direct Drive Open Rotor

WP3.5 will evaluate the aero and acoustic performances of the Contra Open Rotor Blades and Pylon designed in WP3.2, using wind tunnel installations at TsAGI (Russia) and adapting an existing test rig VP107

- First campaign was performed in 2009 (Historical blade)
- Second campaign started in March 2010 (Baseline blade)
- Last campaign will start in August 2010 (Advanced blades)

WT104 tests (TsAGI)

WT107 tests (TsAGI)

(*continued*)

SP3
Direct Drive Open Rotor

Validation of radical engine architecture systems

WP3.3 Develop a design for a contra-rotating turbine

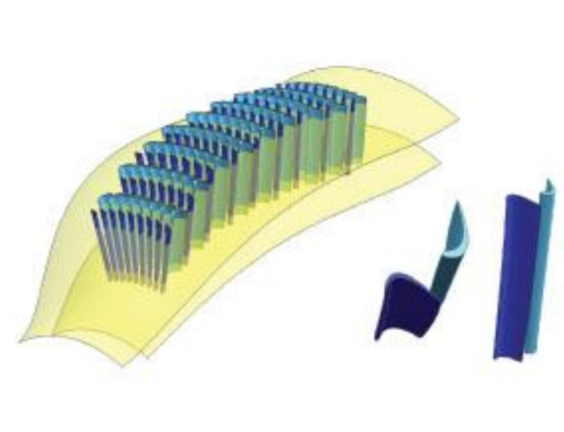
- Contra-Rotating DRUM

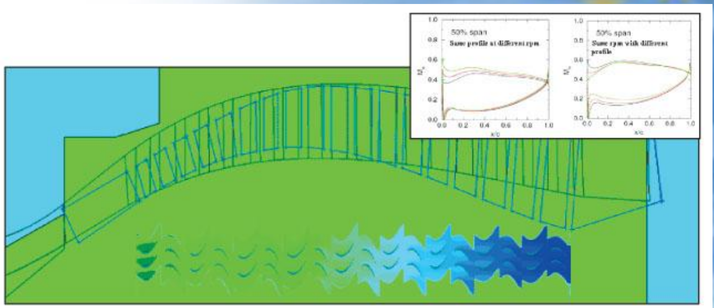
The CR drum containment capabilities is assessed with dedicated mechanical test campaign.

- Contra-Rotating Strut, which transfers the load from the Drum to the Contra-rotating Shaft.

- Contra-Rotating Blades:

The effect of compression tensile status of vibratory capabilities of the blades is studied thru a dedicated engineering test on a rotating drum with simplified blades.


3D airfoils geometry generated for all stages


Turbine layout and Aero Design

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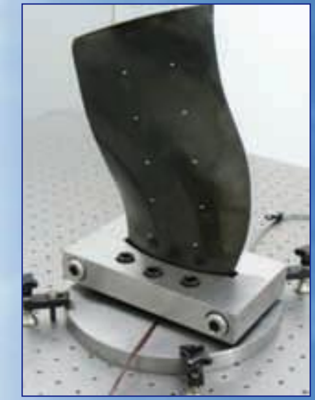
SP4

Innovative Systems

Four work packages that provide enabling technologies for low weight and low cost future engines and also an efficiency improvement of 0.5 % by adding innovative functionality and active solutions for turbines

• Specification and Assessment

• Active vibration control engine structure with piezo actuator damping systems and elastomer damping rings for passive vibration control and cost efficiency and Low Noise Structural Fan OGV



Active Damping of Fan Blades

Low noise structural fan OGV

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SP4
Innovative Systems

Results & achievements

WP4.2 Cold Structures

- First rig measurements and simulations of piezoelectric actuators accomplished
- First component tests with elastomer rings are finished, long time ageing tests have started
- The final aerodynamic and acoustic OGV design resulted in a vane count of 8 and is designed for an 18 blade fan

Specimens for high temperature investigations

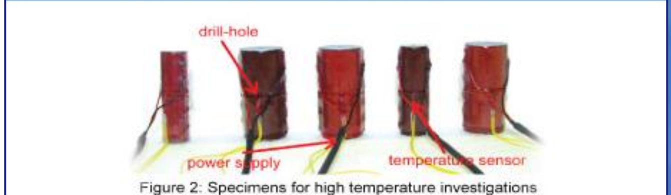

Figure 2: Specimens for high temperature investigations

Final ULC OGV aero design

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SP4

Innovative Systems

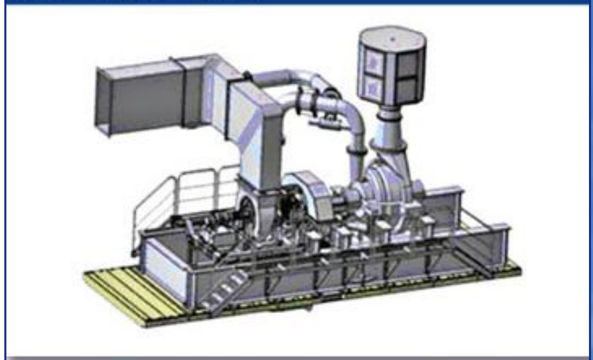
WP4.3 Novel Structure for Mid Turbine Frame

• Evaluation of the MTF components hot flow path structure, load carrying radial structure and load carrying outer casing structure completed.

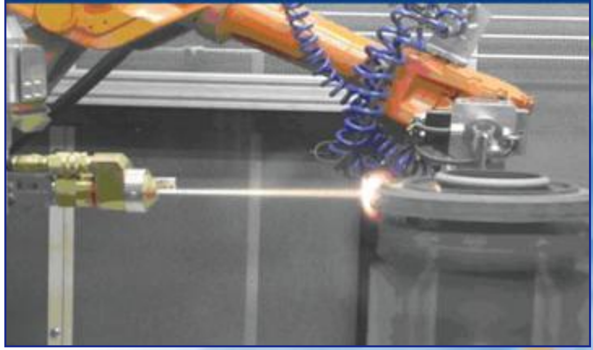
• For the base material of MTF flow path, 15 materials were examined and four were chosen for further investigation.

• Successful first run of the test vehicle accomplished.

Two spool transonic turbine rig



Evaluation of high velocity oxygen fuel thermal (HVOF) spraying coating



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SP4

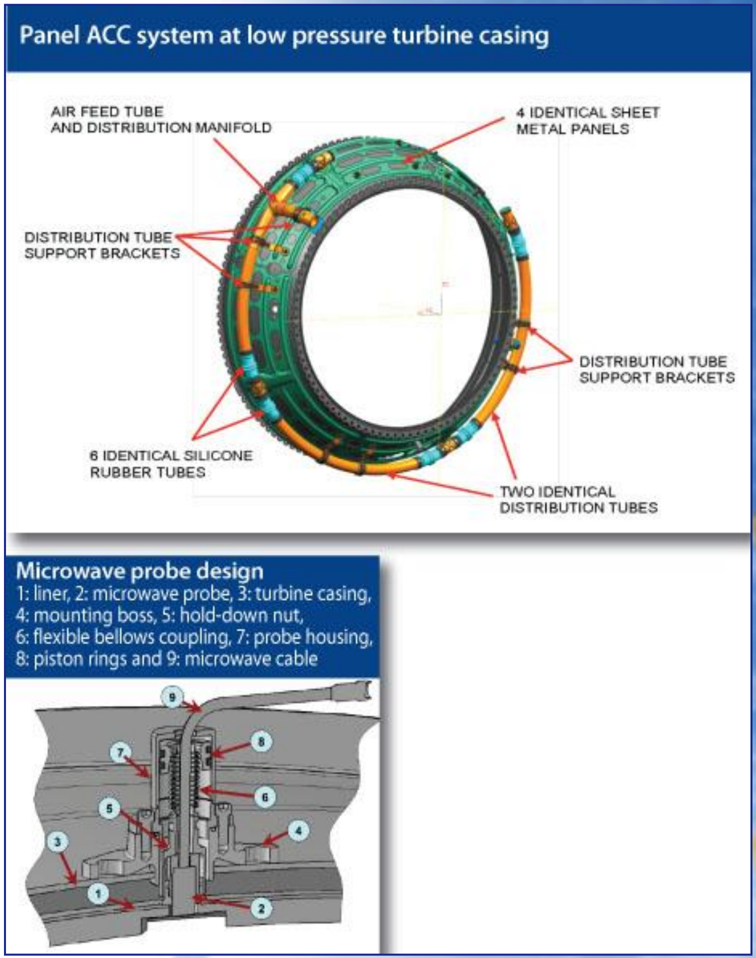
Innovative Systems

WP4.4 Active Turbine

• A panel ACC system was designed and manufactured. From the CFD simulations, Nusselt numbers and heat transfer coefficients for impingement cooling heat transfer were derived

• The engine test with the radial clearance sensors was successfully completed.

• Results are being analyzed.



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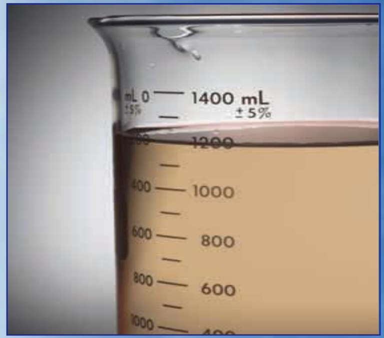
SP**5**

Alternative fuels demonstration

This will demonstrate the performance of an existing available fuel (a Shell GTL type and a 3rd generation UOP SPK (HVO) fuel from Camelina):



The requirements are:

- No significant modification of aircraft or engine is needed (‘drop-in’ fuels)
- Investigate the advantages on emissions of pollutants (NOx, CO, HCs, soots…)
- Contribute to the reduction of green house gas emissions (CO_2 emissions will be measured and compared with standard aviation fuel)
- The demonstration will be conducted on a turboshaft engine and a paper work extension to aero-engines will be performed

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SP5

Alternative fuels demonstration

Results & achievements

Fuel selection. Fuel suppliers identification. Fuel purchase.

- Preparation and start of component tests.
- Rubber immersion, and fuel systems tests at Turbomeca
- Combustion tests at Pars Makina
- Ignition in low pressure conditions at ONERA.

Combustion test on Allison RR 2500 C18 Combustor at Pars

Ignition test at ONERA MERCATO

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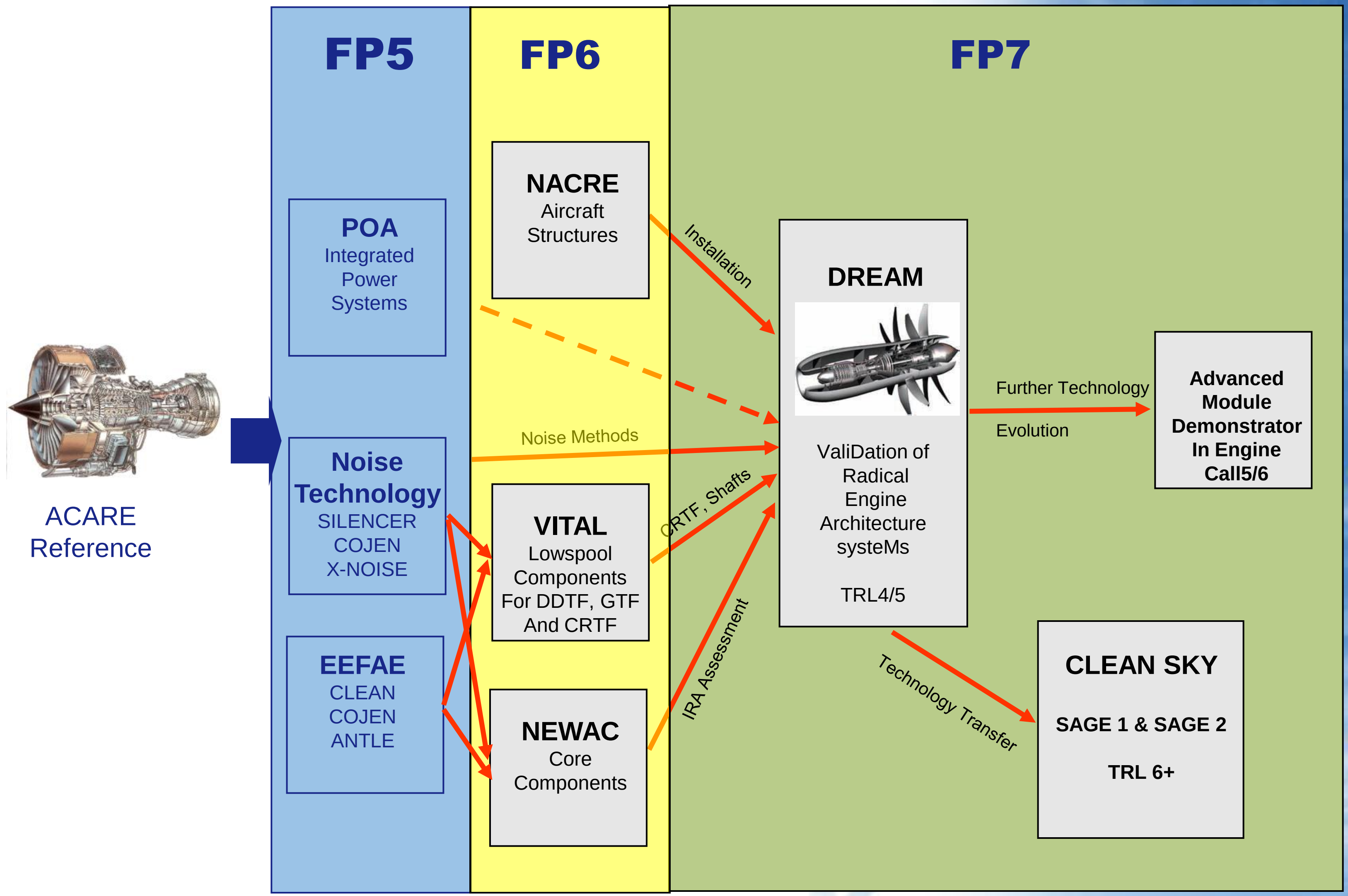
DREAM Technology Roadmap



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DREAM technologies (1)

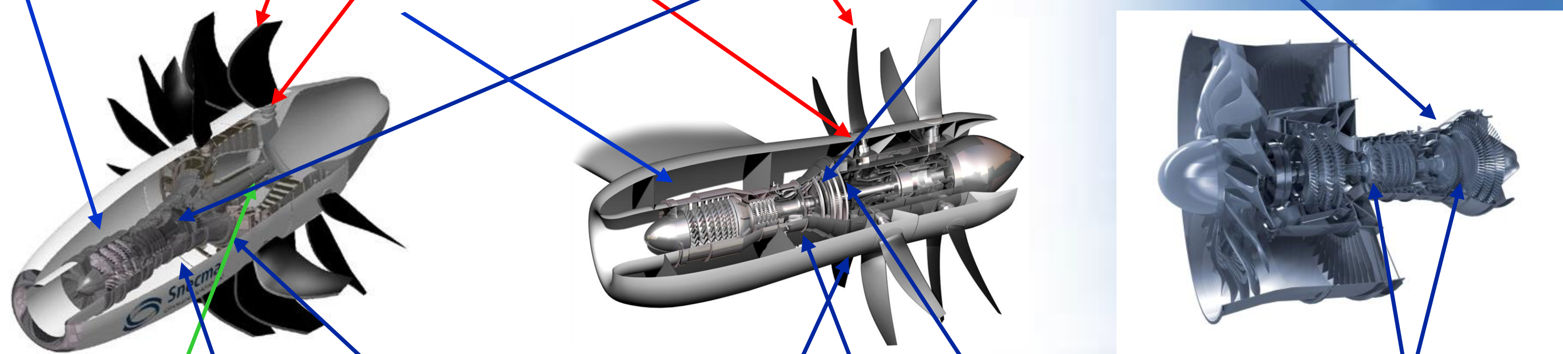
dream
Validation of radical engine architecture systems

Low ...
2nd blade sets mfr

Low pr...
Rig ready
...sor

Initial tests completed

Mid turb... ...ture des... ...optimisation
Rig in assembly



Direct Drive OR

Geared OR

Advanced TF

Co...
Design complete
Damping + impact tests

Hot st...
Design optimisation complete

High sp...
2nd blade set proposed

...e fuels
Initial tests completed

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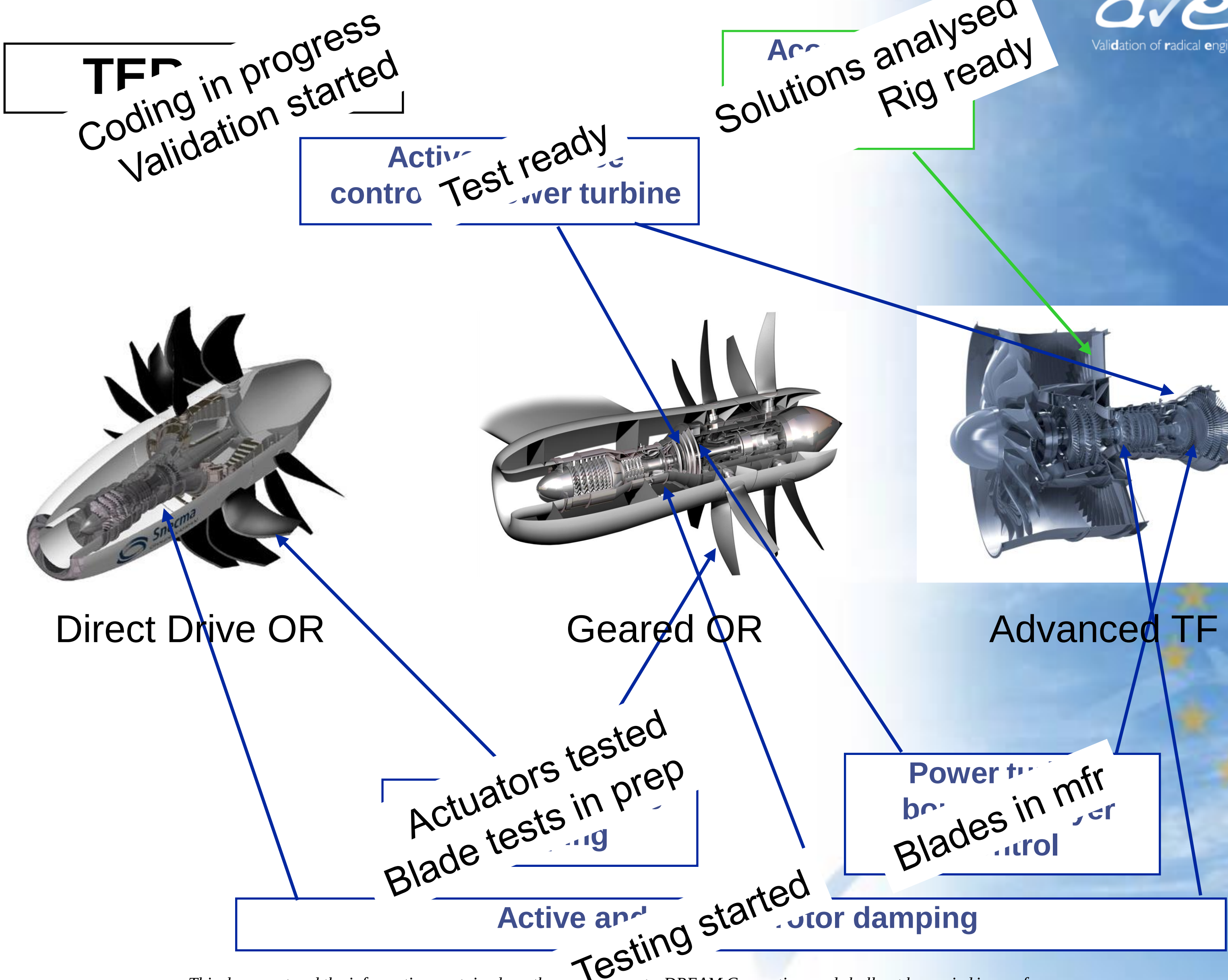
DREAM technologies (2)



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Thank you very much for your attention

http://www.dream-project.eu/

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