VITAL, AN EUROPEAN R&D PROGRAM FOR GREENER AERO-ENGINES

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Abstract

VITAL (EnVIronmenTALly Friendly Aero Engine) identifies and endorses the breakthrough engine architecture that will enable the next generation of commercial engines to meet the ACARE environmental goals in terms of CO2 and noise reduction.
VITAL has started the 1st of January 2005 for 4 years duration. This paper presents the rational and a first status of activity after one year.

1 Introduction

Global air traffic is forecast to triple by 2015. At present air traffic growth (5% growth rate per annum according to ICAO) is greatly impeded by the noise generated by current aircraft as well as the harmful effects of aircraft pollutants on the environment (3% growth in CO2 emissions per annum). Consequently, Europe's aviation industry faces a massive challenge to satisfy the demand whilst ensuring economic, safe and environmentally friendly air travel.

Aircraft engines are the sole source of CO_2 and NOx emission and a large contributor of noise. The quantity of these gases emitted into the atmosphere is controlled by operational factors as well as engine and aircraft design technologies. This is why the engine is judged to require a further 20% CO2 reduction when the ACARE SRA[1] requires a 50% reduction by 2020. As well as the environmental and societal effects of aircraft noise and pollution, there are operational restrictions on the airlines themselves. This is to comply with national or local regulatory aspects such as landing quotas and night flights.

Large investments have already been made in Europe and the US through R&D programmes and collaborations to reduce negative environmental effects of aircraft use (for example: SILENCE(R), EEFAE…) and research is providing the technologies to improve the performance of existing engine components. However even if these technologies will allow for improvements in noise and pollution emissions, their existing limitations will not allow to reach the goals set in the field of aeronautics research in the Strategic Research Agenda Vision 2020[2] report made by ACARE (Advisory Council for Aeronautics Research in Europe).

Radical and innovative engine structures and architectures need to be investigated in order to meet these extremely challenging targets for acoustic and pollution. Such reductions will only be achieved by reconsidering completely, in a first step, the different components of an engine with innovative breakthrough designs, and in a second step, by assembling and optimising these components in new engines.

VITAL is an initiative from the EIMG (Engine Industry Management Group) that brings together the key European stakeholders in this field: Snecma (Coordinator), Rolls-Royce Plc, MTU, AVIO SPA, Volvo Aero Corporation, Techspace Aero, ITP, Rolls-Royce Deutschland and Airbus. Technology providers accompany them from the academic world and the industry, including SMEs, universities and research centres. The VITAL project involves 52 partners from 14 European countries including COMOTI from Romania, and CIAM, a Russian Research centre.

2 Objectives and expected results

VITAL contributes to achieve the ACARE goals for 2020 by developing innovative engine technologies at affordable cost to a:

- 6dB reduction in noise emissions per aircraft operation point
- 7% reduction in CO_2 emissions and fuel consumption

The VITAL and at the same time, the ACARE 2020 objectives cannot be reached through the improvement of existing proven technologies. Breakthroughs are needed in the design of engines and in the technologies used in the various components.

This is achieved in VITAL by developing a new set of technologies for producing a very high By-Pass Ratio (BPR) engine reducing noise emissions and fuel consumption from engines and avoiding or minimising the drawbacks of engine drag and weight associated with low specific thrust engines. VITAL is focussed on Low Pressure parts and installation. The project develops these new technologies via:

I. New fan concepts with the design of two types of fans: counter-rotating and light-weight fans
II. New booster technologies: high load boosters, low speed and high speed, associated aerodynamics technologies and new lightweight materials.
III. 30% weight saving in the engine structure through the use of polymer composite and corresponding structural design and manufacturing techniques
IV. 50% torque capability without weight impact of the shaft through the development of innovative materials TiMMC shaft (Titanium Metal Matrix Composites) and Multi Metallic Shaft with associated concepts
V. 20% weight saving in the low-pressure turbine through innovative ultra high lift airfoil design, ultra high stage loading, lightweight materials and design solutions and low noise design measures
VI. Optimal installation of high BPR engines related to nozzle, nacelle, reverser and positioning to optimise weight, noise and fuel burn reductions

The VITAL technologies are tested and validated using major aerodynamic, acoustic and mechanical rig tests throughout the project lifetime. They provide a validated set of engine technologies and integrated research infrastructure supported by a validated exploitation plan for the use of these technologies in a next generation low-noise, cost-efficient engines.

In addition to technical objectives, VITAL prepares the deployment of the technology by preparing the European Engine supply chain, including internal production departments of the VITAL contractors, through dissemination and training actions.

3 Approach

The architecture of an aircraft engine can be split into relatively independent parts. In a first step each part can be studied in parallel provided the interfaces, characteristics and expected performances specified. Than in a second step a system prototype demonstration preparing engine qualification can be set up.
Consequently, the work in VITAL is organised along 7 sub-projects, themselves split into work packages and tasks related to each part of the engine. To ensure good integration of the components, the architecture of the project has also been designed around a transversal subproject that defines the component requirements and assesses at the whole engine level, the benefits coming from all modules and installation studies.

The whole engine assessment is performed on the 3 main engine architecture candidates for large noise and emission reductions: Direct

Drive Turbo Fan (DDTF), Geared Turbo Fan (GTF) and Counter Rotating Turbo Fan (CRTF) architectures.

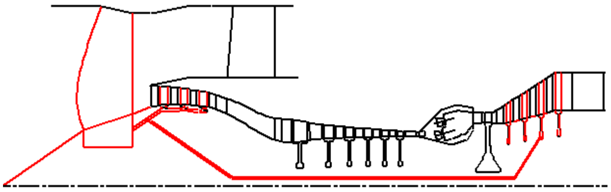

Fig. 1. DDTF Architecture

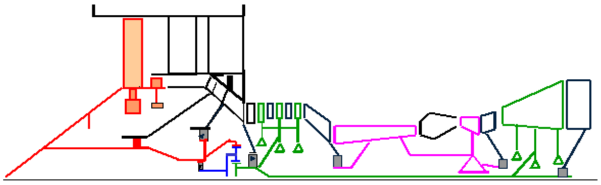

Fig. 2. GTF architecture

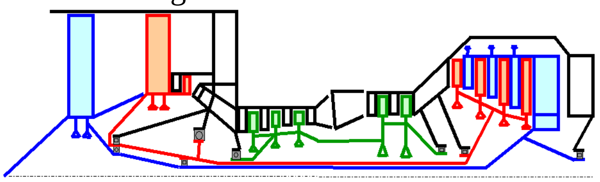

Fig. 3. CRTF architecture

4 Year 2005 major results

VITAL programme has started on the 1st of January 2005. First annual review occurs the 21st and 22nd of February 2006 and was the opportunity to present the first results in front of the European Commission and all the partners involved in the project.

4.1 Management

Management is a key issue of the success of a project that puts together 52 partners from 14 European Countries having their own process and organisation.

Coordination is performed by SNECMA with the support of ARTTIC, a company that has an expertise in the management of large European RTD collaborations. The project decision-making is handled through two committees, the Steering Committee representing all partners and a smaller operational Management Committee that includes the 8 EIMG partners - Snecma, Rolls-Royce plc, Rolls-Royce Deutschland, MTU Aero Engines, Techspace Aero, ITP, AVIO and Volvo Aero Corporation - to conduct the close up management.

4.2 Specification and assessment

Two airplane specifications have been provided by Airbus to cover short range (A320 type, 30 000 lbs) and long-range (A330 type, 70 000 lbs) applications.

These specifications have been derived into 6 engines in order to cover a wide range of architectures: DDTF, CRTF and GTF.

TERA (Techno-economic and Environmental Risk Analysis) is an integrated tool developed under Cranfield University leadership to assess the technological, economical and environmental risks of aircraft engines studied in VITAL. A set of modules are developed and will be provided by university partners: aircraft performance, engine performance, engine weight, powerplant cost, engine maintenance cost, noise, emissions, economic model, environmental model.

4.3 Fan Modules

Lightweight materials have been down-selected and tested for blades (aerofoil and root) and casings applications after extensive design and analysis of two concepts of blades.

Design reviews were held for DDTF aero-acoustic evaluation to be held at Anecom in 2007. Manufacturing of CRTF mock up fan module and adaptation parts is launched for aero and acoustic tests to be held at CIAM, Russia, end of 2006.

Fig. 4. CRTF engine *(Snecma Property)*

In parallel, extensive spin tests for fan containment studies (Dresden University), Ballistic tests and Fatigue tests (Oxford University) are performed in 2005 and 2006 to support full scale single-arm Bird Strike Test, and Fan Blade-off Test in 2008.

4.4 Booster Modules

Advanced Aerodynamic Technologies are studied on a scaled down highly loaded booster mock up at VKI, Belgium, that have been designed and built to perform a test campaign in 2006.

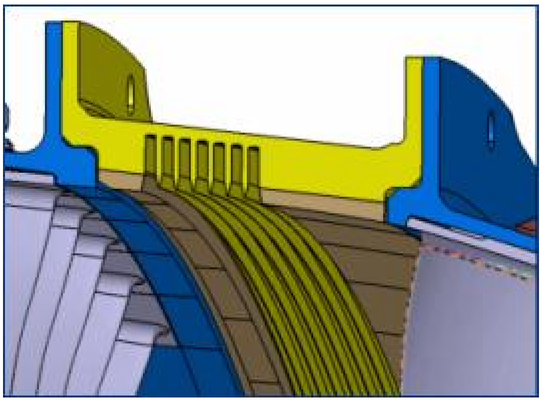

Fig. 5. Casing treatment concept study for Booster application *(CIAM and Techspace Aero Property)*

A full-scaled highly loaded low speed booster has been designed by Techspace Aero and manufacturing launched for aero tests in 2007 at CIAM, Russia.

Volvo Aero Corporation performed high-speed booster design for aero evaluation DDTF 3-shaft engines in 2008 at FOI, the Swedish Defence Research Agency.

4.5 Casing Modules

Typical engine structures have been selected as application examples for developing light weight cold and hot structural components. The cold structure consists of a core engine structure utilising automated titanium fabrication technology on a by-pass structure with fan outlet guide vanes and outer ring in polymer composite. Manufacturing and material technologies for hot structural components are also being developed to reduce weight and increase competitiveness compared to integrally cast designs.

An automation system architecture has been outlined to respect weight and lead-time reduction objectives.

4.6 Shaft Modules

MMC Cylindrical samples have been manufactured and tested. First Steel – Titanium joins have been evaluated. Promising shaft material combinations have been selected for Multi Metallic shaft.

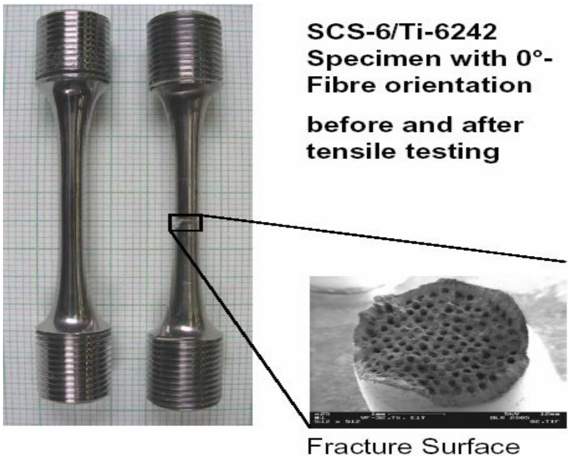

Fig. 6 – MMC samples for mechanical studies *(DLR property)*

4.7 Turbine Modules

Concept studies and numerical investigation on Ultra High Lift, Ultra High Stage Loaded and Low Noise technologies have been carried out.

Design of linear cascades for aero-design technologies validation have been finalised for cascade test campaigns.

Ceramic NGV design has been completed.

4.8 Installation

Wind Tunnel Test configuration has been established for a first test run at Cepr 19 facility, France, by end of 2006. It includes a conventional and an advance nozzle at BPR 9 evaluated in SilenceR programme, a wing coming from Europiv, and a couple of pylons designed to be representative of a close coupling configuration.

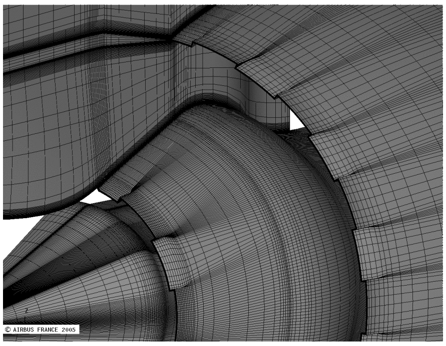

Fig. 7 – Mesh for aero acoustic evaluation of installed advance nozzle *(Airbus, Snecma, Roll-Royce and ONERA property)*

5 Conclusion

VITAL is an ambitious programme that integrates a large number of European industrials, universities and research centres to prepare the future of the European Aeronautical Industry.

Year 2005 was focussed on specifications, material characterisations and first design studies. First significant test campaign are going to be realised in 2006, providing a first assessment of the 3 architectures DDTF, GTF and CRTF for 2 ranges of application. Year 2007 will be devoted to the most significant aero and acoustic tests for fans, turbines and booster modules.

6 Acknowledgement

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7 References

[1] SAR21 Strategic Aerospace Review for the 21st century, July 2002

[2] European Aeronautics: A vision for 2020, January 2001