COLLABORATIVE EUROPEAN AERO-ENGINE ENVIRONMENTAL RESEARCH PROJECTS LED BY SNECMA AND ROLLS-ROYCE

Christian Mari*, Richard Parker**
***Snecma, **Rolls-Royce plc**

Keywords: *collaborative research, environment, noise, emissions, Europe*

Abstract

Rolls-Royce and Snecma have been developing collaboration in the field of Research and Technology, especially on environmental issues in order to meet the challenges to the Air Transport System for the next two decades.

In the past 4 years, RR and Snecma have been involved in the preparation of the ACARE Strategic Research Agenda, setting up a common view of the research needed for the next 20 years in the field of civil aero-engines.

Rolls-Royce and Snecma have been collaborating for several years in the frame of the 4th and 5th European Framework Programme for Research and Technology Development. They are particularly involved in two major projects focussing on environment : EEFAE, aimed at reducing emissions, led by Rolls-Royce, and SILENCE(R), aimed at reducing noise, led by Snecma-Moteurs. Both projects are under way and have already proven innovative concepts to be successful in reducing emissions and noise. A step further can be made by a new project, submitted in the 6th Framework Programme. Under the coordination of Snecma-Moteurs, with major technical contribution from Rolls-Royce, the VITAL proposal addresses new engine architectures that are needed to achieve the ACARE goals for noise and CO_2 emissions.

1 Introduction

Rolls-Royce and Snecma are the two major aero-engines manufacturers in Europe.

Snecma is an aerospace propulsion and equipment group with sites in France, Europe, North America and other parts of the world. Its industrial activities include commercial and military aeronautics propulsion (CFM56 family, M88, SM146, etc.) equipment (landing and breaking systems, power transmission, control systems, nacelles, etc.), services, helicopters propulsion, space propulsion and defense products.

Rolls-Royce operates in four global markets - civil aerospace, defence aerospace, marine and energy. The Rolls-Royce Trent gas turbine is the basis of its latest products for large civil air-transport, marine propulsion and power generation. Rolls-Royce also has a major share in the latest military engine programmes such as the EJ200 and the F136 for JSF. It is the supplier of the complete LiftSystem® for the Joint Strike Fighter. The company now has a total of 54,000 gas turbines in service.

The Aeronautics engine industry is facing challenges that are becoming so difficult and costly to achieve, that they cannot be met without strong collaboration in pre-competitive research involving companies, research establishments and universities. In particular in the engine industry, partnership has become a key factor to success. In Europe Rolls-Royce and Snecma have entered joint projects in order to achieve the goals set for the next 20 years by ACARE (Advisory Council for Aeronautics Research in Europe) and detailed in their Strategic Research Agenda (SRA). Perhaps the most demanding challenges concern the environment.

2 ACARE and the Strategic research Agenda

In 2001, the European research commissioner Philippe Busquin launched the "European Aeronautics : Vision 2020" [1] initiative. A group of high level personalities gathered to establish an integrated vision of the European Aeronautics in 20 years. Along with defining a number of high level objectives, they recommended the creation of the "Advisory Council for Aeronautics Research in Europe" (ACARE), in charge of writing the "Strategic Research Agenda" (SRA) for the next 20 years. One year later, ACARE published its first edition of the SRA [2]. This agenda was built of five challenges :

- The challenge of Quality and Affordability
- The challenge of Environment
- The challenge of Safety
- The challenge of Air Transport System Efficiency
- The challenge of Security

Engine manufacturers were particularly involved in the "challenge of environment" working team. Rolls-Royce and Snecma co-chaired this working team and wrote together this chapter of the SRA.

In line with more and more stringent noise and local emissions regulations, as well as the growing concern for global warming, the environmental goals of Vision 2020 and the SRA are very challenging :

- Reduce the perceived noise by half
- Reduce the emitted CO_2 by 50%
- Reduce the emitted NOx by 80%

A large part of these goals rely on engine technology. The contribution of the engine to the CO_2 reduction goal, through fuel burn reduction, is a reduction of Specific Fuel Consumption (SFC) between 10% and 15%. The fuel burn reduction will indirectly contribute to NOx reduction but it will not be enough to reach the NOx reduction goal : at least 60% reduction of cruise NOx emissions should be achieved by the engine (essentially through combustor technologies) in order to achieve the overall ACARE 80% reduction objective for cruise emissions. It appeared that, in order to meet the environmental challenge, a strong collaboration was necessary between the European engine manufacturers and Rolls-Royce and Snecma are major players in building this collaboration.

3 Collaboration between Snecma and Rolls-Royce – a success story

The collaboration between Snecma, particularly the company Snecma-Moteurs, and Rolls-Royce has taken place under the European Commission funded Framework Programme (FP) for Research and Technology Development and has involved cooperation with all the European aero-engine companies, coordinated through an Engine Industry Management Group (EIMG). All FP projects involve a balanced share of large companies, SME, research establishments and academia. Some projects also welcome partners from non-European countries.

In the Fifth Framework Programme, Rolls-Royce and Snecma have collaborated on approximately 30 projects, including two large-scale projects in the field of environment: EEFAE and SILENCE(R).

3.1 Collaborative Research in FP4 and FP5

The seeds of this collaboration were set in the earlier FP4 and FP5 EU funded projects. The ENHANCE project on extended enterprise has allowed manufacturers to significantly reduce time to market. TURBONOISECFD, CERES and ICAS GT delivered validated methods that allowed the engineer to commit designs to product more quickly and for less cost than before. A number of projects on low emissions technologies (LOWNOX III 1 and 2, LOPOCOTEP…) and on emissions modeling methods (CF4D, ICLEAC…) have contributed to the development of low NOx combustion technology. Rolls-Royce and Snecma have also both participated actively to the network of excellence Aeronet II (now followed by the coordination action Aeronet III) which gathered major players involved in air-quality or climate change issues in relation to aviation (with experts on the atmosphere or air-quality). They have provided specific views and technical inputs of the aero-engine manufacturers.

3.2 EEFAE

The "Efficient and Environmentally Friendly Aircraft Engine", EEFAE, is a 4 year project of 101 M€, started in 2000 under the 5th Framework Programme, involving 19 partners from 9 countries and led by Rolls-Royce. The EEFAE objective is to integrate and test a range of new aero-engine technologies which could lead to cost and emissions reduction, in particular :

- reducing fuel consumption and CO_2 emissions by 12 to 20%
- reducing NOx emissions (relative to 1996 ICAO standard) by 60 to 80 %

The project involves building two test vehicles :

- the ANTLE vehicle, led by Rolls-Royce, to test near term (entry in service 2008-10) technologies on a 3-shaft engine.
- the CLEAN vehicle, led by Snecma and MTU, will test longer term technologies (entry in service between 2010 and 2015) for a geared turbofan engine with inter-cooled recuperator.

3.3 ANTLE

ANTLE is based on an existing Trent 500 with the engine being totally changed from the rear of the IP compressor (Fig. 1). The programme synergistically combines EC funded elements with improved combustor and HP turbine funded by the UK Department of Trade and Industry (DTI). As part of the project to achieve lower emissions there is a new HP compressor designed to reduce the complexity of existing designs whilst driving a higher pressure ratio. The turbines are then re-designed to cope with higher temperatures.

These fundamental cycle pressures and temperatures enable designs of engines with lower fuel burn and consequently less CO_2. Additional fuel burn benefits are being demonstrated within ANTLE by the development of secondary air seals that pass lower quantities of air.

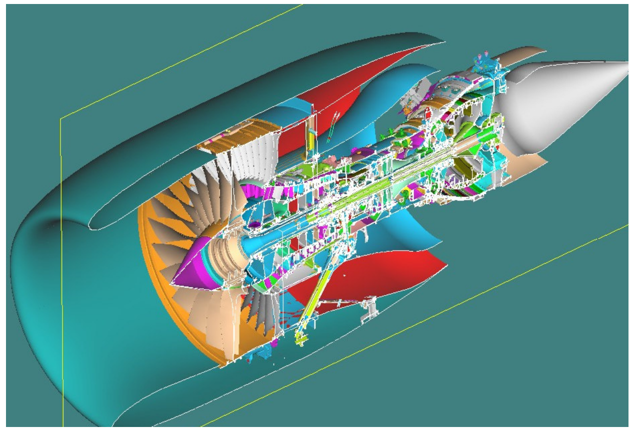

Fig. 1. ANTLE test vehicle

The Low Pressure (LP) turbine has increased stage loading to significantly reduce the weight of this component, enabling turbofan designs to be optimized at higher bypass ratios, further reducing fuel consumption.

Fig. 2. ANTLE combustor injector vs. conventional

The combustor is a concentric fuel staged system, incorporating lean-burning fuel injection technology. This concept aims to avoid the high temperature regions where NO_X is formed by premixing the fuel and air prior to combustion. Such lean-burn systems generally have the disadvantage of limited power range, however by staging of the fuel, which increases the number of injectors flowing the fuel as the power is increased, the full operability requirements for the engine can be met. This technology is the preferred low-cost single annular configuration utilising a novel fuel injector (Fig. 2).

Combustion rig tests undertaken as part of the EEFAE project have already demonstrated NO_X values of less than 40% of the CAEP/2 regulations.
The ANTLE sub-project commenced with the design of the test vehicle and rigs to validate the technologies. The first rig test was of the HP compressor (Fig. 3) which ran in 2001. This demonstrated the use of a "casing treatment" to maintain the surge margin at low powers without invoking variable vanes and their inherent complexity, whilst still able to achieve the high efficiencies at cruise and take-off conditions.

Fig. 3. ANTLE HP compressor rig

After further rig tests of all three of the turbines and the already mentioned combustor and control system the full test vehicle has been assembled and testing is due to start at the INTA testbed in Madrid in the later part of this year.

3.4 CLEAN

The CLEAN test vehicle (Fig. 4) is based on a core from Snecma-Moteurs, combined with a high speed-low-pressure turbine and heat exchanger both designed and manufactured by MTU Aero-engines.

In view of reducing the CO_2 emissions, the German partner MTU Aero engines have been working on an optimised low-pressure turbine and a heat exchanger designed to further improve the thermodynamic cycle.

Snecma-Moteurs is particularly involved in two modules : the high-pressure compressor with active surge control and the combustor.

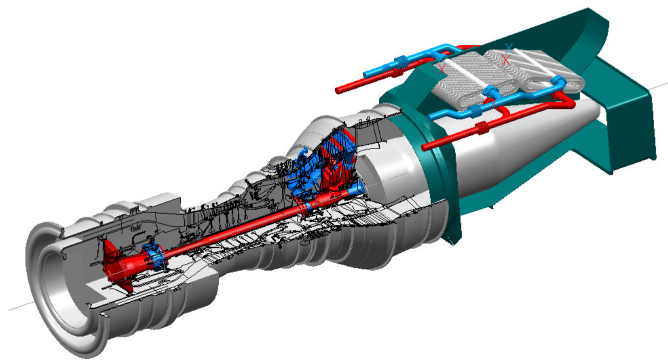

Fig. 4. CLEAN vehicle

The compressor features an active surge control system, aimed at improving the engine efficiency and therefore reduce fuel consumption. This highly innovative system offers very prompt detection and real-time control of surge precursor events, through 36 pressure sensors distributed over the compressor stages and linked to a system control algorithm to detect signals and interpret them correctly. This system was validated using a comprehensive database gathered from demonstrators and engines that have been exposed to surge. In case of surge, the system activates variable stator vanes and rapid response relief valves which release the excess pressure in the compressor. If the system proves feasible, it will deliver a significant increase in engine reliability and efficiency.

The CLEAN combustor (Fig.5) is designed by Snecma-Moteurs, while Avio of Italy is handling the mechanical design and manufacture. Hispano-Suiza, a Snecma group company, is developing the injectors. While ANTLE is testing a concentric staged combustor, CLEAN explores another technological route with an axially staged combustor. This combustor features a Lean Premix Prevaporised (LPP) technology, aiming at reducing the NOx emissions by reducing the flame temperature without altering total air flow, fuel volume or combustor outlet temperature. A regulated fuel/air mixture is prepared in a pre-chamber before being injected into the combustor main stage. A greater proportion of air is mixed with the fuel, creating a lean mix which decreases the flame temperature and therefore the NOx production. This technology requires validation in particular in light of the associated risks of flashback and instability.

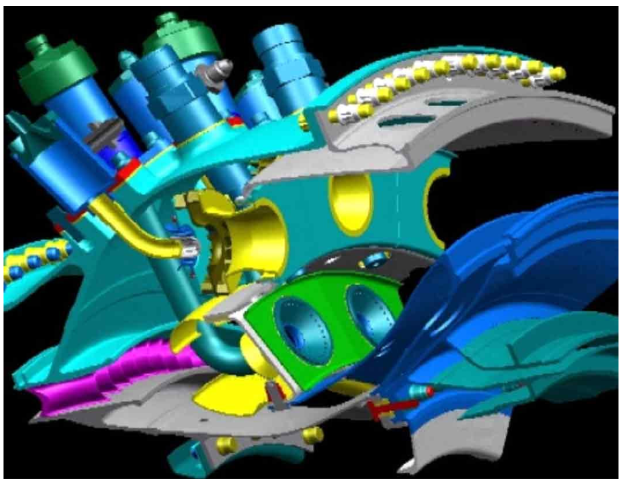

Fig. 5. CLEAN LPP combustor

Testing of the demonstrator will take place this year on a test rig at the University of Stuttgart, Germany. The CLEAN test will demonstrate the effective CO_2 and NOx reduction resulting from the technologies and methods developed in previous FP4 and FP5 projects. Its objective is to demonstrate a 80% NOx reduction.

3.5 SILENCE(R)

In April 2001 the largest aircraft noise research project ever supported by the European Commission was launched. Under the leadership of Snecma Moteurs, 51 companies from 16 countries combined their efforts for a 5-year research project with a budget of 112 M€.

The main objective of SILENCE(R) (Significantly Lower Community Exposure to Aircraft Noise) is to perform a large-scale validation of over 20 noise technologies that were initiated through EC and national projects in 1998. These aircraft, engine, nacelle and landing gear technologies, combined with new noise abatement procedures, will allow new aircraft to be developed with a noise reduction of 6 dB per aircraft operation.

The noise reduction components are being tested in the most appropriate environments, rigs within acoustic facilities, on engines or on aircraft, to ensure the best possible understanding of the technologies prior to commitment to production aircraft and engines.

Figure 6. SILENCER test rig

The project has two distinct phases for each of the technologies. The first covers the initial laboratory testing of the technology concept and the design of the technology prototype, the second covers the prototype manufacture and testing. Between the two phases a critical design review is held for all the technology stakeholders, from research institutions to aircraft manufacturers to agree that the technology is worthwhile to proceed to the full phase two part of SILENCE(R). The project has seen many technologies successfully validating noise benefits in phase two, with many more successfully through the phase one of the project.

Currently the project is in its second half and has completed the last optimization step. Rig and full model tests have confirmed design predictions and concepts will meet the low noise targets identified. Most technologies, including some very innovative concepts, have proven to be successful and have gained approval to continue to the 2nd and final phase : large-scale validation. Preparation for the large scale validation is ongoing and several test campaigns using wind tunnels, static engine tests and flight tests are taking place from 2003 through 2005.

Although the industry launched several large commercial programmes during the course of this research project, commitment from partners to provide necessary resources have been maintained.

4 The next step : VITAL

The collaboration between Rolls-Royce and Snecma will continue under the 6th Framework Programme (FP6). Among the FP6 first call projects awarded last year, 9 projects involve both companies.

Although significant improvement will be made on noise and emissions with the EEFAE and SILENCER projects, in order to reach the demanding ACARE goals for 2020, some further technological breakthroughs will be necessary.
Another large scale project, enVIronmenTALly friendly aero-engine (VITAL), focussing on reducing the environmental impact of engines was submitted to the European Commission in the FP6 second call. This proposal, involving 55 partners from 13 countries, is led by Snecma-Moteurs. It is focused on low-pressure component technologies for reducing noise and CO_2. While SILENCE(R) is addressing engine and aircraft technologies aiming at reducing the noise produced by a conventional architecture engine, VITAL proposes to focus on new engine architectures. The VITAL proposal is also complementary to the EEFAE project as it addresses the CO_2 reduction through propulsive efficiency improvement, while EEFAE addresses the thermal efficiency.

The project has as its core three engine concepts that have the potential to achieve the overall aims. These are the conventional direct drive turbofan, but at a much higher bypass ratio than is typical of today's engines, the geared turbofan and the contrafan (Fig. 7).

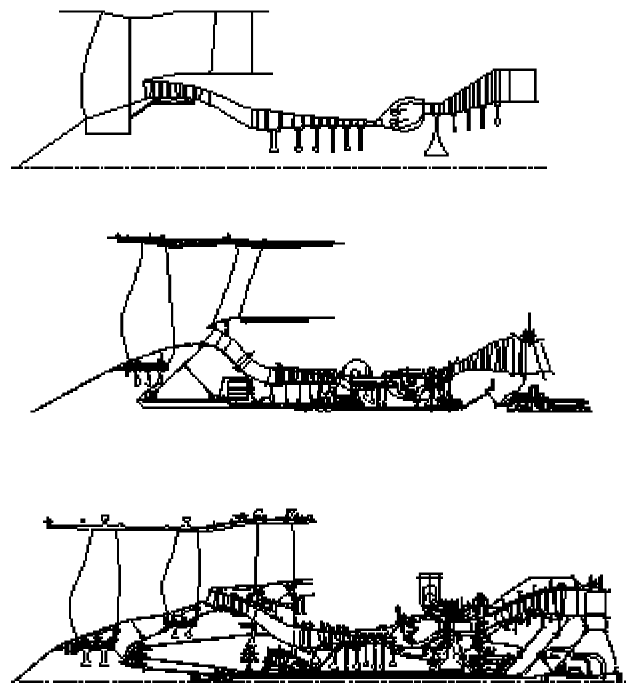

Fig. 7. VITAL engine concepts

All three concepts rely on technology developments to reduce the weight of fan blades, containment systems, structures and nacelles. In addition, the direct drive turbofan and the contrafan rely on increasing the torque carrying capability of the LP shafts without increasing in diameter, which would have a detrimental effect on the size and hence weight of the core and its efficiency due to the higher hub-tip ratios forced into the rear of the compression system. Each engine will have a unique concept of LP turbine, but there are many common threads of technology required. The LP boosters of each design also brings issues with increasing bypass ratio, be they the low speed designs of the direct drive turbofan and the contrafan, or the high speed design of

the geared turbofan. By increasing the efficiency of the fan system due to contra-rotation the benefits of the higher bypass ratios of the direct drive and geared turbofans may be achieved at a slightly lower bypass ratio.
The VITAL project will address all the component technologies required for these configurations. The most promising designs will then form the basis of a major new whole-engine validation project in Framework 7.

Rolls-Royce propose to take the technical responsibility of 2 major work-packages : fan and engine integration, while Snecma Moteurs, along with coordinating the project, propose to lead the engine installation and the high torque shaft work-packages. This very balanced share of responsibility between the two companies is against a background of a large partnership where all other European large aero-engine companies (Avio, ITP, MTU, RRD, Techspace Aero, Volvo Aero) have a significant contribution.

5 Conclusion

Reductions in noise and emissions are essential to enable the continued growth of the aviation industry in the face of continued pressures for clean local air, avoiding disturbances and the threat of global warming. Snecma and Rolls-Royce are demonstrating that by working together we can achieve the reductions required and can then take them to the market place in separate products that enable the commercial needs of our customers to be met whilst achieving the environmental benefits for the community in the shortest timescale.

Snecma and Rolls-Royce have had several years of common experience in R&T and will continue. Such collaboration contributes to the creation and development of a European research momentum towards the two top level objectives set by the European Group of Personalities for Aeronautics: meeting the citizens' needs and ensuring global leadership of European Aeronautics industry. Their collaboration tackles particularly the issue of environment in order to allow air traffic growth at no environmental cost. By learning to work together, Rolls-Royce and Snecma are demonstrating that it is possible to combine the commercial competition which brings dynamism to our industry with a common strategy for upstream activities which will ensure the future and will bring benefit to the European Aeronautics industry.

References

[1] Report of the Group of Personalities. *European Aeronautics: A Vision for 2020.*, European Commission, 2001.

[2] Advisory Council For Aeronautics Research in Europe. *Strategic Research Agenda*, ACARE, 2002.