Research and Technology at Snecma
to ensure sustained development of air transportation

Abstract

The sustained development of air transportation requires that all progress already achieved in the past should be continued in terms of the reduction of costs, while reducing the impact of air transportation on the environment.

The European Community and the industry have set a number of very ambitious objectives, to be fulfilled by 2020.

In order to achieve the 3 main objectives of reducing the emissions of CO2, NOX and noise, while reducing costs, Snecma develops several technologies in the short – medium - and the long-term.

The emissions of CO2, and hence consumptions, will be reduced through ever higher dilution rates. This is made possible with lighter technologies, and particularly with composite materials: woven structural materials for FAN blades and the cold parts of the engine, ceramic matrix composite materials for hot parts of the engine and metallic titanium matrix composite materials for compressors.

The emissions of NOX will first be reduced with Lean Premixed concentric-staged injection, and then with Lean Premixed Prevaporized injections, when combustor operability issues will have been settled.

The noise will be reduced naturally as the dilution rates increase and also with better-optimized shapes, using new acoustic methods. But to go further, it might be useful to use new architectures at engine level, like the Contrarotating FAN, and/or new positions of engines on the aircraft.

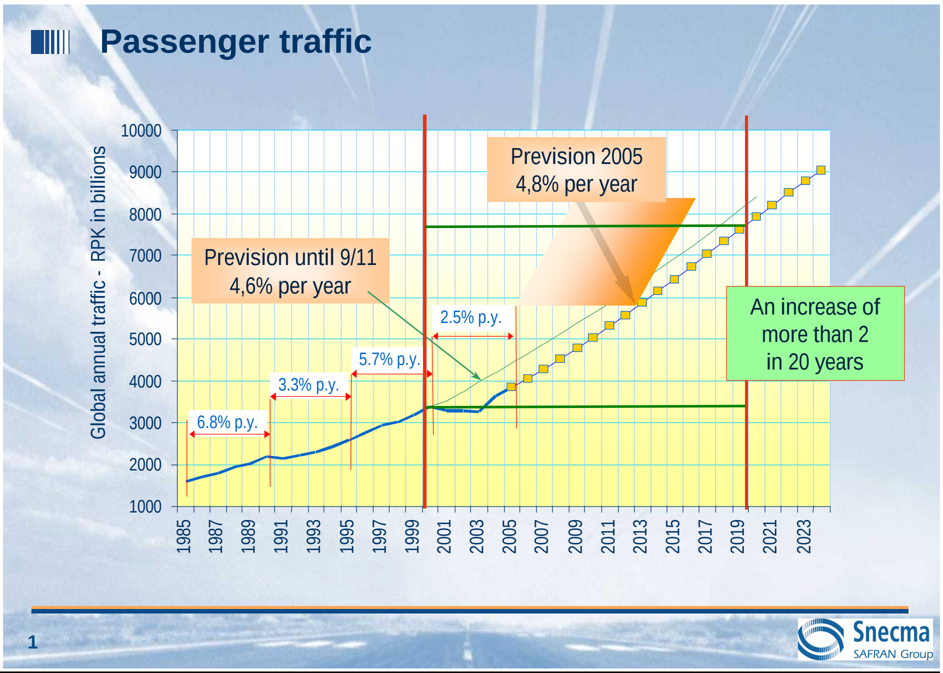
Acoustic control – in terms of prediction using better calculation codes and of attenuation using active devices – certainly is an area for research on which efforts should be focus.

Snecma is preparing all these new concepts and new technologies under a number of in house and national programs and within the European frame work programs, in particular with SILENCER, VITAL and NEWAC.

With all this R&T investment, major progress will be achieved on aircraft engines in terms of the emissions of CO2, NOX and noise, in line with the Vision for 2020.

INTRODUCTION

The growth in air transportation has been almost continuous for the last 40 years and on the whole is correlated with the growth of the worldwide GDP. Is this growth going to be everlasting or will it reach its limits, as it happened to be for some other means of transportation?



Today, the plane is an economical and safe means of transportation for passengers and remains the only practical means for traveling over long distances. What would be the reasons for limiting its growth?

This could be the air space overcrowding, but there still remains a high potential for the optimization of the traffic and the number of passengers by plane can be increased as it is rather low on average.

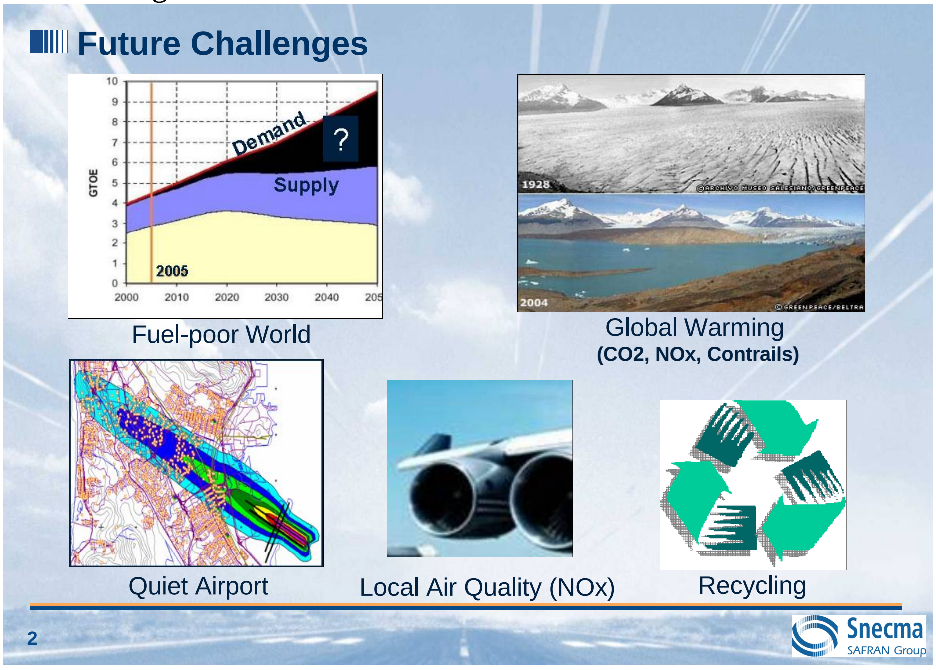
Another limitation can be related to the image among the public of the impact of air transportation on the environment. This impact is felt at two different levels.

Around airports, which, even though they were built in the countryside, are nowadays surrounded by houses. For these people living in the vicinity of airports, noise is an indisputable trouble.

Emissions of nitrogen oxide, though they are not more extensive than the ones produced by land transports in connection with activities induced by the airports, represent another problem.

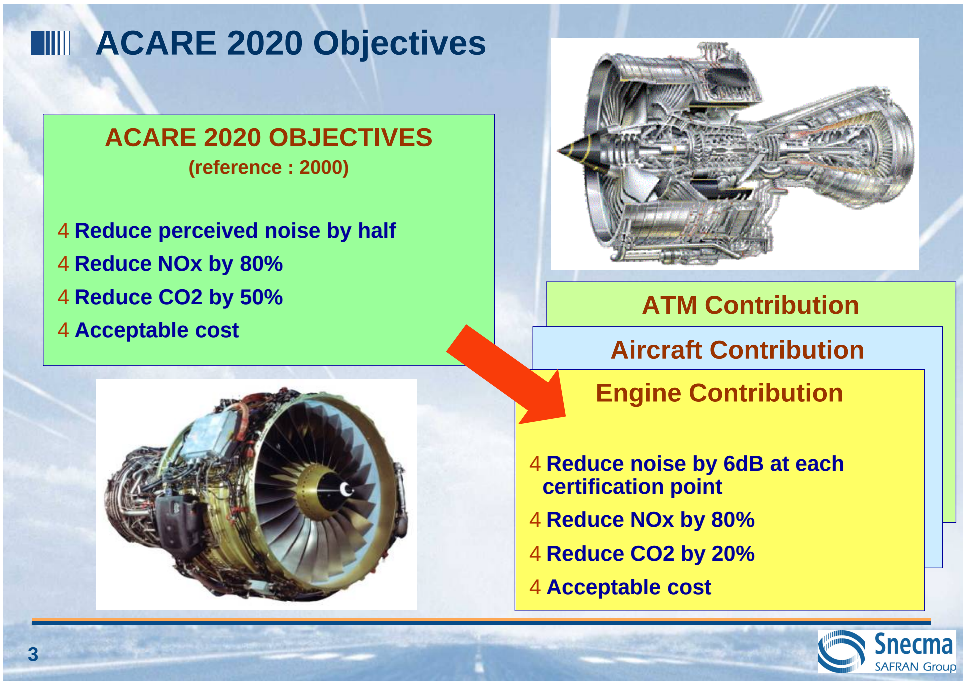
In altitude, the general concern about the effects of human activities on the climate and particularly greenhouse gases, also applies to air transportation.

It is to be noticed that today the air transport represents only 3% of the overall emissions of CO_2, and that the aircraft consumption is only 3 to 5 liters of kerosene for one person over 100 km.
For all these reasons, the aeronautic community is faced today to many challenges which oblige to invest in technologies to be overcame.



In Europe, highly urbanized countries where populations are aware of the pollution problem and climate warming, the aeronautical community has set itself a highly ambitious objective of progress.

In a "Strategic Research Agenda", the European Community has set progress targets for aircraft manufacturers, engine manufacturers and for air transportation management. Compared to the year 2000 situation, the three main emissions of air transportation must be drastically decreased before 2020.



If all these objectives are reached, nitrogen oxide emissions will have become negligible, the noise-related trouble will be limited to the inside of the airports and the decrease in the fuel consumption and corresponding CO_2 emissions will make the air transportation still one of the most efficient means of transport.

Progress already performed on these three topics are important, but the generation of today's engines, embodied by the CFM 56-7 and the GE 90-115 is still far away from these objectives and progress is asymptotic for the time being.

The objectives set by ACARE in Vision 2020, which need a move of the asymptotes are therefore a real technical challenge for the aerospace manufacturers. In order to distribute the efforts and to make each actor responsible, the objectives have been shared between the aircraft manufacturers, the engine manufacturers and the air control management.

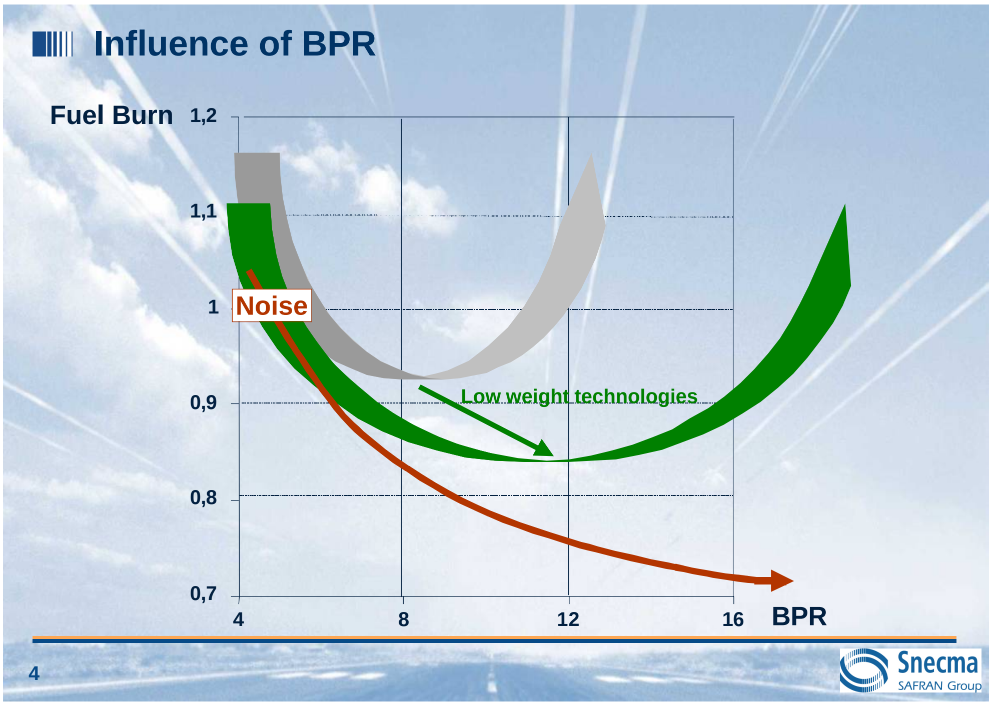
We can think they will be reached in two new generations of engines entirely new, the first generation arising around 2012 and the second one around 2017 which will have to respect the VISION 2020 objectives.

REDUCTION IN CO_2 EMISSIONS

In the future, emissions of CO2 are not intended to decrease thanks to a change in fuel, such as liquefied natural gas or liquid hydrogen. Safety issues related to the distribution of these products and their low density will prevent their use on planes for a long time yet and perhaps for ever.

So, the reduction in emissions of CO2 is in any way submitted to the decrease in fuel consumption.

It cannot be expected either to reduce the cruising speed of the planes, the actual speed having become a habit for the customers, it is difficult now to revise it downwards.



To improve the engine efficiency, the best solution is to increase the dilution ratio to the optimum, when the gain in propulsion efficiency is compensated by the increase in the engine diameter and the resulting weight and drag increase. The use of lighter technologies will move this optimum upwards. With today's technologies, the optimum dilution ratio is approximately 8, it will be ≈ 10-12 around 2012. It is difficult to forecast dilution ratios for 2017.

The general solution of the problem is the use of new light technologies, and Snecma develops several of these technologies based on composite materials.

OMC (Organic Matrix Composites)

Taking advantage of their expertise in the weaving technologies developed at Snecma Propulsion Solide for hot composite materials and the experience of cold composites at Aircelle, Snecma has developed a new category of composites made of woven carbon fibers.

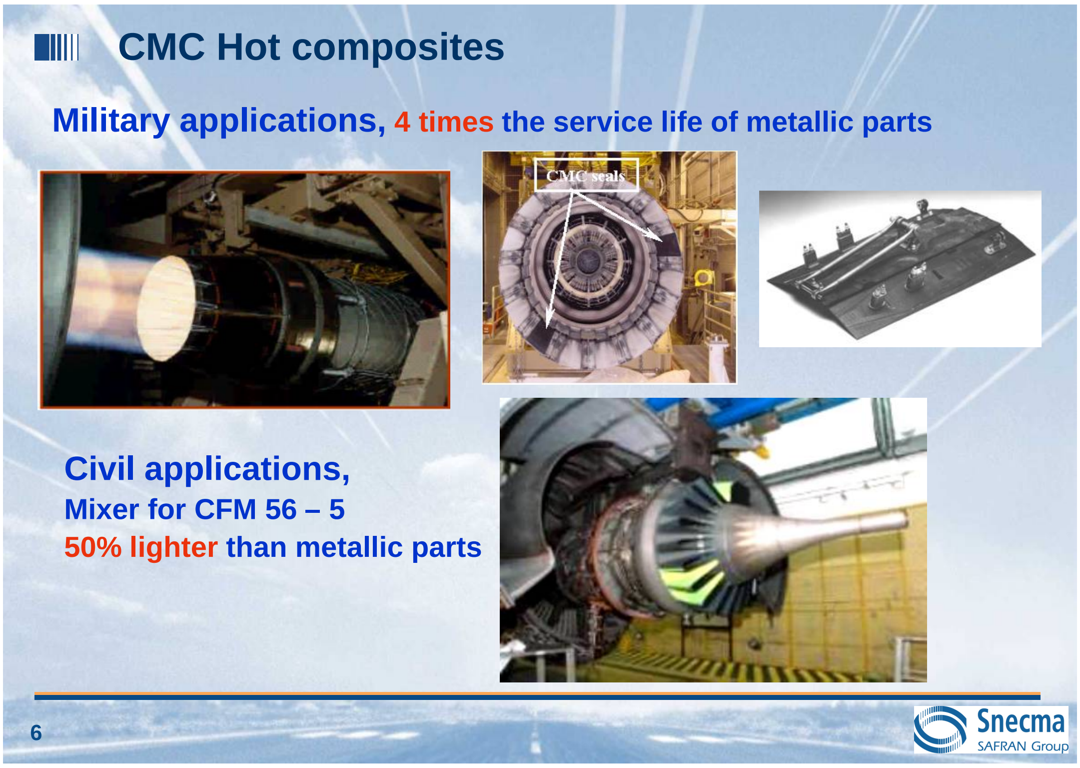
This three-dimension weaving technique is used to create a web of carbon fibers with evolving thickness which is then placed in a mould to inject resin (RTM process). The part thus obtained has the advantages of the carbon fiber resistance in three-dimension, the lightness of the composite and the possibility of complex shapes. In this technology, the two main operations, weaving and injection of resin are automated, which makes it a cheaper technology than the ones it will replace.

This technique was tested for the production of FAN blades with a wide chord geometry optimized for aeroacoustics purposes. The weaving allows part resistance to be optimized in order to give it high resistance to bird impact, together with lightness. The validation program for this technology is in progress.

It will be possible to apply this technology to other elements of the engine, such as structural OGV (Outlet Guide Vanes), casing struts, and also to other parts of the plane structure.

CMC (Ceramic Matrix Composites)

The Ceramic Matrix Composites technologies developed by Snecma Propulsion Solide for rocket propulsion applications, are also used for nozzle flaps on military engines.



This type of material has already demonstrated its remarkable endurance life for military applications (more than 4 times the life of metallic parts), and particularly its excellent resistance to heat and oxidation. This resistance is due to the self-cicatrizing design of the material, which makes it original.

Wiser for this experience, Snecma and Snecma Propulsion Solide are developing afterbodies for commercial engines using these materials which will reduce weight by 50% in relation to metallic solutions.

A CFM56-5 mixer has been produced and tested on engine to get the technology validated.

The verification of a lifetime of a few dozens of thousands hours for commercial applications remains to be confirmed by very long duration testing.

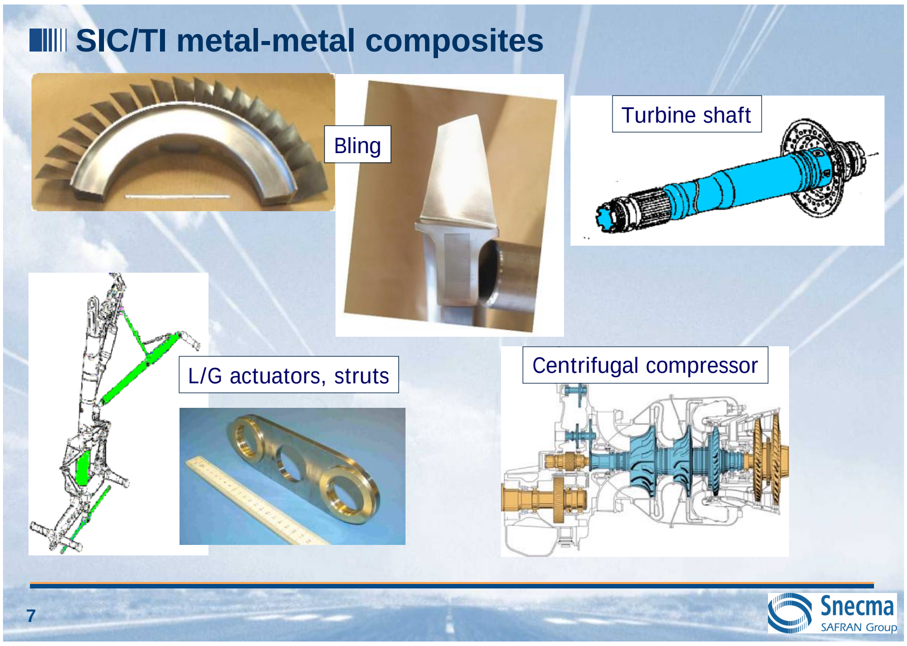
Thanks to this technology, the whole afterbody of the engine could be lightened by 50%.

MMC (Metallic Matrix Composites)

The third type of composite materials developed by Snecma is a Titanium Metallic Matrix Composite. The originality of this Snecma process is the high-speed induction of Silicon Carbide fibers. To that end, they go at high speed through a bowl of melted titanium held in magnetic levitation in a crucible.

This original process is probably the only means of producing fibers coated with Titanium for a reasonable cost. From these coated fibers, it is then possible to make titanium parts reinforced by Silicon Carbide fiber strands and in this way to increase their mechanical characteristics.

Concerning the engines, this will allow to manufacture compressor stages with integrally bladed rings lighter by 30 % than the blisks.
This technology could be used on many different applications for engine parts, or landing gear struts.



Thanks to these three types of composite materials, the engine weight can be reduced, which will allow to increase the dilution ratio and therefore the propulsion efficiency of the engine.

These three technologies are developed within the framework of national programs with the support of the French DPAC and DGA directorates.

Aerodynamics

Another way to improve the engine efficiency is to reduce internal losses thanks to improved aerodynamics. An engine is a nightmare for aerodynamicists, because they have to master transonic aerodynamics with multiple interactions between the ≈ 2000 rotor blades and stator vanes of the engine.

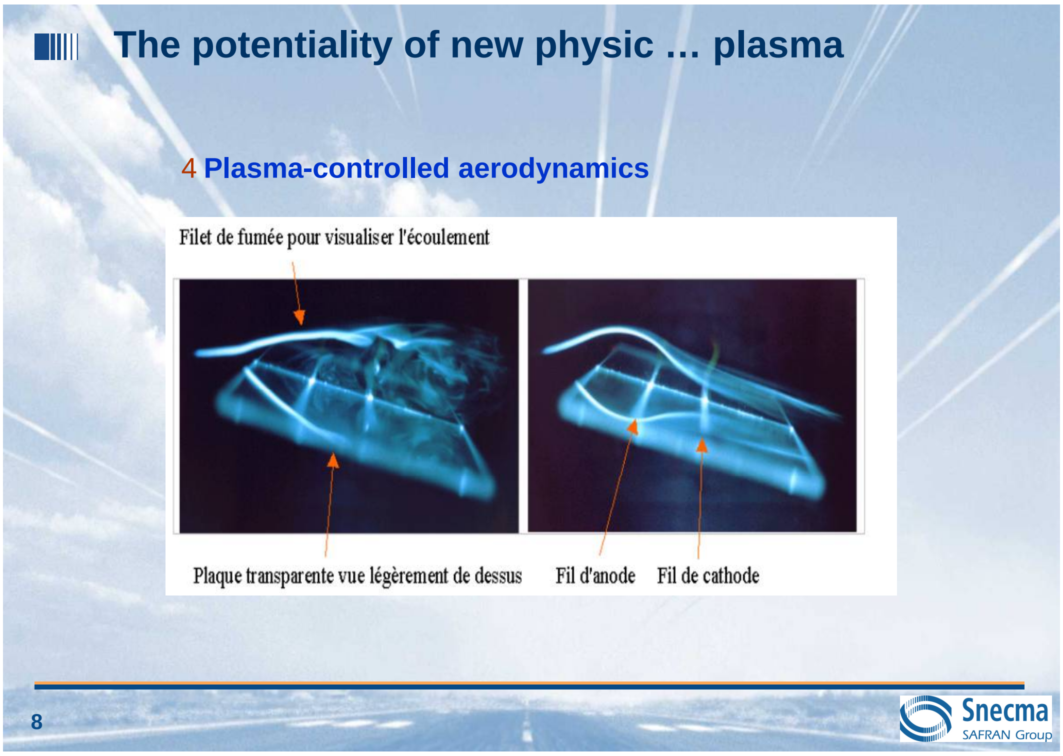
The optimization of the geometry requires the use of 3D fluid mechanic calculation codes capable of modeling turbulences as well as unsteady phenomena.

Codes adapted to the aerodynamics of gas turbine engines are developed by research organizations such as ONERA.

Today, we have already made the most of the optimization of 3D shapes, the next progress will come from several advances : wall aerodynamics control together with casing treatments, recirculation, separation control thanks to blowing or suction operations and active controls.

Within the framework of the European program CLEAN, Snecma tested a system of active surge control which operated perfectly with the measurement of surge precursors and the actuation of fast acting bleed valves.

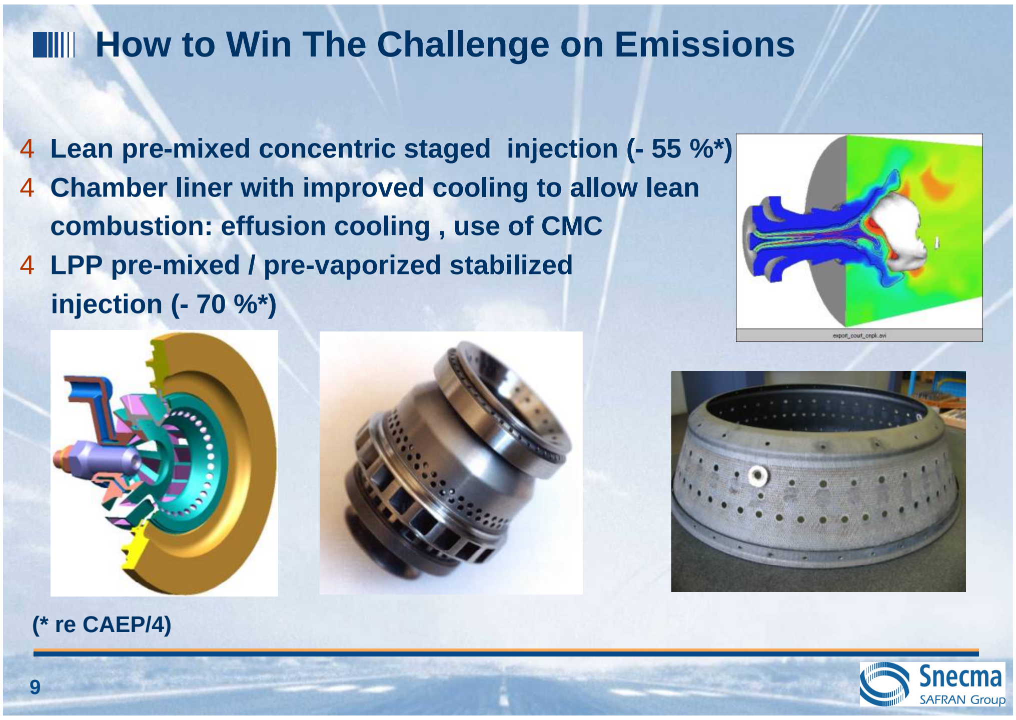
In the long term, the new technology of the “cold plasmas” will maybe offer a simple and fast means of active control of the flows in a gas turbine engine .



<u>REDUCTION IN NOX EMISSIONS</u>

To reduce the nitrogen oxide emissions Snecma has chosen the classical way of a lean combustion with limited temperature, which will naturally reduce the emission of NOX.

To do so, three particular technologies are being developed to have a lean combustion and to perfectly master the combustion.



In the short term, the LP (Lean Premixed) injection while ensuring a better mixture of the fuel with the air will allow a reduction of NOX between 50 to 55 %. These new injectors must perform with a single annular combustor, the same level of performance reached with specialized double-annular combustors, one for Idle, the other one for Full Throttle. A single annular combustor is of course more desirable for turbine performance and durability as so for engine operating cost than a double-head combustor.

To achieve a less hot combustion, there must be a maximum quantity of air for combustion, by decreasing the cooling air in the combustor body. The development of a combustor body made of ceramic composite material will meet this objective. A combustor of this kind was produced and tested on a CFM56-5 chamber in the framework of the technological cooperation program between GE and Snecma (JTDP).

The LP injection associated with a combustor body in CMC should allow a reduction of 65 % to be reached for high OPR engines.

The third technology in a longer term is the LPP injection (Lean Premixed Prevaporized) which was tested on a double annular combustor within the framework of the European program CLEAN. This technique is highly effective in the NOX domain, but it is very unstable, particularly during idle phases.

New physical solutions make us hope to solve this problem. In these conditions, this technology would allow to reduce the NOX emissions by 80% and by the way to go beyond the objective set in VISION 2020.

Combustion codes

In order to master combustion, specialized codes are necessary. Snecma has developed in partnership with Renault and EDF the N3S Natur code which allows today the simulation of all the flows in 3D in a combustion chamber whose aerodynamics is particularly complex and deliberately very turbulent.

The calculations take into account the combustion phenomena including NOX production, the thermal transfers with the walls, but also the radiation phenomena which cannot be ignored. This phenomena is simulated by the ASTRE code developed by the ONERA.

In order to study the phenomena of combustion instability and flame blow out limits, the LES (Large Eddy Simulation) technique is efficient and the calculations are performed with the code AVBP of the CERFACS. This type of calculation is now operational for a complete combustion chamber and shall be used during the design phase for new chambers.

Thanks to the technologies mentioned above and with the available means of simulation, the development of a perfectly clean combustion chamber will be a reality and the objectives of VISION 2020 could be reached.

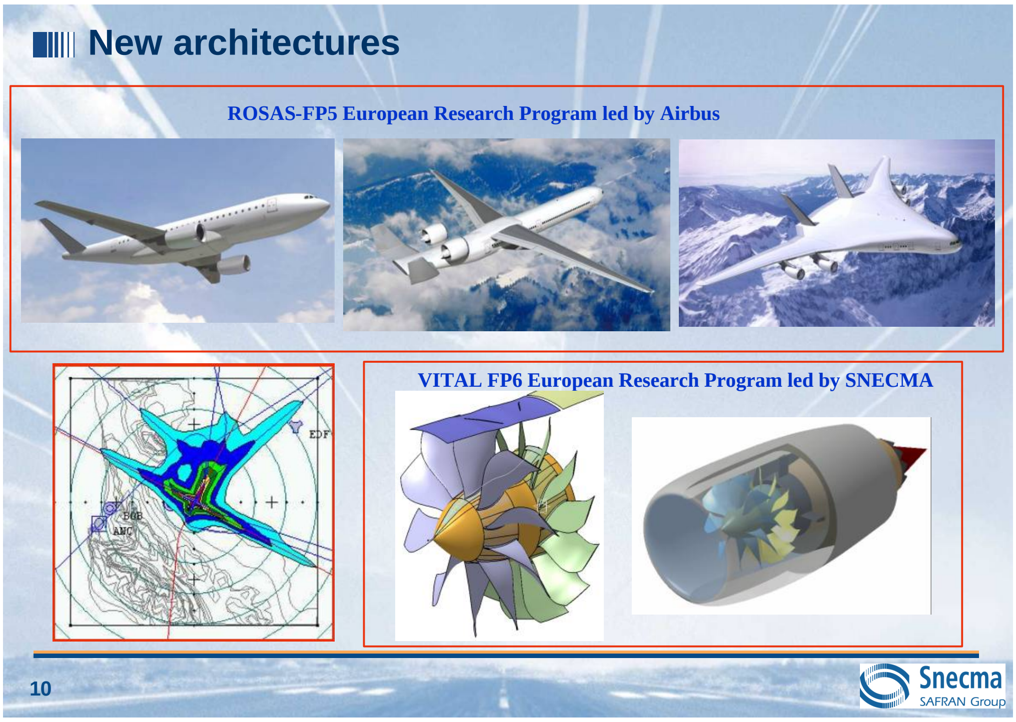
NOISE REDUCTION

The objective of noise reduction in the VISION 2020 program is very ambitious and equals to - 40 EPNdB in relation to OACI § 3.

To reach this goal, we will have to progress along all the possible ways: reduce at source, absorb, carry out active controls. Maybe it will also be necessary to change the architectures of planes and engines.

Architectures

On the engine side, Snecma is studying the acoustic interest of architectures with Contra FAN within the framework of the European program VITAL and will carry out aeroacoustic tests in Russia on a CIAM test bench.

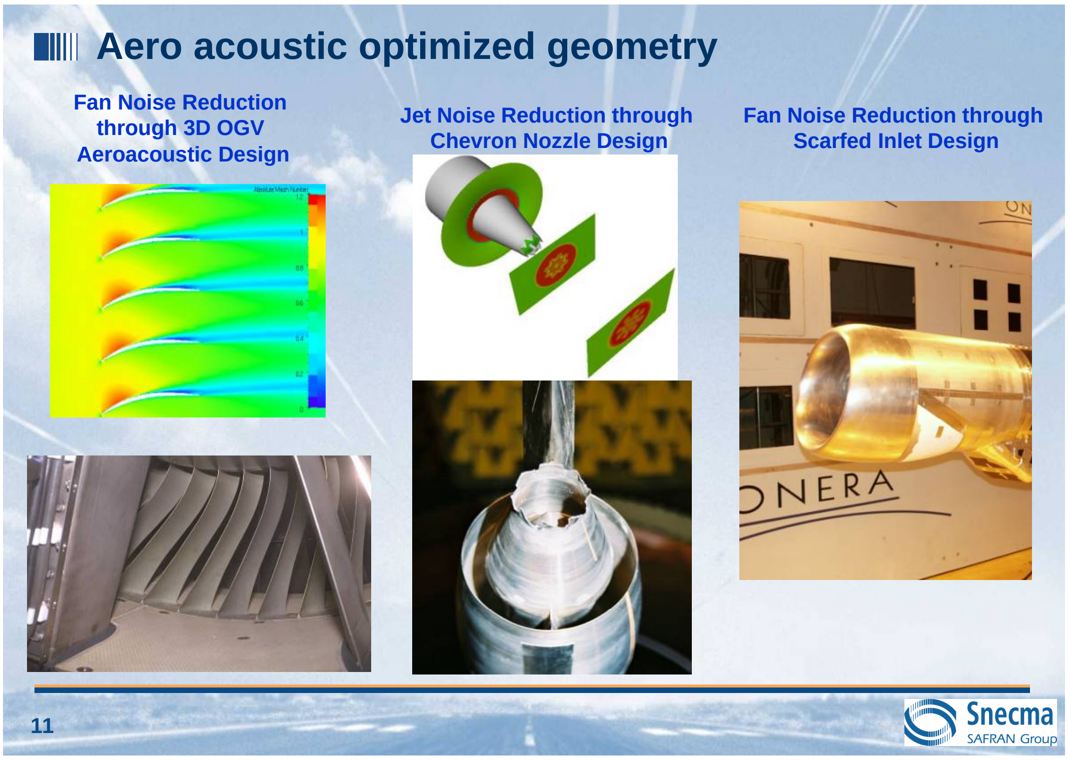


On the plane side, the European programs ROSAS and NACRE headed by Airbus and to which Snecma participates, examine the interest of masking engine noise by the wings or the tail units.

One must remind that the more the noise of the engines decreases, the more other sources of noise on the plane become perceptible and consequently must be also attenuated.

Reduction at source

In order to reduce noise at source, which, for the engines means mainly the noise coming from the FAN and the noise of the exhaust jet, the tendency is to increase the dilution ratio down to the point where there is not any drawback for the consumption. The consequence is the decrease in the FAN and jet speeds, which is favorable to acoustics. The technologies developed to reduce the consumption by increasing the dilution ratio are by the way very useful for the noise reduction.



Above this, the decrease in noises at source depends on the optimization of geometry in order to prevent turbulence and interactions. On the FAN side, this leads to very complex "large chord swept blade" geometries, associated to optimized OGV geometries in order to limit wake interactions.

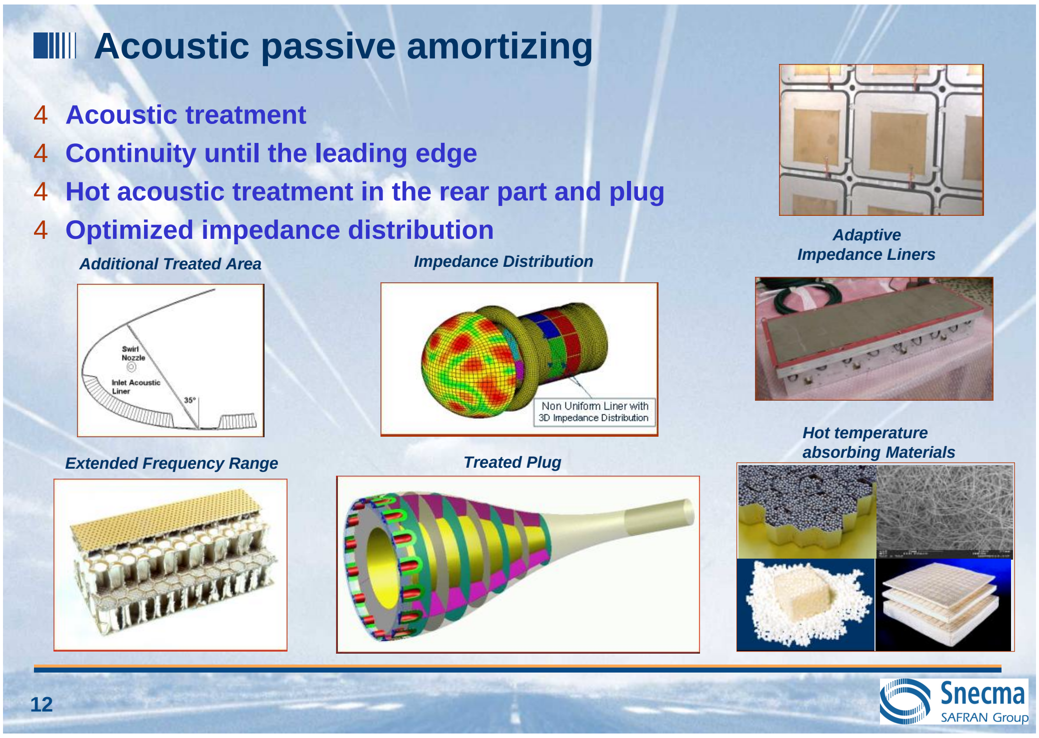
On nozzles side, this leads to a large range of "chevrons" type geometries which accelerate the mixture of fluxes and therefore reduce the noise, if possible, without degrading performances.

On air intake side, a scarfed intake which sends the FAN noise back upwards and on outlet side a special primary nozzle geometry, called "Squid" drawn by Snecma was tested in flight on an Airbus A320 within the framework of the European program SILENCER and gave good results.

Damping

A better efficiency of noise damping depends on the implementation of acoustic treatments, without discontinuities and on the maximum available surfaces. At the front, up to the nacelle leading edge, and at the rear, down to the engine plug and nozzle thanks to acoustic treatments which are heat resistant.

The optimized impedance of acoustic treatment panels will also have a positive effect on noise damping.

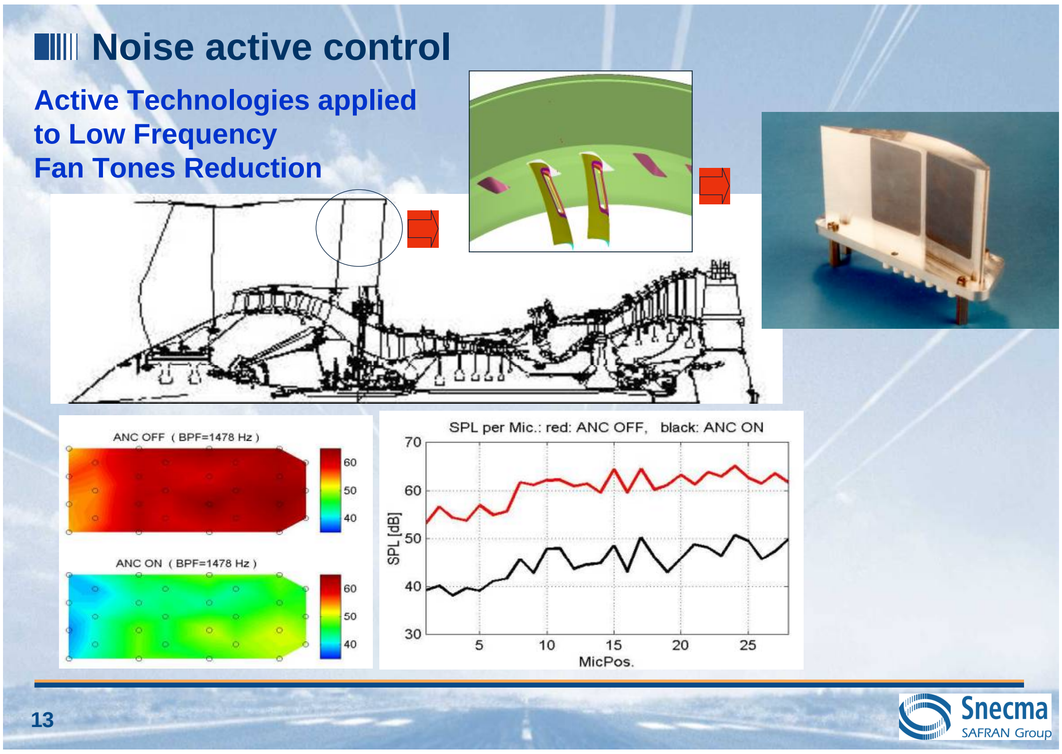


Active means

Beyond passive measures to absorb noise, there are active means. In order to reduce FAN noise, specially tone noise, experiences were carried out with noise generators in opposite phase, implemented on the wall of the air intake but also on the strut arms downside of the FAN. The results are encouraging, but still progress remains necessary in the algorithms for noise control and in the miniaturization and the weight of noise generators.

On the jet noise side, fluidics with continuous or pulsed air jets will be able to perform the chevrons equivalent effect and reduce noise.

But, in order to master this type of device, empiricism is not enough and simulation tools must be available.


Noise active control
Active Technologies applied
to Low Frequency
Fan Tones Reduction
ANC OFF (BPF=1478 Hz)
ANC ON (BPF=1478 Hz)
SPL per Mic.: red: ANC OFF, black: ANC ON
SPL [dB]
MicPos.
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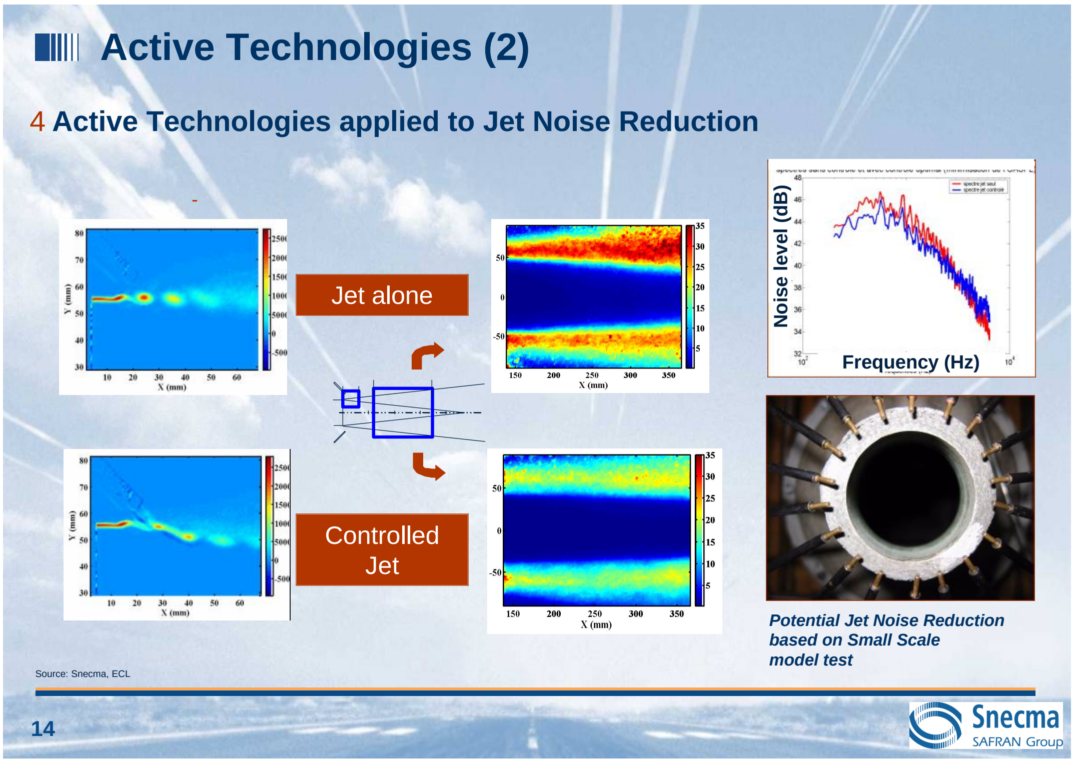
Active Technologies (2)
4 Active Technologies applied to Jet Noise Reduction
Jet alone
Controlled
Jet
Noise level (dB)
Frequency (Hz)
Potential Jet Noise Reduction
based on Small Scale
model test
Source: Snecma, ECL
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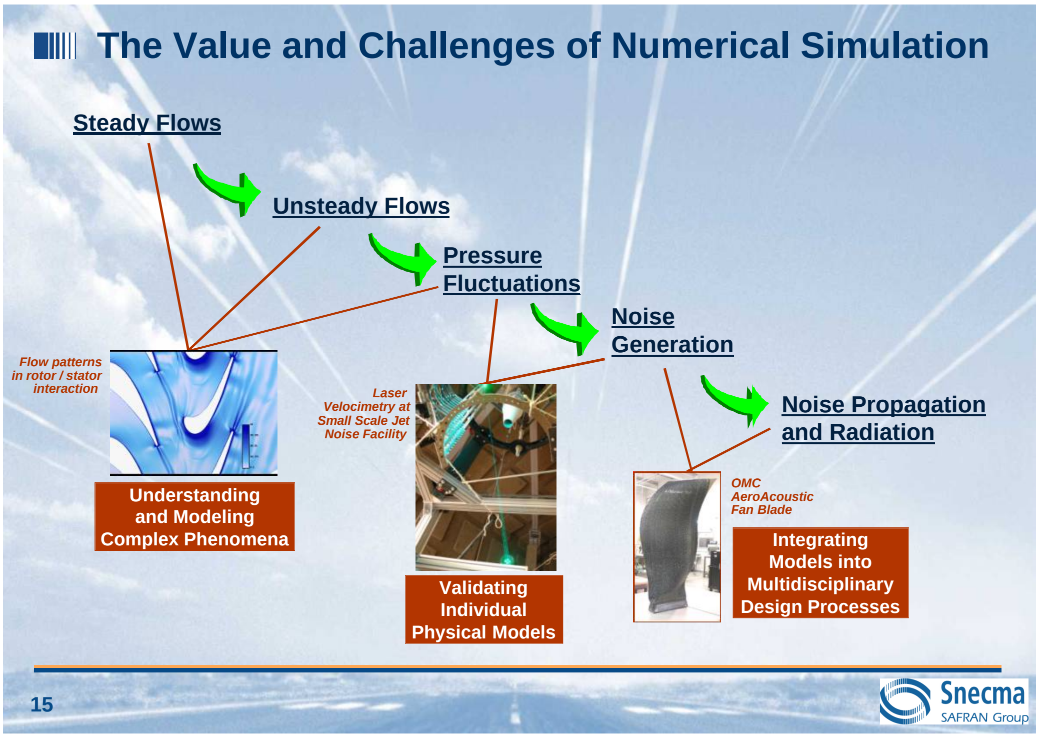
Calculation Codes

The task of optimizing the geometries is based on powerful aerodynamics codes to highlight turbulence and noise production and acoustic propagation codes to check acoustic impact far away from the engine.

Today, the simulation tools are qualitatively representative but quantitatively imprecise. Progress in these aeroacoustic simulation tools is essential.

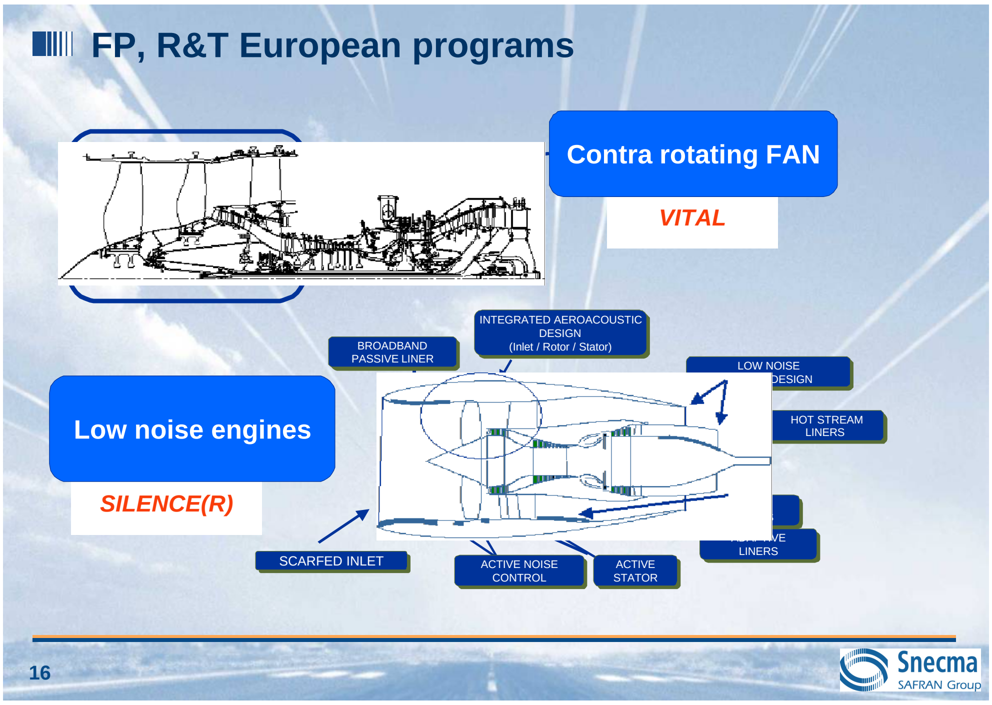
Progress in acoustics should be like the one obtained in aerodynamics in the last years, thanks to the use of 3D Navier Stockes fluid mechanics codes.



The possibility of correctly simulating noise generation will give the designers the tool which will allow them to really optimize the shapes and the active devices. This will enable considerable progress in acoustics which is still nowadays very empiric.

CONCLUSIONS

Snecma plays a significant role in the great "environment-oriented" European Programs. Snecma specially coordinates the SILENCER program of the 5th PCRD and VITAL of the 6th PCRD.



In addition to environmental requirements, the aircraft and engine manufacturers have to respect another constraint : economy. All progress in the emission domain, which will be possible thanks to new technologies, shall be offered at ever reduced costs.

The challenge of the industry is to invest in the development of new technologies to be able to offer always higher performance products, and to remain competitive.

This is a necessary long-term investment whose success and profitability are not always guaranteed. This is why this effort is encouraged, either thanks to national programs, or to European programs.

In relation to today’s situation, the newly developed engines such as the SaM146 by Snecma for regional aircraft or the GENX by General Electric for the long range aircraft which will fly around 2007 will represent a first step.

A second step will occur with a new generation of engines around 2012.

A third step which has to fulfill the ambitions VISION 2020 objectives will be achieved before 2020, maybe with new architectures of planes and or engines.

The positive results already obtained in the R&T programs, the opportunities offered by the various technologies described above, associated to improved simulation means, in aerodynamics, in combustion and especially in acoustics, all of these parameters would make it more realistic to reach the ambitious objectives set by VISION 2020.