Toward ACARE 2020: Innovative engine architectures to achieve the Environmental goals?

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OVERVIEW

The Advisory Council for Aeronautical Research in Europe (ACARE) identified the research needs for the aeronautics industry for 2020, as described in the Strategic Research Agenda (SRA), published in October 2002. Concerning the environment, ACARE fixed, amongst others, the following objectives for 2020 for the overall air transport system, including the engine, the aircraft and operations:

- Reducing fuel consumption and CO_2 emissions by 50% with 20% for the engine alone
- Reducing perceived external noise by 50%, with 6dB per operation for the engine alone
- Reducing NOx by 80%, with 60 to 80% for the engine alone

Furthermore, since these objectives have been defined the commercial and political pressure to reduce Fuel Consumption and then CO_2 has increased considerably.

During the last thirty years, the common trend in turbofan design has been to improve thermal and propulsive efficiencies by raising component efficiency and temperatures for the first one and above all by increasing the by-pass ratio (BPR) for the last one. This trend has been amplified in the past decade by the more and more challenging requirements in terms of noise emissions.

With the current technologies, the increase in BPR has reached its limit in terms of fuel burn on mission. Although a higher BPR offers a clear reduction in specific fuel consumption (SFC), it also leads to a significant increase of the engine weight as well as the nacelle and installation drags. Above an optimum BPR value, the penalties brought about by weight and drag, offset the benefits provided by higher BPR.

In this frame, Snecma has proposed a strategy with three engine architectures answering ACARE 2020 objectives and recent global warning concerns in different ways. The first architecture is a conventional one consistent with the one developed with GE through the LEAP56 program launched in 2005.

The LEAP56 program is a “balanced” concept that relies on the CFM56 experience with similar architecture but also on the introduction of very innovative technologies such as new metallic and composite materials, improved 3D aerodynamic…to answer ACARE goals depending on the EIS. At current 2015 EIS milestone target, the LEAP56 baseline already reaches a great proportion of ACARE 2020 requirements.

Then, two more radically innovative engine architectures have been identified to go a step further towards two different environmental priorities:

- first one, the CRTF is a more complex concept, with a new fan concept, Low speed contra rotating fan, which allows a 5dB benefit as well as a slight improvement in performance. The higher number of parts will be outweighed by a smaller needed BPR and lightweight structures. This concept goes beyond ACARE 2020 goals on noise at a given BPR, which might become essential especially if optimal BPR slides to non-installable under the wing diameters or noise requirements increase under public pressure.

- second one, the Open rotor architecture is an even more complex concept that delivers a breakthrough on Fuel Burn and CO_2 emissions thanks to a record propulsive efficiency and no duct penalties. Nevertheless, some key points remain to be solved: community and cabin noise, and reliability of such a complex machine.

Finally, particularly through current EU Project VITAL and to be launched EU Project DREAM, Snecma has already started and will continue the detailed assessment of two main general architectures selected to go toward or beyond ACARE 2020 goals. In parallel, Snecma and GE through the LEAP56 program will carry on to build up technological bricks applicable on any of these three architectures in order to be ready to answer any future environmental requirements.

ACRONYMS

ACARE	Advisory Council for Aeronautical Research in Europe
BPR	By-Pass Ratio
CAEP	Committee for Aviation Environment Protection
CFD	Computational Fluid Dynamics
CLEAN SKY	‘The Greening of Air Transport’ Joint Technology Initiative (tube launched in FP7)
CO_2	Carbon dioxide
CRTF	Contra-Rotating Turbo Fan
DD	Direct Drive (No PGB)

DREAM	valiDation of Radical Engine Architecture systems (to be launched in FP7 EU project)
EIS	Entry Into Service
EPNdB	Effective Perceived Noise level in decibels
EU	European Union
GE	General Electric Company – CFM, CFM56 and LEAP5 are trademarks of CFM International, a 50/50 joint company between Snecma and General Electric Company
GTF	Geared Turbo Fan
HP	High Pressure
IP	Intermediate Pressure
LP	Low Pressure
MMC	Metal Matrix Composite
NACRE	New Aircraft Concept Research (FP6 EU project)
NEWAC	NEW Aero Engine Core concepts (FP6 EU project)
NO_X	Nitrous Oxide
PGB	Power (reduction) GearBox
RANS	Reynolds-Averaged Navier-Stokes
SFC	Specific Fuel Consumption
SRA	Strategic Research Agenda
TRL	product Technology Readiness Level
UHBR	Ultra-High BPR
VHBR	Very-High BPR
VITAL	enVIronmenTALly Friendly Aero Engine (FP6 EU project)
WTT	Wind-Tunnel Test

1. DESIGN STRATEGY REGARDING ENVIRONMENT

1.1. Environmental Goals

The Advisory Council for Aeronautical Research in Europe (ACARE) identified the research needs for the aeronautics industry for 2020, as described in the Strategic Research Agenda (SRA), published in October 2002. Concerning the environment, ACARE fixed, amongst others, the following objectives for 2020 for the overall air transport system, including the engine, the aircraft and operations:

- Reducing fuel consumption and CO_2 emissions by 50% with 20% for the engine alone
- Reducing perceived external noise by 50%, with 6dB per operation for the engine alone
- Reducing NOx by 80%, with 60 to 80% for the engine alone

FIG 1 hereafter presents the ACARE 2020 overall objectives and their translation at engine level.

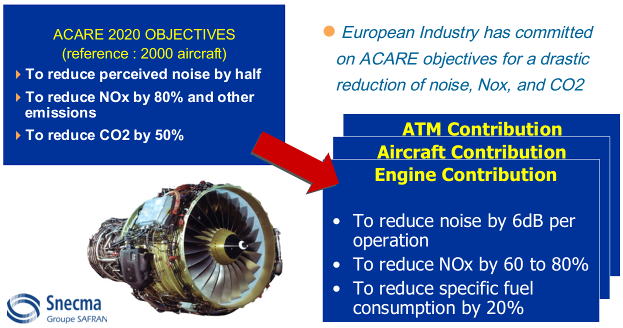

FIG 1. ACARE 2020 Objectives

Furthermore, since these objectives have been defined the commercial and political pressure to reduce Fuel Consumption and then CO_2 has increased considerably.

Indeed, Fuel Burn share increases in usual market driven operating-cost calculations when fuel price rises and very few experts consider that the fuel price won't follow its inflating path. Therefore, even on short-range aircraft where high costs usually counteract slight benefit in Fuel burn, trend may change in future in parallel to fuel price.

Subsequently, in a one-year period, the debate over climate change has dramatically changed, especially in USA following Europe, with the general acceptance that global warming is caused by the amount of carbon emitted into the atmosphere, of which the aviation industry contributes about 2-3%. As a result, at the commonly agreed traffic growth rate of 3-5% a year, the aviation industry faces a moral challenge that should become the main future requirement, as political debates speed up, illustrated by the European Union that have announced at the end of 2006 its plan to impose emission charges for all flights arriving at or departing from member states.

1.2. Engine design past trends

Since commercial aviation beginning, engines design has been the result of a fine compromise between weight, drag and SFC resulting in Fuel Burn, and speed, costs, noise, emissions and reliability while safety has always been mandatory. Improving thermal and propulsive efficiencies are the two paths to decrease SFC but have collateral negative effects on other parameters.

During the last thirty years, the common trend in turbofan design has been to improve these two parameters by raising components efficiency and temperatures for the first one and above all by increasing the by-pass ratio (BPR) for the last one. This trend has been amplified in the past decade by the more and more challenging requirements in terms of noise emissions.

Indeed, fan noise and jet noise are the two largest contributors to engine noise. The trend to increase BPR has had a strong impact on jet noise reduction through decreased jet velocity and has also benefited noise emissions through reduced fan tip speed. Consequently, engine manufacturers have started to propose turbofans with BPR going up to values around 10.

FIG 2 illustrates the evolution of the Fuel Consumption during the past 40 years.

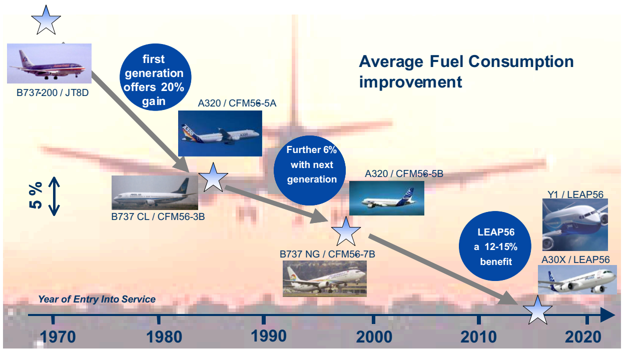

FIG 2. Fuel Consumption Trend over years

1.3. Design Strategy for the future

With current technologies, the increase in BPR has reached its limit in terms of fuel burn on mission. Although a higher BPR offers a clear reduction in specific fuel consumption (SFC), it also leads to a significant increase of engine weight as well as nacelle and installation drags. Above an optimum BPR value, the penalties brought about by weight and drag, offset the benefits provided by higher BPR.

The challenge that is proposed today to engine manufacturers is to find technology solutions that will enable the use of higher BPR architectures without inducing fuel burn penalties whilst providing an optimum BPR value.

In this frame, Snecma has proposed a strategy with three engine architectures answering ACARE 2020 objectives and recent global warning concerns in different ways. The first architecture is a conventional one consistent with the one developed with GE through the LEAP56 program launched in 2005.

The LEAP56 program is a “balanced” concept that relies on the CFM56 experience with similar architecture but also on the introduction of very innovative technologies such as new metallic and composite materials, improved 3D aerodynamic…

Then, two more radically innovative engine architectures have been identified to go a step further towards two different environmental priorities:

- A new fan concept, Low speed contra rotating fan, for Contra-rotating Turbofan (CRTF) that reduce noise levels and fuel burn without the need to significantly increase the BPR.
- Open rotors architectures, which are well known as the best concepts for SFC and Fuel burn but with more limited noise improvements.

2. BALANCED CONCEPT: BASELINE

2.1. Concept Target and main properties

Timed for a target service entry of around 2015, conventional architecture is aimed at producing an engine with 10-15% lower specific fuel consumption than current available engines, 15% lower maintenance costs, up to 15dB lower cumulative noise levels and 25% longer life-on-wing.

This baseline is the best compromise for a fuel price up to 100$/barrel because of its relative simplicity with a low part counts (therefore reduced manufacturing and maintenance cost), and high reliability. At current EIS target, this baseline already reaches a great proportion of ACARE 2020 requirements.

The engine would produce lower nitrous oxide and other emissions than the CAEP/6 standards due for introduction from 2008. It will also have a higher bypass ratio of 9:1 versus 5:1 on CFM56 engines, and a HP pressure ratio of more than 15:1 against the 11:1 of today's high-pressure spools. Although, a two-stage HP turbine concept has been studied to achieve this result, the best performance is reached with a 15% higher loaded single HPT stage and an eight-stage HP compressor.

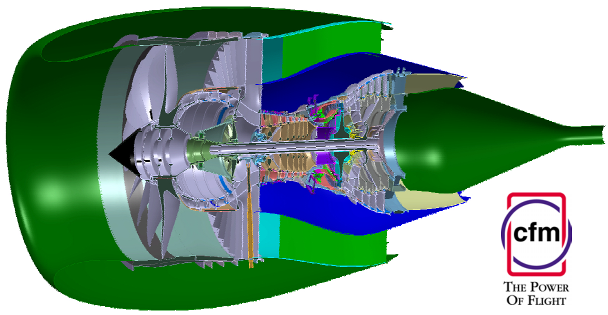

FIG 3. Baseline Engine

2.2. Advanced technologies

Even though, the global architecture is similar to CFM56 engines, this baseline is a highly innovative Turbofan that includes, in addition to a great reduction of number of stages and airfoils, a remarkable amount of advanced technologies: amongst others, a resin transfer-molded 3D woven composite fan blade set, that greatly reduces weight and allows increased BPR, a composite fan case, next-generation 3D aerodynamically designed HP compressor and turbine, advanced low-pressure turbine with titanium aluminide blades…

FIG 4 hereunder shows the time scale of different advanced technologies developed by Snecma for the next CFM56 engine.

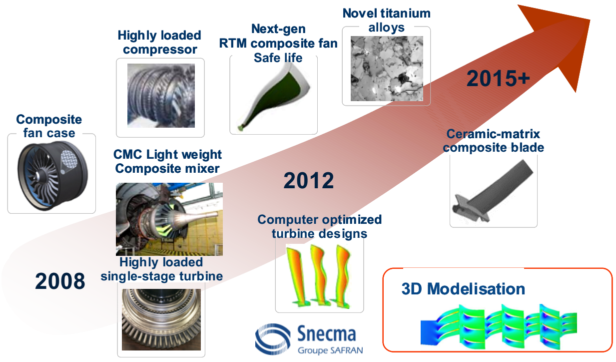

FIG 4. Weight reduction & Aerodynamic improvement

3. NOISE ORIENTED CONCEPT: CRTF

3.1. Concept Target

The EIS targeted for this architecture is 2015-2017. The main objectives are a 10-15% lower Fuel Burn, 20% longer life-on-wing and a 20dB reduction in cumulative noise which go beyond ACARE 2020 target. At same BPR and technological level, this architecture should bring about a 5dB benefit and is consequently identified as a cut noise concept, which might become essential especially if optimal BPR slides to non-installable under the wing diameters or noise requirements increase under public pressure.

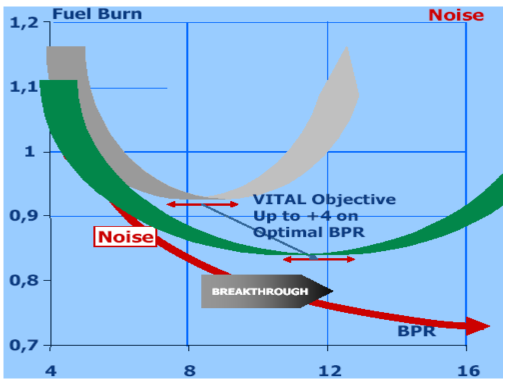

FIG 5. VITAL Fuel Burn and Noise targets

3.2. Concept principles

The aim of this concept is to reduce the fan tip speed without a reduction gearbox that induces a lost in efficiency. This solution consists of two contra-rotating fan stages, mounted on contra-rotating shafts linked to a low-pressure turbine with contra-rotating blade rows. This architecture allows, at a given aerodynamic load, to decrease the rotational speed by about 30%. The fan module being directly linked to the kinetic energy of the rotating parts, this concept provides, at the same technology level, a weight reduction. It is estimated that thrust to weight ratio of the corresponding whole engine is increased by 10 to 12%.

FIG 6 describes the macro-design of the CRTF with the HP Core rotor in green, the LP front fan and turbine rotor in blue and the LP rear fan and turbine rotor in red.

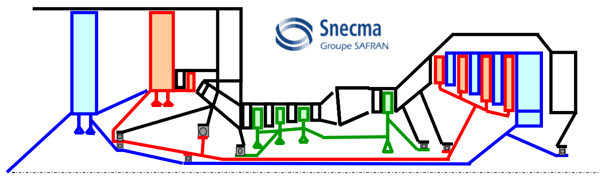

FIG 6. CRTF Architecture scheme

In the past, some studies have been conducted on concepts apparently close to CRTF, but they dealt with configurations using a reduction gearbox, having very high BPR, very low pressure ratio and low numbers of blades, closer to ducted propellers than fans. The solution proposed here is different, as each fan row works aerodynamically at a low tip speed fan. Moreover, variable blade stagger or nozzle throat variable area, are not needed.

FIG 7. CRTF Engine

3.3. VITAL Studies

The Contra-Rotating TurboFan (CRTF) is particularly developed and tested by Snecma within the European Union FP6 VITAL Project. This project has a full duration of 4 years with a termination at the end of 2008 and brings together 52 partners with a total budget of about 90 millions Euros.

The main components investigated in VITAL in order to prove the feasibility and level of general performance of the concept are:

- Low speed contra rotating fan that tackles low Fuel Burn through efficiency and lightweight components, and low noise through low fan tip speed
- New low speed low-pressure compressor (booster) concepts and technologies for weight and size reduction
- New lightweight structures using new materials as well as innovative structural design and manufacturing techniques
- New MMC shaft technologies enabling the high torque needed by the new fan concepts through the development of prototypes that will be tested

- New contra rotating slow low-pressure turbine (LPT) technologies for weight and noise reduction

- Optimal installation of VHBR engines related to nozzle, nacelle, thrust reverser and positioning to optimise weight, noise and fuel burn reductions

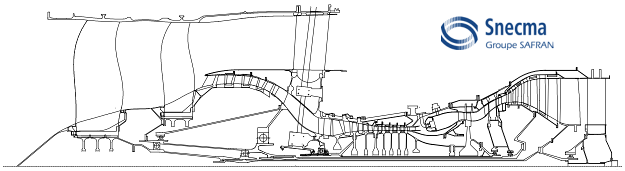

FIG 8. CRTF X-section

This radically innovative concept will reduce noise levels and fuel burn without the need to significantly increase the BPR and new lightweight technologies are studied to compensate the weight penalties induced by the added components.

These technologies will be tested and validated during aero-acoustic WTT and mechanical rig tests in order to bring the Technology Readiness Level (TRL) of these technologies to a level ranging between 3 (proof-of-concept) and 5 (Module and/or subsystem validation in relevant environment).

3.4. VITAL Achievements

In 2005, Snecma made a first design called CRTF1 with the support of CIAM and DLR for aerodynamic, acoustic and mechanical evaluation.

In 2006, CIAM and Comoti have manufactured the mock up hardware of the CRTF1 module and adaptation parts for the test bench. All of them are available for tests. In parallel, a large concept study project was launch in between DLR, CIAM, Cenaero, with ONERA and UPMC support, in order to study CRTF1 design and potential improvement using the state of the art of the advance aerodynamic and acoustic design tools.

In 2007, three tasks are managed in parallel with CRTF1 mock up tests to start in C3-A anechoic chamber at CIAM, Russia, SRF final detail studies and manufacturing performed by COMOTI, Romania, and design of 2 optimized Contra Fan that exploit the conclusions of the advance studies performed in 2006.

FIG 9. Manufactured fan parts *(CIAM Property)*

4. FUEL BURN / CO_2 ORIENTED CONCEPT: OPEN ROTOR

4.1. Targets

The major aim of this architecture is to answer the recent and growing pressure on aviation industry to tackle faster and deeper the global warming issue. Therefore, the main target is to reduce fuel consumption and CO_2 emissions up to 7% beyond the ACARE 2020 objectives, which means 22-27% lower Fuel burn versus 2000 engines. This step will primarily be achieved thanks to the very high propulsive efficiency reached compared to an equivalent Turbofan with a BPR around 40 and to the weight and drag benefit of duct non-existence.

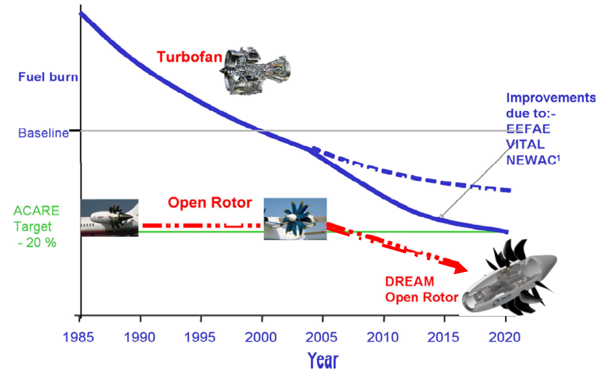

FIG 10. Fuel Burn evolution

However, this breakthrough is achieved at the expense of moderated noise reduction with a targeted reduction of about 9dB in cumulative noise, considering the fact that at same state of the art an Open rotor is intrinsically noisier than an equivalent (same thrust) high bypass ratio turbofan engines. To reach better noise level, an aircraft dedicated installation becomes necessary to take benefit from shielding effects.

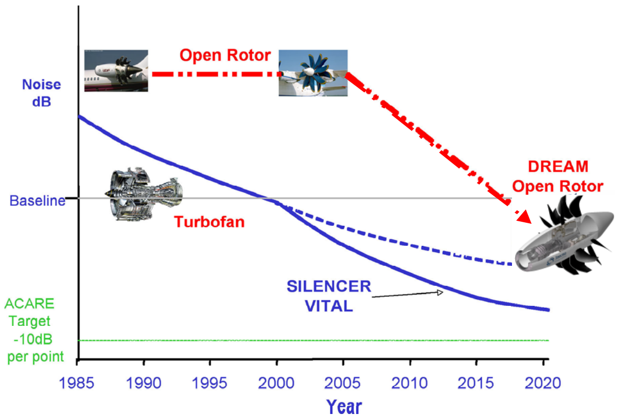

FIG 11. Noise evolution

At the same time, the level of reliability have to be at the same level as current engines; which is not the easiest target as this architecture is noticeably more complex than current ones.

The EIS targeted for this architecture is 2017-2018.

FIG 12 presents the Fuel burn vs cumulative noise design space for open rotors engines without aircraft noise shielding.

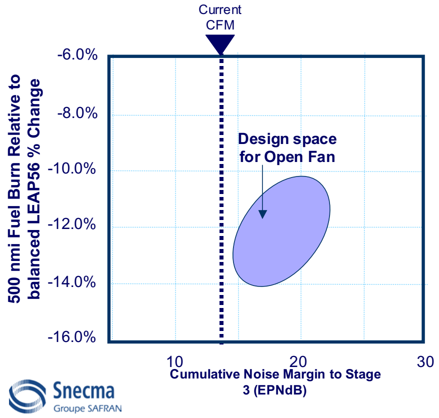

FIG 12.Open Rotor Fuel Burn vs noise design space

4.2. European projects

The Open Rotor concept will be developed and tested by Snecma within the European Union FP7 to be launched DREAM Project. This project should have a full duration of 3 years with a termination at the end of 2010 and brings together 47 partners.

DREAM will deliver integrated technologies at TRL 4-6 by studying and testing these advanced technologies mainly devoted to fuel consumption / CO_2 reduction, pollution reduction, whilst retaining acceptable noise levels. For instance, several intensive aero-acoustic WTT campaign will be performed at low and high speed to verify both efficiency and noise levels of propellers.

These technologies will constitute candidates ready to be used for the CLEAN SKY engine platform, which is plan to be the direct global exploitation path for DREAM. In CLEAN SKY, a selection of engine architectures will be made on the basis of the results of VITAL, NEWAC and DREAM to develop engine demonstrators. Snecma will develop a contra-rotating open rotor engine as an option for the single aisle aircraft engine demonstrator in CLEAN SKY and in other potential collaborative programs.

On the longer term, DREAM engines might be installed on new aircrafts in particular those having noise shielding capabilities (such as the PROGREEN 2 aircraft from NACRE) to further reduce noise emissions.

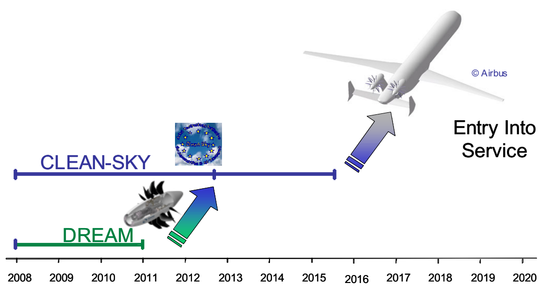

FIG 13. EU Open rotors projects

4.3. Concept design and choice

In addition to future European projects and to fulfil ambitious objectives defined, Snecma has already started for two years, as an internal project, to work deeply on different Open rotors concepts.

First, whatever the Open rotor concept retained at the end of the selection, Open rotor engines design raises major issues that need to be addressed and resolved (in no particular order):

- Improve propeller efficiency to reach ambitious CO_2 reduction targeted. To comply with this requirement, new 3D RANS CFD codes will be calibrated on 80's results and optimised for this kind of application and finally coupled with optimisation software. Then, WTT at low and mainly high speed will validate predictions.

- Reduce both community and cabin noise even if Open rotor engines are intrinsically noisier than ducted concept. To achieve this goal, new 3D RANS CFD unsteady codes will be calibrated on 80's results and optimised for this kind of application and finally coupled with optimisation software. Then, WTT at low and high speed will validate predictions.

- Improve Mechanical design of the propellers to ensure that the safe life design is viable, especially regarding fatigue and bird ingestion. This point is a showstopper as safety is never a compromise.

- Make Pitch change mechanism as reliable as possible to obtain an overall engine reliability at least equivalent to current engines. For this purpose, multiple brainstorming and advanced-concepts will be performed and assessed. This component will then be rig tested.

- If required by the concept, design a Power Gear Box as reliable and efficient as possible. PGB has certain advantages, which needs to be less than compensated by commonly known drawbacks that are reliability and cost, efficiency loss and thermal dissipation.

- Prove engine operability at low power with a more electric configuration. Indeed, core size resulting from open rotor concepts design is low compared to equivalent Turbofan while Aircraft power demands remain the same. Consequently, new concepts have to be identified, as current Turbofan design does not meet the need.

- Answer certification questions over the type of certification to be applied, Turboprop or Turbofan, and UERF issues at Aircraft level depending on the installation configuration, for engines aimed at short-range aircrafts that should account for more than two third of next 20 years commercial deliveries.

Then, once the general assumptions have been set, a large number of degree of freedom is still available to reach the best configuration, with for instance concepts with or without a Power Gear Box, the propellers located in front (Puller) or at the rear (Pusher) of the Gas generator… Consequently, each relevant concept has been studied in details to compel the pros and cons in order to build a first rating of the different configuration regarding the different criteria of selection. These studies will carry on and be completed during the course of DREAM to select the best-optimised configuration.

FIG 14 describes the macro-design of the CR Direct Drive Pusher design, as an example of open rotor architecture, with the HP Core rotor in green, the IP core rotor in yellow, the free turbine front propeller rotor in orange and the free turbine rear propeller rotor in pink.

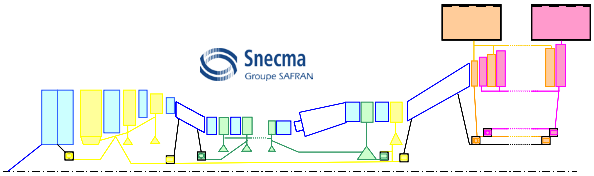

FIG 14. CR DD Pusher Architecture Scheme

FIG 15 hereunder shows four concepts designed and assessed by Snecma, amongst others: a CR Direct Drive Pusher, a CR Pusher with a PGB, a CR Puller with a PGB and a Single propeller Puller with a PGB.

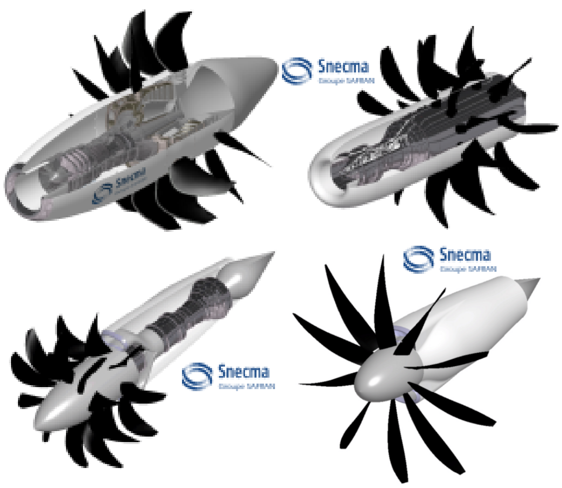

FIG 15. Different Snecma Open rotor Concepts

FIG 16 shows the still evolving relative rating obtained by the four different concepts with regards to performance, weight, noise margin and costs.

The CR Direct Drive Pusher concept is the reference, as characteristics of this concept are well known thanks to 80's GE engine studies called GE36 in which Snecma owned a 35% share. The noise margin used for Pushers includes pylon blowing at Take-Off to decrease the interaction between wakes of the pylon and the front propeller.

The CR Pusher with PGB concept is slightly lighter thanks to an important reduction in number of free turbine stages and slightly less noisy thanks to a reduction in propeller rotational speed. These gains are obtained with a PGB but at the expense of worse maintenance costs, as the complex gear assembly is a relatively low reliable component.

The CR Puller with a PGB concept is slightly lighter and less noisy thanks to same reasons as the CR Pusher with PGB but with an additional gain coming with the reduced interaction between pylon wakes and front propeller. Drawbacks are the same as previous architecture with a supplementary deficit on performance because of the inlet efficiency penalty.

The Single-propeller Puller with a PGB concept is lighter as it gets fewer parts even if the propeller diameter is greater. The noise margin is slightly better because of the slower rotational speed but blades are more loaded than the CR Puller with a PGB. Maintenance costs are higher like all PGB concepts but the main drawback is a performance penalty because of higher loaded blades and primarily the swirl induced by single propeller.

Snecma	Performance @M0,78	Weight	Noise margin vs chap3	M/C
CR R-DD	Ref	Ref	Ref	Ref
CR R-G				
CR F-G				
M F-G				

Color code	
	Better
	Slightly better
	Neutral
	Slightly worse
	Worse

FIG 16. Four Open rotor concepts relative rating

4.4. Aircraft integration

In addition to key Open Rotor issues and concepts relative rating, the Aircraft integration is a subject by itself as the installation of an Open rotor engine will need a close and strong work with Airframers to develop an optimise configuration for both performance and acoustic while solving certification issues.

The challenge of installing an Open rotor on a short-range aircraft is illustrated by FIG 17 hereafter that shows a comparison between an Open rotor and a CFM56-7B and an GE90-115B, the world biggest Turbofan.

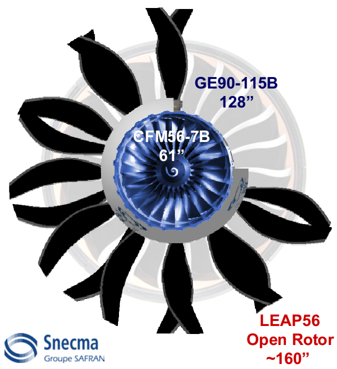

FIG 17. Diameter comparison between Open rotor and Turbofans

Snecma has started to study different aircraft configurations and FIG 18 shows four Aircraft installation configurations, amongst others: a CR Pusher installed on sides of rear fuselage, a CR Puller installed on sides of rear fuselage, a CR Puller under high-wing and a CR Pusher over wing for acoustic shielding.

FIG 18. Four Aircraft integration concepts

Each configuration has pros and cons that need to be assessed regarding main criteria: Community noise, Cabin noise, Certification aspects, Installation drag, Propeller inflow quality and Aircraft balance.

Preliminary main conclusions of the Aircraft installation evaluation are the following:

- Configurations with acoustic shielding are promising but includes high risks on certification aspects and minor risks on installation drag

- Configurations under or over wing should bring some benefits regarding certification aspects, propeller inflow quality and family extension but are highly risked for cabin noise since the only solutions are cabin passive treatment (inducing weight) and/or active devices.

5. SUMMARY

Following ACARE 2020 objectives that tackle Fuel Burn, noise and emissions, and the recent growing sense of urgency regarding climate change and especially aviation impact, engines designed for future Short-range aircrafts that will replace A320s and B737s will have to fulfil requirements presented in FIG 19, which correspond to existing criteria with a greatly amplified influence of noise and emissions.

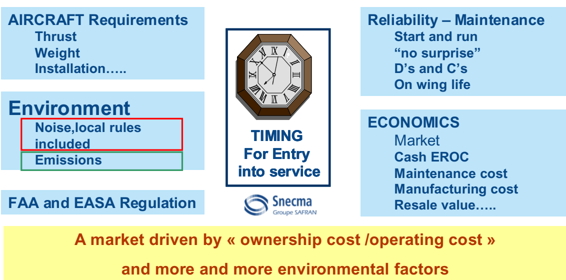

FIG 19. Engine design criteria

To answer this challenge, Snecma has considered three different architectures that reach different targets as presented in following FIG 20.

The baseline LEAP56 is a balanced engine resulting from a compromise between main criteria that could answer ACARE goals depending on the EIS. At current 2015 EIS milestone target, the LEAP56 baseline already reaches a great proportion of ACARE 2020 requirements.

Then, the CRTF is a more complex concept that brings a 5dB benefit as well as a slight improvement in performance. The higher number of parts will be outweighed by a smaller needed BPR and lightweight structures. This concept goes beyond ACARE 2020 goals on noise at a given BPR, which could become necessary, especially if optimal BPR slides to non-installable under the wing diameters or noise requirements increase under public pressure.

Finally, the Open rotor architecture is an even more complex concept that delivers a breakthrough on Fuel Burn and CO_2 emissions thanks to a great propulsive efficiency and no duct penalties. Nevertheless, some key points remain to be solved: Community and cabin noise, and reliability of such a complex machine.

In parallel, a Geared Turbo-Fan is presented as Snecma has studied and is continuously studying the potential of all other possible architectures but the noise level and slight performance gains are far outweighed by the drawbacks of PGB reliability, efficiency losses and thermal dissipation. The drawbacks are too important and risky for a minor improvement in comparison with the baseline LEAP56.

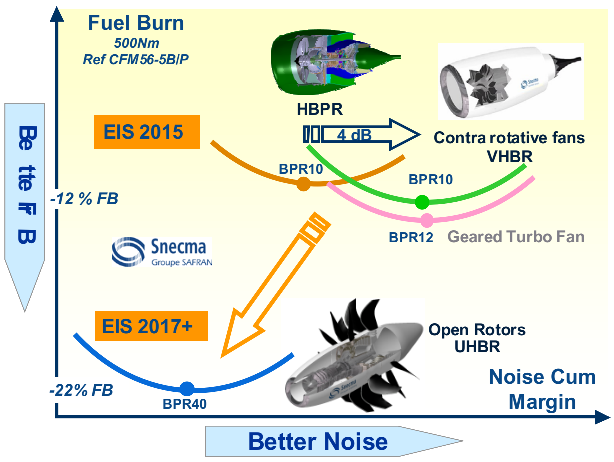

FIG 20. Fuel burn vs noise for different architectures

With this multiple concepts strategy, Snecma has defined a plan to develop several architectures relevant for the Short-range aircrafts replacement coming in the next decade, whatever is the environmental lobby that wins: noise or emissions.

Indeed, particularly through current EU Project VITAL and to be launched EU Project DREAM, Snecma has already started and will continue the detailed assessment of two main general architectures selected to go toward or beyond ACARE 2020 goals. In parallel, Snecma and GE through the LEAP56 program will carry on to build up technological bricks applicable on any of these three architectures in order to be ready to answer any future environmental requirements.

FIG 21. Snecma strategy

6. REFERENCES

[1] enVIronmenTALly Friendly Aero Engine
Annex 1 – "Description of Work"

[2] valiDation of Radical Engine Architecture systeMs
Annex 1 – "Description of Work"