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TABLE OF CONTENTS

1. **PREAMBULE** 3
   - 1.1 Document issues 3
   - 1.2 List of updated pages 3
   - 1.3 Acronyms 3

2. **EXECUTIVE SUMMARY** 4

3. **LIST OF PARTNERS INVOLVED IN THE DOCUMENT** 5

4. **PROJECT OBJECTIVES AND MAJOR ACHIEVEMENTS** 6
   - 4.1 Introduction 6
   - 4.2 HISAC project objectives achievements and conclusions 6

5. **WORK SUMMARY** 10
   - 5.1 Work Package 1 10
     - 5.1.1 WP 1.1 : Noise criteria 10
     - 5.1.2 WP 1.2: Atmospheric emissions criteria 14
     - 5.1.3 WP1.3: Sonic boom criteria 21
   - 5.2 Work Package 2 28
     - 5.2.1 Task 2.1: Noise modelling 28
     - 5.2.2 Task 2.2: Emission modelling 30
     - 5.2.3 Task 2.3 Sonic Boom modelling 33
     - 5.2.4 Task 2.4 Engine modeling 36
     - 5.2.5 Task 2.5 Aerodynamic modeling 38
     - 5.2.6 Task 2.6 MDO Process 47
   - 5.3 Work Package 3A 51
     - 5.3.1 WP3.1 - Variable Cycle Engine Technologies 51
     - 5.3.2 WP3.2 - Nozzle Noise Reduction Technologies 53
   - 5.4 Work Package 3B 59
     - 5.4.1 WP3.3 Forced laminar flow 60
     - 5.4.2 WP3.4 High Lift Devices 64
     - 5.4.3 WP3.5 Variable Geometry Wing 69
   - 5.5 Work Package 4 74
     - 5.5.1 Aerodynamic Design and Assessment 74
     - 5.5.2 Sonic Boom Design and Assessment 86
     - 5.5.3 Acoustic Design and assessment 87
   - 5.6 Work Package 5 91
     - 5.6.1 Technical Aspects 91
     - 5.6.2 Description of the exchanges between WP5 and the other work packages 91
     - 5.6.3 Design activities 92
     - 5.6.4 Trade-off activities 112
     - 5.6.5 Synthesis task (WP5.4.1 and WP5.4.2) 115

6. **CONSORTIUM MANAGEMENT** 117
   - 6.1 Publications 117
   - 6.2 Official meetings 119
   - 6.3 Official deliverables 120

1. PREAMBULE

1.1 Document issues

Date	Issue	Revision	Author	Updating Purpose
06/16/2008	0	0	Ph. DE SAINT MARTIN	Document Creation
07/21/2008	1	0	Ph. DE SAINT MARTIN	Document issue

1.2 List of updated pages

1.3 Acronyms

APU : Auxiliary Power Unit

BFL : Balanced Field Length

BPR – By-Pass Ratio

CONV : Conventional

CVC : Cycle with Variable Confluence

EW : Empty Weight

ICAO : International Civil Aviation Organization

L/D : Lift to Drag ratio

LW: Landing Weight

MDO : Multidisciplinary Design Optimization

MRW : Maximum Ramp Weight

MTOW : Maximum Take-off Weight

PAX : ¨Passenger

S4TA : Small Size SuperSonic Transport Aircraft

SFC : Specific Fuel Consumption

2. EXECUTIVE SUMMARY

This document describes a summary of the main achievements of the project with regards to the general objectives first, and then to the work carried out in each work package by each partner during the full duration of the project.

3. LIST OF PARTNERS INVOLVED IN THE DOCUMENT

N°	ACRONYM	CHECK IF INVOLVED
1	DASSAV	X
2	ALA	X
3	CFS	
4	EADS M	
5	RRUK	
6	RUAG	
7	SCA	X
8	SENER	
9	SnM	X
10	SONACA	
11	VOLVO	
12	ADSE	
13	ESTECO	
14	IBK	
15	INASCO	
16	NUMECA	
17	ARA	
18	CIAM	
19	CNRS	
20	DLR	X
21	FoI	
22	INRIA	
23	IoA	
24	NLR	X
25	ONERA	
26	TsAGI	
27	EEC	
28	Chalmers	
29	CU	
30	ECL LMFA	
31	EPFL	
32	ISVR	
33	KTH	
34	NTUA	
35	TCD	
36	Uni-NA-DPA	
37	ITAM	

4. PROJECT OBJECTIVES AND MAJOR ACHIEVEMENTS

4.1 Introduction

The HISAC general objectives are described in the Description of Work of the Project.

As a global goal, it can be reminded that HISAC addresses Research Area 2 « Improving environmental impact with regard to emissions and noise» of FP6 Thematic Priority 1.4 Aeronautics and Space.

The general objectives, their achievements and the conclusions are described hereafter.

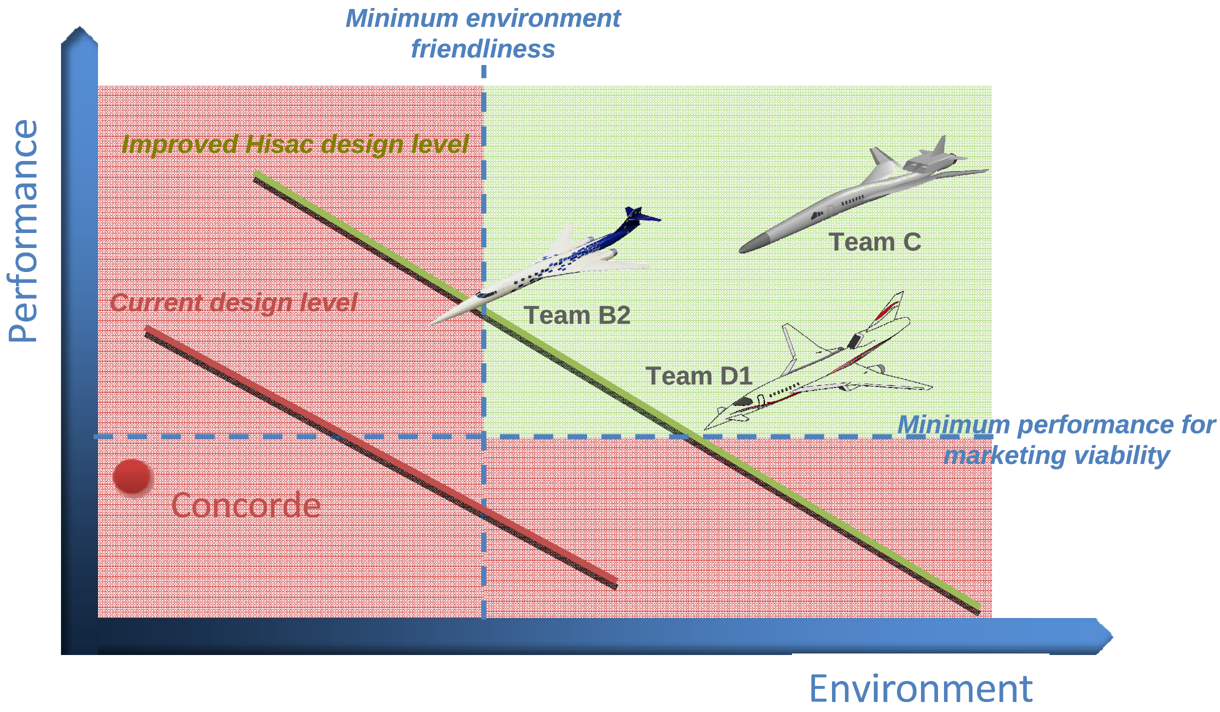
4.2 HISAC project objectives achievements and conclusions

- ***To identify the characteristics of aircraft that could meet the prospective requirements***

Three classes of concepts have been designed by different Teams with the highest environmental objectives in terms of noise, emissions and sonic boom. The design activities haven't shown any big issue in satisfying these constraining specifications, nevertheless HISAC project is a necessary intermediate step towards demonstrating the full feasibility of such aircraft which will be achieved by technology maturation, demonstrations in parallel with international standards development.

- A supersonic overland concept (Team C) with a MTOW of 53t. This is the only overland M1.8 concept studied in HISAC. Such a configuration is intimately linked to challenges, scattered over different areas: regulation, technical, and certification. But this is the only concept which fulfills all the specifications.
- A supersonic overwater concept: different M1.6 configurations have been studied: a delta wing (Team A), a laminar wing (Team B1) and a variable geometry configuration (Team B2). The 3 designs all present pros and cons. As the variable geometry may present an interesting compromise one with a MTOW evaluated below 45t. and a great flexibility of operations between subsonic overland cruise and supersonic overwater cruise, this comes with technical and certification issues that may be very difficult to overcome. More conventional configurations, associated with less flexibility, appear less risky on the technical standpoint. Generally speaking, the overwater concepts although they will not have to face regulation issues linked to supersonic overland flight, still face technical risks and complexity.
- A low supersonic concept: 2 families have been studied, a high subsonic version (M0.95) capable of supersonic dash (M1.2) named Team D1, a low supersonic version named Team D2. In terms of sizing, Team D2 appears very close to high supersonic families, but with limited supersonic capabilities. The MTOW of Team D1 is around 34t. The interest of this family is to decrease the global aircraft weight and to decrease emissions.

These 3 concepts can be included in the Performance / Environment figure which was provided in the Description of Work document.



- ***To provide policy makers with a set of recommendations for future environmental regulations (several sets of commercial characteristics of the aircraft will be considered)***

A set of specifications has been initiated at the beginning of the Project and has been revised at each design loop. This set is composed of:

- Operational and aircraft targets like cruise speed (M0.95 to M1.8), range (4000 to 5000NM), field performances (BFL of 6000ft), cabin size (8 to 20 passengers),…
- Environmental targets: closed loops have been performed between the different Work Packages, Research Centers and Industry in order to quantify objectives in terms of noise, sonic boom and emissions. Links with regulation authorities have also been established. The targets are the following:

<u>Community noise</u>: the targets are considered as mid-term objectives for subsonic aircraft, Stage IV-10dB.

<u>Sonic boom</u>: the level of 65 dBA has been set as technical target for unrestricted operations. Due to the non mature definition of an internationally approved criteria, this figure should not be regarded as an "acceptable" or "regulatory" level.

<u>Emissions</u>:

- For LTO operations (ground emissions), the targets are considered as mid-term objective for subsonic aircraft.

- For cruise emissions, an integrated approach combining aircraft + engine design and ways to operate it, allowed to optimize the emissions during cruise and to demonstrate the very low climate impact of a supersonic fleet. In terms of species quantification, the mid-term objective of EI(NOx) has been revised to 10 -12 g/kg fuel burnt.

It can be also mentioned that in order to contribute to policy development, links with ACARE goals have been established.

- ***To provide progress on:***
  - ***Elementary technologies***
  - ***Associated design and optimization multidisciplinary methods***

Promising technologies have been identified. Among them we can quote: variable confluence engine, innovative noise suppression systems, low boom technologies, challenging architectures and structures. Some of these technologies have links with subsonic aircraft ones (for ex. low NOx combustion chambers). Links with other relevant projects (concerning sub and supersonic aircraft) have been identified. In most of the cases the Technology Readiness Levels of the specific technologies identified in HISAC is rather low. In addition, the risks linked to novel architectures or to specific operation constraints are medium or high. This is the reason why there is a clear need for additional studies and future demonstrations or proof of concepts.

An ambitious multidisciplinary design optimization process has been successfully implemented within HISAC. It has allowed all the involved partners, to combine high fidelity environmental models to more classical design models in an integrated manner with a goal to increasing the robustness of the results achieved.

- ***To identify the roadmaps for further technology maturation***

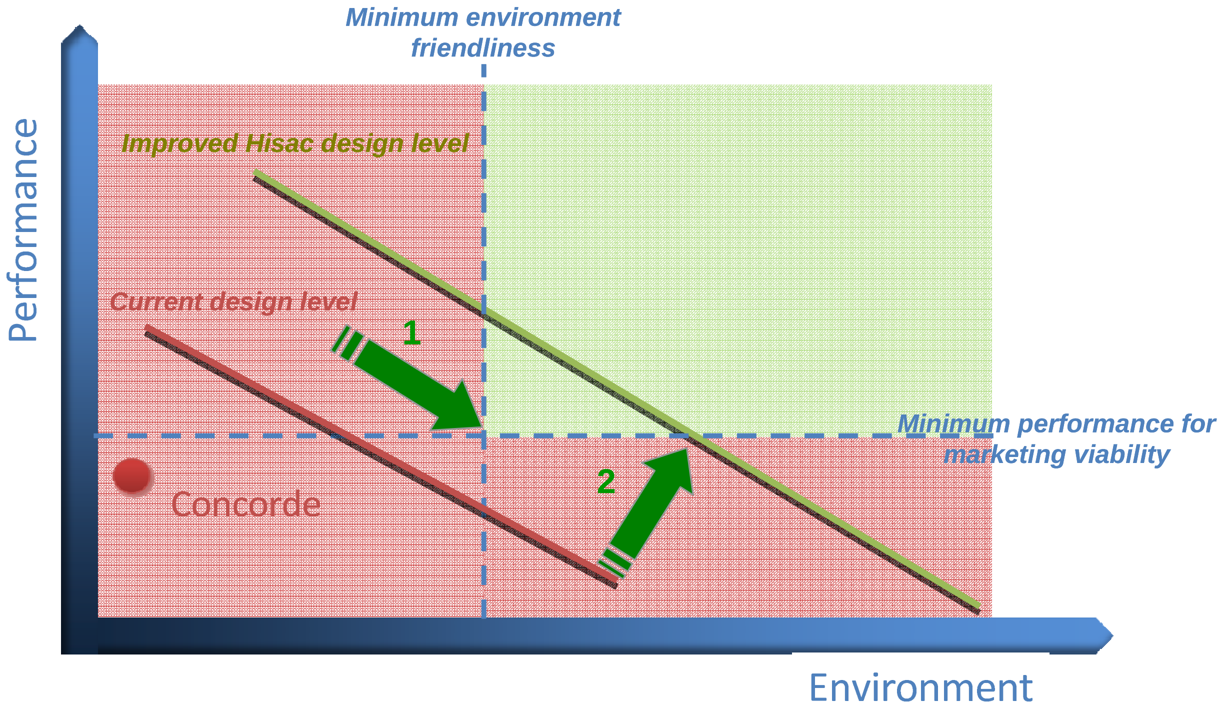
A short / mid term technology development roadmap has been proposed for engines and aircraft. Aircraft design activities have been identified in these roadmaps to address the integration issues and to mitigate the risks linked to new aircraft architectures and operations.

A future standard roadmap has been also given.

Finally, an aircraft development roadmap has been also provided in order to give a more long term perspective. A distinction has been made between the 3 concepts.

- ***To provide general trade-offs***

The upper mentioned figure illustrates also the sensitivity studies which have been performed in HISAC.



The 2 main directions of these trade-offs (1 and 2 in green) were:

1/ Specifications trade-offs: the sensitivity of the design to the specifications (range, Mach, noise, sonic boom, emissions,…) has been quantified. One of the main lessons is the careful compromise to be made between noise and emissions target.

2/ Architecture and technology trade-offs: the high benefit of innovative architectures and of some specific technologies has been pointed out.

The high sensitivity of high speed aircraft design to its assumptions demonstrates the need of maturation of the specifications (driven for environmental targets by the future international standards) and of the necessary technologies.

HISAC Project has been an important intermediate step towards the feasibility of an environmentally compliant S4TA. Today, no major issue to overcome has been identified. Nevertheless, the international research efforts currently carried out show that there is a strong interest in this subject and that the maturation of the required technologies and of the new international standards is a long term process.

5. WORK SUMMARY

5.1 Work Package 1

5.1.1 WP 1.1 : Noise criteria

The International Civil Aviation Organisation (ICAO) defines noise limits for different categories of aircraft as a function of the certified values at these three points. These limits are given in the Chapters of Volume 1, part II of Annex 16, Environmental Protection, to the Convention on International Civil Aviation - generally referred to simply as “Annex 16”.

These chapters give values for certification, at the time of certification (“Application”), and cover jet airplanes, propeller-driven airplanes and helicopters as shown in Figure 1, below.

Chapter	Aircraft	Application
2	Subsonic Jet	→ 1977
3	Subsonic Jet and large Prop	1977 → 2005
4	Subsonic Jet and large Prop	2006 →
	…	…
12	Supersonic	-----

Figure 1 - Applicability of ICAO Annex 16 Chapters

For example, subsonic jets certified on or after 1st January 2006 must respect the articles of Chapter 4. No restrictions are implied on the rights of aircraft certified to Chapter 3, between 1977 and 2005, to use any given airport.

The following figure (Figure 2) shows the reduction of community noise requirements between the different chapters.

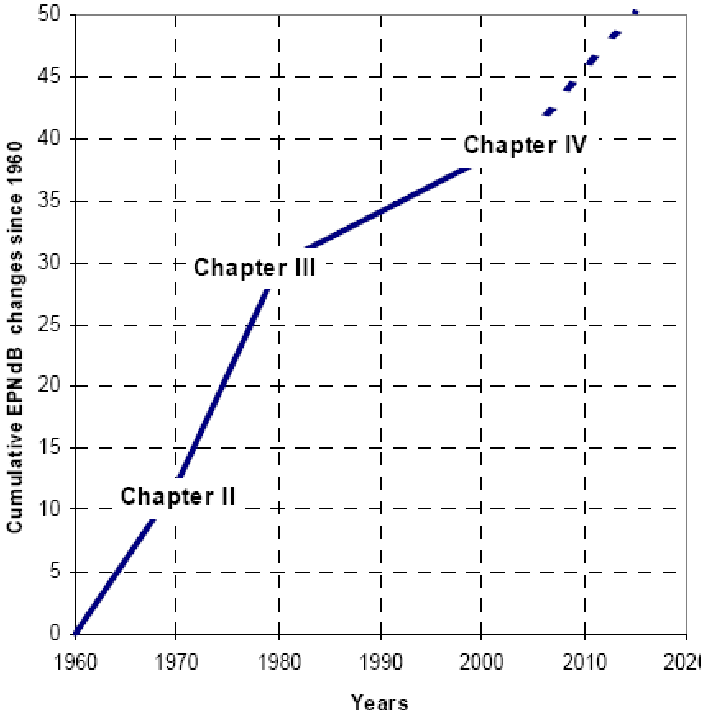


Figure 2 - Reductions in aircraft community noise requirements

Eurocontrol, ONERA, NLR, and CIAM participated in the analysis of future noise constraints and concluded that progress in technology would seem realistic, and a new class for noise certification is likely to be created, with a new cumulative gain which is 10 dB less than in Chapter 4. Maximum noise level limits for chapter 3 and chapter 4 depend on the aircraft weight: higher levels are allowed for heavier aircraft, with constant levels below and above some critical weights. To illustrate this, the maximum noise levels at MTOW=45t are shown in Figure 3, below.

MTOW = 45 t	**Lateral:**	**Approach:**	**Flyover:** Number of engines		
			1 or 2	3	4 or more
Chap 3 In EPNdB	94.94	98.84	89.00	91.62	93.62
	Cumulative				
			282.78	285.40	287.40
Chap 4 In EPNdB	**Cumulative**				
			272.78	275.40	277.40
2020 In EPNdB* In dBA	**Cumulative**				
	Chap4-10 EPNdB		262.78	265.40	267.40
	EPNdB=dB+12 ±4dB		**226.78**	**229.40**	**231.40**
In dBA	EPNdB=dB+12 ±4dB		**246.78**	**249.40**	**251.40**

Figure 3 - ICAO Annex 16 Chapter Stringencies

The correspondence between the two levels (ground level for environmental airport protection purposes, and aircraft certification level), using different metrics, needs to be verified; furthermore, a short safety margin must be added to the certification level as a technical precaution.

Regarding future local noise constraints, a review of the current local noise constraints has been performed. This overview of the practices of about one hundred airports, and their development over recent years, has been used to establish a draft typology of airports based on the effective combination of elementary actions to cope with noise.

A noise level in the region of 87-88 EPNdB for a twin-engine S4TA (88.5 for a three-engine S4TA, 89.1 for a four-engine S4TA), which roughly corresponds to a level of 75 dBA in LAmax, can be expected on the ground as a limit in 2020, based on the evolution of European Directives.

The most restrictive noise levels have been found in medium-sized airports in the USA: currently 78 dBA during the day at New Haven airport (68 dBA at night). With such a limit, the analysis of the above mentioned database of current noise constraints at airports of all sizes (small, medium, large and major) gives the following results:

LA max In dBA In 2006	LA max In dBA In 2020 (2006-10dBA)	% of airports which can be used by the S4TA (*)
85	75 target	86%
78 Lowest level	68	90%
75	65 If lower target	92%

(*) assuming stability on local constraint levels

Figure 4 - Local noise constraints

This implies that with the target of 75 dBA for the S4TA 86% of the airports can be used and with a more stringent target of 65 dBA for the S4TA 92% of the airports would be available.

A number of operational procedures were analysed, which are aimed at minimizing local noise and which are partly in force at airports or discussed at scientific levels.

As a conclusion, noise restrictions are frequent in Europe and Australia-New Zealand, less severe in the USA and in Japan, and the requirements are low on the other continents. The most probable scenario for the future consists of a general set of noise restrictions, mainly through the adoption of Noise Abatement Procedures in countries where there are few restrictions today, and by the enforcement of local noise limit levels for an individual aircraft where NAPs are already applicable today.

Globally speaking, the benefit for the noise exposure footprint is largely positive for many new take-off procedures. The data from a recent noise impact assessment, as a part of the

SOURDINE II project, are also expected to be positive for approach procedures, as with CDA.

The concept of RNP SAAAR is a significant enhancement to navigable airspace design, use, and management. It was developed by the International Civil Aviation Organization (ICAO) Special Committee on Future Air Navigation Systems (FANS) and is an integral part of the communication, navigation, surveillance, and air traffic management (CNS/ATM) plan envisioned by the Special Committee.

RNP SAAAR enables improved capacity and arrival efficiency through parallel approaches to closely spaced runways at busy airports during Instrument Meteorological Conditions (IMC). This is accomplished using narrow, linear approach segments and the RNP Parallel Approach Transition (RPAT) that is being pursued in the near-term as a core Operational Evolution Plan (OEP) activity, or the future application RNP Parallel Approach (RPA) with no transition, using low RNP and high containment integrity.

When looking at future standards for an S4TA, it is clear that there are currently no specific rules on which to base our concepts. Chapter 12 (supersonic aircraft) only applies to Concorde and is essentially void.

Within ICAO (SSTG of Working Group 1), current discussions regarding Chapter 12 were held in 2009, and concluded the following

"

The SSTG reviewed the information in Chapter 12 of Annex 16, applicable to supersonic aeroplanes. That review found that Chapter 12 contains the statement that the noise levels of Chapter 3 be used as guidelines for supersonic aeroplanes, while the standard applicable to current new subsonic aeroplanes is the more stringent Chapter 4. All SSTG agreed that Chapter 3 was not stringent enough for new supersonic aeroplanes. It was learned that at least one member state has already adopted policy that new supersonic aeroplanes would have to satisfy Chapter 4. The SSTG agreed that there was insufficient information yet available about the technologies that could be used in designing new supersonic aeroplanes that it could not yet define appropriate testing procedures unique to supersonic aeroplanes. […].

"

As a result, a new redaction for Chapter 12 was proposed (see Figure 5) and highlighted the fact that noise levels limits for an S4TA should be coherent of applicable noise level limits for subsonic jet aeroplane (currently Chapter 4).

CHAPTER 12. SUPERSONIC AEROPLANES

12.1 Supersonic aeroplanes — application for Type Certificate submitted before 1 January 1975

[…]

12.2 Supersonic aeroplanes — application for Type Certificate submitted on or after 1 January 1975

Note.— Standards and Recommended Practices for these aeroplanes have not been developed. However, the maximum noise levels of this Part that would be applicable to subsonic jet aeroplanes may be used as a guideline. Acceptable levels of sonic boom have not been established and compliance with subsonic noise standards may not be presumed to permit supersonic flight.

Figure 5 - SSTG preferred text for Chapter 12

5.1.2 WP 1.2: Atmospheric emissions criteria

EPFL, DLR, and CIAM participated in WP 1.2. The initial objectives were to identify future international emission standards and policies, including airport requirements, to summarise different impacts from aviation: airport, climb, cruise, descent, airport, and derive from this synthesis emissions data sets, giving an assessment of permissible emission index regulations for S4TA. This database provided by the studies enable a comparison for an assessment of influence of fleet of small high speed jets dependent on altitude and latitude. The studies for the emissions criteria are based on a synthesis of

- Current airport constraints
- Constraints imposed by international bodies (ICAO, FAA, ICAO/CAEP)
- Current discussions on the integration of air transport into the Kyoto Protocol
- Literature review of recent project on atmospheric emissions,

Air transportation is a sector of growth, the impact of aviation emissions on the environment is hence an important question; keeping in mind that air traffic emissions still remains less than 2% of total man-made emissions (Energy(53%), industry(23%), road traffic(16%), other transportation means, miscellaneous sources (5%)) .

For global emissions concerns CO2 is confirmed to be a predominant contributor and is retained within the Kyoto protocol, whereas for aviation, most data and gauges are based on NOx indices. CO2 has to be also considered in aviation requirements as also NOx is now introduced in Kyoto agreement considerations.

The work performed in HISAC by DLR-O, EPFL and CIAM have aimed to provide an emission data base which

- summarises different impacts from aviation, local (airport (ground), near ground), global (atmosphere) and international (worldwide, latitude and altitude)
- derives from this synthesis emissions data sets
- provides emissions data similar to subsonic aircraft

This enables a comparison for an assessment of influence of fleet of small high speed jets dependent on altitude and latitude.

Atmospheric emissions are gauged on local and international standards for pollution, and concern also an assessment on climate impact such as contrails and cirrus cloud formations.

Aviation noise and emission standards are regulated by the FAA and ICAO, and in particular the CAEP (Committee for Aviation Environmental Protection) of ICAO (International Civil Aviation Organisation). They are mainly engine based although there is now a tendency to include airframe, ICAO reglementation is not and has never been technology forcing but follow technological improvements. ICAO, until recently, did not legally bind the contractant states. There is a historical drive for fuel efficiency.

In order to assess the climate impact of any perturbation to the atmosphere-ocean system a methodology is required, which relates perturbations, e.g. induced by emissions to the effect of global atmosphere evolution.

The standards introduced are resumed in the Annexe 16 Vol II of the CAEP, and are mainly engine based, and concern essentially the "local" emissions (airport to 1000 metres) and concerns:

- Subsonic aircraft engines
- Supersonic aircraft engines (although ICAO standards for high speed-supersonic aircraft are not in place)

taking into account the ratio of the following species

- Smoke number
- Unburnt hydrocarbons (HC)
- Carbon monoxides (CO)
- Nitrogen oxides (NOx)

with regard to the maximum thrust, and emission indices of the engine. No airframe, flight phase, aircraft performance considerations are for the moment included. However, there are now (from 2007 onwards) recommendations that include these.

The whole Take-Off to Landing (LTO) and cruise flight phase performance cycle is included in the ICAO-CAEP 2010-2015 methodology, with the climb and descent phases.

For high speed/supersonic fleet, the goal is to obtain standards of the same quantities as those of subsonic aircraft, and to remain within close limits to them. The technological advances for efficient high speed flight, in matters of engine improvement, combustion efficiency, optimised airframe and flight path considerations lead to plausible trade-offs to remain environmentally friendly. The constraints of high speed/supersonic are mainly: fuel consumption (partially compensated by the fact that mission time is reduced for fixed range), cruise altitude, cruise NOx emissions, engine operating temperature, landing and take-off phases similar to subsonic aircraft.

The climate change concern the effects of emissions at cruise altitudes, concerning the emissions of CO2, NOx, H2O mainly, whereas airport concerns are smoke, unburned hydrocarbons, carbon monoxide, and nitrogen oxides.

The assessment of the climate and ozone depletion impacts from the considered S4TA fleets were performed by DLR. Emission calculations and a simplified climate-chemistry model delivered by WP 2.2 were used to calculate the atmospheric impacts.

Changes in the atmospheric composition were calculated for a fleet of S4TA in 2050 and compared to a SCENIC fleet, scaled to the same fuel consumption in order to compare the non-CO2 effects. Water vapour shows an increase of around 0.1 ppbv, which is in the order of ~0.01 to 0.05 % of the background water concentration. Scaled SCENIC emissions, i.e. with the same total water vapour emissions, lead to a much larger water vapour accumulation of up to 3 ppbv due to the higher cruise altitude. Ozone depletion is in the order of 10 to 20 ppbv, accompanied with an ozone increase at lower altitudes. The impact on the ozone layer is in the order of 0.0005%.

Figure 6 shows the temporal evolution of the climate impact caused by a supersonic fleet for the different configurations and for comparison for the SCENIC fleet, scale to the same fuel consumption. The fleets have an entry in service in 2015 and reach full size of 250 aircraft in 2050. The temperature change by 2100 is calculated to be around 0.08 mK. Around 50% of the climate impact arises from CO_2 emissions, 20% from water vapour and 30% from ozone. Here we neglect impacts from contrails, because a substitution of subsonic aircraft with supersonic leads to a negligible contrail climate change impact, since the contrail occurrence is shifted from mid latitudes to lower latitudes and lower altitudes to higher altitudes (Stenke et al., 2008).

Figure 7 shows the intercomparison of the climate impact of configuration A, B, and C. The figure shows the temperature change in 2100 of either configuration compared to the mean value of all three configurations. The climate change calculations have a large number of uncertainties, i.e. the residence time of a stratospheric perturbation, the radiative forcing calculation, or the calculation of the climate sensitivity of a perturbation (for details see Grewe and Stenke, 2008). A range of parameter settings is calculated to cover the range of uncertainty in a conservative approach. For each calculation the ratio between the three configurations is calculated and the mean ratio and standard deviation of the ratio is calculated and presented in Figure 6.

For a conventional combustion chamber (CONV), configuration A and C are better than configuration B. For LPP technology (Lean Premixed Prevaporized), configuration A has the lowest overall climate impact. This result is independent from the inclusion of contrails (not shown).

Circles in Figure 7 indicate the results based on the climate functions as developed within HISAC (Grewe et al., 2009). They are only meant to give a qualitative picture of the climate impact, i.e. a rough estimate. However, the results are in agreement with the more accurate calculations with AirClim, showing the applicability of the climate functions.

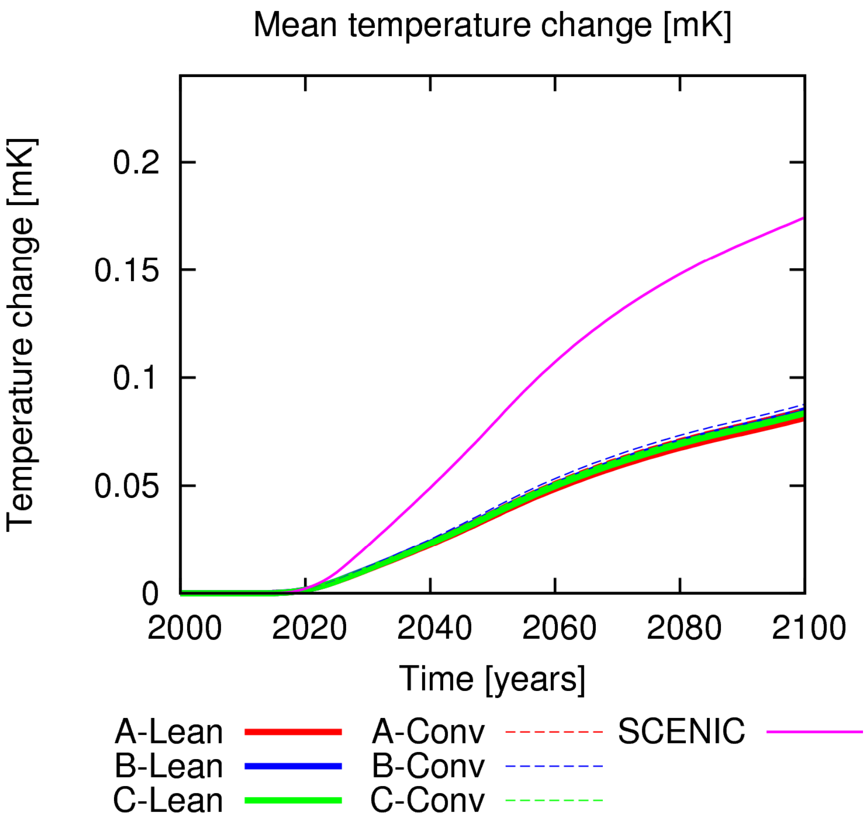


Figure 6: Temporal development of the temperature response due to a different HISAC fleets. The dashed curves show results for a conventional combustor chamber, the solid for LPP technology. SCENIC results are scaled to give the same fuel consumption as the HISAC fleet in order to provide an estimate for non-CO2 effects.

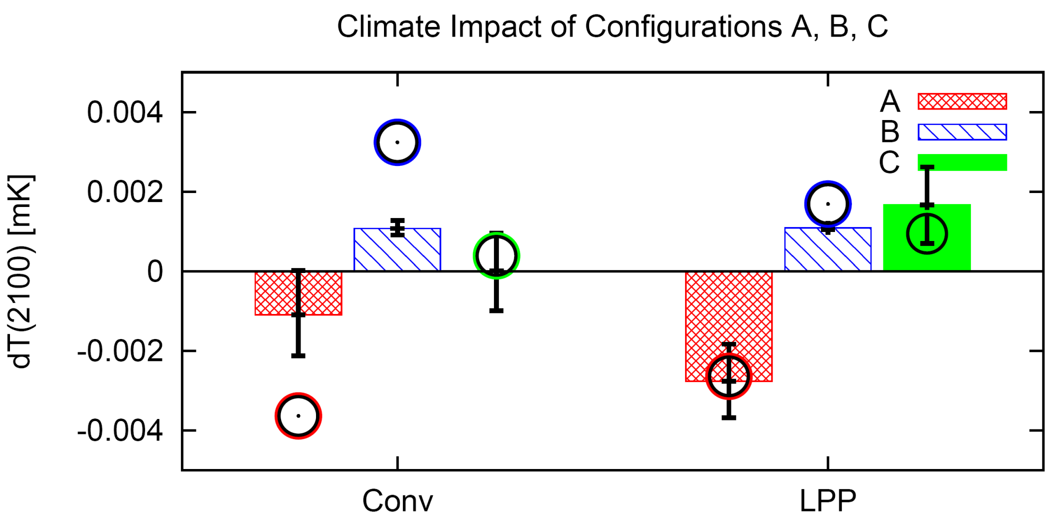


Figure 7: Climate impact of configurations A, B, and C in comparison to mean climate impact of all three configurations. The error bars indicate an uncertainty based on atmospheric processes. The error estimation is conservative. Circles indicate the results based on climate functions [Grewe et al., 2009].

Supersonic transport has a higher impact on climate than subsonic transport because of two reasons. (1) The ratio between the fuel consumption (and thereby CO2-emissions) of a sub and a supersonic fleet is roughly 3 (conservative approach based on the fuel consumption of the best subsonic small size aircraft; this figure could be lowered to 1.5 / 2 when taking into account mean aircraft). (2) The non-CO2 effects on climate are higher because of the longer residence times of species in the stratosphere. A direct intercomparison of the climate impact of a fleet of subsonic aircraft with a fleet of a comparable supersonic aircraft has been published by IPCC [1999] and Grewe et al. [2007], however for large scale aircraft with very different flight trajectories (altitude). Assuming that the climate impact due to contrail formation is similarly for sub and supersonic transport [Stenke et al., 2008], fleets of supersonic large-scale aircraft have 6 (SCENIC) to 14 (IPCC) times the climate impact of a respective subsonic fleet (Figure 8). For HISAC, a comparable subsonic aircraft has not been evaluated. To perform an intercomparison 2 assumptions for such an aircraft were made: (1) the ratio of CO2 to non-CO2 effects is assumed to be the same as for the SCENIC subsonic counterpart; (2) the ratio between the fuel consumption of the super- to the subsonic aircraft is 3. A 15% uncertainty range is taken into account for these 2 assumptions as well as for the non-CO2 effects of the supersonic HISAC fleet. A parameter variation leads then to a best estimate of a factor of 3 with and an uncertainty range of ±0.4. This corresponds to roughly 0.04 mW/m2 radiative forcing for the subsonic fleet.

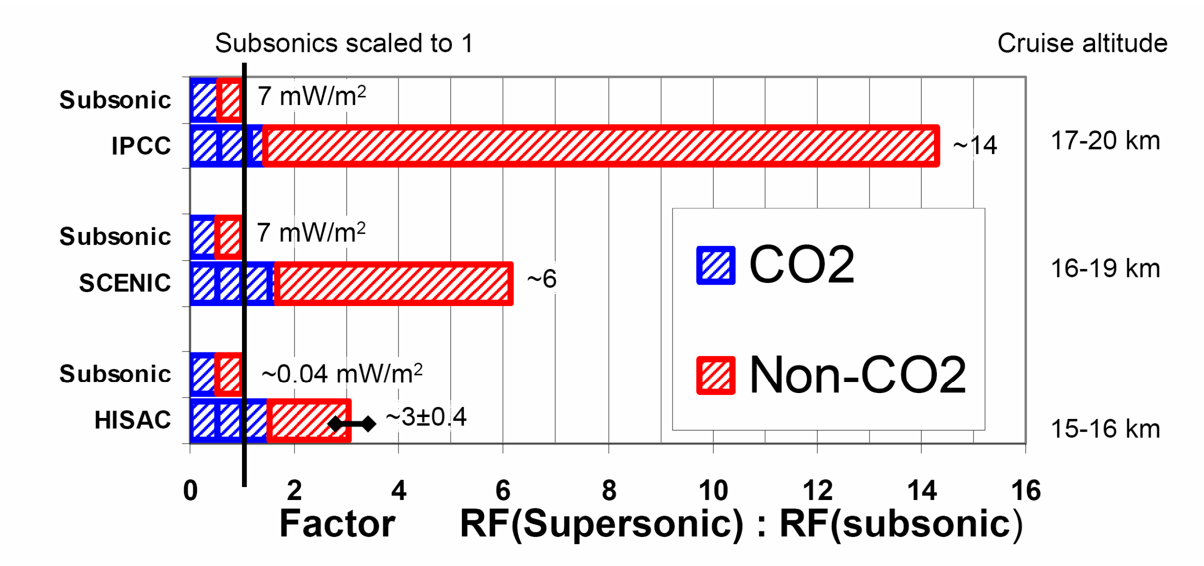


Figure 8: Intercomparison of subsonic and supersonic aircraft configurations from various programs (IPCC, SCENIC, and HISAC) with respect to radiative forcing.

Concerning ground emissions, the following work has been performed:

Current ICAO regulation addresses EI(NOx) as a function of engine pressure ratio for supersonic and subsonic aircraft. Combustion technology is one of the main factors controlling emissions. In fact combustor technology applied for supersonic aircraft is the same as the one considered for subsonic aircraft. However, engine operation for supersonic aircraft is very different from subsonic aircraft one since engine dimensioning design points are different. Combustion chamber inlet and exit temperatures at cruise for supersonic engine will be almost as high as a subsonic engine will have at Take Off, with OPR twice lower than subsonic engine ones because of the natural compression due to the high velocity. Due to noise constraints, supersonic engine will have also reduced power level at Take Off reducing further the temperature at the combustor exit, and hence the EI(NOx).

Among all the engine models generated in HISAC project, 5 engines have been considered to assess emission indexes (characteristics in Tableau 1 - HISAC engines). Within HISAC two technological levels have been considered for combustion chamber: current conventional combustion chamber and lean burn combustion chamber (as e.g. LPP). The latter has not been directly addressed by HISAC since this technology is already developed in other project focused on engine technology.

Engine #	Engine 2	Engine 5	Engine 16	Engine 24	Engine 31
Combustor	**Lean Burn Combustion**				
Architecture	CONV	CONV	CCV	CCV	CCV
Thrust (KN)	150	75	158	158	158
OPR @TO	21,2	27,1	23,0	28,0	24,4
Cruise XM	1,8	1,6	1,8	1,6	1,8
Jet velocity	350	350	350	350	400

Tableau 1 - HISAC engines

Figure 9 and Figure 10 presents thrust related NOx emission production Dp/Foo computed for the five listed above HISAC engines, with the lean burn combustion technology. All five engines (with LPP technology) have comfortable margins for versus ICAO Annex 16 Part3 Chap3 regulation current NOx emission. standard (CAEP/6) and foreseen standard CAEP/8.

This technology for combustors in HISAC is consistent with the emissions indices target for engine manufacturers in the Mid Term Band (around 2016). An Entry Into Service in a Long Term band (around 2026) would allow taking benefit for more advanced combustion chambers, designed to gain an additional 15% to 20% versus CAEP/6 limitations.

Furthermore it has to be noted that whatever the technological level, the lower OPR of supersonic engines leads to lower absolute DpNOx/Foo than the ones of subsonic engines.

In conclusion, LTO emissions are not constraining for supersonic aircraft, if the same lean burn combustion technologies as for subsonic aircraft are included.

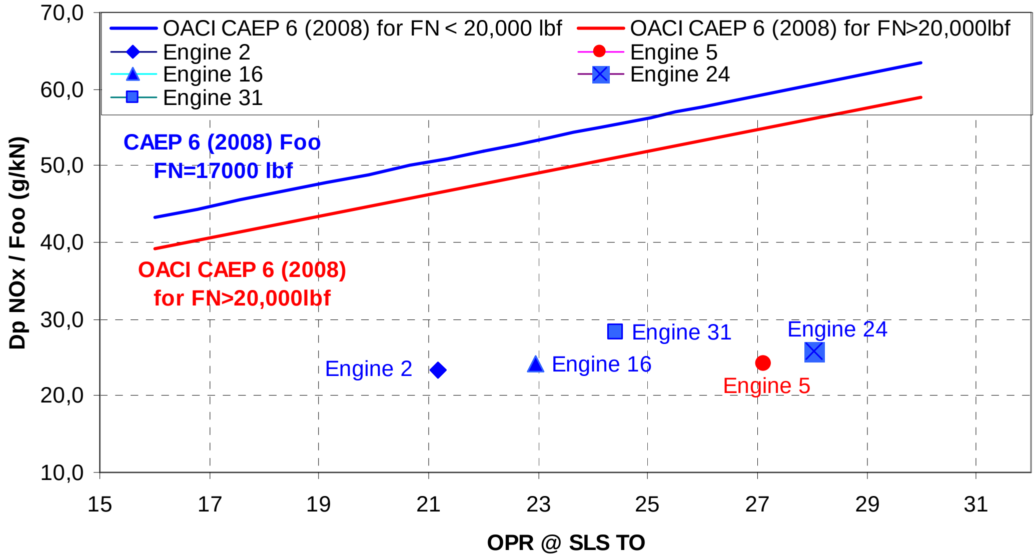


Figure 9 - HISAC Engines LTO NOx emissions compared to CAEP/6

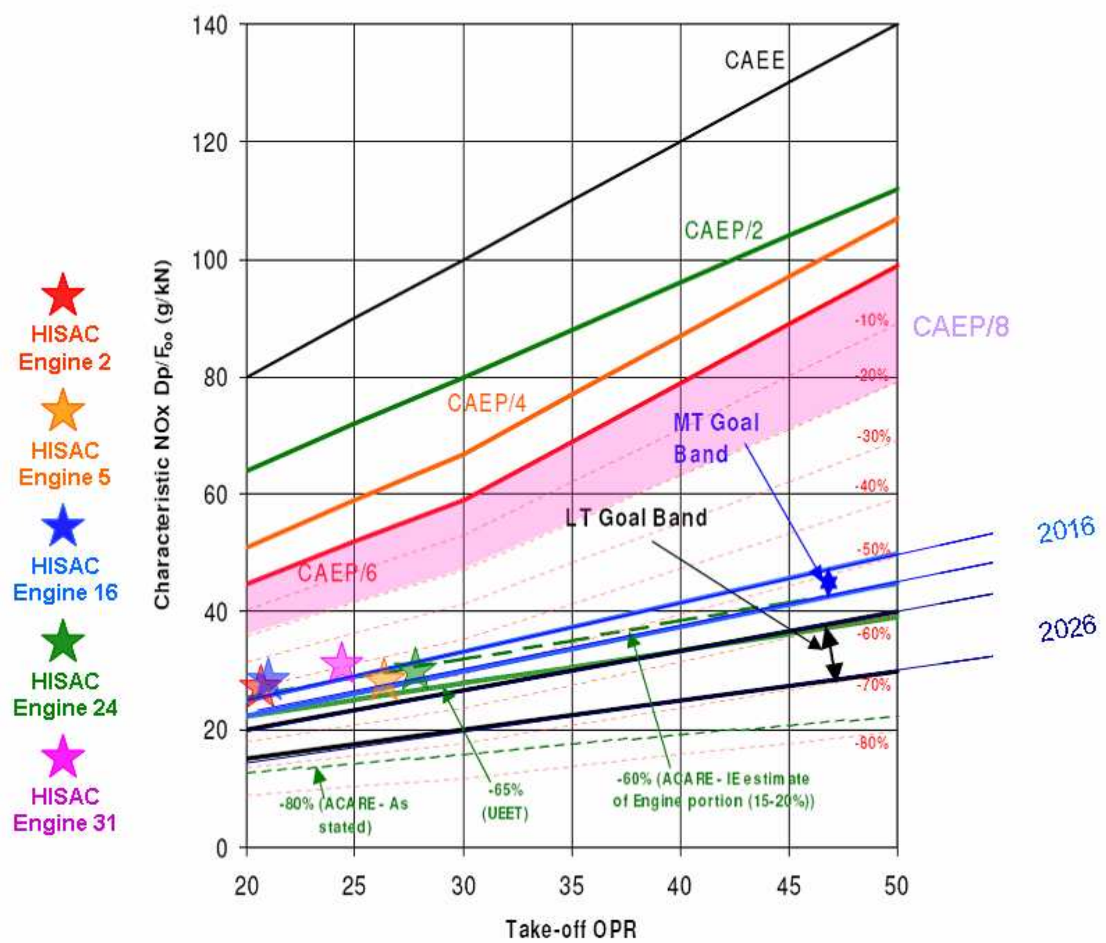


Figure 10 - HISAC Engines LTO NOx emissions compared to future regulations

5.1.3 WP1.3: Sonic boom criteria

CNRS, TsAGI, SCA, Dassav and ECL participated in WP 1.3. CNRS reviewed human response to sonic boom, ECL reviewed animal response to sonic boom, CNRS and TsAGI defined HISAC objectives in terms of low boom, TsAGI, SCA and Dassav evaluated low boom configuration, CNRS, SCA and Dassav participated to the SSTG process.

What is a sonic boom ?

Sonic boom is the ground trace of the pressure disturbance created by the passage of an aircraft, or any other object, flying faster than the speed of sound. A typical conventional (non-minimized) sonic boom time waveform measured at the ground looks roughly like the letter “N” (see Figure 11 as an example) and hence is commonly called an “N” wave. The distinctive characteristics of conventional sonic booms compared to other types of noise are:

1) the presence of two (or more) shock waves, e.g., large and sudden pressure variations that may be perceived like detonation noise (sonic boom is sometimes also called "ballistic detonation")

2) the slow variations in time of the part of the sonic boom between the shock waves. This portion of the waveform is slow enough to be inaudible by the human ear. However, because low frequency energy is present, it may induce some indirect noise and other non-audible effects that should be considered when assessing human acceptability to sonic boom.

So sonic boom is characterized as simultaneously a loud, low frequency and impulsive noise. It is impulsive because of its short duration (of the order of 0.1 to 0.3 ms, closely related to the length of the aircraft) with a relatively distinct termination (the last shock). Moreover the pressure increase through the shock waves takes place over a very short time, defined as the rise time, which is of the order of a few milliseconds. It is loud because of the overall peak overpressure is of the order of 50 to 100 Pa (1 to 2 psf). It is low frequency because the main part of its frequency spectrum is in the infrasonic or low audible frequency range (1-30 Hz).

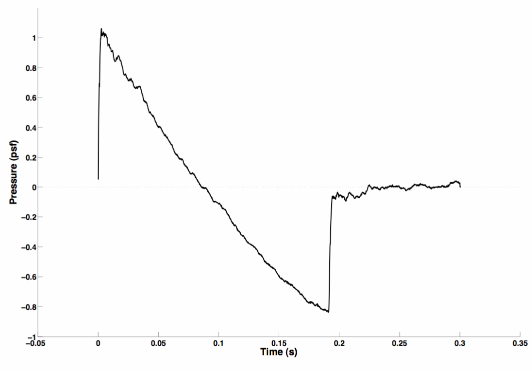


Figure 11 - Example of an N wave: sonic boom recording from a SR71

Existing regulations and recommendations

As conventional sonic booms are known be obtrusive to the public, this lead to very drastic regulations concerning supersonic flight. Regulations in the United States since 1973 (US Code of Federal Regulation 14 Part 91.817) assumes any and all sonic boom noise is unacceptable and currently prohibits i) civil aircraft from exceeding Mach 1 over US territory and ii) supersonic operations to or from a US airport that would make any sonic boom reach the ground. Some other countries have also issued some similar ban. Such very protective regulations date from the time where Concorde was the only civil supersonic aircraft in service. At the international level, ICAO resolution 33-7 (1998) aims “at ensuring that no unacceptable situation for the public is created by sonic boom from supersonic aircraft in commercial service”. However, a less stringent criteria has been proposed in 1974 by the US Environmental Protection Agency. Based on extrapolations of outcomes of the Oklahoma survey to lower booms, it recommended that a boom peak pressure level should not exceed $35.91/\sqrt{N}$ Pa, where N is the number of sonic booms per day. Note that Concorde when causing a sonic boom exceeding that level of 35.91 Pa (0.75 psf), arouse a report from FAA to the operating company. This EPA recommendation outlines the importance of the frequency of occurrence of sonic booms in terms of acceptability. This is confirmed by a more recent community surveys (1997). In general, poor correlation is observed between several metrics (such as peak overpressure, ASEL or CSEL) and annoyance, and the best correlation is with the number of booms perceived daily. This is important to take into account, as high adverse reactions might be expected from people likely to be frequently exposed to even low level booms. This arises the question whether the supersonic traffic (if any) should be made "homogeneous", with the risk of touching a large percentage of population (for instance large cities), or on the contrary "concentrated" over low populated "sonic boom corridors", at the risk of having a strong adverse reaction of a relatively small percentage of the population. This strong adverse effect will be enhanced as people in such corridors leave in a relatively quiet, undisturbed environment.

Human response to sonic boom

Human response to sonic boom includes physiological response (startle, sleep disturbances), outdoor response (noise), and indoor response (noise) coupled with building response (vibrations, rattle noise and structural damages) (Figure 16).

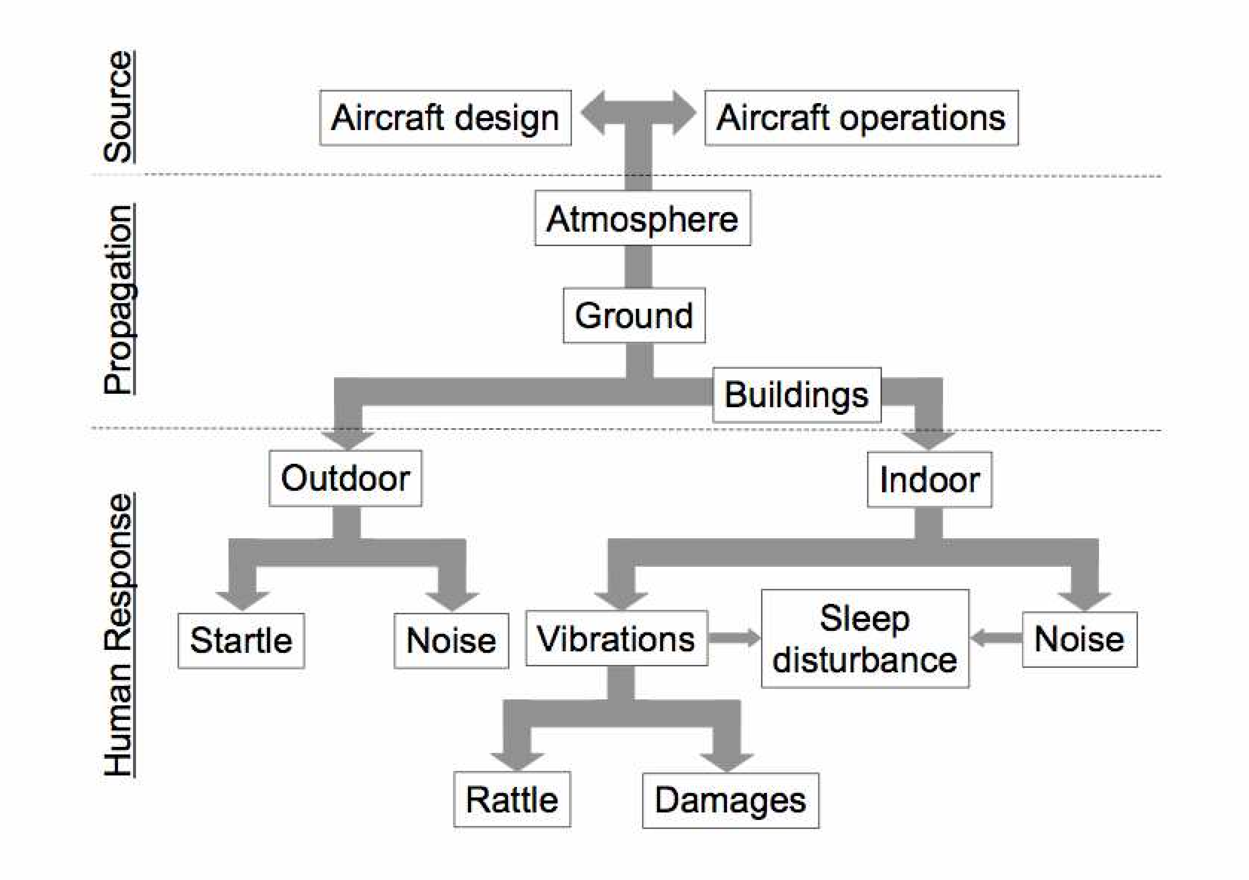


Figure 16 **– Human reaction to sonic booms.**

Physiological responses

Physiological responses of humans to sonic booms have been considered in the form of startle, effects on the auditory system, and sleep interference.

As the human auditory system is adapted to respond to very small pressure fluctuations, concern arose about its sensitivity to intense sonic booms. Several experiments concluded that the sonic boom can be disregarded as a threat to the auditory system.

Startle is one of the main components of adverse reaction to sonic booms. Startle effect can be measured through muscular response.

Only preliminary results about the effect of simulated booms on sleep have been reported, with the following effects:

- more awakening (during first stages 1 and 2 of sleep) occurred for louder booms (1.6 and 2.1 psf) than for less loud ones (0.6 and 0.8 psf)
- some adaptation effect was observed for low booms but not for loud ones
- awakening was about the same for all booms during the REM stage of the sleep (Rapid Eye Movement stage)
- old subjects are more likely to be awakened by sonic booms than young ones.

Note that for night noise, World Health Organization recommends individual noise events should not exceed an *indoor* equivalent sound level of 45 dB LAmax - or equivalently SEL values of 55-60 dBA.

Loudness of outdoor booms

The reasons why a conventional sonic boom is considered annoying are now quite reasonably well understood, following several community surveys, laboratory studies, in home studies and recent low boom flight tests combined with psychoacoustical investigations. Outdoor, conventional sonic boom is considered annoying because of the startle effect (which is a physiological effect, sometimes producing some uncontrolled movements) linked to the loud and sharp pressure jumps of the shocks. Laboratory studies show the highest correlation between boom level and loudness or annoyance response for the Perceived Level (Mark VII) and A-weighted Sound Exposure Level metrics.

Multiple effects of indoor booms

However, and at least for ways of lifes of developed countries, people spend most of their life time indoor (for work, sleep, home work, social life...). Indoors, the direct audible noise from a sonic boom may be reduced because of filtering by the building structure. However the damping rate may be strongly dependent on the construction quality of the house (materials and thickness of the walls, windows or roofs, height of the building, open or close windows...).

Vibrations and rattle

The low frequency content of the sonic boom spectrum may induce vibrations (of the walls, the windows, the furniture, etc.) that can be perceived directly (through visual and / or tactile perception), or indirectly through rattle noise (indirect noise at audible frequency created by nonlinear contact conditions of an object subject to high amplitude, low frequency vibrations - a typical example is rattle from a window pane loosely fitted to its frame). It is known that this rattle can be very annoying to some individuals. C-weighting may be recommended for sound metrics for impulsive noises as it puts more weight to low frequency and hence better takes into account the perception of vibrations and rattle.

Concerning levels of vibrations, an ANSI standard (ANSI 2006) recommends satisfactory vibration magnitude with respect to human response in the 1 to 80 Hz range. Though this standard is mostly conceived for continuous vibrations, some recommendations are provided for impulsive shock excitations with three or less occurrences per day.

While window vibrations may not be perceived as such, they are a good candidate for rattle. A suggested criterion for rattle threshold of 0.024 g is about 2 orders of magnitude *smaller* than some of the recently observed values during flight tests. As a sonic boom from a civil aircraft will anyway impact a wide area and a large number of constructions of unverifiable quality, there seems to be no way to escape from a significant percentage of the overflown population hearing boom-induced rattle noise.

Structural damages

A few surveys report about complaints about damages suspected to be caused by sonic booms. The most frequent compensated complaints are windows and glasses breaking, damages (mostly cracks) to inner walls, ceilings and floors, and those to roofs and chimneys. The US surveys indicate no damage incident occurs for boom exposure below 0.8 psf (40 Pa), and a number of damage incidents of about of 1 per flight and per million people for larger boom exposure. The general trend is that the mechanical effect of such a conventional boom is

- larger by about one magnitude order than most of the usual disturbances (for instance air or road traffic)

- comparable to the effect of some in-home disturbances (such as a loud HI-FI sound system, a slamming door, a shoulder push or a person jump);

- smaller than the effect of a wind with a mean velocity of 60 km/h; iv) one magnitude order smaller than the value required for the structural breaking.

As a conclusion, sonic booms of Concorde-type amplitude (100 Pa overpressure) mostly affect light structures (windows, light ceilings or walls) with poor quality (assembling and/or maintenance), which are close to failure. That conclusion will be all the more valid for a low-boom designed aircraft, for which vibrational effects will be smaller and more comparable to those of other environmental sources. However, compared to Concorde sonic boom, the smaller size of an S4TA will also imply a shift of the peak frequency to higher frequencies (from 4 to 10 Hz). As a consequence, an S4TA will affect different structural elements that have a higher resonance frequency (for example smaller window panels). In that case, the structural effects from a low-boom designed aircraft would be a major adverse effect against acceptability of overland sonic boom. Between these two extreme cases, and according to the knowledge from the present review, it is difficult to conclude definitely about the level required for an acceptable overland sonic boom in terms of structural damages and further research is needed.

Key issues for an acceptable sonic boom overland

Low boom design has been largely driven by the above conclusions that the *first* cause of annoyance from conventional booms is startle (and loudness) due to sharp shocks. To reduce sonic boom perception, first it is necessary to reduce the mass of the aircraft. This is why business jets appear as good candidates for supersonic overland flight, as they are smaller and lighter than, for instance, Concorde. So there is a natural and immediate benefit in terms of sonic boom level, and one can expect to more or less halve the peak overpressure Figure 17, from 100 Pa (2 psf) to around 50 Pa (1 psf). However, the mass effect alone is not sufficient. For instance, a 50 Pa boom remains well above the criteria of 36 Pa proposed by EPA. Consequently, boom shaping is also required to further decrease the boom amplitude at the ground. The objective in such design studies has generally been chosen to decrease the amplitude of the head shock of the "N" wave, and increase its rise time. Several techniques can be employed (aerospike, fuselage tailoring, highly swept and diedral wings, over-the-wings engines...) but in all cases the target remains (at least up to now) smaller and longer shocks, so that most part of the audible high frequency spectrum is filtered and the startle effect is hoped to be suppressed.

However, once the startle is suppressed, the effect of indoor vibrations and rattle (and the associated concern for structural damages) will come out at the main source of concern for low boom acceptability.

Figure 17 illustrates the sonic boom challenges: A small aircraft like a business jet produces a boom lower than Concorde's one (typically 50 Pa instead of 100 Pa) but probably higher than a yet unknown "acceptable" value that might be lower than the value of 36 Pa suggested by EPA in 1974 based solely on extrapolations from community surveys in the 60's. The shown correspondence between peak overpressure, ASEL and CSEL metrics is here purely indicative and is based only on best-fit extrapolations from the BoomFile data base for conventional N waves. The variability is also here indicative and may vary with metrics. Low boom design aims at obtaining further benefits for a given metric with respect to N waves. The value of 15 Pa is the initial target of the Quiet Supersonic Platform program from DARPA. The value of 85 dBC is the limit of CHABA for a loud impulsive noise, and the value of 60 dBA is the threshold recommended indoor by WHO during night for single noise events, not taking into account the additional disturbances due to vibrations and low frequencies.

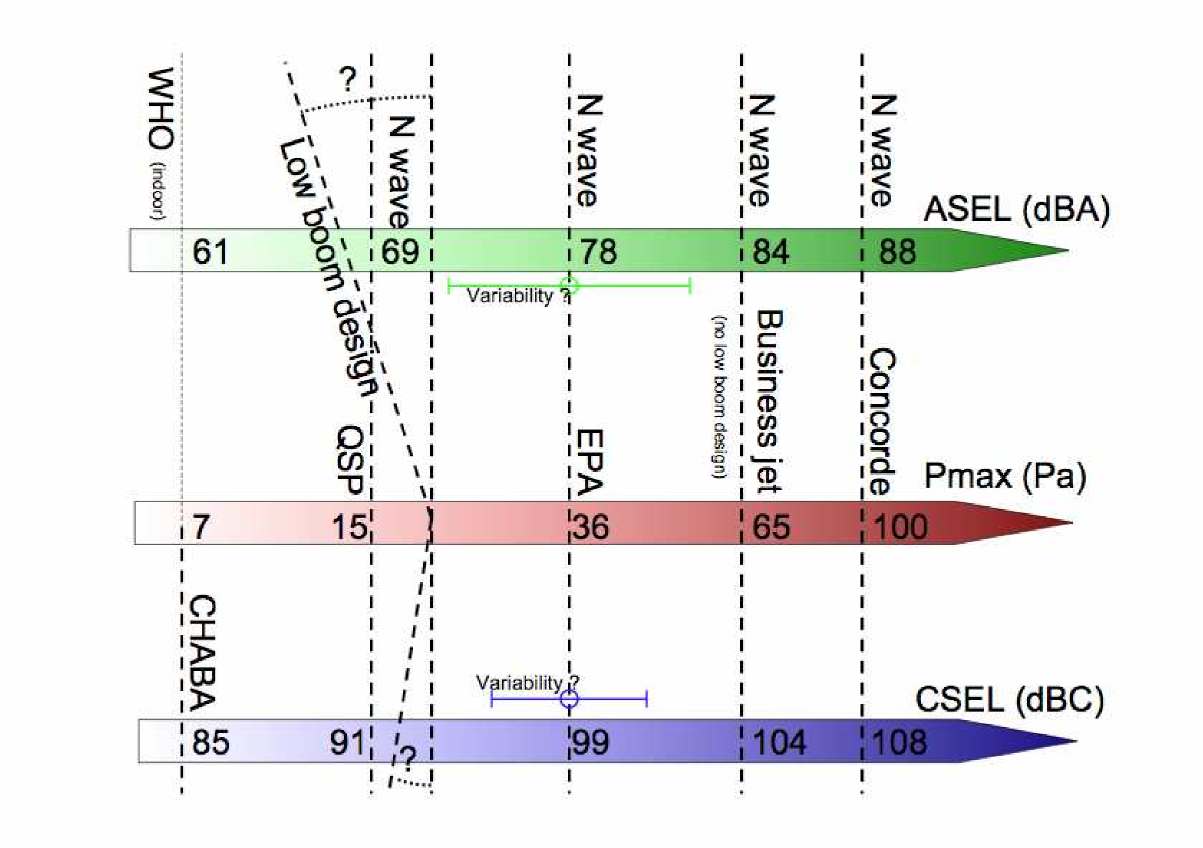


Figure 17 - The sonic boom challenge.

Hence, the sonic boom issue has recently shifted, in terms of design, from a noise mitigation issue to a multiple response mitigation issue, even though the variety of the human response to sonic boom is known since the 60's.

So one key question is to quantify the efficiency of boom shaping in terms of the various boom effects, and not only in terms of noise. With this in view, the lack of an appropriate metric for measuring indoor boom annoyance is critical.

The second key issue is the boom variability (that is dependent on the metric, as exemplified by the comparison between ASEL and CSEL) due to climate, meteorology, turbulence and buildings. Because of this variability, the ground sonic boom appears as a stochastic process. Hence any regulation will have to take this into account, and also suggest adapted certification processes. Given the fact that it will be impossible to produce a "global" experimental database relying only on flight tests, a massive use of numerical predictions will probably be necessary. In particular, that will require careful validation with flight tests, and benchmarking of various numerical procedures.

A third essential issue will be the fact that the human response depends not only on the aircraft but also on the way it is operated. Repeated booms, focused booms due to transonic acceleration, and night booms may already be identified as likely critical issues Figure 18. Hence, even though if a low boom aircraft with an "acceptable" cruise boom can be designed, this one may suffer from operational restrictions (such as a night curfew or restricted acceleration areas) that may reduce or even compromise its profitability.

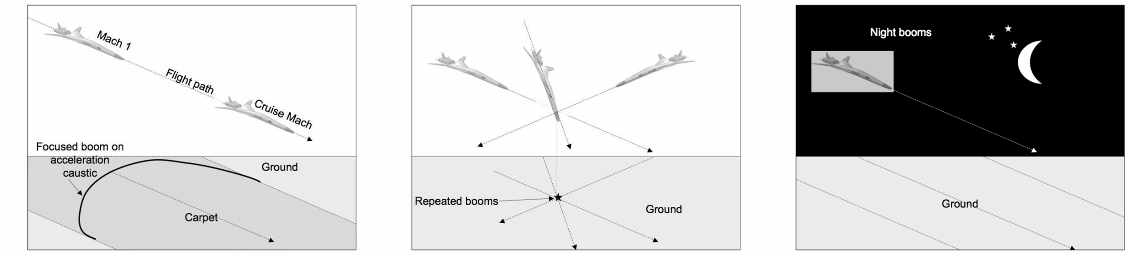


Figure 18– Focused booms due to transonic acceleration (left), repeated booms (centre) and night booms (right)

HISAC sonic boom targets

In the absence of existing or foreseeable regulation on sonic boom overland, targets of the HISAC project in terms of low boom performances were chosen according to figures and indications found in the literature and compatible with aircraft feasibility.

The suggested levels of 72 dBA for overland flight over low populated corridors and of 65 dBA for unrestricted operations have been selected within HISAC as technical targets. These figures should not be regarded as an "acceptable" or "regulatory" level.

The percentage unacceptability due to simulated boom function of A-weighted Sound Exposure Level according to NASA is reproduced below in Figure 19.

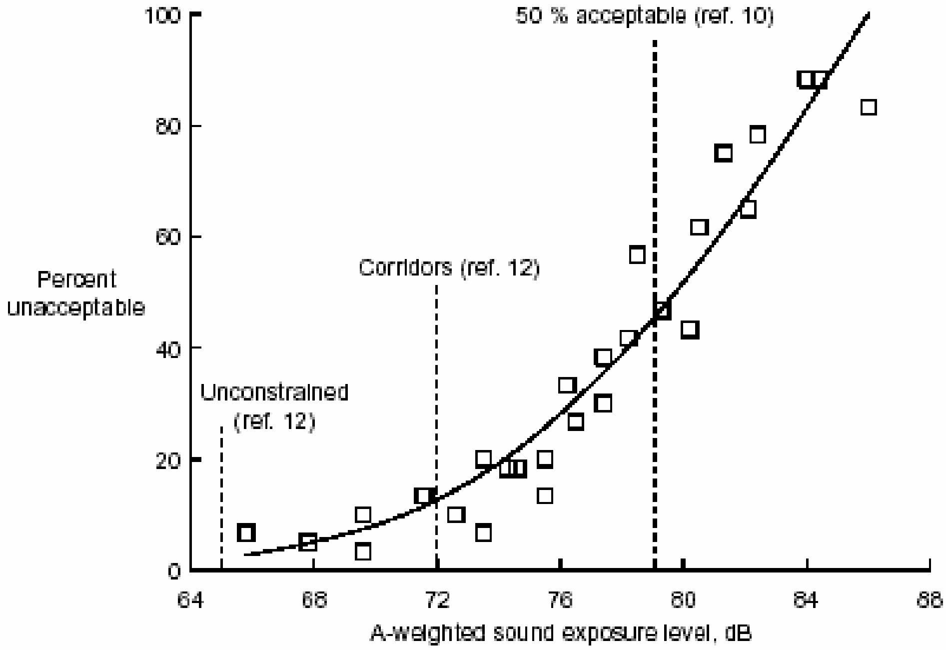


Figure 19 – Percentage of unacceptable ratings versus ASEL level (dBA) with comparison to proposed criteria based on laboratory studies

5.2 Work Package 2

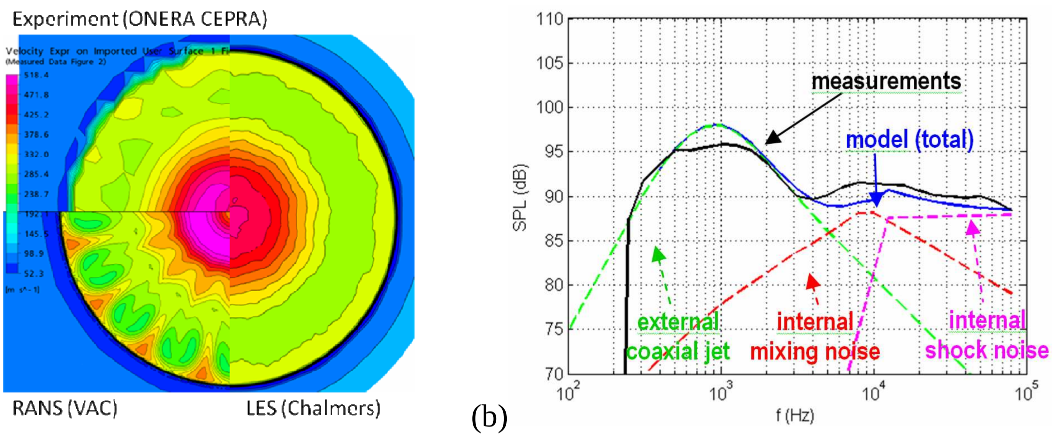
The objectives of Workpackage 2 are:
• to select and validate analysis and design models, tools and methods,
• to perform focused improvements, in the fields of noise, emissions, sonic boom, engine models, aerodynamics, and multidisciplinary design optimization (MDO). Input to this task are pre-existing modelling tools available at each partner.
Results from this WP have been used:
• for the detailed configuration assessment in WP 4,
• for the MDO process in WP 5.

5.2.1 Task 2.1: Noise modelling

The noise objectives within HISAC have included noise from the engine fan (ISVR and Snecma) and various airframe components (ISVR) as well as jet noise. However, for a S4TA, jet noise is identified as possibly the most serious problem and this has therefore been the activity to which the bulk of the effort has been placed. There are two aspects of this problem that required further investigation.

The first (and primary) objective was to develop and benchmark noise prediction models for the mixer-ejector nozzles proposed for use in the HISAC project. This work was undertaken by ISVR, DASSAULT, Snecma, NLR , TCD and Chalmers. Since noise is a critical factor in aircraft certification, it is important that tools must be available at the design stage to predict the noise generated by any engine configuration. The challenge in the current study arose from the fact that, while more traditional engine designs have been studied and modeled for many years, no satisfactory model for mixer-ejector nozzles fitted to coaxial engines existed.

The work was composed of three parts: an experiment to measure the flow through the nozzle and the noise generated, the use of Computational Fluid Dynamic (CFD) tools to see if this flow could be predicted, and then the development and use of acoustic models (some based on the CFD) and the testing of these models against experiment. The experimental test was successful, providing flow and acoustic data at a range of engine operating conditions. The CFD predictions showed that for the mixer-ejector nozzle, where the mixer lobes introduce additional vorticity into the flow, RANS calculations cannot predict the mixing of the fluids inside the ejector nozzle, but LES is much more successful in this case. A comparison of the predictions with the measurements is shown in Figure 16(a). For the acoustic predictions, three methods were tested: the traditional Tam and Aurialt method, a Ffowcs Williams-Hawkings prediction, and a semi-empirical approach. The first two of these methods require input from the CFD calculations mentioned above, while the third is freestanding. It was found that both of the CFD-based methods gave poor results for the nozzle geometries considered in HISAC. The third approach, whilst based on fairly traditional methods and ideas, was newly developed for the project: the concept was to consider different regions in the complicated mean flow as independent acoustic sources, and to model each of these source regions in terms of a simplified flow for which traditional methods could be applied. The final form of the model included a large number of these source regions, but it was found that the predicted results compared well with the measured acoustic data (see Figure 1616(b)) and was able to explain the different sources causing different arts of the radiated noise (including a breakdown into shock and mixing noise sources).



(a) (b)

Figure 16: (a) Velocity on the measurement plane.(b) Example of comparison of model predictions to measured data.

The main outcome of this task was the generation of an acoustic prediction code for mixer-ejector noise, which is computationally cheap and can therefore be used at an early stage in the engine design process; in addition, a body of experimental results exists against which future improved prediction methods can be tested.

A second requirement was to ensure that the effects on noise of the aircraft superstructure could be properly predicted. While the noise from components such as the engine exhaust can be modeled and measured --- these are usually done for isolated components in the first instance. When engines are installed on the airframe this noise changes (installation effects) and it is necessary to have reliable tools for predicting these effects. DASSAULT, EPFL and the ISVR undertook this task, developing a number of different models for the task.

The main impact for industry from WP2.1 is the provision of new and/or improved methods for mixer-ejector noise, fan noise and installation effects.

5.2.2 Task 2.2: Emission modelling

WP 2.2 on emission modelling has two main parts, which consists of (a) simulating emissions and (b) developing a simplified climate-chemistry model based on a complex climate chemistry model. The simplified model has been applied to the calculated emissions in WP1.2.
The emission modelling has been a common activity performed by a DLR-Cologne, DLR-Oberpfaffenhofen, FOI, and CIAM. DLR-Cologne calculated emissions for surface conditions applying correlation methods (Figure 17), which were intercompared with detailed combustion chamber calculations, performed by CIAM. These emission characterizations were then combined with trajectory calculations to actually calculate emissions along flight paths.

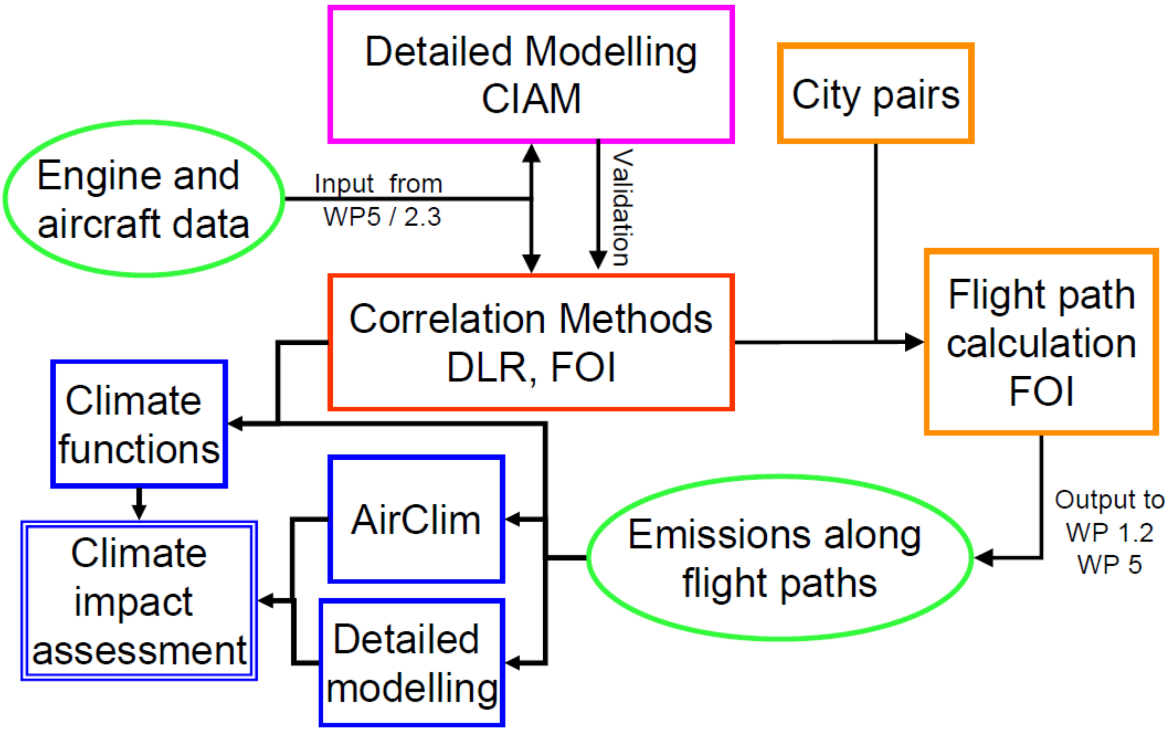


Figure 17 Overview on Task 2.2.1

The second part is an activity performed by DLR and comprises detailed climate-chemistry simulations in order to form a basis for the simplified climate-chemistry model AirClim and a validation of the AirClim model.

Results from the emission modelling can be seen in Figure **18**. Differences in fuel consumption (left) of the 3 configurations arise from differences in specific fuel consumption, weight, etc..The general shape of the profiles is similar. Mean values are given in Table 2. Taking into account 250 aircraft with 100 flights each, this sums up to 0.4 Tg fuel per year, clearly less than for large passenger aircraft considered in previous programs: SCENIC: 62 Tg per year and IPCC: 137 Tg per year. The NOx emissions peak at the same altitude as the fuel consumption (Figure 18 mid). The NOx emission index is estimated to be between 10.5 and 12 g(NO_2) per kg fuel. Earlier studies (HSRP, IPCC, and SCENIC) have estimated a theoretical possible emission index of around 5 g/kg, whereas here the results are based on expert knowledge from actual measurements of emissions in a test bed. A conventional combustion chamber as characterized in the HISAC project is not recommended, since the emissions indices are locally up to 40 g/kg fuel and around 30 g/kg fuel at supersonic cruise. However, combustion chamber technologies were not specifically addressed in the HISAC project. Therefore the results have to be considered as upper limits and outdated for the conventional combustion chamber.

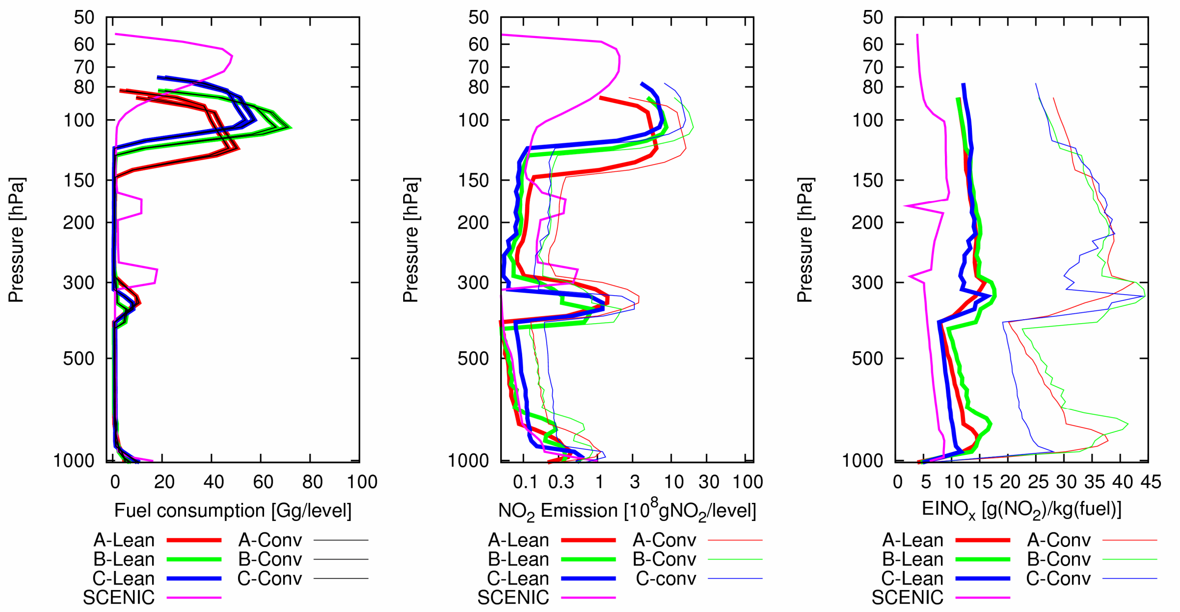


Figure 18 Profiles for fuel consumption (left), NO_x emissions (mid) and emission index of NO_x (right) of flights P1 to P4 and SCENIC. Some of the profiles are close, so that they are overlaid. The SCENIC data are scaled to represent the same total annual fuel consumption.

Results from the detailed climate modelling approach are discussed in the following. In order to derive a basis for a linearization approach 24 emissions regions were defined (Figure *19*). For each of these emission regions a multi-annual climate chemistry simulation was performed to investigate the response of the atmosphere to a unified emission at that location. Figure 20 gives a summary of the results, which indicate the impact of the emission location on the atmospheric parameters, like the perturbation lifetime of water vapour (a) and methane (b); as well as water vapour (c) and ozone

(d) radiative forcings of a unified emission. Clearly, the higher a water vapour emission occurs, the longer is the background concentration perturbed. The radiative impact of a unified emission is dominated by ozone in the troposphere, whereas in the stratosphere water vapour becomes much more important.
The results form the basis of the simplified climate-chemistry model AirClim (Grewe and Stenke, 2008). A validation of the simplification is shown in Figure 21, where key components are shown in the top row for the detailed simulation and in the bottom row with the AirClim model. The agreement with respect to pattern and absolute values is excellent. The computing resources for the detailed calculation are in the order of week on a supercomputer, whereas AirClim runs in seconds on a normal desktop computer.

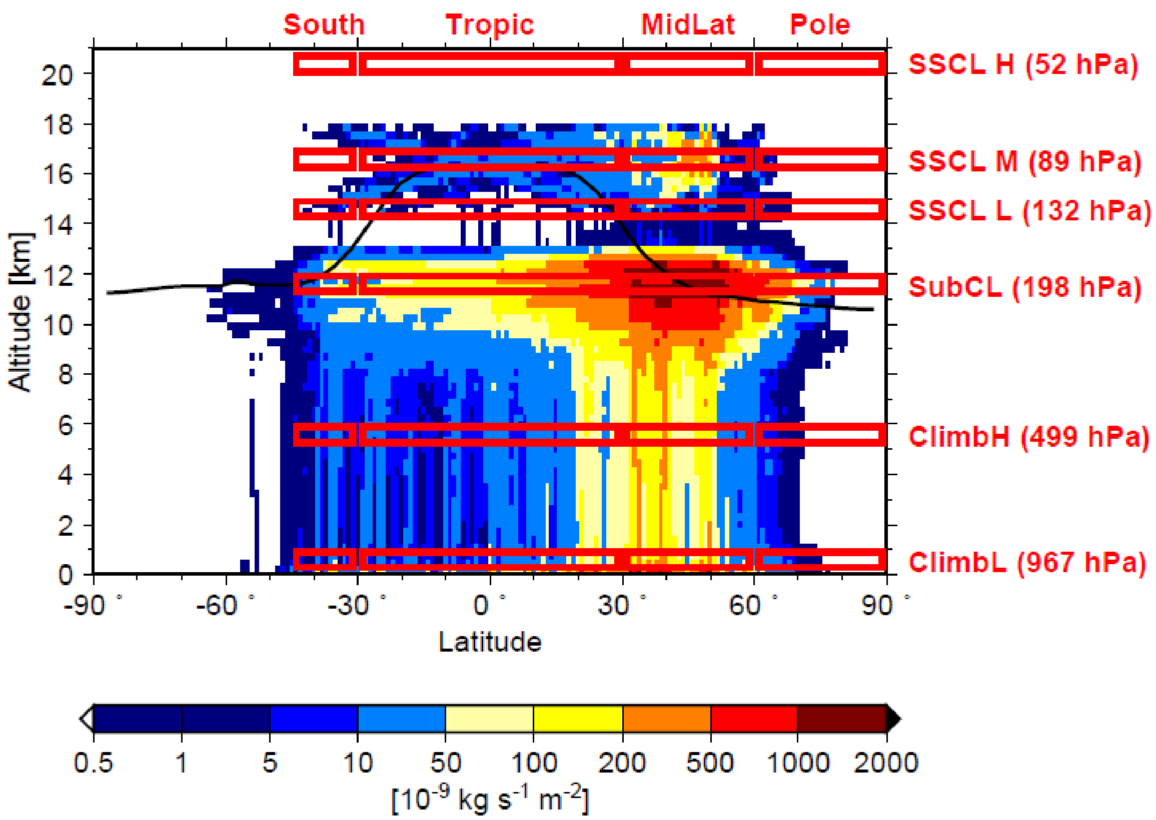


Figure 19 Location of 24 emission regions used for the linearisation of perturbations of the atmospheric composition. Fuel consumption (zonally integrated) of a mixed fleet (SCENIC 2050 data) is underlaid for illustration [kg/s/m2].

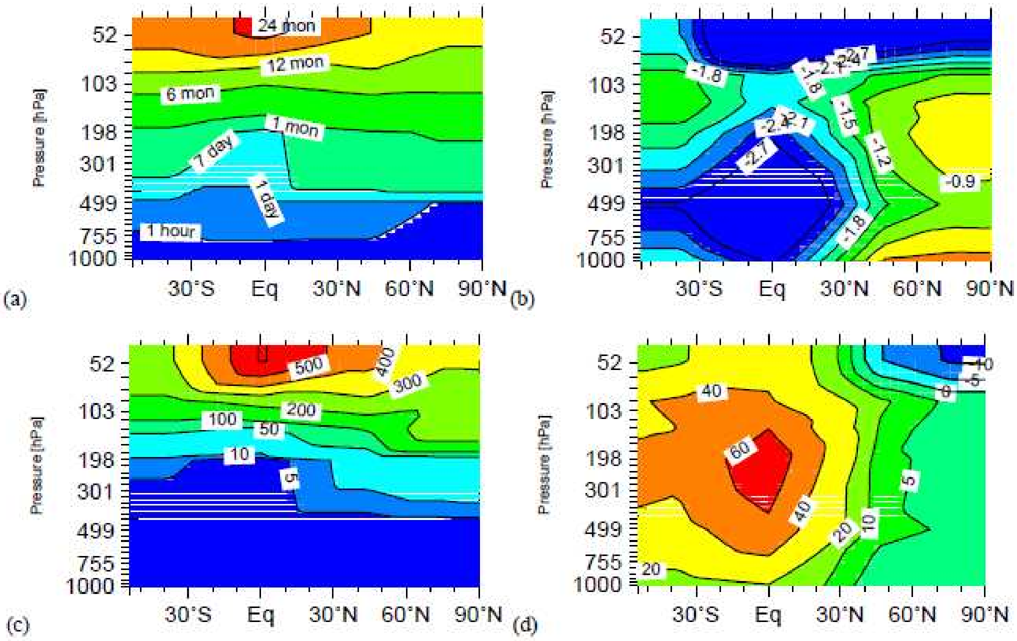


Figure 20 Water vapour perturbation lifetime (a), methane lifetime change [%] (b), and radiative forcing at the tropopause for the water vapour (c) and ozone perturbations (d) normalised to the same total annual emission of 1 Pg water vapour and 1 TgN of NOy in mW/m2.

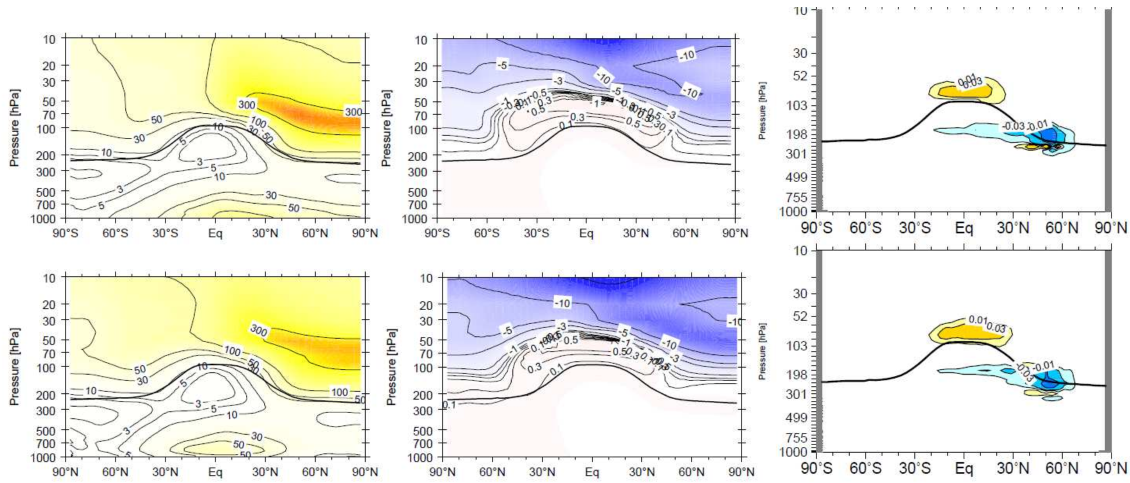


Figure 21 Annual mean changes in water vapour (left) [ppbv], ozone (mid) [ppbv], and contrail coverage (right) [0.1%] caused by a supersonic fleet (here: SCENIC S5 mixed fleet minus subsonic fleet S4). Top: Results derived with E39/C; Bottom: Calculated with AirClim. Thick lines indicate the location of the tropopause. Isolines for contrail changes are −0.3, −0.1, −0.03, −0.01, 0.01, 0.03, 0.1, 0.3.

5.2.3 Task 2.3 Sonic Boom modelling

One of the prerequisites for an environmentally friendly supersonic jet is that the signatures are reduced to a level acceptable for flight over populated areas. Task 2.3 is devoted to sonic boom prediction and minimisation methods. The studies have been conducted for a common reference

aircraft configuration in order to dispose of validated tools capable of achieving low(or no) boom constrained design assessment and optimisation.
The task relied on the results of the SOBER European project which was dedicated to sonic boom modelling and was be finished in 2004. The work also relied on the very successful sonic boom minimisation work performed within the COS French national program in particular by INRIA and in the US with the support of DARPA.
The results obtained in this task helped to improve the MDO processes used in WP5. The objective of task 2.3.1 was to improve fast sonic boom evaluation tools using Whitham function. Task 2.3.2 provided the tools and the methodology for the sensitivity analysis performed in WP4. (e.g. : range of the aircraft performance due to shape modifications vs sonic boom reduction).
The main conclusions and perspectives of both tasks are summarized below.

Task 2.3.1 Sonic boom modelling

- New tools for sonic boom evaluation have been built. These involve models for predicting physical effects related to meteorological conditions (DLR's contribution) together with effects related to turbulence (ECL-LFMA's contributions). Data bases have been built.
  A strong influence of latitude in Europe has been put in evidence in term of no-boom days in a year.

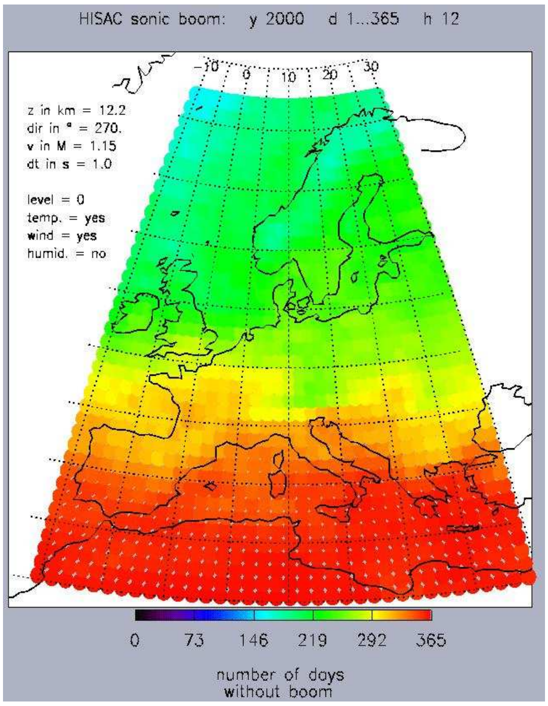


Figure 22: An example of output of the study: number of days without sonic boom in a year.

- Several tools for directly predicting sonic boom at ground have been studied and validated. Their accuracy is interesting and validate their use in design process.

- Novel tools for sonic boom emission, near-field and far-field propagation has been designed and developed. The effect in choosing one of the far field model has been measured. The multi-pole variant is the most accurate. The effect of computing accurately the near field propagation, in particular with new mesh adaptation algorithms has been studied. The golden choice today seems a matching a distance of about 5 with adaptive Euler flow. The increased power of mesh adaptive Euler prediction is not yet able to take into account the whole propagation down to ground, but allowed a mid-path validation of the multi-pole propagation model at R=40.

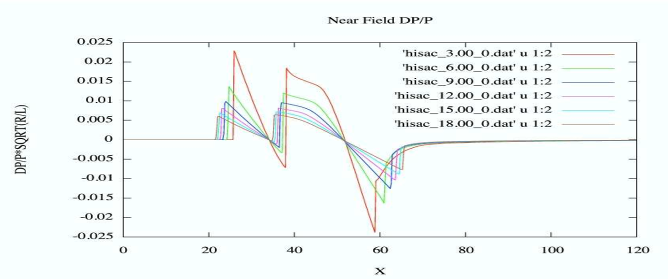


Figure 23 Near-field shock propagation computed with mesh-adaptative Euler model.

Task 2.3.2 Sonic boom minimization

- A series of sensitivity studies have been applied in order to evaluate the impact of shape modification on sonic boom.
- Different new approaches for sonic boom reduction have been designed, developed and studied.
- Results on the benchmark show potential sonic boom loudness reduction by reduction of near field overpressures with fixed lift and drag coefficients: 16% on the initial shock pressure rise and 49% on the second shock (Far field:3 dBA). Our automatic optimization process is coherent with the design procedures used by aerodynamicist. Sensitivity analysis allows us to assess the relative importance of the different design variables and exchange rates cost-constraints. A large set of information concerning sonic boom behaviour and sensitivity has been gathered.
- Mesh adaptation on baseline and optimized shapes confirm sonic boom reduction.
- Drag constraint relaxation led us to small additional improvement.
- Wing's dihedral angles from WT configuration 1 derivative have been assessed. Only small improvement has been obtained. In order to obtain a larger sonic boom loudness reduction, we need investigate several more complex geometrical devices:
    - Additional lifting surfaces: canard, tail, …
    - New design wing parameters: wing sweep angles, …
    - A sophisticated near field target, a mid field target (multipoles), a far field target.

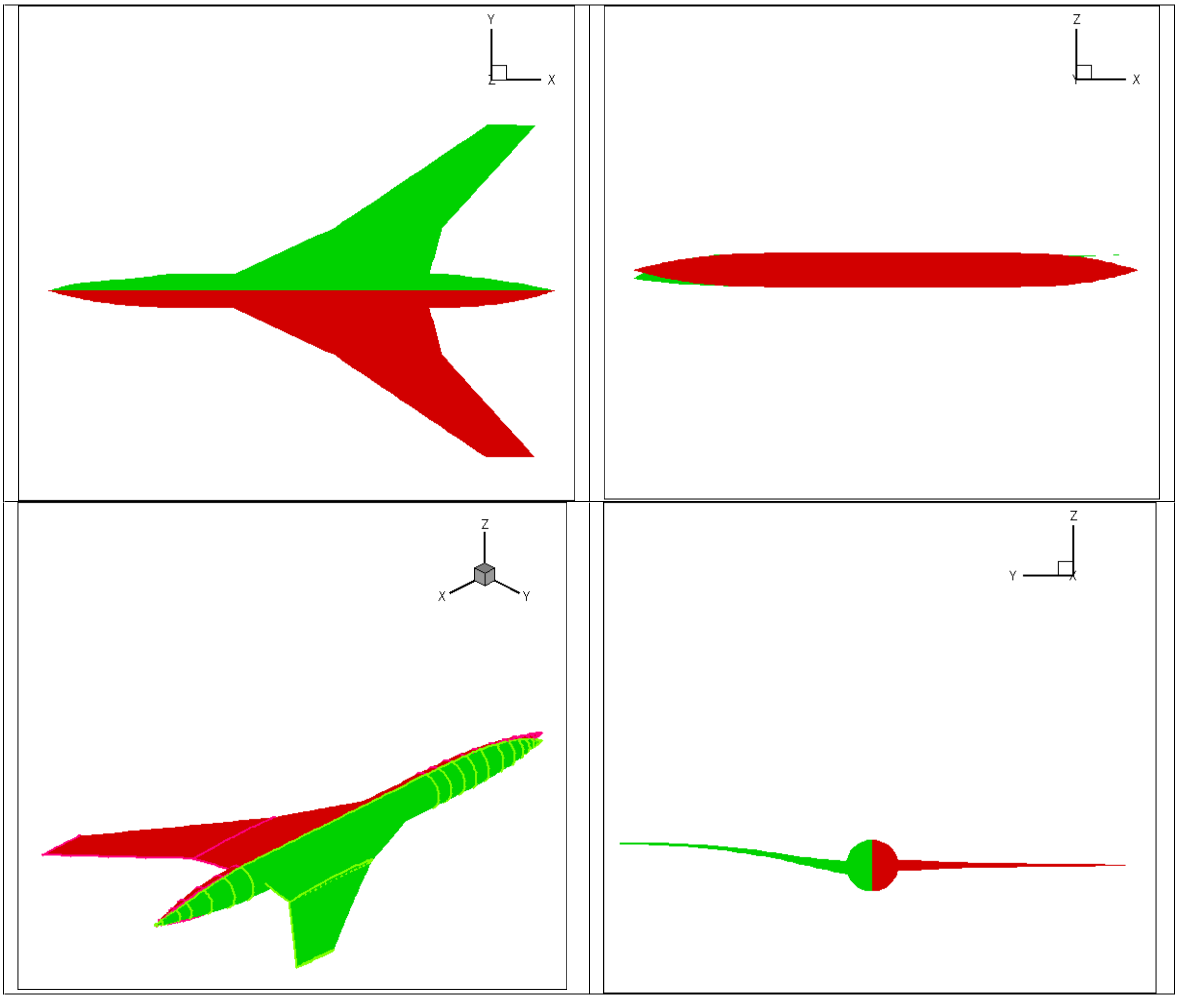


Figure 24 Example: Geometry before / after optimization.

Task 2.3.2 Sonic boom minimization using plasma
EPFL performed innovative experiments using plasma actuators made of a dielectric surface discharge (DBD) on the surface of a wing under high speed conditions to investigate the effect of using locally ionized environment on the shock strength and rise time by measuring the far field pressure signature, and performed Schlieren imaging to compare the situation of "plasma on-plasma off". The results showed negligeable effects on the shock sharpness and strength, and a small effect on the rise time. However the flow modifies considerably the plasma, leading to filamentary edge effects on the DBD.

5.2.4 Task 2.4 Engine modeling

The objective of this task is the deployment of engine modeling tools capable of representing HISAC engine configurations including variable cycle technologies. The resulting engine models must be able to be easily scalable and configurable for HISAC trade-off studies, interface with HISAC aircraft models and represent state-of-the-art engine technologies for supersonic propulsion, including variable cycle concepts
(variable geometry inlets, nozzles, bypass valves, inlet doors, midfan concepts, ejector nozzles etc.).

Description of work:
1) Requirements definition in collaboration with other HISAC WP's.
2) Inventory of candidate modeling tools and –environments. A list of candidate tools needs to be setup with sufficient information and a reasonable outlook to the generic modeling and other HISAC requirements.
3) Modeling tools assessment
The modeling tools have been assessed on compliance to the HISAC requirements and also (or including) the following criteria:
◊ genericity / flexibility,
◊ covering of all component models required
◊ producing required output (including emissions)
◊ fidelity / accuracy
◊ interfacing to aircraft models
◊ user friendliness
◊ compliance to standards
◊ future support
◊ more criteria may be added depending on the results of sub-tasks 1 and 2.
4) Selection of tools for the HISAC studies
5) Preparation of engine models for HISAC

An inventory has been made of existing engine modeling tools. The result of this inventory has been documented in the report 'List of candidate modeling environments' (HISAC-T-2-10-18). Preliminary engine designs, both conventional and the CCV concept were provided by Snecma. Both CIAM and NLR provided spot point tables for the conventional engine. Assessment of the results is carried out. As the NLR model (GSP) was not designed to give weight or dimensions estimates, and also did not include supersonic mixer-ejector combinations, it was decided to generate all spot point tables with the CIAM tool.

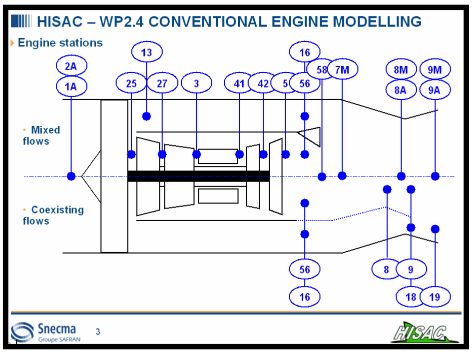


Figure 25 Definition of engine stations used in the spot point tables

All tables were checked and approved by SNECMA.

The CIAM initial activity was focused on selection and adjustment of modeling tool as well as on definition of model specifications for A/C MDO studies.
The set of the models comprised different engine architectures, incl. CONV, Variable Cycle and first Mixer-Ejector models. Sensitivity studies were made on engine performance, dimensions and dry weight, having thrust specifications, size, jet velocity at take-off and cruise Mach number as main drivers in order to cover requirements of MDO process. The synthesis has shown trade-offs

between engine dimensions, weight and performance versus jet velocity (jet noise driver) and architecture (Figure 26, Figure 27).

The full MDO design matrix was completed at T0+36.

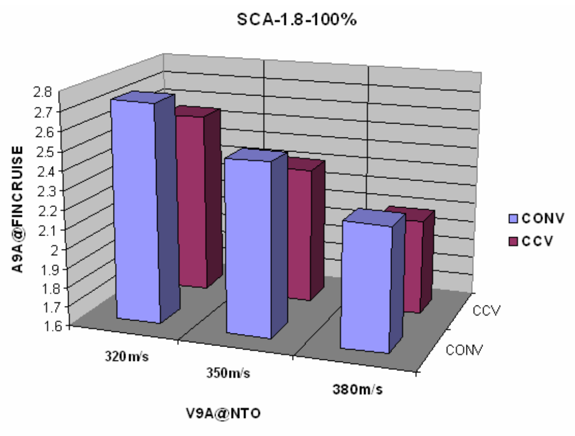


Figure 26 Impact of engine jet velocity at normal take-off V9A@NTO and engine architecture on nozzle maximum diameter A9A@fincruise. Fixed thrust specifications. XM cruise=1.8. Reference engine size.

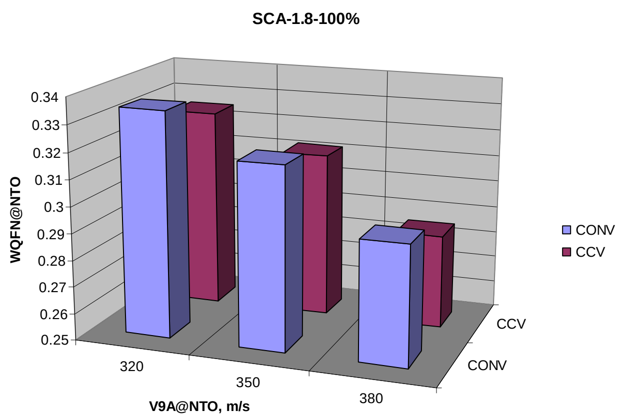


Figure 27 Impact of engine jet velocity at normal take-off V9A@NTO and engine architecture on engine specific weight at normal take-off WQFN@NTO. Fixed thrust specifications. XM cruise=1.8. Reference engine size.

Some additional models have been delivered for 'Low speed' aircraft engines (i.e. high subsonic to low supersonic speeds). In total 48 engine models have been delivered.

5.2.5 Task 2.5 Aerodynamic modeling

Introduction

The objective of the task 2.5 was to develop and validate methods, tools and approaches for aerodynamics analysis and design. Therefore this task covered a rather large spectrum of aerodynamics phenomena and various types flows and it was split into 5 sub-tasks:

- Laminar flow modelling ;
- High-lift off-design analysis and control;
- Wing off-design analysis and control;
- Inlet off-design analysis and control;
- Aerodynamic optimisation.

Each of these 5 sub-tasks are described in the following paragraphs.

<u>Task 2.5.1 – Laminar flow modelling</u>

At first, calculations of a 2D test case have been performed. The flow conditions corresponded to Mach number between 1.3 and 2.0 and Reynolds number close to the experimental condition in typical WT test facilities such as the ONERA S2MA. The different results for this 2D test case have been analyzed and compared. These results were produced with very different methods and

approaches regarding transition prediction, ranging from simple empirical criteria to non-local non-linear stability analyses (Parabolized Stability Equations, PSE). New methods such as CFD-RANS including transition criteria have also been tested.
In order to further validate these methods and to trigger synergies with WP4, some partners have also studied a 3D test case consisting in the laminar wing design tested in S2MA during the HISAC high-speed tests. These additional results provided useful information for extrapolating the results regarding laminar extent from wind tunnel to flight conditions.

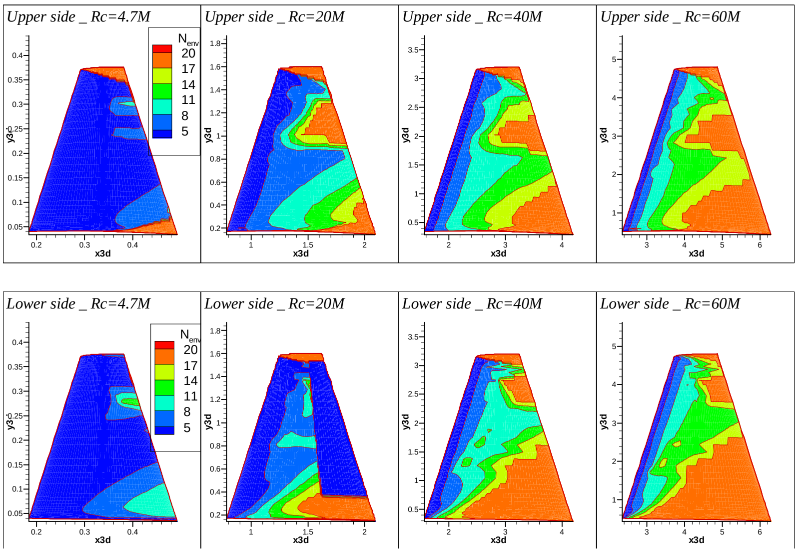


Figure 28 : Reynolds effect on the development of boundary layer instabilities triggering transition; HISAC laminar wing.

Task 2.5.2 - Assessment of CFD prediction capability for high-lift systems

The work performed in Task 2.5.2 of WP2 is split in two parts, one focusing on the CFD capability for off-design high-lift systems and a second dedicated to the assessment of the impact of flow control on the flap.

In the first part, the configuration selected is the EPISTLE aircraft (see Figure) with long hinge as high-lift device. All partners involved in the task, EPFL, DLR, ONERA, NTUA and ALENIA, completed their computations and delivered data to finalise the task. In total, 5 meshes were generated - 2 structured and 3 hybrid meshes - and near 100 Navier-Stokes computations were performed.

At the main flow condition (AoA=11.22º; Mach=0.25; Re=22.5×10^6), the standard deviation obtained by the partners is about ±3% in lift and ±10% in drag, which is quite good if one considers the complexity of the flow at such high angle of attack. The computation of the polar confirms this tendency at other angles of attack.
The influence of the turbulence model, the mesh size and the flow solver were additionally investigated in detail. It was for instance concluded that the Reynolds stress model (RSM) turbulence model predicted the most coherent values compared to wind-tunnel experiment with a deviation of about -3% in lift, +5% in drag and 1.1% in pitching moment.
In conclusion, CFD techniques have been evaluated and validated for the prediction of low speed flows on a supersonic aircraft wing featuring high-lift devices. The techniques used can thus be

applied to assess the low-speed performances of the HISAC wind tunnel model in the frame of WP4.

In the second part, DA explored the aerodynamic performances of the HISAC low speed wind tunnel configuration equipped with Vortex Generators (VG) on the flap to reduce the extend of areas of flow separation. This CFD study shows that the VG permits to reduce the separation on the flap by up to 50% of the chord length (see Figure). However, the overall flow over the wing is adversely impacted by the VG, leading to an earlier vortex burst and reducing the lift. As the results were obtained at a given single condition, it would be valuable to consider other angles of attack and flap settings and to perform additional wind tunnel tests to gain a better understanding.

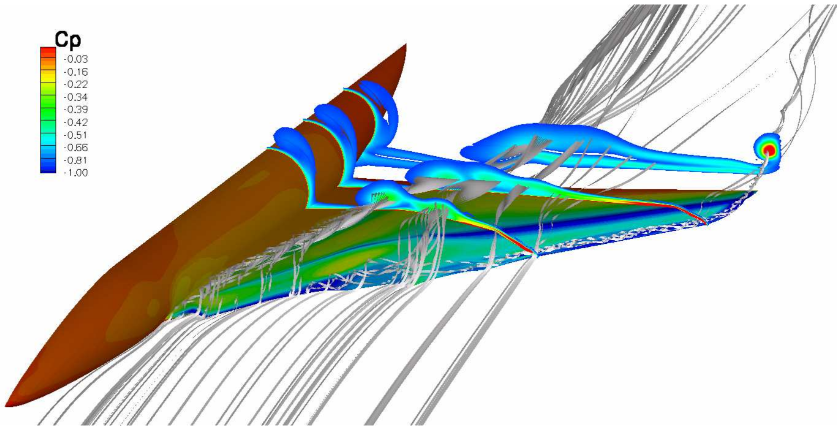


Figure 29: Pressure coefficient distribution and 3D streamlines at 11.22° AoA over the EPISTLE configuration
(DLR computation with RSM turbulence model)

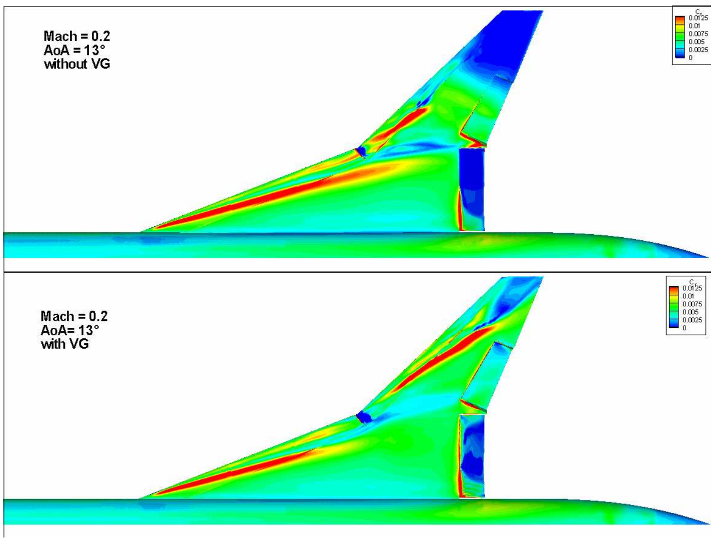


Figure 30: Effect of the vortex generators (VG) located on the flap of the HISAC low-speed wind tunnel model - Top view of skin friction coefficient distribution

Task 2.5.3: Wing off-design analysis and control

Added to the previously completed work (month T0+36) are a report on TsAGI studies on the LBC low speed aerodynamics with working power plant (added to Deliverable 2-38). The low speed aerodynamics was investigated in order to extend the operational envelope of the LBC and to provide the airframe final design with nozzles incidence angle and aerodynamic control surfaces values determination (for WP5). RANS computations aero were carried out giving the aerodynamic loads for M=0.25 in the range α=0 to 29°. In summary the operational envelope of the Team C LBC and the airframe final design recommendations were provided within this work.

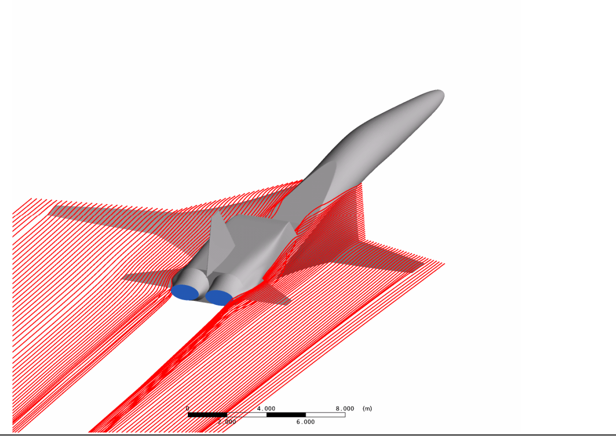


Figure 31: a: Wing streamlines at M=0.25 and α = 3°

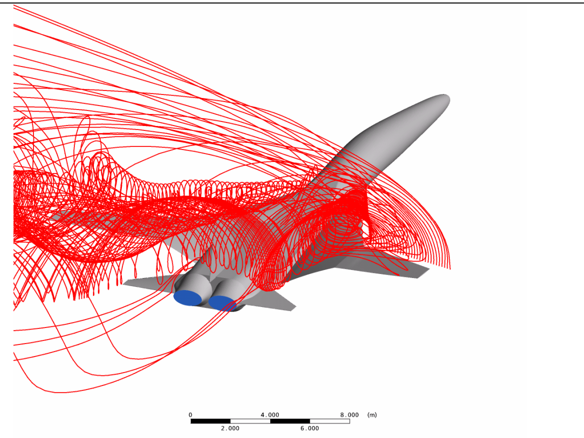


Figure 32: b: Wing streamlines at M=0.25 and α = 26°

Task - 2.5.4 Inlet off-design analysis and control

Numerical investigations of a low drag, diverterless intake without bleed system integrated on the upper side of the wing at off-design engine operating conditions were carried out by EADS-M and the evaluation of intake performance parameters was performed (Figure 33). The analysis of the CFD results at supersonic Mach numbers shows that the external shock system of the bump intake above the wing is clearly distinctive in the simulations, and the local total pressure downstream of the terminal shock approaches the theoretical total pressure recovery across the shock system.

For higher flight Mach numbers and/or for thicker boundary layers (depending on the position of the bump on the aircraft), it may be desirable to adjust the contour of the bump according to the boundary layer to obtain a more "conical" shock contour.

Downstream of the bump (internal duct flow), flow separation was encountered at each off-design condition investigated. A longer duct would be required to reduce the local expansion angles and thus avoid this flow separation. Also a bleed system could prevent flow separation in this region.

An intake performance data set for general applications was generated.

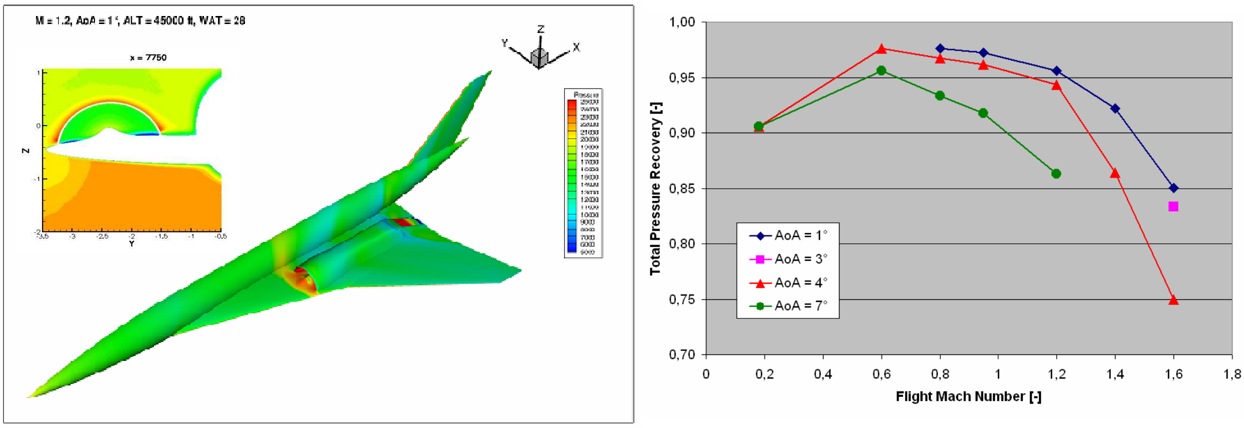


Figure 33: HISAC Configuration S4 BPR 1.5. Surface pressure distribution with Mach number contours at intake entry face and total pressure recovery

An experimental investigation of the inlet off-design buzz phenomenon has been conducted in the ONERA S5Ch wind tunnel on a mock-up representative of an inlet with external compression (Figure34). A control device (suction through a perforated plate or a slot) was manufactured and tested in order: 1) to diminish the thickness of the incoming boundary layer, 2) to reduce the separation region in front of the inlet model. A study was carried out on the effect of the incoming Mach number on the buzz cycle: a compression ramp was built and placed ahead of the inlet to decrease the Mach number from 1.6 to 1.4. This new configuration was tested with and without the control device. Unsteady RANS computations were performed to simulate the subcritical buzz phenomena of the inlet obtained during the S5Ch wind tunnel tests.

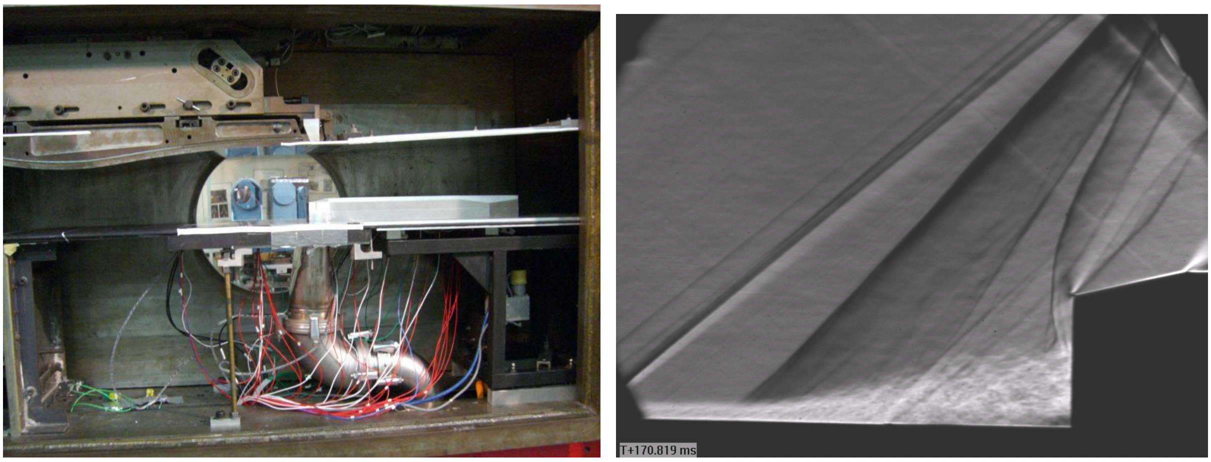
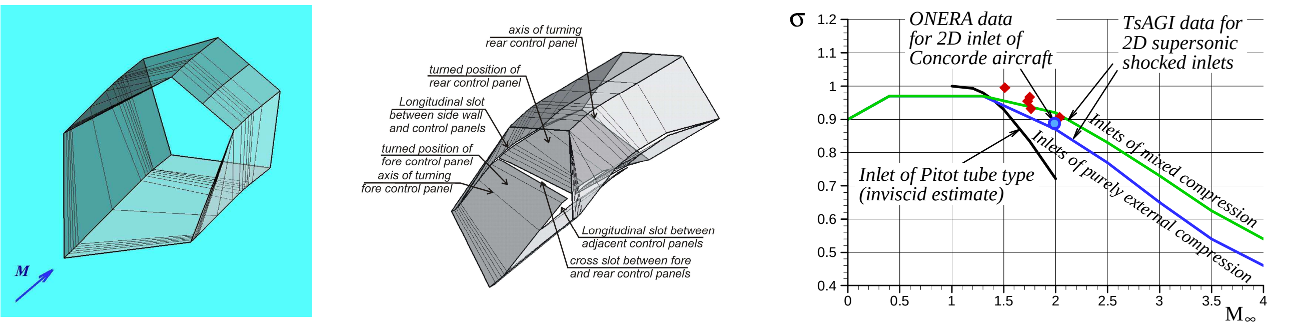


Figure34: ONERA S5Ch inlet model test set-up (left); Schlieren visualizations (right)

Theoretical development and design drawings of a three-dimensional (3D) supersonic inlet (
Figure35a) were carried out at ITAM. An innovative device for starting and controlling the inlet-throat cross-sectional area of the considered inlet has been developed. It incorporates consecutively located paired turning control panels (starting flaps), at turning of which both longitudinal and cross slots for diversion of the boundary layer form in the inlet throat region (
Figure35b). The model inlet was designed for $M_D = 2$, it was manufactured and tested for Mach numbers between 1.5 and 2.0 in the supersonic wind tunnel T-313 at ITAM. The results obtained at ITAM confirmed the workability of the starting/controlling device. It was demonstrated that a supersonic inlet flow close to the design one at $M_\infty \cong M_D = 2$ is realized if the inlet is started. The tested flow regimes display no separation of the boundary layer in the inlet duct, even at places of incidence of shock waves onto the walls, with respect to which these shock waves are glancing. The data obtained on the efficiency of the model inlet show that it ensures good characteristics in terms of the total pressure recovery (Figure 35c)



a) View of model inlet duct in design configuration for $M_\infty \cong M_D = 2$

b) View of model inlet duct with opened starting flaps for $M_\infty < 2$

c) Pressure recovery factor of ITAM model 3D inlet (rhombic symbols) in comparison with 2D inlets

Figure 35: General views of ITAM model inlet and its performance characteristics

A complete report of subtask 2-5.4 “Inlet Off-Design Analysis and Control” is given in Deliverable 2.40 (HISAC-T-2-69-4): Final Models for Predicting Inlet Operating Regime and Performance.

Task 2.5.5 – Aerodynamic Optimization

The task focused on propulsion integration methods for supersonic configurations. Based on previous aircraft optimisation experience, a relevant method for the optimisation of supersonic configurations has been identified and applied by each partner.Partners were: Alenia Aeronautica, Dassault Aviation, DLR, ONERA.
The geometry that has been selected is representative of the reference geometry derived from SUKHOI proposal. The planform of the wing is the same that of the reference geometry, but generic wing section airfoil have been added since wing sections were not available for the reference configuration. The length of the fuselage is 40 m. Figure 36 illustrates the geometry.

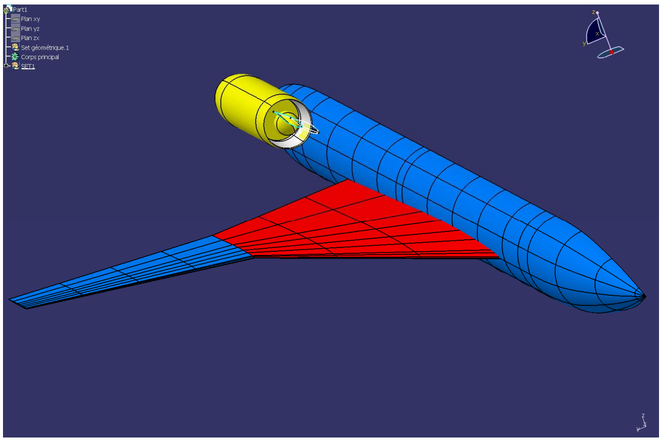


Figure 36: General view of the geometry

Optimisation Problem Definition

- Pressure drag minimization (inviscid flow, Euler CFD)
- Main design point: Mach number=1.6, altitude= 15545m (close to 51000 feet), aoa =0°
- Geometrical constraints:
  Fuselage length frozen (40 m)

  Wing: geometry + position frozen

  Nacelle + pylon: geometry frozen

  Cabin constraints: fuselage geometry frozen between x=0.5 m and x=7.7 m (xnose=-11 m)
- Cost function
  Pressure integration wing + fuselage + pylon + nacelle, non integration on inlet and outlet engine surfaces.

Two teams have been formed with respect to the choice of the optimisation problem to solve:
- Team A, fuselage automatic optimisation: ALA, DA, DLR, ONERA
- Team B, fuselage optimisation + nacelle position: ONERA

The contribution of all partners focused on the use of automatic shape optimisation procedures for propulsion integration of the wing-body-nacelle configuration. A preliminary trade-off study on the engine was performed by Dassault, to minimise the spillage and to position the engines in a way to be able to perform zero-lift drag minimisation without having to impose a constraint on the lift using a fixed angle of attack at 0°.
Multipoint optimisation wrt drag using automatic non-axisymmetric parametric representation of the surfaces (~100 parameters) was used by Alenia (Figure37).
Dassault performed a drag minimisation by changing thickness, scale and camber distribution of the fuselage shape (Figure38).
DLR developed and used two optimisation chains making use of CATIA-V5 to create a parameterised CAD geometry. The process wsa applied to the wing-fuselage-pylon-nacelle configuration at supersonic speed (Mach=1.6) and 0° angle. Both shape and engine position were optimised (Figure39). The position of the engine was controlled by three parameters: x-position, distance to the fuselage and circumferential angle. The fuselage shape was controlled by five circles with adjustable radius and the x-position. The nose and tail were vertically moveable.

Wasp waist optimisations have been carried out by ONERA to derive a representative fuselage shape.Multi-point shape optimisation wad performed in addition, resulting in moderate further shape modifications. In addition, ONERA performed optimisation of the nacelle position only (3 parameters) on the reference shape and on the previously optimised fuselage, using chimera meshing techniques. A very interesting drag gain could be achieved on the reference fuselage when pushing the nacelle forward. Nevertheless, no gain could be achieved on an optimised fuselage.
In conclusion, the gain in pressure drag (wing + body) obtained by partners with respect to the baseline shapr ranged from 50% to 60% in the computation of all participants. Multi-parameter shape optimization, applied by all partners, resulted to be by far the most effective optimization technique for this test case. Concerning the optimization of engine position (DLR and ONERA), the tendency shown by the computations in order to minimize the drag was to move the nacelle farther from fuselage, in the forward direction and to lower circumferential angles.

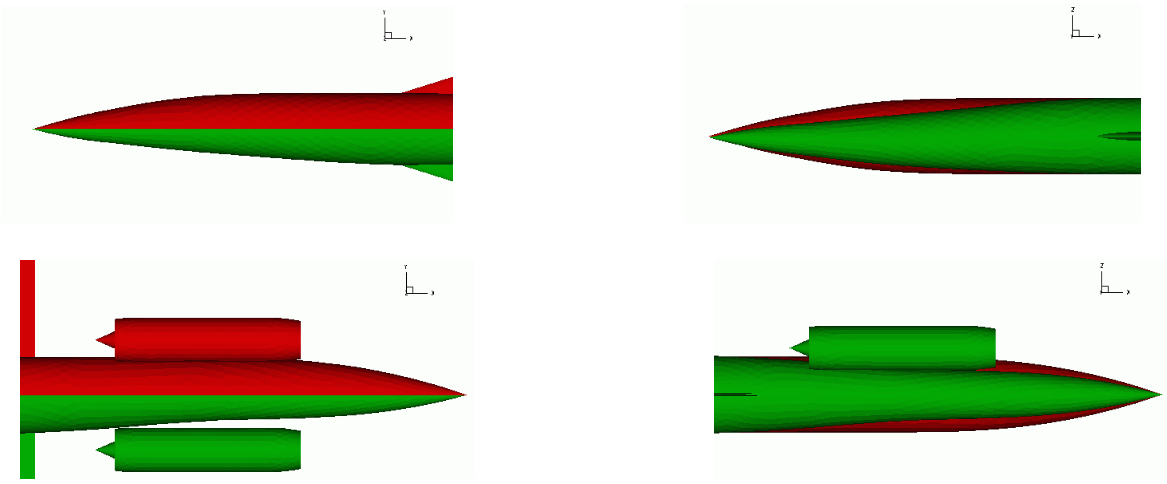


Figure 37: Alenia computations. Original (red) and optimized (green) shapes of forebody (top) and afterbody (bottom). Top (left) and side (right) views.

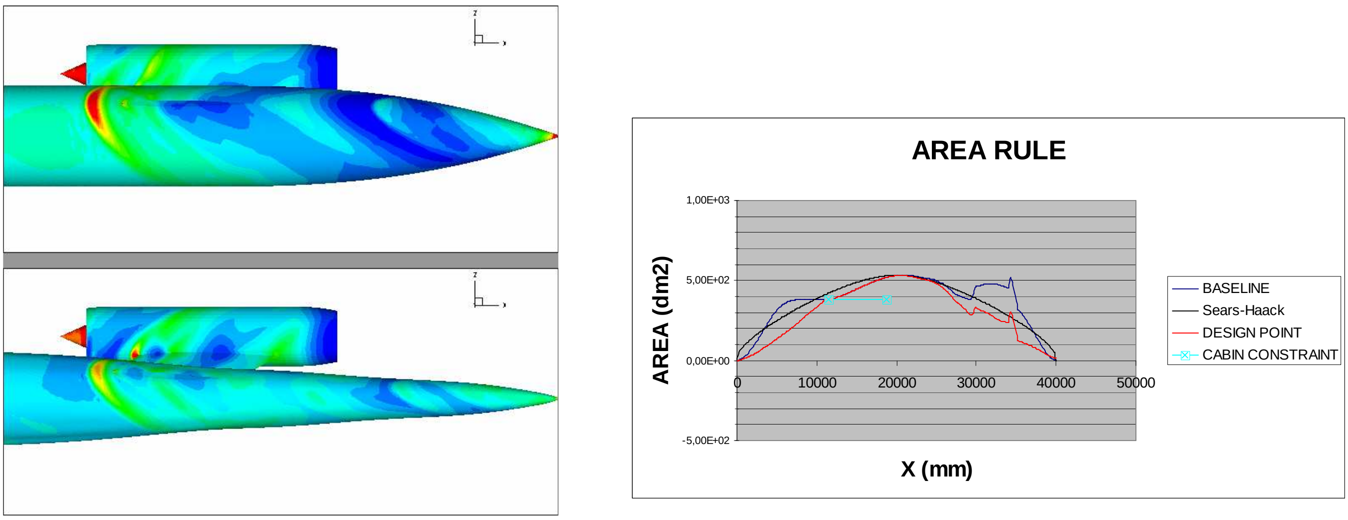


Figure 38: Dassault computations. Side view of pressure distribution at the rear part (baseline: top left optimised: bottom left). Area rule for basic and optimised shape (right).

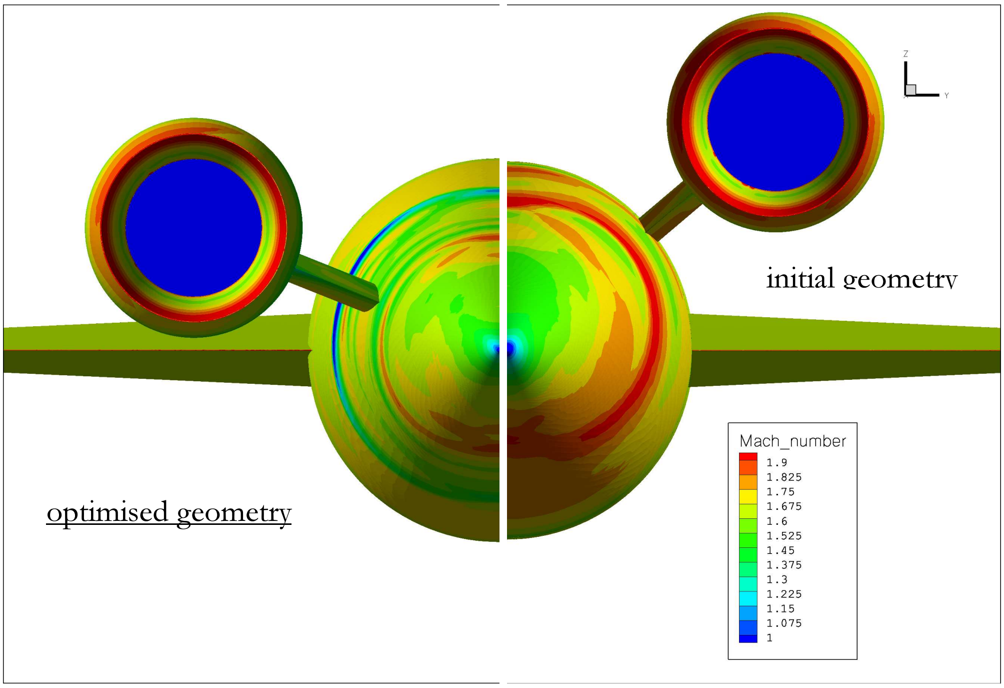


Figure 39: DLR computations. Initial/optimised engine position, rear view

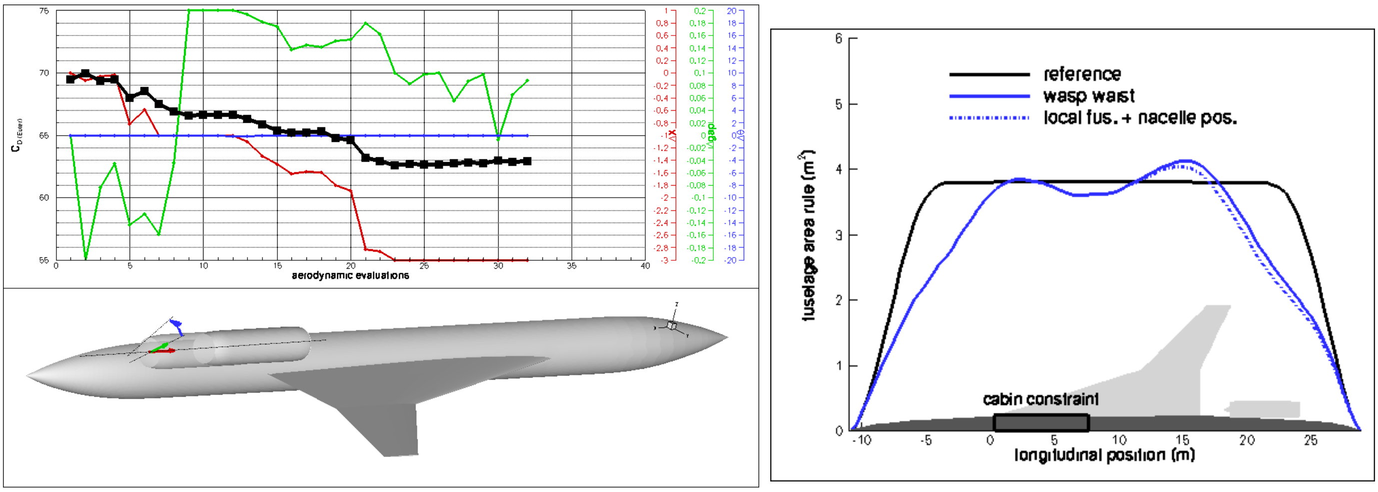


Figure 40: ONERA computations. Nacelle position optimisation on the reference fuselage and optimisation history (left), area distribution of some optimisations (right).

5.2.6 Task 2.6 MDO Process

This task (Multi-Disciplinary Optimization, MDO Process) aimed at preparing and supporting MDO activities in WP5 (Multidisciplinary Design Plateau). Task 2.6 is concerned with MDO tools for which enhancements are proposed and their efficiency was evaluated mainly on a small-scale benchmark problem defined by Dassault Aviation. Ready-to-use MDO platforms (such as modeFRONTIER and EASY) are made available to the interested partners and, along with their own tools, have been used to solve the problem defined by DASSAV. The MDO processes and tools make use of reduced-model technology in order to improve the convergence performance and reduce the overall CPU cost. The reduced model used in this task are based either on semi-empirical method (such as simplified aerodynamics models, simplified weight models etc…) or on approximation model built "on the fly" from the higher-fidelity models.

One of the additional gains from this task is that, based on its outcomes and the conclusions drawn, partners may optimally select the low-level MDO optimisation systems for sub-optimisation between various interacting modules e.g. structures and aerodynamics etc. Finally, this task helps the specification and selection of optimisation algorithms and strategy for implementation within the MDO systems developed or used by the partners.

Next a summary is given of the methods used by the individual partners:

Dassault:

The MDO process in use is presented in the figure below. It is a two level process where the actual multidisciplinary optimization is performed at the system level. The system level optimization is supported by detailed mono-disciplinary optimizations. The mono-disciplinary optimizations are driven by the global level in terms of objectives, constraints or region of search. The results of the mono-disciplinary optimizations are stored in databases. From these data surrogate models are constructed and are then used in the global optimization process.

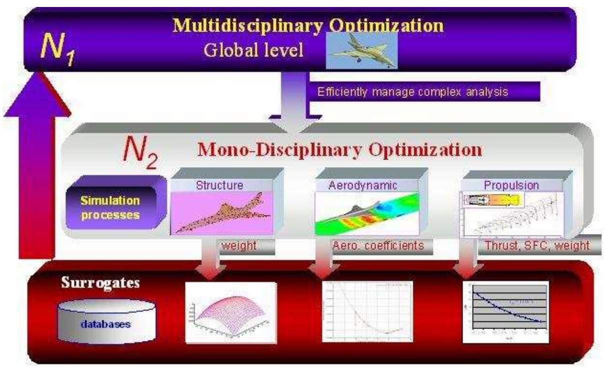


Figure 41 Dassault two level MDO process

The three key ingredients in this two level approach are (1) the choice of the optimization strategy depending on the level and the discipline, (2) the coupling between the levels and (3) the post-processing enabling the analysis of the design point.

Alenia:
The optimisation framework is formed by an optimisation module, an analysis module and an interface module that handles the parameterisation. The interface module is integrated within a Multi-Model Generator which provides the difierent disciplines with related updated models, e.g. the CFD (Computational Fluid Dynamics) system with a modified geometry and the CSM (Computational Structural Mechanics) system with a new finite element model.
The mutidisciplinary optimisation process are applied to the aero-structural shape design of aircraft. Within the procedure, the mappings of the computational grid with the geometry that evolves and with the parametrisation are key elements. It is important to maintain as much as possible the quality of the initial grid when the geometry is update in order not to introduce noise due to the grid in the optimisation process.

ESTECO:
ESTECO contributed to the integration of the optimization environment modeFrontier v3.1 with a Matlab script for the benchmark MDO/S4TA problem. After the benchmark equations have been corrected, other optimization strategies have been applied and tested on it, including Response Surface Methodologies to reduce the overall computational time, and Robust Design Optimization to take into account design uncertainties.

INASCO:

INASCO worked on an optimization framework called Gradual Kriging Optimization – GKO, applied on various studies such as i) Sampling for efficient Design of Experiments, ii) Surrogate modelling by generating accurate Kriging Approximations, and iii) Design Optimization, especially for large-scale Optimization.

GKO is a method of solving Multidisciplinary Design Optimization problems. Initially, a design of experiments is generated in order to compute the model's response at a representative amount of design sites. Kriging model acts as a Surrogate model and replaces the analysis model by using its responses. Kriging approximation accuracy is measured through a cross validation procedure and if the accuracy has not reached the desired levels, refinement is performed using additional evaluations points. Additional points are arranged with the inherited ones and the next Kriging approximations are performed. As soon as the accuracy reaches satisfying levels, a typical evolutionary algorithm for constrained optimization is employed in order to calculate the point where the Kriging response is minimal. Finally, the original analysis model and Kriging predictor are compared at the minimization point and a new refinement takes place if necessary.

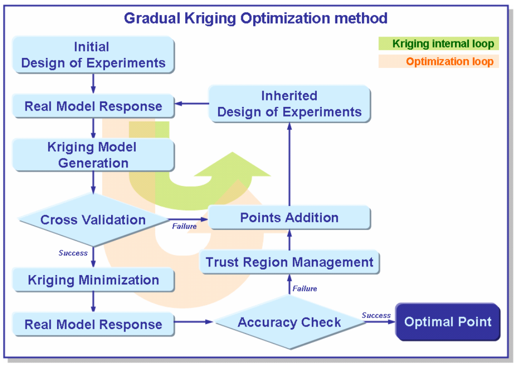


Figure 42: Flowchart of Gradual Kriging Optimization method. Green loop shows the Kriging internal optimization procedure which generates the most likely Kriging hyper – surface, while red loop shows the global optimization process

DLR:

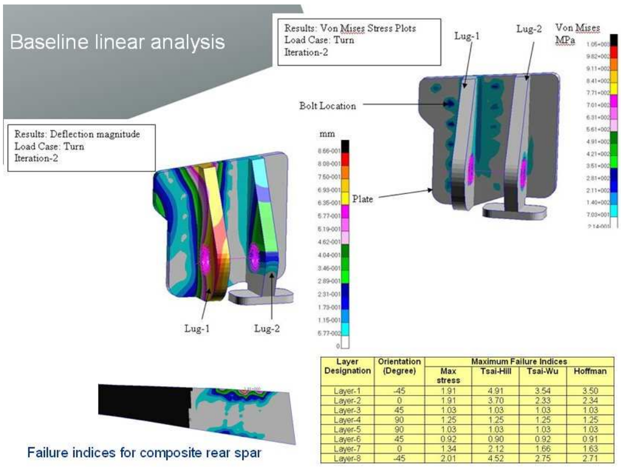
DLR set up a Matlab-based implementation of a modified version of the multi-level optimisation algorithm Bi-Level Integrated System Synthesis (BLISS 2000) of NASA. Based on this tool, the MDO/S4TA Problem was implemented in Matlab using six disciplinary modules. DLR worked also on the generation of response surfaces which is critical to the success of a BLISS optimisation. Since linear response surfaces proved to be inadequate for most of the subsystems of the HISAC test case, emphasis was laid to quadratic modelling and the Kriging model.

ONERA

ONERA worked on the Dassault problem by building it within an integration environment called ModelCenter. Two MDO formulations were tested (the Multidisciplinary and the Individual Design Feasible, MDF and IDF) which highlighted that the present multidisciplinary analysis model converges with difficulty.

Cranfield University

CU implemented the problem in MathCAD and this implementation enabled the order of the optimisation process to be identified and provided an alternative implementation of the problem, which could be used to provide top level Lagrange Multiplier information. The higher level structural model was analysed through the structural optimiser in NASTRAN in order to get a better understanding of the code for a relatively inexpensive finite element model. Sensitivity studies were performed for thickness optimisation, together with the sensitivity of the number/distribution of spars. Finally, CU implemented the Benchmark specification within OPTRAN.



Layer Designation	Orientation (Degree)	Maximum Failure Indices			
		Max stress	Tsai-Hill	Tsai-Wu	Hoffman
Layer-1	-45	1.91	4.91	3.54	3.50
Layer-2	0	1.91	3.70	2.33	2.34
Layer-3	45	1.03	1.03	1.03	1.03
Layer-4	90	1.25	1.25	1.25	1.25
Layer-5	90	1.03	1.03	1.03	1.03
Layer-6	45	0.92	0.90	0.92	0.91
Layer-7	0	1.34	2.12	1.66	1.63
Layer-8	-45	2.01	4.52	2.75	2.71

Figure 43 Initial baseline linear analysis to assess the applicability of SOL200

EPFL:
EPFL used the Queuing Multi-Objective Optimizer (QMOO), which is a multi-objective optimizer developed at EPFL. Convergence speed of this optimiser is good compared to classical genetic algorithms. The Evolutionary Operator Choice, the clustering techniques and the Pareto based sorting all contribute to the speedup of the convergence process. These techniques can be seen as the main output of this Work Package.

NTUA:
NTUA offered the optimization tool EASY 1.5 to the interested partners and developed metamodels that can be used along EASY as well as any other optimization method. Using metamodels and hierarchical schemes, effort was made to reduce considerably the optimization cost which is a useful message to the partners. Work on the so-called gradient-assisted radial-basis function networks, i.e. a new type of metamodels is under progress, assisted by an automatic differentiation tool. NTUA cooperated with DLR to demonstrate the gain that WP5 should expect from the outcome of the work carried out in 2.6.

The main conclusion of this task is that the benchmark problem distributed by Dassault Aviation, even after the corrections made by the involved partners, does not lead to realistic optimum solutions. The main reason for this is the predefined bounds. Several partners have been relaxed these bounds and by doing so, their results cannot be compared. However, despite this, the benchmark was extremely useful that allowed us to work on a common problem.

The capability of algorithms of different nature (Queuing Multi-Objective Optimizer by EPFL, Evolutionary Algorithms by ESTECO and NTUA, a multi-level platform by DLR) to handle the MDO problem, at least as defined in the MDO problem, was demonstrated. Irrespective of the optimization tool, the use of surrogate models has been proved to be important. It suffices to take into consideration that, in a more realistic problem, the computational cost per evaluation will be much higher. Consequently, the optimization cost (in particular of some “rich” optimization methods, such as for instance, those implementing robust design concepts) is expected to increase too. For these problems, surrogate evaluation models (response surface models or metamodels, including kriging or support vector machines, as these can be found in the reports by various partners may reduce the CPU cost. Surrogate models (accompanied by Design of Experiment techniques is this is needed) are reported by many partners (ESTECO, INASCO, ALENIA, NTUA, etc).

Enhanced optimization methods, such as multilevel optimization tools (see, for instance, the multilevel optimization platform BLISS 2000 that DLR employed or the hierarchical evolutionary algorithm employed by NTUA) are proved to tackle the problem with success. Though the aforementioned two methods sound different, they are both based partially on the same concept (splitting the optimization task in subtasks that perform better than the single task).

The effort made by two of the partners to incorporate optimization methods developed in 2.6 in a real analysis procedure (from WP5) demonstrated that the gain from the use of metamodels is important and WP5 partners may really profit of optimization methods reported in 2.6.

5.3 Work Package 3A

5.3.1 WP3.1 - Variable Cycle Engine Technologies

5.3.1.1 WP 3.1.1 - Adjustment of CCV modeling environment.

The work started on definition of requirements to CCV modeling tool update. It was done upon CCV cycle and performance analysis. First loop cycle analysis of CCV engine was performed on a base of pre-existing engine cycle model in WP2.4 for Engine Specifications coming from WP5.1.

The conclusion was made that modeling of CCV engine requires higher degree of model resolution and fidelity to be confident that engine cycle and performance are adequate. The work continued for model adjustment in respect of multi fidelity.

Multi-fidelity cycle matching engine model with zoomed high-fidelity Variable Confluence Area Component was developed (fig.44). It was tested on simplified straight splitter component (D3A.01 at T0+18).

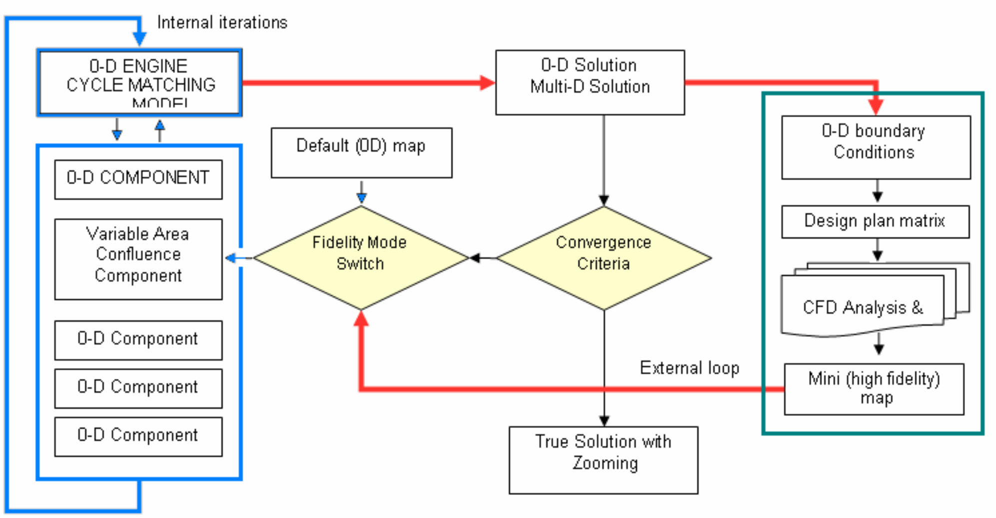


Fig.44. Multi fidelity cycle matching engine model communication.

5.3.1.2 WP3.1.2 - Engine Complete definition.

Reference cycle model: CCV model #16 (SCA-CCV-350-1.8-100%) of WP2.4.

Geometry model of variable confluence component was designed (fig.45a, 45b). Flow structure was adequate at both take-off and cruise conditiond (fig. 46a, 46b)

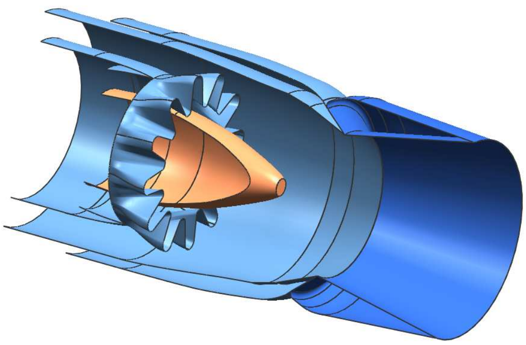


Fig. 45a: Variable confluence component geometry model. Lobed mixer. Supersonic cruise.

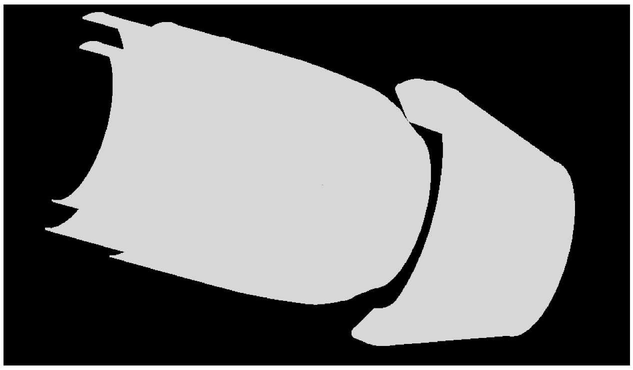


Fig. 45b: Variable confluence component geometry model. Lobed mixer. Normal take-off.

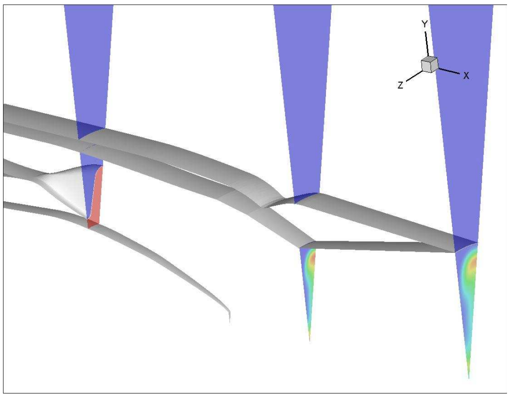


Fig. 46a: Variable confluence component CFD model. Lobed mixer. Supersonic cruise.

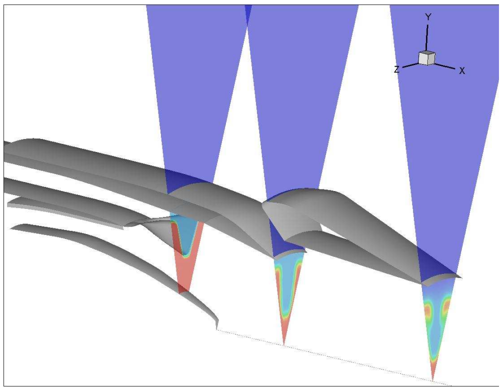


Fig. 46b: Variable confluence component CFD model. Lobed mixer. Normal take-off.

In order to know values of EPMIX for candidate variable geometry mixers the computation of EPMIX was done at supersonic cruise conditions for both simple straight splitter and forced lobed splitter. The results are summarized in Table 1.

Mixer configuration	Simulation mode	EPMIX
Straight splitter	2-D	0.05
Lobed mixer	3-D	0.33

Table 1

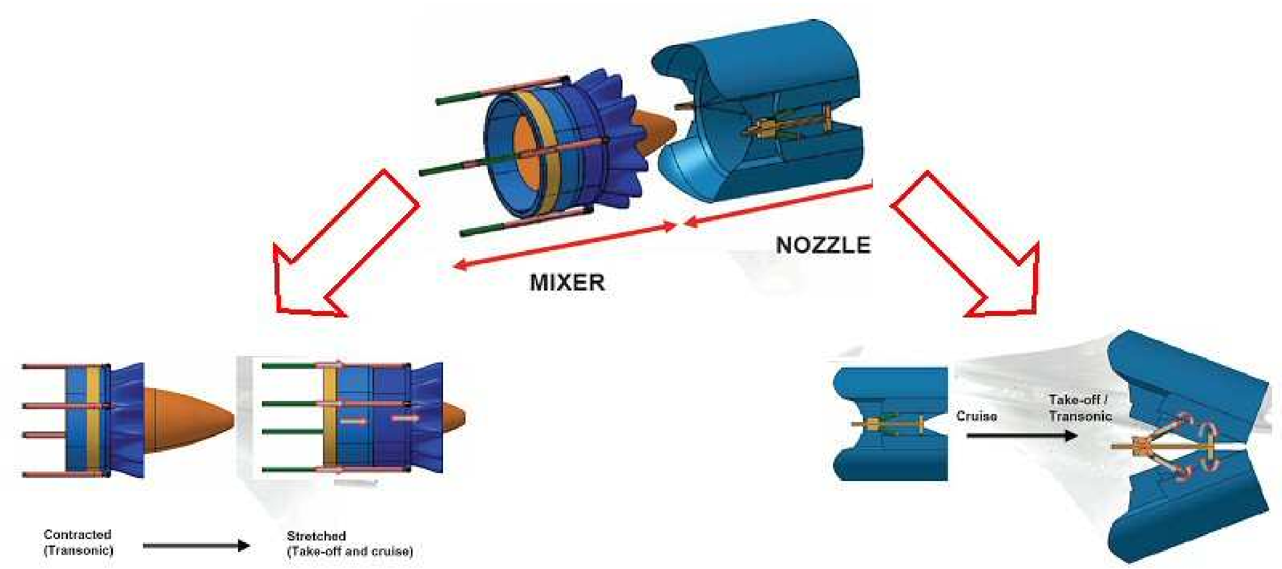
The analysis showed that advantages of CCV cycle with respect to performance, jet noise, dimensions and etc. over CONV cycle, that were given in WP2.4, still exist.

Geometry models of variable confluence component were delivered to SENER in order to have the first preliminary mechanical considerations.

SENER investigated several versions of the mechanical design, to take into account:

- Reduction of the envelope diameter
- Reduction of the leakage, improvement of the sealing

- Uniformity of the flow
- Reduction of weight
- Actuators location
- Variability of at least A8, A9 and A95
- Reverse ability…

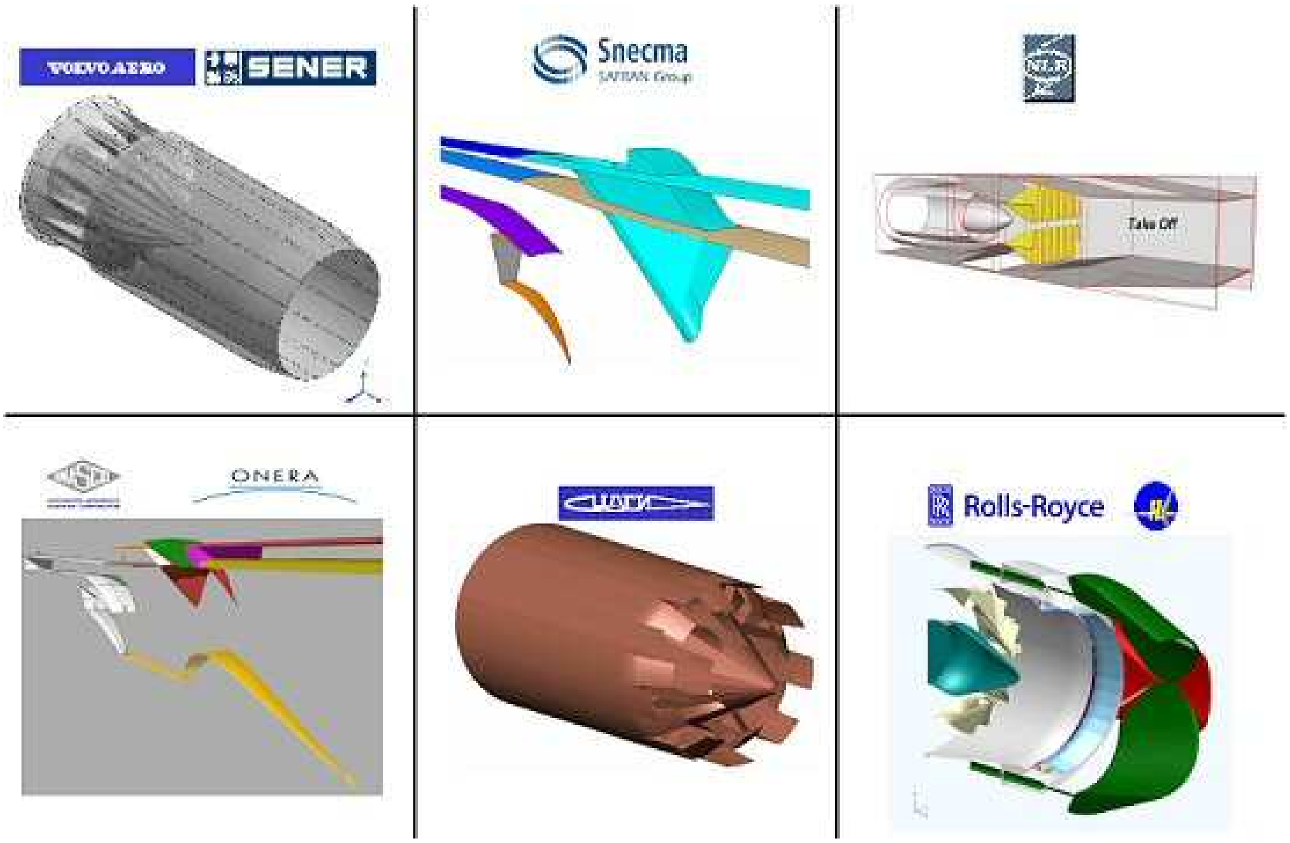


The final design is a promising design for future engine development, since engine cycle areas have been fully respected (aerolines modifications are minimal and agreed with partners), and since the solution adopted meets all the mechanical requirements acknowledged at this point.

5.3.2 WP3.2 - Nozzle Noise Reduction Technologies

5.3.2.1 WP3.2.1 - Mixer-Ejector aerodynamic and acoustic design

During the first phase, all partners worked on different designs based on thermodynamic data of gas generators provided by Snecma. Particularly, the aerodynamics, the acoustics, and the mechanical feasibility of each concept had been studied, in order to select one of them, following a given selection process, for acoustic WTT.



In order to have some parameters to play with if the acoustics target is not reached, the study should be done with the most restrictive configuration (Static Induced Air Intake and 2 D long Ejector). So that, the most interesting choice for WTT campaign (and the best compromise) is the Volvo-SENER concept.

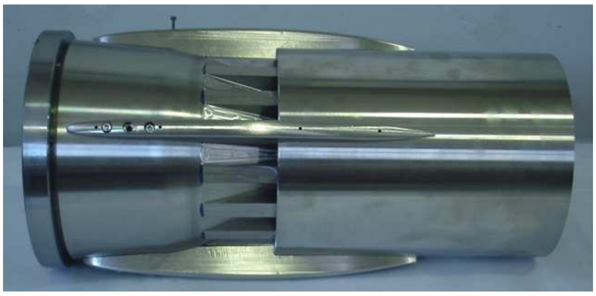
This concept will be the basis for the following parametric study, allowing us to see some effects that could also be seen on Snecma or INASCO concepts:

- Plug (Regular or Wave)
- Internal Mixer (Yes or No)
- Liners (Hardwall, #1 or #2)
- Length of the ejector

5.3.2.2 WP3.2.2 - Exhaust nozzle and acoustic liners manufacturing

Liner tests happened in the NLR facility between T0+7 ½ and T0+9 ½. 2 concepts had been proposed by INASCO, and 2 by ONERA, and insertion loss and impedance measurements had been completed without troubles. Two concepts has been chosen to be tested during the acoustic WTT campaign: ON1 and IN1.

During the following months, INASCO and SENER started with the detail design of the ejector and of the mixer. The VOLVO Aero aerolines and the manufacturing process were the two main drivers of the design. Once design and manufacturing process were finished, the model was delivered to the anechoic wind tunnel at T0+36, before the beginning of the tests, that suffers from further delays due to other European projects, such as VITAL. Because the tests are planned at T0+37, it has been agreed that INASCO could use more time for the manufacturing, in order to have a better hardware.

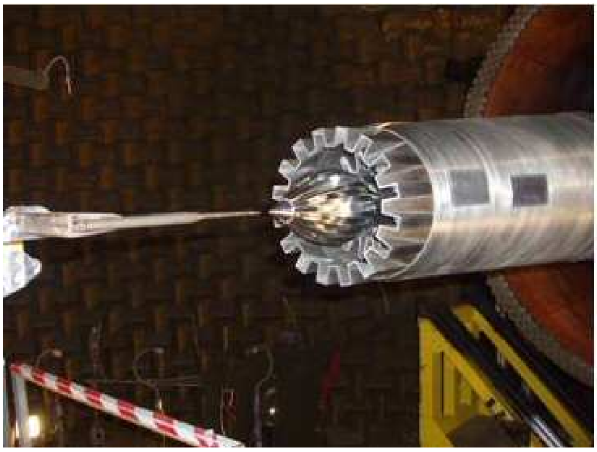


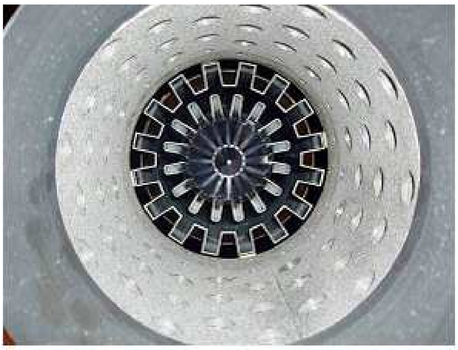
5.3.2.3 WP3.2.3 - Acoustic and severe/vibratory tests

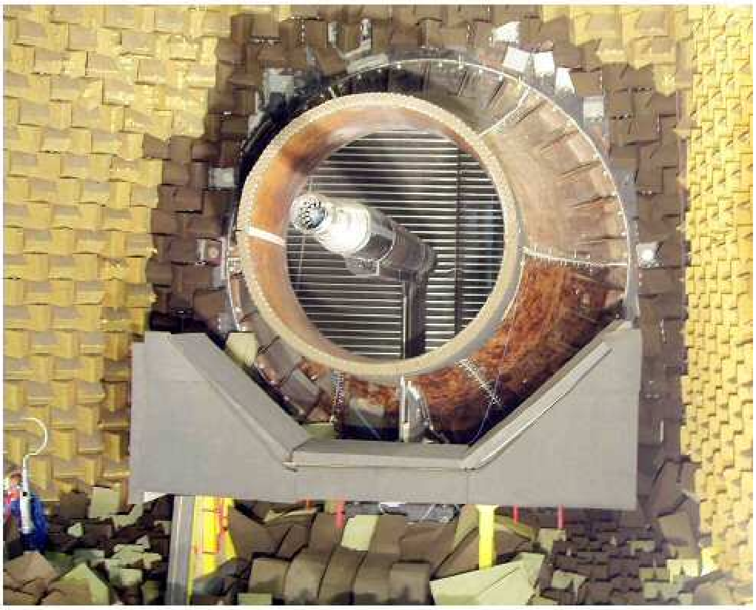
Snecma proposed a test matrix, which includes acoustics and extra aerodynamic measurements. This test matrix allowed the acoustic assessment of different ejector lengths, different types of liner, different liner lengths, for 2 different take off conditions (representative of Cut Back and Sideline certification points), with and without external flow. In the end, 8 configurations (instead of 7) were tested, in order to assess:

- Length of the ejector
- Liner effect
- Clocking
- Length of the liner

The tests were done in two parts (Q2 2008 and Q1 2009) due to a failure of the SOLIVENT (engine generating the external flow) at CEPRA19 in 2008.







As far as the vibratory tests are concerned, they were done in two campaigns. The main campaign was devoted to test the materials themselves. The matrix was the following:

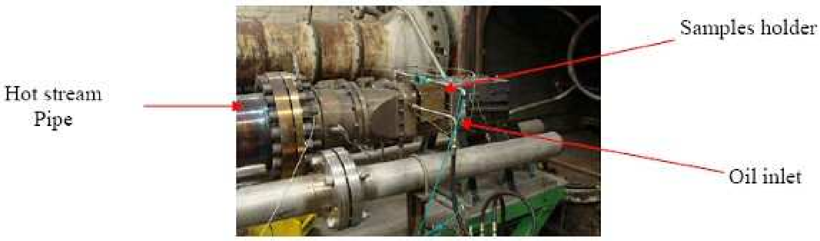
- 3 samples for both ON and IN liners
- 3 durations (5h, 50h and 500h)
- 2 different vibrations
- Acoustic impedance tests before and after vibratory tests

The purpose of the second campaign was to investigate the effect of vibrations on a cylindrical shaped material. The matrix was the following:

- 1 CEPRA19 liner
- 1 duration
- 1 vibration
- Visual check

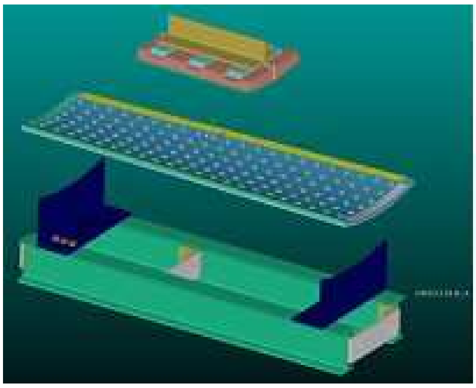
The severe tests were done at ONERA facility. The purpose of these tests was to investigate the acoustic properties of the materials once they suffer from oil and sand injection in a realistic environment. The matrix was the following:

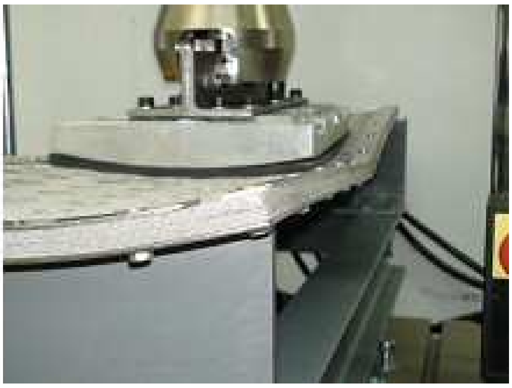
- 16 samples for both ON and IN liners
- 2 representative flow conditions (M, W and T)
- 2 angles of attack
- Oil injection on clean and sanded samples



Finally, INASCO proposed some extra work with the same allocated budget. Indeed, no study take into account the fact that the liner material is installed on a moving flap to go from TO to cruise position. Therefore, INASCO proposed the following matrix:

- 3-point bending cyclic loading on scale 1 sector liner
- Five deflection levels
- 300 cycles per deflection level
- Acoustic characterisation tests before and after each deflection level



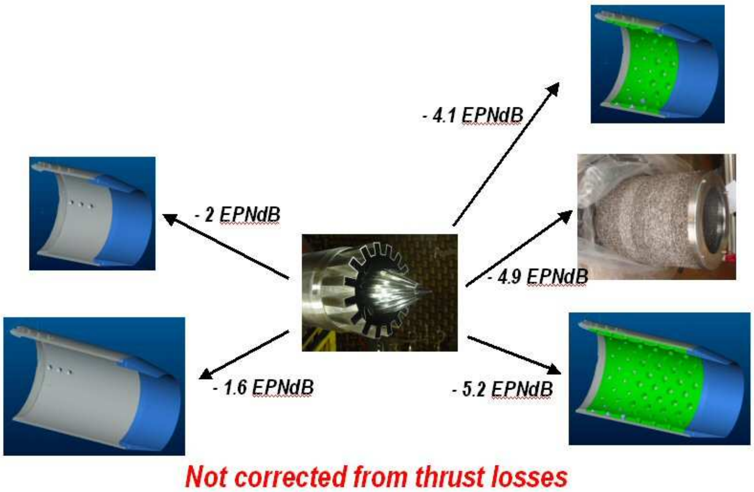


5.3.2.4 WP3.2.4 - Tests results analysis

The main conclusions of the several tests campaigns are the following.

Aeroacoustic tests:

- Higher high frequency noise source due to the direct interaction of core flow with external flow
- 30% induced mass flow rate for all power settings
- Both liners are correctly designed (peak attenuation frequency)
- Both liners are more efficient than initial WP2.1 predictions
- Clocking is efficient for the high frequency source, but increase the main low frequency source
- 5 EPNdB reduction between no ejector and long lined ejector configurations, which means 6 to 7 EPNdB vs confluent nozzle (with the same gases generator, the same jet velocity and the same diameter) BUT without aircraft loop and without taking into account thrust losses (mixer and ejector), extra drag and extra weight



Severe tests:

- INASCO samples have not been damaged by either the high temperature or the low temperature test. Their acoustic properties remained unchanged too.
- ONERA samples have not been damaged by the low temperature test but destructed by the high temperature test. For the samples which passed the low temperature test, acoustic properties remained unchanged too.

Vibratory tests:

- Neither the ONERA samples not the INASCO samples have been affected by the vibratory tests
- No substantial deterioration was observed on the INASCO large scale liner, even for 500h

Fatigue tests:

- Acoustic properties are unaffected at high frequency (target), but affected at low frequency (10 to 15% less efficiency)

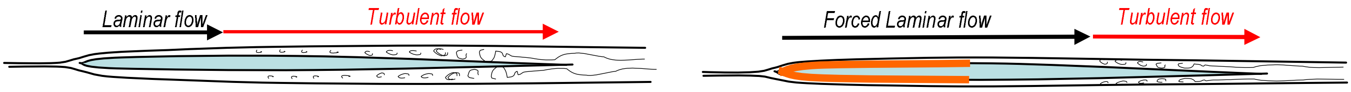
5.4 Work Package 3B

WP3B focus on wing airframe technologies that are critical and specific to supersonic aircrafts. The aim of WP3B is to optimize the global efficiency of the wing along the different phase of a mission by identifying technologies that are able to meet both requirements for supersonic cruise and low speed configurations (take-off, transonic flight, landing).

Three research axis were identified:

- **Forced Laminar Flow (WP3.3)**

The objective of such a technology is to delay laminar-turbulent transition in order to maintain laminar boundary layer flow over the greatest possible extend of a swept wing at supersonic Mach numbers and then reduce the global drag of the wing in cruise.



- **High Lift Devices (WP3.4)**

The objectives of High lift device investigation are to identify the feasibility of a high-lift system for low-thickness and high leading-edge sweep wings that will give :

- the maximum L/D ratio during the take-off phase
- the maximum CL max during the landing phase
- a sufficient L/D ratio during transonic cruise
- the best compromise in term of aerodynamic performance, manufacturing cost and weight.

Structural concepts of movable surfaces are investigated as well as kinematics devices and ice protection system. Specific care is devoted to the actuation system and their integration within the wing structure. Flushed actuation devices and mechanisms are sought in order to minimize the wave drag at supersonic speed.

- **Variable Geometry Wing (WP3.5)**

The variable geometry design is based on the philosophy that a variable geometry wing allows a better match of low speed and high speed properties. The wing can be better optimised for take off and landing, leading to a much reduced wing area, which in supersonic cruise enables operation closer to the best lift/drag ratio. In addition the wing in supersonic configuration can be developed with much fewer constraints arising from low speed requirements. As a result a considerable reduction in fuel consumption is achievable with a reduced airframe length and reduced design weights.

The global objectives of variable geometry investigation is to provide all information to assess whether and under what conditions a variable sweep wing can be feasible for a supersonic business jet, including an assessment about certification issues:

- to provide a baseline aircraft configuration for a variable sweep wing
- to assist to integrate this baseline configuration in a reference aircraft architecture

- to identify technological issues which are critical for the commercial application of a variable geometry wing.

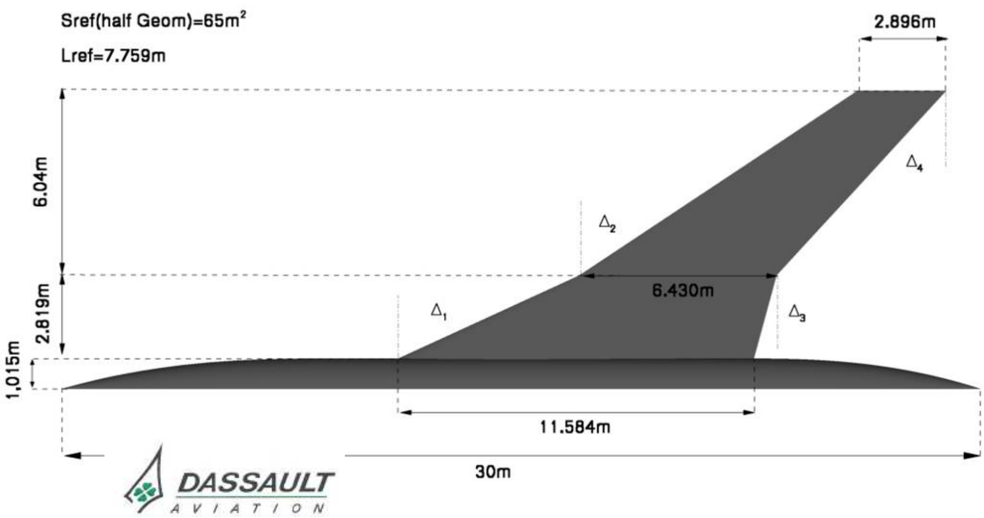
5.4.1 WP3.3 Forced laminar flow

5.4.1.1 WP3.3 work logic overview

5.4.1.1.1 Preparatory phase

The first 12 months have been dedicated to natural laminarity studies in order to build a reference for the assessment forced laminar flow concept.

The first objective was to defined the flight cases that will have to be considered (Computation matrix) for studies of natural laminarity on the S4TA wing and performed Inviscid flow Computation based on Euler code on a preliminary reference shape to defined the initial pressure distribution on the wing before profile optimization and addition of active or passive devices to delay the laminar flow to turbulent flow transition.



Based on the configuration matrix and a baseline geometry, the pressure distribution and the streamlines on the reference wing were defined

5.4.1.1.2 Transition control investigation

These results will then be used for the optimization of the natural laminar flow on the wing airfoil and the assessment of active or passive devices on the boundary layer transition:

- Optimisation of the wing airfoil
- Definition of a optimized theoretical suction distribution to delay the boundary layer transition.
- Effect of discrete suction holes on the boundary layer transition.
- Effect of cooling on the boundary layer transition
- Effect of micro roughness elements on the boundary layer transition

- Definition of the transition control methodology.

5.4.1.1.3 Hardware Layout Investigation

Based on the selected transition control methodology, a hardware system was developed in order to balance drag reduction, weight penalty and additional power consumption at aircraft level.

5.4.1.2 WP3.3 work sharing

- **IBK** (task leader) — Configuration Matrix; Hardware & Layout; Performances, Synthesis
- **ARA, ONERA** — Transition Control Methodology
- **DLR** — Micro roughness & Suction holes
- **FOI** — Optimisation of wing airfoil & suction

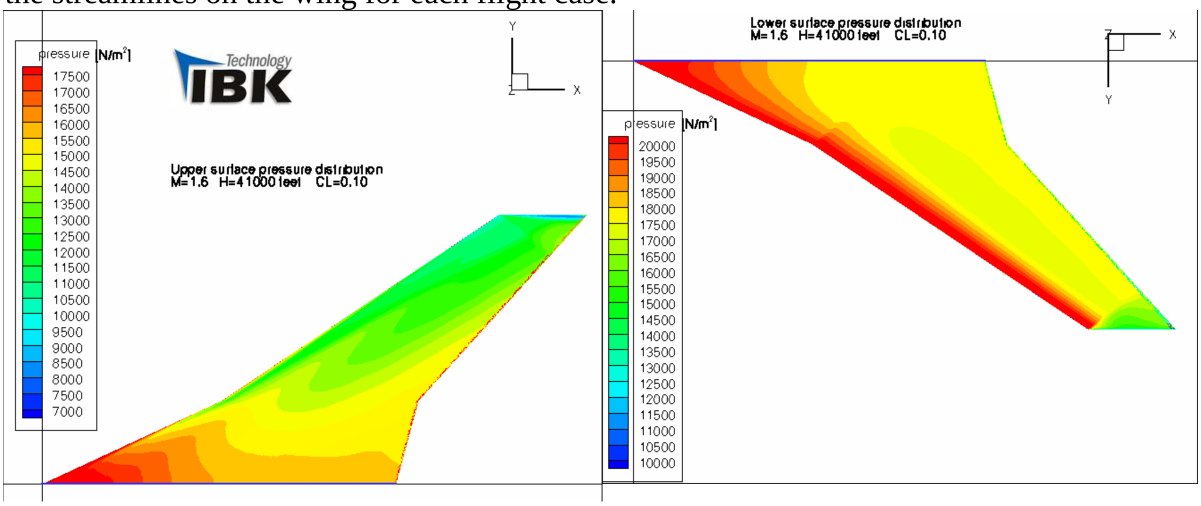
5.4.1.3 WP3.3 MAIN RESULTS

5.4.1.3.1 Configuration Matrix

Finally, 39 points were investigated and Ranges of parameters considered are:

- Variation of Lift coefficient and altitude at fixed cruise Mach number 1.6
- Variation of Mach number and Lift Coefficient at fixed Altitude 25 000 feet, 35 000 feet and 51 000 feet.

Based on this configuration matrix and baseline geometry, IBK is defining the pressure distribution and the streamlines on the wing for each flight case.

Ex: 

5.4.1.3.2 Laminary flow control by micro-roughness

In an exploratory numerical study the potential of laminar flow control by micro-roughness has been assessed by DLR for selected cases of the test matrix. For those cases where laminar-turbulent transition is dominated by crossflow instability, the numerical results suggest that it may be possible to reduce the growth of stationary crossflow vortices by the application of micron-sized roughness elements.

However, the numerical study also indicates that without additional suction the absolute gain in laminarity for this configuration most likely will remain very small.

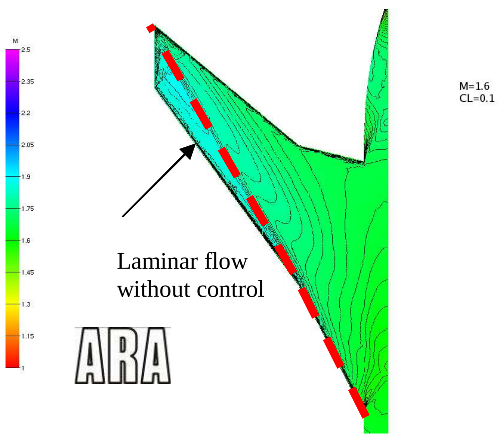
Additional investigations with both micro roughness and suction were also made by DLR.
On the lower side of the wing rather large suction rates are required for a significant gain in laminarity, whereas on the upper side moderate suction rates are sufficient for those cases where transition is not triggered by laminar separation.

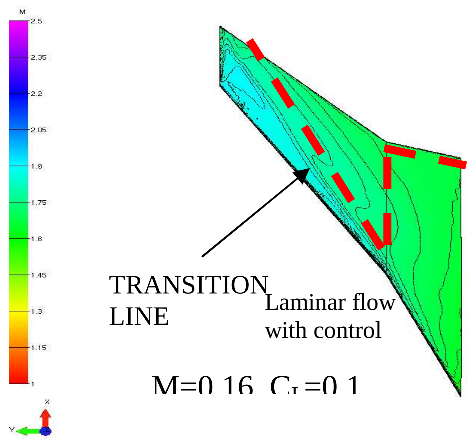
5.4.1.3.3 Transition control methodology using suction and cooling

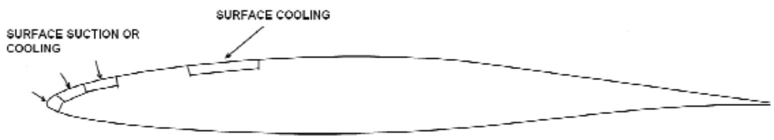
A transition control methodology of applying surface suction at the leading edge for stabilising crossflow instabilities and surface cooling further downstream for stabilising Tollmien-Schlichting waves has been investigated by ARA for the HISAC baseline configuration. For certain flow conditions, the results obtained show that a significant region of laminar flow can be achieved, mostly on outboard wing.

ONERA, DLR and FOI implemented suction-alone methodology while ARA implemented suction in combination with surface cooling for transition control. The effect of slat was also assessed. Furthermore, the attachment line flow instability was also investigated and appropriate devices have been proposed (ARA/IBK) to avoid leading edge contamination.

The results obtained and conclusions drawn so far has been used to construct a wider range of pressure distributions and leading edge sweep angles generally applicable to supersonic configurations relevant to HISAC. This has been used in a transition control parametric study to evaluate the effect of leading edge sweep angle effect. A 5 deg inboard wing sweep reduction is not enough for reducing contamination and the outboard sweep angle can be slightly increased (5 deg) without major impact.





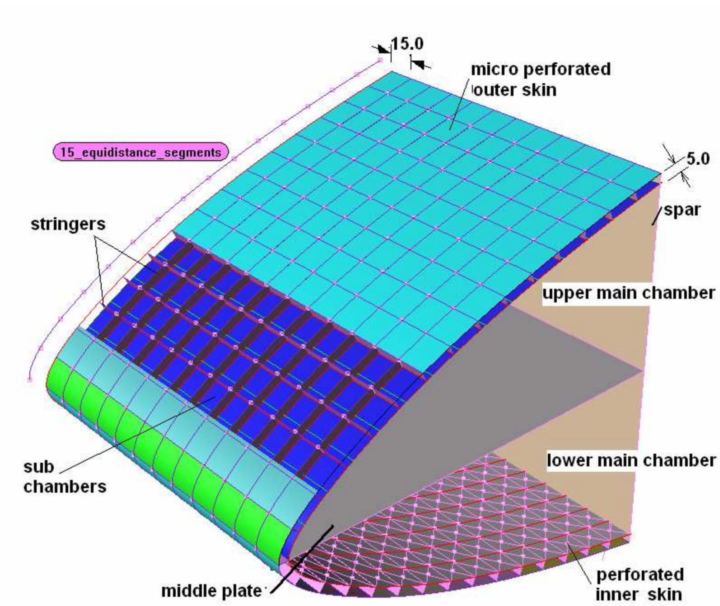


5.4.1.3.4 Hardware system layout

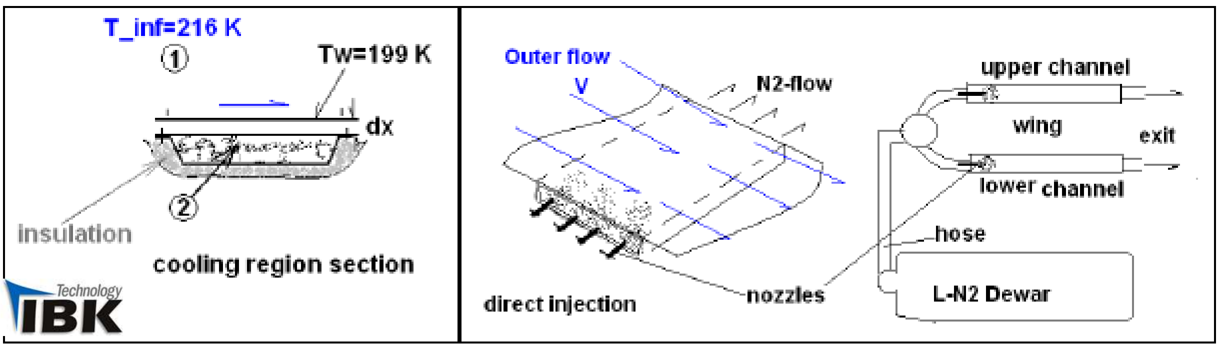
The transition control methodology which was proposed by previous Task regarding flow suction and surface cooling was then adopted to develop an hardware system concept.(IBK) A simplified suction system and a cryogenic surface cooling system was developed and proposed.

The suction system was designed using engineering methods to estimate pressure drop and mass flow rate. Finally, assessment was carried out regarding weight of suction system and power required. The total net power required is 30 kW and the total suction system weight is ca. 130 kg for an optimistic prediction.

Suction system



Cryogenic cooling system



5.4.1.3.5 Assessment of gain at Aircraft level

In order to allow for fair trade-off studies at A/C level for concepts using such technologies and other concepts studied in Hisac, gain in laminar extent were translated into drag counts reduction at A/C level. ONERA and ARA have investigated the gain of forced laminar flow on the wing at A/C-level compared to the fully wing turbulent flow.
ARA showed, that for the forced laminar flow, there will be a viscous drag reduction of 28.5% or about 7.2dc at low lift coefficient. At high lift coefficient the gain in only 11.7% or equivalent to 3 dc.

In case that only the slat is assumed to be fully laminar (the rest is turbulent), the drag reduction remains 5 dc at low lift and the viscous drag reduction for forced laminar is even not better than that of slat laminar.
On the other side, ONERA predicts that the friction drag reduction at corresponding high lift coefficient (CL=0.175) is more optimistic, namely 6.74 dc at suction rate of 0.1%. Assuming an installation of conventional slat only at wing inboard, the friction drag reduction remains only 3.7 dc.

Investigations by ARA and ONERA have shown that the most optimistic gain of drag lies around 7 dc in the A/C-level. This is in fact not very large, if one considers that the gain in drag has also to compensate the increase in weight, system complexity and operating & maintenance cost.

Having studied all investigated methods of forced laminar flow, a synthesis was made and recommendation was given concerning the transition control method and system which may is the most feasible for an aircraft level of S4TA

5.4.2 WP3.4 High Lift Devices

5.4.2.1 WP3.4 work logic overview

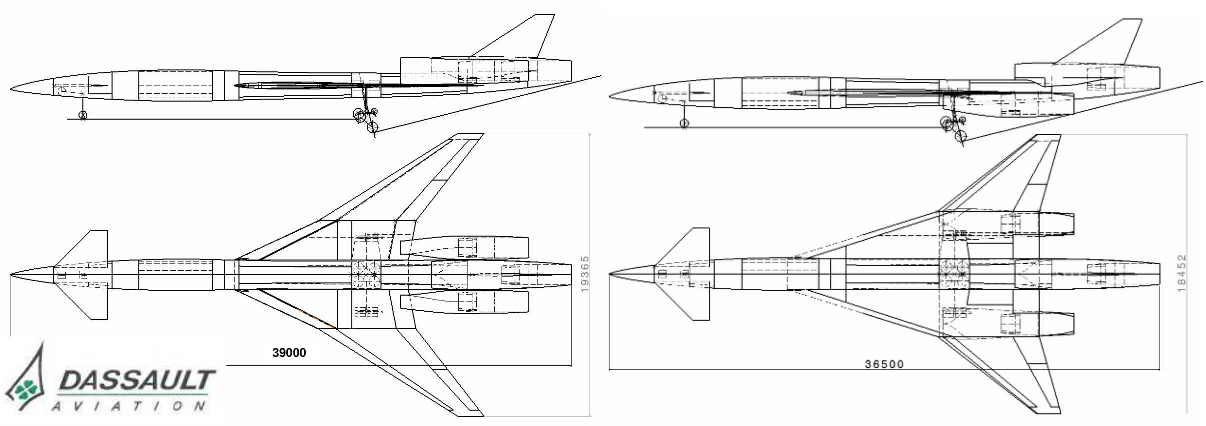
This activity started at T0+6, after the definition of preliminary reference wing shapes. During a preparatory phase, a first version of the High Level Requirement and space allocation for High Lift Devices were defined. It gave a preliminary framework on how partners involved have to perform feasibility studies.

The general work logic was as following:

5.4.2.1.1 T0+6 → T0+12: Feasibility phase

Partners performed comparison of the feasibility of several concept for slats, anti-icing, flaps and actuation systems in order to assess their advantages and drawbacks and their aerodynamic performances (feasible displacement / targeted displacement).These feasibility studies were based on first aerodynamic requirement for two different aircraft configurations:

Configuration #1: High sweep wing   Configuration #2: Delta wing



This phase will end with the pre selection of 2 different concepts for each system and for each configuration.

5.4.2.1.2 T0+12 → T0+18: Trade-off phase

Systems pre selected during the previous phase were further analyzed in order to select the best compromise for slats, anti-icing, flaps and associated actuation systems for the targeted aircraft architecture after WP5 team A first loop.
A synthesis was performed at T0+18 for each subject It supported WP5 teams A/B/C in their choices of high lift architecture during their second loop.

5.4.2.1.3 T0+18→ T0+42: Detailed Implementation, Design Loops #1 & #2

At T0+18, a single targeted configuration was chosen in close collaboration with WP5 for the detailed implementation of high lift devices on the targeted aircraft. The best concept for each item (slat architecture, slat actuation, anti-icing, flap architecture, flap actuation) was then chosen and resized regarding updated requirements and preliminary sizing loads defined within task 3.4.

A second design loop started at T0+30 to implement evolutions of the targeted aircraft configuration. This loop ended with the delivery of final reports describing selected High Lift concepts for an S4TA from structural and system point of view. A global synthesis of WP3.4 was also delivered by the task leader.

5.4.2.2 WP3.4 work sharing

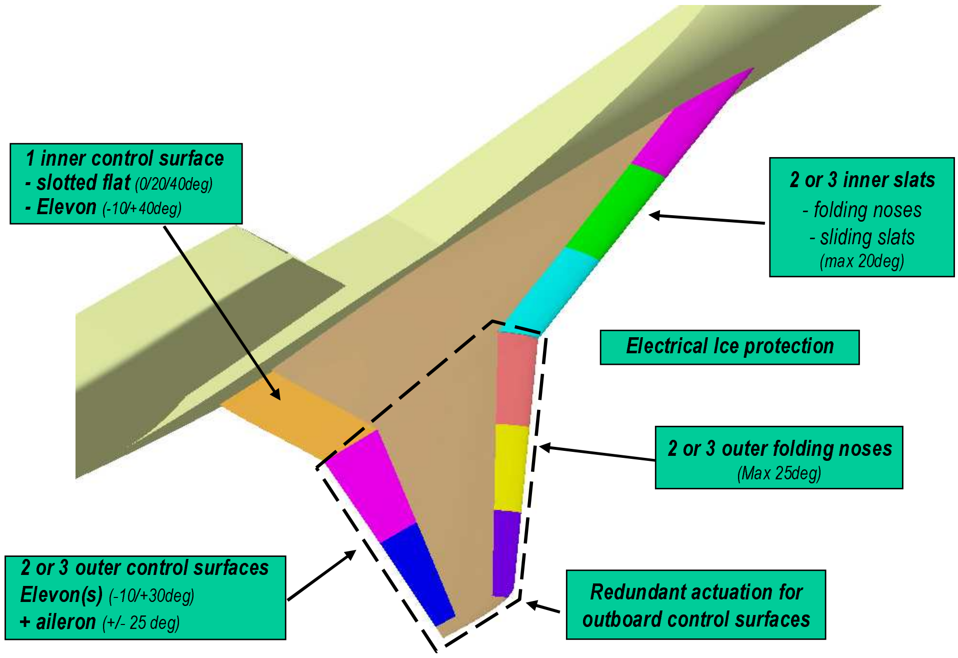
- **Dassault Aviation** — High Level Requirement; Flap design
- **Sonaca** (task leader) — Slat & Flap design; Ice Protection system; Synthesis
- **Sukhoi Civil Aircraft** — Actuation Systems
- **IBK** — Slat & Flap Loads
- **ADSE** — Ice Protection

- **FOI** Slat & Flap Loads

5.4.2.3 WP3.4 MAIN RESULTS

5.4.2.3.1 Wing general layout

At the end of the trade-off phase, the wing general arrangement for the targeted aircraft was identified as following:



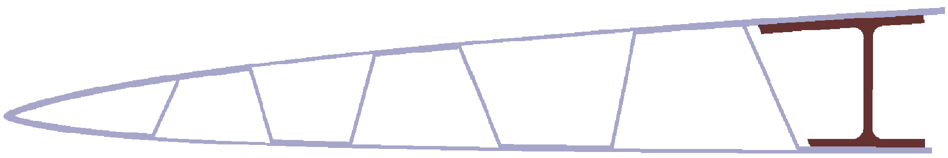
5.4.2.3.2 Slats: folding nose baseline concept

Preliminary studies highlighted that the integration of sliding slat is feasible on inboard wing only. During detailed implementation phase, studies were focused on the outboard slat conception that was more challenging.

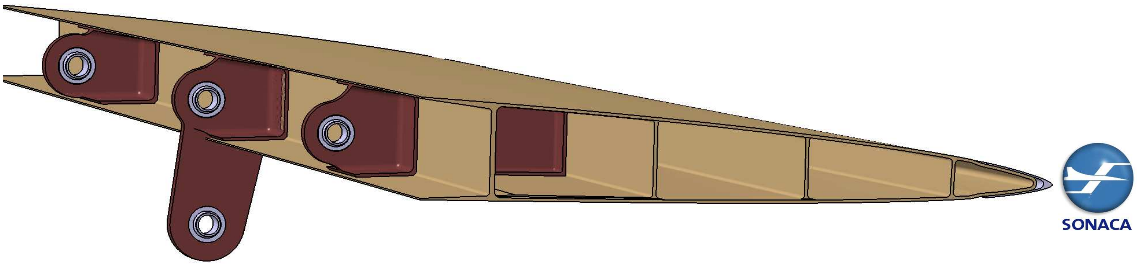
5 structural concepts were compared by relatively to the following « requirements » :
Load Transfer, Cost, Weight, Aerodynamic Steps, Nose erosion protection, Bird impact, Anti-icing feasibility.

Two kind of folding nose box structure could be adapted to these very thin wing:
If no system against ice accretion is required, the Titanium SPF-DB could be envisaged (but high costs)

SONACA



If system against ice accretion is required, composite solution associated to RTM manufacturing could be envisaged



A rough stress analysis and weight estimation based on the RTM folding nose box structure were performed. No showstopper was identified

5.4.2.3.3 Ice protection system: Electrical De-icing concept

As the ice protection requirement really depends on the wing leading edge shape and as the portion of wing leading edge to be protected wasn't well known at this stage of project, a wide range of ice protection systems were investigated during the feasibility phase, both for inboard and outboard wing, for 2 different aircraft configurations.

It was defined that Classical Hot air protection system can not be integrated to the outboard wing because of space allocation constrains (volume of fixed leading edge already filled with actuation system).

Electrical anti-icing system was then considered. A preliminary sizing of the system showed that the global electrical effective power needed for the whole aircraft is 186 kW if it is required that every folding noses of both wings shall be anti-iced.

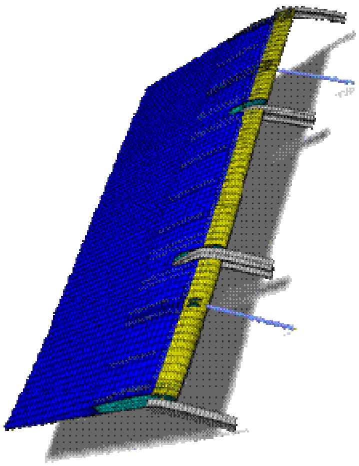
Electrical De-icing systems (heater mat integrated into the folding nose structure) was finally investigated and was selected as the baseline concept for the targeted aircraft. The electrical power needed for de-icing System of whole wing leading edge is approximately 45 kW.

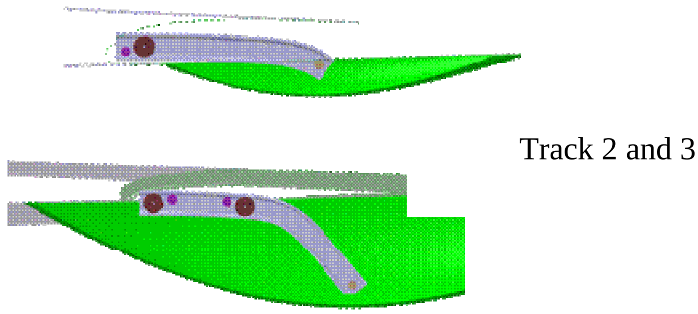
An aerodynamic validation is required (acceptable ice accretion between two de-icing cycles).

5.4.2.3.4 Flap definition: slotted flap variant investigated

Regarding aileron and elevons, no showstopper were during the feasibility phase. Structural concept could be inherited from military aircraft. Partners focused on a slotted flap variant during the detail implementation phase.

A slotted flap box structure could be adapted to a very thin wing profile, but on inner wing only. Studies show that flap box should be supported by four titanium track supports. All tracks protrudes outside the wing profile A fairing is necessary for each one.



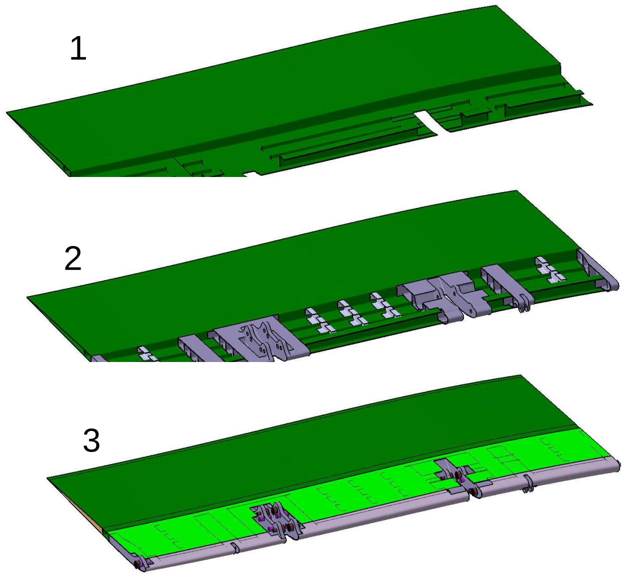


The favoured structural concept is following (bottom view):

1 One-shot Carbon RTM structure including
- Upper skin with stiffeners
- Rear lower skin (Rohacell core)
- rear and front spars

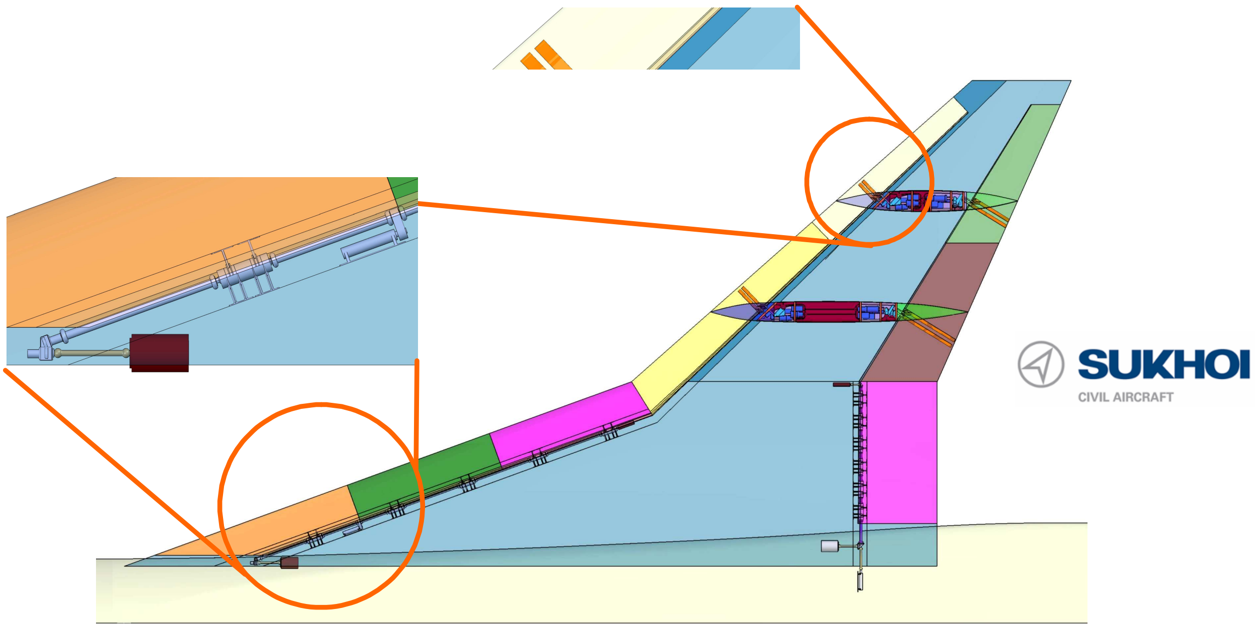
2
- Alu allow machined tracks ribs
- Alu allow machined actuators ribs
- carbon secondary ribs

3
- Carbon front bottom skin (hand lay-up)
- RTM Carbon front D nose



5.4.2.3.5 Actuation general layout

The main design drives of this work were to cope with very low wing thickness and high sweep. These constrains lead to adapting actuation system inherited from military aircraft according to civilian aircraft safety requirements and reducing drag by optimal actuators arrangement.



Inner Wing hinged leading and trailing edges control system that drives inboard slats and flaps consists of:

- single-channel electro-hydro-mechanical control actuators of rotary type;
- hinged gearboxes actuate the control devices of wing leading edges;
- the limit-stop device mechanism provides the limit positions of the wing leading edges.

The transmission of outboard slats and flaps actuates high-lift devices by linear servo actuators. For improvement of aerodynamic performances the leading edge's and trailing edge's actuators are located in one fairing (one for outboard elevon + outboard slat #4 and one fairing for aileron + outboard slat #5)
Mechanical and hydraulic parts of this actuation system are duplicated: destruction of any chain link does not lead to catastrophic situations.

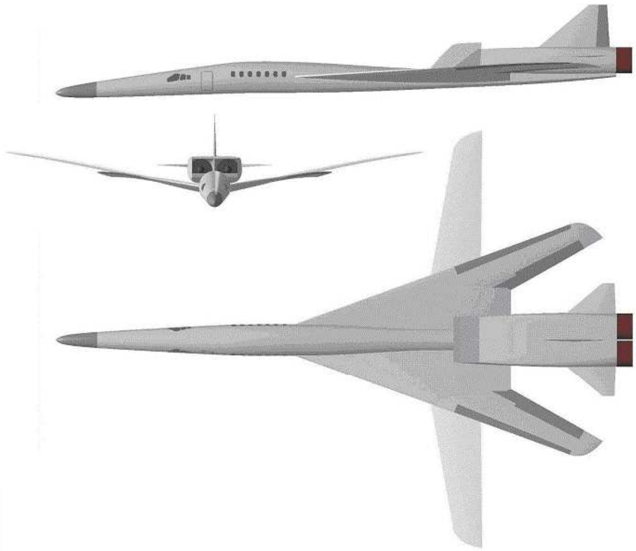
5.4.3 WP3.5 Variable Geometry Wing

5.4.3.1 WP3.5 work logic overview

Studies started with initial research into the status of swing-wing aircraft designs and a preliminary investigation in the certifications aspect of such a civil aircraft.

5.4.3.1.1 Concept Design phase

In the next 6 months the first half of "Concept design phase" was be executed. These studies were based on the aircraft configuration with swing wing provided by Sukhoi Civil Aircraft.



The main objective for this period was be to get all the information required for the concept integration phase and to prepare information for a detailed identification of relevant issues in the second part of concept design phase. This period was concluded with the release of report about airworthiness issues and Variable Geometry Wing Concept definition for a S4TA.

5.4.3.1.2 Concept Integration phase

During this last 6 month period, the VG concept was integrated to an aircraft configuration in order to assess the performance at aircraft level all along the mission. Comparison with a fixed wing configuration having the same specification (range, cabin size….) was also performed. This task stopped at T0+18.

As it was showed that swing wing is a very promising concept, ADSE carried on studying variable geometry configuration in the frame of Hisac design plateau (WP5).

5.4.3.2 WP3.5 team

- **ADSE** (WP leader) Concept design and integration
- **Sukhoi Civil Aircraft + TsAGI** Concept design and integration
- **Dassault Aviation** Certification issues

5.4.3.3 WP3.5 MAIN RESULTS

5.4.3.3.1 Swing wing state-of-the-art

A synthesis which includes a state of the art and a first analysis of foreseen issues for certification was delivered at T0+6.

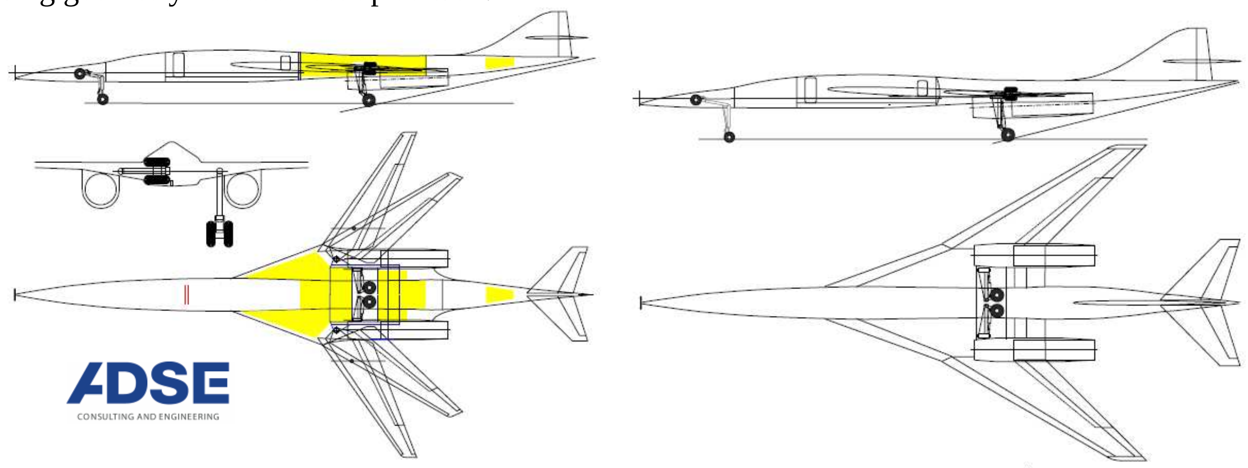
It was established that swing-wing configurations attracted much interest in the second half of the 20th century. Swing-wing technology has always been used on military projects only, though with the nearly 267 tonnes heavy Tupolev 160 was not limited to small fighters only. The last all-new design (Tu-160) first flew in 1981.Main technical difficulties were found with fatigue in the wing design around the hinge as well with the flying stability. It is envisioned that current techniques should be much more capable to identify and manage these aspects.

Certification issues were the main hurdle to overcome for using swing-wing concepts in commercial airplanes. A preliminary investigation in the certification aspects indicated that the main expected difficulties are following:

- Justification of the wing hinge regarding fatigue and damage tolerance (JAR 25-571)
- Emergency landing in case of malfunction of the wing actuation device (wing locked in high speed position)

5.4.3.3.2 Variable geometry concept integration

ADSE showed that using the variable sweep, the aircraft configuration can be optimised for field performance as well as cruise performance. To assess these effects a reference design with fixed wing geometry has been set up as well.



It proves that with variable wing geometry the wings and propulsion system can be considerably smaller with a major positive impact on aircraft size and weight. This will have a positive effect on the fuel consumption and engine noise, which both have a positive contribution to the environment.

Additionally the subsonic performance is much better, which leads to a significant reduction of reserve fuel and mission fuel allowances –which contribute to a lower overall all up weight- and much better range when flying subsonically as may be required for overland segments.

In takeoff and landing a conventional angle of attack is required, which eliminates the requirement or reduces the criticality of a synthetic vision system. Contrary to highly swept fixed wing configurations there will be no dependence on leading edge vortices to obtain a high maximum lift, and the aspect ratio of the wing in landing and takeoff configuration is much higher. Therefore the required thrust will be 30%to 40% less, resulting in lower airport noise (More details about the ADSE variable geometry concept can be found in Hisac WP5 public activity report).

Possible risk areas are the weight and drag of the hinge system, the integration of structures and systems in the hinge area and the requirement to define a relatively sophisticated high lift system in a thin wing without using external tracks.

There is no experience with civil certification of variable geometry wings, therefore this may lead to additional effort and higher technical risks

5.4.3.3.3 Variable geometry substantiation

- General issues

For HISAC application, major differences with current day variable geometry wing equipped aircraft leads to the following issues:

- Certification requirements typical for supersonic transports as affecting the wing sweep system;
- Feasibility of storing fuel in the moving wing box. This might be attractive from the point of view of fuel volume and CG control;
- Options to control the aircraft shift due to wing movement and supersonic speeds. Passive solutions will be attractive from the point of view of certification, but these may have too high cruise drag penalties:
  - Passive solutions: Tailplane trim by brute force,
    Offloading wing tips with skewed hinge axis or slight dihedral.
  - Active solutions: Fuel transfer (limited by practical reserve fuel mass),
    Extending surfaces forward of CG with aft swept wings (F-14, Beech Starship),
    Artificial longitudinal stabilisation with wings forward.
- Hinge concepts, including systems runs, flexible fuel lines etc.;
- Outboard position of hinge: exchange of problems against benefits;
- Integration with engine positions.

- Failure cases

The concept studies of the structure and systems associated must be managed to avoid any locking of the rotating device. The same attention must be paid to avoid any non-symmetrical behaviour of the left and right wing panels.
This implies a redundant and damage tolerant interconnection and coordination system substantiation..

- Configuration change

It is assumed that the wing position variation may be considered as a conventional configuration change, equivalent to slats or flaps extension, using a discretisation of flight phases during the mission, which must be described and substantiated.

- Substantiation principle

The hinge shall be considered as one of the most critical parts for a variable geometry wing. It must be designed in order to avoid any catastrophic failure due to an initial or accidental damage and its propagation under repeated loads in service.

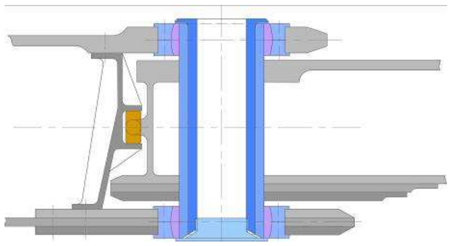
First analysis showed that it seems to be very difficult to substantiate a single load path hinge. Hinge structural concept studies were then driven by a multiple load path design associated to a damage tolerance substantiation.

5.4.3.3.4 Hinge structural concept and actuation system

The most challenging aspect of the hinge is its required capability to pass normal forces as well as moments to the airframe, all by using a single pivot point, taking into account multiple load path requirements.

Following concept from Sukhoi Civil Aircraft was selected as a baseline:

- Elements exposed to heavy tensile loads consist of three parts
- The rotation axis is redundant.



The actuation system was also addressed:

The system is operated from the cockpit by dedicated dual control units
The system actuator represents two-channel hydro-mechanical servo of rotary type and emergency auxiliary electro-mechanical drive. The actuators of wing sweep angle variations are ballscrew transforming units with electro-mechanical brakes incorporated.
All mechanical links are duplicated to ensure fail safe operation.

Outer wing panels extension/retraction time is between 30-35 seconds.
The total weight of OWTCS (outboard wing turning control system) without panel-turning assemblies is approximately 400 kg and the power of two-channel hydraulic actuator is about 30 kW.

5.5 Work Package 4

Work Package 4 (Key integration issues) focus was on the "key issues" (e.g. "hard points") of the integration in the aircraft shape of the noise, boom and drag requirements: reduction of uncertainties on fuselage/nacelle/wing acoustic and aero-interactions, calibration of global models of the latter, combined local shape design for simultaneous noise/sonic boom/drag minimisation, investigation of high performance shape designs compatible with extended laminarity, and/or with very low sonic boom. Airworthiness issues have also been addressed in this WP.

5.5.1 Aerodynamic Design and Assessment

The very first period was devoted to investigate, in a parametric way, several different concepts proposed by different partners (see. Fig.47).

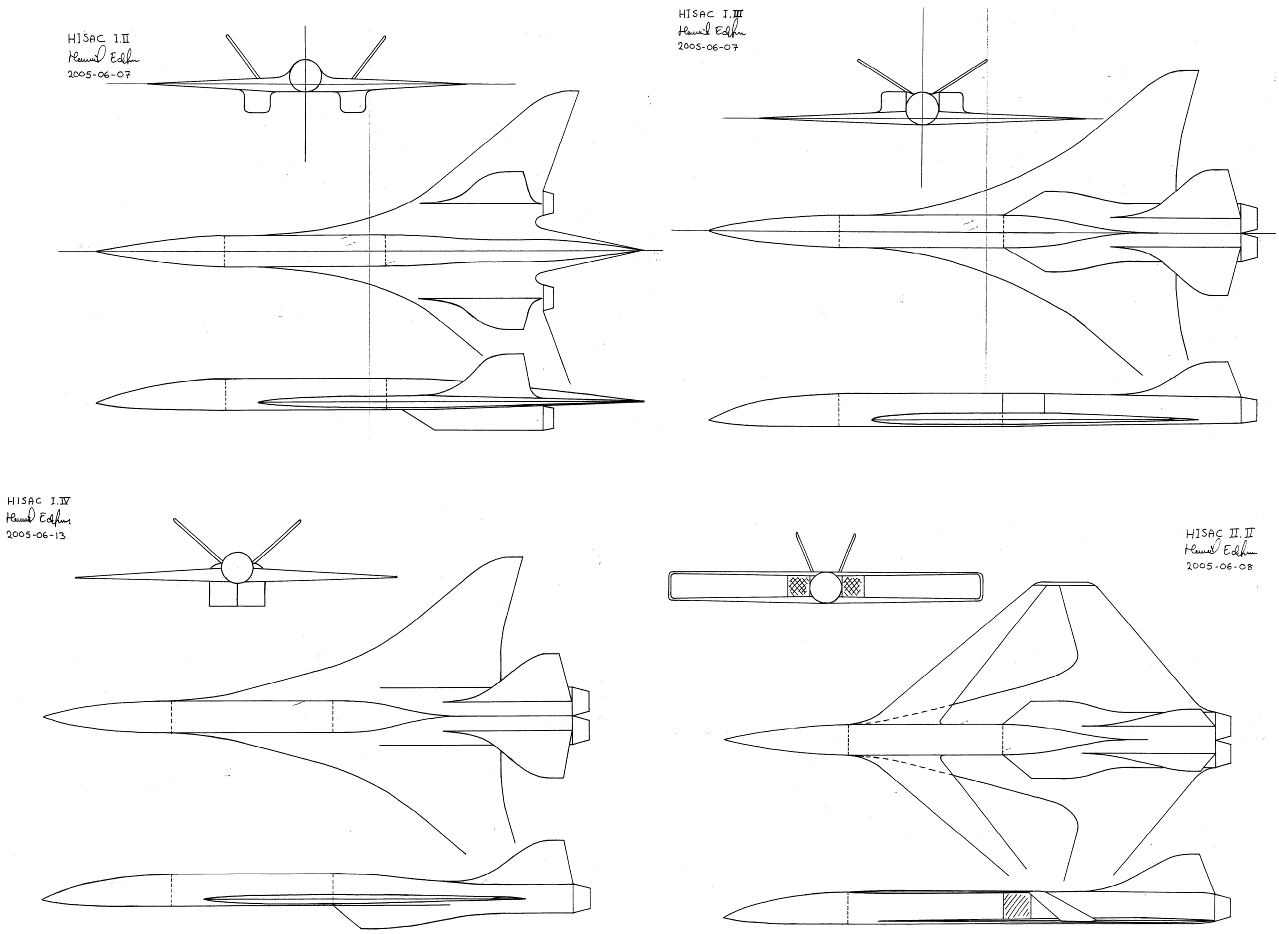


Figure 47 – Early stages of HISAC – Proposed concepts

In depth investigations of several different effects were performed, including sweep angles, wing thickness, aspect and taper ratios, crank position, etc. in order to design a reference configuration which could be considered the most promising both from the aerodynamics (WP4) and architectural (WP5) point of view.

These studies led to the selection of two potential candidates for the aerodynamic reference shape (one delta wing and one high-sweep wing, see next figure).

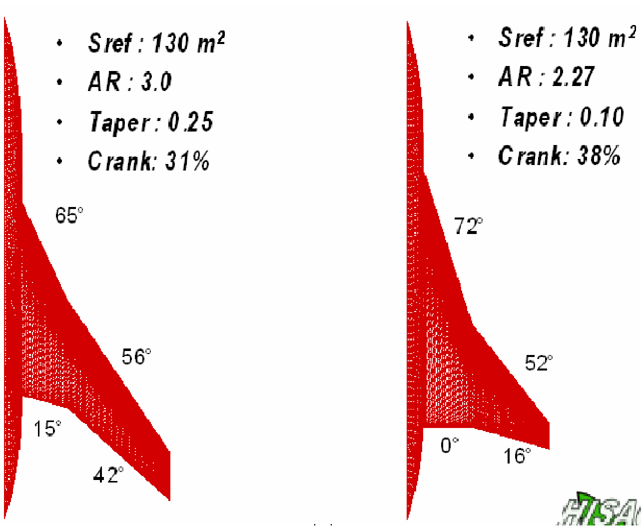


Figure – 48 - Potential candidates for the aerodynamic reference shape

At T0+9, following a preliminary aerodynamic assessment, a reference shape was chosen: it was a delta wing, the same of Team C without any dihedral.

The choice was driven by the possible minimum sonic boom impact (the most challenging requirement to cope with) embedded in that concept. The “Reference Aerodynamic Shape” was then fully developed.

In particular, the following aspects were investigated:

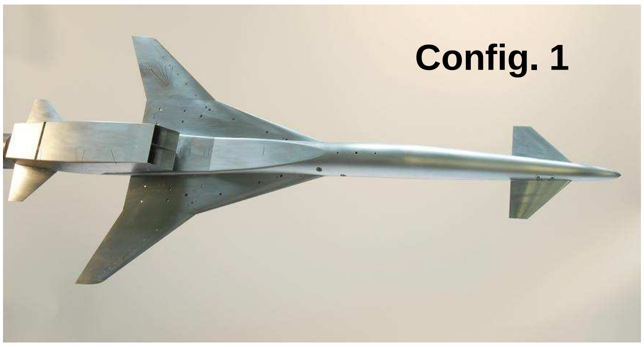
- wing airfoil design/optimization
- wing twist and camber optimization
- canard/tail configuration and sizing
- control surface airfoil design

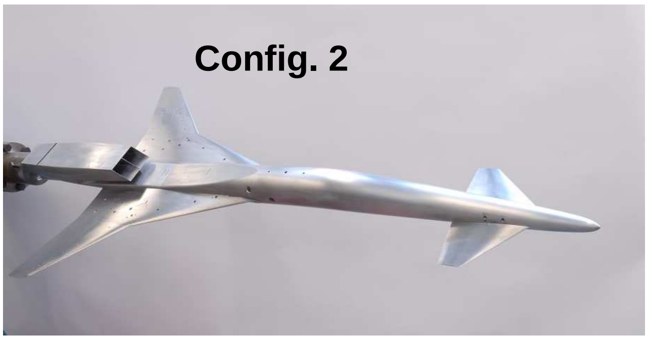
➢ high-lift systems detailed definition (flaps/slats size and position)

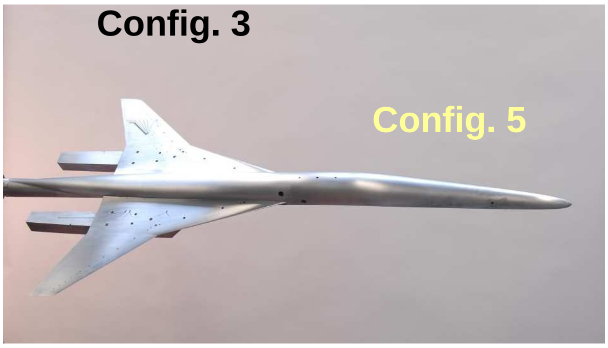
➢ fuselage shape (including area rule for engine integration)

➢ air inlet/nozzle design/optimization

At the end of the optimisation loops two different wind tunnel models both low and high speed were also designed. Beside that common work Team A, Team B and Team C developed their own configurations. WT models (including Team B laminar wing) are shown in the following pictures.







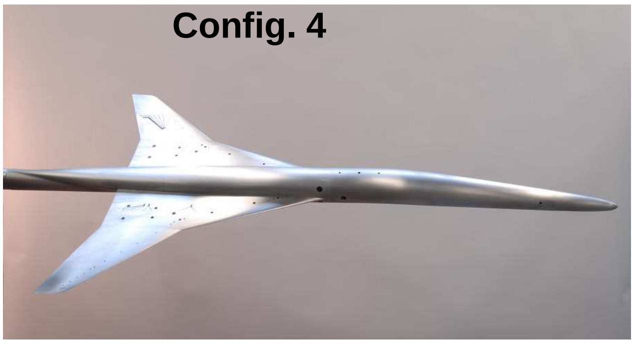


Figure 49 – High speed wind tunnel model shapes

The high speed models were tested in ONERA (supersonic) and TsAGI (transonic) test facilities whereas the low speed model was tested in RUAG plant.

Figure 50 – Alenia wing tested at ONERA WT

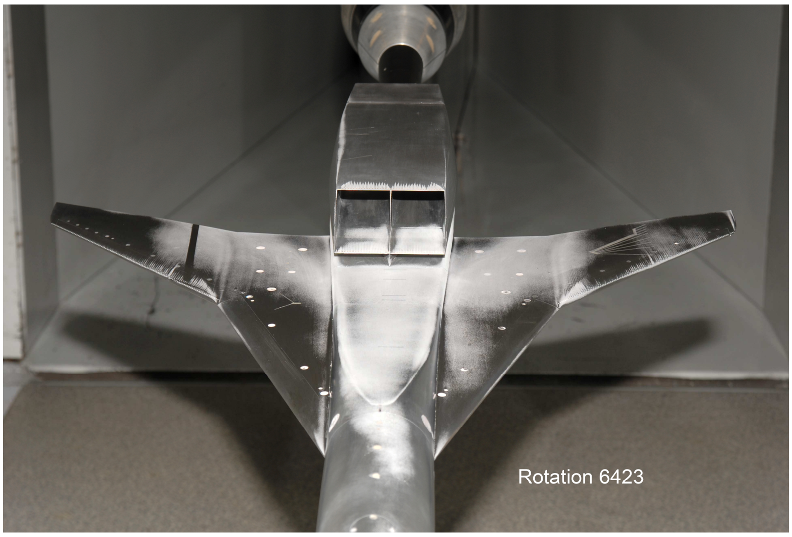


Figure 51 – WT tests at ONERA plant

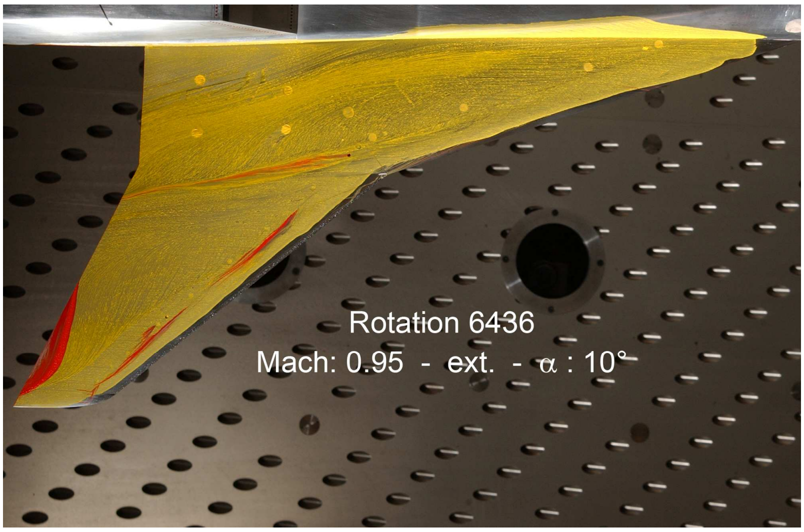


Figure 52 – Transonic oil flow visualization

Figure 53 – Reference shape in TsAGI plant

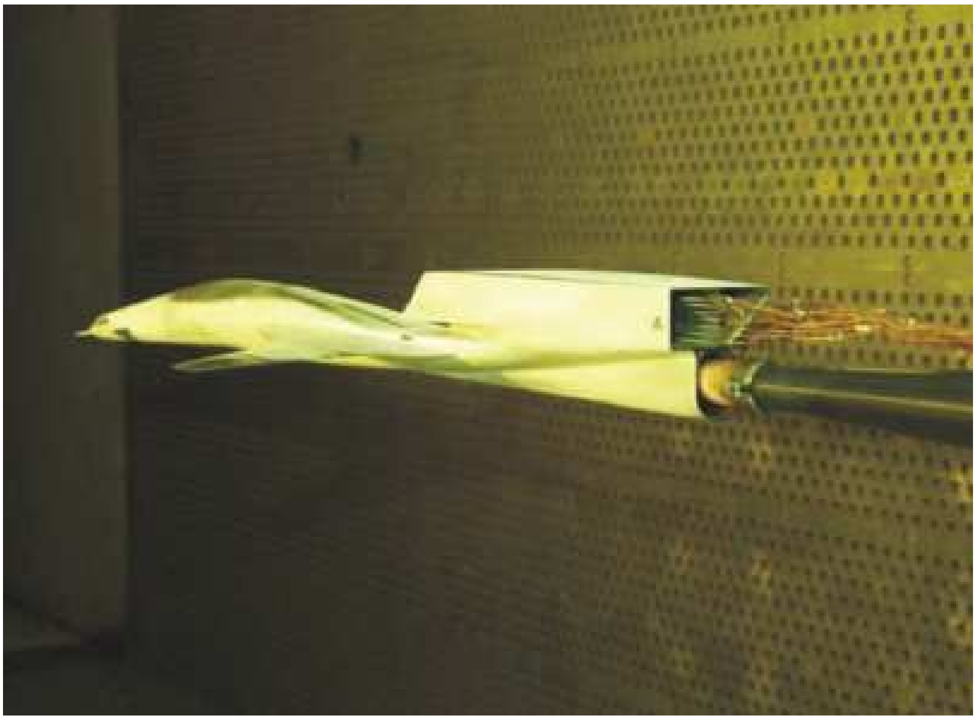


Figure 54 – Nacelle internal drag measurements apparatus

Figure 55 – Reference shape at RUAG plant

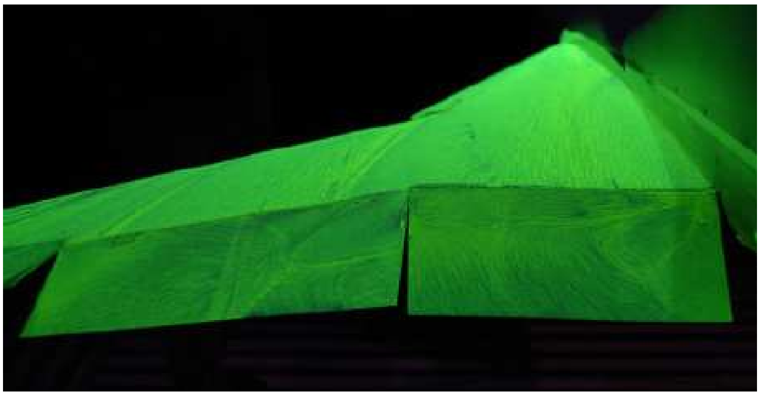


Figure 56 – High lift oil flow visualization

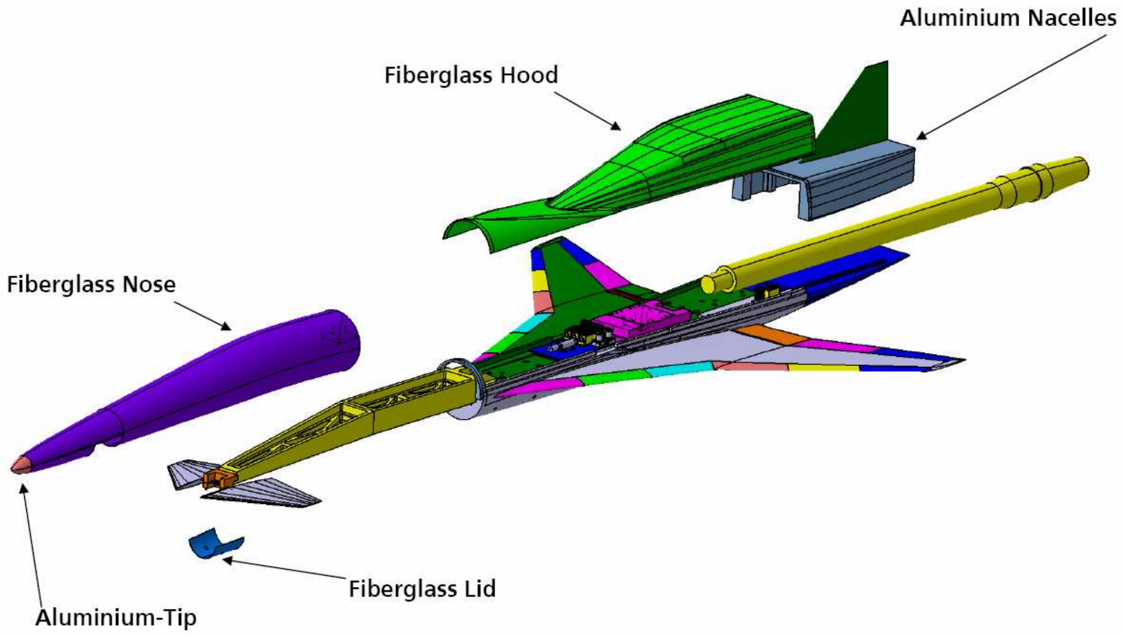


Figure 57 – Low speed wind tunnel model

The main objectives of supersonic test campaign were:

- Assess the engine integration impact on total drag in supersonic conditions : 4 different engine integration solutions to be tested (large vs. small nacelles, upper aft fuselage mounted vs. under-wing mounted nacelles, compared to "glider") at different engine mass flow rates
- Investigate the impact of trim on drag polar in supersonic conditions (small / large canards, HTP)
- Perform a transonic test to have a reference before T-128 (TsAGI) test
- Investigate Alenia laminar wing aerodynamic performances (L/D and laminar flow extension)

The main objectives of transonic test campaign were:

- Investigate the performance of the baseline aircraft configuration in transonic regime
- Investigate the impact of slats on drag polar in transonic regime

➢ Investigate the impact of trim on drag polar in transonic conditions (with/without small canard planes or HTP)

➢ Investigate wing performance around buffet onset

➢ Evaluate the nacelle internal drag at different free stream conditions

Transonic tests were also necessary to correctly evaluate the additional drag generated by the nacelle flow restrictor which was evaluated and subtracted from the total drag. This evaluation was performed at different Mach numbers (Mach 0.85 / 0.95 /1.2 / 1.3 /1.4). A dedicated experiment was conducted with a rake of total and static pressure probes attached to the rear end of the nozzle (see Figure below):

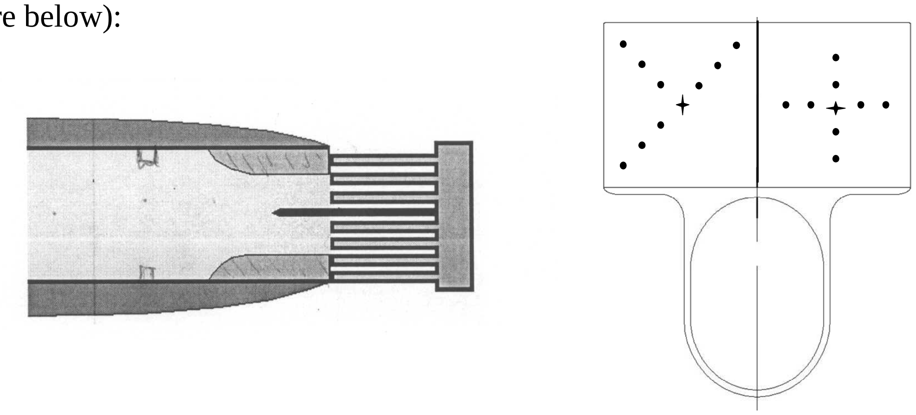


Figure 58 – Apparatus to measure nacelle internal drag

The main objectives of low speed test campaign were:

➢ Investigate CLmax performances at landing

➢ Investigate L/D max performances at take-off

➢ Compare slotted vs. non-slotted inboard flap performances

➢ Investigate canards impact on trim and on optimal slats settings at both take-off and landing

➢ Investigate elevons/ailerons effectiveness (longitudinal + lateral performances)

In the meanwhile CFD computations of reference shape were carried on, using WT data as benchmark, with the aim to transpose WT gathered data to real flight conditions. This transposition takes into account:

➢ Reynolds effects

- Nacelle internal drag

- Diverter thickness (different in real conditions from WT conditions since of boundary layer thickness)

- Vertical tail plane

Figures 59 and 60 shows an example of the CFD analyses.

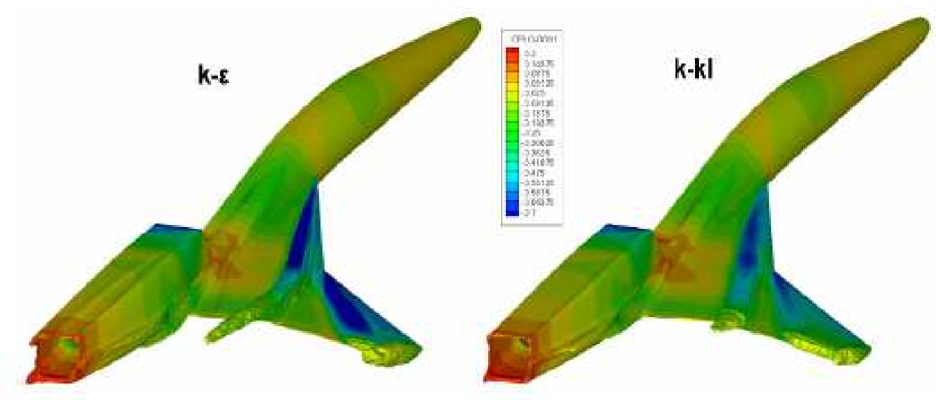


Figure 59 – CFD assessment of the reference configuration

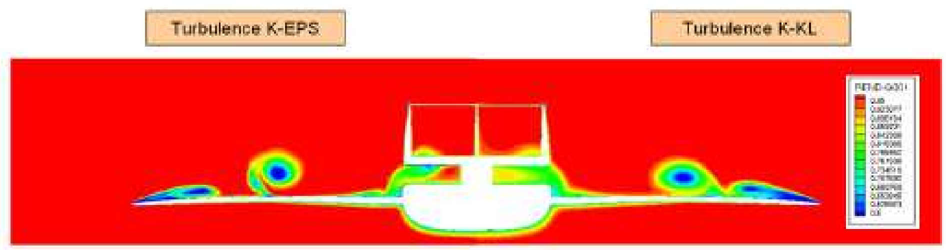


Figure 60 – Assessment of the reference configuration with different turbulence models

Overall outputs coming from the transposition process were collected, in a suitable form to be used by WP5, in a database delivered by Task 4.0.3.

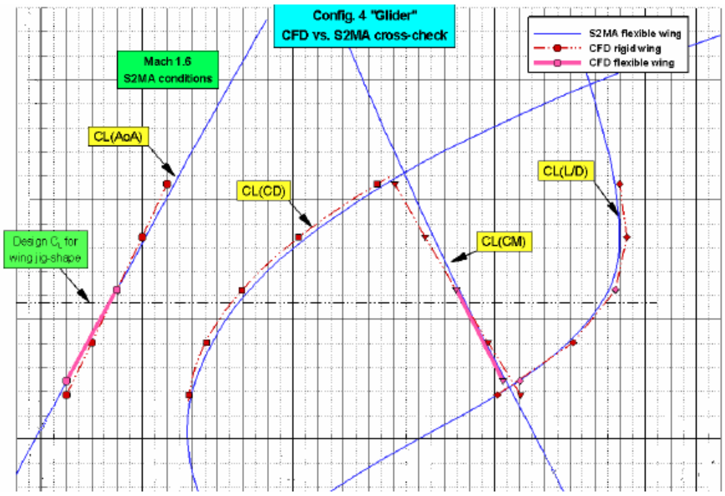


Figure 61 – CFD results comparison

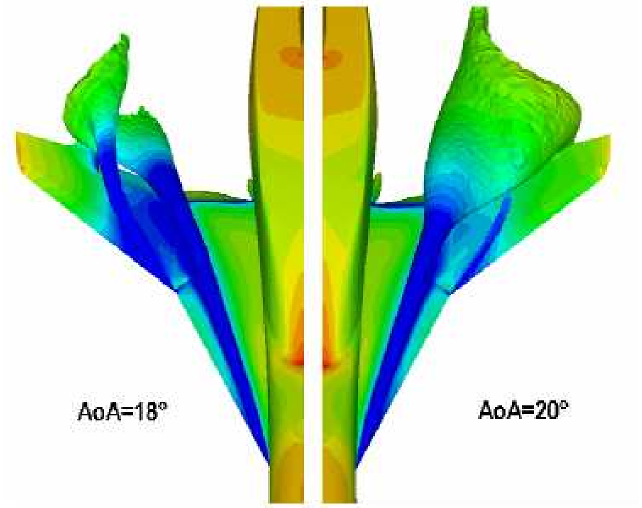


Figure 62 – CFD computation comparison

Concerning alternative aerodynamic propulsion integration solutions, CFD investigations for a variety of low drag/low noise engine integration derivatives with an engine bypass ratio of 1.5 showed that axisymmetric inlets with a profiled cowl lip have advantages over other intake designs in terms of total pressure recovery. This is mainly caused by the circular shape of the inlet.

Other intakes with a higher level of integration into the airframe, such as diverterless bump intakes, benefit of reduced friction drag due to the smaller wetted surface of the propulsion system and feature reduced noise propagation due to the geometrical shielding.

Figure 63 illustrates some of the configurations which were developed to carry out the drag and intake performance assessment. For cruise flight conditions at Mach 1.6 total pressure recoveries at the engine face were computed and a data base for the aerodynamic coefficients of specified aircraft parts was established. The magnitude of the total drag of the intake and the nacelle together proves to be in the order of the fuselage drag or the wing drag underlining the importance of minimizing the aerodynamic drag originating from the propulsion system installation.

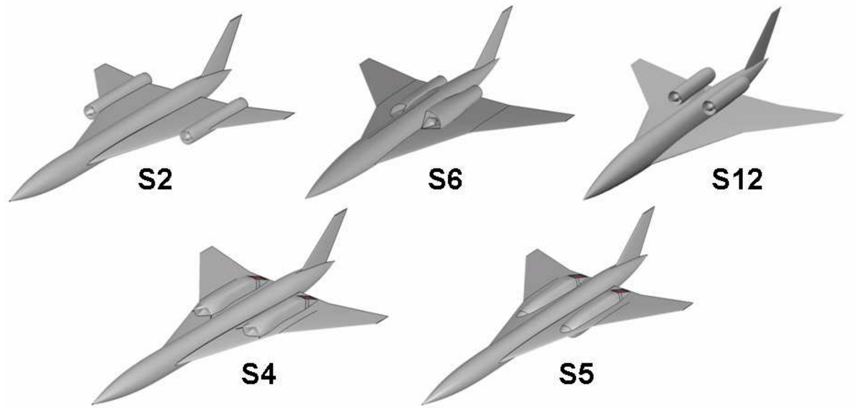


Figure 63 - Engine integration derivatives

Also Low Boom Shape (LBS) and Laminar Shape (LS) aerodynamic performance, at the end of their assessment, have been reported in the database (supersonic regime only). Regarding lift, the LBS have a significant loss with respect HISAC Reference Shape (Config. 1), almost compensated by a lower induced drag. Nonetheless a ΔL/D decrease of some 0.1 is reported in supersonic cruise conditions. As far as the LS, whose wing proven to be almost completely laminar at WT conditions, transposition at real flight conditions has shown a 3.7% drag increase with respect to HISAC glider configuration.

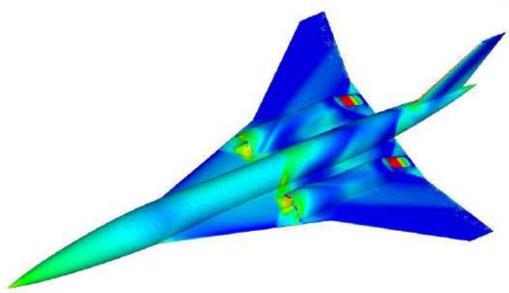


Figure 64 – Example of CFD computation low drag/low noise engine integration

5.5.2 Sonic Boom Design and Assessment

As far as the sonic boom assessment, a direct back to back comparison of results coming from different partners is almost impossible due to the large differences existing between the different processes and tools used to compute the sonic boom signature; nevertheless results are quite similar and provide evidence that Team C configuration is close to the design objective. The LBS scores roughly 20 dB less than a conventional (non low boom) shape.

The following picture depicts graphically the evolution of the sonic boom up to the ground.

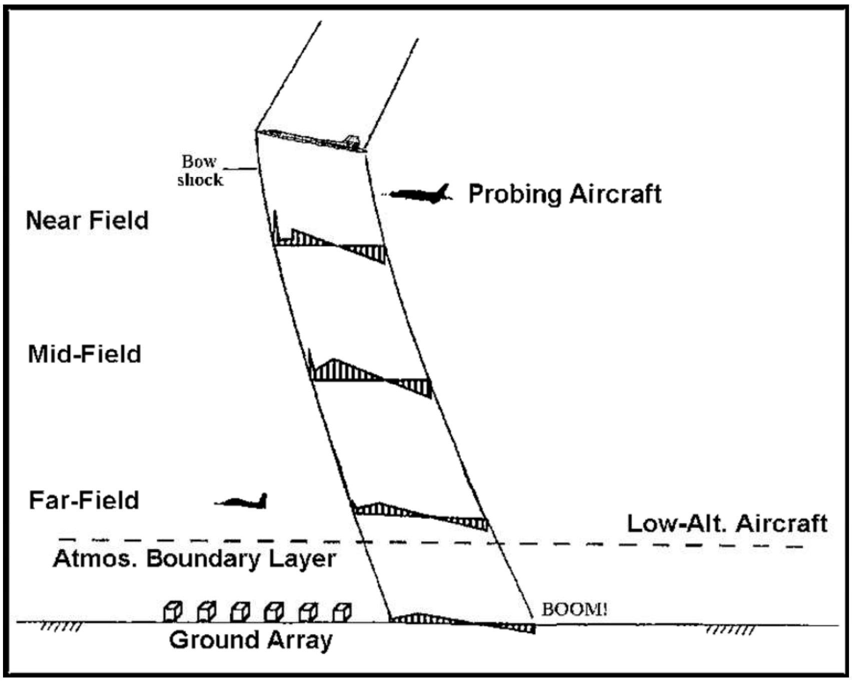


Figure 65 – Sonic Boom evolution

On the other hand, high level of sonic boom annoyance, are scored by the laminar shape whose lifting surfaces must accelerate external flow to get the widest laminar area.

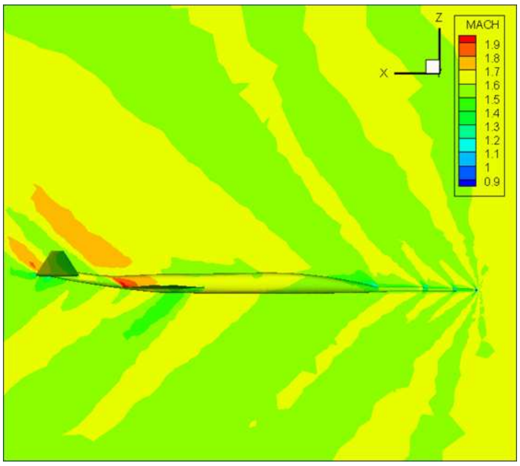


Figure 66 – Possible device to reduce boom signature

To try to reduce this drawback as much as possible a device was designed and assessed. Results highlight that the shocks induced by a laminar configuration, as designed by Team B, are likely to merge regardless the presence of a sonic boom suppression device.

5.5.3 Acoustic Design and assessment

The acoustic assessment was carried on both on the HISAC Reference Shape and on its derivatives. Reference Shape is an airplane powered by two high bypass (BPR = 3.5) conventional type engines, defined as engine #2 in the HISAC project.

For the reference shape results of computations carried on at different flight conditions (sideline, flyover and approach) lead to conclude that this configuration comply with Chapter 4 requirements. Moreover an important indication to designers is that sideline noise levels could approach critical values. Therefore, noise reduction efforts should be carried out with this in mind and the use of smaller engines with lower bypass ratios ought to be avoided. Last point to underline is that the long intake is able to strongly attenuate noise so that the fan noise radiated by the intake should not be a critical problem.

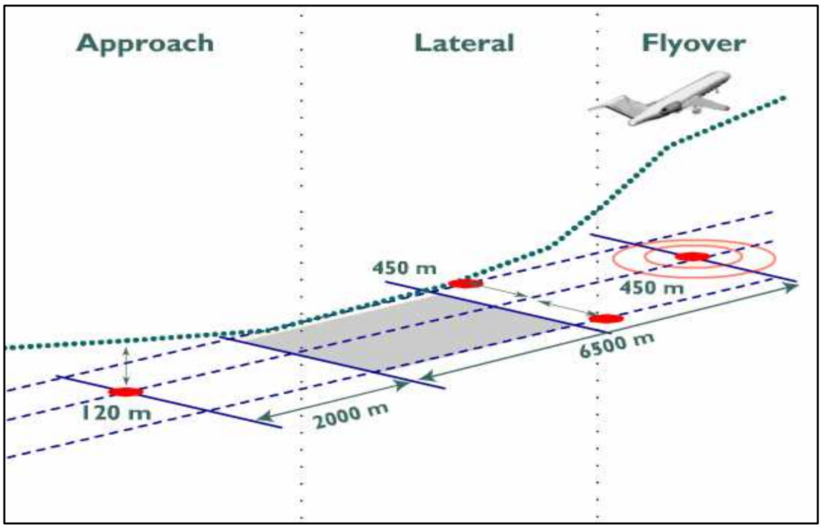


Figure 67: Noise certification points according to ICAO Annex 16

Derivatives include a lower BPR configuration and under wing nacelles. The objective of these engine integration derivatives was to reduce the aircraft drag mainly through the reduction of the engine size and to know how much does that cost in term of noise. The agreed conclusion is that low drag engine integration can not satisfy even Chapter 3 of the Annex 16 of ICAO regulations.

Beside HISAC, TSAGI reported investigations of alternative engine configurations and the evaluation of the effect of hypothetical noise reducing devices. They concluded that, the aid of noise suppression system would help greatly. The calculation showed that the mixer ejector could not suppress the noise sufficiently to stay within ICAO limits. However, they recommended though to further expend the study of this type of noise suppression system.

Figure 68 – Proposed plug sector nozzle to reduce noise

Other noise reduction solutions were investigated in other WP, like "thrust management" in WP5 by CIAM.

5.5.3.1 Airworthiness issues

HISAC certification and airworthiness issues are dealt with in Task 4.5 which is divided into three parts:

- Identification of the general list of certification key points relative a supersonic aircraft;
- Special Condition key points relative to HISAC configurations;
- Main recommendations for a Special Condition relative to HISAC configurations in agreement with civil aviation authorities.

Relying upon an analysis of the intermediate design configurations, an exhaustive review of the certifications issues was produced, general and peculiar for each configuration.

General specificity are crew visibility, supersonic flight (overland / over water), CVC engine (i.e. engine thrust management). Then each configuration has specific issues to be investigated: Landing gear with rotating boogies for Team A, laminarity management and V-tail for Team B, side by side engine configuration for Team C.

Out of them five issues were deemed the most challenging so descriptive sheet on the certification items were prepared. These sheets were then sent to EASA experts in order to start a dialogue with the authorities to prepare the special conditions.

The following issues were selected for the sheet redaction:

- Engine thrust reduction
- Artificial Visibility
- Side by side engine
- Variable geometry wing
- High altitude condition

Following the discussion with EASA experts no insurmountable problems have been identified from the technical point of view. Technical solutions seem to be available to meet future certification requirements.

In addition, slight modifications or clarifications about noise requirements, cabin depressurisation and laser anemometry could be necessary. In the domain of operations, new regulations shall be needed in relation with the sonic boom, altitude limitations, air traffic management and laminar flow, while legislation about the noise abatement take-off procedures may require some modification.

5.6 Work Package 5

5.6.1 Technical Aspects

WP5, over the span of the project, focused on the following aspects :

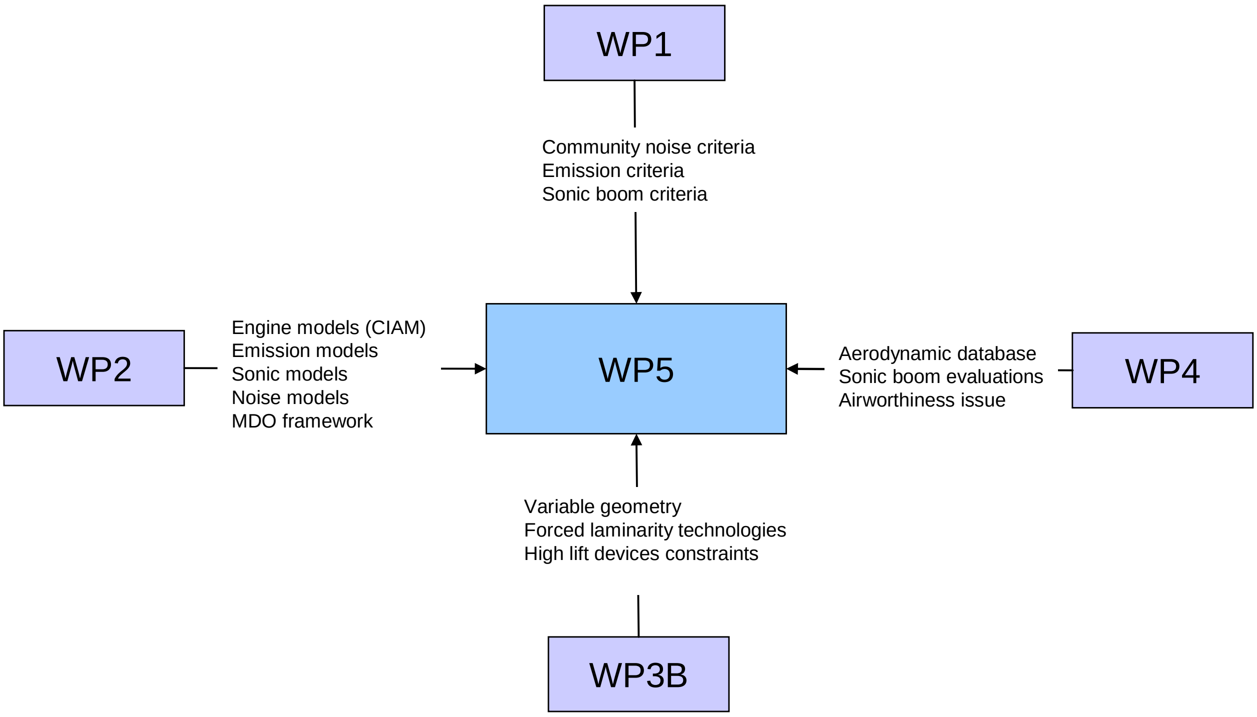
- Proposing rationale and coherent designs of the aircraft and its main components, meeting conflicting operational and environmental constraints and requirements
- Assessing at the aircraft level the overall gains obtained on the design through the use of advanced key technologies (engine, airframe) or key integration solutions
- Managing at the aircraft level the trade-offs between operations requirements, the environmental constraints and the global performance of the aircraft

5.6.2 Description of the exchanges between WP5 and the other work packages

WP5 synthesized and integrated a lot of results coming from the activities performed within the different work packages of HISAC :

- The translation of the environmental objectives into quantified design criteria for community noise, atmospheric emissions, sonic boom, applicable to an S4TA done in WP1 is used as input in WP5 for building the requirement set
- WP5 suite of tools benefited from the adaptation of numerical models and tools (noise, emissions, sonic boom, engine and aerodynamics, as well on MDO process itself) performed in WP2
- Engine models performed in WP2 are used as backbone of the aircraft design in WP5, and span over different engine architectures (conventional, variable confluence and mixer-ejector)
- The development and validation of critical engine and airframe technologies (forced laminar flow, high lift devices and variable geometry wing for airframe) performed within WP3 are integrated at aircraft level in WP5, and impact is assessed comparatively to more conventional technologies
- Performance estimations are backed up by the computations (CFD) and the wind tunnel tests carried out within WP4. Activities related to sonic boom minimization, engine integration, noise reduction are also directly integrated into aircraft design activities.

The interaction between the different work packages is illustrated on the figure below.



5.6.3 Design activities

5.6.3.1 Introduction

The design activities within WP5 focused on six configurations (4 "supersonic" configurations, 2 "low supersonic" configurations), studied by Team A (Dassault Aviation), B (Alenia and ADSE) and C (Sukhoi, TsAGI and CIAM).

The 4 “supersonic” configurations that have been studied are the following :

- Configuration A – Low noise concept – Dassault Aviation
    - Share the common set of requirements detailed underneath, but will include an additional constraint regarding the acceptable noise level (Stage IV – 10 dB + operation constraints on the individual certification points)
- Configuration B1 – Long range concept – Alenia
    - Share the common set of requirements detailed underneath, but will include an additional constraint regarding the minimum range (5000 NM)
- Configuration B2 –Variable geometry concept – ADSE
    - Share the common set of requirements detailed underneath, but will include an additional integration of a variable geometry wing architecture
- Configuration C – Low boom concept – Sukhoi, TsAGI, CIAM
    - Share the common set of requirements detailed underneath, but will include an additional constraint regarding the acceptable overland boom signature

In addition, two low supersonic configurations have been studied :

- High subsonic configuration (with supersonic capabilities) – Dassault Aviation
  - Share the common set of requirements detailed underneath, but will have as a primary requirement for cruise speed a Mach number equal to M0.95, with supersonic capabilities up to M1.2.
- Low supersonic configuration – ADSE
  - Share the common set of requirements detailed underneath, but will have as a primary requirement for cruise speed a Mach number equal to M1.2. High cruise speed may be foreseen.

5.6.3.2 Common requirements

All configurations have been designed based on a common set of requirement. An overview of the relevant common requirements is presented hereunder (Figure 69).

Common requirements

General requirements		
	Entry into Service	2015
	Airframe design life	20000 hrs / 10000 flight cycles / 20 years
Environmental objectives		
	Sonic boom signature	Overwater
	Sonic boom focusing	not taken into account
	Pollutant emission	not taken into account
Weights		
	MLW	OEW +1000 kg payload + 2 x reserve fuel
	Reference payload	8 PAX
	PAX mass	200 lbs
Mission performances @ reference payload		
	Maximum cruise speed	1.6
	Overland cruise speed	0.95
	Minimum supersonic cruise altitude	FL410
	Maximum cruise speed range	4000 nm
	Overland cruise speed range	4000 nm
	Approach speed @MLW @SL @ISA	<140 kt
	Field length @SL @ISA	<6500 ft
	ACN for flexible pavement	23
	ACN for rigid pavement	25
Cabin dimensions		
	Maximum PAX	19 PAX
	Seating area external diameter	2030 mm
	Seating area height	1785 mm
	Seating area length	200 in
	baggage volume	100 cu ft
Airworthiness constraints		
	General certification Requirement	JAR/FAR 25 + supersonic special conditions
Powerplant requirements		
	General certification Requirement	JAR/FAR 33 + supersonic special conditions
	Engine TBO	2000 hr
	Fuel density	6.75 lb/US gallon
	Fuel heating value	18400 BTU/lb
	APU	Required

Figure 69 - Common requirements

In addition, sensitivity to design requirements which impact strongly the designs is assessed:

- Supersonic cruise Mach number between M0.95 and M1.8

- Minimum range between 3000 and 5000 Nm with 8 passengers
- Max landing weight = between 70% and 95% of max take-off weight
- Approach speed at landing = between 120 and 140kt
- Maximum balanced field length = between 5500 and 6500ft

5.6.3.3 Description of the six configurations

5.6.3.3.1 Low noise configuration

5.6.3.3.1.1 Overview

The low noise configuration is based on the following design drivers:

- Delta wing and canards
- 3 high by-pass ratio CVC engines :
  - 1 engine is buried in the rear fuselage
  - 2 engines are mounted in lateral nacelles located under the wings
- The main landing gears are attached on the wing structure, between the two lateral nacelles and the wheels retract in the fuselage
- A vertical fin is attached on the rear fuselage, above the buried engine

Figure 70 illustrates the external shapes of the low noise configuration:

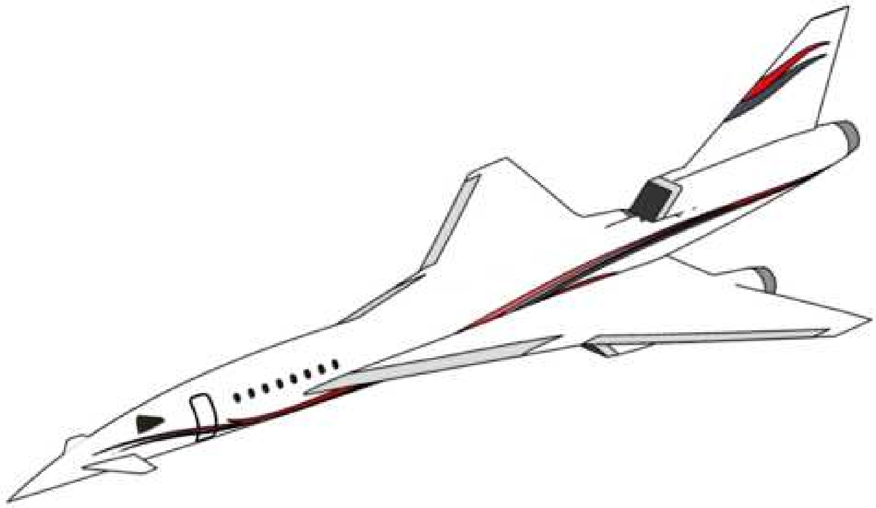


Figure 70 - External shapes of the low noise configuration

The internal layout of the fuselage allows accommodating the following areas:

- A nose section with the radome, that includes radar equipments
- A front fuselage non-pressurized area accommodating the avionics bay and the canard hinges.
- A pressurized area, which includes the cockpit, the forward galley, the passenger compartment, the lavatory and the baggage compartment. The passenger cabin is soundproofed and insulated, and measures 7.70m (including lavatories). Access to the baggage compartment is available from inside or outside the aircraft.
- The auxiliary landing gear bay that is located in front of the cockpit
- A Non pressurized equipment bay
- A forward fuselage fuel tank
- The main landing gear bay, positioned by center of gravity management constraints
- A rear fuselage fuel tank
- The aft non-pressurized section including the equipment bay, the air duct and the APU
- The fuselage buried engine bay

The overall layout of the low noise configuration is illustrated on Figure 71.

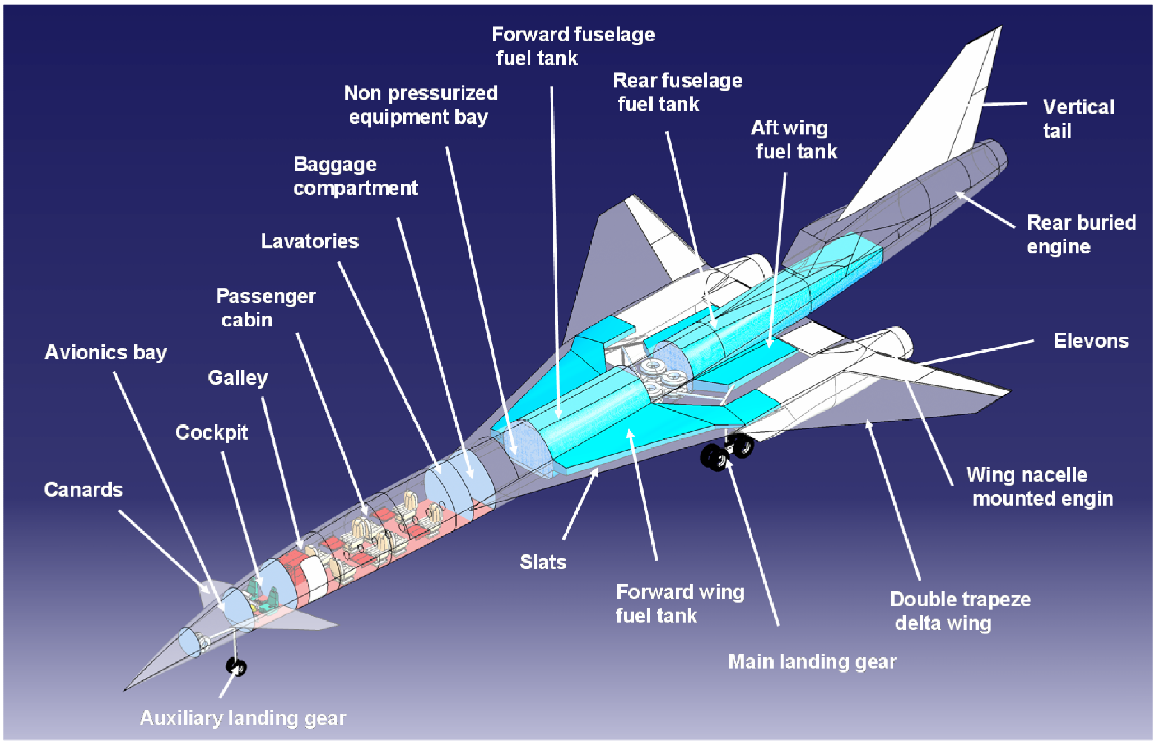


Figure 71 - Internal layout of the low noise configuration

The internal layout of the cabin is illustrated on Figure 72.

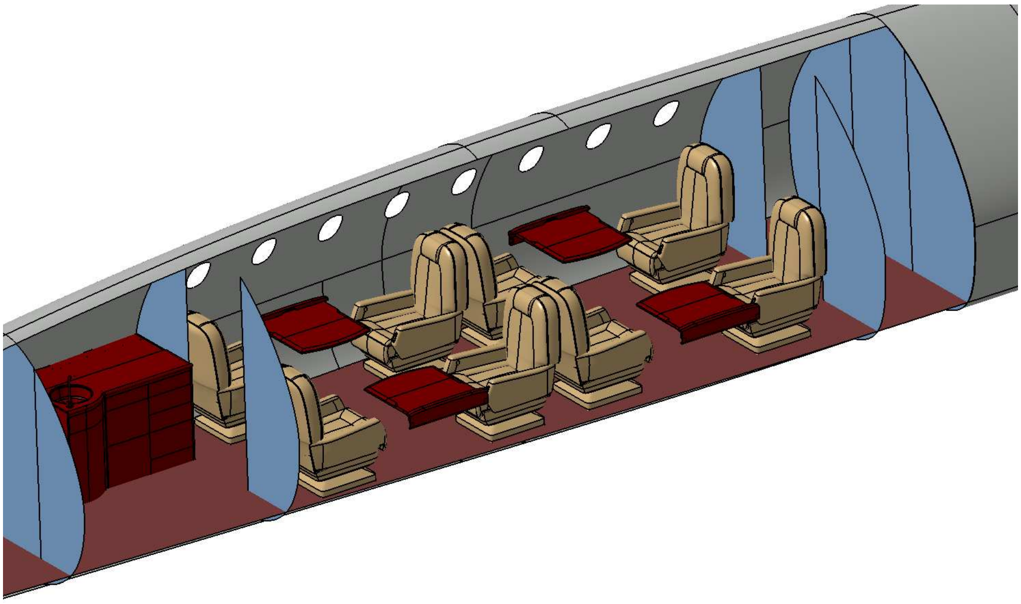


Figure 72 - Low noise configuration cabin layout

5.6.3.3.1.2 Main characteristics

The main characteristics of the low noise configuration are shown in Table 1.

Configuration	Low noise configuration
Geometry	
Length (m)	**36.8 m**
Maximum diameter (m)	**2.3 m**
Wing area (m2)	**150.0 m²**
Wing span (m)	**18.5 m**
Relatives thicknesses	**3 %/ 2.5% / 2%**
Outer Wing sweep angles at leading edge (deg)	**72.5 deg / 52 deg**
Dihedral angles (deg)	**0 deg**
Engine	
Number of engines	**3**
Type of engine	**CVC**
Total max net take-off thrust (daN)	**22000 daN**
Jet velocity at take-off (m/s)	**350 m/s**
Weights	
EW (kg)	**23100 kg**
Fuel weight (kg)	**26900 kg**
Payload weight (kg)	**726 kg**
MRW (kg)	**51200 kg**
MTOW (kg)	**51100 kg**
Fuel/MTOW	**53%**
Performances	
Cruise Mach number	**1.6**
Range (nm)	**4000 nm**
Initial cruise altitude (m)	**14340 m**
Mean cruise SFC (kg/daN/hr)	**1.00 kg/daN/hr**
Mean cruise L/D	**7.00**
BFL (m)	**1910 m**
Approach speed at nominal LW (kts)	**125.0 kts**
Dry runway length at nominal LW (kts)	**1700 m**
Environmental impact	
Community noise	**Stage IV - 10 EPNdB**
Emission impact / flight (10e-6 mK)	**14.49 (10e-6 mK)**
Mean cruise sonic boom overpressure (Pa)	**45 Pa**
Mean cruise sonic boom (dBa)	**86 dBA**

Table 1 - Low noise configuration characteristics

5.6.3.3.2 Long range configuration

5.6.3.3.2.1 Overview

The long range configuration is based on the following design drivers:

- Laminar wing and V tail
- 2 high by-pass ratio CVC engines : the 2 engines are located above the rear part of the fuselage
- The undercarriage is a retractable tricycle type landing gear. The main landing gears is mounted on the wing structure, and the wheels retract in the fuselage between the fuselage fuel tanks
- A V tail configuration provides yaw and longitudinal control

Figure 73 illustrates the external shapes of the long range configuration:

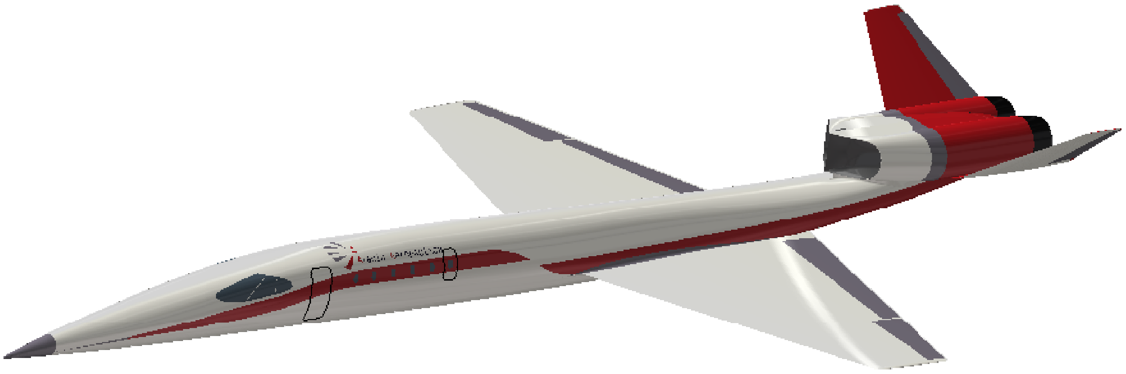


Figure 73 - External shapes of the long range configuration

The internal layout of the fuselage allows accommodating the following areas:

- A pressurized area, which will include the flight compartment, the passenger compartment, the galley, the lavatory and cargo compartment.
- The forward fuselage shape are based on the supersonic area rule to minimize drag, there are no constraint concerning the direct pilot visibility. The end of the fuselage shape is driven by the ground clearance during the landing and the take off phases. Its length is function of the fuel needed to perform the required mission profile.

- An un-pressurized area which will contain the nose landing gear, the fuselage aft of the rear pressure bulkhead which shall allocate the fuselage fuel tanks and main landing gear bay, support the tail and engines structure and provide a mounting for the ECS system, equipment bay and APU.

The overall layout of the long range configuration is illustrated on Figure 74.

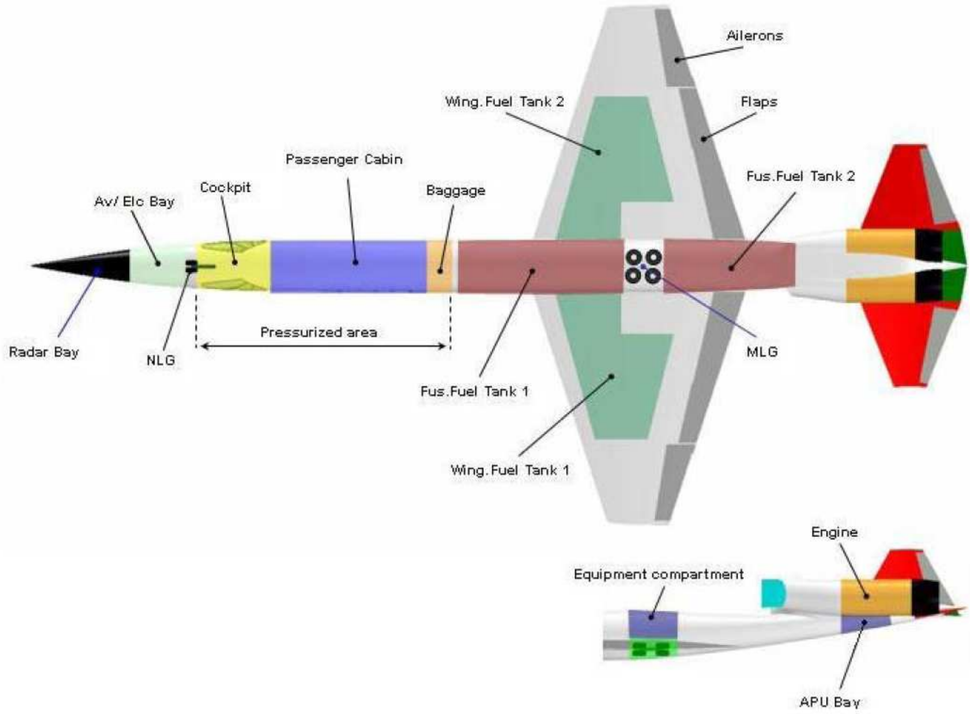


Figure 74 – Internal layout of the long range configuration

5.6.3.3.2.2 Main characteristics

The main characteristics of the long range configuration are shown in Table 2.

Configuration	Long range configuration
Geometry	
Length (m)	**41.6 m**
Maximum diameter (m)	**2.4 m**
Wing area (m2)	**146.4 m²**
Wing span (m)	**24.0 m**
Relatives thicknesses	**3% / 2%**
Outer Wing sweep angles at leading edge (deg)	**18 deg**
Dihedral angles (deg)	**1.5 deg**
Engine	
Number of engines	**2**
Type of engine	**CVC**
Total max net take-off thrust (daN)	**31350 daN**
Jet velocity at take-off (m/s)	**350 m/s**
Weights	
EW (kg)	**27100 kg**
Fuel weight (kg)	**32300 kg**
Payload weight (kg)	**726 kg**
MRW (kg)	**60600 kg**
MTOW (kg)	**60500 kg**
Fuel/MTOW	**53%**
Performances	
Cruise Mach number	**1.6**
Range (nm)	**5000 nm**
Initial cruise altitude (m)	**15240 m**
Mean cruise SFC (kg/daN/hr)	**0.97 kg/daN/hr**
Mean cruise L/D	**7.45**
BFL (m)	**1865 m**
Approach speed at nominal LW (kts)	**125.0 kts**
Dry runway length at nominal LW (kts)	**1680 m**
Environmental impact	
Community noise	**Stage III - 5 EPNdB**
Emission impact / flight (10e-6 mK)	**25.60 (10e-6 mK)**
Mean cruise sonic boom overpressure (Pa)	**75 Pa**
Mean cruise sonic boom (dBa)	**85 dBA**

Table 2 - Long range configuration characteristics

5.6.3.3.3 Variable geometry configuration

5.6.3.3.3.1 Overview

The variable geometry configuration is based on the following design drivers:

- A variable geometry wing. The wing has 2 positions: a subsonic position both for transonic flight and takeoff/landing, and a supersonic position optimized for the M1.6 design cruise speed
- 3 high by-pass ratio conventional engines :
  - 2 engines are located in the wing roots, structurally supported from the fuselage.
  - 1 engine is mounted semi submerged in the rear of the fuselage
- The undercarriage is a conventional twin wheel main landing gear, with trailing link suspension. The nose landing gear is conventional, and will retract forward into the nosewheel bay
- A vertical stabilizer mounted to the aft of the rear nacelle
- A tailplane sized for neutral static stability with the wings swept forward at subsonic speeds in the clean condition

Figure 75 illustrates the external shapes of the variable geometry configuration:

Figure 75 - External shapes of the variable geometry configuration

5.6.3.3.3.2 Main characteristics

The main characteristics of the variable geometry configuration are shown in Table 3.

Configuration	Variable geometry configuration
Geometry	
Length (m)	**40.8 m**
Maximum diameter (m)	**2.2 m**
Wing area (m2)	**75.0 m²**
Wing span (m)	**15.4m / 20.6m**
Relatives thicknesses	**4.5% (swept aft)**
Outer Wing sweep angles at leading edge (deg)	**60 deg / 35 deg**
Dihedral angles (deg)	**0 deg**
Engine	
Number of engines	**3**
Type of engine	**Conventional**
Total max net take-off thrust (daN)	**14310 daN**
Jet velocity at take-off (m/s)	**350 m/s**
Weights	
EW (kg)	**20700 kg**
Fuel weight (kg)	**20700 kg**
Payload weight (kg)	**726 kg**
MRW (kg)	**42600 kg**
MTOW (kg)	**42500 kg**
Fuel/MTOW	**49%**
Performances	
Cruise Mach number	**1.6**
Range (nm)	**4000 nm**
Initial cruise altitude (m)	**13100 m**
Mean cruise SFC (kg/daN/hr)	**0.98 kg/daN/hr**
Mean cruise L/D	**7.80**
BFL (m)	**1940 m**
Approach speed at nominal LW (kts)	**129 kts**
Dry runway length at nominal LW (kts)	**1390 m**
Environmental impact	
Community noise	**Stage IV - 15 EPNdB**
Emission impact / flight (10e-6 mK)	**10.00 (10e-6 mK)**
Mean cruise sonic boom overpressure (Pa)	**N/A**
Mean cruise sonic boom (dBa)	**N/A**

Table 3 - Variable geometry configuration characteristics

- Sonic boom impact assessment not available

5.6.3.3.4 Low boom configuration

5.6.3.3.4.1 Overview

The low boom configuration is based on the following design drivers:

- Low aspect ratio wing with trapezoid inner wing and swept outer wing
- 2 CVC engines located above the rear part of the fuselage
- The undercarriage is a retractable tricycle type landing gear. The main landing gear is mounted on the fuselage structure, and the wheels retract ahead looking forward and are arranged in the fuselage well
- A horizontal all-moving stabilizer located on the engine bay in the aircraft tail part

Figure 76 illustrates the external shapes of the low sonic boom configuration:

Figure 76 – External shapes of the low sonic boom configuration

The internal layout of the fuselage allows accommodating the following areas :

- Radar equipment bay
- Forward cargo compartment
- Avionics bay
- Nose wheel bay
- Pressurized compartment with crew and passenger cabins
- Equipment compartment
- Fuel tanks
- Main landing gear well
- APU compartment.

The overall layout of the low sonic boom configuration is illustrated on Figure 77.

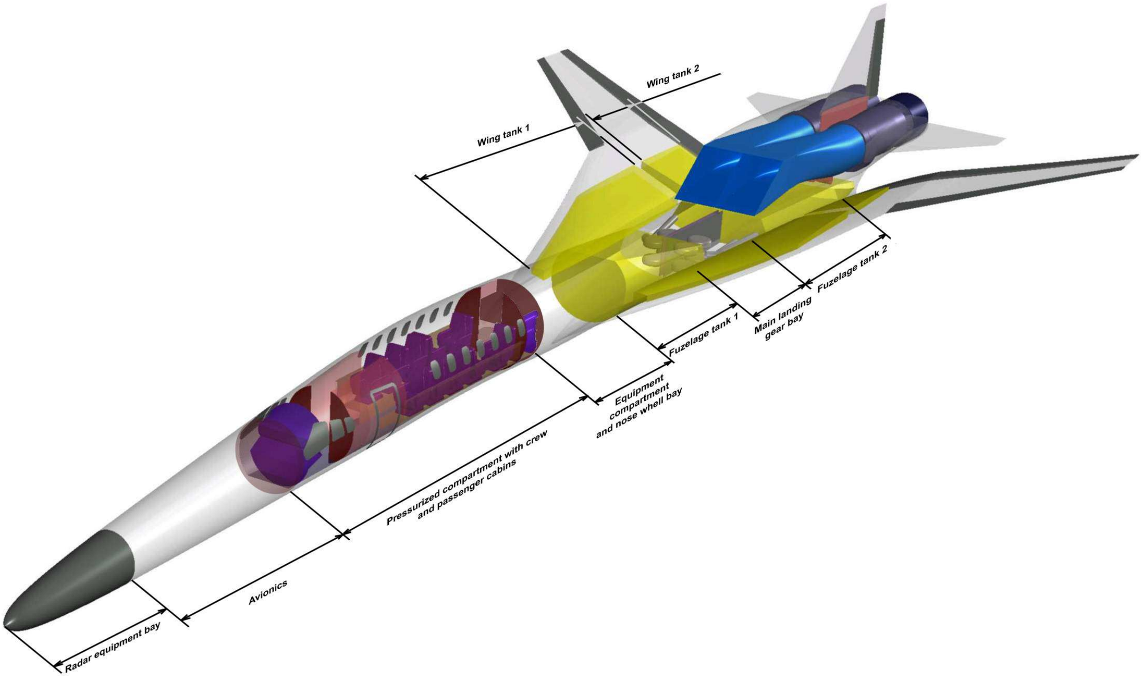


Figure 77 - Internal layout of the low sonic boom configuration

5.6.3.3.4.2 Main characteristics

The main characteristics of the low sonic boom configuration are shown in Table 4.

Configuration	Low boom configuration
Geometry	
Length (m)	**40.9 m**
Maximum diameter (m)	**2.2 m**
Wing area (m2)	**139.0 m²**
Wing span (m)	**19.1 m**
Relatives thicknesses	**2.7% / 2.5% / 2%**
Outer Wing sweep angles at leading edge (deg)	**79 deg / 72.5 deg / 46 deg**
Dihedral angles (deg)	**18 / 0**
Engine	
Number of engines	
Type of engine	**CVC**
Total max net take-off thrust (daN)	**29260 daN**
Jet velocity at take-off (m/s)	**400 m/s**
Weights	
EW (kg)	**25100 kg**
Fuel weight (kg)	**27300 kg**
Payload weight (kg)	**726 kg**
MRW (kg)	**53600 kg**
MTOW (kg)	**53300 kg**
Fuel/MTOW	**51%**
Performances	
Cruise Mach number	**1.8**
Range (nm)	**4000 nm**
Initial cruise altitude (m)	**15750 m**
Mean cruise SFC (kg/daN/hr)	**1.09 kg/daN/hr**
Mean cruise L/D	**7.74**
BFL (m)	**1980 m**
Approach speed at nominal LW (kts)	**138 kts**
Dry runway length at nominal LW (kts)	**1675 m**
Environmental impact	
Community noise	**Stage IV - 2.5 EPNdB**
Emission impact / flight (10e-6 mK)	**14.20 (10e-6 mK)**
Sonic boom overpressure (initial shock) (Pa)	**20 Pa**
Mean cruise sonic boom (dBa)	**68.5 dBA**

Table 4 - Low sonic boom configuration characteristics

5.6.3.3.5 High subsonic configuration

5.6.3.3.5.1 Overview

The high subsonic configuration is based on the same configuration than the low noise configuration:

- Delta wing and canards
- 3 high by-pass ratio conventional engines :
    - 1 engine is buried in the rear fuselage
    - 2 engines are mounted in lateral nacelles located under the wings
- The main landing gears are attached on the wing structure, between the two lateral nacelles and the wheels retract in the fuselage.
- A vertical fin is attached on the rear fuselage, above the buried engine

Figure 78 illustrates the external shapes of the high subsonic configuration:

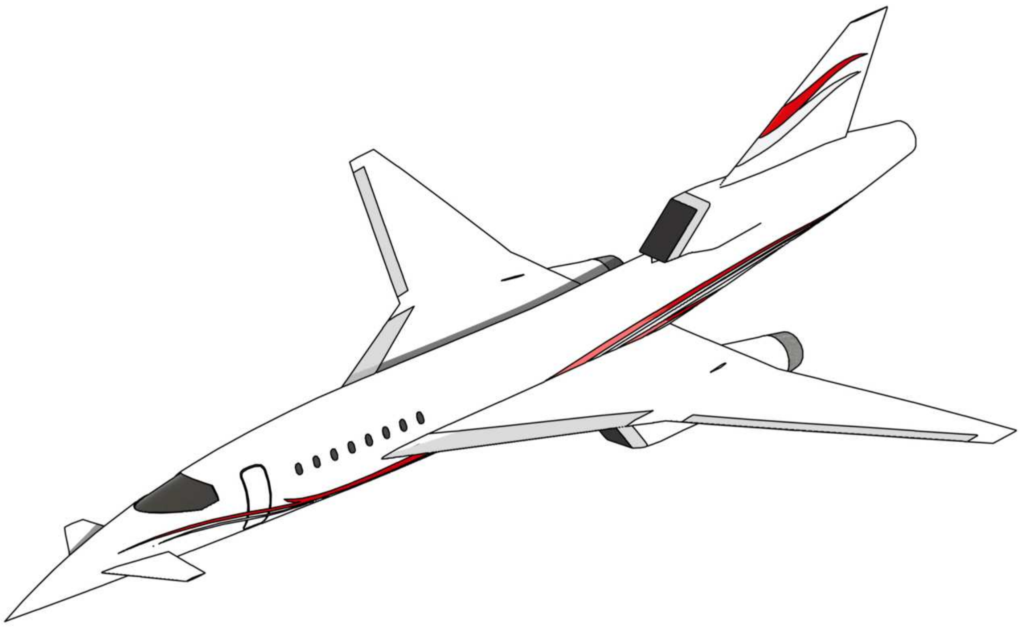


Figure 78 - External shapes of the high subsonic configuration

The internal layout of the fuselage allows accommodating the following areas :

- A nose section with the radome, that includes radar equipments
- A front fuselage non-pressurized area accommodating the avionics bay and the canard hinges.
- A pressurized area, which includes the cockpit, the forward galley, the passenger compartment, the lavatory and the baggage compartment. The passenger cabin is

soundproofed and insulated, and measures 7.70m (including lavatories). Access to the baggage compartment is available from inside or outside the aircraft.

- The auxiliary landing gear bay that is located in front of the cockpit
- A Non pressurized equipment bay
- A forward fuselage fuel tank
- The main landing gear bay, positioned by center of gravity management constraints
- A rear fuselage fuel tank
- The aft non-pressurized section including the equipment bay, the air duct and the APU
- The fuselage buried engine bay

The overall layout of the high subsonic configuration is illustrated on Figure 79.

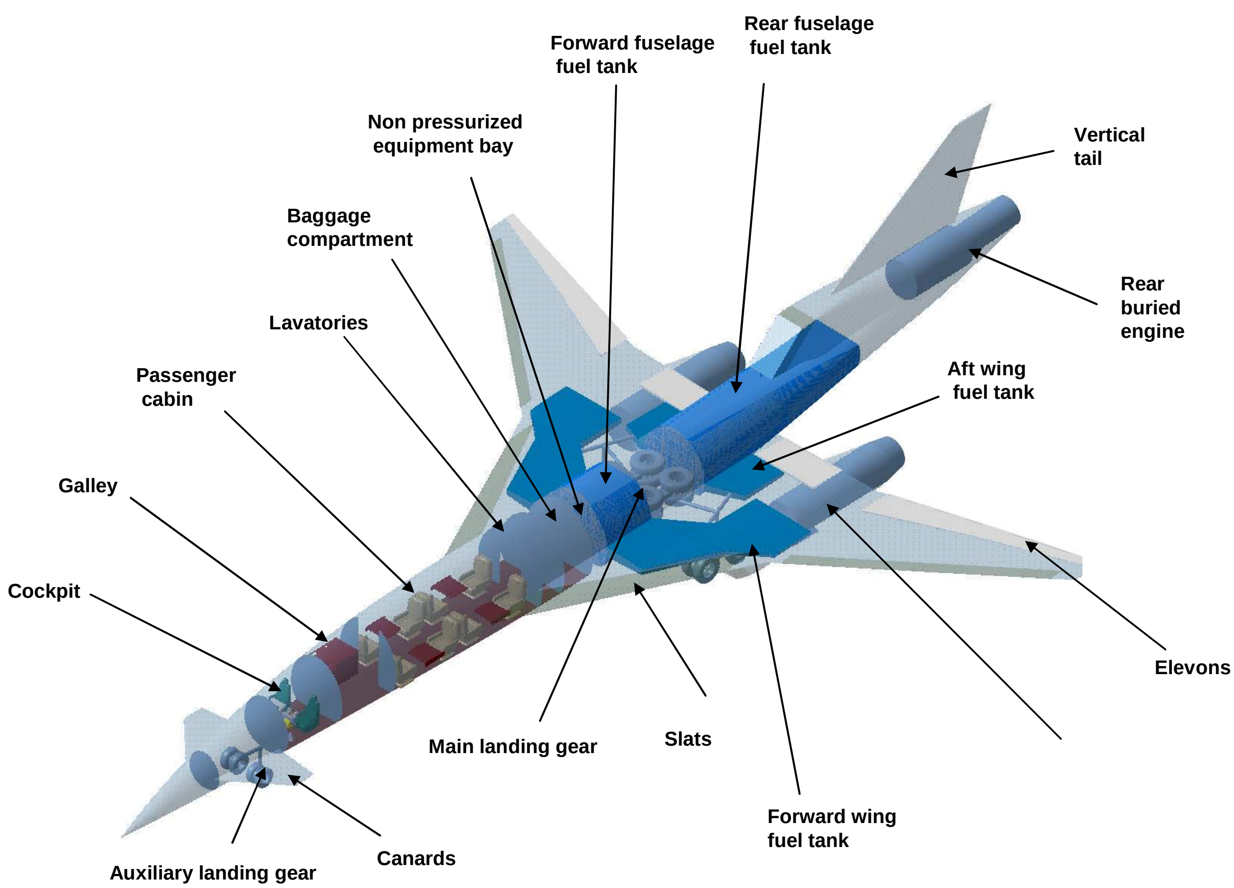


Figure 79 - Internal layout of the high subsonic configuration

The internal layout of the cabin is illustrated on Figure 80.

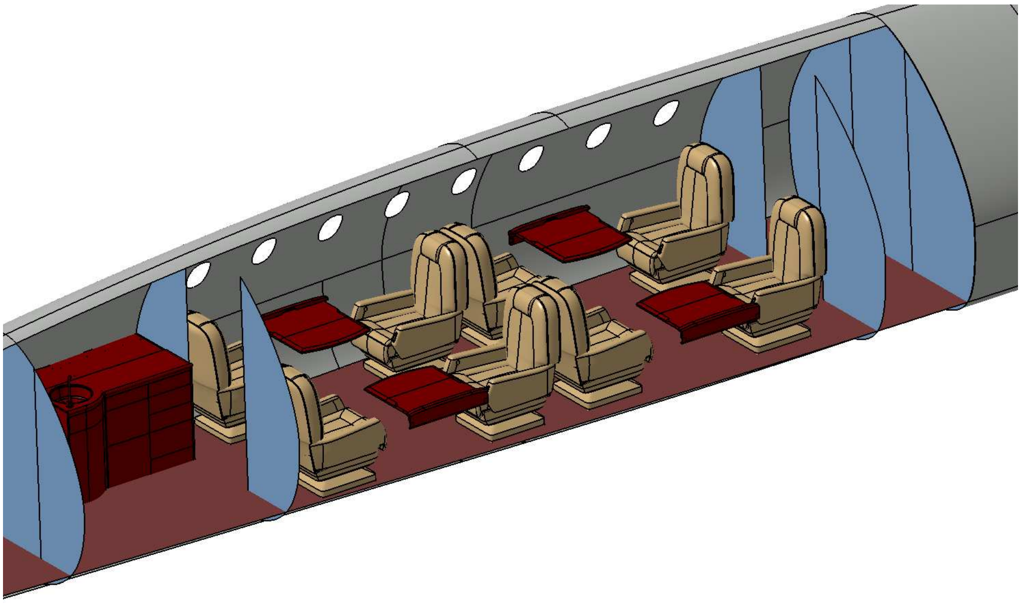


Figure 80 – High subsonic configuration cabin layout

5.6.3.3.5.2 Main characteristics

The main characteristics of the high subsonic configuration are shown in Table 5.

Configuration	High subsonic configuration (DA)
Geometry	
Length (m)	**31.6 m**
Maximum diameter (m)	**2.3 m**
Wing area (m2)	**95.0 m²**
Wing span (m)	**19.9 m**
Relatives thicknesses	**4% / 3% / 3%**
Outer Wing sweep angles at leading edge (deg)	**65 deg / 40 deg**
Dihedral angles (deg)	**0**
Engine	
Number of engines	**3**
Type of engine	**Conventional**
Total max net take-off thrust (daN)	**17660 daN**
Jet velocity at take-off (m/s)	**350 m/s**
Weights	
EW (kg)	**18600 kg**
Fuel weight (kg)	**14050 kg**
Payload weight (kg)	**726 kg**
MRW (kg)	**33850 kg**
MTOW (kg)	**33750 kg**
Fuel/MTOW	**42%**
Performances	
Cruise Mach number	**0.95**
Range (nm)	**4000 nm**
Initial cruise altitude (m)	**12500 m**
Mean cruise SFC (kg/daN/hr)	**0.80 kg/daN/hr**
Mean cruise L/D	**13.00**
BFL (m)	**1600 m**
Approach speed at nominal LW (kts)	**121.0 kts**
Dry runway length at nominal LW (kts)	**1550 m**
Environmental impact	
Community noise	**Stage IV - 10 EPNdB**
Emission impact / flight (10e-6 mK)	**5.12 (10e-6 mK)**
Mean cruise sonic boom overpressure (Pa)	**N/A**
Mean cruise sonic boom (dBa)	**N/A**

Table 5 - high subsonic configuration (DA) characteristics

5.6.3.3.6 Low supersonic configuration

5.6.3.3.6.1 Overview

The low supersonic configuration is based on the following design drivers:

- A swept back wing with fixed geometry
- 3 high by-pass ratio conventional engines :
  - o 2 engines are located in the wing roots, structurally supported from the fuselage.
  - o 1 engine is mounted semi submerged in the rear of the fuselage.
- The undercarriage is a conventional twin wheel main landing gear, with trailing link suspension. The nose landing gear is conventional, and will retract forward into the nosewheel bay.
- A vertical stabilizer mounted to the aft of the rear nacelle
- A tailplane sized for neutral static stability at subsonic speeds in the clean configuration

Figure 81 illustrates the external shapes of the low supersonic configuration:

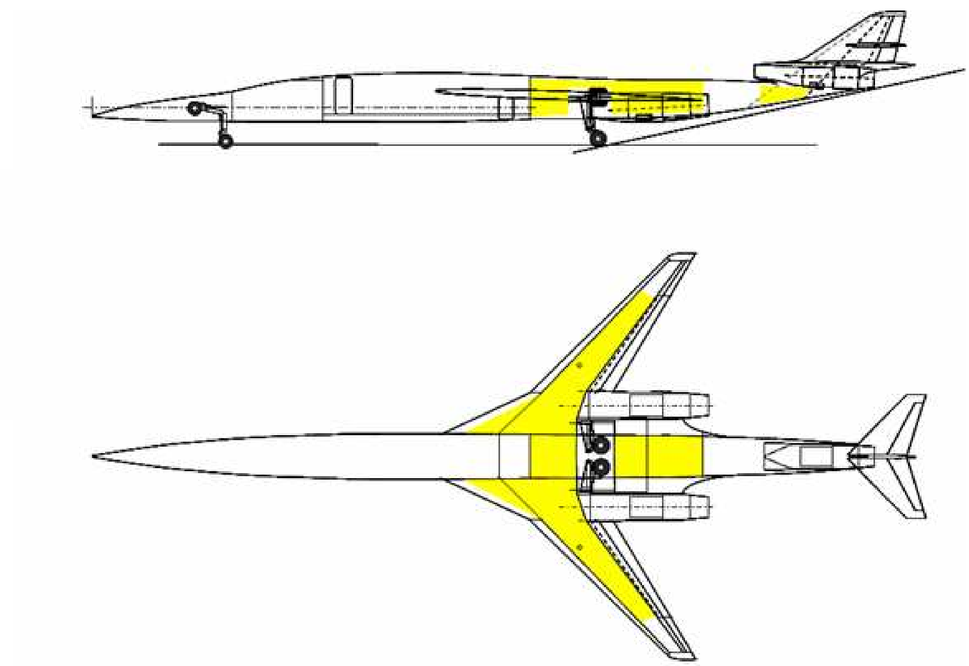


Figure 81 - External shapes of the low supersonic configuration

5.6.3.3.6.2 Main characteristics

The main characteristics of the low supersonic configuration are shown in Table 6.

Configuration	Low supersonic configuration (ADSE)
Geometry	
Length (m)	**38.4 m**
Maximum diameter (m)	**2.25 m**
Wing area (m2)	**70.0 m²**
Wing span (m)	**18.7 m**
Relatives thicknesses	**4.5%**
Outer Wing sweep angles at leading edge (deg)	**65 deg / 45 deg**
Dihedral angles (deg)	**0**
Engine	
Number of engines	**3**
Type of engine	**Conventional**
Total max net take-off thrust (daN)	**12900 daN**
Jet velocity at take-off (m/s)	**350 m/s**
Weights	
EW (kg)	**18700 kg**
Fuel weight (kg)	**17200 kg**
Payload weight (kg)	**726 kg**
MRW (kg)	**37100 kg**
MTOW (kg)	**37000 kg**
Fuel/MTOW	**46%**
Performances	
Cruise Mach number	**1.2**
Range (nm)	**4000 nm**
Initial cruise altitude (m)	**13700 m**
Mean cruise SFC (kg/daN/hr)	**0.86 kg/daN/hr**
Mean cruise L/D	**9.90**
BFL (m)	**1890 m**
Approach speed at nominal LW (kts)	**130.0 kts**
Dry runway length at nominal LW (kts)	**1390 m**
Environmental impact	
Community noise	**Stage IV - 13 EPNdB**
Emission impact / flight (10e-6 mK)	**7.00 (10e-6 mK)**
Mean cruise sonic boom overpressure (Pa)	**N/A**
Mean cruise sonic boom (dBa)	**N/A**

Table 6 - Low supersonic configuration (ADSE) characteristics

5.6.4 Trade-off activities

5.6.4.1 Introduction

Figure 82 reminds the general objectives of the HISAC project.

The first objective is identifying the correlations between the different requirements, either dealing with customer satisfaction (range, time to destination, comfort, cost), or with environmental acceptability of the S4TA (community noise, sonic boom, emissions with impact on public health or climate change).

The second one is to provide data supporting the establishment of standards for environmental acceptability. These data are the exchange rates between the requirements and the achievable levels with usable technologies.

The third one is improving some key technologies beyond the current state of the art, in order to relax the conflicts between the different requirements.

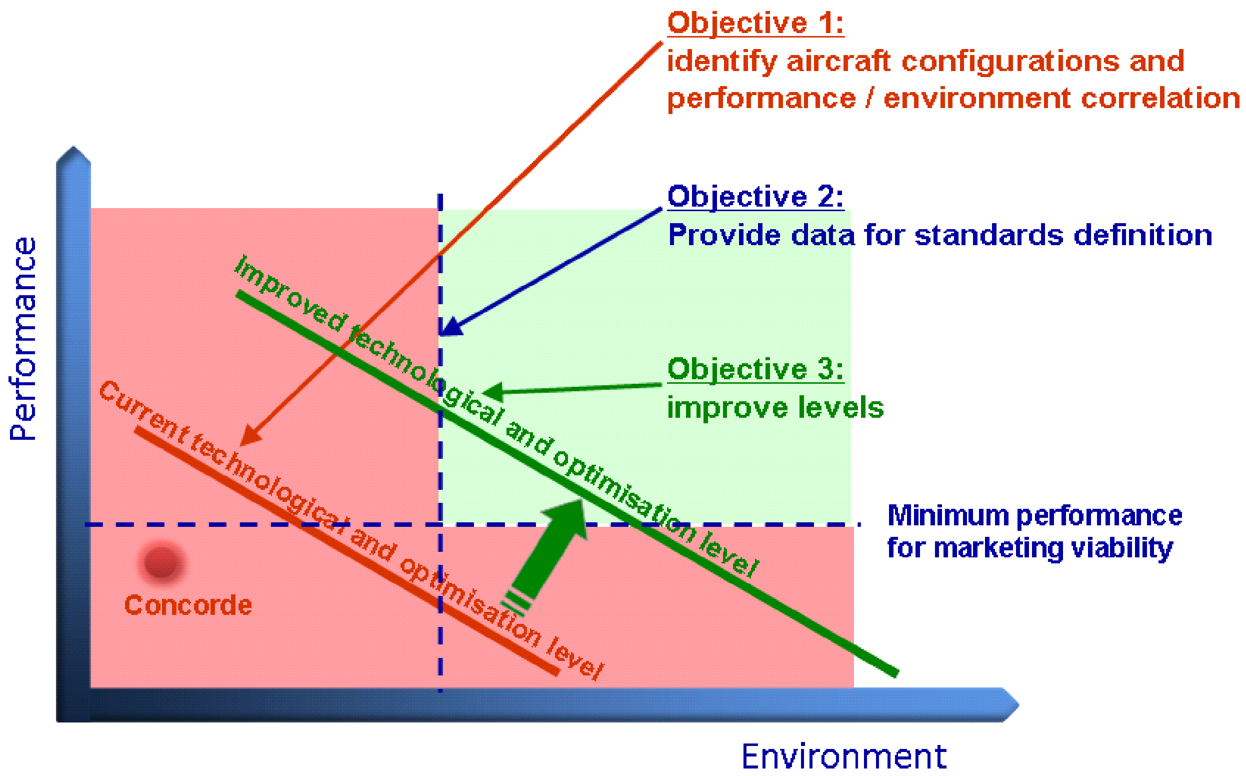


Figure 82 - HISAC general objectives

The trade-off activities performed in WP5 answered these objectives by addressing the following aspects:

- Trade-off on a given aircraft configuration : impact of flight parameters on aircraft mission performance and environmental impact :
    - o Cruise Mach number
    - o Initial cruise altitude

- Throttle ratio during take-off
- Climbing cruise

- Trade-off on performance and environmental specifications :
  - BFL
  - Range
  - Cruise Mach number
  - Sonic boom
  - Cruise emission
  - Community noise
- Assessment of the impact of architecture and technology integration :
  - engine architecture: impact of engine architecture (conventional, CVC or mixer-ejector)
  - Engine integration technologies
  - Wing planform
  - Throttle management and BPR
  - Number of engines
  - Fuselage length
  - PAX density
  - Aerodynamic improvement
  - Forced laminarity
  - Sonic boom reduction devices
- Assessment of uncertainties and robust design

5.6.4.2 Results

Detailed results of the different trade-off analyses will not be provided in this document.

However the following table (Figure 83) provides an overview of the impact at the aircraft level in terms of MTOW, sonic boom levels, cruise emissions (impact on temperature change), and noise levels for three main characteristics (low boom, low noise and long range. These figures are compared to a "conventional" supersonic S4TA, with no specific low boom features, compatible with Chapter 4, with a range of 4000nm.

	Low boom	Low noise	Long range
MTOW	+12%	+10%	+19%
Sonic boom	- X dBA	~ +2dBA	~ +4dBA
Emissions	+16%	+16%	+50%
Noise	-	-10 EPNdB	-

Figure 83 - Synthesis of specification costs

The main conclusion regarding S4TA trade-offs are summarized on Figure 84. This figure illustrates the main trade-offs between overland (optimized for low sonic boom) and overwater concepts in one hand, and low noise and non low noise configurations in the other hand. It also highlight the fact the cumulating stringent environmental specifications for a given configuration may drive the MTOW to values not compatible with what is expected for such a configuration (commercially speaking), and as a result, environmental impact (fuel consumption) and eventually prices (acquisition and operating costs).

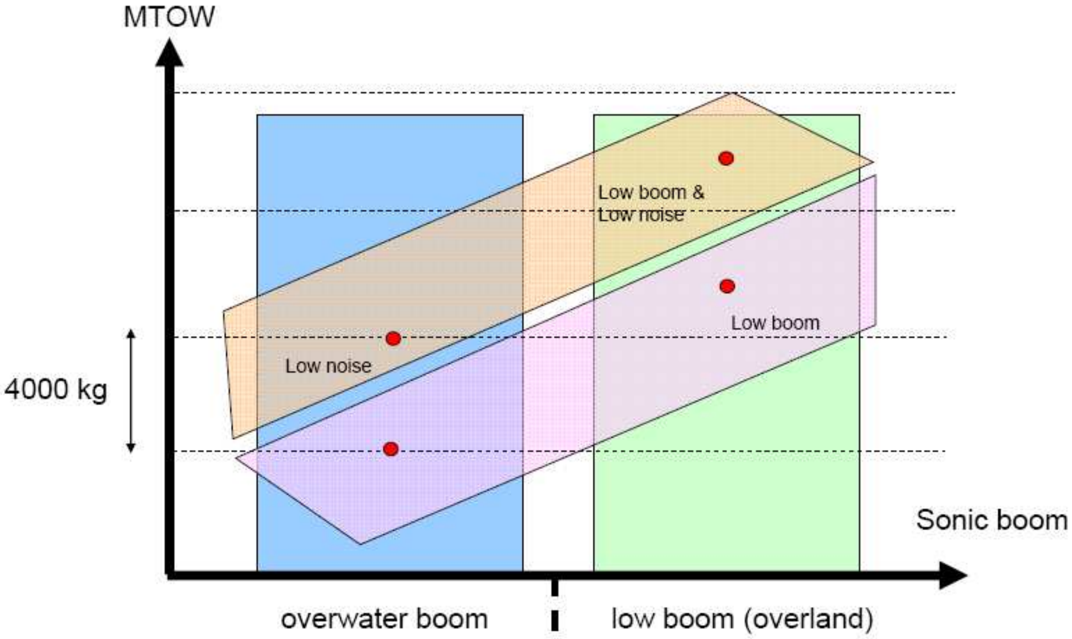


Figure 84 - S4TA main trade-offs between overwater and overland concepts.

5.6.5 Synthesis task (WP5.4.1 and WP5.4.2)

Based on all information provided by WP1, WP2, WP3A & WP3B, WP4 and WP5, WP5 with the help of WP6, built an overall synthesis of the project. The main objectives of this task were the following :

- Build an overall synthesis of the HISAC program activities, including design, trade-offs and risk assessment
- Define the progress beyond state of the art
- Highlight the benefits of technological achievement and integration solutions in terms of environmental impact
- Propose orientations or viable solutions for an environmentally viable S4TA
- Outline recommendations in terms of technology roadmap and risk mitigation demonstrator path
- Conclude on S4TA technical feasibility

For example of the work performed, an overview of the technological roadmap is given hereafter:

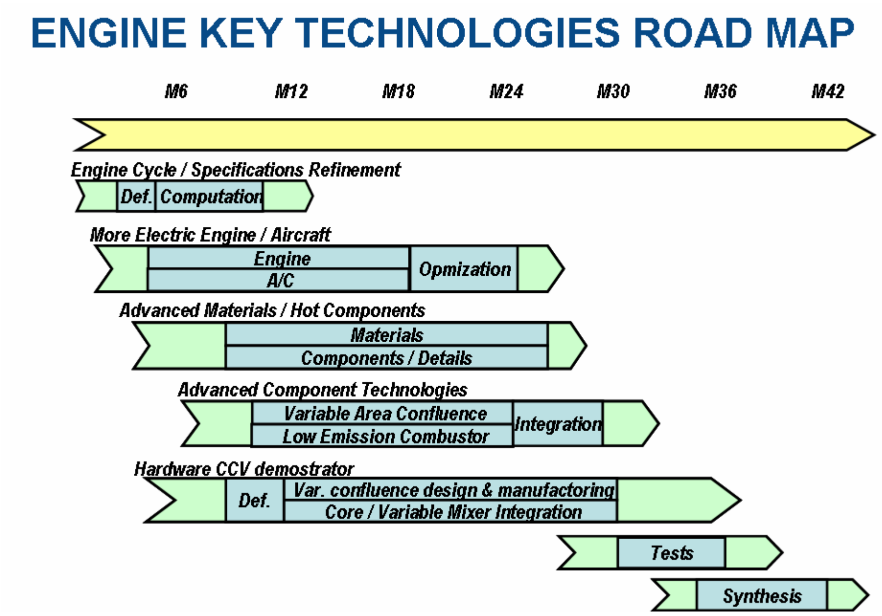


Figure 85 - Engine key technologies road map

AIRCRAFT KEY TECHNOS ROADMAP

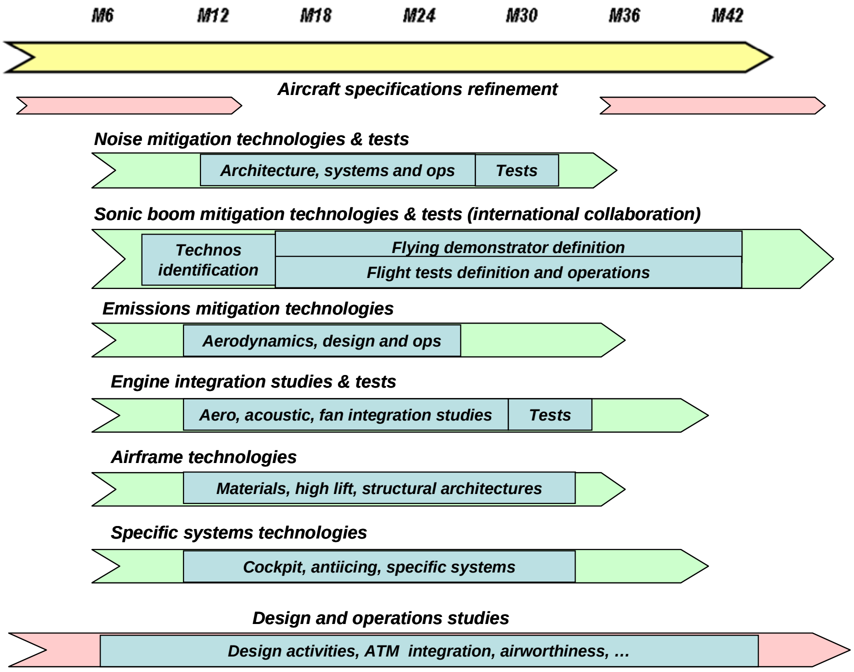


Figure 86 - Aircraft key technologies road map

6. CONSORTIUM MANAGEMENT

The general management of the project is ensured by Dassault Aviation (Co-ordinator - WP3B & WP5 Leader - Team A Manager) assisted by DLR (WP1 Leader), NLR (WP2 Leader), SNECMA (WP3A Leader), Alenia (WP4 Leader, Team B Manager) and SCA (Team C Manager).

6.1 Public dissemination

HISAC Public web site: www.hisacproject.com

The full list of dissemination activities is in the deliverable D6.23 "Final plan for using and disseminating the knowledge".

You will find hereafter the list of Conferences and Publications performed during HISAC project and planned in 2010.

Date	Author	Entity	Framework	Title
20101101	*A Kharitonov*	*ITAM*	*Conference ICMAR2010*	*Aerodynamic design and experimental modelling of an innovative 3D supersonic inlet*
20100919	*E, Jesse*	*ADSE*	*Conference ICAS2010*	*Design Study of a Mach 1.6 Supersonic Business Jet with Variable Sweep Wing*
20100725	*T, Berens*	*EADS-M*	*Conference AIAA*	*Aerodynamic Propulsion Integration for Supersonic Business Jets*
20100601	*V. Grewe & some partners*	*DLR*	*The Aeronautical Journal*	*Climate functions for the use in multi-disciplinary optimization in the pre-design of supersonic business jet*
20100601	*V. Grewe & some partners*	*DLR*	*The Aeronautical Journal*	*Estimates of the Climate Impact of Future Small-Scale - Supersonic Transport Aircraft - Results from the HISAC EU-Project*
20100201	*F, Coulouvrat & al*	*CNRS*	*8th Meeting of the CAEP, ICAO, Montréal (Canada)*	*Status of sonic boom knowledge December, 2009*
20090930	T. Berens	EADS M	AIAA 2009 Year Review	HISAC - High Speed Aircraft SSBJ
20090622	V. Grewe & some partners	DLR	TAC conference on Transport, Atmosphere, and Climate,	Supersonic business jets – Is the impact upon the atmosphere acceptable? - Results from the HISAC project
20090618	Ph De Saint Martin & some partners & other speakers	DA, ALA, CIAM, EADS, ARA, CNRS, SCA, DLR, RR, TsAGI, EEC, EPFL, NLR, EC	3AF Conference	
20090513	Ph De Saint Martin	DASSAULT	KATnetII	Hisac general presentation
20090512	J.V. Krier, T.Sucipto, J.P. Archambaud, J.P. Godard, R.Donelli, D.Arnal	IBK ONERA CIRA	KATnetII	Passive and Active Device for Laminar Flow Control of Swept Wing
20090512	P. Wong	ARA	KATnetII	Laminar Flow control and Drag reduction for Supersonic Aircraft Configurations
20090511	F. Coulouvrat	CNRS	AIAA Aeroacoustics Conference	The Challenges of Defining an Acceptable Sonic Boom Overland
20090505	G. Carrier; R. Grenon; M.-C. Le Pape; I. Salah El Din	ONERA	Canadian Aeronautics and Space Institue AERO'09	Sonic boom prediction methodology in use at ONERA and its application to sensitivity analysis of a SuperSonic Business Jet configuration
20090423	Ph De Saint Martin	DASSAULT	OACI Supersonic Task Group	Preliminary conclusions of European Hisac Project
20080331	Ulf Tengzelius	FOI	Annual report	
20090823	P. Malbequi; L. Bourrat	ONERA	Inter-Noise 2009	Numerical optimisation of liners for the aero-engine intake of a supersonic aircraft
20090213	F. Alauzet; A. Loseille	INRIA	Research Report	High Order Sonic Boom Modeling by Adaptive Methods
20081114	Ph De Saint Martin & some partners	Dassault; Alenia; CIAM; EADS; ARA; Numeca; Inasco; ONERA; CNRS	Ville Européenne des Sciences European City of Science	Towards a small civil supersonic european aircraft environmentally friendly ?
20080914	A. Mirzoyan	CIAM	26th ICAS	Studies on MDO of Engine Design Parameters with Mission, Noise and Emission criteria at SSBJ Engine Conceptual Design
20080914	B. Stoufflet; Ph. De Saint Martin	Dassault	26th ICAS	Design of a small supersonic transport aircraft with high environmental constraints
20080911	G. Carrier	ONERA	Internal & external communication	CFD Hisac illustration
20080910	Y. Deremaux; N. Pietremont; J. Négrier; E. Herbin; M. Ravachol	Dassault	12th AIAA / ISSMO 2008 Multidisciplinary Analysis and Optimization Conference	Environmental MDO and Uncertainty Hybrid Approach Applied to a Supersonic Business Jet
20080818	S. Vigneron; Z. Johan; A. Bugeau; M. Stojanovski; A. Merlet	Dassault	26th AIAA Applied Aerodynamics Conference Applied CFD and Experimental Validation Session	Numerical Aerodynamic Assessment and Experimental Validation of Innovative Supersonic Business Jet Concepts
20080630	A. Bugeau; Z..Johan; A.Merlet; M.Stojanowski; S. Vigneron; M. Mallet; G. Rogé	Dassault	ECCOMAS 2008 5th. European Congress on Computational Methodsin Applied Sciences and Engineering	Aerodynamic design of innovative business jet
20080630	F. Alauzet; A. Dervieux; A. Loseille; Y. Mesri	INRIA	ECCOMAS 2008 5th. European Congress on Computational Methodsin Applied Sciences and Engineering	Sonic boom modeling: numerical methods (and optimization)
20080401	J.L. Hantrais-Gervois	ONERA	Presentation of Applied Aerodynamics Department	Optimisation d'une installation motrice par technique Chimère
20080401	J. Mueller	RUAG	RUAG Annual Report	RUAG Aerospace 2007 Annual report
20080313	Ph De Saint Martin.	Dassault	OACI WG	Environmental Trade-Offs for a SuperSonic Small Size Transport Aircraft
20080305	S. Vigneron & Ph. De Saint Martin	Dassault	News Page	Add : High-speed wind tunnel test campaign at TsAGI T-128 transonic wind tunnel
20080205	D. F. Vos	NLR	Publication to inform the Dutch government about the EU-projects NLR is involved in.	Illustration from "HISAC Executive public summary of the aircraft shape design detailed definitions"
20080201	A. Dervieux; F. Alauzet; A. Loseille; S. Borel-Sandou; Y. Mesri; G. Rogé; Q. Dinh; L. Daumas	INRIA Dassault	European Journal of Computational Mechanics.	Multi-model design strategies applied to sonic boom reduction
20080131	Ph De Saint Martin.	Dassault	Documentary	Future of Aviation : Civil Supersonic Projects
20080128	Y. Deremaux	Dassault	KATnet II Workshop Multidisciplinary Design & Configuration Optimization Workshop	HISAC : Project Perspectives
20080108	A. Bugeau & Ph. De Saint Martin	Dassault	HISAC Public Site / News Page	Add : Low -speed wind tunnel test campaign at RUAG Aerospace
20080108	M. Aschwanden	RUAG	Aerodynamics Center Prospectus	HISAC CFD illustration from CFS for RUAG Aerospace Aerodynamics Center Profile leaflet
20080101	Y. Robins	Dassault	CD & Dassault web site New Year Greetings	CFD HISAC animation
20071126	Eliasson	FOI	7th ACFD	Aerodynamic shape optimization
20071119	S. Vigneron	Dassault	WEHSFF 2007	Innovative Supersonic Design within the European Project HISAC
20071119	L. Temmerman	Numeca	NUMECA Worldwide user Meeting	HISAC project
20071031	S. Vigneron	Dassault	HISAC Public Site / News Page	High-speed wind tunnel test campaign at ONERA-S2
20071018	J. Bonnet; N. Heron ; F Coulouvrat	Dassault - CNRS	WG1 OACI	HISAC mid-term sonic boom issues
20071015	B. Gustafsson	Volvo Aero	Flygteknik 2007	Mixer/ejector nozzle - HISAC
20071009	T. Berens	EADS M	EUROAVIA Workshop	Aerodynamic Propulsion Integration for SSBJs HISAC – A European „Integrated Project" of the 6th Framework Programme
20070926	C. Czinczenheim	Dassault	HISAC Public Site / Forum & Conferences Page	MAJ Page
20070911	S. Crippa; A. Rizzi	KTH	CEAS 2007	Reynolds number effects on blunt leading edge delta wings
20070911	F. Coulouvrat	CNRS	CEAS 2007	The Challenges of an « Acceptable » Sonic Boom
20070911	M.Mallet & al.	Dassault	CEAS 2007	Special Technology Session on "Technologies for High-speed Transport"
20070902	N. Heron; F. Dagrau; G. Rogé; Z. Johan; F. Coulouvrat	Dassault CNI	19th ICA International Conference on Acoustics	HISAC midterm Overview of sonic boom issues
20070902	F. Dagrau; N. Heron; G. Rogé; Z. Johan; F. Coulouvrat; R. Marchiano	Dassault Par	19th ICA International Conference on Acoustics	A complete process for sonic boom assessment with atmospheric and manœuvres effects
20070902	V. Korovkin; V. Makarov; M. Galerneau; P. Coat	CIAM D	ISABE 2007	An Approach to Performance Simulation of Variable Confluence Turbofan for Future Supersonic Civil Aircraft in Multifidelity Distributed Environment
20070819	Y. Deremaux ; A. Mirzoyan; P.A. Ryabov	Dassault CIAM	ASTEC 07	Engine and a/c MDO regarding environmental and mission criterias at the
20070618	E. Jesse	ADSE	47e Salon du Bourget	Display of a model of ADSE variable wing design
20070618	Direction de la Communication	Dassault	47e Salon du Bourget	
20070521	M. Burak; L.E. Eriksson	Chalmers University	13 th AIAA/CEAS	Prediction of flow induced noise for a mixer-ejector engine configuration using LES
20070423	P. Parnis	Dassault	KATnet II Workshop	HISAC Overview
20070423	U. Hermann; M. Laban	DLR ˝ NLR	3rd AIAA Structures, Structural Dynamics & Materials Conference	Multi-Disciplinary Analysis and Optimisation Applied to Supersonic Aircraft : Part 2 - Applications & Results
20070312	Robert Wall		Aviation Week	Gaining speed
20070309	S. Vigneron	Dassault	20th meeting JSASS	Innovative design of a supersonic business jet
20061203	M. Burak; L.E. Eriksson; N. Andersson	Chalmers University	Inter-Noise 2006	LES based jet noise prediction for mixer-ejector configurations including acoustic liner model
20061120	V. Grewe	DLR	AERONET 3	From the SCENIC and HISAC Projects : application of a metric for the assessment of climate impact (of supersonic air transport)
20061107	G. Rogé	Dassault	ICFD 2006	High Speed Aircraft (HISAC) - A European "Integrated Project"
20061017	J.C. Courty	Dasault	AEROCHINA 2006	Aeorynamic and Acoustic Design of Environmentally Friendly Supersonic Business Jets
20061005	P. Leyland; M. Vittal Durand; S. Pavon; M. Gaffuri & al	EPFL	Swiss Aerodays 2006	Contribution of EPFL to HISAC
20060907	M.Mallet	Dassault	ECCOMAS 2006	Aeorynamic and Acoustic Design of Environmentally Friendly Supersonic Business Jets
20060619	P. Parnis	Dassault	AERODAYS	High Speed Aircraft (HISAC) - A European "Integrated Project"
20060427	V. Guénon	SAFRAN	Workshop EU-Russia	Cooperation with Russia in the European framework programme - View of the European Aeronautics industries
20060427	E. Oloventsov	CIAM	Workshop EU-Russia	CIAM participation in the FP6 HISAC Integrated Project
20060302	Jirasek	FOI	AERONET	
20051206	P. Parnis	Dassault	CIAM	High Speed Aircraft (HISAC) - A European "Integrated Project"
20050721	N. Heron	Dassault	17th ISNA International Symposium on Nonlinear Acoustics - Sonic Boom Forum	HISAC Overview

6.2 Official meetings

SC (Steering Committee) minutes of meeting are available on the Web Site (https://hisac.projects.nlr.nl and public address : www.hisacproject.com):

- SC1: HISAC Meeting Report M_0_1_1 (2005)
- SC2: HISAC Meeting Report M_6_25_1 (2006)
- SC3: HISAC Meeting Report M_6_36_1 ("Virtual Meeting" in November 2007).
- SC4: HISAC Meeting Report M_6_45_1 ("Virtual Meeting" in January 2009)

The day to day Management at Project Level is ensured by the Program Management Committee composed by the Co-ordinator, Work Package Leaders and Configuration Manager.

PMC (Program Management Committee) minutes of meeting are available on the Web Site :

- PMC1: HISAC Meeting Report M_0_2_1
- PMC2: HISAC Meeting Report M_6_9_1
- PMC3: HISAC Meeting Report M_6_13_1
- PMC4: HISAC Meeting Report M_6_19_1
- PMC5: HISAC Meeting Report M_6_28_1
- PMC6: HISAC Meeting Report M_6_30_1
- PMC7: HISAC Meeting Report M_6_38_1
- PMC8: HISAC Meeting Report M_6_40_1
- PMC9: HISAC Meeting Report M_6_44_1

2 forums have been decided at PMC/SC level and organised during the previous year:

- Organized during the French Presidency of the European Union by the Ministry for Higher Education and Research, the European City of Science welcomed 50000 visitors in Paris from the 14th to 16th of November 2008.
- Organized by the 3AF (Association Aéronautique et Astronautique de France), with the support of the European Commission and some partners, the Hisac Project International Conference took place in Paris on 2009 June & 18th & 19th.

Program Management Committee team has planned and ensured the organisation of Periodic Technical Work Shop at Project Level.

- Work Shop 1 in Naples on the 11/12 of July 2005 HISAC-M-0-3-1
- Work Shop 2 in St Cloud on the 6/7 of October 2005 HISAC-M-6-6-1

- Work Shop 3 in St Cloud on the 23/24 of February 2006 HISAC-M-6-11-1
- Work Shop 4 in Napoli on the 7/8 of June 2006 HISAC-M-6-22-1
- Work Shop 5 in Moscow on the 5/6 of October 2006 HISAC-M-6-26-1
- Work Shop 6 in Saint-Cloud on 13/14 of December 2006 HISAC-M-6-29-1
- Work Shop 7 in Turin on the 28/29/30 of March 2007 HISAC-M-6-30-1
- Work Shop 8 in Amsterdam on 2/3 of July 2007 HISAC-M-6-32-1
- Work Shop 9 on September 2007 in SNECMA facilities HISAC-M-6-35-1
- Work shop 10 in Naples on the 16/17 of January 2008 HISAC-M-6-37-1
- Work shop 11 in Moscow on the 23/24 of April 2008 HISAC-M-6-39-1
- Work shop 12 in Stockholm September, 25/26 2008 HISAC M-6-41-1.
- Work shop 13 in Munich - Ismaning December 1-4 2008 HISAC M-6-43-1
- Workshop 14 in Saint Cloud - June 22/23 2009 HISAC-M-6-46-1

The Project Final Review has been organized in Dassault-Aviation - Saint-Cloud (France) the 5th of November 2009. The general conclusions of the EC Project Officer and of the Reviewers are positive. Congratulations have been addressed to all partners for the success of this cooperation.

6.3 Official deliverables

All technical deliverables have been issued.

Year deliverables prepared by all partners with the coordination of PMC members are: :

- Intermediate Activity Report (D6.03) HISAC-T-6-1-1
- First Period Activity Report (D6.04 ; D6.08 ; D6.09) HISAC-T-6-15-1
- Draft Planning for the next 18th months (D6.05) HISAC-O-6-17-1
- 1st Periodic Management Report (D6.06 / D6.10) HISAC-A-6-16-1
- Annual Cost Audits (D6.07) HISAC-A-6-18-1
- 18 month Technical Progress Report HISAC-O-6-18-1
- 2nd Periodic Management Report (D6.12) HISAC-A-6-19-1
- Second Period Activity Report (D6.13) HISAC-T-6-20-1
- Revised Project planning
  and cost breakdown for the next 18 months (D6.14) HISAC-O-6-21-1
- 30 month Technical Progress Report (D6.15) HISAC-T-6-22-1
- 3rd Periodic Management Report (D6.16) HISAC-A-6-19-1
- 36 months Technical Progress Report (D6.17) HISAC-T-6-24-1

- Revised Project planning
  and cost breakdown for the next 12 months (D6.18) HISAC-T-6-23-1
- 42 months Technical Progress Report (D6.19) HISAC-T-6-25-1
- Publishable activity report (D6.20) HISAC-T-6-26-1
- Last period management report (D6.21) HISAC-A-6-27-1
- Final management report (D6.22) HISAC-A-6-28-1
- Final plan for using and disseminating the knowledge (D6.23) HISAC-T-6-29-1
- Last period activity report (D6.24) HISAC-T-6-30-1