# HISAC - T - 5 - 1 - 1

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# Executive public summary of the three preliminary aircraft configuration families

| OWNER COMPANY LEVEL | | PROJECT LEVEL | |
|---|---|---|---|
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# 1. CONTENTS

# 2. PREAMBLE

## 2.1. Document issues

| Date | Issue | Revision | Author | Updating Purpose |
|---|---|---|---|---|
| | | | | Document Creation |

## 2.2. List of updated pages

## 2.3. Summary

This document reminds the main objectives of the HISAC project, gives an overview of the key requirements (in terms of impact on the design candidates), and presents a preliminary description of the potential aircraft configurations for three families :

- Low noise family
- Long range family
- Low boom family

# 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 | X |
| 13 | ESTECO | |
| 14 | IBK | |
| 15 | INASCO | |
| 16 | NUMECA | |
| 17 | ARA | |
| 18 | CIAM | X |
| 19 | CNRS | |
| 20 | DLR | X |
| 21 | FoI | |
| 22 | INRIA | |
| 23 | IoA | |
| 24 | NLR | X |
| 25 | ONERA | X |
| 26 | TsAGI | X |
| 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. OVERVIEW OF THE HISAC PROJECT

## 4.1. Background

Many projects have been carried out in Europe as well as in other countries, addressing the large supersonic transport aircraft market. None has already emerged due to the difficulty to overcome the economic and environmental issues. But beyond the current market for small subsonic aircraft there is a substantial segment of customers interested in flight time being reduced by 20 to 50% as compared with current subsonic business aircraft on distances over 6500km which is the minimum required for transatlantic flights.

## 4.2. Project objectives

The stopping issues are strongly alleviated by reducing the size. The HISAC project aims therefore at establishing the technical feasibility of an environmentally compliant small size supersonic transport aircraft (S4TA), through a Multidisciplinary Optimisation (MDO) approach and focused technological improvements.

The first general objective is to identify the characteristics of aircraft that could meet prospective environmental requirements, namely:

- Reduction of external noise by 8dB cumulative margin re ICAO Chapter 4,
- NOx emissions: less than 5g per kg fuel burnt in the long term, 10g in the medium term,
- Emissions at landing and take-off comparable to those of a subsonic aircraft,
- Reduction of the sonic boom signature overland, while offering attractive performance for the customer:
- Time reduction from 20% to 50% compared to current aircraft,
- Range at least transatlantic,
- Operation from small airports,
- Cabin suitable for 8 to 19 passengers.

The second objective is to provide policy makers with a set of recommendations for future environmental regulations which could reasonably be met with an optimised S4TA.

As a third objective, HISAC will provide progress on critical elementary technologies and associated design and optimisation multidisciplinary methods as well as a plan for further research.

## 4.3. Description of the work

Based on their experience, the HISAC partners have chosen the following avenue:

- Translation of the environmental objectives into quantified design criteria for community noise, atmospheric emissions, sonic boom, applicable to an S4TA (WP1)
- Adaptation of numerical models and tools essential to the multidisciplinary design process; emphasis will be put on noise, emissions, sonic boom, engine and aerodynamics, as well on MDO process itself (WP2)

- Development and validation of the most critical engine and airframe technologies; technologies considered will be variable cycle and nozzle noise reduction for engine, forced laminar flow, high lift devices and variable geometry wing for airframe; mixer-ejector nozzles will be designed and tested for a better assessment of this engine technology (WP3)
- Establishment of rules and methods to solve key integration issues; for this purpose specific shape design work, supported by wind tunnel tests, will be performed, focusing on engine integration (compromise between low noise and low drag), boom minimisation, and maximisation of laminar boundary layer; specific airworthiness issues will also be overviewed in order to identify the key points of the future specific conditions for certification (WP4)
- Application of MDO methods (WP5), using the results of the above, to obtain:
    - Aircraft specifications compliant with environmental objectives; to explore the broadest range of concepts and address all design and environmental issues, the work will be shared between the partners with the constitution of three aircraft configuration teams;
    - Quantified trade-offs between aircraft performance and environmental constraints

## 4.4. Expected achievements

HISAC will provide:

- Achievable specifications for an environmentally compliant and economically viable small size supersonic transport aircraft
- Recommendations for future supersonic environmental regulations (community noise, emissions, sonic boom)
- Enabling technologies, and a road-map for their further maturation and validation, up to a future Proof Of Concept

# 5. DESCRIPTION OF THE THREE PRELIMINARY AIRCRAFT CONFIGURATION FAMILIES

## 5.1. Overview

Three different aircraft configuration families are to be studied in the scope of WP5, taking into account different environmental constraints and/or mission objectives.

Three teams are carrying out the analyses:

- Team A : Dassav, SnM
- Team B : ALA, DLR, NLR, ONERA, ADSE, SnM
- Team C : SCA, CIAM, TsAGI

The three families to be studied are:

- Configuration A – Low noise:
  - Team A
  - Share the common set of requirements detailed underneath, but will include an additional constraint regarding the acceptable noise level : Stage IV – 8 dB
- Configuration B – Long range:
  - Team B
  - Share the common set of requirements detailed underneath, but will include an additional constraint regarding the minimum range: 5000 Nm
- Configuration C – Low boom:
  - Team C
  - Share the common set of requirements detailed underneath, but will include an additional constraint regarding the acceptable boom signature : overpressure of 15 Pa

## 5.2. High Level Requirements

During the 6 months from T0 and T0+6, high level requirements for the 3 baseline families have been discussed and the 3 teams agreed on a list of high level requirements with their associated range of values. These requirements are described in specific documents: HISAC-T-5-17-1 Reference configuration & aircraft families requirements and HISAC-T-5-18-1 High level requirements (Excel file). An overview of the relevant common requirements is hereunder presented. This set of common requirements will be used throughout the first loop of designs.

### 5.2.1. Common set of requirements

The requirements that will support the three analyses and may impact the designs can be summarized as follows:

- Supersonic cruise between M1.4 and M1.8
- Minimum range between 3000 and 5000 Nm with 8 passengers
- Floor plan at least the one of Falcon 50
- Max landing weight = between 70% and 95% of max take-off weight

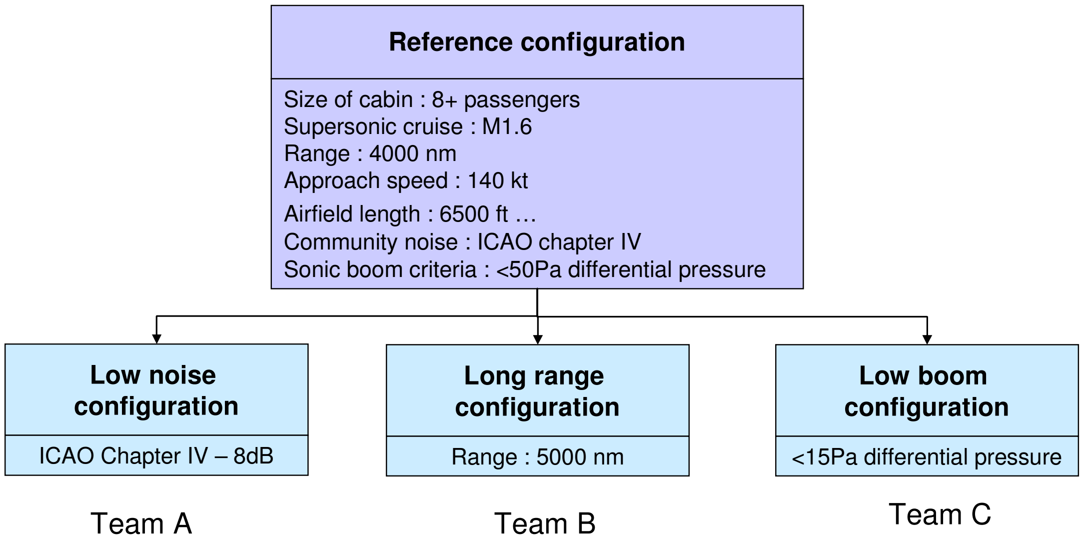
- Approach speed at take off = between 120 and 140 kt
- Maximum balanced field length = between 5500 and 6500 ft

In parallel, desirable environmental constraints are defined (for non specific configurations):

- Community noise : Stage IV
- Sonic boom signature (maximum overpressure) : 50 Pa

### 5.2.2. Main design requirements

In the first iteration, to compare specificities of each family, all teams will use a same common set of high level requirements (described above). Only the environmental objectives and the mission performances will be adjusted to the objective of each family:




This process will allow comparing the 3 families, identifying the needed technologies to comply with the 3 main objectives (low noise, long range or low boom) and consequently evaluating the exchange rates between the mission performances and these objectives.

Moreover, in each family, trade-off studies between the requirements will be performed in order to understand the impacts of these hypotheses on the family and to reach the aircraft sensitivities. In these studies, the range of values of all the requirements will be explored. For example, each team will evaluate the impact of a bigger fuselage or a lower approach speed on the performances and masses.

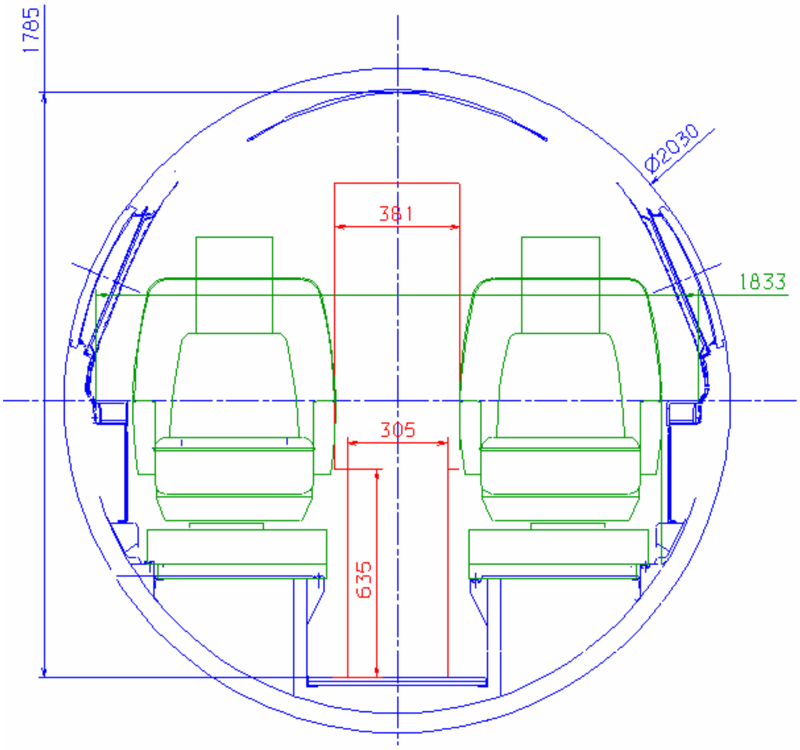
In addition of the common set of requirements, some common architecture elements have been agreed in order to get the same level of constraints about the layout.

### 5.2.3. Common design features

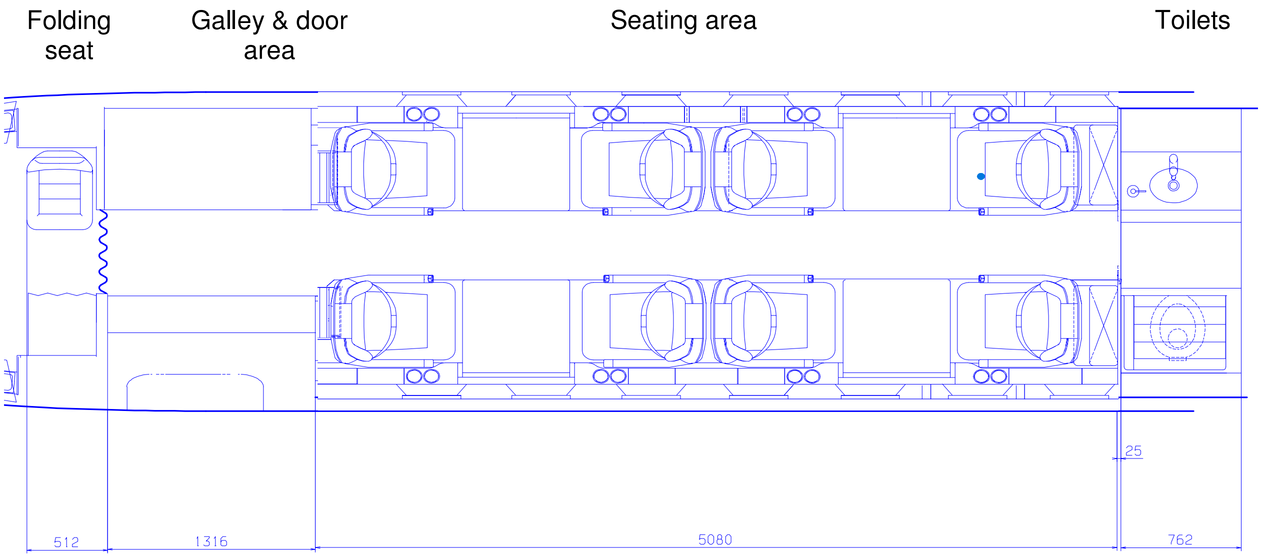
#### 5.2.3.1. Cabin & floor plan

It has been decided for the initial iteration to have the same floor plan that a Falcon 50. The fuselage diameter will be updated if the trade-off studies show that a bigger fuselage is feasible.

The floor plan of the Falcon 50 is described below:




Circular cross section




Standard configuration (8PAX) with a seating area of 200 inches (5.08 m)

#### 5.2.3.2. Vision

The direct visibility JAR constraints will not be taken into account for the cockpit & nose design. We consider that a synthetic vision or a periscopic system will complete a natural lateral visibility. However, the pilot will be able to see the airstrip even if at reduced angle, with respect to JAR criteria.

## 5.3. Definition of the 3 families

### 5.3.1. Important remark

All the data presented in the following chapters are first estimations, given each team's hypotheses. These estimations will be refined in the next phase. Potential discrepancies between first estimations and more detailed results will be assessed and explained.

In addition, design hypotheses may vary from one team to another and may lead to discrepancies on data that can be found performing cross-checks. This issue will be addressed later in the project.

### 5.3.2. Description of the Low Noise Family

This paragraph is devoted to give a preliminary description of the low noise family. work done by team A from T0 to T0+6. This work has been focusing on the definition of the reference configuration (other task of WP5). Trade-offs between delta wing and high-sweep wing configurations are being carried out.

The two configurations present an interesting trade-off in terms of structures and aerodynamics, coupled with engine and landing gear integration problems, for example :

- Aerodynamic performances of high sweep wing seem good compared to performances of delta wing.
- High sweep wing favours low relative thickness that may not be compatible with structural constraints
- Integration of control surface actuators, landing gears and engine must be taken into account to compare both configurations
- Trim surfaces type (canard or horizontal tail) plays an important role.

These trade-offs are being assessed by team A and will lead to interesting results, used to define the reference configuration.

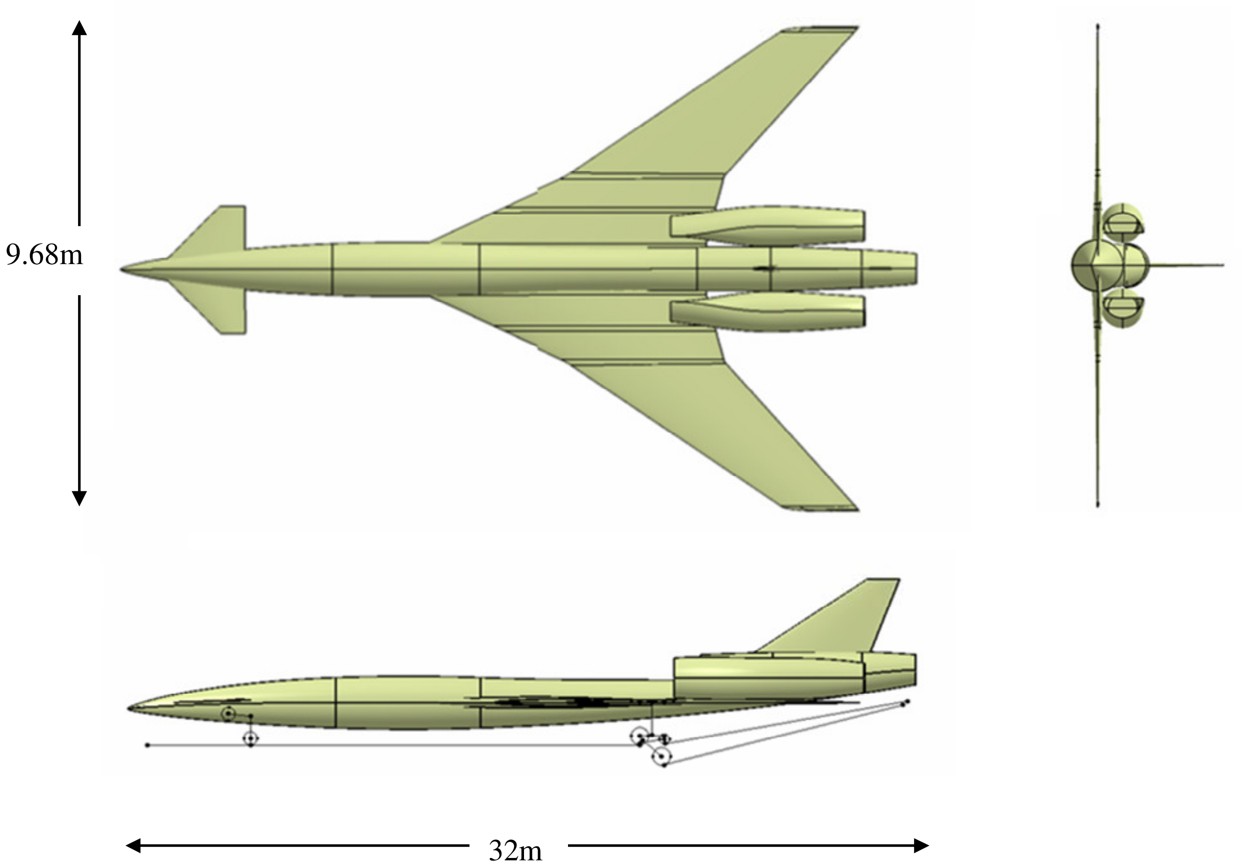
Compared to the reference configuration, the main drivers of the low noise configuration are to improve significantly the community noise and to comply with stage IV - 8dB. Different ways of improvement are explored to reach lower noise levels:

- Analysis of the impact of the engine architecture (engine derivatives): the way to reduce the jet velocity during the low speed phase is to increase the engine bypass ratio, or to use a mixer / ejector, or use unconventional architecture like variable cycle.

- Analysis of the impact of the number of engines: 2 / 3. This trade off includes the engine integration and the associated drag.
- Analysis of the plan form impact to improve low speed aerodynamic efficiency and impact on community noise.
- Sensitivity to trajectories (approach or take-off), impact of noise reducing manoeuvres, etc…

#### 5.3.2.1. High sweep wing configuration

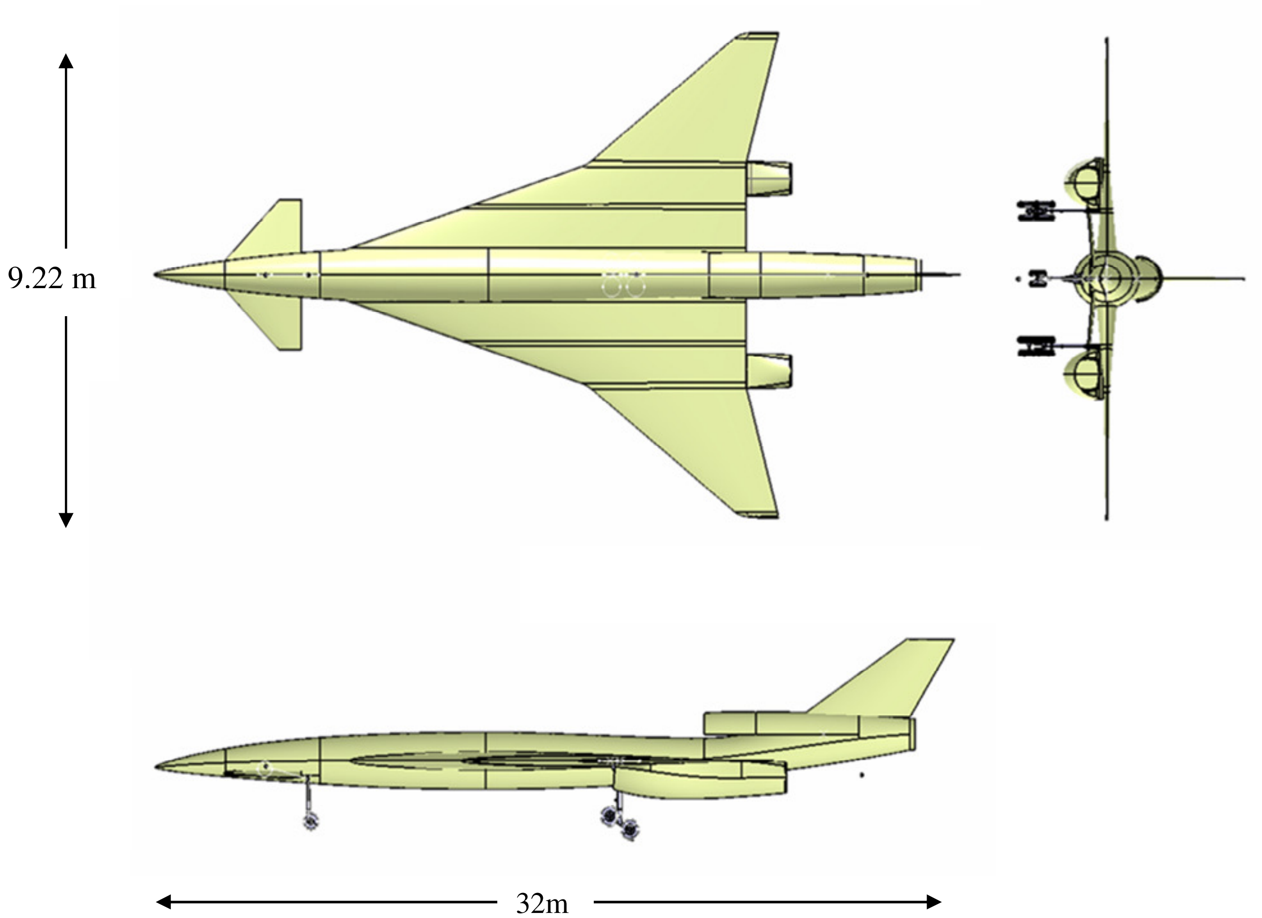
This variant is based on an aerodynamics scheme which is composed of a high sweep wing with canards. The canards are located in front of the cockpit. The wing is located after the pressurized part of the fuselage. The current architecture is based on 3 engines, 1 engine is buried in the rear of the fuselage and the 2 others are mounted in lateral nacelles, located at the end of the wing root chord. The landing gears are attached on the wing structure and the wheels retract in the fuselage. A vertical fin is attached on the rear fuselage.




#### 5.3.2.2. Delta wing configuration

This variant is based on an aerodynamics scheme including a delta wing and canards. The canards are located in front of the cockpit. The main structure of the wing is located after the pressurised part of the fuselage. The current architecture is based on 3 engines, 1 engine is buried in the rear of the fuselage and the 2 others are mounted in lateral nacelles, located under the wings. The landing gears are attached on the wing structure and the wheels retract in the fuselage. A vertical fin is attached on the rear fuselage.

A specific configuration with horizontal tail will be taken into account and assessed in comparison with canard configurations.




### 5.3.2.3. Engine architecture

The current engine architecture is a conventional dry engine with a variable nozzle throat. Different engine architectures such as an ejector mixer or a variable cycle engine will be implemented in the trade off studies on this variant.

The engine has been designed with a jet velocity specification (below 300m/s) that will be evaluated later on the certification trajectories to be compared to the chapter IV levels.

A specific configuration with horizontal tail will be taken into account and assessed in comparison with canard configurations.

5.3.2.4. Weight & balance

| Description | Unit | Delta | High sweep |
|---|---|---|---|
| Fuel | kg | 24723 | 21570 |
| Empty Weight | kg | 20509 | 21974 |
| Max Take Off Weight | kg | 46339 | 44651 |

## 5.3.3. Description of the High Range Family

### 5.3.3.1. Laminar configuration

Long Range configuration was developed, according to relevant requirements and relying upon the above listed design drivers, implementing a usual aerodynamic layout with horizontal stabilizer and vertical fin.

Wing and horizontal tail planforms must be tailored in order to keep the flow laminar on a large area aft the leading edge exploiting a design imposed negative pressure gradient over the largest possible length of local chords.

Supersonic area ruling has to be extensively used to minimise wave drag in supersonic cruise.

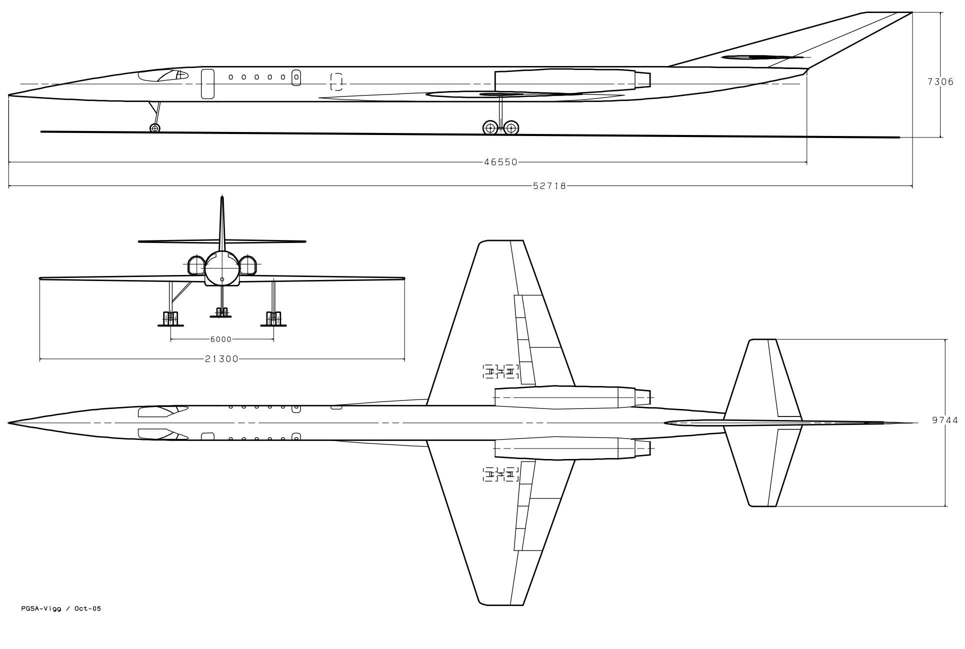
The two engines are placed on the upper rear part of the wing close to the fuselage. A trade off, between a conventional podded engine installation and a more integrated one, will be carried out before to take the final decision about engine position/installation.

Drag, airworthiness, installation, maintenance and operational issues will be the drivers and the constraints of such a study.

### 5.3.3.2. General architecture

The aircraft is a swept wing monoplane with a pressurized cabin and capable of accommodating a pilot , a co-pilot, an attendant and up to11 passengers.

The A/C has two engines installed in the rear part of fuselage with a conventional tail configuration. The undercarriage is a retractable tricycle type landing gear. The fuel tanks are three: two in wing and one in fuselage. The electrical and avionics bays are located in forward part of fuselage.



5.3.3.3. Weight & balance

| Description | Unit | Long range |
|---|---|---|
| Fuel | kg | 25400 |
| Empty Weight | kg | 22340 |
| Max Take Off Weight | kg | 46610 |

### 5.3.4. Description of the Low Boom Family

#### 5.3.4.1. Configurations description

Three configurations are implemented according to normal aerodynamic scheme with horizontal stabilizer, with conventional architecture engine (no afterburner, variable nozzle throat, twin spool, mixed flow). They have the same passenger cabin.

#### 5.3.4.2. Configuration 1

The aircraft wing has a low-aspect ratio with trapezoid inner wing and swept outer wing. The distinctive feature of this wing is the big dihedral angle.

The power plant consists of two engines situated near each other in the same compartment over fuselage tail part. Vertical stabilizer is situated over the engine bay. Horizontal all-moving stabilizer is situated on the engine bay in the aircraft tail part.

| | |
|---|---|
| Airplane Length, m | 42,7 |
| Wing Span, m | 19,3 |
| Take off Thrust (One Engine), tons | 14 |
| Take off Weight, ton | 55,8 |

### 5.3.4.3. Configuration 2

Configuration 2 has a variable swept wing. The outboard wing panel has three fixed positions:

- Takeoff-Landing,
- Transonic acceleration,
- Cruise flight at supersonic speed.

The wing has a positive dihedral angle.

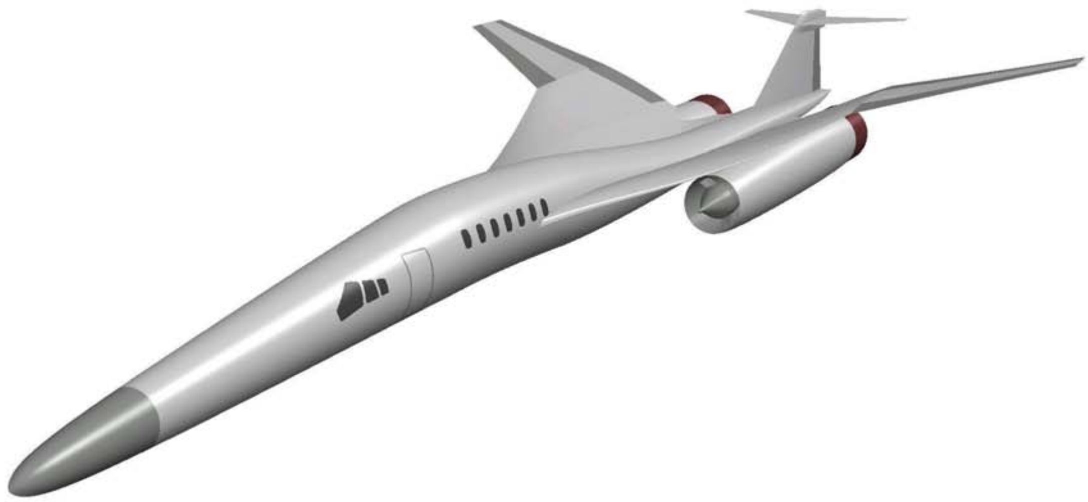
The power plant consists of two engines situated near each other in the same compartment over fuselage tail part. Vertical stabilizer is situated over the engine bay. Horizontal all-moving stabilizer is situated on the engine bay in the aircraft tail part.

| | |
|---|---|
| Airplane Length, m | 42 |
| Wing Span, m | 30,6/ 17,1 |
| Take off Thrust (One Engine), tons | 15,5 |
| Take off Weight, tons | 63,4 |

#### 5.3.4.4. Configuration 3

The aircraft wing has a low-aspect ratio with trapezoid inner wing and swept outer wing. The distinctive feature of this wing is the big dihedral angle.

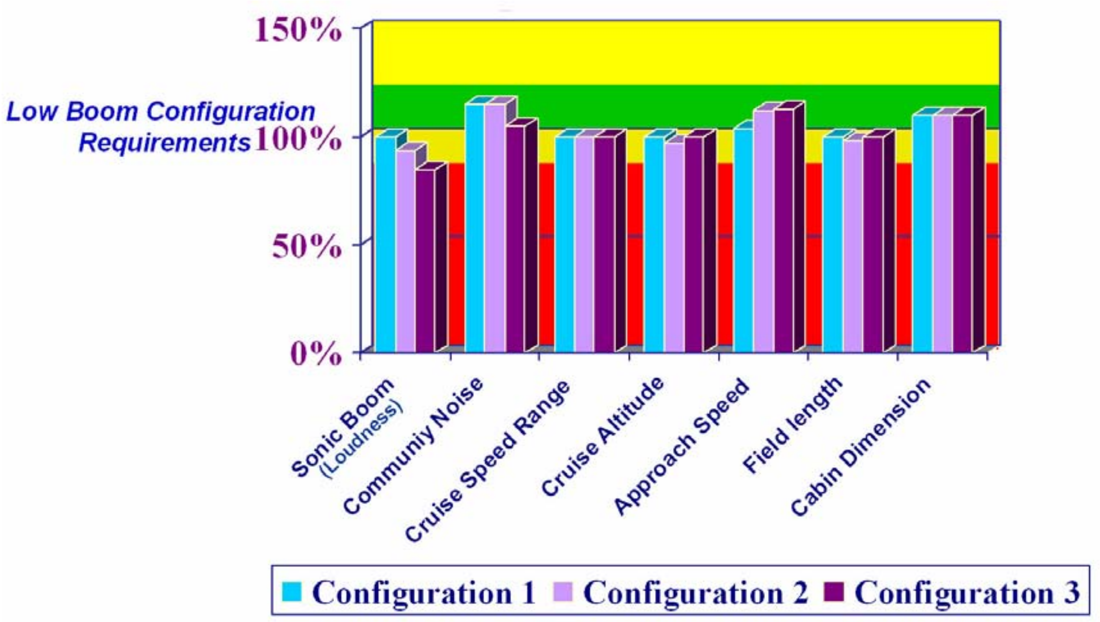
The configuration has a T-empennage and a two-engine power plant situated under the wing.



| | |
|---|---|
| Airplane Length, m | 42 |
| Wing Span, m | 20,1 |
| Take off Thrust (One Engine), tons | 14,7 |
| Take off Weight, tons | 59,2 |

#### 5.3.4.5. Compliance

The diagram below shows main characteristics of tree Team C configurations in percents to High Level Requirements (100%). The diagram shows that the preliminary A/C configurations meet all High Level Requirements basically. It is the Sonic Boom characteristic that is the most difficult in the requirements compliance. These requirements will be met for further developments of the project during detail design phase.



# 6. FUTURE WORK

From T0+6 to T0+18, the three teams will refine the configurations presented in this document and perform more detailed trade-off for design optimization.

In parallel, a detail evaluation of the reference configuration will be carried out, to provide the three teams with benchmarked results that allow design evaluation and comparison of the candidates.

A detailed evaluation of final candidates for each configuration family will be provided at T0+18, including sensitivities to environmental constraints.