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Executive public summary of aircraft shape design global definitions

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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 describes the aerodynamic shapes that are studied in the frame of WP4. It presents the status of their definition at T0+9.

3. LIST OF PARTNERS INVOLVED IN THE DOCUMENT

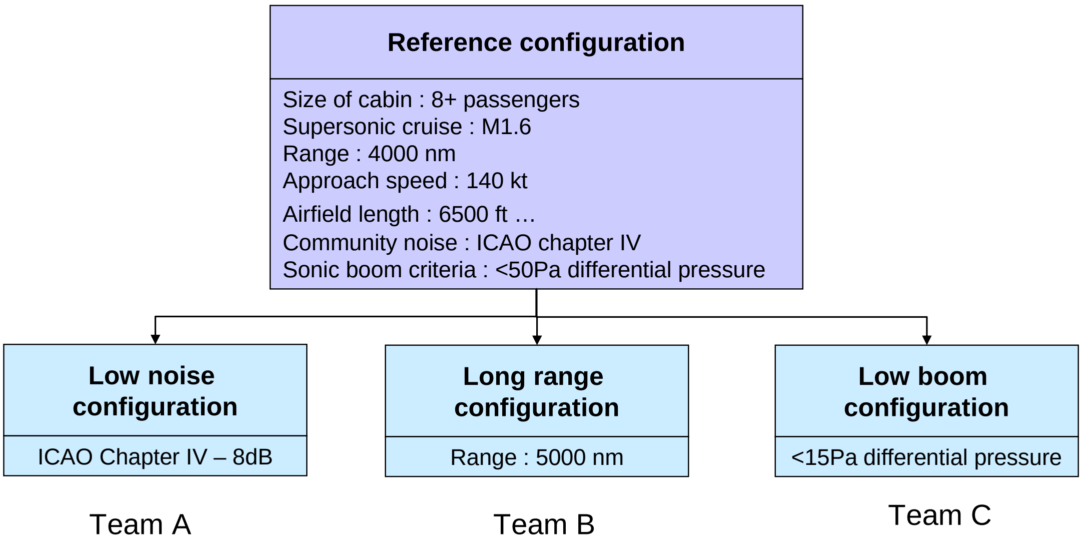
N°	ACRONYM	CHECK IF INVOLVED
1	DASSAV	X
2	ALA	X
3	CFS	
4	EADS M	X
5	RRUK	
6	RUAG	
7	SCA	X
8	SENER	
9	SnM	
10	SONACA	
11	VOLVO	
12	ADSE	
13	ESTECO	
14	IBK	
15	INASCO	
16	NUMECA	
17	ARA	
18	CIAM	
19	CNRS	
20	DLR	X
21	FoI	X
22	INRIA	
23	IoA	
24	NLR	
25	ONERA	
26	TsAGI	X
27	EEC	
28	Chalmers	
29	CU	
30	ECL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

4. INTRODUCTION

In the frame of the HISAC project, three different aircraft will be studied. These three configurations will take into account different environmental constraints and mission objectives, as stated below:

- Configuration A – **Low noise**:
  - o Team A (Dassav, SnM)
  - o 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**:
  - o Team B (ALA, DLR, NLR, ONERA, ADSE, SnM)
  - o Share the common set of requirements detailed underneath, but will include an additional constraint regarding the minimum range: 5000 Nm
- Configuration C – **Low boom**:
  - o Team C (SCA, CIAM, TsAGI)
  - o Share the common set of requirements detailed underneath, but will include an additional constraint regarding the acceptable boom signature : overpressure of 15 Pa

The common set of high-level requirements that will share these three aircraft is summarized on the following chart:



This process will allow comparing the three configurations, identifying the needed technologies to comply with the three main objectives (low noise, long range or low boom) and consequently evaluating the exchange rates between the mission performances and these objectives. All this work will be done in the frame of WP5 ("Multidisciplinary design plateau").

Nevertheless, WP4 ("Key integration issues") will also play an important part in this process since it aims at focusing on the aerodynamic "key issues" (e.g. "hard points"), and it will feed WP5 with parametric aerodynamic models.

More precisely, the objective of WP4 is to quantify the impact of the aircraft shape design on specific hard design points, i.e. **engine integration drag**, **low sonic boom**, and **flow**

laminarity. Several shape designs and assessments will be undertaken in relation with the other workpackages (like WP5) to analyse these hard points, including:

- a **reference aircraft shape** with engine integration derivatives, to be assessed both numerically and experimentally in low-speed and high-speed wind tunnels
- **low-noise and low-drag engine integration** derivatives of the reference shape
- a **low sonic boom aircraft shape**
- a **laminar wing aircraft shape**

Once these shapes are designed, experimental and numerical assessments will take place.

The purpose of this document is to describe the global geometry of the different aerodynamic shapes that are studied in the frame of WP4 and to present the status of their definition at T0+9. The reference shape is then introduced. The way the wind tunnel model shape will be designed is also addressed.

5. LOW DRAG/LOW NOISE SHAPES

The main drivers of the low drag/low noise shapes design are:

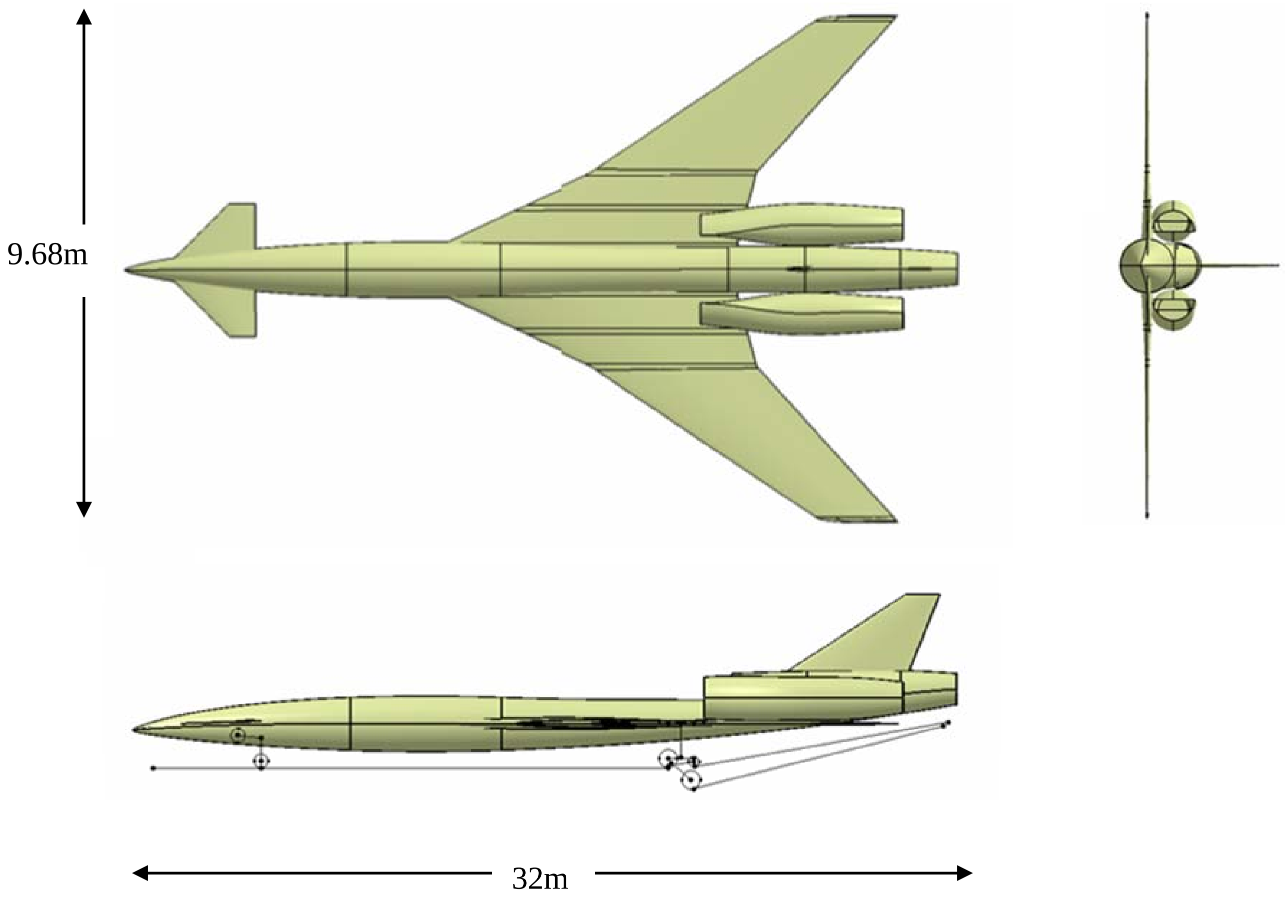
- to improve significantly the community noise and to comply with stage IV - 8dB,
- to reduce significantly the aircraft drag during supersonic cruise.

For now, only wing planforms and engine integration derivatives have been investigated, and two aircraft shapes have been studied in parallel:

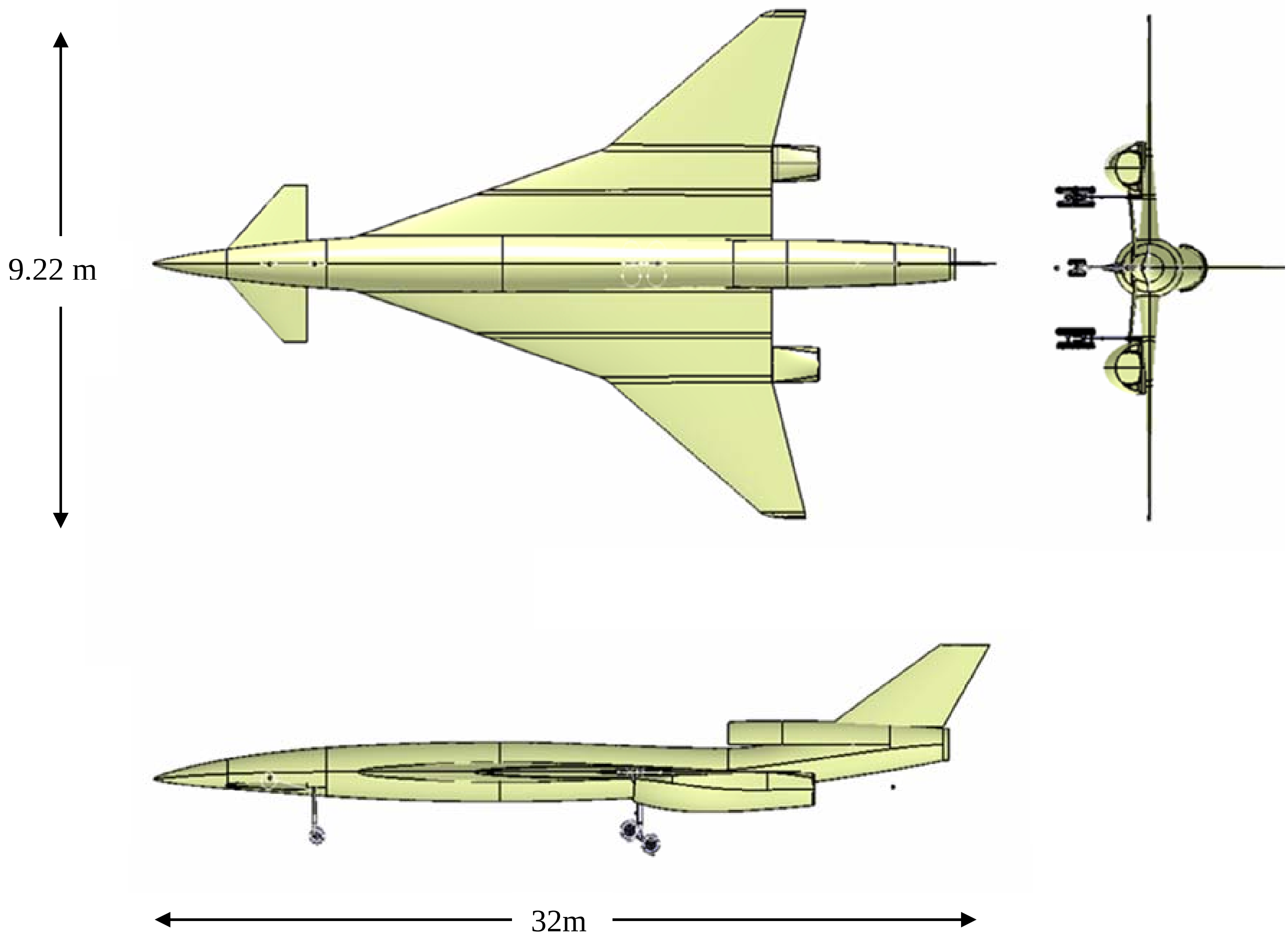
- one high-sweep wing with 2 pod-mounted nacelles on the aft portion of the fuselage, and a third engine buried in the rear part of the fuselage
- one delta wing with 2 nacelles located under the wings, the third engine being buried in the rear part of the fuselage

These shapes are basically the external shapes of the Team A configurations.

The following figure shows a view of the high-sweep wing shape:



The following figure shows a view of the delta wing shape:



Both wings present an interesting trade-off in terms of structure and aerodynamics:

- The high-sweep wing shows better subsonic and transonic performances (in terms of lift-to-drag ratio) due to its larger aspect ratio and lower wetted area compared to the delta wing. This lift-to-drag ratio increase in the low-speed regime may lead to substantial EPNdB noise reduction during take-off and landing.
- Both wings show similar supersonic performances but this result is very sensitive to the wing relative thickness distribution.
- The high-sweep wing needs low relative thickness that may not be compatible with structural constraints (due to the large values of leading edge and trailing edge sweep angles).
- Engine integration drag has a large impact on the aircraft total drag.
- Trim surfaces type (canard or horizontal tail) also plays an important role.

6. LOW BOOM SHAPE

The low boom shape is the external shape of the Team C configuration 1 aircraft studied in WP5, whose design driver is to have an acceptable boom overpressure of 15 Pa.

The main characteristics of the low boom shape are as follows :

Aircraft configuration: delta V-wing + horizontal tail
Type of fuselage: low-boom shaped front fuselage
Type of landing gear: fuselage landing gear
Number and position of engines: 2, upper rear fuselage
Type of air intake: 2D
High lift devices: leading and trailing edge devices

The following figure shows a view of the low boom shape:

Airplane length (m)	42.7
Wing span (m)	19.3

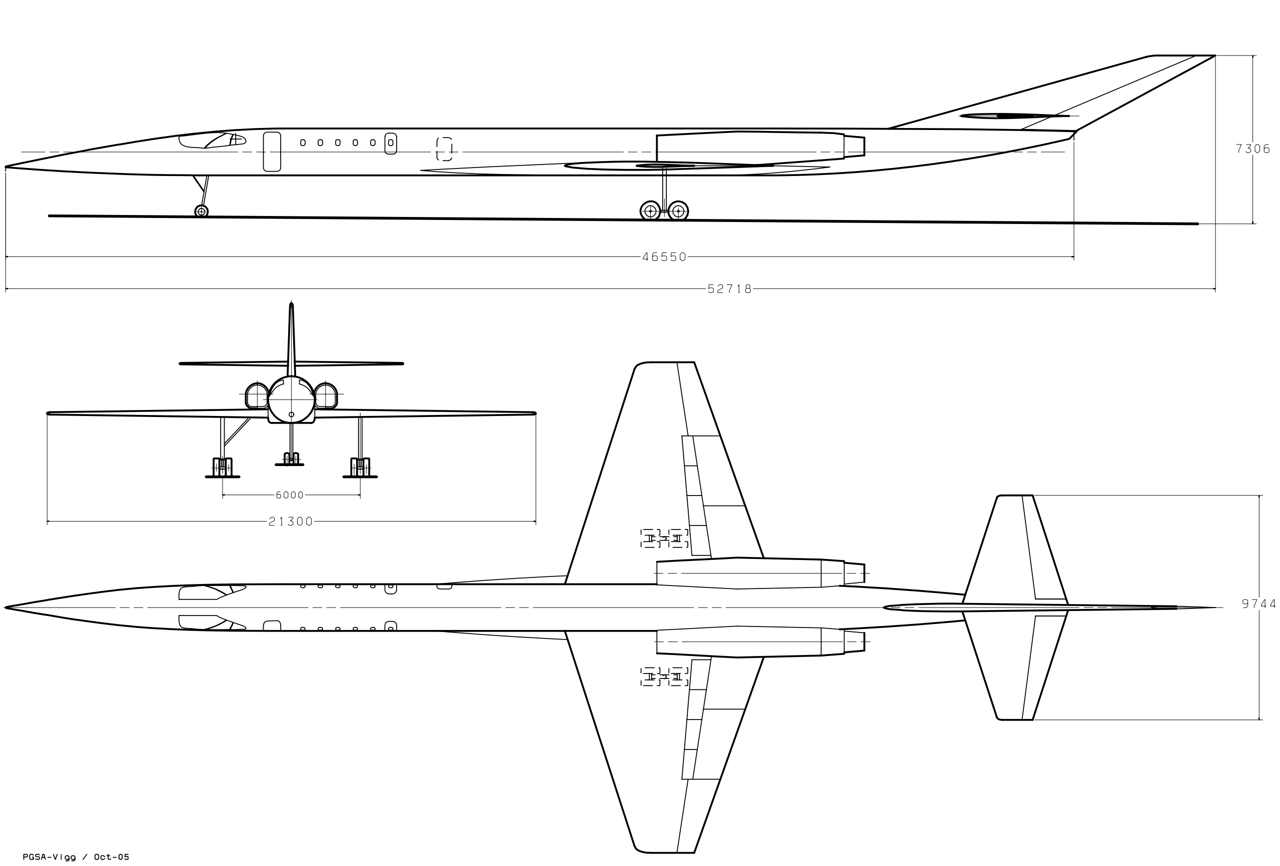
The wing has a low-aspect ratio with trapezoid inner wing and swept outer wing. The distinctive feature of this wing is its large dihedral angle.

The two engines are located near each other in the same compartment on the aft part of the fuselage. The vertical stabilizer is located over the engine bay. The horizontal stabilizer is located on the engine bay in the aircraft tail part.

7. LAMINAR SHAPE

The laminar shape is made of the external shape of the long range configuration studied in WP5. This configuration was developed according to the requirement of extended range (5000Nm).

The following figure shows a view of the laminar shape:



The wing and horizontal tail planforms are tailored in order to keep the flow laminar over a large portion of the wing/tail area. The two engines are placed on the upper rear part of the wing close to the fuselage. Supersonic area ruling optimization has now to be extensively used to minimise wave drag in supersonic cruise.

8. CHOICE OF THE REFERENCE SHAPE

In the frame of WP5, a common reference configuration was selected at T0+9. The multiple objectives of this configuration are:

- A common aircraft architecture used in the tools and process crosschecks,
- The initial design point for the MDO benchmark,
- The initial aircraft shape from which is designed the wind tunnel model shape

Moreover, the selected reference configuration should also:

- Address key technology and architecture issues
- Be useful to each team's designs
- Meet most of the requirements
- Be one of the existing configuration

The key technology and architecture issues that were identified are listed below:

- Airfoil thickness
- Feasibility of a fuselage landing gear
- Feasibility of an upper 2-engine integration
- Dihedral (V-shaped wing)
- Nose shape (low-boom shape)

In order to address the best the key technology and architecture issues listed above, the reference configuration that was chosen is : Team C - Configuration 1. This configuration addresses most of the issues that were identified, and is mature enough to represent a solid base for further analyses and crosschecks.

Concerning WP4, the reference shape is defined as the external shape of the reference configuration. **The reference shape is thus the low boom shape.**

9. UPCOMING WORK

As it has been stated above, the reference shape will be assessed both numerically and experimentally in low-speed and high-speed wind tunnels. The major part of the upcoming work in the frame of WP4 is thus dedicated to the detailed design of the model shape that will be used during these tests.

Then, the other WP4 shapes (low noise/low drag shapes, laminar shape) will be assessed numerically.

9.1. Objectives of the wind tunnel testing

Two aircraft models (low-speed and high-speed) will be designed and manufactured between T0+18 and T0+24:

- low-speed model by DLR
- high-speed model by ARA

Three wind tunnel campaigns will take place between T0+24 and T0+27:

- low-speed:
  - test at RUAG, Emmen (CH)
- high-speed:
  - transonic and supersonic (up to Mach 1.4): test at TsAGI T-128
  - Mach 1.5 to 1.8 and additional testing below Mach 1.3: test at ONERA S2 Modane

High-speed wind tunnel tests (WTT) priority is put on engine integration which has a major impact on the aircraft drag in supersonic cruise.

WTT will be used to validate and calibrate computational fluid dynamics (CFD) tools and aerodynamic sensitivity models, the first objective of these tests being to assess the aerodynamic performances of the reference shape. WTT data together with calibrated CFD data will be used to build and improve parametric aerodynamic models for MDO processes.

9.2. Wind tunnel model shape design

During the upcoming months, the external shape of the reference shape will be optimized from an aerodynamic point of view. The result of this process will be the external shape of the model that will be tested in wind tunnels. At first sight, there is no reason why these two geometries should differ.

Nevertheless, even though some constraints lead to slight differences between the two geometries, the quality of the transposition that will be done between the two shapes will not be impacted. A first aerodynamic database will be generated for the wind tunnel model shape (by combining wind tunnel test data and CFD computations). This database will serve as an anchor point for a parametric model that will be generated and that will include multiple geometrical parameters, like:

- wing planform

- wing thickness
- control surfaces
- nacelles
- fuselage

The validity of the parametric model should be good in the vicinity of the wind tunnel model shape. Furthermore, the reference shape will be a very precise point in the parametric model in order to reach the best achievable precision in the aerodynamic coefficients prediction.

The validity of the parametric model will be further assessed through CFD evaluations of the other WP4 shape designs :

- low noise/low drag shapes
- laminar shape