# DESIGN OF A SMALL SUPERSONIC TRANSPORT AIRCRAFT WITH HIGH ENVIRONMENTAL CONSTRAINTS

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## ABSTRACT

The feasibility of a small size supersonic transport aircraft during the conceptual design phase is mainly defined by the ability to match selected design parameters (A/C architecture and shapes, wing and thrust loading, fuel quantities, engine bypass ratio, temperature and overall pressure ratios, engine size, etc.) with the mission and environmental requirements (range, field length, sonic boom, community noise, emission, engine life, etc…).

This paper describes the problematic and the tools developed and used in the frame of the European FP6 Integrated Project HISAC.

## 1. THE "HISAC" PROJECT

Business productivity would benefit from a significant reduction in air travel time, especially for long haul flights.

The main objective of the HISAC project is to establish the technical feasibility of an environmentally friendly supersonic business jet through a multidisciplinary optimization (MDO) approach and focused technological improvements.

Lead by Dassault Aviation, this European project involves 37 partners which come from 13 different countries, including Russia.

Major aircraft manufacturers (Dassault Aviation, EADS, Sukhoï Civil Aircraft, Alenia) and engine manufacturers (Snecma, Rolls Royce, Volvo, Central Institute of Aviation Motors) associated with SMEs represent the industrial backbone of the HISAC consortium. Research centers and Universities lead the scientific activities.

## 2. BACKGROUND

Over the last twenty years a number of projects have been carried out in Europe as well as in Russia, in Japan and in the USA which addressed the large supersonic transport aircraft market. The fact that none of them has already emerged is not due to issues on marketing or technology aspects considered as such, but rather on their compatibility with environmental regulations. These are linked to community noise, emissions, sonic boom and high altitude requirements which will condition the feasibility of such aircraft.

The stopping issues are strongly alleviated by reducing the aircraft size. Moreover, market studies show that there is a substantial segment of business jets customers interested in flight time being reduced by 20% to 50% as compared with current subsonic aircraft on distance over 6500 km which is the minimum required for transatlantic flights. The HISAC project aims therefore at establishing the technical feasibility of an environmentally compliant small size supersonic transport aircraft (S4TA).

## 3. DESIGN REQUIREMENTS

The first general objective is to identify the characteristics of aircraft that could meet prospective environmental requirements. At the early stage of the project, these requirements were identified as follows:

- Reduction of external noise by 8 dB cumulative margin ICAO Chapter 4
- NOx emissions at high altitude: less than 10 g per kg fuel burnt,
- Emissions at landing and take-off comparable to those of a subsonic aircraft,
- Reduction of the sonic boom signature overland (less than 15 Pa differential pressure), while offering attractive performance for the customer
    - time reduction from 20 % to 50 % compared to current aircraft,
    - range at least transatlantic (6000 to 9000 km),
    - operation from small airports,
    - cabin suitable for 8 to 16 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 optimized S4TA.

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

## 4. DESIGN APPROACH

The SSBJ preliminary design activities at Dassault Aviation are supported by a two-level MDO approach. Low to medium fidelity tools, at preliminary design level (level 1) allows global optimizations, trade-off studies and uncertainty management analyses. In addition, level 1 tools are supported by a high fidelity methods and tools (level 2), that allows calibrating and validating. Figure 1 illustrates this 2-level approach.

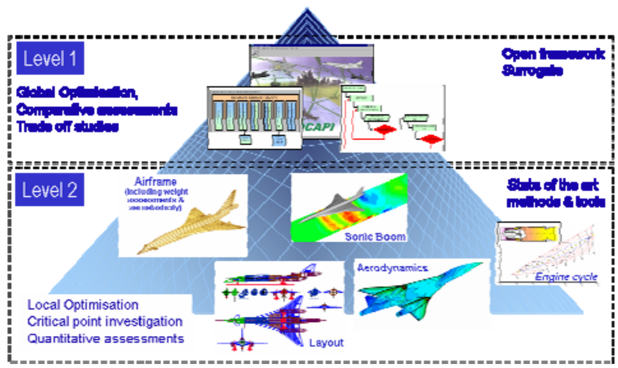


**Figure 1 - Dassault Aviation two level approach**

Level 1 tools are supported by a common structure that operates as a computer plug-in structure, which allows any user to incorporate a "module" linked to an aeronautical discipline.

Each individual module is composed of:

o A list of design variables

o A set of rules and models connecting the previous variables

o A user graphic interface to manage the calculations and variables

The modules are then integrated in the plug-in structure in order to benefit from fast computation times for interactive design processes and global optimizations.

All the modules can be organized to create a design process adapted to the aircraft configuration to be designed. The following figure (Figure 2) shows the design process used in the SSBJ design activities at Dassault Aviation.

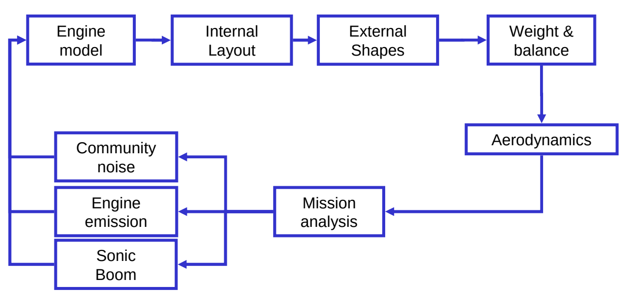


**Figure 2 - SSBJ design process**

Dassault Aviation MDO process, at level 1, is designed as a way to gain insight on the design space, quantify potential compromises and find or evaluate innovative design. It can also propose directions to level 2 activities for design refinement.

The different modules used for SSBJ design can be described as follows :

- The "engine performances" module incorporates parametric models. Engine cycles are scaled (rubber engine) and tuned (air inlet efficiency adaptation, nozzle losses corrections) to satisfy design needs
- The "Internal layout / shapes" module performs an assessment of the geometrical dimensions, describes the general aircraft arrangement (internal layout) and provides shape analyses (area rule, wetted areas, volume estimations)
- The "Weight and balance" module carries out assessment of aircraft weights and computes the center of gravity position, based on an aircraft functional analysis. All estimations are based on rules calibrated on in-house knowledge and validated through detailed analyses (structures, systems, etc…).
- The "Aerodynamics" module is based on a geometrical description and generates a parametric database based on high-level computations and in-house rules. It also generates untrimmed aircraft coefficients and trimmed drag polars.
- The "Mission analysis" module proposes a detailed computation of aircraft performances over typical flight profiles (e.g: NBAA IFR mission). A simpler tool, calibrated on detailed computations, may be used for quicker turn-around times. Detailed estimation of BFL and landing field length is also available.
- The "Community noise" module provides an assessment of the aircraft impact in terms of community noise over three certification trajectories: lateral, flyover and approach.
- The "Sonic boom" and "Engine emission" modules are also part of the SSBJ design process.

These modules provide the sufficient information, at the preliminary design level, for aircraft design and global optimization.

## 5. AIRCRAFT DESIGN

Within HISAC, Dassault Aviation is currently focusing on the design of a low-noise configuration. This configuration is currently based on a three-engine architecture supported by high BPR engines. Based on engine manufacturer experience, engine jet velocities are kept compatible with the Stage IV minus 8 EPNdB requirements. Common requirements have been agreed between HISAC partners. The project assumes a supersonic aircraft carrying 8 passengers over a 4000 NM long-range mission, and addresses environmental constraints, including sonic boom, emissions and community noise.

The Figure 3 describes the low noise architecture that is foreseen by Dassault Aviation. The architecture takes into account certification constraints and also addresses center of gravity displacement issues, via fuel tank locations and fuel transfer.

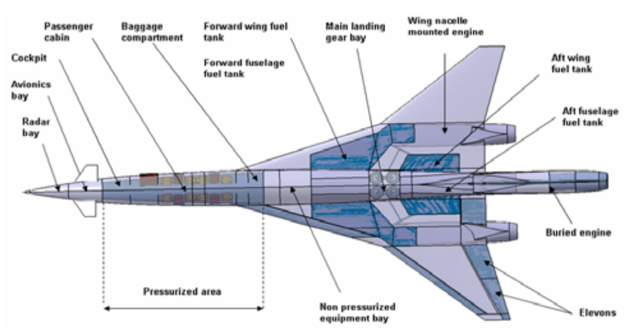


**Figure 3 - Low noise configuration architecture**

## 6. AIRCRAFT SENSITIVITY TO PERFORMANCE PARAMETER UNCERTAINTIES

Sensitivity of aircraft design to performance pa--rameters is important (mission L/D, cruise specific fuel consumption), especially for aircraft such as SSBJ.

Indeed, the amount of fuel compared to MTOW is much larger on SSBJ (ratio greater than 0.5 compared to ratio comprised between 0.3 and 0.4 for current DA Falcons). This leads to a high sensitivity of the range value to performance parameters, simply illustrated through the simplified Breguet range equation (Equation 1):

$$Range = \frac{L/D}{g \times SFC} \times V \times \ln\left( \frac{\frac{MTOW}{Mission\_Fuel}}{\frac{MTOW}{Mission\_Fuel} - 1} \right) \quad (1)$$

The impact of parameter uncertainty on environmental parameters is direct: sonic boom increases directly with MTOW; community noise levels and required thrust increase with poorer climbing performances while higher pollutant emissions are associated to higher SFC.

## 7. CONCLUSION

This paper has described the methodology developed to study a low noise configuration which is one of the three concepts investigated in HISAC project. Intermediate results on the conditions of feasibility of such an aircraft are already available. Final conclusions are to be drawn at the end of 2009 when HISAC project will be ended.