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23 December 2024

ESATTO: the holistic framework to support the design of sustainable supersonic aviation

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Abstract

The request for faster and greener civil aviation is urging the worldwide scientific community and aerospace industry to develop a new generation of supersonic aircraft, which are expected to be environmentally sustainable and to guarantee a high-level protection of citizens. To pursue this purpose, MORE&LESS (MDO and REgulations for Low boom and Environmentally Sustainable Supersonic aviation), answering the EC call “Towards global environmental regulation of supersonic aviation” (LC-MG-1-15-2020), aims to support Europe in shaping global environmental regulations for future supersonic aviation. Specifically, the project aims to provide the Scientific Community with an integrated multi-disciplinary framework consisting of validated and accepted tools to holistically assess the environmental impact of supersonic airplanes on the future global air navigation system. This paper aims to describe the overall architecture of the ESATTO Framework, providing the readers with details on the development status of the different constituent modules and the planned ideas for its exploitation.

Keywords: H2020 MORE&LESS Project, supersonic aviation, environmental sustainability, holistic framework

1. Introduction

Over the last years, an increased worldwide attention and accelerated efforts towards the introduction of new commercial supersonic aircraft have been observed. At the same time, the International Civil Aviation Organisation (ICAO) Assembly Resolution Act A39-1 [1] instructs the Council to review its Annexes to ensure that they take due account of the problems that the operation of supersonic aircraft may create for the public. In this context, to pursue this goal, MORE&LESS (MDO and REgulations for Low boom and Environmentally Sustainable Supersonic aviation), answering the EC call “Towards global environmental regulation of supersonic aviation” (LC-MG-1-15-2020), aims to address the challenge of contributing to help Europe shape together with the International community, high environmental standards in line with ICAO Assembly Resolution A39-1 by a thorough and holistic analysis of the environmental impact of supersonic aviation, through basic and advanced research and experimental activities. Main efforts are devoted to noise and pollutant emissions modelling, validated thanks to dedicated test campaigns, as well as to the development of environmental impact models for noise and atmospheric composition changes, including air quality, ozone layer, and climate. Furthermore, in line with the emerging issues on supersonic aviation summarized in the ICAO Working Paper on emissions from supersonic airplanes (presented by Austria, on behalf of the European Union and its Member States, the other Member States of the European Civil Aviation Conference and the European Organization for the Safety of Air Navigation - EUROCONTROL, in October 2018, in Montreal (Canada) at the 13th Air Navigation Conference), MORE&LESS aims at providing the Scientific Community with an integrated multi-disciplinary framework consisting of validated and accepted tools to holistically assess the environmental impact of supersonic airplane on the future global air navigation system. This framework shall also support the definition of new environmental standards for supersonic aviation, focusing on noise emissions, that encompass jet noise during Landing and Take-Off (LTO) operations as well as sonic boom, pollutant emissions, and climate impact.

In the full-length paper, this section will include a literature review of developed and under-development multi-disciplinary frameworks to support sustainable aviation initiatives. Then, Section 2 will provide the readers with a thorough overview of the ESATTO framework layout, starting from a critical analysis of the major requirements and stemmed capabilities. Then, details on the three main modules of the framework will be revealed, highlighting the analytical, numerical, and experimental activities hiding behind the implemented routines. Eventually, Section 3 will discuss future planned activities and ideas for the exploitation of the framework after the completion of the H2020 MORE&LESS project.

2. The ESATTO Framework

2.1 Requirements

Before looking at the structure of the framework, it is fundamental to understand which have been the major requirements driving the definition of functionalities to be embedded and consequently the overall layout of the framework.

The ESATTO Framework shall be able to reproduce all the case studies foreseen in the H2020 MORE&LESS project. The project has been conceived to encompass a set of meaningful real case-studies to be further analyzed, at first, by the different disciplines through analytical and numerical modelling and tests and then to evaluate the environmental impact of these aircraft concepts through the holistic framework. To further extend the validity of theories and models, the entire spectrum of supersonic speed regimes ranging from Mach 2 to Mach 5 is considered. Moreover, the analysis is not only restricted to aircraft using traditional hydrocarbon fuels, but it moves beyond, addressing aircraft concepts exploiting alternative fuels, such as bio-fuels and cryogenic fuels. The idea of considering more case-studies with different configurations, performances, and fuels fosters the enhancement of the flexibility of the tools, which, starting from the case-studies, are developed based on modelling activities and test campaigns as products that can be flexible enough to be applied not to just one single aircraft concept. Figure 1 graphically depicts the case studies under investigation. In the full-length paper, additional technical details on the case studies will be included.

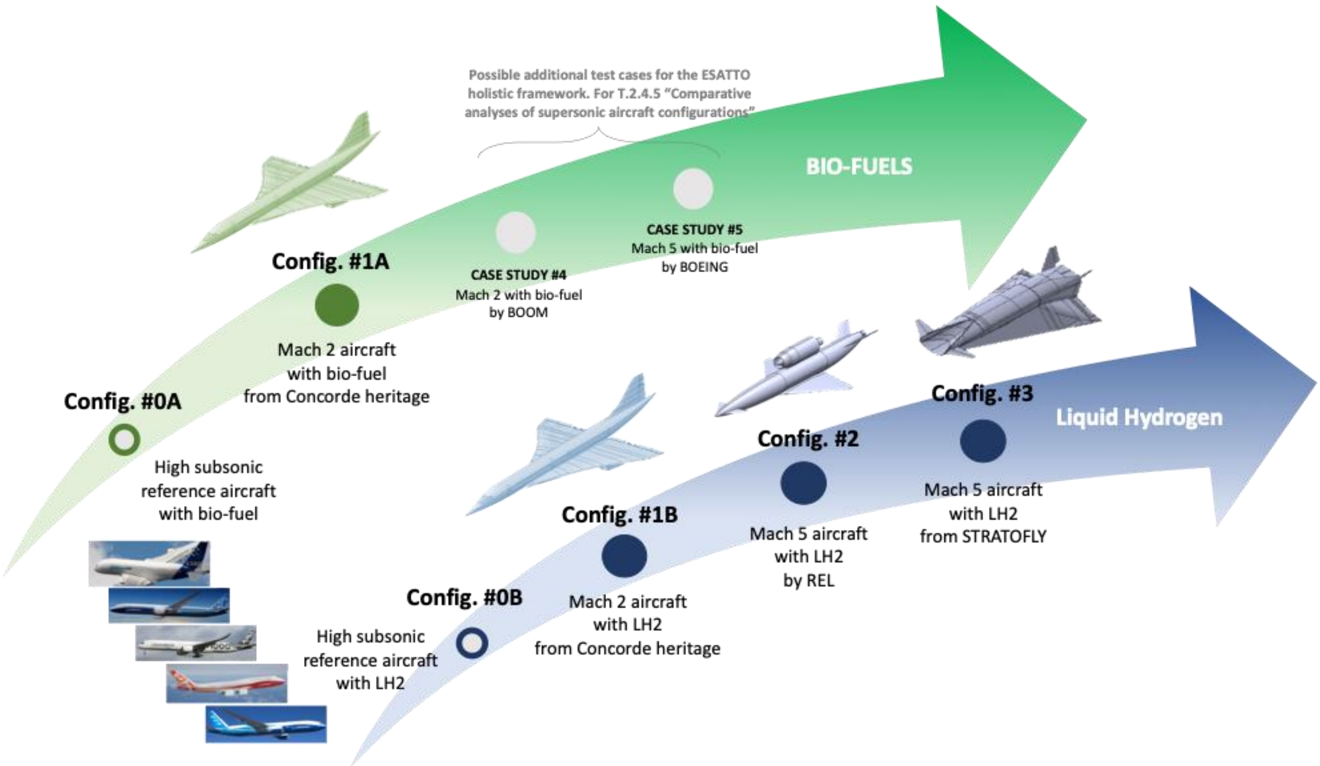

Figure 1 – H2020 MORE&LESS Case studies.

In accordance with the relative EC call, *the ESATTO Framework shall include accepted and/or validated software tools.* To achieve this goal, the various analytical, numerical, and experimental investigations carried out in MORE&LESS aim at upgrading and/or updating already available tools already developed and validated in previous EC projects, such as ASTRID-H [2] [3], HISAC [4] [5], and TCM, as well as proposing new routines to allow the future upgrade of internationally accepted tools

such as IMPACT and AEDT. In addition, *the upgrades shall be released as open-source routines, available to the entire scientific community*.
Moreover, it is worth noting that different from what is available in the literature, the ESATTO Framework does not aim at implementing any design optimizations; instead, *the ESATTO Framework shall guarantee multi-objective optimization of supersonic trajectory and operations to minimize the environmental impact.*

2.2 The framework

Based on the requirements described in the previous section, the ESATTO Framework has been conceived as reported in Figure 2.

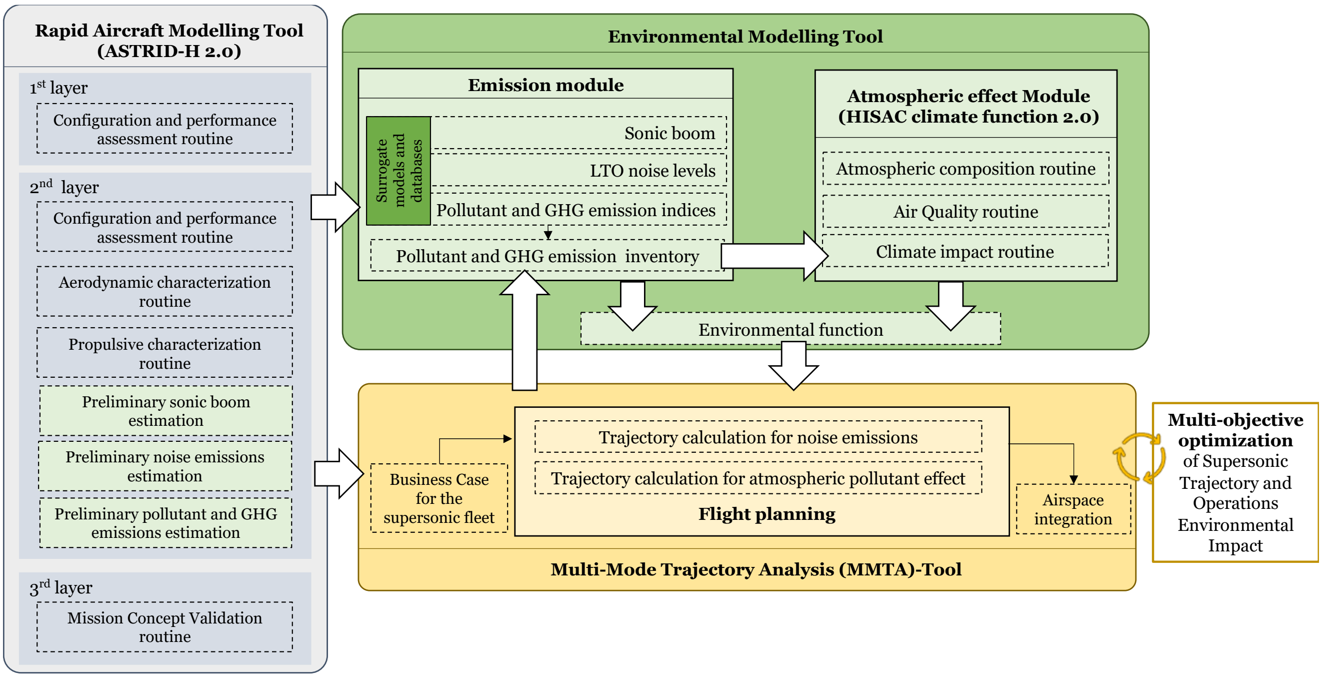

Figure 2 – ESATTO Framework.

ESATTO integrates three main modules: the Rapid Aircraft Prototyping tool (ASTRID-H 2.0), the Environmental Modelling tool, and the Multi-Mode Trajectory Analysis (MMTA)-Tool. Each module incorporates software tools that have been enhanced to broaden their applicability to supersonic case studies benefiting from the activities of the MORE&LESS project.

The initial step towards the application of the framework is the definition of the case study. ASTRID-H 2.0 serves this purpose, facilitating the rapid identification of a reference concept based on a specific set of requirements.

All the data related to the aircraft feeds the Environmental Modelling tool and the Multi-Mode Trajectory Analysis (MMTA)-Tool. The MMTA-tool is firstly applied to refine the initial trajectory from the reference mission profile in order to prepare all the data needed for the environmental analysis of the Environmental Modelling tool at both local and global level. The Environmental Modelling tool consists of the Emission Module and the Atmospheric Effect Module (HISAC climate function 2.0) to assess the environmental impact through a unique combined climate metric.

Secondly, the Environmental Modelling tool and the MMTA-Tool interact with each other to realize the multi-objective optimization process, aiming at identifying trajectories where environmental impact is minimized for the fixed design.

2.3 Rapid Aircraft Modelling Tool (ASTRID-H 2.0)

ASTRID (Aircraft on-board Systems sizing and TRade-off analysis in Initial Design) is a proprietary tool of the research group at Politecnico di Torino developed over the years to enable the conceptual and preliminary design of aircraft, as well as the sizing and integration of subsystems, primarily for aircraft that operate at subsonic and low supersonic speeds. ASTRID-H is an extension of this tool, designed specifically for high-speed vehicle applications. The latest version (2.0) has been tailored to address civil supersonic aircraft designs, encompassing the entire spectrum of supersonic speeds ranging from Mach 2 to 5, while also considering the impact of alternative fuels on aircraft design, in line with the objectives of the MORE&LESS project.

While upgrading towards ASTRID-H 2.0, efforts have been made to revise the conceptual design process to achieve more accurate estimates of high-speed aircraft performance and include preliminary evaluations of the environmental requirements. The proposed upgraded stratified structure is depicted in Figure 3.

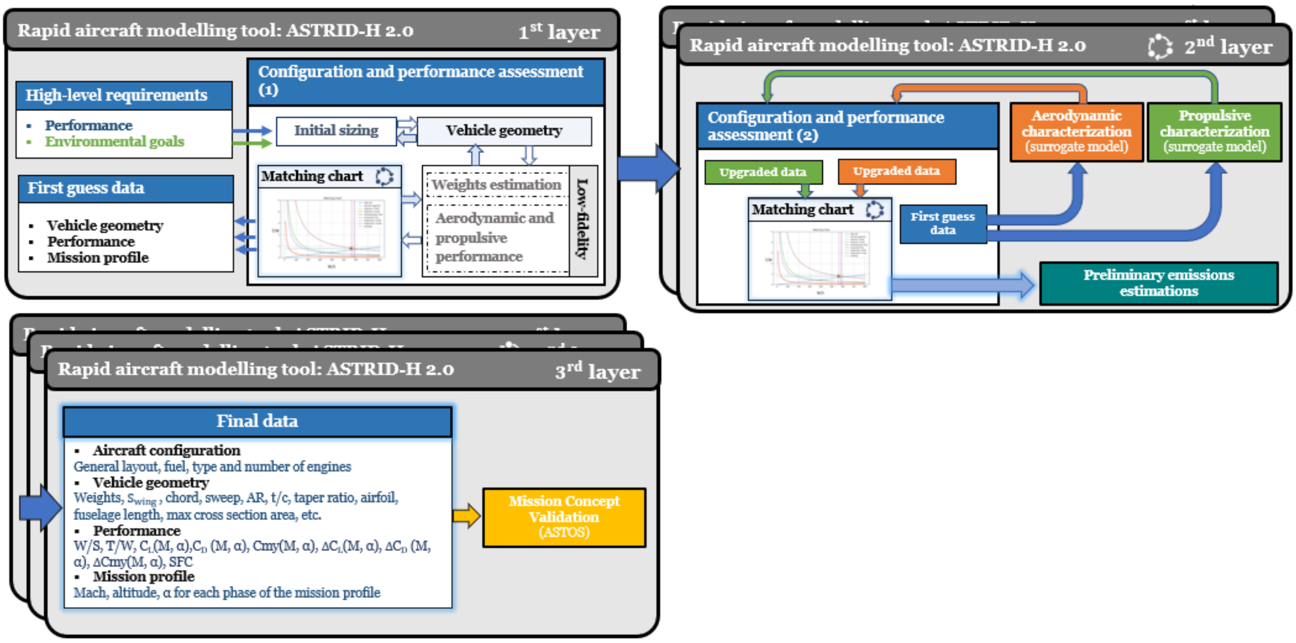

Figure 3 – ASTRID-H 2.0.

The first layer (Fig. 4) uses the high-level requirements and a statistical basis to initialize the first sizing, as well as to progressively move within the iteration loop dedicated to the conceptual design of the aircraft. This loop is based on low-fidelity algorithms, specialized depending on the aircraft configuration, that allow to evaluate the mass of the vehicle as well as its geometry within a proper convergence loop. At the same time, a design space in terms of thrust-to-weight ratio as function of wing loading is defined for the aircraft by means of a translation of mission requirements into performance and environmental requirements using the so-called Matching Chart approach, which ensure the representation of the design space itself and of the resulting design point in a simple 2D chart. The introduction of both performance requirements and environmental requirements ensure to produce, as output, feasible aircraft candidates for subsequent assessment in the ESATTO Framework. Conceptual design model is based on literature processes that use simplified characterization method to estimate the mass of the aircraft, while equation populating the Matching Charts [2] are derived according to aero-propulsive equilibrium in different mission conditions.

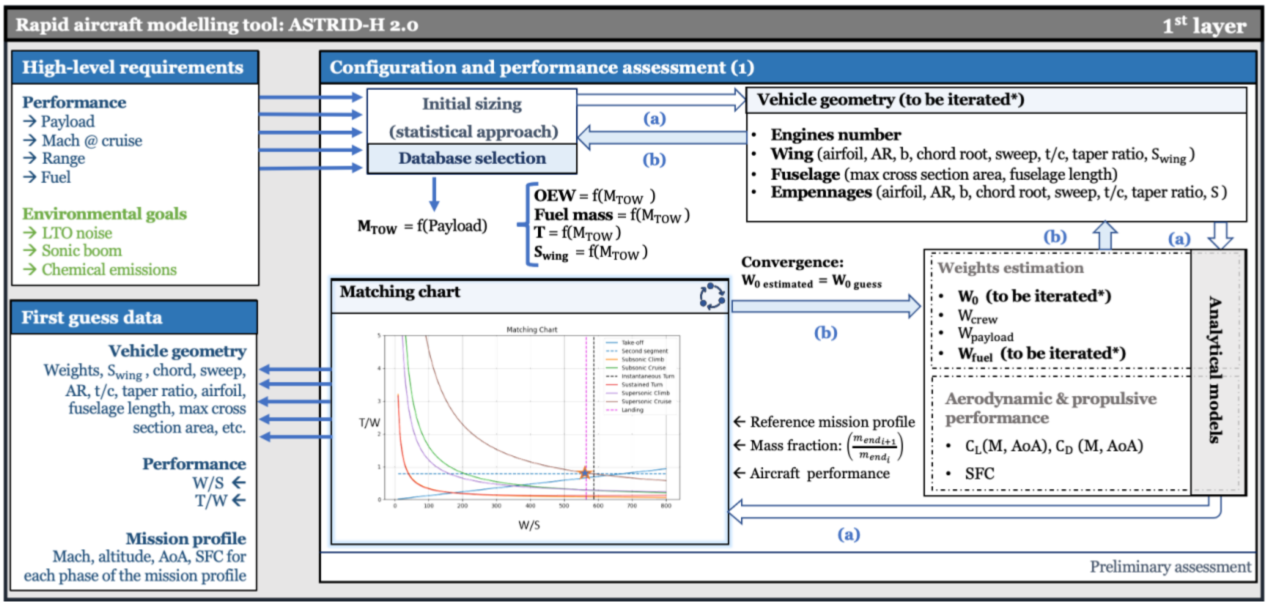

Figure 4 – ASTRID-H – 1st Layer

The second layer (Fig. 5) aims at refining the results obtained in the first layer by means of surrogate aerodynamic and propulsive surrogate models elaborated from the analyses carried out by the specialists of the project through numerical and experimental activities. These models are conceived as a flexible way to better estimate the related characteristics when applied to similar vehicles with reference to the one from which the original analysis was performed. They are expected to be much accurate than literature analytical model, still requiring a low computational power. The main reason to rely on surrogate models is that, even though the original generation of the model is time and resource consuming, the derived surrogate instance is much quicker to be applied, being more consistent with the idea of the rapid aircraft prototyping tool. For what concerns the surrogate models related to aerodynamics, the exploitation of data coming from the numerical and experimental assessment of selected case studies developed by the specialists in the project is fundamental [6-9]. A simple approach based on scaling laws has been developed and implemented. If the aircraft configuration is maintained, it is possible to rely on either global or lumped scaling based on mutual ratios of reference lifting and wetted surfaces, as well as on specific distances between reference points. For the general scaling, it is possible to obtain the reference aerodynamic database of the original vehicle, and apply the corrections to evaluate the updated coefficients

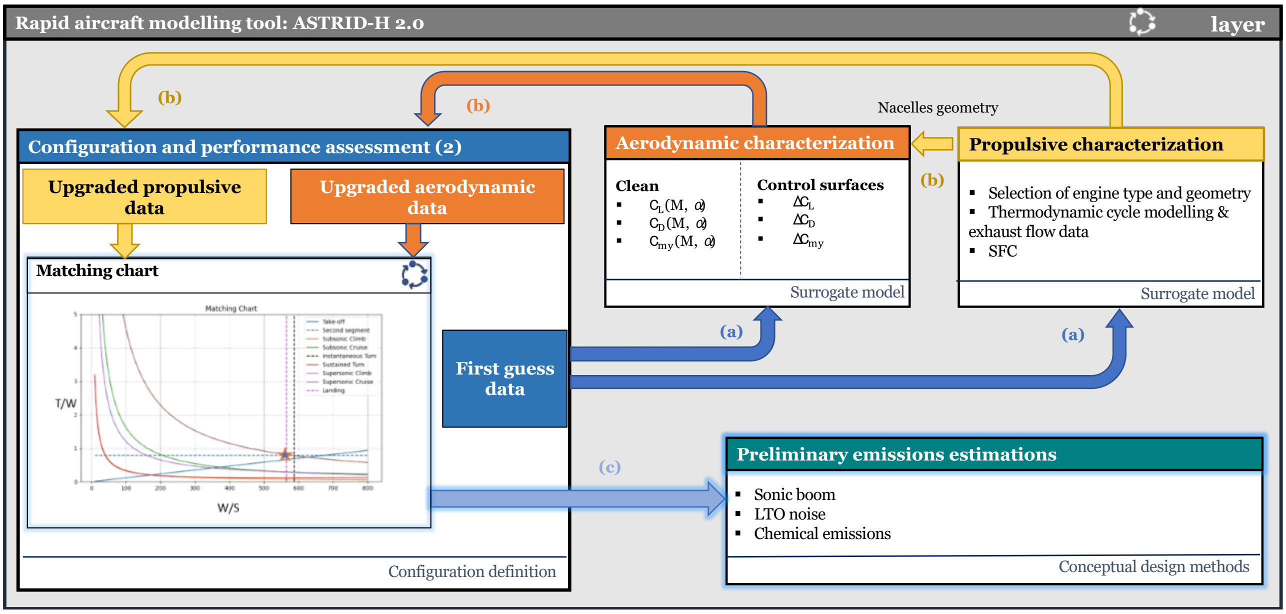

Figure 5 – ASTRID-H – 2nd Layer

On one side, the enhanced aero-propulsive characterization paves the way for the preliminary emissions estimation, which is carried out thanks to the derived analytical formulations for chemical emissions [10-12], jet-noise [13] and sonic boom level [14].
On the other side, it allows for a more accurate mission concept validation through ASTOS simulation (3rd layer) (Fig. 6). The opportunity to validate the concept within a more accurate mission simulation was judged to be crucial, especially for high-speed vehicles, because of the need of assessing the operational effectiveness in terms of fuel consumption as well as of requirements and constraints verification. Aero-propulsive characterization made up thanks to the surrogate models in the second layer will constitute the basis of the aero-propulsive database used to simulate the mission.

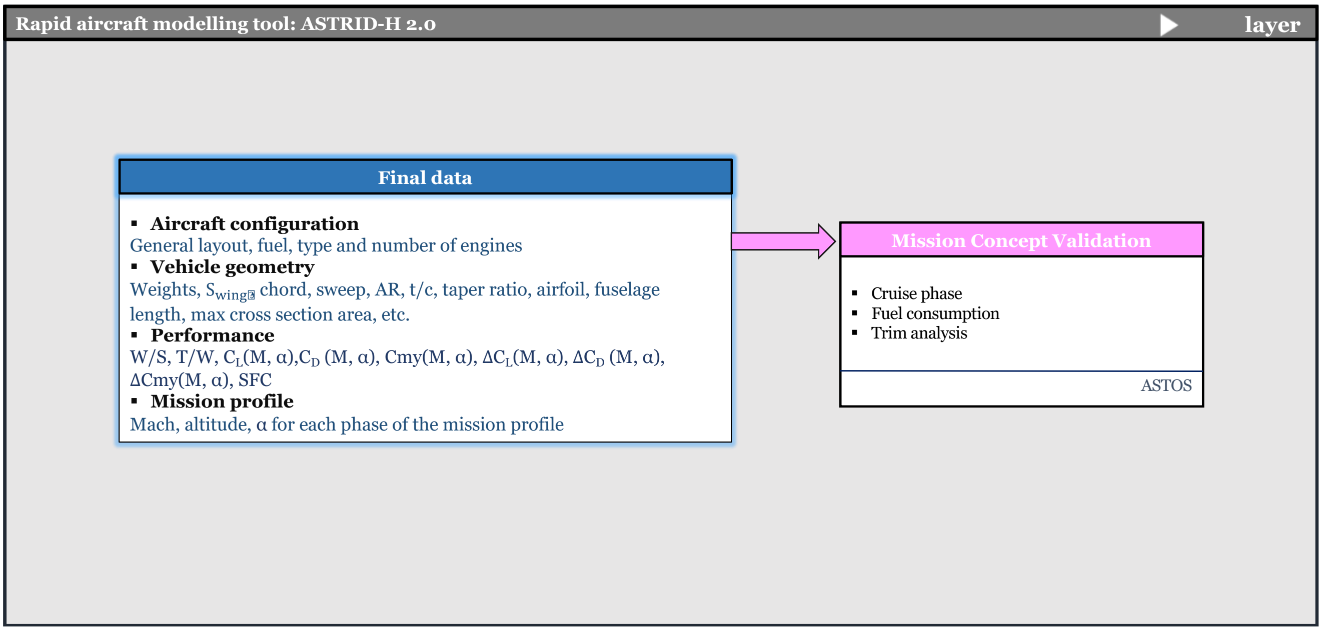

Figure 6 – ASTRID-H – 3rd Layer

As already said, a specialization of conceptual design models shall be made according to the actual vehicle to be analyzed. Moreover, according to the objective of WP6, the ASTRID-H 2.0 tool shall be able to perform the conceptual design of a wider set of aircraft in the supersonic regime (from around Mach 2 up to Mach 5), with respect to those analysed with high-fidelity simulations and experimental activities. This means that a certain flexibility in the conceptual design models shall be included to manage different configurations, powerplant arrangements and fuels. The drop-in stream includes traditional Jet A1 and Sustainable Aviation Fuels (SAF) / Biofuels in general, with similar energy per unit mass, thus not influencing the aircraft layout in terms of storage issues. From Mach 2 up to Mach 4 a conventional “Concorde-like” configuration has been hypothesized for the sizing loop, while for Mach numbers higher than 4 a blended/waverider layout is considered. Similarly, from the powerplant point of view, from Mach 2 to Mach 3 a turbojet/turbofan architecture can be considered, while for higher Mach numbers a combined cycle engine (e.g. Air Turbo Rocket, ATR) + Ramjet assembly is selected. Three main routines are under development for the drop-in stream to characterize the three flight regimes, while two algorithms are under study for the cryogenic stream, using the same approach for configuration and powerplant management (with the potential extension of the intermediate routine from drop-in stream to cryogenic stream as well).
In summary, the main differences between the routines are associated to the actual vehicle configuration, the type of powerplant and the type of propellant, the latter inducing also additional constraints in terms of layout definition. The process, however, is the same for all combinations, while the algorithms are specialized in order to be able to catch the peculiarities of each design combination.

2.4 Environmental Modelling Tool

The second module of the ESATTO Framework is the Environmental Modelling tool. The goal of the framework is to develop commonly agreed approach to define an objective function to be used in the trajectory optimization of a supersonic aircraft, by minimizing its environmental impact through a thorough analysis of the flight's effects on the environment at local, regional, and global scales. To achieve this objective, various surrogate models are currently under development based on the findings from other high-fidelity and experimental activities, encompassing combustion and emissions test campaigns, air quality and climate impact modelling, etc. The surrogate models will initially estimate individual environmental impacts and subsequently integrate different metrics for optimization purposes.

Looking at the chemical emissions surrogate model, advancements have been made for the especially for the hydrogen fuelled configurations. In particular, for the cryogenic hydrogen-fuelled case-studies, the development of the surrogate models benefits from the previous building of the related Emission Database for each configuration achieved through medium fidelity 0D/1D chemical kinetic simulations carried out at parametric thermodynamic and flow pre-combustion operative conditions, defined in agreement with the mission trajectory. This approach has been selected as the optimal trade-off between the available precision of the calculated emission indexes and the required computational cost. The accuracy and reliability of the medium fidelity 0D/1D methodology has been assessed through a first numerical comparison between computational tools of different accuracy and complexity operated in the same geometrical and boundary conditions. This preliminary verification consisted of the matching between the average NO mass fraction predicted by a high-fidelity chemical/physical CFD-LES simulation performed on an experimental test rig by the University of Lund (see Figure 7) with the same kind of value achieved by a Cantera run using the Perfectly Stirred Reactor model under the homogeneous premixed assumption and the identical kinetic mechanism i.e., Z22_NOx20.

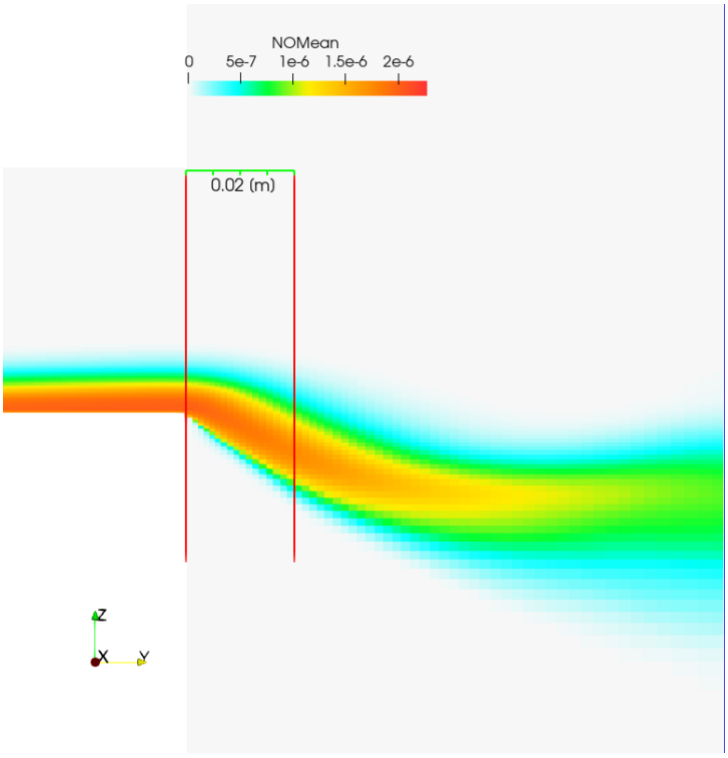

Figure 7 – Contour plot of the NO mass fraction calculated by the University of Lund CFD-LES simulation of an experimental single-injector combustion test rig at DLR.

The 0D/1D simulation has been conducted starting with the same pre-combustion conditions i.e., hydrogen and air inlet temperatures, pressures, and composition. However, the mass flow rate of the fuel in the 0D simulation has been suitably scaled down to account for the volumetric size of the effective combustion zone in the real test diffusive rig.
A scaling factor of 1200, which is equal to the ratio between the overall experimental facility

combustion chamber volume and the actual volume of the diffusive combustion region around the injector element, has been implemented in the 0D simulation. It is worth noting that in avoiding this scaling proportion, the 0D kinetic simulation fails to ignite the reacting mixture since the mixture ratio is outside the flammability limits for the hydrogen/air system at the examined operative conditions. Instead, the adoption of this reasonable hypothesis allows the achievement of a mass fraction of NO of the same order of magnitude as the outcome of the LES simulation i.e., 10^{-6}.

In Table 1, the values of NO mass fraction computed around the injector element in the segment included by the two red lines traced in Figure 4 by the CFD-LES simulation and the outcome of the 0D Cantera run are reported.

	Y_{NO}
0D Cantera	$1.10\ 10^{-6}$
CFD-LES	$1.90\ 10^{-6}$

Table 1. NO mass fraction comparison

The second step of the validation process will consist of the comparison between the CFD-LES outcomes and the experimental measurements.

The <u>surrogate models for jet-noise</u> and particle emissions will generate input data in ANP (Aircraft Noise Performance) format and the Engine Emissions DataBank format, respectively. Those datasets can be utilized in ICAO-CAEP validated models such as IMPACT and AEDT. Additionally, the results can offer guidance on extending the models of such tools towards supersonic speed regimes and innovative propellants, e.g., Sustainable Aviation Fuel. Currently, the models usually only apply for conventional aviation fuel and subsonic aircraft.

For the evaluation of <u>sonic boom</u>, a simplified estimation routine is under development. The Carlson method has been evaluated. It is a simplified methodology for estimating characteristic sonic boom parameters, such as peak pressure and signal duration of an N-shaped shock wave on ground. Additionally, lateral cut off (azimuth) angles and the geometric position of ground intersection of the sonic boom shock wave front can be estimated under the assumption of an International Standard Atmosphere (ISA). The predictions showed no significant errors in comparison to the results of the high-fidelity toolchain for sonic boom modelling implemented in the project. The high-fidelity toolchain consists of CFD simulations of an aircraft configuration in the near-field and a ray tracing solver, coupled with a lossy, non-linear wave propagation model (Augmented Burgers Equation) for the far-field propagation. In addition to the implementation of the Carlson method, a new algorithm (namely the Hybrid Whitham method) was derived to support the sonic boom experimental test campaign, which is published under the name. This method extends the classic Whitham theory for linearized shock wave propagation and allows up-scaling of the projectiles used for the outdoor sonic boom test campaign. The method could be used for the surrogate model as well. Future comparisons of the predictions to the high-fidelity toolchain, as well as a possible merging of different models (e.g., nearfield modelling with a simplified linearized theory; far-field modelling with a non-linear theory) have been discussed. Moreover, the lack of an established metric to correlate with the annoyance of sonic boom, or in a more mathematical sense, the cost of sonic boom yet has to be highlighted. The open questions in that matter are more of a psycho-acoustic nature, such that the results from the project cannot give more insights, than the literature already available. Possible candidates for the output variable of the simplified sonic boom algorithm are: Stevens' Mk VII Perceived Level of Noise in dB (abbreviation: PL; an industry standard for sonic boom loudness especially in the U.S.), Sound Exposure Level with frequency weightings B or D in dB (abbreviation: SEL(B) or SEL(D); standardized acoustic metrices that correlated to sonic boom loudness), the peak pressure in Pa and signal duration in seconds and of an N-shape shock wave (assuming an N-wave, i.e., no low-boom configuration), or even geometric properties, such as carpet width of a primary sonic boom carpet in meters. Last but not least, the possibility to use geometric sonic boom carpet predictions or simplified N-wave predictions as a direct constraint for the trajectory calculation has been considered. In this sense, the sonic boom would not be part of the emissions module, as its output would not feedback into the optimizer, but would return directly to the trajectory calculation module MMTAT, such that only trajectories are computed, who do not expose landmasses to the sonic boom.

The other component of the Environmental Modelling Module is the Climate Function. The Climate Function, originally established in HISAC, will be enhanced by incorporating evaluations of ozone layer changes and Local Air Quality assessments. In particular, the Local Air Quality routine provides guidance on the input data necessary to run emissions and dispersion modelling around an airport, using already existing ICAO-CAEP approved air quality models, such as LASPORT or Eurocontrol's OpenALAQS. The guidance includes updated flight profiles and emissions indexes for the supersonic aircraft under consideration, as well as for the subsonic aircraft fleet. In addition, it addresses any other factor that could influence air quality around an airport, such as non-aircraft emission sources and the meteorological conditions.

In practice, to conduct an air quality study around an airport, considering the introduction of a Supersonic Aircraft with known characteristics, several steps must be undertaken. After selecting an airport, it is necessary to retrieve general information, such as the airport's layout (such as the locations of runways, stands, taxiways, non-aircraft related emission sources, SIDs/STARs), details about the subsonic aircraft fleet, and the meteorological conditions for the study period. Subsequently, outputs of the ESATTO framework will be exploited as follows:

- The characteristics of the Supersonic Aircraft under consideration will be used as an input in ASTRID-H, which will provide as an output the pollutant Emission indexes in the LTO cycle
- MMTAT will be used to get the departure and arrival flight profiles for the Supersonic Aircraft under consideration
- The Air Quality Routine's guidelines developed as part of HISAC 2.0 will be used to set-up the Air Quality model (eg. LASPORT).

At this stage, the model is ready for execution. One of the uses of such modelling exercise could be to compare scenarios with and without the supersonic aircraft, to understand what the impact on air quality could be after introducing a new generation of Supersonic Transport (SST) at an airport. Results can be compared both as emission inventories and as pollutant concentration maps, as reported in Fig. 8 for a case study performed at Paris Charles-De-Gaulle airport as part of the MORE&LESS project.

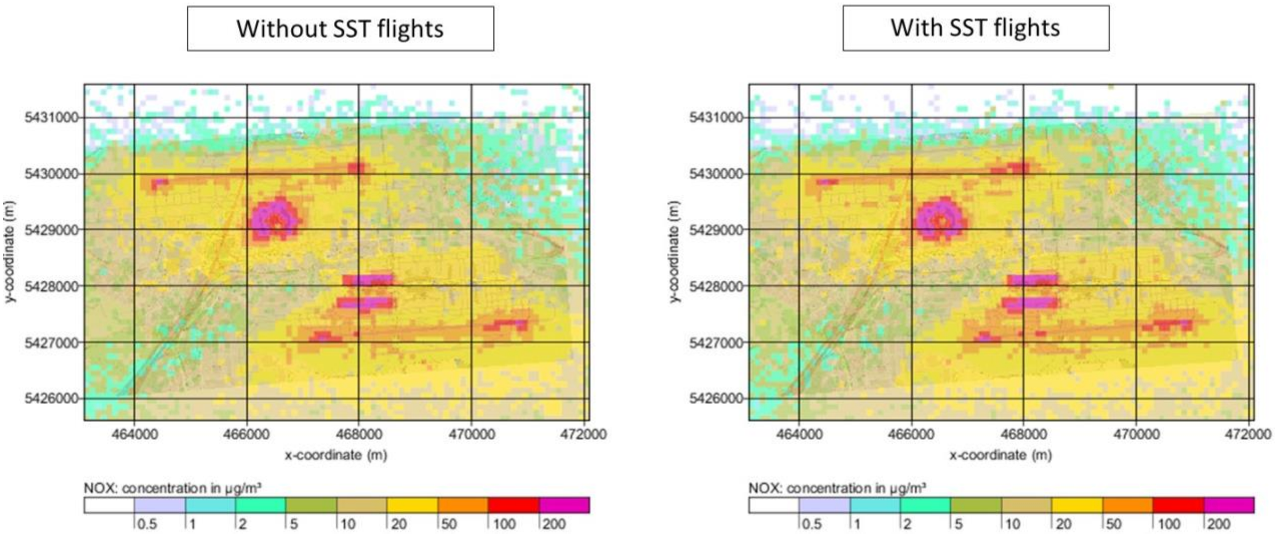

Figure 8 –Resulting NOx concentration for the two scenarios

2.5 Multi-Mode Trajectory Analysis-Tool (MMTAT)

The third module within the ESATTO Framework is the **M**ulti-**M**ode **T**rajectory **A**nalysis **T**ool (MMTAT), which has been developed at the Institute of Air Transportation Systems (ILT) at Hamburg University of Technology (TUHH). It is capable of calculating realistic 4D-trajectories of current subsonic airliners (mode A) as well as supersonic (Mach 2; mode B) and hypersonic (Mach 5; mode C) aircraft concepts based on numerical simulations. These 4D-trajectories represent the physical space curve (3D) along which the aircraft is moving as a function of time (1D) containing the complete history of the aircraft's state vector as well as all variables that collectively describe the overall model state at any given point in time, e.g., the engine mass flow or the ambient pressure. Gaseous engine emissions being released along the aircraft's trajectory can be analyzed using engine specific emission indices provided by the environmental modelling tool (refer to section 2.4). Since these indices are given in units of g/kg, i.e., mass (g_i) of the exhaust gas product of a species i per kilogram of burned fuel, they are multiplied with the fuel consumption profile to determine the 3D emission profile of the particular species. These 3D emission profiles will then serve as the foundation for assessing the environmental impact of the respective aircraft concept. A schematic structure of the MMTAT is presented in Figure 9:

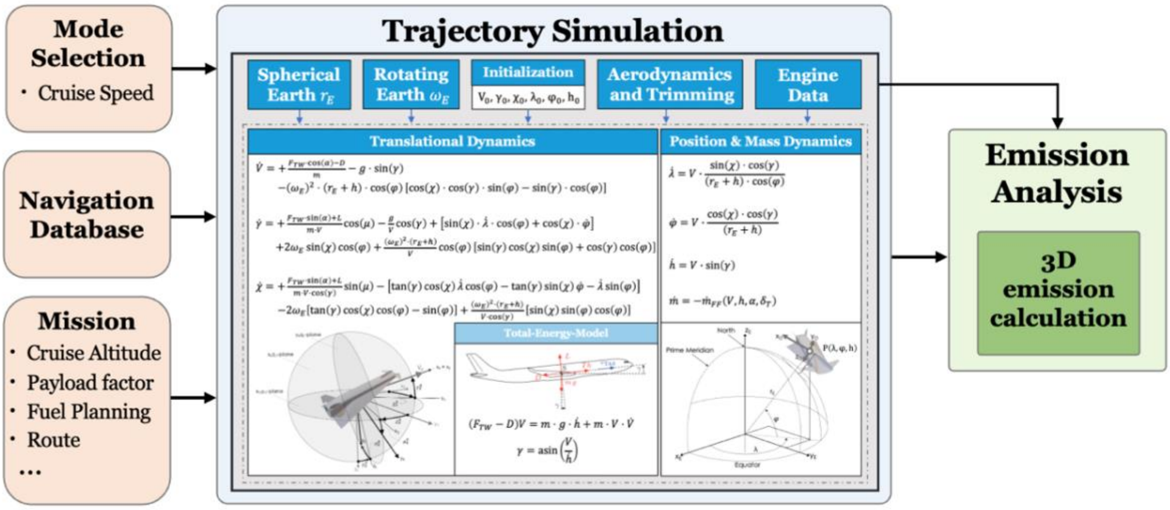

Figure 9 – Schematic overview of the Multi-Mode Trajectory Analysis Tool (MMTAT)

Mode A employs the state-of-the-art **T**rajectory **C**alculation **M**odule (TCM) [15] software which allows to simulate subsonic aircraft movement from lift-off to touch-down by applying simplified equations of motion, known as the Total-Energy-Model [16]. The geodetic longitude, latitude, and altitude form the aircraft's position state variables, whereas the true airspeed, course and climb angle compose the aircraft's translation state. This simplified flight mechanics approach has proven to be fully sufficient for the purpose of large-scale mission simulations and complies with today's regulations of Air Traffic Control (ATC), regarding speed and altitude constraints, such as maintaining a speed limit of 250 kts below FL100 (10 000 ft). The TCM uses tabulated target and exit conditions to establish linear control laws for each flight phase. This approach allows for flexible adjustment of speed schedules and flight levels to accommodate particular requirements of the ATC. Since aerodynamic and engine databases are similar to the Base of Aircraft Data (BADA) in version 4, it is possible to calculate flight movements for a variety of conventional aircraft types, as e.g., Airbus A380. Additional information and theoretical basics of the software can be found in [17] and [18].

Mode B and C of MMTAT employ the **H**ypersonic **T**rajectory **C**alculation **M**odule (HTCM) [19] software that incorporates a detailed modelling of the intricate mechanics of super- and hypersonic flight, which causes distinct phenomena that are not present in subsonic aircraft movements, such as fictitious forces due to the curvature of Earth. Within these modes, special emphasis is put on guaranteeing a sufficient numerical calculation accuracy of super- and hypersonic aircraft movements that enables a realistic implication of fuel consumption for a single flight mission, which can subsequently be scaled to a global fleet level. Therefore, the HTCM simulates the aircraft movement from lift-off to touch-down based on a nonlinear 3-degree-of-freedom (3DoF) point mass model in which the equations of motion are solved numerically using Euler's method. Processed flight performance data from the ASTRID-H tool in version 2.0 (refer to section 2.3) is incorporated. It provides the aerodynamic behavior and engine data of the specific Mach 2 or Mach 5 vehicle configuration. As it is shown in Fig. 4, the flight-path velocity, the flight-path azimuth and inclination angles are forming the aircraft's translational state, whereas the position and mass dynamics are described by the time derivatives of the geocentric latitude, longitude, and geometric altitude as well as the engine's mass flow. To guide the 3D aircraft movement in lateral (2D) and vertical (1D) direction, a closed-loop control system is embedded within HTCM that affects the aircraft dynamics by a feed-forward thrust force control as well as a virtual pseudo control vector which is resulting from the linear feedback laws of the navigation, speed and flight-path controller and is bounded by limiters. To define the (commanded) aircraft reference states for translation and position control in each flight phase of the mission a path and state generator is used.

To assess the noise being generated by super- and hypersonic aircraft at airport level during take-off and landing (LTO) operations, the capabilities of the HTCM software presented in [19] were extended in the scope of the MORE&LESS project to be able to simulate the lift-off of the aircraft including the acceleration phase on the runway.

3. Conclusions and Future work

This paper summarizes the main activities carried out in the H2020 MORE&LESS Project to provide the Scientific Community with an integrated multi-disciplinary framework consisting of validated and accepted tools to holistically assess the environmental impact of supersonic airplane on the future global air navigation system. This framework, named ESATTO Framework, supports the definition of new environmental standards for supersonic aviation, focusing on noise emissions, that encompass jet noise during Landing and Take-Off (LTO) operations as well as sonic boom, pollutant emissions, and climate impact. The paper summarizes the status of the framework development. Currently, all major routines have been defined thanks to the results of high-fidelity simulations and experimental activities. In the next months, the framework will be formalized thanks to the open source AGILE MDO Suite developed during the H2020 AGILE project and currently exploited and improved in the follow-up H2020 AGILE 4.0. The overall platform will be set up allowing for the multi-objective optimization of Supersonic Trajectory, Operations and Environmental Impact. In particular, considering the complexity of the framework due to the high number of tools and their diversity, special attention will devoted to cross-organizational aspects and to the management of data models, defining proper standards to ease and guarantee data-exchange among the different tools.

Acknowledgment

This work has been carried out within the frame of “MDO and REgulations for Low boom and Environmentally Sustainable Supersonic aviation” (MORE&LESS) project. This project has received funding from the European Union’s Horizon 2020 research and innovation program under grant agreement No 101006856.

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