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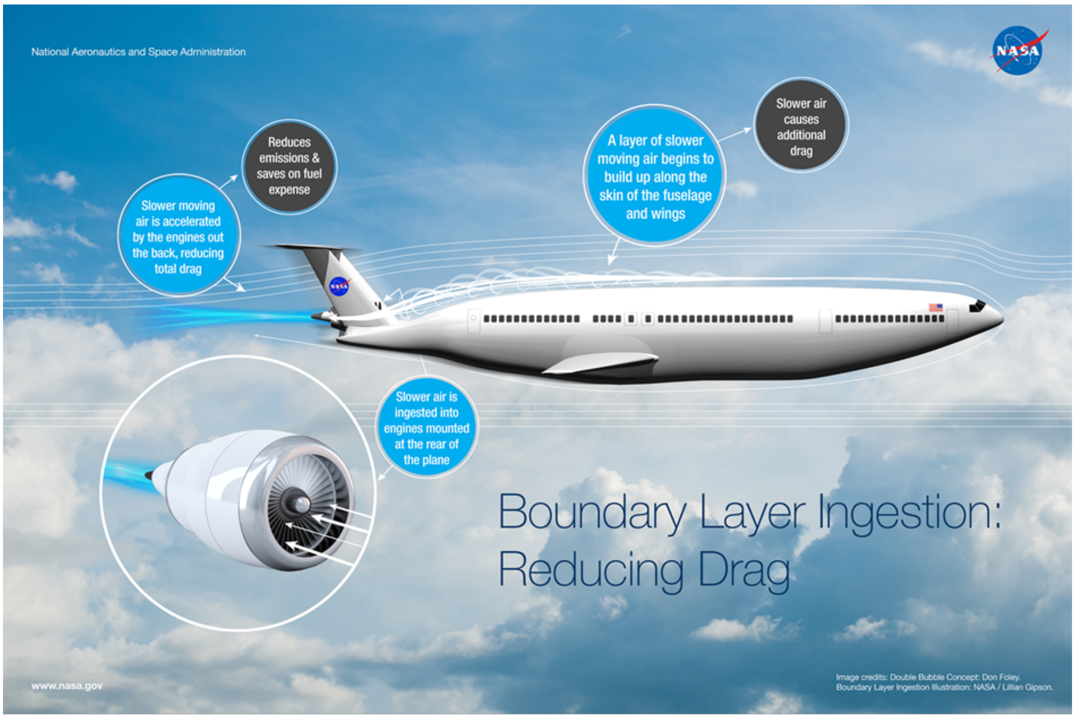
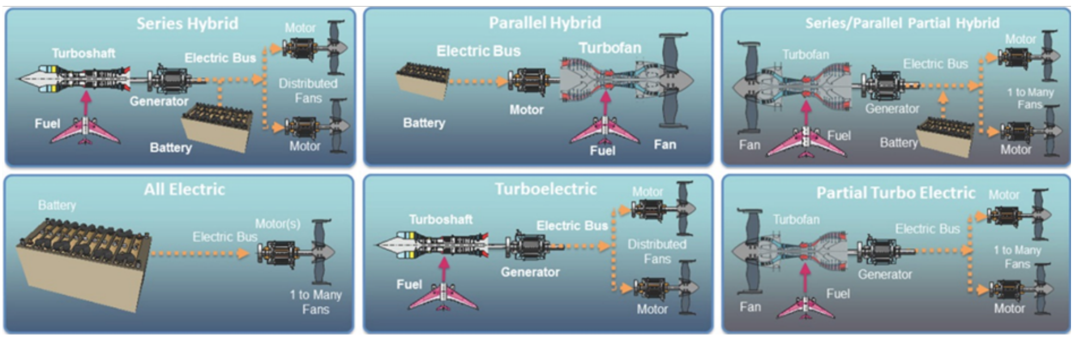
METHODOLOGY FOR PRELIMINARY SIZING OF AIRCRAFT WITH HYBRID-ELECTRIC PROPULSION AND BOUNDARY LAYER INGESTION

DESCRIPTION:

Contemporary environmental and economic circumstances impose a necessity to rethink the civilian aeroplane design, and most importantly its propulsive system. The most prominent candidates for more fuel efficient future propulsive systems are **Boundary Layer Ingestion ("BLI")** and **Hybrid-Electric (Distributed) Propulsion**. The goal of this project is development of a methodology for **preliminary sizing** of an aeroplane that can employ a **hybrid-electric and/or BLI propulsion**.



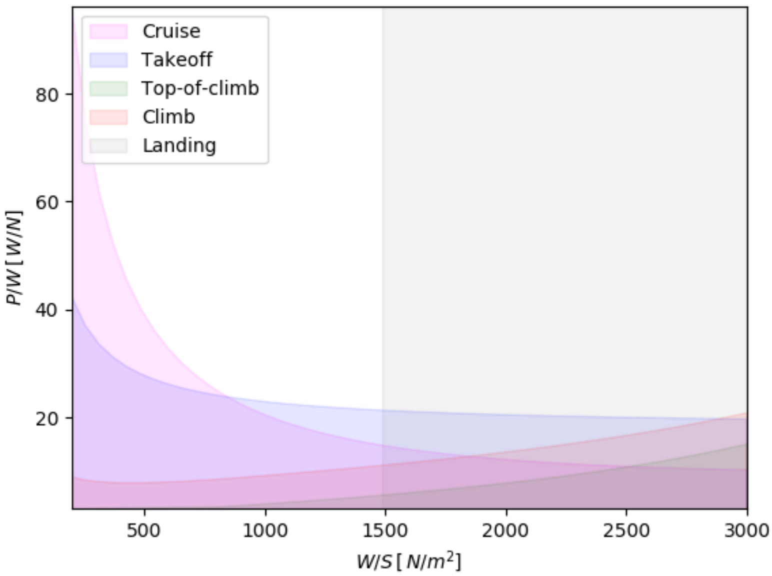


(above) Example of a BLI aeroplane concept[1];
(below) schematic representations of possible hybrid-electric propulsive architectures[2].

[1] https://www.nasa.gov/aero/reduce-fuel-burn-with-a-dose-of-bli/

Preliminary sizing is the calculation loop which allows an initial identification of the design space that responds to the provided top level requirements (i.e. mission specification) for the aeroplane. Macroscopic performance parameters such as (among others) preliminary drag polar, weight breakdown and thrust/power loadings are typically the target output of a preliminary sizing.

A working version of a methodology to treat the two indicated propulsive system families has already been established at the Department of Aerodynamics, Energetics and Propulsion (DAEP) at ISAE-SUPAERO; this tool will be used as the starting point for the current work. The tool is modular in nature, and enables a parametric description of various hybrid-electric propulsive architectures, as well as propulsive power production under BLI. Important developments to be verified and further developed include power equations for a generic hybrid architecture space, as well as a preliminary range equation for hybrid-electric aeroplane. The developed tool takes the user input in terms of desired mission profile and top level requirements (passenger number, payload, cruise speed, etc.), and produces a constraint diagram which allows for the aeroplane design point selection in terms of characteristic propulsive power, max takeoff weight and wing surface. (example in the image below)



Example of design space (white) identification in terms of power loading and wing loading on the so-called "Constraint Diagram", obtained for a hybrid-electric PC12 type aircraft application case.

Given that the current work is derived from an existing semi-empirical methodology, it was chosen to not attempt to change its nature in that respect. However, for that reason, there remains an important limitation to it with respect to obsolescence of many empirical factors used traditionally in the sizing equations, due to technological evolution assumed for the hybrid-electric and BLI systems. Therefore, additional methods have been implemented in the current tool, which enable the user to draw the parameter values from external databases; a part of the work will revolve around further development of this approach.

[2] National Academies of Sciences, Engineering, and Medicine (2016), "Commercial Aircraft Propulsion and Energy Systems Research: Reducing Global Carbon Emissions", National Academies Press, Washington, DC, USA. DOI: 10.17226/23490.

Once completed in the long run, the resulting methodology shall enable performing preliminary sizing of any aircraft to be equipped with the range of propulsive technologies that, depending on the objectives of the user, span:

- From classic gas turbine (turbofan);
- Through either turbofan with BLI or HE distributed propulsors separately;
- To a combined BLI and HE propulsion.

The internship is done within the scope of **"AEGIS"**, collaborative research initiative between ISAE-SUPAERO (DAEP) and SAFRAN, which deals with questions on preliminary modelling of integrated aeroplane propulsion.

EXPECTED OUTPUT:

- Advanced and consolidated next version of the preliminary sizing tool, with improvements relative to the current state (among other possibilities):
  - Range equation for the hybrid-electric aeroplane,
  - More coherent integration of BLI-related physics,
  - Including non-propulsive powers in the performance calculation,
  - Including battery recharge possibilities in the performance calculation,
  - Database handling for model initialisation and calculation of regression parameters.

REQUIRED SKILLS:

Useful theoretical knowledge: aeroplane sizing/design; aeroplane propulsion, aerodynamics, certification, aircraft systems, on-board energy management, and aeroplane structures/weight analysis are welcome.

Useful technical skills: coding in Python (indispensable), database handling in SQL (useful, optional); multidisciplinary analysis, numerical mathematics (useful, optional).

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