IAF SPACE SYSTEMS SYMPOSIUM (D1)
Interactive Presentations - IAF SPACE SYSTEMS SYMPOSIUM (IPB)

Author: Mr. Tommaso Molinari
Politecnico di Torino, Italy

Ms. Valeria Borio
Politecnico di Torino, Italy
Dr. Roberta Fusaro
Politecnico di Torino, Italy
Prof. Nicole Viola
Politecnico di Torino, Italy

# DEVELOPMENT OF AN INTEGRATED MULTI-FIDELITY TOOL FOR THE PRELIMINARY DESIGN OF A SINGLE-STAGE-TO-ORBIT VEHICLE

**Abstract**

Despite the technological progress made since the beginning of space exploration, to date space launchers remain prohibitively expensive and their low reliability compared to commercial aircraft stands out as the main obstacle to future space exploration plans. To address these challenges, future launch vehicles necessitate a paradigm-shift towards more reusable and sustainable assets. In the current fast evolving landscape of competitive launch vehicle design, the development of a dedicated Reusable Launch Vehicle (RLV) design methodology becomes crucial. This work aims at devising an innovative highly-integrated multi-fidelity tool to support the preliminary design of reusable access to space and re-entry vehicles. Specifically, given the great number of possible RLV configurations, this work outlines the development steps towards an innovative sizing methodology for a Single Stage to Orbit (SSTO) vehicle with Horizontal Take-off and Horizontal Landing (HTOL) capabilities. Beginning with the elicitation of mission requirements, constraints, and initial assumptions, the methodology encompasses considerations such as vehicle geometry, propulsion strategy, and technological availability from which a series of conceptual configuration alternatives are defined. These configurations are complemented by initial estimates of dimensions and performance based on statical data in order to determine the technical feasibility of the planned mission. The iterative nature of this process aims at matching the hypothesized variables with the estimated ones, considering different Mach regimes, evaluating the thermal loads, and satisfying performance requirements across flight phases. During this highly iterative process, the definition of suitable propulsive configurations is critical to achieve the required thrust across different altitudes and minimizing propellant consumption. While this design procedure seeks convergence toward system volume and mass, a multiple-matching chart is developed to delineate the design space available for the chosen mission. Particular attention is also directed to the selection and the sizing of a Thermal Protection System (TPS) suitable for the intended mission. With the idea of subsequently integrating a graphical user interface developed in Matlab environment, this work provides a complete methodology and toolbox that contributes to advancing the conceptual design phase of future launch vehicles, essential for realizing cost-effective and reliable access to space. Eventually, the methodology and the developed tool are applied to the case study of the SKYLON vehicle, a future reusable SSTO spaceplane developed by Reaction Engines Limited (REL), which exploits the Synergetic Air-Breathing Rocket Engine (SABRE) technology, a combined-cycle engine able to cover the entire mission profile of the vehicle using liquid hydrogen as propellant.