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Author: Ms. Raquel Marey
Deimos Space SLU, Spain

Dr. Federico Toso
Elecnor Infrastrutture e Aerospaziale S.R.L., Italy
Mr. Giuseppe Guidotti
Deimos Space SLU, Spain

MULTIDISCIPLINARY VEHICLE DESIGN AND TRAJECTORY OPTIMISATION FOR THE PRELIMINARY SIZING AND PERFORMANCE ASSESSMENT OF REUSABLE LAUNCHERS.

Abstract

The trend of commercial space transportation is towards increasing degrees of launch vehicle reusability, with the ultimate goal of developing fully reusable vehicles.

The REVOLUTE project relies on European technologies in production or development, to establish a common ground for the future reusable launchers. The objective of the study is to identify the main building blocks and their technology challenges to reach a strong and competitive space transportation sector in Europe.

This paper proposes a methodology to obtain the design and optimised reference trajectory of launch vehicles for mission analysis purposes, developed in the scope of the REVOLUTE project. The vehicle is designed to achieve the reference mission objectives and be successfully recovered. A set of constraints are imposed on the launch vehicle design search-space by the current technological limits, such as the structural index and engine performances. A review of the current European launch market technological maturity and development roadmap is performed to define the performance indices and correlation between subsystems. While the reference mission of the study is achieving full reusability, the launcher mission envelope is further expanded to assess a partial or fully expendable vehicle. For the trajectory analysis, the ascent and recovery flights of all stages are jointly optimised, leveraging synergies. The ascent trajectory covers from lift-off to payload deployment. The re-entry trajectory is simulated to recover the first stage. The recovery of the second stage is sized by the de-orbit and landing ΔV requirements. The methodology is scalable to a wide variety of missions different from the reference one.

The vehicle definition is performed through a multidisciplinary design optimisation (MDO) approach, sizing the vehicle, and at the same time the trajectory is designed with the solution of an optimal control problem. A modular approach is followed, where the models for each discipline can be changed to accommodate several needs of model accuracy or computational runtime. The level of fidelity of the models used in this study is selected to be compatible with the computational load required for MDO. This approach makes use of Deimos Tool EndoSim (Endoatmospheric Simulator) to simulate both the 3dof ascent and re-entry trajectories, tracking the evolution of the structural and thermal constraints.

The outcome of the analysis provides a valuable insight on the vehicle's chances to compete in the market, comparing it with similar vehicles from other companies and organizations, underlying the potential of a future European launchers family.