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# LAUNCH VEHICLES MULTIDISCIPLINARY OPTIMIZATION, A STEP FROM CONCEPTUAL TO EARLY PRELIMINARY DESIGN

**Abstract**

A recent collaboration between Politecnico di Milano and Universität Bremen within ESA's PRESTIGE PhD program has stemmed a significant research effort in the field of Multidisciplinary Design Optimization (MDO) for launch vehicles. This work is aimed at the development of optimization algorithms and engineering methods for the conceptual and early preliminary design of launchers, potentially leading to relevant reductions in development costs and times. The implemented MDO approach allows to efficiently explore the design space throughout successive global and local, single and multiobjective optimization processes, guided by the engineering experience of the designer. The main obstacle to the successful application of MDO lays in the difficult task of finding a compromise between models simplicity and accuracy. To tackle this issue, the engineering models have been developed in two successive levels of detail, from conceptual to early-preliminary design. The paper first presents an overview of the conceptual level models, together with a quantitative assessment of their accuracy and of the disciplinary errors impact on global performance indexes. The models selection has converged towards well-known disciplinary tools (CEA and Missile DATCOM), complemented by ad hoc models in the following disciplines: propulsion, geometry, aerodynamics, weights, trajectory, guidance and control, costs estimation and reliability assessment. The validation has shown how system-level errors in the order of 20% can be expected, and has allowed identifying the most critical modeling aspects to be first improved. In a second part, the paper focuses on these model enhancements, in particular: solid grain geometric and internal ballistics analysis, pressurization systems and engine cycles modeling, simplified structural sizing and flexibility assessment, dynamic controllability, and safety-related analyses (boosters/stages fall-down, upper stage end-of-life). Besides, the concurrent optimization of different launcher configurations in the same family has been introduced, allowing for mission flexibility oriented design. Validation results of these early-preliminary models are presented in the paper, highlighting accuracy advantages in front of an increase in computational effort. The paper also presents a brief summary on a study for an expendable European Next Generation Launcher family. Starting from published requirements, several optimization iterations have led to a set of mass or cost optimal feasible design solutions. Obtained with less than two-week one-man and one-pc effort, these can be used as good starting points for concepts refinements with more traditional design methodologies. The foreseen future research lines are finally discussed, especially those aimed at targeting less traditional launch systems, such as manned and reusable vehicles.