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MULTI-DISCIPLINARY DESIGN OPTIMIZATION FOR LAUNCHER FAMILY DESIGN

Abstract

The design of new launch vehicles (e.g. ESA Future Launcher Preparatory Programme FLPP) is a very complex task, which is traditionally solved in an iterative process during which experts from various disciplines (structures, aerodynamics, guidance&control, propulsion) refine and update their subsystem designs until they converge to a consistent, good design. This process is motivated by the need for an optimized configuration that yields sufficient payload performance at minimum cost, while complying in full to the user requirements.

The key to an efficient and effective launcher staging optimization process is to tackle the problem as a multi-disciplinary design optimization (MDO) and not to decompose the system. The methodology of All-at-Once (AAO) optimization has demonstrated superior potential, when it comes to launch vehicle design, permitting the concurrent consideration of certain design choices not only towards the related subsystems, but also towards performance and feasibility of the overall system.

The presentation provides an overview of the latest multi-disciplinary optimization capabilities for launch vehicle design as currently under development in an ESA RD project with implementation in ASTOS. The objective of the activity is to mature the technology for industrial-grade utilization. Consequently, the focus is on key improvements of the existing framework on subsystem modelling and algorithmic cross-over layer.

In this regard, the presentation takes a close look at preliminary results in the following areas:

- Integration of a detailed stage structural model generator for metallic as well as fibre reinforced structures. Semi-analytic method for computation of mass and stress properties of tanks, interstages and other key structural elements in-the-loop;
- Automatic identification of critical load cases (ground, windgust, engine thrust, aerodynamic loads, tank pressure, mech. fluxes, motor/engine ignition and shutdown, thrust oscillations) out of a set of multiple mission scenarios;
- Launcher controllability analysis including identification of maximum static deflection of the thrust vector control (TVC), computation of COG/MOI and A6/K1 coefficients as function of time;
- Enhanced coupling and interaction of structure, aerodynamics, GNC and performance in the MDO (i.e. collaborative optimization) process,
- Exploitation of the WORHP/eNLP non-linear programming solver for AAO optimization;
- Sensitivity analysis for aerodynamic coefficients and investigation of alternative aerodynamics data generation methods;
- Consideration of critical load cases and TVC/general GNC constraints in the optimization process.

The MDO architecture is presented along with some results to illustrate the advanced capabilities of the MDO implementation in ASTOS for conceptual design of space transportation systems.