Paper ID: 64276
oral
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IAF SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Upper Stages, Space Transfer, Entry & Landing Systems (3)

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CONCEPTUAL STUDY OF TECHNOLOGIES ENABLING NOVEL GREEN EXPENDABLE UPPER STAGES WITH MULTI-PAYLOAD/MULTI-ORBIT INJECTION CAPABILITY

Abstract

The growing demand for cheaper space access calls for a more economically and environmentally sustainable approach for launchers. Concurrently, the shift to smaller satellites and the rise of constellations necessitate launchers capable of precise multi-payload/multi-orbit injection. ASCenSIon (Advancing Space Access Capabilities - Reusability and Multiple Satellite Injection), a Marie Skłodowska-Curie Innovative Training Network funded by H2020, aims to respond to these demands. This paper describes

the activities explored within ASCenSIon dedicated to developing novel green upper stages with multi-payload/multi-orbit injection capability. The aspects investigated here include the general system architecture, innovative solutions for the propulsion system (e.g. Hybrid Rocket Engines (HREs), green propellants and electric pump feeding), Guidance Navigation and Control (GNC) solutions for the multi-payload/multi-orbit injection capability, and reliability aspects of upper stages.

First, relevant mission profiles and their main requirements for upper stages are identified. Then, solutions for more environmentally friendly propulsion systems are proposed. Since identifying a good substitute for toxic hydrazine recently became a priority, the use of green propellant technologies will be assessed, tackling specific problems such as benchmarked propulsive performances, storability and material compatibility. Another promising solution for future propulsion systems with lower environmental impact are HREs. They bring benefits in terms of flexibility, safety, reliability and cost. However, high residual mass, oxidizer/fuel ratio shift during operation, low regression rate and combustion inefficiency are some of the challenges that still need to be addressed in their application. In addition, electric pump fed systems, powered by green propellants, may be a game-changer technology for future upper stages. Compared to pressure-fed, it can provide improved performance and lower inert mass. Regarding turbopumps, it may also be advantageous in terms of simplicity and costs. On the other hand, battery mass and thermal control represent some of the drawbacks to overcome.

Additionally, the implementation of novel GNC solutions is critical to ensure the multi-payload/multi-orbit injection capability. Different GNC solutions for launchers are presented, as well as an analysis on the optimization techniques for this challenging payload delivery. Finally, the reliability of the launchers is a key aspect to protect both the space environment and the safety of the missions. Novel methods for reliability modelling of launchers are discussed and advantageous system architectures are proposed.

These novel technologies being jointly assessed, this paper presents a preliminary analysis of the discussed topics and their interconnections within ASCenSIon, aiming at satisfying new requirements for novel green upper stages.