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ASSESSMENT OF PROPULSION SYSTEM ARCHITECTURES FOR GREEN KICK-STAGES

Abstract

Green Propulsion is a recurring trend in the space sector that has grown exponentially over the last decades. The researchers' shared goal is to find good alternatives to current liquid propellants, usually toxic and hard-to-manage during ground operations. The current toxic leading compounds are Hydrazine and its derivatives that covered and still cover a key role in the space propulsion arena: as a matter of fact, despite the well-known complications for incompatibilities with human health, and despite the dozens of proposed replacements, the propellants still have some advantages over many of the suggested alternatives and are commonly used. Over the years only a few replacement technologies matured enough to have actually flown, and many of them are still at a Technology Readiness Level of 5-6.

The main and natural application of green technologies is doubtlessly the in-space propulsion since the main features of long-term storability, stability and acceptable performance are a perfect match for engines working outside the atmosphere and far from the support of ground operations.

In this study, the identified most attractive technologies are evaluated on their applicability to upper stages. In particular, a specific class of systems, often referred to as kick-stages, are taken as reference. These systems are designed, as usually, to remain as light as possible to carry more payload, but concomitantly to be able to fulfil a very diverse type of missions. Between others: active space debris removal, multi-payload to multi-orbit delivery, in-orbit experiments with a few providers planning also the reusability and return to the ground.

It is clear that, in terms of propulsive system requirements, long-term storability and reliability are the crucial functions that grant the stage the capability of remaining in orbit for long periods. The analysis expands on possible integrations of different green technologies for these systems, outlining advantages and disadvantages. The comparison is performed considering different architectures and design choices and using decision-making tools such as the Analytical Hierarchy Process.

Particular focus is dedicated to the attainable performance with respect to required dry mass. By analysing the System Specific Impulse, the rate between the total impulse and the total propulsive system mass, it is possible the comparison of very different architectures, taking into account the extra weight that some technologies require for cooling, pressurization and storing. The different contributions are calculated or estimated.