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THE SELECTION OF AN ELECTRIC PROPULSION SUBSYSTEM ARCHITECTURE FOR HIGH-POWER SPACE MISSIONS

Abstract

The arise of high-power electric propulsion is paving the way towards new horizons of space exploration. Hall thrusters represent a promising propulsion concept, able to fulfil challenging mission requirements for both commercial and exploration applications. This technology offers several benefits in terms of flexibility of operation, extensive lifetime and high reliability. However, the design of a high-power electric propulsion subsystem (E-PROP) still presents challenges to address. Filling the corresponding technological gaps will open new market opportunities, owing mainly to the extension of mission capabilities and the reduction of the overall mission costs. Therefore, investigations of innovative technology alternatives will allow to identify the most promising E-PROP architectures for various high-power mission scenarios. One of the most critical trade-off to perform is between a high-power monolithic thruster and a cluster of thrusters of lower power. Another criticality is the amount of propellant necessary to perform high delta-v missions. The high price of xenon prompted the investigation on alternative propellants, such as krypton. The propellant selection should consider the impact on different aspects of the platform design, including performance, system complexity and mission costs. Last, due to the high-power levels that the E-PROP shall manage, a different architecture can be implemented by adopting the direct-drive approach, i.e. a direct and non-isolated connection between the solar array and the thruster. However, even if the disruptive direct-drive technology allows a significant reduction in the EP system mass and cost, its implementation rises additional challenges to the design of the spacecraft power subsystem. This paper analyses the impact of innovative architecture solutions on the design of a high-power E-PROP. In the framework of this research, we first carried out an extensive investigation of possible mission scenarios and we derived corresponding mission requirements and constrains. Then, we performed three technological trade-offs: monolithic 20 kW vs 5 kW cluster configuration, Xe vs Kr propellant and direct-drive vs standard PPU. We characterized each design option through several figures of merit, evaluating them for each identified mission scenario. We exploited an Analytical Hierarchy Process for the trade-off analyses and a Monte Carlo method to perform the preliminary evaluation of the trade-off weights. The analyses are based on the research activities that are currently ongoing at SITAEL and PoliTo in the framework of 20 kW E-PROP development programmes. The results of the work highlight the effects of each architecture alternative on both platform design and mission performance.