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A COMPREHENSIVE MODELING FRAMEWORK FOR INTEGRATED SPACECRAFT AND TRAJECTORY DESIGN OF AN ELECTRIC SPACE TUG

Abstract

Extended lunar stays build the experience and expertise needed for the long-term space missions required to reach the final goal, Mars. To achieve this exceptional goal, several technological gaps shall be fulfilled, improving and maturing critical technologies to future human exploration. Envisioning the presence of future deep space infrastructures, including the Deep Space Gateway (DSG), cargo transferring and in-orbit servicing become a major issue that could be enhanced by improved in-space propulsion capabilities and highly reliable, Autonomous Rendezvous and Proximity Operations. On one hand, high-power Solar Electric Propulsion (SEP) has been identified as a key enabler to propel cargo missions to Deep Space, in advance of crewed missions, much more efficiently than conventional chemical propulsion systems. Due to its high specific impulse and low thrust provided, SEP platforms have been recognized as a substantial improvement in transporting cargo, where relaxing the transfer duration for resupply and logistic modules is not time critical, also thanks to the fuel saving capability and considerable operation lifetime of electric propulsion. On the other hand, the advancement of robotics and autonomous systems will be central to the transition of space missions from current geocentric architectures to self-sustainable, independent systems. In particular, Automated Rendezvous and Docking (ARVD) represents the cornerstone of the future exploration scenarios, in which each mission architecture will heavily rely on the ability to rendezvous and mate multiple elements in space. In order to meet the exploration enterprise goals of affordability, safety and sustainability, this critical technology must become routine and autonomous. In this paper, a comprehensive modeling framework is presented to enable integrated trajectory and vehicle design for this high-power SEP space tug. The Lunar Space Tug (LST) is a reusable electric platform, which could represent a valid alternative to the actual resupply cargo ships adopting rocket engines, to deliver from a Geostationary Transfer Orbit (GTO) food, oxygen, water and fuel necessary to sustain the DSG crew and the station itself. The MATLAB/Simulink design tool is composed by three main routines: (i) MIssion and Space System (MISS), design tool for platform subsystems sizing; (ii) low-Thrust Trajectory Tool (TH3), sub-optimal trajectory propagator ; (iii) Simulated Trajectory for Automated Rendezvous (STAR), attitude and trajectory control strategies for ARVD in different environments based on Model Predictive Control (MPC). Main results on the LST sizing and low-thrust and ARVD trajectory in both GTO and Cislunar environments are discussed and main conclusions are drawn.