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OPTIMIZATION OF NUCLEAR THERMAL PROPULSION COOLDOWN PHASE USING REAL-TIME SIMULATIONS

Abstract

In this paper, the potential performance improvement of nuclear thermal propulsion (NTP) systems is measured, resulting from optimizing the amount of propellant expended during the cooldown period after the engine has been shut down. Legacy NTP designs did not thoroughly address the cooldown propellant mass flow profile, and instead implemented a vague closed-loop control system. Because such systems are reactionary in nature and greatly depend on the specific algorithm controlling the propellant mass flow rate, there is a strong potential for unnecessary propellant being wasted in such a configuration. The innovation in our new approach results from the use of real-time simulations, which predict the propellant-mass-flow required in order to maintain tie-tube components below their thermal and material thresholds. This methodology has been demonstrated in adjacent technologies (such as in nuclear power plants) for monitoring and decision-making purposes, and is applied here to the preliminary design of an NTP reactor core. Furthermore, NTP has been identified as a key element of future interplanetary human spaceflight missions, for example in the recent publication of the United States' National Academy of Science and Engineering related to Nuclear Propulsion and Human Exploration of Mars. Any improvements to the operational efficiency of the NTP system will have a direct and measurable impact on the rest of the spacecraft, such as an increase of payload capacity or reduction of propellant mass.