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NUCLEAR THERMAL PROPULSION (NTP) POST-BURN TRANSIENT: COOL-DOWN PROPELLANT CONSUMPTION AND ITS EFFECT ON TOTAL DELTA-V

Abstract

Nuclear Thermal Propulsion (NTP) is an enabling technology for both human and robotic missions to deep space destinations like Mars, because of its unique combination of high thrust and high specific impulse. One of the many important ways in which NTP is different from conventional chemical propulsion is the presence of decay heat, a phenomenon wherein the products of nuclear fission continue to release heat through radioactive decay for a period of time even after the engine is shut down. To remove this heat, extra hydrogen propellant must be fed through the reactor and exhausted out the nozzle after shutdown until the energy being generated has diminished enough to be removed by less wasteful means, such as an active heat removal system, a power generation loop, or passive radiation of heat to the environment. During the phase of engine cool-down where hydrogen is being spent, some impulse is exerted on the vehicle, though it is far less than is exerted during the full-power burn phase. This paper quantifies the extent to which the impulse from the engine cool-down phase affects an NTP vehicle's mission profile. It also examines how this impulse changes when heat removal systems or power generation loops are incorporated to mitigate cool-down hydrogen usage. Ultimately, it is shown that reducing the proportion of hydrogen spent during the engine cool-down phase can have a demonstrable benefit to mission performance, yielding more delta-v for the same total hydrogen supply.