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RELIABILITY ASSESSMENT OF NUCLEAR THERMAL ENGINE CONFIGURATION AND HEALTH MONITORING SYSTEM

Abstract

Today's space nuclear technology programs are often confronted with two fundamental challenges early in the project life cycle: 1) development and testing will be more expensive than a non-nuclear alternative, and 2) the consequences of failure will be more severe. As a result, many space nuclear programs have been designed to minimize testing and maximize their probability of success: their reliability. The United States' Nuclear Engine for Rocket Vehicle Applications (NERVA) Program recognized these facts early on, and by 1961 the program's primary objective set safety and reliability as the overriding considerations. This focus on reliability greatly influenced the engine's design towards minimizing the possible number of catastrophic failures modes. As such, the final configuration heavily relied on duplicate components for redundancy, including duplicate turbopumps. Despite these efforts, at program cancellation in 1972, the non-nuclear subsystem only achieved a mission predicted reliability of 33Some of the most significant contributions to rocket engine reliability in the last 50 years have been from advancements in the Health Monitoring System (HMS). Through rigorous instrumentation and control an engine's HMS has the potential to convert over 90Unfortunately, a standard liquid rocket engine HMS will likely not be compatible with a nuclear rocket engine (NRE). The HMS for a liquid rocket engine most often prevents catastrophic failure by shutting off flow to the combustion chamber. This would not work for a NRE, as removing flow to the reactor could result in reactor overheating and meltdown. Maintaining flow to the reactor is often essential for safe NRE operation, such that reliance on an advanced HMS system alone may not be sufficient. This work investigates the feasibility of an NRE HMS by comparing the HMS designs for liquid rocket engines and terrestrial nuclear power plants and evaluates the necessity for redundant components to maximize overall system reliability.