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APPLICATION OF MODEL-BASED SYSTEMS ENGINEERING (MBSE) TO ROCKET ENGINE AFFORDABILITY AND POTENTIALS

Abstract

Model Based Systems Engineering (MBSE) has garnered increased application and utilization in NASA's recent missions such as the Mars Ascent Vehicle (MAV) Project. In the context of a rocket engine, MBSE approaches has helped critical System Engineering (SE) processes such as requirements verification, post processing test data, and automate verification validation. Subsequently, employing model-based strategies can help counter developmental challenges in rocket engine architectures early in its system life-cycle. This indicates a potential opportunity to reduce the lead time in certification of rocket engines.

Rocket engine development lessons learned in the past indicate that a significant amount of development costs is spent on test-fail-fix (TFF) - the engine redesign, remanufacturing, retest, and recertification. The initial scrubs especially due to the Space Launch System (SLS) core stage issues during the Artemis I mission indicates the inherently high costs of TFF. With a model-based approach, it will however be possible to foresee the nature of scrubs and developmental challenges earlier in the lifecycle and make informed decisions. Minimum TFF cycles may be acceptable for a liquid rocket engine, for instance the SLS core stage engines, the RS-25's (formerly the Space Shuttle Main Engine [SSME]). However, for an advanced propulsion system such as a Nuclear Thermal Propulsion (NTP) engine, there is a need to eliminate TFF. Furthermore, engines such as the RS-25's are repurposed versions of the reusable SSME's, and the NTP designs heavily rely on lessons learned from the Nuclear Engine for Rocket Vehicle Application (NERVA) and the Rover programs.

The RS-25's and NTP designs have not been manufactured in a few decades and there exists a need to foresee the developmental challenges early its life-cycles. For instance, affordability is of primary importance considering the development of such engines at this juncture using technologies such as Additive Manufacturing (AM). Employing MBSE is one among the many approaches to foresee nature of high costs of TFF while utilizing AM process, thereby delivering affordability. This paper will subsequently demonstrate how MBSE can be employed for production of these engines utilizing newer technologies such as AM, and how SE processes for design change decisions can be wrapped in a model-based realm. The lessons learned from such an approach and its potentials within the context of TFF shall be expressed. This will thereby help in reducing certification lead times, and contribute in enabling future missions to moon, mars, and beyond quickly and affordably.