SPACE LAUNCH SYSTEM ENGINE OUT CAPABILITIES

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NASA's Space Launch System (SLS) is being developed with the primary purpose of returning people to the Moon and eventually landing people on Mars. With these lofty goals, ensuring mission completion is paramount even in the event of an in-flight mishap. One possible mishap is the loss of an engine in flight. While SLS was not required to show full engine out capability, the program took an "assess to" approach to see when the launch vehicle could complete the mission after an engine failure versus when the launch vehicle targets required a down-mode to an alternate mission target to ensure at least some flight objectives were complete, or at a minimum ensure safe return of Orion and the Crew. While this paper will focus on Artemis I, an uncrewed mission, some comparisons will be made to how the engine out capability will change for the subsequent Crewed flights of SLS and Orion.

INTRODUCTION

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Very early in the SLS program, the decision was made to utilize Space Shuttle and Constellation developed hardware to the greatest extent possible. This meant that the Core would be similar to the Shuttle External Tank, the Solid Rocket Boosters (SRB) would be derived form the Constellation 5 segment variant of the Shuttle 4 segment SRB's, and the Core engines would be the Space Shuttle Main Engines (SSME), otherwise known as the RS-25's. While the RS-25's have shown significant reliability, there is one flight, STS-51-F in 1985, where an engine shutdown due to a sensor failure. This required the Space Shuttle to perform and Abort to Orbit (ATO) and achieved a lower than

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planned orbital altitude (Reference 1). Despite the multiple successful launches without an in-flight engine shutdown, NASA will still prepare for the worst and have plans in place to correct for unplanned engine shutdowns.

The SLS Launch vehicle has four RS-25's on the Core and analysis has shown that the Block 1 configuration can recover from an unplanned engine shutdown in almost all phases of flight. Late in flight, SLS would press to Main Engine CutOff (MECO) and continue on its nominal mission profile. Two other targets, an Alternate MECO Target (AMT) High for engine failures in the middle portion of flight, and an AMT Low target for failures very early in flight rounds out the engine out capability of SLS. For Artemis I, the AMT High target was derived to ensure Orion could meet its high-speed reentry test objective for its heat shield by inserting the Interim Cryogenic Propulsion Stage (ICPS) and Orion stack into an orbit where the ICPS could insert Orion into a highly elliptical Earth orbit. The Artemis I AMT Low target was derived to help Orion achieve all its other flight test objectives in Low Earth Orbit. The switching between targets is handled either through flight software or by Mission Control. Both the vehicle and Mission Control will monitor SLS's velocity on ascent to make the determination as to which AMT the vehicle is capable of achieving. The AMT's are also derived so that the Core reentry, even in the event of an engine failure, has a high probability of impacting water instead of land.

REFERENCES

[1] R. D. Legler and F. V. Bennett, *Space Shuttle Missions Summary*. NASA Johnson Space Center, September 2011. NASA/TM-2011-216142.