Closed Loop Guidance Trade Study for Space Launch System Block-1B Vehicle

Paul Von der Porten

Naeem Ahmad

Matt Hawkins

NASA is currently building the Space Launch System (SLS) Block-1 launch vehicle for the Exploration Mission 1 (EM-1) test flight. The design of the next evolution of SLS, Block-1B, is well underway. The Block-1B vehicle is more capable overall than Block-1; however, the relatively low thrust-to-weight ratio of the Exploration Upper Stage (EUS) presents a challenge to the Powered Explicit Guidance (PEG) algorithm used by Block-1. To handle the long burn durations (on the order of 1000 seconds) of EUS missions, two algorithms were examined. An alternative algorithm, OPGUID, was introduced, while modifications were made to PEG. A trade study was conducted to select the guidance algorithm for future SLS vehicles. The chosen algorithm needs to support a wide variety of mission operations: ascent burns to LEO, apogee raise burns, trans-lunar injection burns, hyperbolic Earth departure burns, and contingency disposal burns using the Reaction Control System (RCS). Additionally, the algorithm must be able to respond to a single engine failure scenario. Each algorithm was scored based on pre-selected criteria, including insertion accuracy, algorithmic complexity and robustness, extensibility for potential future missions, and flight heritage. Monte Carlo analysis was used to select the final algorithm. This paper covers the design criteria, approach, and results of this trade study, showing impacts and considerations when adapting launch vehicle guidance algorithms to a broader breadth of in-space operations.