

## Executive Summary (100 Words)

Given Artemis II as the first crewed lunar mission in decades, significant effort is directed towards understanding Space Launch System (SLS) response to failures of the three inertial sensors: two Ring-Laser Gyro Assemblies (RGAs) and the Redundant Inertial Navigation Unit (RINU). Parametric studies identify Loss of Mission (LOM) or Loss of Crew (LOC) sensitive mission phases. Fault Detection & Isolation (FDI) algorithms' thresholds' performance is assessed with respect to detecting LOM or LOC causing sensor failures. Monte Carlo studies are performed targeting specific trajectory phases for insight into re-optimizing FDI thresholds and improving knowledge of SLS sensor failure response statistics.

## Extended Abstract (500 Words)

With the Artemis II mission returning astronauts to cis-lunar space more than fifty years after Apollo 17, diligent analysis assesses any potential challenges to the crew's safety in the event of the failure of one of the Space Launch System's (SLS) three inertial navigation sensors: two RGAs and the RINU.

Analysis of parametric and Monte Carlo studies for Ring-Laser Gyro Assemblies (RGA) and Redundant Inertial Navigation Unit (RINU) failure modes along a reference trajectory, namely bias shifts and loss of sensor communications, emphasizes Loss of Mission (LOM) and Loss of Crew (LOC) outcomes and Guidance, Navigation, and Controls (GNC) Fault Detection and Isolation (FDI) algorithms' performance. Results inform FDI thresholds' re-optimization in addition to any necessary updates to the mission's abort logic that minimize the chance of either a LOM or LOC, as well as informing the SLS Artemis II Probabilistic Risk Assessment (PRA).

This paper describes simulated sensor failure modes, how parametric studies inform the selection of Monte Carlo cases, the process for determining whether LOM or LOC occurred for a given test case, and the processes for re-optimizing FDI thresholds for both sensor types in addition to evaluating SLS behavior statistics.

The RGA and RINU failure studies are performed, with the specifics of test cases differing to match the characteristics of the sensor types as well as the roles they perform for the SLS vehicle. This is reflected by the use of two FDI algorithms: Sensor Data Quality (SDQ) checks, which compare rate outputs from all three sensors to detect and isolate a single failed RGA, and the RINU-internal Fault Detection Isolation & Recovery (FDIR) checks, which use parity-space calculations to isolate faulty accelerometers and gyroscopes and remove their outputs from the 5-to-3-space mapping.

Previous analyses indicate SLS robustness to single RGA failure. Therefore, gyroscope bias shifts are induced at a magnitude just below SDQ detection thresholds at the time of the fault. These test cases indicate the bounds of undetected faulty RGA induced behavior at various trajectory phases.

The RINU, being the sole sensor for acceleration and roll rate measurements, presents a large sensor failure parameter space to be explored. Parametric studies are performed to identify specific failure space regimes demonstrating sensitivity to lack of FDIR detection, LOM, and LOC events. Monte Carlos are performed targeting those regimes to explore failure detection and mission performance boundaries within the failure parameter space.

Test case results are evaluated for violation of orbital insertion accuracy requirements which result in LOM. Test cases are also evaluated for violations of vehicle structural demise criteria resulting in LOC. Further analysis generates statistical knowledge of SLS response to sensor failures including likelihood of LOM and probable time from failure detection to potential LOC event. Results further inform SDQ and FDIR threshold re-optimization processes to minimize the chance that any sensor failure that would cause LOM or LOC goes undetected and maximize the margin between time of detection and probable LOC time, increasing the likelihood of a successful abort maneuver if necessary.