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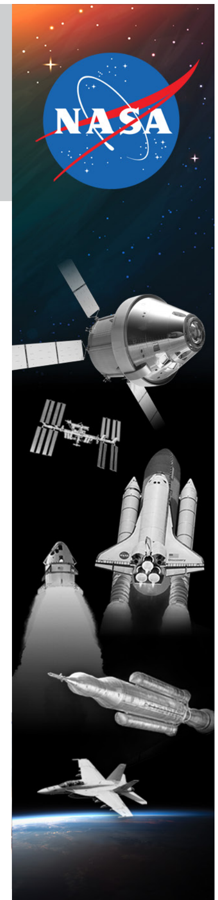

NESC tech bulletin

# Mitigating Risks of Single-Event Effects in Space Applications

Since most Electrical, Electronic, and Electromechanical (EEE) parts are intended for terrestrial applications, they are susceptible to a range of radiation threats in the space environment if the resulting effects are not properly characterized and mitigated. Even specially designed radiation-hardened parts may not be tolerant to all types of radiation effects. Radiation hardness is a multi-dimensional property of any part that describes intrinsic abilities to tolerate various radiation environments [1,2]. Effects to be concerned with include total ionizing dose, total non-ionizing dose, and single-event effects (SEE) – all of which depend on the mission, environment, application, and lifetime. Radiation effects concerns may be the same whether a EEE part is Commercial-Off-The-Shelf (COTS), MIL-SPEC, or some other variant, all of which are susceptible to the same radiation threats [3]. SEE consequences range from recoverable faults to catastrophic failure. Like other random faults, SEE can be mitigated with informed circuit design practices at the device, card, and/or system level.

## Background

Good fault-tolerant design practices, broad use of radiation-hardened and minimally-radiation-susceptible parts, determined through radiation characterization in applicable environments, and sufficient shielding have minimized severe radiation-induced effects in NASA missions over the years. Unfortunately, the difficulty, cost, and time-consuming nature of radiation testing has often meant that knowledge of radiation susceptibility of the parts or circuits was not available until late in the design process. As such, modeling, earlier testing, and analysis at the part, board, and box level are increasingly important so that SEE induced failures can be included in reliability models and all of their consequences assessed. The illustration depicts how irreparable and reparable (recoverable) errors factor into a notional reliability calculation. Radiation-induced SEE that fall into these categories can be accounted for in such calculations assuming that failure rates and repair times can be accurately determined.

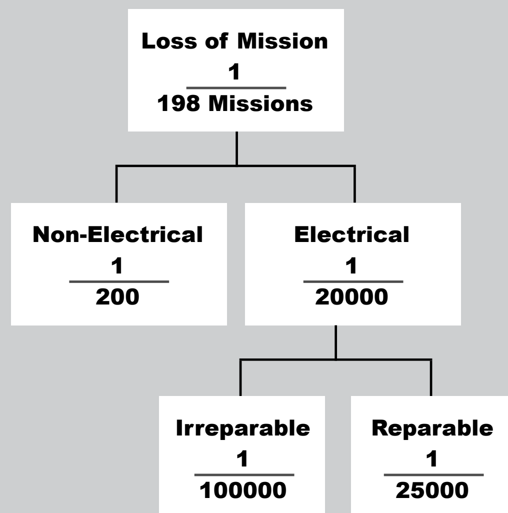


Illustration of how errors from various causes flow upward resulting in the total Loss of Mission (LOM) requirement.

## Best Practices

In systems using redundant mitigation, system failure rates scale nonlinearly with unit failure rates, so limiting SEE rates is important. In particular, destructive SEE can cause failure rates to increase with time. To prevent SEE-induced failures from overwhelming system-level redundancy, it is recommended that:

1. Irreparable and reparable SEE rates should be included in system models.
   a. Include irreparable SEE rates in reliability models with other hard failures.
   b. Include reparable SEE rates in system availability models.
   c. Explore model parametric sensitivities (e.g., SEE rates, repair times, etc.) over a range of values to establish where system performance degrades unacceptably.
2. SEE testing and analysis should be prioritized based on expected benefit according to such system modeling, and function criticality.
3. System redundancy may be used for multiple purposes (e.g., a 3-unit redundant element can ensure availability if at least 1 unit remains functional, or a voting system to correct unit errors if ≥2 of 3 units remain functional). In addition, a mission may have several phases with different risk postures. System reliability and availability models should be detailed enough to assess the system risk for all the different mission phases or modes.
4. To minimize design process disruption, work-around or redesign strategies should be developed for use if parts selected for test exhibit unacceptable SEE performance.
5. For SEE susceptible functions, ensure through design, test, and analysis that devices are protected from SEE-induced transient effects and have sufficient margin to account for bounding conditions defined by the mission, environment, application criticality, and lifetime requirements.

## References


1. NASA/TM-2019220269, Radiation Single Event Effects Impact on Complex Avionics Architecture Reliability, April 2019
2. NASA/TM-20210018053, Avionics Radiation Hardness Assurance (RHA) Guidelines, July 2021
3. NASA/TM-20205011579, Recommendations on Use of Commercial-Off-The-Shelf (COTS) Electrical, Electronic, and Electromechanical (EEE) Parts for NASA Missions, June 2021