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SOLVING SPACE MYSTERIES - BEST PRACTICES FOR DETERMINING ROOT CAUSE OF SPACECRAFT ANOMALIES

Abstract

The need to rapidly and accurately ascertain why satellites have exhibited anomalistic behavior or failed in orbit is motivated by operational, scientific, political, and fiscal reasons. Operationally, anomaly root cause attribution can be used to provide feedback to space system design and parts selection/qualification in addition to helping develop efficient/effective operational work arounds. From a science and engineering perspective, root cause attribution can corroborate and validate mission vulnerability, system/parts failure, and space environmental models. Getting to the crux of a satellite failure will also contribute insights to geo-political discussions about disruption of space system operations which might prevent unnecessary and escalatory actions. Lastly, unambiguous identification of the cause for anomalies and failures can provide valuable input for insurance processing. Spacecraft anomaly and failure attribution is very difficult to perform because of complex science realities, engineering constraints, and the involvement of people. The space environment is a complicated, dynamic combination of chemical, radiation, micro-particles (sub-atomic), and macro-particles (manmade debris and micrometeoroids) being generated and traversing to/from the Sun, the Earth, our atmosphere, and other satellites. All of these factors will drive the design and operations of space systems that will in turn cloud anomaly investigations. Investigations are complicated by engineering constraints such as (1) lack of spacecraft (system, subsystem, and component) design information and (2) inconsistency between the design and the final state in which a satellite was launched. Lack of onboard diagnostics to aid in anomaly investigations further degrades the assessment process. Lastly, failures often are the result of more than one trigger. Anomaly attribution is further confounded by the lack of common terminology or a standard anomaly attribution process. This disconnect is amplified by the fact that different sizes, missions, and pedigree of spacecraft may react differently to hardware losses or environmental challenges. There is also often a lack of motivation for space programs to determine root cause especially for inexpensive missions with short lifetimes, like many of the current commercial satellites being deployed. Lastly, there is often hesitance to share failures with others since there is no desire to educate competition and adversaries or to make issues related to national security assets publicly available. A sequence of anomalistic events has been compiled that were potentially related to orbital debris impacts in LEO that provide insights into the evolving debris collision risk. This analysis highlights the utility of tracking, aggregating, and analyzing anomalies.