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Impact-Induced Mission Effects and Risk Assessments (3)

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ASSESSING DEBRIS STRIKES IN SPACECRAFT TELEMETRY: DEVELOPMENT AND COMPARISON OF VARIOUS TECHNIQUES

Abstract

Debris strikes on operational spacecraft are becoming more common due to increasing numbers of space objects. Sample return missions indicate hundreds of minor strikes, but rigorous analysis is often only performed when a strike causes an anomaly in spacecraft performance. Developing techniques to identify and assess minor strikes that do not immediately cause anomalous behavior can help to validate models for debris populations, perform risk assessments, and potentially aid in attribution of future anomalies. This study introduces debris strikes to a spacecraft dynamics simulation and assesses the effect on spacecraft telemetry. Various signal processing and change detection techniques are used to identify strikes in noisy telemetry and estimate strike parameters. A family of match filters is developed to identify the effects on telemetry streams in which errors are corrected by the spacecraft control system, in a manner similar to the Magill filter. Filters are also developed which estimate the debris strike-induced wavelet as a signal with some unknown parameters which translate to an estimate of the debris strike parameters. A Monte-Carlo analysis is conducted where the spacecraft parameters are distributed relative to the parameters used to develop the match filters, i.e, representing the spacecraft's as-built configuration relative to the as-designed configuration. State noise and measurement noise are introduced to the simulation for the Monte-Carlo analysis. In this analysis, strikes are introduced to the simulation and the filters are used to identify and assess the strikes. Maximum likelihood estimates for the strike parameters (magnitude and direction) are developed. In parallel, other classical change detection algorithms (Sequential Probability Ratio Tests) are run on the telemetry streams which are expected to experience lasting, rather than transient, effects from debris strikes. The results of the various techniques are compared in terms of correctly identifying the debris strikes and accurately estimating the strike parameters. This research utilizes signal processing techniques to develop algorithms for processing standard spacecraft telemetry to both identify debris strikes and to estimate the parameters of any strikes that occur. Sample return missions indicate that minor debris strikes are routine, so developing the capability to catalog and characterize these strikes allows any spacecraft to be used as an *in situ* debris sensor.