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STATE MACHINE FAULT PROTECTION FOR AUTONOMOUS PROXIMITY OPERATIONS

Abstract

The capability to recover gracefully from hardware or software faults is critical for many aerospace applications. This is particularly true for missions involving proximity operations, where multiple vehicles are operating at close range. Previous proximity operations missions have experienced faults that resulted in a failure to meet mission objectives. Fault protection systems are used to detect, identify the location of, and recover from faults. Typically, aerospace systems use a rule-based paradigm for fault protection, where telemetry values are monitored against logical statements such as static upper and lower limits. The model-based paradigm allows more complex decision logic to be used. State machines are a particular tool for model-based fault protection that have been explored by industry but not widely adopted. This study develops a generic and modular state machine fault protection architecture that is portable to flight software. This architecture applies to a wide variety of missions and vehicles, and it contains components that can be rearranged, added, or removed easily. The architecture is developed in a way that is straightforward to export to flight software via autocoding.

This study focuses on fault protection for the Guidance, Navigation, and Control vehicle subsystem, which is essential for any aerospace vehicle and has many complex and interrelated hardware and software components. Two separate case studies are analyzed, one for atmospheric flight and one for space flight. High-level failure modes are identified in each scenario and linked to individual root cause events via a fault tree analysis. This study builds on capabilities developed for small satellite projects, including a high-fidelity proximity operations simulation and a processor-in-the-loop testbed for testing of avionics boards. The first case involves detecting hardware faults on an unmanned aerial vehicle used for aerial surveying and mapping. The dynamic, real-time environment allows the fault protection system's qualities to be explored. Results from flight tests are used for verification and validation of the fault protection architecture. The second case involves automated proximity operations during approach and capture of the orbiting sample canister for a Mars Sample Return mission. The processes for proximity operations are complex, providing a relevant case study for the fault protection architecture being developed in this study. A closed-loop verification and validation test will be performed with autocoded fault protection algorithms on a flight-like processor connected to simulation models using the MATLAB's Simulink Real-Time toolbox.