ON-BOARD FAULT MANAGEMENT FOR AUTONOMOUS SPACECRAFT

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Statement of technical details of the capability being described

The dynamic nature of the Cargo Transfer Vehicle's (CTV) mission and the high level of autonomy required mandate a complete fault management system capable of operating under uncertain conditions. Such a fault management system must take into account the current mission phase and the environment (including the target vehicle), as well as the CTV's state of health. This level of capability is beyond the scope of current on-board fault management systems.

This presentation will discuss work in progress at TRW to apply artificial intelligence to the problem of on-board fault management. The goal of this work is to develop fault management systems that can meet the needs of spacecraft that have long-range autonomy requirements.

We have implemented a model-based approach to fault detection and isolation that does not require explicit characterization of failures prior to launch. It is thus able to detect failures that were not considered in the failure and effects analysis. We have applied this technique to several different subsystems and tested our approach against both simulations and an electrical power system hardware testbed.

We present findings from simulation and hardware tests which demonstrate the ability of our model-based system to detect and isolate failures, and describe our work in porting the Ada version of this system to a flight-qualified processor. We also discuss current research aimed at expanding our system to monitor the entire spacecraft.

History of the origins & evolution of the capability

TRW has been actively researching the application of artificial intelligence to on-board fault management since 1987. Initial work focused on rule-based and fault-modeling approaches, but because these methods can only detect a subset of possible failures, they were deemed inadequate for autonomous fault monitoring. In 1988, we began to examine a model-based fault-management technique called constraint suspension and have successfully used this technique to isolate faults in both simulations and an electrical power system testbed. We have developed a tool for building model-based diagnostic systems, called MARPLE, and used this tool to build in-house fault management systems as well as a contingency analysis monitoring system for the NASA LeRC Space Station Freedom power testbed.

The level of maturity of the capability

The MARPLE fault management approach is in its third year of development. It has been through the design, code, and prototype phases. We are currently addressing the remaining issues to make MARPLE a realizable on-board system. These issues include verification and validation, real-time response, and integration into a flight software package.

Test experience and/or experimental results

The MARPLE system has been through two years of prototype testing. A MARPLE-based power diagnostic system was first tested against a software electrical power system simulator. This simulator enabled extensive testing of many fault scenarios, including sensor failures, component degradations, and external threats such as laser and pellet attacks. This same diagnostic system was then integrated into a hardware power system testbed, and failures were induced into the actual hardware (to the extent allowed by the power engineers). These hardware tests demonstrated one of the major strengths of the MARPLE-based technique -- its ability to isolate failures without characterizing the symptoms a priori.

Capabilities and limitations of the MARPLE technique were realized through these tests. Modifications are currently planned to enable MARPLE to realize its own limitations and thereby avoid false diagnoses.

Source/sponsorship and current funding estimates

This effort is being pursued on Internal Research and Development funds. In addition, NASA LeRC sponsored a contract effort to apply the results of this IR&D to the Space Station Freedom Power System.