IAF SPACE EXPLORATION SYMPOSIUM (A3)
Moon Exploration – Part 3 (2C)

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INTELLIGENT HEALTH MANAGEMENT OF A LUNAR ROVER

Abstract

The demand for extended duration missions and autonomous spaceflight systems is increasing with in-situ resource utilization become more feasible. To extend operational lifetime and increase onboard autonomy of space vehicles, a dedicated system with the ability to prognose and mitigate faults across multiple vehicle subsystems is required. An Artificial Intelligence (AI) based Integrated Vehicle Health Management (IVHM) system addresses this functionality by using real time sensor data to diagnose and prognose system faults and recommend restorative actions and reconfiguration of specific vehicle subsystems. This protects safety-critical subsystems from catastrophic failures as well as exhibits a graceful degradation of performance. An intelligent IVHM system of this nature would significantly improve system safety, availability, reliability, and reduce overall mission cost.

This paper presents a framework for the development of an AI based IVHM system to support an autonomous lunar polar rover as a part of NASA's Resource Exploration and Science of Our Cosmic Environment (RESOURCE) mission to develop in-situ resource utilization (ISRU) capabilities on target bodies, including the Moon, near Earth asteroids, Phobos and Deimos (Mars' Moons). In addition, this paper presents details of the modelling and simulation carried out to address the Failure Modes and Effects Analysis (FMEA), and Fault Detection and Exclusion (FDE) functionalities for mission-critical communications and navigation subsystems. Mathematical models and algorithms are developed for FMEA/FDE and digital tools implemented in Systems Tool Kit (STK) and MATLAB to simulate and categorize the effects of faults on subsystem performance. Finally, an Adaptive Neuro-Fuzzy Inference System (ANFIS) engine is trained to interpret the data obtained from the simulated communications subsystem allowing the generation of predictive integrity flags (early diagnosis) and rapid reconfiguration of subsystem functionalities in representative mission scenarios. Preliminary results indicate a high degree of accuracy with the ANFIS engine able to detect early signs of faults.