

mature set of HDA software for the manned lunar landing problem.

Landing hazards exist everywhere on the Moon, and many of the more desirable landing sites are near the most hazardous terrain, so HDA is needed to autonomously and safely land payloads over much of the lunar surface. The HDA requirements used in the ALHAT project are to detect hazards that are 0.3 m tall or higher and slopes that are 5° or greater. Steep slopes, rocks, cliffs, and gullies are all hazards for landing and, by computing the local slope and roughness in an elevation map, all of these hazards can be detected. The algorithm in this innovation is used to measure slope and roughness hazards. In addi-

tion to detecting these hazards, the HDA capability also is able to find a safe landing site free of these hazards for a lunar lander with diameter ≈15 m over most of the lunar surface.

This software includes an implementation of the HDA algorithm, software for generating simulated lunar terrain maps for testing, hazard detection performance analysis tools, and associated documentation. The HDA software has been deployed to Langley Research Center and integrated into the POST II Monte Carlo simulation environment. The high-fidelity Monte Carlo simulations determine the required ground spacing between LIDAR samples (ground sample distances) and the

noise on the LIDAR range measurement. This simulation has also been used to determine the effect of viewing on hazard detection performance. The software has also been deployed to Johnson Space Center and integrated into the ALHAT real-time Hardware-in-the-Loop testbed.

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*This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at [danielb@caltech.edu](mailto:danielb@caltech.edu). Refer to NPO-47178.*

## Onboard Nonlinear Engine Sensor and Component Fault Diagnosis and Isolation Scheme

*John H. Glenn Research Center, Cleveland, Ohio*

A method detects and isolates in-flight sensor, actuator, and component faults for advanced propulsion systems. In sharp contrast to many conventional methods, which deal with either sensor fault or component fault, but not both, this method considers sensor fault, actuator fault, and component fault under one systemic and unified framework.

The proposed solution consists of two main components: a bank of real-time, nonlinear adaptive fault diagnostic estimators for residual generation, and a residual evaluation module that includes adaptive thresholds and a Trans-

ferable Belief Model (TBM)-based residual evaluation scheme. By employing a nonlinear adaptive learning architecture, the developed approach is capable of directly dealing with nonlinear engine models and nonlinear faults without the need of linearization. Software modules have been developed and evaluated with the NASA C-MAPSS engine model. Several typical engine-fault modes, including a subset of sensor/actuator/components faults, were tested with a mild transient operation scenario. The simulation results demonstrated that the algorithm was able to success-

fully detect and isolate all simulated faults as long as the fault magnitudes were larger than the minimum detectable/isolable sizes, and no misdiagnosis occurred.

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*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18518-1/9-1.*

## Network-Capable Application Process and Wireless Intelligent Sensors for ISHM

**This technology can be used for wireless sensor monitoring in vehicles, home security, system automation, and radio-frequency identification (RFID) for smart tags.**

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Intelligent sensor technology and systems are increasingly becoming attractive means to serve as frameworks for intelligent rocket test facilities with embedded intelligent sensor elements, distributed data acquisition elements, and onboard data acquisition elements. Networked intelligent processors enable users and systems integrators to automatically configure their measurement automation

systems for analog sensors. NASA and leading sensor vendors are working together to apply the IEEE 1451 standard for adding plug-and-play capabilities for wireless analog transducers through the use of a Transducer Electronic Data Sheet (TEDS) in order to simplify sensor setup, use, and maintenance, to automatically obtain calibration data, and to eliminate manual data entry and error.

A TEDS contains the critical information needed by an instrument or measurement system to identify, characterize, interface, and properly use the signal from an analog sensor. A TEDS is deployed for a sensor in one of two ways. First, the TEDS can reside in embedded, nonvolatile memory (typically flash memory) within the intelligent processor. Second, a virtual TEDS can exist as a