# Technology Focus: Sensors

## Distributed Aerodynamic Sensing and Processing Toolbox

*Dryden Flight Research Center, Edwards, California*

A Distributed Aerodynamic Sensing and Processing (DASP) toolbox was designed and fabricated for flight test applications with an Aerostructures Test Wing (ATW) mounted under the fuselage of an F-15B on the Flight Test Fixture (FTF). DASP monitors and processes the aerodynamics with the structural dynamics using nonintrusive, surface-mounted, hot-film sensing. This aerodynamic measurement tool benefits programs devoted to static/dynamic load alleviation, body freedom flutter suppression, buffet control, improvement of aerodynamic efficiency through cruise control, supersonic wave drag reduction through shock control, etc.

This DASP toolbox measures local and global unsteady aerodynamic load distribution with distributed sensing. It determines correlation between aerodynamic "observables" (aero forces) and structural dynamics, and allows control authority increase through aeroelastic shaping and active flow control.

It offers improvements in flutter suppression and, in particular, body freedom flutter suppression, as well as aerodynamic performance of wings for increased range/endurance of manned/unmanned flight vehicles. Other improvements include inlet performance with closed-loop active flow control, and development and validation of advanced analytical and computational tools for unsteady aerodynamics.

*This work was done by Martin Brenner and Christine Jutte of Dryden Flight Research Center and Arun Mangalam of Tao Systems, Inc. Further information is contained in a TSP (see page 1). DRC-009-031*

## Collaborative Supervised Learning for Sensor Networks

**This technique could be applied to sensor networks for intruder detection, target tracking, and data mining in cell-phone networks.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Collaboration methods for distributed machine-learning algorithms involve the specification of communication protocols for the learners, which can query other learners and/or broadcast their findings preemptively. Each learner incorporates information from its neighbors into its own training set, and they are thereby able to "bootstrap" each other to higher performance.

Each learner resides at a different node in the sensor network and makes observations (collects data) independently of the other learners. After being "seeded" with an initial labeled training set, each learner proceeds to learn in an iterative fashion. New data is collected and classified. The learner can then either broadcast its most confident classifications for use by other learners, or can query neighbors for their classifications of its least confident items. As such, collaborative learning combines elements of both passive (broadcast) and active (query) learning. It also uses ideas from ensemble learning to combine the multiple responses to a given query into a single useful label.

This approach has been evaluated against current non-collaborative alternatives, including training a single classifier and deploying it at all nodes with no further learning possible, and permitting learners to learn from their own most confident judgments, absent interaction with their neighbors. On several data sets, it has been consistently found that active collaboration is the best strategy for a distributed learner network. The main advantages include the ability for learning to take place autonomously by collaboration rather than by requiring intervention from an oracle (usually human), and also the ability to learn in a distributed environment, permitting decisions to be made *in situ* and to yield faster response time.

*This work was done by Kiri L. Wagstaff of Caltech, Umaa Rebbapragada of Tufts University, and Terran Lane of the University of New Mexico for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46914*

## Hazard Detection Software for Lunar Landing

*NASA's Jet Propulsion Laboratory, Pasadena, California*

The Autonomous Landing and Hazard Avoidance Technology (ALHAT) Project is developing a system for safe and precise manned lunar landing that involves novel sensors, but also specific algorithms. ALHAT has selected imaging LIDAR (light detection and ranging) as the sensing modality for onboard hazard detection because imaging LIDARs can rapidly generate direct measurements of the lunar surface elevation from high altitude. Then, starting with the LIDAR-based Hazard Detection and Avoidance (HDA) algorithm developed for Mars Landing, JPL has developed a 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 addition 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.

*This work was done by Andres Huertas, Andrew E. Johnson, Robert A. Werner, and James F. Montgomery of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.*

*This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at 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 Transferable 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 successfully detect and isolate all simulated faults as long as the fault magnitudes were larger than the minimum detectable/isolable sizes, and no misdiagnosis occurred.

*This work was done by Liang Tang and Jonathan A. DeCastro of Impact Technologies, LLC and Xiaodong Zhang of Wright State University for Glenn Research Center.*

*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.**

*Stennis Space Center, Mississippi*

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