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## ▶ Onboard Sensor Data Qualification in Human-Rated Launch Vehicles

**Applications include sensor data qualification and equipment condition monitoring in commercial power plants.**

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

The avionics system software for human-rated launch vehicles requires an implementation approach that is robust to failures, especially the failure of sensors used to monitor vehicle conditions that might result in an abort determination. Sensor measurements provide the basis for operational decisions on human-rated launch vehicles. This data is often used to assess the health of system or subsystem components, to identify failures, and to take corrective action. An incorrect conclusion and/or response may result if the sensor itself provides faulty data, or if the data provided by the sensor has been corrupted. Operational decisions based on faulty sensor data have the potential to be catastrophic, resulting in loss of mission or loss of crew. To prevent these later situations from occurring, a Modular Architecture and Generalized Methodology for Sensor Data Qualification in Human-rated Launch Vehicles has been developed.

Sensor Data Qualification (SDQ) is a set of algorithms that can be implemented in onboard flight software, and can be used to qualify data obtained from flight-critical sensors prior to the data being used by other flight software algorithms. Qualified data has been analyzed by SDQ and is determined to be a

true representation of the sensed system state; that is, the sensor data is determined not to be corrupted by sensor faults or signal transmission faults. Sensor data can become corrupted by faults at any point in the signal path between the sensor and the flight computer. Qualifying the sensor data has the benefit of ensuring that erroneous data is identified and flagged before otherwise being used for operational decisions, thus increasing confidence in the response of the other flight software processes using the qualified data, and decreasing the probability of false alarms or missed detections.

At a high level, SDQ is called by the flight computer, as required each cycle, to qualify a specific sensor or set of sensors. SDQ first determines the update-rate of the data, and obtains the specified data from the sensor data table. SDQ then consults the data provided by the Mission Manager Function to determine the appropriate subset of pre-defined algorithms, thresholds, and parameters to be used in qualifying specified sensor data. Next, appropriate algorithms are applied to the data. If a given algorithm determines that the data is faulty, the associated data signal accrues a strike from that algorithm for the current flight computer cycle, and

the algorithm or algorithms that failed the data are recorded. Having run all applicable fault detection algorithms, the strike counters for each of the applicable algorithm/sensor pairs are then tested for the persistence of any failures. Sensors associated with data that meets persistence criteria are flagged as permanently failed.

Alternate embodiments of some of the qualification algorithms used in the Ares SDQ architecture have prior implementations that were incorporated into commercial data qualification development and analysis tools under the SureSense trademark. SureSense has been used to develop and implement real-time data qualification algorithms for ground-based nuclear power generation systems.

*This work was done by Edmond Wong and Kevin J. Melcher of Glenn Research Center; William A. Maul, Amy K. Chicatelli, Thomas S. Sowers, and Christopher Fulton of QinetiQ North America; and Randall Bickford of Expert Microsystems, Inc. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18633-1.*

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## ⊕ Rugged, Portable, Real-Time Optical Gaseous Analyzer for Hydrogen Fluoride

**Applications include trace gas sensor applications where rapid sampling is required, particularly in human-occupied closed volumes.**

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

Hydrogen fluoride (HF) is a primary evolved combustion product of fluorinated and perfluorinated hydrocarbons. HF is produced during combustion by the presence of impurities and hydrogen-containing polymers including polyimides. This effect is especially dangerous in closed occupied volumes like spacecraft and submarines. In these sys-

tems, combinations of perfluorinated hydrocarbons and polyimides are used for insulating wiring. HF is both highly toxic and short-lived in closed environments due to its reactivity. The high reactivity also makes HF sampling problematic.

An infrared optical sensor can detect promptly evolving HF with minimal sampling requirements, while providing

both high sensitivity and high specificity. A rugged optical path length enhancement architecture enables both high HF sensitivity and rapid environmental sampling with minimal gaseous contact with the low-reactivity sensor surfaces. The inert optical sample cell, combined with infrared semiconductor lasers, is joined with an analog and digital electronic

control architecture that allows for ruggedness and compactness. The combination provides both portability and battery operation on a simple camcorder battery for up to eight hours.

Optical detection of gaseous HF is confounded by the need for rapid sampling with minimal contact between the sensor and the environmental sample. A sensor is required that must simultaneously provide the required sub-parts-per-million detection limits, but with the high specificity and selectivity expected of optical absorption techniques. It should also be rugged and compact for compatibility with operation onboard spacecraft and submarines.

A new optical cell has been developed for which environmental sampling is accomplished by simply traversing the few-mm-thick cell walls into an open volume

where the measurement is made. A small, low-power fan or vacuum pump may be used to push or pull the gaseous sample into the sample volume for a response time of a few seconds. The optical cell simultaneously provides for an enhanced optical interaction path length between the environmental sample and the infrared laser. Further, the optical cell itself is comprised of inert materials that render it immune to attack by HF. In some cases, the sensor may be configured so that the optoelectronic devices themselves are protected and isolated from HF by the optical cell. The optical sample cell is combined with custom-developed analog and digital control electronics that provide rugged, compact operation on a platform that can run on a camcorder battery.

The sensor is inert with respect to acidic gases like HF, while providing the

required sensitivity, selectivity, and response time. Certain types of combustion events evolve copious amounts of HF, very little of other gases typically associated with combustion (e.g., carbon monoxide), and very low levels of aerosols and particulates (which confound traditional smoke detectors). The new sensor platform could warn occupants early enough to take the necessary countermeasures.

*This work was done by Jeffrey Pilgrim and Paula Gonzales of Vista Photonics, Inc. for Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18892-1.*

## A Probabilistic Mass Estimation Algorithm for a Novel 7-Channel Capacitive Sample Verification Sensor

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

A document describes an algorithm created to estimate the mass placed on a sample verification sensor (SVS) designed for lunar or planetary robotic sample return missions. A novel SVS measures the capacitance between a rigid bottom plate and an elastic top membrane in seven locations. As additional sample material (soil and/or small rocks) is placed on the top membrane, the deformation of the membrane increases the capacitance. The mass estimation algorithm addresses both the calibration of each SVS channel, and also addresses how to combine the capacitances read from each of the seven channels into a single mass esti-

mate. The probabilistic approach combines the channels according to the variance observed during the training phase, and provides not only the mass estimate, but also a value for the certainty of the estimate.

SVS capacitance data is collected for known masses under a wide variety of possible loading scenarios, though in all cases, the distribution of sample within the canister is expected to be approximately uniform. A capacitance-vs-mass curve is fitted to this data, and is subsequently used to determine the mass estimate for the single channel's capacitance reading during the measurement phase. This results in seven different

mass estimates, one for each SVS channel. Moreover, the variance of the calibration data is used to place a Gaussian probability distribution function (pdf) around this mass estimate. To blend these seven estimates, the seven pdfs are combined into a single Gaussian distribution function, providing the final mean and variance of the estimate. This blending technique essentially takes the final estimate as an average of the estimates of the seven channels, weighted by the inverse of the channel's variance.

*This work was done by Michael Wolf of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48143*

## Low-Power Architecture for an Optical Life Gas Analyzer

**A simple camcorder battery can be used for as long as eight hours.**

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

Analog and digital electronic control architecture has been combined with an operating methodology for an optical trace gas sensor platform that allows very low power consumption while providing four independent gas measurements in essentially real time, as well as a user in-

terface and digital data storage and output. The implemented design eliminates the cross-talk between the measurement channels while maximizing the sensitivity, selectivity, and dynamic range for each measured gas. The combination provides for battery operation on a sim-

ple camcorder battery for as long as eight hours. The custom, compact, rugged, self-contained design specifically targets applications of optical major constituent and trace gas detection for multiple gases using multiple lasers and photodetectors in an integrated package.