Technology Focus: Sensors

Analysis of SSEM Sensor Data Using BEAM

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A report describes analysis of space shuttle main engine (SSME) sensor data using Beacon-based Exception Analysis for Multimissions (BEAM) [*NASA Tech Briefs* articles, the two most relevant being "Beacon-Based Exception Analysis for Multimissions" (NPO-20827), Vol. 26, No.9 (September 2002), page 32 and "Integrated Formulation of Beacon-Based Exception Analysis for Multimissions" (NPO-21126), Vol. 27, No. 3 (March 2003), page 74] for automated detection of anomalies. A specific implementation of BEAM, using the Dynamical Invariant Anomaly Detector (DIAD), is used to find anomalies commonly encountered during SSME ground test firings. The DIAD detects anomalies by computing coefficients of an autoregressive model and comparing them to expected values extracted from previous training data. The DIAD was trained using nominal SSME test-firing data. DIAD detected all the major anomalies including blade failures, frozen sense lines, and deactivated sensors. The DIAD was particularly sensitive to anomalies caused by faulty sensors and unexpected transients. The system offers a way to reduce SSME analysis time and cost by automatically indicating specific time periods, signals, and features contributing to each anomaly. The software described here executes on a standard workstation and delivers analyses in seconds, a computing time comparable to or faster than the test duration itself, offering potential for real-time analysis.

This work was done by Michail Zak, Han Park, and Mark James of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-30664

Hairlike Percutaneous Photochemical Sensors

Mass-produced, inexpensive sensors would be small enough to be minimally invasive.

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Instrumentation systems based on hairlike fiber-optic photochemical sensors have been proposed as minimally invasive means of detecting biochemicals associated with cancer and other diseases. The fiber-optic sensors could be mass-produced as inexpensive, disposable components. The sensory tip of a fiber-optic sensor would be injected through the patient's skin into subcutaneous tissue. A biosensing material on the sensory tip would bind or otherwise react with the biochemical(s) of interest [the analyte(s)] to produce a change in optical properties that would be measured by use of an external photonic analyzer. After use, a fiber-optic sensor could be simply removed by plucking it out with tweezers.

A fiber-optic sensor according to the proposal would be of the approximate size and shape of a human hair, and its sensory tip would resemble a follicle. Once inserted into a patient's subcutaneous tissue, the sensor would even more closely resemble a hair growing from a follicle (see Figure 1). The biosensing material on the sensory tip could consist of a chemical and/or cells cultured and modified for the purpose. The biosensing material would be contained within a membrane that would cover the tip. If the membrane were not permeable by an analyte, then it would be necessary to create pores in the membrane that would be large enough to allow analyte molecules to diffuse to the biosensing material, but not so large as to allow cells (if present as part of the biosensing material) to diffuse out. The end of the fiber-optic sensor opposite the sensory tip would be inserted in a fiber-optic socket in the photonic analyzer.

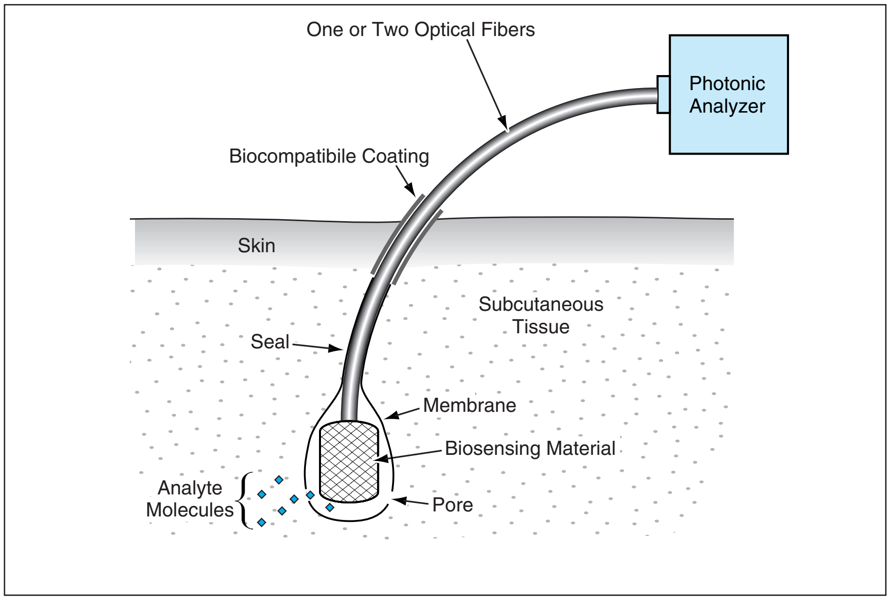

Figure 1. A **Fiber-Optic Sensor** would be implanted through the skin into subcutaneous tissue. The sensory tip would contain a biosensing material that, upon reaction with analyte molecules, would undergo a change in optical properties.

The basic concept of photonic detection of an analyte admits of the use of

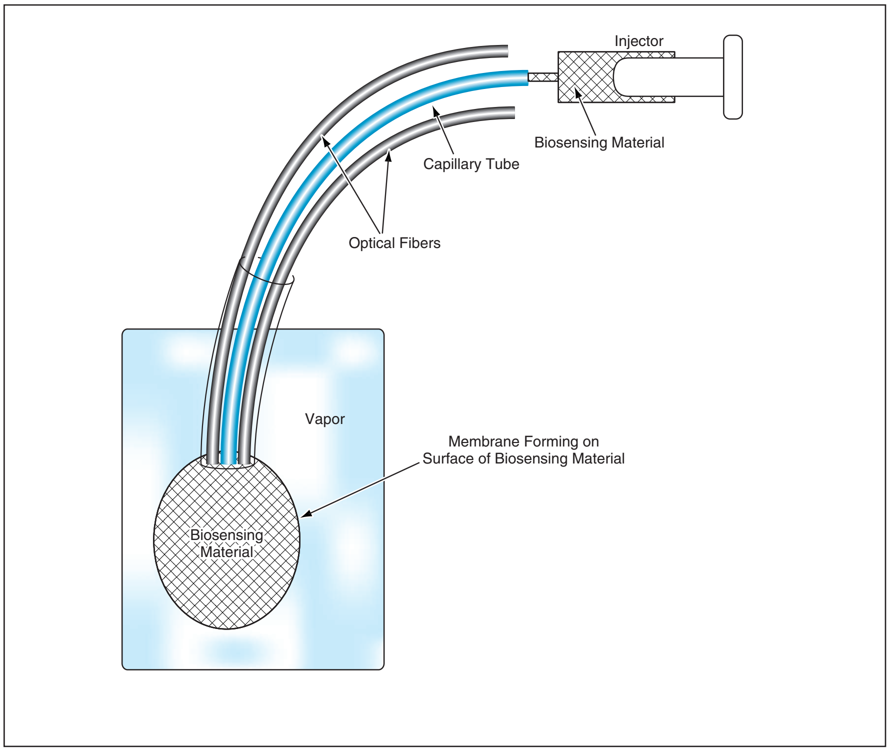

Figure 2. A **Fiber-Optic Sensor Could Be Fabricated** in a process that would include placement of a droplet containing biosensing material on the tip and vapor deposition of a polymer on the droplet and the optical fibers.

any of several alternative techniques. In one well-known technique, the biosensing material would be illuminated with light having the proper wavelength to excite fluorescence. The intensity and/or wavelength of the fluorescence would depend on the presence or absence of the bound analyte. In some cases, it may be desirable to use the same optical fiber to transmit the exciting light to the sensor and to transmit the fluorescence back to the photonic analyzer. The use of a single fiber would be appropriate if, for example, a brief excitation pulse of light could be expected to produce a longer-lived fluorescence that could be detected after the excitation pulse had been extinguished. In other cases, it may be necessary to use one optical fiber to transmit the excitation light to the biosensing material and another fiber to transmit the fluorescence back to the photonic analyzer. Alternatively or in addition to using fluorescence, it could be possible to measure the concentration of an analyte in terms of the amount of absorption of light of a particular wavelength from a broadband or spectrally modulated illumination.

Figure 2 illustrates a process that might be used to fabricate a two-fiber sensor according to the proposal. The two optical fibers would be bundled with a capillary tube at the end destined to become the sensory tip. The bundled end would be placed in a chamber, which would be partly evacuated and then back-filled with the vapor of a vapor-depositable material. As the vapor condensed and polymerized on the surface of the bundle, a droplet of biosensing material would be injected through the capillary tube. The droplet would become cooled rapidly by rapid evaporation in the partial vacuum. The cooling of the droplet would increase the rate of condensation of vapor and polymerization on the surface of the droplet, thereby causing the formation of the aforementioned membrane, which would be continuous with a tightly adherent coat over the contiguous optical fibers and capillary tube.

A suitable vapor-depositable material could be Parylene — a thermoplastic polymer made from poly-para-xylylene. Parylene is a highly biocompatible material that tends to discourage the adhesion and tracking of epithelial cells. Because Parylene exhibits little or no permeability by typical analytes that one might seek to detect, it would be necessary to create pores in the membrane. This could be done by, for example, burning holes by use of a tightly focused laser beam.

This work was done by Thomas George of Caltech and Gerald Loeb of the University of Southern California for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

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Refer to NPO-30651, volume and number of this NASA Tech Briefs *issue, and the page number.*

Video Guidance Sensors Using Remotely Activated Targets

These systems would not rely on wire connections or GPS signals for synchronization.

Marshall Space Flight Center, Alabama

Four updated video guidance sensor (VGS) systems have been proposed. As described in a previous *NASA Tech Briefs* article, a VGS system is an optoelectronic system that provides guidance for automated docking of two vehicles. The VGS provides relative position and attitude (6-DOF) information between the VGS and its target. In the original intended application, the two vehicles would be spacecraft, but the basic principles of design and operation of the system are applicable to aircraft, robots, objects maneuvered by cranes, or other objects that may be required to be aligned and brought together automatically or under remote control.