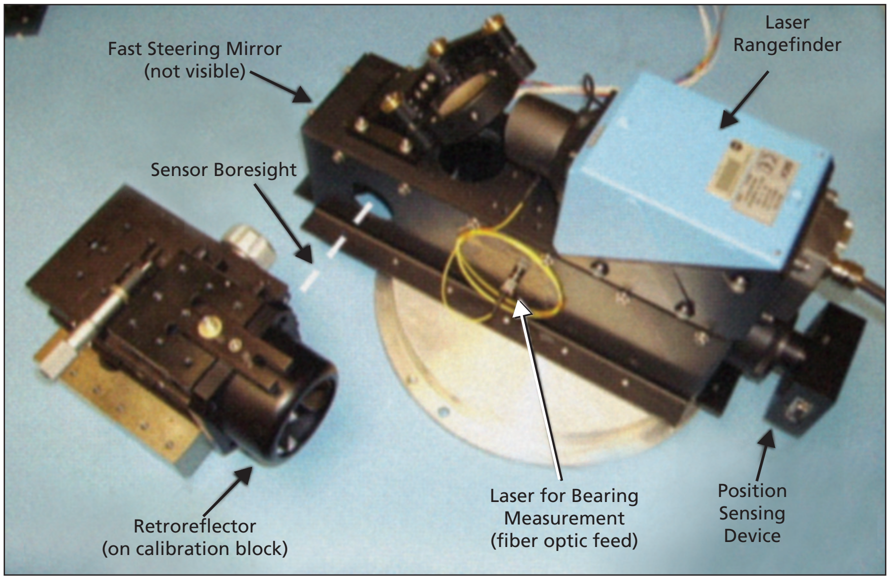

The **Formation Control Testbed Optical Pointing Loop** hardware is shown. The sensor system is composed of a laser rangefinder, fast steering mirror, back-end shear sensor, and a large-aperture, open-face retro target.

the return will be separated (sheared) from the outgoing beam by twice the distance between the impact point and the center of the retroreflector. Provided that shear amount is small enough, the return will hit the aperture of the steering mirror and go back through the beam splitter and be imaged on the back end of the scanner with the shear sensor. A telescope placed in front of the shear sensor serves to compress the image of the return beam to the size of the detector.

To acquire the retroreflector within the field of view of the shear sensor, the system operates by first performing an open loop search for the retroreflector target. Once a return from the retroreflector optic is detected, a servo loop is closed with the fast steering mirror and shear sensor to center the laser beam on the vertex of the retroreflector. Once locked, any motion of the retroreflector will be tracked by keeping the servo error small. Once in track mode, the IR rangefinder can be used to give range measurements. Bearing measurements are available from a local sensor used by the steering mirror.

In comparison to flash LIDAR systems, this work represents a system with much less complexity and a lower cost. The rangefinder used by the sensor system is a low-cost COTS (commercial off-the-shelf) unit. The camera in a flash LIDAR system is replaced with a much lower cost, two-dimensional shear sensor that reports only the center of light of the image. This sensor serves as both a detector for determining whether or not the retroreflector is hit by the pointing laser and as a feedback sensor for the tracking system when the retroreflector is moving.

This work was done by Joel F. Shields and Brandon C. Metz of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47001

Radio-Frequency Tank Eigenmode Sensor for Propellant Quantity Gauging

This sensor has applications in cryogenic liquid storage tanks.

John H. Glenn Research Center, Cleveland, Ohio

Although there are several methods for determining liquid level in a tank, there are no proven methods to quickly gauge the amount of propellant in a tank while it is in low gravity or under low-settling thrust conditions where propellant sloshing is an issue. Having the ability to quickly and accurately gauge propellant tanks in low-gravity is an enabling technology that would allow a spacecraft crew or mission control to always know the amount of propellant onboard, thus increasing the chances for a successful mission.

The Radio Frequency Mass Gauge (RFMG) technique measures the electromagnetic eigenmodes, or natural resonant frequencies, of a tank containing a dielectric fluid. The essential hardware components consist of an RF network analyzer that measures the reflected power from an antenna probe mounted internal to the tank. At a resonant frequency, there is a drop in the reflected power, and these inverted peaks in the reflected power spectrum are identified as the tank eigenmode frequencies using a peak-detection software algorithm. This information is passed to a pattern-matching algorithm, which compares the measured eigenmode frequencies with a database of simulated eigenmode frequencies at various fill levels. A best match between the simulated and measured frequency values occurs at some fill level, which is then reported as the gauged fill level.

The database of simulated eigenmode frequencies is created by using RF simulation software to calculate the tank eigenmodes at various fill levels. The input to the simulations consists of a fairly high-fidelity tank model with proper dimensions and including internal tank hardware, the dielectric properties of the fluid, and a defined liquid/vapor interface. Because of small discrepancies between the model and actual hardware, the measured empty tank spectra and simulations are used to create a set of correction factors for each mode (typically in the range of 0.999–1.001), which effectively accounts for the small discrepancies. These correction factors are multiplied to the modes at all fill levels. By comparing several measured modes with the simulations, it is possible to accurately gauge the amount of propellant in the tank.

An advantage of the RFMG approach of applying computer simulations and a pattern-matching algorithm is that the predictions can be verified through testing on Earth, and the results can be extrapolated to low-gravity liquid configurations using simulations of liquid configurations that would be likely to occur in low gravity. Such liquid configurations can also be solved using other computer software tools such as the Surface Evolver code. RF computer simulations are routinely used in the RF and communications industry to design or predict performance of RF devices. The same software tools can be used to calculate the electromagnetic eigenmodes of large tanks with a two-phase fluid distribution. By having a pre-built library of tank eigenmode simulations, the measured tank eigenmode spectra can be compared with the library of spectra to determine the unknown amount of propellant in the tank.

This work was led by Gregory A. Zimmerli, David A. Buchanan, Jeffrey C. Follo, Karl R. Vaden, and James D. Wagner of Glenn Research Center; Marius Asipauskas of National Center for Space Exploration Research; and Michael D. Herlacher of Analex Corp. 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: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18373-1.

High-Temperature Optical Sensor

The technology significantly extends applicability of optical sensors to high-temperature environments.

John H. Glenn Research Center, Cleveland, Ohio

A high-temperature optical sensor (see Figure 1) has been developed that can operate at temperatures up to 1,000 °C. The sensor development process consists of two parts: packaging of a fiber Bragg grating into a housing that allows a more sturdy thermally stable device, and a technological process to which the device is subjected to in order to meet environmental requirements of several hundred °C.

This technology uses a newly discovered phenomenon of the formation of thermally stable secondary Bragg gratings in communication-grade fibers at high temperatures to construct robust, optical, high-temperature sensors. Testing and performance evaluation (see Figure 2) of packaged sensors demonstrated operability of the devices at 1,000 °C for several hundred hours, and during numerous thermal cycling from 400 to 800 °C with different heating rates.

The technology significantly extends applicability of optical sensors to high-temperature environments including ground testing of engines, flight propulsion control, thermal protection monitoring of launch vehicles, etc. It may also find applications in such non-aerospace arenas as monitoring of nuclear reactors, furnaces, chemical processes, and other high-temperature environments where other measurement techniques are either unreliable, dangerous, undesirable, or unavailable.

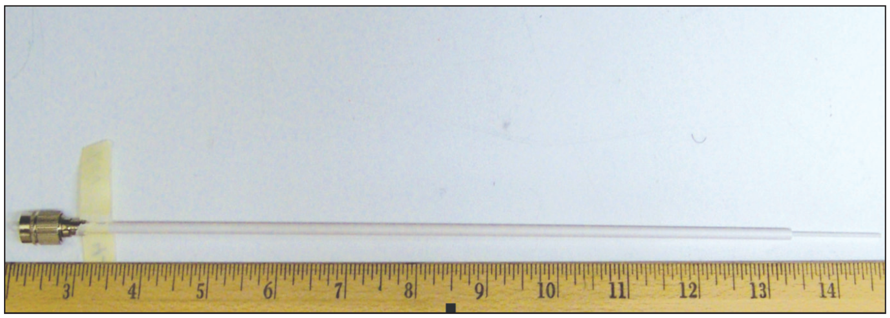

Figure 1. A **Probe** packaged and connectorized with a fiber Bragg grating (FBG) inside. The FBG is located at the end of the probe inside a smaller-diameter ceramic tube.

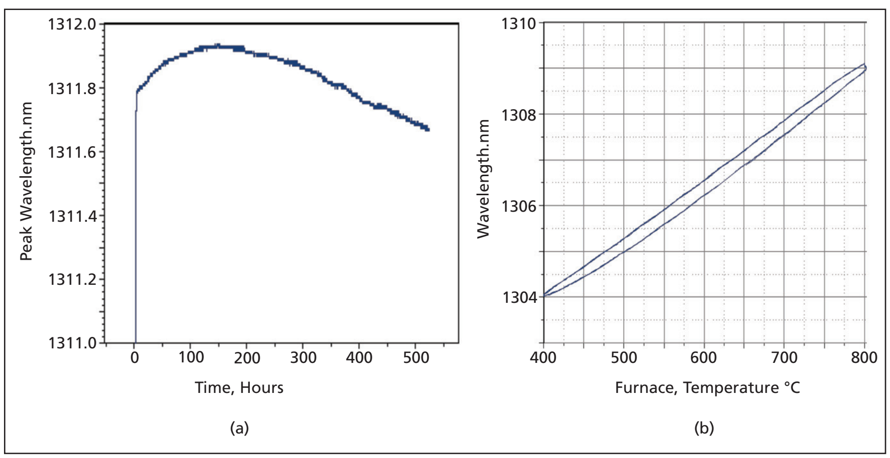

Figure 2. **Performance Characteristics**: (a) Wavelength stability of a sensor exposed to 1,000 °C for 500 hours and (b) wavelength readings as a function of temperature during thermal cycling from 400 to 800 °C.

This work was done by Grigory Adamovsky, Jeffrey R. Juergens, and Donald J. Varga of Glenn Research Center and Bertram M. Floyd of Sierra Lobo, 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: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18381-1.