



### **Semiautonomous Avionics-and-Sensors System for a UAV** Sensors and associated circuitry are packaged compactly on a circuit board.

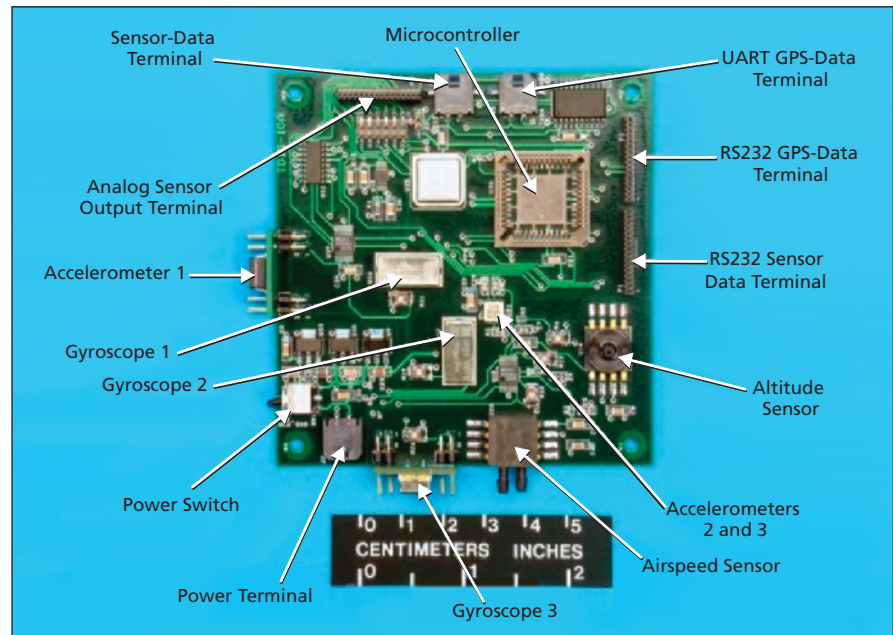
*Langley Research Center, Hampton, Virginia*

Unmanned Aerial Vehicles (UAVs) — autonomous or remotely controlled pilotless aircraft — have been recently thrust into the spotlight for military applications, for homeland security, and as test beds for research. In addition to these functions, there are many space applications in which lightweight, inexpensive, small UAVS can be used — e.g., to determine the chemical composition and other qualities of the atmospheres of remote planets. Moreover, on Earth, such UAVs can be used to obtain information about weather in various regions; in particular, they can be used to analyze wide-band acoustic signals to aid in determining the complex dynamics of movement of hurricanes.

The Advanced Sensors and Electronics group at Langley Research Center has developed an inexpensive, small, integrated avionics-and-sensors system to be installed in a UAV that serves two purposes. The first purpose is to provide flight data to an AI (Artificial Intelligence) controller as part of an autonomous flight-control system. The second purpose is to store data from a subsystem of distributed MEMS (micro-electromechanical systems) sensors.

Examples of these MEMS sensors include humidity, temperature, and acoustic sensors, plus chemical sensors for detecting various vapors and other gases in the environment. The critical sensors used for flight control are a differential-pressure sensor that is part of an apparatus for determining airspeed, an absolute-pressure sensor for determining altitude, three orthogonal accelerometers for determining tilt and acceleration, and three orthogonal angular-rate detectors (gyroscopes). By using these eight sensors, it is possible to determine the orientation, height, speed, and rates of roll, pitch, and yaw of the UAV. This avionics-and-sensors system is shown in the figure.

During the last few years, there has been rapid growth and advancement in the technological disciplines of MEMS, of onboard artificial-intelligence systems, and of smaller, faster, and smarter wireless telemetry systems. The major attraction of



This **Photograph of the Avionics-and-Sensors System** shows the critical sensors used for flight control.

MEMS lies in orders-of-magnitude reductions of power requirements relative to traditional electronic components that perform equivalent functions. In addition, the compactness of MEMS, relative to functionally equivalent traditional electronics systems, makes MEMS attractive for UAV applications. Recent advances in MEMS have made it possible to produce pressure, acceleration, humidity, and temperature sensors having masses in sub-gram range and possessing sensitivities and accuracies comparable to those of larger devices.

Some flight-control sensors, including pressure sensors, incorporate supporting circuitry that enables adjustment of their ranges (to values different from those set at the factory) in order to satisfy mission needs. Hence, the pressure sensors can be set to measure pressures in certain ranges (in effect, an absolute-pressure sensor can be set to be sensitive to a specific altitude and/or a differential-pressure sensor can be set to be sensitive to specific airspeed). If the altitude and airspeed requirements of the UAV are changed, the sensor ranges can be adjusted accordingly. The accelerometers incorporate circuitry that

adjusts their offset output voltages so that an onboard analog-to-digital converter (16-bit ADC) can center on their stable voltages. The data from the various sensors are multiplexed via the ADC, and the data are then gathered by an onboard microcontroller. The microcontroller determines the sample rate for each sensor and processes the digitized sensor data into a serial stream at a user-programmable rate.

An interface between this avionics-and-sensors system and an external system can be established at any of several points in the circuitry — which point depending on the type and level of control needed by the external system. For example, the serial data stream is sent to an onboard UART (Universal Asynchronous Receiver/Transmitter), the 0-to-5-volt output of which can be utilized directly by an external controller or processor. In addition, the data stream is also sent to an onboard RS-232 level converter chip, enabling a direct serial-port connection to an external computer when this avionics-and-sensors system is operated in a laboratory. The onboard microcontroller can be utilized in two ways: enabling an external microcontroller or computer to simply re-

ceive and respond to the sensor data, or controlling the flow of the sensor data.

The UAV control system provides (1) external connections to flight sensors, (2) the computational resources neces-

sary to make flight decisions, and (3) a simple interface through which control can be exerted over the servomotors that actuate the flight-control mechanisms of the UAV.

*This work was done by Qamar Shams of Langley Research Center. For further information, contact the Langley Innovative Partnerships Office at (757) 864-8881. LAR-16736-1*

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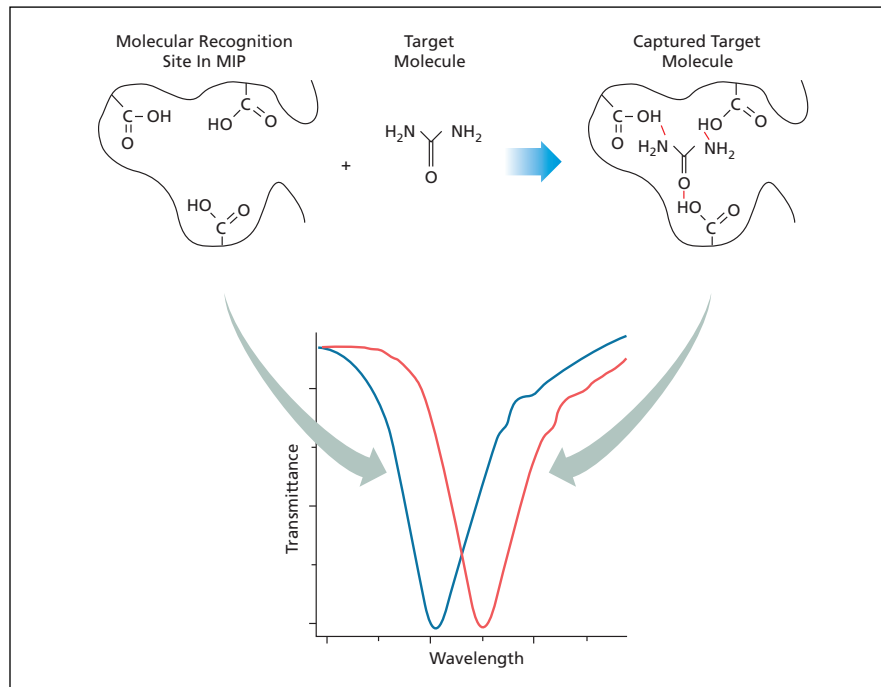
**Bacteria in liquid samples could be detected in real time.**

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

Biomimetic/optical sensors have been proposed as means of real-time detection of bacteria in liquid samples through real-time detection of compounds secreted by the bacteria. Bacterial species of interest would be identified through detection of signaling compounds unique to those species. The best-characterized examples of quorum-signaling compounds are acyl-homoserine lactones and peptides. Each compound, secreted by each bacterium of an affected species, serves as a signal to other bacteria of the same species to engage in a collective behavior when the population density of that species reaches a threshold level analogous to a quorum.

A sensor according to the proposal would include a specially formulated biomimetic film, made of a molecularly imprinted polymer (MIP), that would respond optically to the signaling compound of interest. The MIP film would be integrated directly onto an optical-waveguide-based ring resonator for optical readout. Optically, the sensor would resemble the one described in "Chemical Sensors Based on Optical Ring Resonators" (NPO-40601), *NASA Tech Briefs*, Vol. 29, No. 10 (October 2005), page 32.

MIPs have been used before as molecular-recognition compounds, though not in the manner of the present proposal. Molecular imprinting is an approach to making molecularly selective cavities in a polymer matrix. These cavities function much as enzyme receptor sites: the chemical functionality and shape of a cavity in the polymer matrix cause the cavity to bind to specific molecules. An MIP matrix is made by polymerizing monomers in the presence of the compound of interest (template molecule). The polymer forms around the template. After the polymer solidifies, the template molecules are removed from the polymer matrix by decomplexing them from their binding sites and then dissolving



**Capture of Target Molecules** at molecular recognition sites in an MIP film would cause a change in the wavelength of an optical resonance. The change would be proportional to the concentration of bacteria that secreted the target molecules.

them, leaving cavities that are matched to the template molecules in size, shape, and chemical functionality. The cavities thus become molecular-recognition sites that bind only to molecules matched to the sites; other molecules are excluded.

In a sensor according to the proposal, the MIP would feature molecular recognition sites that would bind the specific signaling molecules selectively according to their size, shape, and chemical functionality (see figure). As the film took up the signaling molecules in the molecular recognition sites, the index of refraction and thickness of the film would change, causing a wavelength shift of the peak of the resonance spectrum. It has been estimated that by measuring this wavelength shift, it should be possible to detect as little as 10 picomoles of a

peptide signaling compound.

*This work was done by Margie Homer, Alexander Ksendzov, Shiao-Pin Yen, and Margaret Ryan of Caltech and Beth Lazazzera of the University of California, Los Angeles, for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

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