

- microfabricated on a quartz substrate.
2. Nanocrystalline SnO<sub>2</sub> is synthesized in a partial sol-gel process. CuO dopant is synthesized through a precipitation process. The dopant and the sol-gel are mixed in proportions chosen to obtain the desired composition of the final product. One composition found to be suitable is a molar ratio of 1:8 CuO:SnO<sub>2</sub>.
  3. The dopant and sol-gel mixture is deposited in drops on (and across the gaps between) the electrodes.
  4. The workpiece is heated at a temperature of 700°C, converting the dopant

and sol-gel mixture to a film of nanocrystalline CuO doped SnO<sub>2</sub>.

In operation, a sensor of this type is heated to a temperature of 450°C while it is exposed to the CO<sub>2</sub> to be detected and the electrical resistance of the film between the electrodes is measured. Preliminary results of tests on a sensor containing a film of 1:8 CuO:SnO<sub>2</sub> showed an approximately linear response at CO<sub>2</sub> concentrations from 1 to 4 percent (see figure). In subsequent research and development efforts, it may be possible to increase sensitivities and/or reduce operating temperatures by combining

CuO-doped SnO<sub>2</sub> with solid-electrolyte materials.

*This work was done by Jennifer C. Xu and Gary W. Hunter of Glenn Research Center and Chung Chiu Liu and Benjamin J. Ward of Case Western Reserve University. 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-18247-1.*

## Improved Airborne System for Sensing Wildfires

**Unlike prior such systems, this system could be operated in daylight.**

*Stennis Space Center, Mississippi*

The Wildfire Airborne Sensing Program (WASP) is engaged in a continuing effort to develop an improved airborne instrumentation system for sensing wildfires. The system could also be used for other aerial-imaging applications, including mapping and military surveillance.

Unlike prior airborne fire-detection instrumentation systems, the WASP system would not be based on custom-made multispectral line scanners and associated custom-made complex optomechanical servomechanisms, sensors, readout circuitry, and packaging. Instead, the WASP system would be based on commercial off-the-shelf (COTS) equipment that would include (1) three or four electronic cameras (one for each of three or four wavelength bands) instead of a multispectral line scanner; (2) all associated drive and readout electronics; (3) a camera-pointing gimbal; (4) an inertial measurement unit (IMU) and a Global Positioning System (GPS) receiver for measuring the position, velocity, and orientation of the aircraft; and (5) a data-acquisition subsystem. It would be necessary to custom-develop an integrated sensor optical-bench assembly, a sensor-management subsystem, and software. The use of mostly COTS equipment is intended to reduce development time and cost, relative to those of prior systems.

The WASP system as envisioned (see figure) would include the three or four cameras, all aimed in the same direction, mounted in a camera subassembly. Three cameras would operate in the long-wavelength infrared (LWIR), medium-wavelength infrared (MWIR), and short-wavelength infrared (SWIR)

wavelength bands, respectively. The fourth camera, if included, would operate in the visible or visible plus near infrared (VNIR) wavelength band.

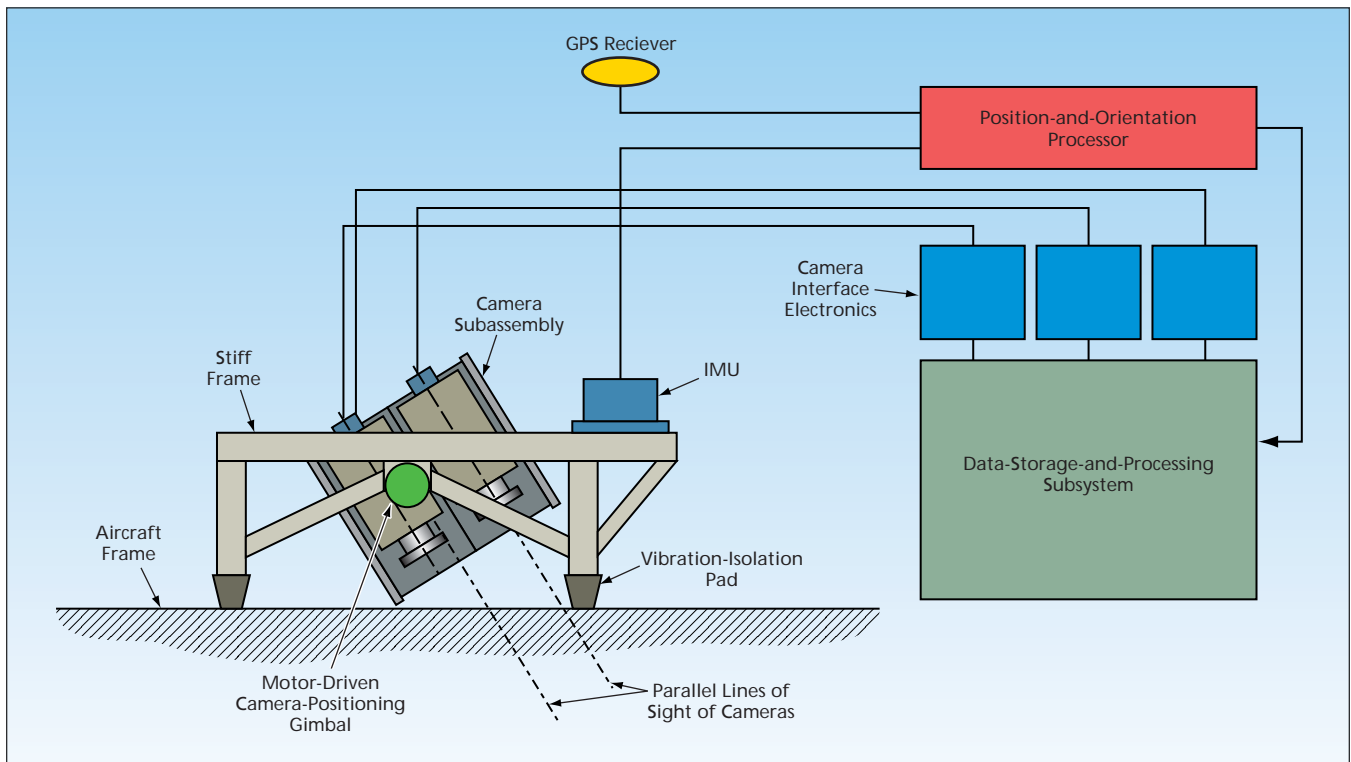
The camera subassembly would be mounted on the camera-positioning gimbal, which would scan the camera line of sight through a cross-track angular range of 40°. Because the half cone angle of the fields of view of the cameras would be 20°, this scanning action would provide coverage of a cross-track swath of 60°. Precise knowledge of the direction of the line of sight would be obtained from the combination of information provided by the GPS receiver, the inertial sensor subsystem, and a precise angle encoder mounted on the gimbal drive axis. Image data from the cameras and position and line-of-sight information would be sent to an on-board data-storage-and-processing subsystem. The estimated total weight of the system is less than 220 lb (equivalent to a mass <100 kg); the estimated maximum operating power of the system is <550 W.

In a typical fire-detection mission using a multispectral line-scanning instrumentation system, a 10-km-wide swath is imaged from an aircraft at an altitude of 3 km. Typically, missions are conducted at night to reduce false alarms attributable to solar heating. The MWIR band is used as the primary-fire detection band, along with an LWIR band, which provides scene context. A hot spot detected in the MWIR band can be located with respect to ground features imaged in the LWIR band. The line scanner provides excellent band-to-

band registration, but it is necessary to use a complex rate-controlled scanning mirror and significant post-processing to correct for variations between scan lines induced by variations in aircraft attitude and ground speed. The sensitive scanning mechanisms are also susceptible to failure and are difficult to service.

The WASP proposes to extend operation into the daytime and to improve operability. The extension into daytime would be enabled by the use of a SWIR camera in addition to the MWIR and LWIR cameras. (SWIR has been determined to be useful for discriminating fire targets in daylight and for detecting hot fires at night.) The fourth (visible or VNIR) camera, if included, would have very high resolution and would be used to provide detailed scene context during daylight operation.

In the WASP conceptual sequence of operation, the line of sight would be stepped across the swath between four discrete angular positions. The camera subassembly would be held steady at each angular position for a short time, during which the cameras would acquire image frames. The collection of frames would be assembled into a mosaic image spanning the cross-track swath. Because the frames would be acquired along momentarily steady lines of sight, there would be no need for complex rate-controlled servomechanisms. The motion of the aircraft would cause a small along-track offset between frames plus a small (typically, subpixel) smear during the image-integration (acquisition) time. Each of the four frames across the swath would be



The WASP System would include a gimbal that would aim several cameras operating in different spectral bands to acquire images at discrete angular increments to build a mosaic spectral image of a cross-track swath.

collected in at least three spectral bands (LWIR, MWIR, and SWIR at night or MWIR, SWIR, and visible or VNIR during the day), necessitating two registration steps. In the first step, the frames from the three spectral bands would be aligned into one frame. Then the frames

from the four angular positions would be aligned to produce the mosaic.

*This work was done by Donald McKeown and Michael Richardson of Rochester Institute of Technology for Stennis Space Center.*

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