

cameras and a polarization camera. For each set of input images, the innovators calculate degree of linear polarization (DOLP), back-project polarization pixels that have high DOLP into the left color image, generate a stereo range image (which is registered with the left color image), and insert detected mud into a world map using the stereo range data. As it is only expected for mud to occur on the ground surface, stereo range data are used to isolate ground surface pixels from the other pixels corresponding to ground clutter. Ground

clutter pixels with high DOLP (such as vegetation) are ignored.

Techniques to estimate soil moisture content have been studied for decades for agricultural applications; however, mud detection for UGV autonomous navigation is a relatively new research area. Ground vehicle methods of soil moisture estimation have used passive microwave sensors, but the antennas tend to be bulky and have been mounted directly downwards. This requires a UGV to drive on potentially hazardous terrain in order to characterize it. This work involves de-

tecting mud hazards from a UGV without having to drive on the hazard first.

Mud detection is a terrestrial application; however, the intermediate image processing steps and world modeling techniques performed for this task are valuable to terrain hazard assessment in general, terrestrial, or planetary situations.

*This work was done by Arturo L. Rankin and Larry H. Matthies of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-46624*

## Gas Flow Detection System

**Commercial applications include flow measurement systems.**

*John F. Kennedy Space Center, Florida*

This system provides a portable means to detect gas flow through a thin-walled tube without breaking into the tubing system. The flow detection system was specifically designed to detect flow through two parallel branches of a manifold with only one inlet and outlet, and is a means for verifying a space shuttle program requirement that saves time and reduces the risk of flight hardware damage compared to the current means of requirement verification.

The prototype Purge Vent and Drain Window Cavity Conditioning System (PVD WCCS) Flow Detection System consists of a heater and a temperature-sensing thermistor attached to a piece of Velcro to be attached to each branch of a WCCS manifold for the duration of the requirement verification test. The heaters and thermistors are connected to a shielded cable and then to an electronics enclosure, which contains the power supplies, relays, and circuit board to provide power, signal conditioning, and control. The electronics enclosure is then connected to a commercial data acquisition box to provide analog to

digital conversion as well as digital control. This data acquisition box is then connected to a commercial laptop running a custom application created using National Instruments' LabVIEW.

The operation of the PVD WCCS Flow Detection System consists of first attaching a heater/thermistor assembly to each of the two branches of one manifold while there is no flow through the manifold. Next, the software application running on the laptop is used to turn on the heaters and to monitor the manifold branch temperatures. When the system has reached thermal equilibrium, the software application's graphical user interface (GUI) will indicate that the branch temperatures are stable. The operator can then physically open the flow control valve to initiate the test flow of gaseous nitrogen (GN<sub>2</sub>) through the manifold. Next, the software user interface will be monitored for stable temperature indications when the system is again at thermal equilibrium with the test flow of GN<sub>2</sub>. The temperature drop of each branch from its "no flow" stable

temperature peak to its stable "with flow" temperature will allow the operator to determine whether a minimum level of flow exists.

An alternative operation has the operator turning on the software only long enough to record the ambient temperature of the tubing before turning on the heaters and initiating GN<sub>2</sub> flow. The stable temperature of the heated tubing with GN<sub>2</sub> flow is then compared with the ambient tubing temperature to determine if flow is present in each branch. To help quantify the level of flow in the manifolds, each branch will be bench calibrated to establish its thermal properties using the flow detection system and different flow rates. These calibration values can then be incorporated into the software application to provide more detailed flow rate information.

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## Mapping Capacitive Coupling Among Pixels in a Sensor Array

**Cross-talk calibration of all pixels can be performed efficiently.**

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An improved method of mapping the capacitive contribution to cross-talk among pixels in an imaging array of sensors (typically, an imaging photodetector array) has been devised for use in calibrating and/or

characterizing such an array. The method is applicable to almost all image detectors in modern electronic cameras for diverse applications, ranging from consumer cellular-telephone cameras at one extreme to

high-performance imaging scientific instruments at the other extreme. In comparison with prior methods of quantifying the capacitive coupling among pixels, this method is a more efficient means of ob-