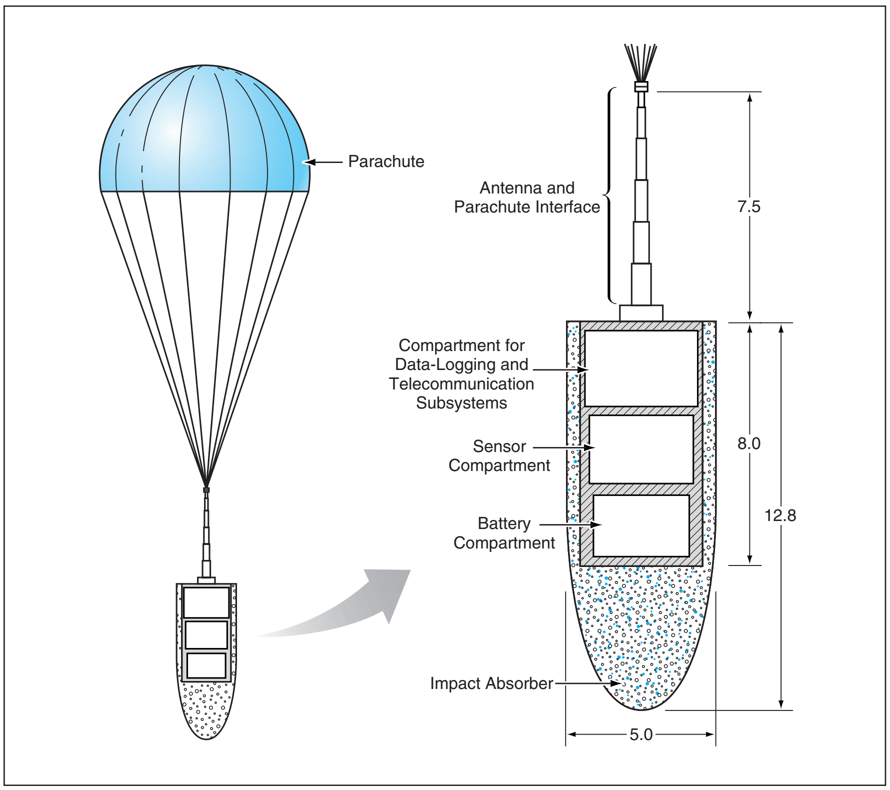
Monitoring Volcanoes by Use of Air-Dropped Sensor Packages

Use of these packages would contribute to understanding and prediction of eruptions.

NASA's Jet Propulsion Laboratory, Pasadena, California

Sensor packages that would be dropped from airplanes have been proposed for pre-eruption monitoring of physical conditions on the flanks of awakening volcanoes. The purpose of such monitoring is to gather data that could contribute to understanding and prediction of the evolution of volcanic systems.

Each sensor package, denoted a volcano monitoring system (VMS), would include a housing with a parachute attached at its upper end and a crushable-foam impact absorber at its lower end (see figure). The housing would contain survivable low-power instrumentation that would include a Global Positioning System (GPS) receiver, an inclinometer, a seismometer, a barometer, a thermometer, and CO_2 and SO_2 analyzers. The housing would also contain battery power, control, data-logging, and telecommunication subsystems. The proposal for the development of the VMS calls for the use of commercially available sensor, power, and telecommunication equipment, so that efforts could be focused on integrating all of the equipment into a system that could survive impact and operate thereafter for 30 days, transmitting data on the pre-eruptive state of a target volcano to a monitoring center.



A **Volcano Monitoring System** would be a package of integrated instrumentation that would be dropped on the flanks of a volcano believed to be about to erupt. The dimensions shown here are in inches and are tentative.

In a typical scenario, VMSs would be dropped at strategically chosen locations on the flanks of a volcano once the volcano had been identified as posing a hazard from any of a variety of observations that could include eyewitness reports, scientific observations from positions on the ground, synthetic-aperture-radar scans from aircraft, and/or remote sensing from aboard spacecraft. Once dropped, the VMSs would be operated as a network of *in situ* sensors that would transmit data to a local monitoring center. This network would provide observations as part of an integrated volcano-hazard-assessment strategy that would involve both remote sensing and timely observations from the *in situ* sensors.

A similar strategy that involves the use of portable sensors (but not dropping of sensors from aircraft) is already in use in the Volcano Disaster Assistance Program (VDAP), which was developed by the U. S. Geological Survey and the U. S. Office of Foreign Disaster Assistance to respond to volcanic crises around the world. The VMSs would add a greatly needed capability that would enable VDAP response teams to deploy their volcano-monitoring equipment in a more timely manner with less risk to personnel in the field.

This work was done by Sharon Kedar, Tommaso Rivellini, Frank Webb, Brent Blaes, and Caroline Bracho of Caltech and Andrew Lockhart and Ken McGee of the USGS for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.techbriefs.com/tsp*** *under the Computers/Electronics category.*

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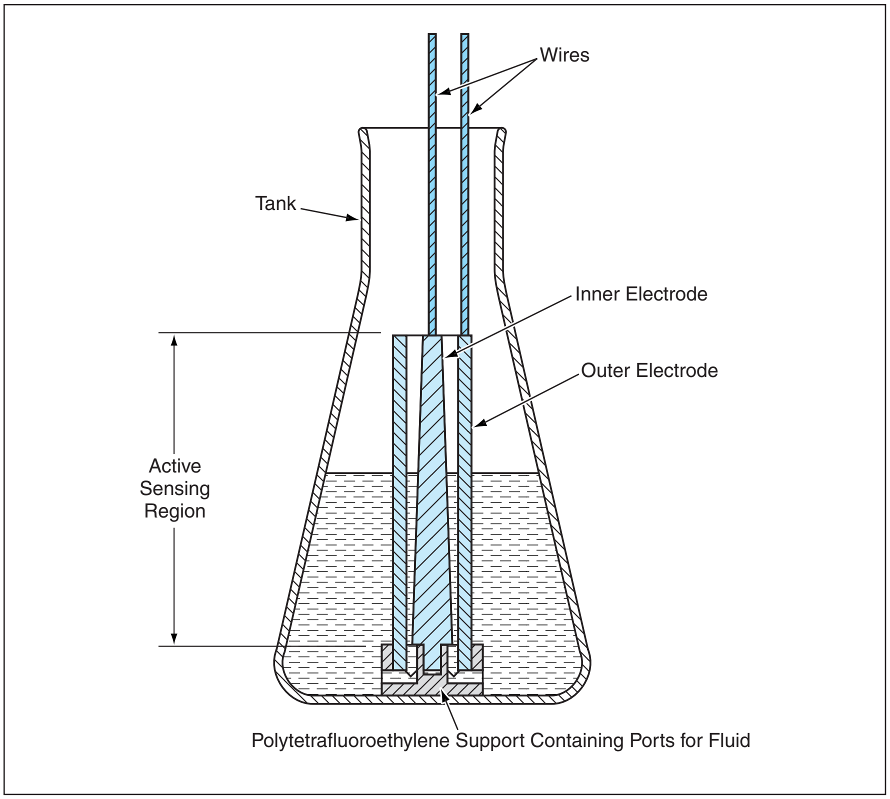
Capacitive Sensors for Measuring Masses of Cryogenic Fluids

A single capacitance reading is linearly related to the mass of fluid in a tank.

John F. Kennedy Space Center, Florida

An effort is under way to develop capacitive sensors for measuring the masses of cryogenic fluids in tanks. These sensors are intended to function in both microgravitational and normal gravitational settings, and should not be confused with level sensors, including capacitive ones. A sensor of this type is conceptually simple in the sense that (1) it includes only one capacitor and (2) if properly designed, its single capacitance reading should be readily convertible to



The **Inner Electrode of the Capacitor** is tapered so that along with the horizontal-plane cross-sectional area, the capacitance per unit height of the electrodes varies with height.

a close approximation of the mass of the cryogenic fluid in the tank.

Consider a pair of electrically insulated electrodes used as a simple capacitive sensor. In general, the capacitance is proportional to the permittivity of the dielectric medium (in this case, a cryogenic fluid) between the electrodes. The success of design and operation of a sensor of the present type depends on the accuracy of the assumption that to a close approximation, the permittivity of the cryogenic fluid varies linearly with the density of the fluid. Data on liquid nitrogen, liquid oxygen, and liquid hydrogen, reported by the National Institute of Standards and Technology, indicate that the permittivities and densities of these fluids are, indeed, linearly related to within a few tenths of a percent over the pressure and temperature regions of interest. Hence, ignoring geometric effects for the moment, the capacitance between two electrodes immersed in the fluid should vary linearly with the density, and, hence, with the mass of the fluid.

Of course, it is necessary to take account of the tank geometry. Because most cryogenic tanks do not have uniform cross sections, the readings of level sensors, including capacitive ones, are not linearly correlated with the masses of fluids in the tanks. In a sensor of the present type, the capacitor electrodes are shaped so that at a given height, the capacitance per unit height is approximately proportional to the cross-sectional area of the tank in the horizontal plane at that height (see figure). This shaping should ensure that the contribution of the fluid at each height to the overall capacitance is proportional to the density of fluid at that height, whether the fluid is pulled down by normal gravitation or becomes stratified in microgravitation.

The feasibility of this sensor concept was demonstrated in an experiment in which a simple cylindrical capacitor was immersed in liquid nitrogen and capacitance readings were taken and correlated with mass readings as the liquid nitrogen boiled off. The results of this experiment, taken together with theoretical calculations, have been interpreted as signifying that suitably designed sensors of this type can be expected to yield mass readings accurate to within about one percent of their full-scale values.

This work was done by Mark Nurge and Robert Youngquist of **Kennedy Space Center**. *Further information is contained in a TSP (see page 1).*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-8130. Refer to KSC-12457.