aircraft communication and navigation systems.

The first level of the system includes one or more remote data-acquisition units (RDAUs) placed at different locations within each aircraft or other vehicle. An RDAU acquires, stores, and analyzes sensor data. The user has the capability to define the number of inputs, type of sensors, sensor input characteristics, aggregate sampling rate, and acquisition period duration. This information is used to configure the sampling interface and its associated multiplexed eight-channel analog-to-digital converter. An RDAU can analyze measurements from each channel individually or from all channels fused together. Programmable data-acquisition circuitry and expert-system software trained to performance baselines in each RDAU make it possible to adapt the system to many types of vehicles and structures. The RDAU has been tested at temperatures from –50 to +55 °C. Pressure testing has verified that RDAUs could be used in non-environmentally-controlled spaces on aircraft at altitudes up to 50,000 ft (15.24 km). Vibration tests have verified that RDAUs can operate during vibrations representative of those of commercial aircraft. The final vibrations used in the tests had an amplitude of 20 times normal Earth gravitational acceleration and a frequency of 2 kHz.

The second level of the system includes a command-and-control unit (CCU) in each vehicle. The CCU regulates the health-monitoring activities in the vehicle. The CCU is a computer-based subsystem that controls communications to and from all RDAUs; regulates all RDAU measurement, collection, and analysis; and retrieves the results of all data-collection and analysis performed by the RDAUs.

The third level of the system is a terminal collection unit (TCU). The TCU provides the means to autonomously retrieve vehicle analysis results from all the CCUs or RDAUs of all vehicles. The TCU analyzes all results collected from all vehicles to identify any fleet-wide anomalies (e.g., all aircraft have the same faulty bearing at a similar location). The TCU is used to develop the final summary of the vehicle health. The summary is routed to the appropriate users (e.g., maintenance workers and airline operations personnel).

The system can also serve as an infrastructure for performing tributary analyses: NASA Langley Research Center has developed a parameterized fuzzy expert-system algorithm that can be trained to a user's subjective analysis of data. The expert-system algorithm and other analysis algorithms can be used at each operational level. The measurements collected at the lowest level can be analyzed at that level. Analysis results are forwarded to next operational level, and then all results are analyzed to ascertain global trends or anomalies for the prior level. This is repeated until all analyses are combined at the hierarchically highest level (e.g., the third level).

The trainable parameterized fuzzy expert system, the wireless communication between components, and the programmable digital interface make the health-monitoring hardware and software infrastructure adaptable to many vehicles and structures. Performing analysis at each level eliminates the need for transmitting and storing large volumes of collected measurements.

The RDAU hardware and the non-analytical portion of the software of the system have been flight-tested on the landing gear of Langley Research Center's Boeing 757 airplane (see Figure 2) — the most severe location on that airplane for mounting a health-monitoring device. During test flights, the CCU was located in the passenger section of the airplane. A portable TCU equipped with the non-analytical capabilities of the TCU was shown to function as intended in downloading of data after flights.

This work was done by Stanley E. Woodart, Keith L. Woodman, and Neil C. Coffey of **Langley Research Center** *and Bryant D. Taylor of Swales Corp. 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 Patent Counsel, Langley Research Center, at (757) 864-3521. Refer to LAR-16516.

Miniature Focusing Time-of-Flight Mass Spectrometer

Resolution is retained despite the reduction in size.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved miniature time-of-flight mass spectrometer has been developed in a continuing effort to minimize the sizes, weights, power demands, and costs of mass spectrometers for such diverse applications as measurement of concentrations of pollutants in the atmosphere, detecting poisonous gases in mines, and analyzing exhaust gases of automobiles. Advantageous characteristics of this mass spectrometer include the following:

- It is simple and rugged.
- Relative to prior mass spectrometers, it is inexpensive to build.
- There is no need for precise alignment of its components.
- Its mass range is practically unlimited.

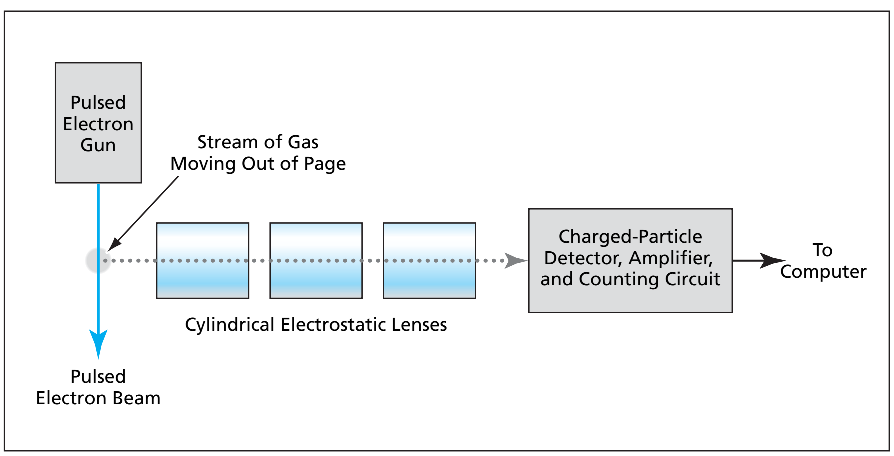

Figure 1. This **Miniature Time-of-Flight Mass Spectrometer** utilizes charged-particle optics in conjunction with ion speeds smaller than those of similar prior instruments.

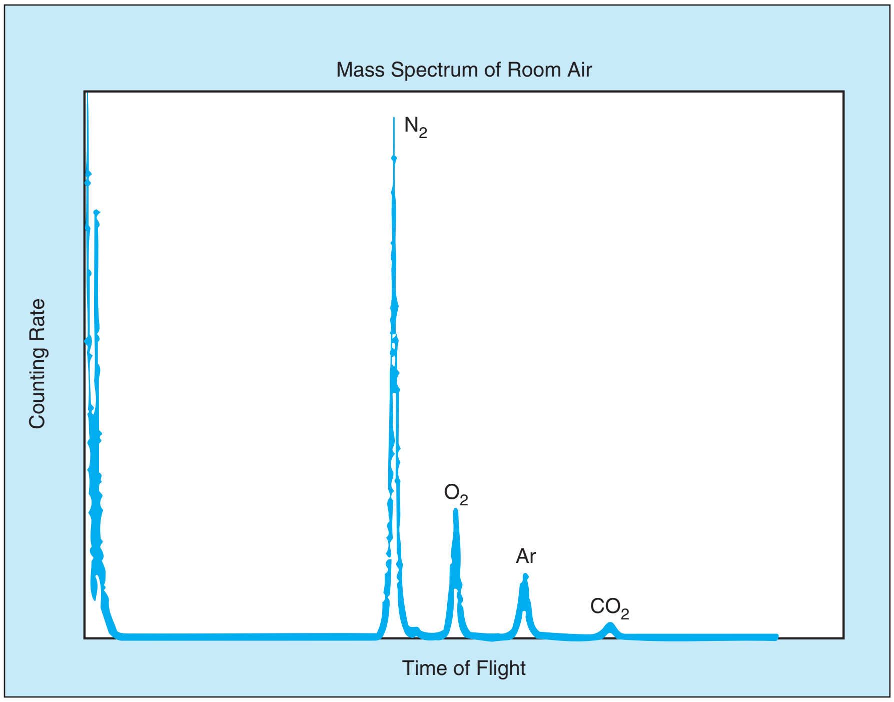

Figure 2. This **Uncalibrated Mass Spectrum** of air was acquired by use of the improved TOF-MS.

- Relative to prior mass spectrometers, it offers high sensitivity (ability to measure relative concentrations as small as parts per billion).
- Its resolution is one dalton (one atomic mass unit).
- An entire mass spectrum is recorded in a single pulse. (In a conventional mass spectrometer, a spectrum is recorded mass by mass.) The data-acquisition process takes only seconds.
- It is a lightweight, low-power, portable instrument.

Although time-of-flight mass spectrometers (TOF-MSs) have been miniaturized previously, their performances have not been completely satisfactory. An inherent adverse effect of miniaturization of a TOF-MS is a loss of resolution caused by reduction of the length of its flight tube. In the present improved TOF-MS, the adverse effect of shortening the flight tube is counteracted by (1) using charged-particle optics to constrain ion trajectories to the flight-tube axis while (2) reducing ion velocities to increase ion flight times.

In the present improved TOF-MS, a stream of gas is generated by use of a hypodermic needle. The stream of gas is crossed by an energy-selected, pulsed beam of electrons (see Figure 1). The ions generated by impingement of the electrons on the gas atoms are then focused by three cylindrical electrostatic lenses, which constitute a segmented flight tube. After traveling along the flight tube, the ions enter a charged-particle detector. The output of the detector is fed to a counting circuit to obtain data on the counting rate as a function of time. Inasmuch as time of flight is directly proportional to the ion mass, a plot of the counting rate versus time of flight is equivalent to a mass spectrum (see Figure 2).

This work was done by Isik Kanik and Santosh Srivastava of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1)*
NPO-30611

Cryogenic High-Sensitivity Magnetometer

Sensitivity would be about a million times that of a flux-gate magnetometer.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed magnetometer for use in a cryogenic environment would be sensitive enough to measure a magnetic-flux density as small as a picogauss (10^{-16} Tesla). In contrast, a typical conventional flux-gate magnetometer cannot measure a magnetic-flux density smaller that about 1 microgauss (10^{-10} Tesla).

One version of this device, for operation near the low end of the cryogenic temperature range, would include a piece of a paramagnetic material on a platform, the temperature of which would be controlled with a periodic variation. The variation in temperature would be measured by use of a conventional germanium resistance thermometer. A superconducting coil would be wound around the paramagnetic material and coupled to a superconducting quantum interference device (SQUID) magnetometer.

The SQUID magnetometer would be used to measure the change in current in the coil as a result of the change in temperature measured by the germanium resistance thermometer. The ratio between the current change and the temperature change would be computed, then used to infer the ambient magnetic field. This inference would be drawn from a lookup table established by prior calibration measurements performed at the same mean operating temperature.

In an alternative version of this magnetometer, for operation at a temperature near the high end of the cryogenic range, the coil and the SQUID magnetometer would be made from a high-temperature superconductor and the coil would be in the form of a thin film deposited on the same substrate as that of the SQUID. The paramagnetic material would be inserted in a hole at the center of the coil. The temperature of the whole substrate would then be modulated during measurements of the type described above.

Because of the oscillatory temperature excitation, this magnetometer would exhibit very little drift. The highest sensitivity and the lowest noise would be achieved by careful selection of the paramagnetic material and operating near the Curie temperature of that material.

Although the SQUID magnetometer and the superconducting coil must be kept cold, it would be possible to measure the magnetic field of a warm environment. For this purpose, the magne-