

tion of the glass panel was cooled by contact with an aluminum plate that was cooled by a thermoelectric module, the exhaust heat of which was dissipated by a heat sink cooled by a fan. A thermocouple was used to measure the interior temperature of the aluminum plate, and six other thermocouples were used to measure the temperatures at six locations on the cooled outer surface of the glass panel (see Figure 2). Thermal grease was applied to the aluminum plate and the thermocouples to ensure close thermal contact.

Power was supplied to the thermoelec-

tric module in small increments, based on previous laboratory tests. A small flashlight and a magnifying glass were used to look for water droplets condensing on the inner surface of the glass. The temperature readings of the thermocouples were taken during cool-down and upon observing condensation.

In determining the dew point, it was necessary to make a correction for the differences between the temperatures measured on the chilled outer surface of the glass and the temperature of the inner surface, where the condensation took place. The correction was derived

from a laboratory test on a measurement setup that was nearly identical, except that the dew location on the inner surface was also instrumented with a thermocouple. The test showed that the temperature at the dew location on the inner surface of the glass panel was 0.9 C° above the temperature determined from the measurements on the chilled outer surface of the panel.

*This work was done by James W. West, Cecil G. Burkett, and Joel S. Levine of Langley Research Center. Further information is contained in a TSP (see page 1). LAR-16422-1*

## Adaptable System for Vehicle Health and Usage Monitoring

Safety can be increased, while costs and downtime can be reduced.

Langley Research Center, Hampton, Virginia

Aircraft and other vehicles are often kept in service beyond their original design lives. As they age, they become susceptible to system malfunctions and fatigue. Unlike future aircraft that will include health-monitoring capabilities as integral parts in their designs, older aircraft have not been so equipped.

The Adaptable Vehicle Health and Usage Monitoring System is designed to be retrofitted into a preexisting fleet of military and commercial aircraft, ships, or ground vehicles to provide them with state-of-the-art health- and usage-monitoring capabilities. The monitoring system is self-contained, and the integration of it into existing systems entails limited intrusion. In essence, it has “bolt-on/bolt-off” simplicity that makes it easy to install on any preexisting vehicle or structure. Because the system is completely

independent of the vehicle, it can be certified for airworthiness as an independent system.

The purpose served by the health-monitoring system is to reduce vehicle operating costs and to increase safety and reliability. The monitoring system is a means to identify damage to, or deterioration of, vehicle subsystems, before such damage or deterioration becomes costly and/or disastrous. Frequent monitoring of a vehicle enables identification of the embryonic stages of damage or deterioration. The knowledge thus gained can be used to correct anomalies while they are still somewhat minor. Maintenance can be performed as needed, instead of having the need for maintenance identified during cyclic inspections that take vehicles off duty even when there are no maintenance problems. Measurements and analyses ac-

quired by the health-monitoring system also can be used to analyze mishaps. Overall, vehicles can be made more reliable and kept on duty for longer times.

Figure 1 schematically depicts the system as applied to a fleet of  $n$  vehicles. The system has three operational levels. All communication between system components is by use of wireless transceivers operating at frequencies near 433 MHz. Electromagnetic-interference tests have demonstrated that the radio-frequency emissions from the transceivers do not influence civilian

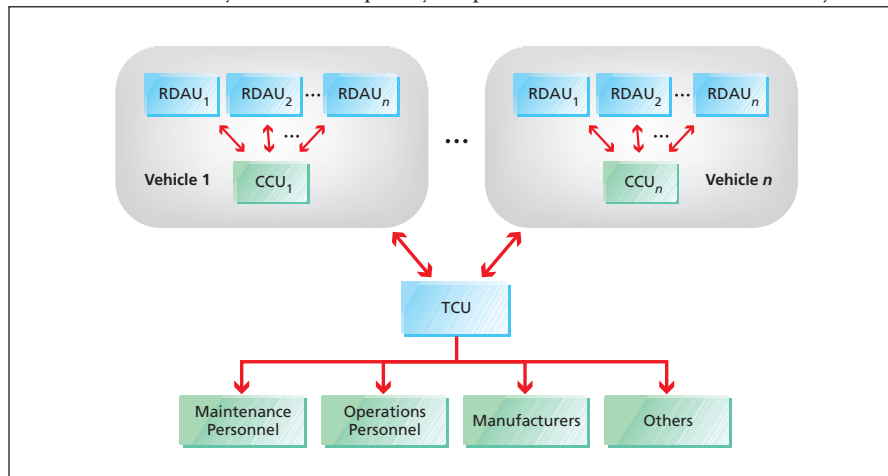


Figure 1. The Adaptable Vehicle Health and Usage Monitoring System is characterized by three levels of operation and analysis.



Figure 2. An RDAU Mounted on a Landing Gear was used to perform a rigorous test of the system.

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.

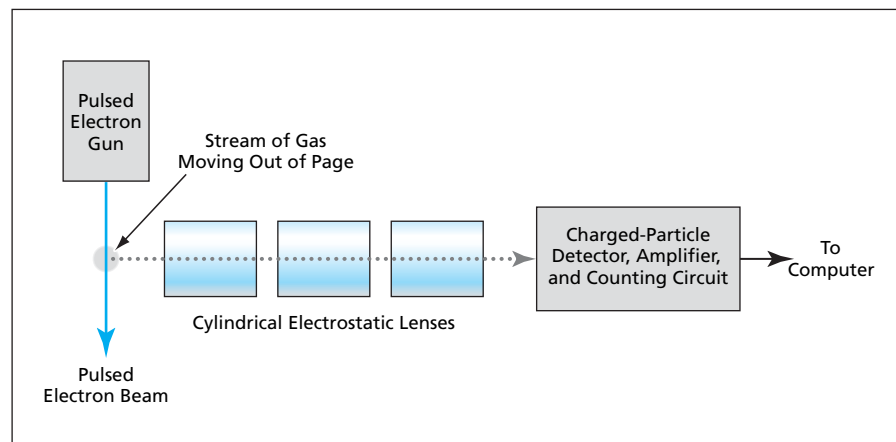


Figure 1. This **Miniature Time-of-Flight Mass Spectrometer** utilizes charged-particle optics in conjunction with ion speeds smaller than those of similar prior instruments.