Micro-Accelerometers Monitor Equipment Health

NASA Technology

Objects that orbit the Earth, such as the International Space Station (ISS), provide a unique environment called zero-g, or more correctly, microgravity. All objects in orbit are pulled by Earth's gravity, but they achieve the lack of gravity when they move at just the right speed (in the case of the ISS, around 17,500 miles per hour) so that the curve of their fall matches the curve of the Earth. The result is a perpetual free fall, creating weightlessness.

Scientists at NASA perform a host of experiments in microgravity in order to ascertain the effects of gravity on biological, chemical, and physical systems. For example, biotechnology research in space has focused on protein crystal growth to see how cells interact with one another, and combustion experiments examine how weightlessness affects the processes of ignition, flame spreading, and flame extinction. Researchers have even gleaned insight into how dangerous pathogens, such as *Salmonella* bacteria (the infamous food-poisoning agent) spread and thrive upon entering the human body.

But even in space, objects are not always free from gravitational effects. Acceleration forces, brought about by anything from performing orbital maneuvers and firing thrusters to opening and closing pumps, will cause a spacecraft to vibrate, causing small accelerations. These disturbances affect the microgravity environment. Despite their very low magnitudes, such vibrations may affect experiment outcomes. Protein crystals may uncharacteristically branch off into different directions; in flame propagation, fires may burn unevenly.

NASA astronaut Karen Nyberg conducts a session with the Capillary Flow Experiment—designed to observe the flow of fluid, in particular capillary phenomena, in microgravity—in the Harmony node of the International Space Station. Accelerometers onboard measure slight gravitational disturbances, which, if left unaccounted for, can skew experiment outcomes.

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To measure these forces, devices called accelerometers are kept onboard to measure them. A traditional accelerometer contains a suspended round or cube proof mass. When the proof mass is excited and tries to move, the magnetic forces that suspend the mass increase and decrease to hold it in place. The current required to hold the mass in place is used to calculate the proportionate force. The forces are matched up with a log of documented actions performed on the spacecraft in a given period, allowing scientists to attribute inconsistent results to acceleration blips.

The drawback to these accelerometers is that they're large and bulky—ranging from the size of a small desk telephone to a tabletop—and also very expensive, sometimes costing hundreds of thousands of dollars. NASA wanted access to accelerometers that were smaller, lighter, and more cost-effective. "Every time you reduce your payload by a pound, you're reducing the cost of flying these instruments," said Bill Foster, an engineer at Glenn Research Center. "And because this is a support instrument and not the main science, you really want to have it be as small as possible."

Technology Transfer

The space agency's call was answered by Ann Arbor, Michigan-based Evigia Systems. Founded in 2004, the company specializes in developing wireless sensing and tracking technologies. In 2005, Glenn awarded Evigia Systems Small Business Innovation Research (SBIR) funding to develop an accelerometer based on microelectromechanical systems (MEMS) technology.

In describing MEMS technology, one should just think of very, very small machines. Components in these devices measure between 1 and 100 micrometers, or between 1- and 100-millionths of a meter. So when Evigia transformed the technology, it did so drastically, shrinking the low-frequency accelerometer from a device the size of a desk telephone or tabletop to a microchip the size of a dime. That meant that the enclosed proof mass was also made much, much smaller.

But shrinking that proof mass also necessitated that the sensor technology be that much more sensitive. "As soon as you start reducing its size, you're losing the amount of gravitational force that you're picking up," said Navid Yazdi, founder and president of Evigia Systems. The company compensated for that by placing the sensors closer to the proof mass, allowing them to perceive its movements more accurately. At the same time, the microchip's compact design stabilized the measurements against sensor drift, which can cause errors in the readings.

While it's evident that the MEMS accelerometer is considerably smaller and lighter than its traditional counterpart, the cost savings are also substantial: They are produced for less than $1,000 each. It's because the device is manufactured in a similar fashion to the integrated circuit chips that are used to run computers and cell phones. "We are able to place our sensors on top of these chips, which have become inexpensive to make because of the economies of scale," says Yazdi. "You can build many units at the same time, which cuts down on costs."

Evigia's line of prognostic sensors, which incorporate NASA-funded technology, are used to monitor the performance of industrial equipment like the machinery used in this automotive plant.

Benefits

While NASA hasn't yet integrated the MEMS accelerometers on the ISS or other spacecraft, Evigia Systems has transferred technical knowledge gained from the partnership to its commercial products. For instance, the company uses a lower-fidelity version of the accelerometer in its line of prognostic sensors, which are designed to monitor the integrity of industrial machinery by keeping track of various data, such as vibration (which uses the accelerometer technology), temperature, humidity, and mechanical shock. Sales from these products have led to the hiring of 5 employees, and Yazdi expects to hire 30 more in the next 5 years.

Meanwhile, the company has also been working in collaboration with other government agencies to advance the technology. Through a contract with the Air Force, Evigia Systems added a gyroscope component to function alongside the accelerometer, resulting in an instrument capable of improving the navigation of air and space vehicles and robotic devices. The Department of Defense is also now working with the company to develop the technology even further.

Yazdi says that the company's partnerships with NASA and other agencies has been very beneficial because they have allowed Evigia Systems the opportunity to develop technologies that are risky and solve very specific, challenging problems. Once matured, these technologies can be incorporated into new and improved products for the public. "Without these initial public-private partnerships, a lot of these innovations will not leave the labs," he says. "They will stay here and not even get off the ground, much less to the market." ❖