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Software Lets Satellite Make Its Own Decisions

NASA's EO-1 Satellite Observed Volcanic Eruption Without Human Help

NASA is successfully using autonomous decision-making software to change a science satellite's priorities without the involvement – or even knowledge – of ground controllers so it can observe unexpected phenomena in its path such as an active volcano.

The software, developed at NASA's Jet Propulsion Laboratory in Pasadena, Calif., is being used aboard the Earth Observing-1 spacecraft (EO-1). On May 7 EO-1 observed an eruption of the Mount Erebus volcano in Antarctica without human interaction.

The onboard software was used to read data collected by the spacecraft's Hyperion spectrometer, which is sensitive to heat released from molten lava, said Ashley Davies, lead scientist for the experiment at the Jet Propulsion Laboratory.

The software detected an unusual area of heat within an image it had collected, and directed EO-1 to capture more images of the volcano about 7 hours later on a separate pass, Davies said. The satellite was able to repeat the experiment May 14, he said.

Normally, an ongoing event such as an eruption might be missed because of the time required for the spacecraft to send its data to ground controllers, who have to process and study the data and then send commands back to the spacecraft to make further observations, Davies said.

"In terms of science return, this was a great success," Davies said. "We are very, very excited about this. We demonstrated how the applications can use a science result from onboard data to drive the spacecraft."

EO-1, launched in 2000 to validate a pair of advanced land imaging instruments, has now completed its main mission and now operates as a NASA test bed.

The Autonomous Sciencecraft Experiment, part of the Space Technology 6 effort under NASA's New Millennium Program, dates back to 2001, said Steve Chien, senior technologist for the software at the Jet Propulsion Laboratory.

Three separate software packages, originally slated to fly on the U.S. Air Force Research Laboratory's experimental TechSat-21 satellite, are in use aboard EO-1. One detects an event, one autonomously reprograms the spacecraft and a third links those two programs, Chien said.

"We tried to encode basic rules in the task execution system," he said. "It's a basic level of smarts that tries to deal with the fact that when you plan something, it never goes exactly as planned."

The software had undergone thousands of hours of ground tests before it was uploaded to EO-1 in March, said Rob Sherwood, the Jet Propulsion Laboratory's experiment manager. Ground controllers had been testing the software since then, confirming EO-1's reprogramming decisions as it studied events such as flooding and the breakup of the Antarctic ice shelf, he said.

"This is the first scientific discovery it had made, but we don't expect one every time we run one of these tests," Sherwood said.

The technology was originally envisioned for space science missions, Sherwood said. One example of a mission that would have benefited from the automated software was NASA's Galileo mission to Jupiter, Sherwood said. The spacecraft made observations of a passing asteroid, and when the scientists studied the data and sent it back to Earth, they found a smaller asteroid orbiting the larger asteroid.

By the time the discovery was made, there were no chances for further study of the orbiting body, Sherwood said. Automated detection software could have identified the unusual object and directed the spacecraft to collect more images, he said.

The software also could help the current Mars Odyssey mission, allowing the spacecraft to automatically make science discoveries as it images the red planet, Sherwood said. Such software could be uploaded to Odyssey within the next few years, he said.

Scientists also have identified Earth observation application s such as detecting natural disasters, and potential uses for the Department of Defense such as monitoring air fields for activity, Chien said. "We are talking to missions flying now, and we're also working with teams to develop new missions," he said. "There is nothing set in stone, but we are very optimistic."

The software could also be used to edit data onboard satellites, eliminating the need to transmit imagery that contains too much cloud cover to be useful, the NASA scientists said. The technique has been especially useful on EO-1, which can only send down six to eight images per day.

"Our archive is 70 percent full of cloudy images that are not that useful," said Dan Mandl, EO-1 mission director at Goddard Space Flight Center in Greenbelt, Md. "If we can identify these images in advance, we can save a lot of money. If you eliminate just 10 percent of those images, that translates into a lot of money."

More experiments are planned, and the team hopes to have EO-1 operating autonomously for a week sometime this fall.

"This experiment was the first step to having a fully automated spacecraft," Davies said. "If we can send this deep into the solar system and can trust it to do good work, it's a great way to detect dynamic events."