STR/AFP/GETTY

The Japan Aerospace Exploration Agency is investigating the factors that led to Hitomi's demise.

ASTRONOMY

Software error doomed Japanese Hitomi spacecraft

Space agency declares the astronomy satellite a loss.

BY ALEXANDRA WITZE

Japan's flagship astronomical satellite Hitomi, which launched successfully on 17 February but tumbled out of control five weeks later, may have been doomed by a basic engineering error. Confused about how it was oriented in space and trying to stop itself from spinning, Hitomi's control system apparently commanded a thruster jet to fire in the wrong direction — accelerating, rather than slowing, the craft's rotation.

On 28 April, the Japan Aerospace Exploration Agency (JAXA) declared the satellite, on which it had spent ¥31 billion (US$286 million), lost. At least ten pieces — including both solar-array paddles that had provided electrical power — broke off the satellite's main body.

Hitomi had been seen as the future of X-ray astronomy. "It's a scientific tragedy," says Richard Mushotzky, an astronomer at the University of Maryland in College Park.

The satellite managed to make one crucial astronomical observation before the accident, capturing gas motions in a galaxy cluster in the constellation Perseus. The instrument that made the observation, a high-resolution spectrometer, had been in the works for three decades. Two earlier versions of it were lost in previous spacecraft failures.

Hitomi's troubles began in the weeks after launch with its 'star tracker' system, which is one of several systems on board designed to keep the satellite oriented in space. The star tracker experienced glitches whenever it passed over the eastern coast of South America, through a region known as the South Atlantic Anomaly. Here, the belts of radiation that envelop Earth dip relatively low in the atmosphere, exposing satellites to extra doses of energetic particles.

> **"We had three days. We'd hoped for ten years."**

By itself, that should not have been a fatal problem. But the star-tracker issue kicked off a series of cascading failures.

At 3:01 a.m. Japan time on 26 March, the spacecraft began a preprogrammed manoeuvre to swivel from looking at the Crab Nebula to the galaxy Markarian 205. Somewhere along the way, the problems with the star tracker caused Hitomi to rely instead on another method, a set of gyroscopes, to calculate its orientation in space. But those gyroscopes were reporting, erroneously, that the spacecraft was rotating at a rate of about 20 degrees each hour. Tiny motors known as reaction wheels began to turn to counteract the supposed rotation.

SPIN CYCLE

Once the reaction wheels reached their maximum spin, a magnetic rod would normally deploy to keep them from accelerating out of control. But the magnetic rod must be oriented properly in three dimensions to work, and so it failed to slow the reaction wheels. Hitomi spun faster and faster.

The spacecraft then automatically switched into a safe mode and, at about 4:10 a.m., fired thrusters to try to stop the rotation. But because the wrong command had been

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uploaded, the firing caused the spacecraft to accelerate further. (The improper command had been uploaded to the satellite weeks earlier without proper testing; JAXA says that it is investigating what happened.)

All of this took place when Hitomi was on the other side of Earth from Japan and unable to communicate with its controllers in real time. In the United States, team scientists went to bed on Friday 25 March, having celebrated what looked like a successful start to the mission. Saturday morning, they woke up to a terse e-mail from the project manager, Tadayuki Takahashi, saying that the spacecraft had been in an emergency.

Ground-based telescopes have since taken pictures of Hitomi spinning roughly once every 5.2 seconds.

LOST OPPORTUNITIES

Dan McCammon, an astronomer at the University of Wisconsin–Madison, helped to design and build Hitomi's premiere scientific instrument, an X-ray calorimeter that measures the energy of X-ray photons with exquisite precision. He has been working on the technology for more than three decades, flying versions of it on the ASTRO-E mission, which failed on launch in 2000, and the Suzaku spacecraft, in which a helium leak rendered the instrument useless weeks after its 2005 launch.

McCammon says that it would take about US$50 million from NASA, and another 3–5 years, to build a replacement calorimeter. A version of it is slated to fly on the European Space Agency's Athena mission, but that is not due to launch until 2028.

The calorimeter is the biggest loss, says Makoto Tashiro, an astrophysicist at Saitama University in Japan. It was to have gathered extraordinary detail on exploded stars, galaxy clusters, the gas between the galaxies and more. "We lose the new science," he says.

But Hitomi could still contribute to science. Because of the early failure with Suzaku, Hitomi scientists planned one important early observation. About 8 days after launch, Hitomi turned its X-ray gaze on the Perseus cluster, about 250 million light years (77 million parsecs) from Earth. By measuring the speed of gas flowing from the cluster, Hitomi can reveal how the mass of galaxy clusters changes over time as stars are born and die — a test of a crucial cosmological parameter known as dark energy.

That one observation may yield a set of Hitomi papers, says Mushotzky. But no more.

"We had three days," he says. "We'd hoped for ten years." ■

PHYSICS

Space–time mission draws global interest

But regulatory hurdles might complicate partnerships in the space-based search for gravitational waves.

BY ELIZABETH GIBNEY

In the wake of the historic detection of gravitational waves by a terrestrial US experiment, a space-borne European effort is drawing interest from a range of parties. But although advisers to the European Space Agency (ESA) recommended increasing international contributions to the billion-euro gravitational-wave detector on 12 April, regulatory hurdles may hinder proposed partnerships with the United States and China.

In February, researchers working on the US-based Advanced Laser Interferometer Gravitational-Wave Observatory (LIGO) announced that they had detected ripples in space-time that had been produced by the merger of two black holes. The space-based observatory planned by ESA would be able to detect ripples with much lower frequencies than would be possible on Earth, bringing into view a greater variety of astronomical events, including mergers between supermassive black holes.

Such a detector is widely seen as "the best thing you could do in gravitational waves", says Robin Stebbins, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. After a mission to test crucial technologies for the observatory proved successful, the ESA advisory team last month concluded that not only are the agency's plans feasible, but also that the launch could even be brought forward, from 2034 to 2029.

Initially, NASA and ESA were partners in the effort, but funding issues led NASA to pull out in 2011. The US space agency has since stated that it wants only a minor role in the observatory. But excitement around the LIGO findings mean that US scientists are keen for NASA to become an equal partner again, says Rainer Weiss, a physicist at the Massachusetts Institute of Technology in Cambridge who was instrumental in creating LIGO.

Stebbins expects that the committee tasked with assessing progress on the US decadal review, which decides the priorities of NASA and other funding agencies, will express support for a larger role in the ESA observatory later this month. But such a role might require NASA to find more money before the next review, in 2020, and that would mean either diverting money away from other projects or persuading the US Congress to give it more.

Any plan to cooperate with ESA on an equal footing could also come up against ESA's policy of capping international contributions to large missions at 20% to stop projects from falling apart if a partner pulls out. It is too early in discussions to know whether the policy will present a problem, says Fabio Favata, head of science planning and community coordination at ESA.

The United States is not the only country seeking to capitalize on the LIGO breakthrough. Japan's gravitational-wave community is also looking for a way to contribute to the ESA mission. And Chinese scientists have expressed interest for several years now, says Stebbins. They could provide financial or in-kind contributions to the ESA mission in exchange for technical know-how, he says.

US participation could also complicate any potential collaboration between ESA and China. An amendment to US law introduced in 2011 blocks NASA scientists from working directly with Chinese counterparts under almost all circumstances. Stebbins's superiors have told him that the law applies to bilateral collaboration, so it might not apply to a collaboration with ESA that also includes China.

But Congress might try to prevent this kind of collaboration anyway, says Brian Weeden, the technical adviser for the Secure World Foundation in Washington DC, which promotes the peaceful use of outer space. And Congress's scepticism of collaboration with China could stop NASA scientists from even trying to participate. That the gravitational-wave detector is purely a science mission may reassure Congress, Weeden adds. "There may be less concern over that type of cooperation than there would be on cooperation with a more political component, such as human spaceflight."

China is a growing space power — it is scheduled to launch several high-profile space-science missions this year — so the United States will eventually work with China in some capacity, Weeden says. And that would probably be through some kind of multilateral project, he thinks. "The challenge is finding a topic that both the United States and China want to work on. I think the gravitational-wave detector could be one of those." ■

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