NEWS IN FOCUS

ASAHI SHIMBUN/GETTY

The Hitomi X-ray astronomy satellite launched in February, but broke up in space after a month.

ASTRONOMY

Troubled Japanese space agency seeks fresh start

Push to resurrect instrument lost during satellite failure highlights JAXA's resilience.

BY ALEXANDRA WITZE

The Japan Aerospace Exploration Agency (JAXA) is on a quest for redemption. In March, a software error caused the agency's Hitomi X-ray astronomy satellite to break up in space, cutting short a planned three-year mission after only one month.

Now JAXA is considering whether to rebuild and relaunch a copy of the spacecraft's key instrument — a US-built X-ray spectrometer — with help from NASA. On 5 August, representatives of the two space agencies will meet to discuss the possibility of resurrecting the instrument that was the heart of Hitomi's science. But whether JAXA can regain the confidence of the Japanese nation, and of its international partners, remains to be seen.

Space experts note that JAXA has pulled off stunning recoveries before. It coaxed its crippled Hayabusa spacecraft to bring back dust from an asteroid, and nudged its Akatsuki probe into orbit around Venus 5 years after an engine failure seemed to render the spacecraft useless.

"It's important to note how resourceful JAXA has been at recovering from failures that typically would be catastrophic," says Ralph Lorenz, a planetary scientist at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, and co-author of the book *Space System Failures* (Praxis, 2005).

Hitomi broke apart because an erroneous software command prompted the spacecraft to spin faster and faster, until its ▶

solar panels flew off into space. A JAXA investigation blamed faulty project-management techniques for not catching the error.

The failure has reverberated at every level of JAXA's Institute of Space and Astronautical Science (ISAS) in Sagamihara, which managed Hitomi. JAXA president Naoki Okumura was one of three leading officials who took a 10% pay cut for four months "to express our regret and caution ourselves", he said in a June press conference. He has also ordered a systems review of the institute's next big project: a mission to study Earth's radiation belts that is slated to launch in the coming months.

Before Hitomi, JAXA's lowest point was perhaps the loss of its Nozomi mission to Mars, which sailed past the red planet in 2003 without entering orbit as it was supposed to. The same year, a new JAXA rocket design failed during a test launch, prompting a review of all agency projects.

TRY, TRY AGAIN

Some have questioned whether JAXA is trying to do too much with too little. It often assigns one person to cover a number of tasks that NASA would spread among multiple project engineers, says Lorenz, who collaborates on the Akatsuki Venus probe.

Okumura has acknowledged as much, saying that ISAS will generally develop a mission using a small in-house team, along with the spacecraft manufacturer. By contrast, Hitomi involved a larger number of complex systems. There were simply not enough safeguards built into the process to catch the software error. "The previously conventional ISAS methods were not necessarily suited for the production of modern satellites and spacecraft," Okumura said.

"It's important to note how resourceful JAXA has been at recovering from failures."

JAXA has released an extraordinary level of technical detail about the failure. Agency officials have said that because Hitomi was meant as a community mission to serve X-ray astronomers across the globe, they feel obligated to explain what happened so that nobody makes the same mistake.

Because of this determination and openness, "I think Hitomi's successor is in safe hands with JAXA," says Elizabeth Tasker, an astrophysicist at Hokkaido University in Sapporo, Japan.

But such projects may be a hard sell to politicians. "High-profile setbacks like Nozomi and Hitomi make it difficult for JAXA to justify big-ticket science missions in today's political atmosphere," says Saadia Pekkanen, an expert in Japanese space policy at the University of Washington in Seattle.

JAXA has not yet decided whether a Hitomi successor would fly or which instruments it would carry, says ISAS spokeswoman Chisato Ikuta. But Hitomi's premier scientific instrument was the spectrometer provided by NASA; data that it collected before the spacecraft died revealed secrets about gas flows in the Perseus galaxy cluster.

The spectrometer seems to be thrice cursed; two earlier versions on different satellites were lost to a launch failure and a coolant leakage. Even so, a NASA advisory group reported on 5 July that launching a copy of the instrument no later than 2023 "would fulfill the immense scientific promise of the Hitomi" spectrometer. The cost to rebuild would be roughly US$70 million to $90 million.

Paul Hertz, NASA's astrophysics director, will meet with JAXA representatives to discuss the options. "Certainly we would not be overseeing JAXA," he told a NASA advisory committee on 20 July. "We can discuss practices that NASA implements to prevent us from making avoidable mistakes."

Other international missions in the works from JAXA include a magnetospheric orbiter, which is scheduled to launch next year on the European Space Agency's BepiColumbo mission to Mercury.

"The Olympics of engineering is when things go wrong," says Lorenz. "Maybe the best time to fly is right after a failure." ■

MATHEMATICS

Grand proof fazes theorists

Conference on Shinichi Mochizuki's 'revolutionary' work inspires cautious optimism.

BY DAVIDE CASTELVECCHI

Nearly four years after Shinichi Mochizuki unveiled an imposing set of papers that could revolutionize the theory of numbers, other mathematicians have yet to understand his work — although they have made modest progress.

Some four dozen mathematicians converged in Japan last week for a rare opportunity to hear Mochizuki present his monumental proof of the 31-year-old *abc* conjecture, which sits at the heart of number theory. The conference took place on his home turf, at Kyoto University's Research Institute for Mathematical Sciences (RIMS).

Mochizuki is "less isolated than he was before the process got started", says Kiran Kedlaya, a number theorist at the University of California, San Diego. At first, Mochizuki's proof, which stretches over more than 500 pages (available at go.nature.com/2amidei), seemed like an impenetrable jungle of formulae. But experts have slowly discerned a strategy, and have zeroed in on particular passages that seem crucial, Kedlaya says.

And Jeffrey Lagarias, a number theorist at the University of Michigan in Ann Arbor, says that he got far enough to see that Mochizuki's work is worth the effort. "It has some revolutionary new ideas," he says.

Still, Kedlaya says that the more he delves into the proof, the longer he thinks it will take to reach a consensus on whether it is correct. He used to think that the issue would be resolved perhaps by 2017. "Now I'm thinking at least three years from now."

Others are even less optimistic. "The constructions are generally clear, and many of the arguments could be followed to some extent, but the overarching strategy remains totally elusive for me," says mathematician Vesselin Dimitrov of Yale University in New Haven, Connecticut. "Add to this the heavy, unprecedentedly indigestible notation: these papers are unlike anything that has ever appeared in the mathematical literature."

THE *ABC* PROOF

The *abc* conjecture relates to prime numbers — whole numbers that cannot be evenly divided by any smaller number except 1. The conjecture comes in a number of different forms, and explains how the primes that divide two numbers, a and b, are related to those that divide their sum, c.

If Mochizuki's proof is correct, it would have repercussions across the entire field, says Dimitrov. "When you work in number theory, you cannot ignore the *abc* conjecture," he says. "This is why all number theorists eagerly wanted to know about Mochizuki's approach." For example, Dimitrov showed in January how, assuming the correctness of Mochizuki's proof, one might be able to derive many other results, including an independent proof