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HAYABUSA: TEAM RE-ESTABLISHES CONTACT WITH ITS "FALCON"

By A.J.S. Rayl
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The intrepid Hayabusa mission team has restored communication with its injured asteroid probe. Although communications are now ongoing at a low speed of 32 bits per second, the link that was lost last December has been reestablished and the team has managed to locate its ship.

Hayabusa
Artist's depiction of Hayabusa at asteroid Itokawa. Credit: JAXA

For the last 3 months, the Hayabusa team has been "gradually finding out" the status of its charge, and, on March 6, was able to estimate the spacecraft's current position and speed for the first time in three months. "We are simply very pleased to have this contact resumption," Jun'ichiro Kawaguchi, the mission project manager, told The Planetary Society via email yesterday.

Some 190 million kilometers (118 million miles) from the Sun and 330 million kilometers (205 million miles) from Earth, Hayabusa is currently 13,000 kilometers (about 8,100 miles) leading Itokawa, which means it is in the same orbit but ahead of the asteroid and moving away from it slowly at about 3 meters (almost 10 feet) per second.

The team has uploaded new software to help shift the spin axis toward Earth for better, faster communications. "The spacecraft orientation is slowly working its way and the high gain antenna is working its way toward the Earth direction and as they do that they will be able to communicate with Earth at a higher rate than the current bare minimum," said Donald K. Yeomans, senior research scientist at the Jet Propulsion Laboratory (JPL) and the U.S. project scientist for the mission, in an interview earlier today.

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The restoration of communication is only a small, first step to bringing the damaged spacecraft home. Still, it is a major accomplishment and something even the team had not anticipated happening quite so soon. That's the good news. The bad news is that the team has learned in recent days even with the slow data rate that Hayabusa has suffered even more damage. Just as they have throughout the trials and tribulations of this mission, the team members of this diehard Japanese mission have vowed to continue working to bring their bird home.

Hayabusa -- which means "falcon" in Japanese -- is the Japan Aerospace Exploration Agency's mission to the near-Earth asteroid named Itokawa. The world's first spacecraft to attempt to land on an asteroid, collect samples, and return them to Earth, Hayabusa was challenged and battered by solar flares and the loss of a reaction wheel along the way, but pulled through it all and arrived at Itokawa a little late but ready to roll last September. Despite the loss of another reaction wheel shortly after arrival, the falcon proceeded to study the big rock and swoop down to the asteroid's surface on several different occasions in November and take off again.

On the first test run (November 12), Hayabusa lost its lander, MINERVA, but on the first swoop down a week later succeeded in releasing a target marker -- a softball-sized, artificial ball -- onto the asteroid, but did not collect a sample of the asteroid's surface, the Holy Grail of the mission. After the second swoop down (November 26), confused data reports first indicated the falcon had

collected a sample, but subsequent data seemed to indicate it had not. During its second flyaway after touching down on the big rock, Hayabusa sprung a leak in one of its redundant rocket [thruster] subsystems. The team managed to stop the leak but on December 8, when Hayabusa should have been preparing to head home, the spacecraft suffered a "torque disturbance" apparently caused by the "out-gassing" of fuel vapor generated by the evaporation of leaked propellant [hydrazine] from the rocket (thruster) subsystem. The team lost communication as the attitude of the spacecraft swayed off course and had to delay its departure for home.

The new data indicate that Hayabusa's power was completely lost at least once after the spacecraft lost its attitude last December. That means a lot of the data the spacecraft stored onboard are probably lost, including any new data that might have solved the mystery as to whether the falcon collected a sample has not been found yet. Kawaguchi did say, however, they may be able to salvage some of it. But first, the team must focus on assessing the damage and doing what needs to be done to the spacecraft operationally right now.

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Hayabusa's shadow on Itokawa
Hayabusa captured this photo of Itokawa as it passed between the Sun and the tiny asteroid on November 10, 2005. Hayabusa's shadow is visible on the surface of the asteroid -- a tiny spacecraft causing a tiny solar eclipse on a tiny object. Credit: ISAS / JAXA

As the Hayabusa team is struggling against even greater odds at this point to save its falcon, the rest of the planetary community is marveling. "Hayabusa's mission to asteroid Itokawa certainly is a high point in planetary exploration," said Bruce Murray, co-founder of The Planetary Society. "The successful reestablishment of communications is a great achievement and enhances a mission, which has already furthered our understanding of another mysterious denizen of the inner solar system."

"The control and operation of Hayabusa by the Japanese space agency is a fantastic story of ingenuity and dedication," added Louis D. Friedman, executive director of the Society. "The mission controllers at the Institute for Space and Astronautical Sciences deserve enormous credit."

"They may just pull another rabbit out of the hat, mused Yeomans. "It would be bloody amazing if they did, but they *could* do it."

The Hayabusa team will continue their efforts to get the spacecraft back to Earth by June 2010, confirmed Kawaguchi, of the Institute of Space and Astronautical Science (ISAS) (now the space science research division of JAXA), which designed and developed the asteroid explorer. But to say that will be difficult would be a gross understatement. "There will be still many obstacles," he acknowledged, not the least of which is figuring out how much damage has been done since losing contact last year.

Hayabusa -- which weighs in at only 510 kilograms (1,124 pounds), far lighter than conventional spacecrafts -- first responded on January 23 via a beacon, unmodulated radio signal that came during an "uplink sweep" with commands for transmission. "The signal was quite stronger than expected," said Kawaguchi at a press conference held in Japan yesterday. "Even the operator who reported it to me said, 'I couldn't be sure.' So I swept the ground antenna to different angles and confirmed that it is truly coming from the direction of Hayabusa." The next day, the signal was confirmed.

When the spacecraft was found, the spin axis attitude had shifted almost 90 degrees and Hayabusa was found with its high gain antenna axis offset about 70 degrees from the Earth direction. Last December, the spacecraft spin rate was direct and about 1 degree per second when the team lost communication, but when the signal was recaptured in January, the spin was retrograde at the speed of about 7 degrees per second. "This is bizarre," said Yeomans. "The spacecraft was rotating in one direction in early December and in the opposite direction when they recontacted it in January, so that suggests there was a fuel leak that not only slowed the spacecraft down, but reversed it. It had to be some kind of event like that, because a spacecraft doesn't just shift direction like that on its own -- no way."

As a result of that discovery, power has become an even more critical issue, especially considering that the data Hayabusa has returned also shows that the spacecraft has lost the use of its onboard battery system, Kawaguchi told The Planetary Society. In the data the spacecraft has returned, short circuitry phenomena have been observed in battery cells aboard. "This means the battery may not be used any more," he said. "Now the batteries have developed shunts," he expounded during the press conference. "We'll risk explosion if we charge them; [therefore] we won't use them anymore."

Despite all this, Hayabusa can still maintain control. "As long as the solar panels are in appropriate orientations, planet probes do not have to worry about shading and losing control," Kawaguchi explained. It won't provide enough power for the spacecraft to perform any operations, however, not to mention the trip home. For that, they will have to rely either on getting the one previously good rocket thruster subsystem working along with their ion engines or --more likely -- only their ion engines.

The status of the one rocket thruster subsystem that was good as of last November remains unknown. While the chemical fuel was lost last December, this time the oxidizer seemed lost completely since the instrumentation read zero pressure. "We had been trying since last November to open the latching valve, but were not successful," Kawaguchi said during the press conference. "Currently, the residual quantity sensor [fuel gauge] for the oxidizer also indicates zero. At this point, we're not sure if this is a sensor failure or a real leakage. If it's a sensor failure, and if we could open the latching valve, maybe we can use the oxidizer jet for attitude control."

But they're certainly not going to depend on that. The issue, Yeomans reiterated, is that "the latching valves right now are not open and the fuel gauge reads zero, so they don't really *know* whether they have fuel in there or not. They can still get back using the xenon ion thrusters and the xenon jets without the ion engines for attitude control, and they do think they can do that," he confirmed. "They've been using the xenon jets for attitude control for awhile now and have shown they can do it."

The xenon gas amount aboard remains unchanged. Kawaguchi estimated that 42 to 44 kilograms (92 to 97 pounds) of Xenon is remaining. "By calculation, it's still possible to return by using Xenon for attitude control in parallel. But it's only a calculation. Besides, we haven't yet checked if the ion engines work," he noted.

First, the team must attend to the propellant problem. Since the propellant from the rocket thruster subsystem may have leaked into the spacecraft or the thermal insulators, the team plans to "bake" it out. "We need to perform first the so-called baking operation to exclude gas from the spacecraft," Kawaguchi told The Planetary Society. They do this by raising the spacecraft temperature higher via the heaters aboard.

The "baking" operation is a risky one. In fact, it is possible it could cause another fuel gas eruption risk that could easily cause the spacecraft to tumble out of communication range and out of control again. The concern is that it is possible that if they raise the temperature too much on the spacecraft, they will build up too much pressure inside without the valves open and blow a line. While there is risk, there is also little choice at this point and so the team will take its time to do everything right. "The operation needs to be done very carefully and it may take a few months," said Kawaguchi. Once they make sure all potential propellant or propellant vapor is out of the spacecraft, the team will perform a similar baking operation on Hayabusa's sample recovery capsule, the team wrote in its report that was published online yesterday at the JAXA website.

Hayabusa could prepare for the trip home early next year, Kawaguchi said, with only two working ion engines. If, when they do test the engines and three are "alive," the return could start a year later in early 2008. During the cruise back to Earth, the ion engines will be operated and the temperature of the spacecraft will increase more as a result. In order to ensure that any remaining propellant is baked out during the cruise, an additional baking operation will take place on the spacecraft once the ion engines turned on. At the most, three of Hayabusa's four ion engines will be driven at the same time.

In the meantime, the team has its work cut out for it. The entire spacecraft and all the instruments and equipment need to be checked out -- the ion engines, star tracker, attitude control computer, and other instruments -- all of which must have been exposed to extreme low temperatures between December and January -- must be put through functional verification.

The outlook for Hayabusa's safe return is bleak, everyone agrees. But as every space explorer knows, it isn't over until it's over. Since there is still a possibility, the Hayabusa team is going for it with all its might and know-how, making it very clear that JAXA and this determined mission crew are in it for the long haul. As Kawaguchi put it: "We just we have no choice, but to work for the operation."

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