

Japanese space agency lands two rovers on surface of asteroid

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The Japanese Aerospace Exploration Agency (JAXA) successfully deployed two small hopping rovers from the Hayabusa2 spacecraft onto the asteroid 162173 Ryugu. Initial images and sensor data transmitted back to Earth from the rovers indicate that their systems are operating as expected. It is the first time that robotic craft will be able to travel across the surface of one of the Solar System's oldest objects.

Hayabusa2, a combined effort of Japanese, German and Australian scientists, was launched on December 3, 2014, using a H-IIA launch vehicle. It spent the next three and a half years maneuvering to Ryugu, using its ion engines to synchronize its motion with and enter orbit around the near-Earth asteroid. It is a follow-up to the Hayabusa mission, which launched in 2003 and returned with samples from the asteroid 25143 Itokawa in 2010. That mission's many successes, as well as the failure to land a rover in 2005, have been incorporated into the more recent design and played a significant role in the ongoing success of the current mission.

The target of Hayabusa2, the one-kilometer-wide asteroid Ryugu, was chosen because it is a near-Earth asteroid which is expected to have minerals, ice and organic compounds preserved from the origin of the Solar System. Similar to comets, every asteroid contains a part of the history of humanity's planetary system and every mission to study them has provided new insights into the development of Earth, the other planets in the Solar System and the worlds that have so far been detected elsewhere in the galaxy. Ryugu in particular is thought to contain matter that will provide additional knowledge about the origins of the Solar System's rocky inner planets—Mercury, Venus, Earth, Mars—as well as the origins of the water and organic compounds on Earth.

In order to answer some of these questions,

Hayabusa2 has a variety of tools, including the two currently landed rovers and two rovers which it has yet to deploy. Its rovers are equipped with visual cameras that will eventually be used to make a three-dimensional map of the asteroid, thermometers to measure the temperature at the surface, and instruments to study the mineral composition and magnetic field of Ryugu. The spacecraft itself is equipped with optical and infrared cameras and precision-mapping sensors, as well as tools to capture bits of dust and rock of the asteroid.

These analyses started in June, when the probe arrived and stabilized its orbit at 20,000 meters. A month later, the spacecraft began using the very fine control provided by its ion engines to begin a two month descent to an orbit at a distance of merely 55 meters. From that altitude it successfully deployed ROVER-1A and ROVER-1B using a MINERVA-II landing vehicle. Next week, on October 3, the rover MASCOT will deploy from its parent craft and gather data for sixteen hours before its battery runs out of power. A fourth rover, ROVER-2, will deploy sometime next year to follow up on the analyses made by its siblings.

In between deploying MASCOT and ROVER-2, Hayabusa2 will use its ion engines to almost touch the asteroid, hovering just one meter above its surface. It will then use its specialized asteroid sampling suite to gather material from the asteroid, getting two samples of rock and dust from the surface. The spacecraft is also slated to fire a 2.5 kilogram copper projectile at the asteroid's surface to expose the underlying rock and collect a sample of that as well.

While these samples are being collected, the instruments on board Hayabusa2 and its rovers will be taking as much data as they can to provide information

about the asteroid and its environment. Once the data collection of the asteroid is complete, the spacecraft is slated to fly back to Earth and send the samples to the surface for a more detailed analysis than can be done in space. The sample return is currently scheduled for December 2020, after which Hayabusa2 itself will likely have enough propellant to flyby another asteroid, likely 2001 WR1, before it runs out of fuel and drifts through the Solar System indefinitely.

In addition to the original Hayabusa spacecraft, Hayabusa2 has benefited from the lessons learned during the Galileo and NEAR Shoemaker missions, both of which are NASA missions that had previously visited asteroids. In fact, NEAR was the first spacecraft to land an asteroid, 433 Eros, on February 21, 2001. While it wasn't designed to do so, the attempt was made close to the end of the probe's lifespan. It impacted at a relatively soft 6.5 kilometers per hour and landed with its antenna and solar panels oriented so they could send back data to Earth and collect power, respectively. This allowed the other instruments, particularly the gamma ray spectrometer, to gather data directly at Eros' surface. Observations were made at the landing site for 16 days before NEAR was shut down.

As noted earlier, Hayabusa2's main achievement is successfully landing rovers on an asteroid. While it is more difficult to land on a comet, the weak gravity of asteroids provides many problems for moving around. The most notable is that a standard wheeled craft is just as likely to drive itself off into space as it is to stay on the surface. Instead of this, JAXA designed its ROVER craft as cylinders that are able to hop around, while MASCOT can tumble to change its orientation. It is a very non-traditional but so far effective solution.

Of course, it is not impossible to make some sort of wheeled or tracked vehicle to drive around an asteroid. JAXA was constrained both by physical problems and a stringent budget. The entire Hayabusa2 instrument suite is \$146 million dollars, a relatively small amount when compared to what NASA and the European Space Agency spend on comparable projects. And even those sums are dwarfed by the colossal amount world governments spend on their militaries—\$43 billion for Japan, \$227 billion for Europe and \$717 billion for the United States. If this money was appropriated toward progressive pursuits—the exploration of space, the

promotion of the arts, investing in infrastructure—asteroids across the Solar System could be studied along with a great deal more.



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