Hayabusa2 (JAXA) - Space Mission Report

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1 Introduction

Hayabusa2 is a spacecraft developed by the Japan Aerospace Exploration Agency (JAXA) that explored and retrieved samples from the surface layer of the near Earth C-type asteroid 162173 Ryugu (1999 JU3). Taking what was learnt from the first Hayabusa mission (May 9th 2003) the probe was launched successfully on Dec 3rd 2014, arriving at Ryugu on Jun 27th 2018 using its ion thrusters where it reliably mapped the surface and landed precisely on its target touchdown zones to retrieve samples so it can return them to Earth [1].

In line with Hayabusa2's aims, of studying and sampling a near Earth C-type asteroid, it is helping to unravel the origins of water and organic molecules that have been transferred to the Earth's region considering that carbonaceous asteroids are leftovers from the early solar system. The ability to return samples back to Earth provides for much more extensive analysis as returned material is not limited by the difficulties of regular spacecraft operation like mass, time and precision. Furthermore the scientific resource is available long after the completion of the mission allowing for continued revisiting as our scientific understanding and techniques evolve.

Apart from the primary objective, one of the most notable new achievements was the successful deployment of 2 MINERVA–II-1 rovers to Ryugu's surface that tested and demonstrated the capabilities of remotely operated vehicles on low gravity objects [2].

2 Scientific Measurements

Hayabusa2 is equipped with remote scientific instruments such as: a multiband optical navigation camera-telescopic (ONC-T); an optical navigation camera-wide (ONC-W1) imager; a thermal infrared (TIR) imager; a near-infrared spectrometer (NIRS3); and a laser altimeter (LIDAR). These were primarily used to provide initial observations and to determine landing sites for sample collection [3].

Through the attempts to find suitable landing sites spectral data was obtained by the ONC-T and NIRS3 showing that Ryugu was very carbon-rich and had an albedo of 4.5%. The heliocentric gravitational constant (GM) was also measured to be 30.0 m^3/s^2 which was required data to know for a safe landing on the target. The GM of 30.0 m^3/s^2 is analogous to a bulk density of 1.19 g/cm^3 which suggested that Ryugu is a rubble pile due to large cavities resulting in the high-porosity interior [2]. This was further supported by the observation of a high amount of uniformly distributed large surface boulders as seen in Fig. 1 [4].

Figure 1. Initial ONC-T images taken of Ryugu from a 20 km hover (from asteroid centre) upon arrival of the probe showing a high density of uniformly scattered large surface boulders.

After the initial determination of landing sights, Hayabusa2 was able to land precisely and take samples. Not only was the probe itself able to land but it also carried the Small Carry-on Impactor (SCI) which, after it was deployed, was used to kinetically impact the surface of the asteroid. This created a small crater 13m in diameter, exposing the subsurface material beneath the regolith which has not had long-term exposure to space (Fig. 2), allowing for subsequent sampling following a second touchdown [5].

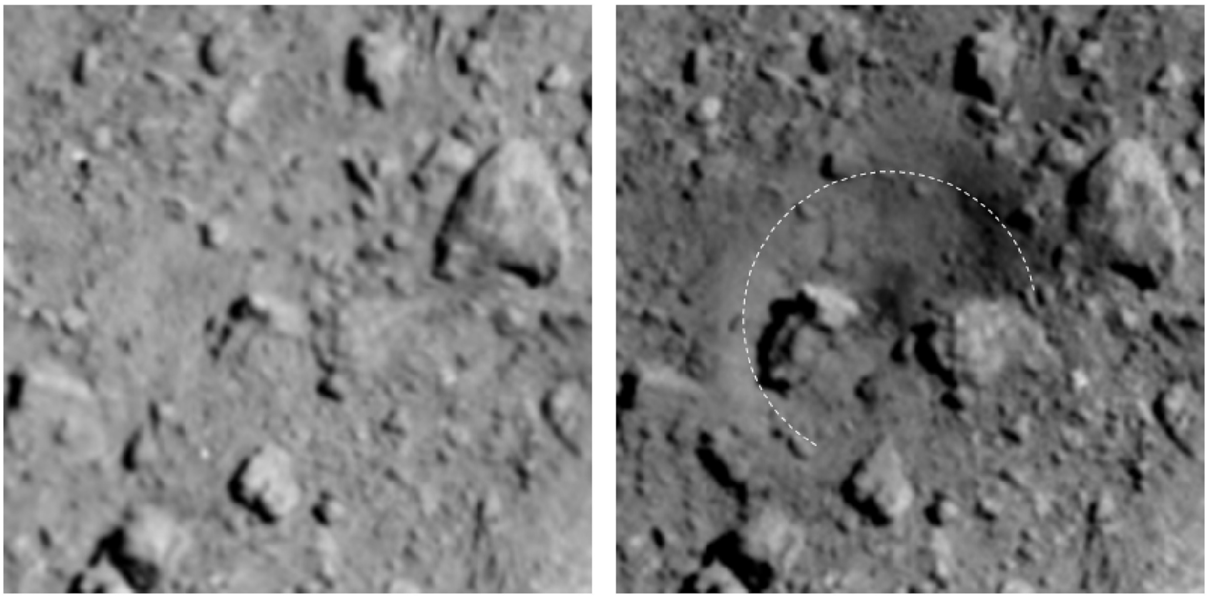

Figure 2. On the left we can see the terrain before the SCI impact. On the right we can see the 13m crater (white dashed line) after the SCI impact.

After taking samples Hayabusa2 returned to Earth and released the re-entry capsule with the asteroid samples on the 5th Dec 2020, allowing for them to be studied. Some initial terrestrial findings about Ryugu included: low density and/or high microporosity; an albedo of ~0.02 from 0.4 μm to 4 μm wavelengths which matched the observed albedo from the ONC-T and NIRS3 on Hayabusa2; the presence of OH, matching NIRS3 measurements, with much stronger correlation to samples excavated by the SCI kinetic impacts. The matching results confirm that the samples returned to Earth are indeed representative of Ryugu and also the accuracy of the in-situ experiments of Hayabusa2 [6].

3 First Time Achievements

A completely new achievement for space exploration was the successful deployment of 2 rovers, MINERVA–II–1 A/B (Fig. 3), that came equipped with onboard cameras and a hopping mechanism to traverse Ryugu without exceeding its escape velocity [7].

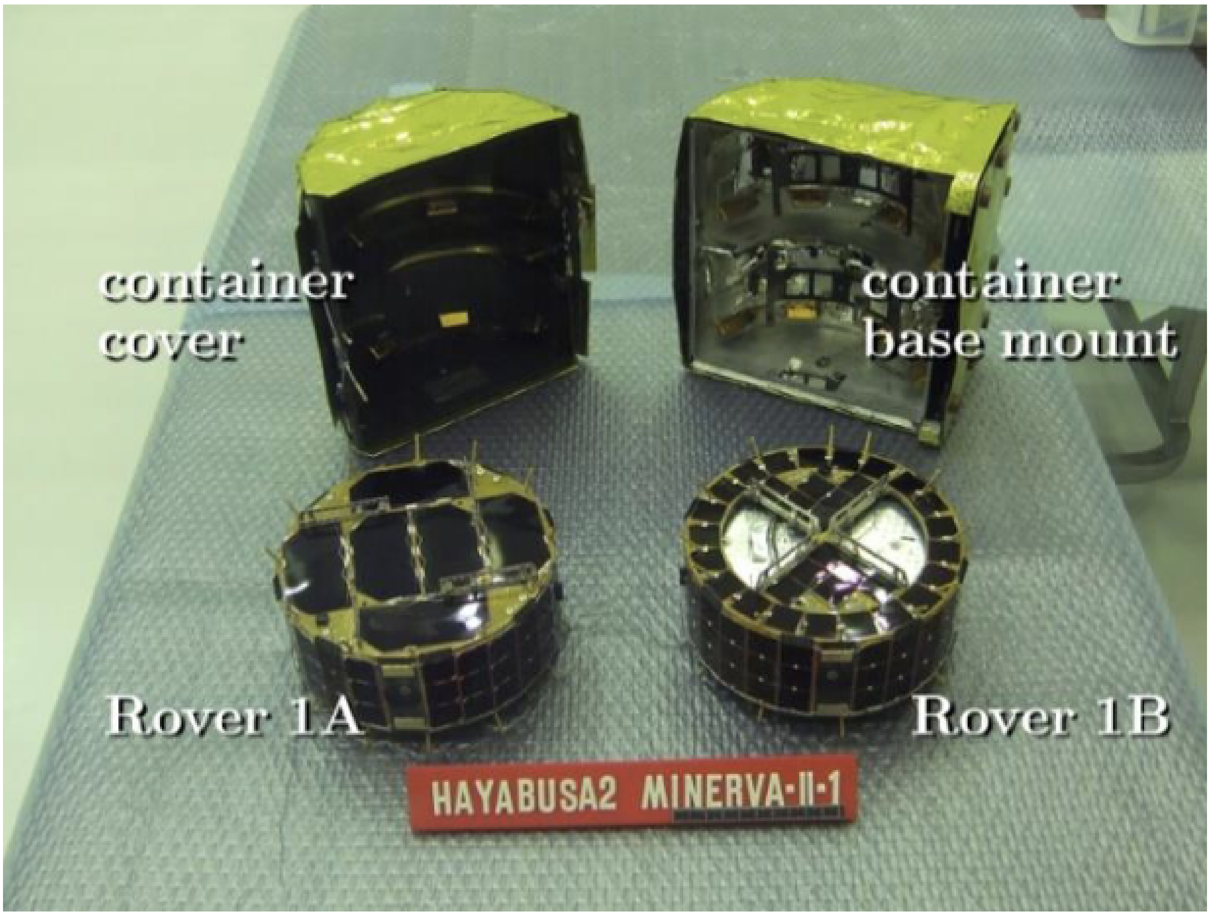

Figure 3. MINERVA-II-1 rovers: left, Rover-A “HIBOU”; right, Rover-B “OWL”.

The evaluation of the hopping mechanism on Ryugu’s microgravity environment was successful and with individual autonomy they were able to take more than 600 images for scientific observation some examples of which can be seen in Fig. 4 [7].

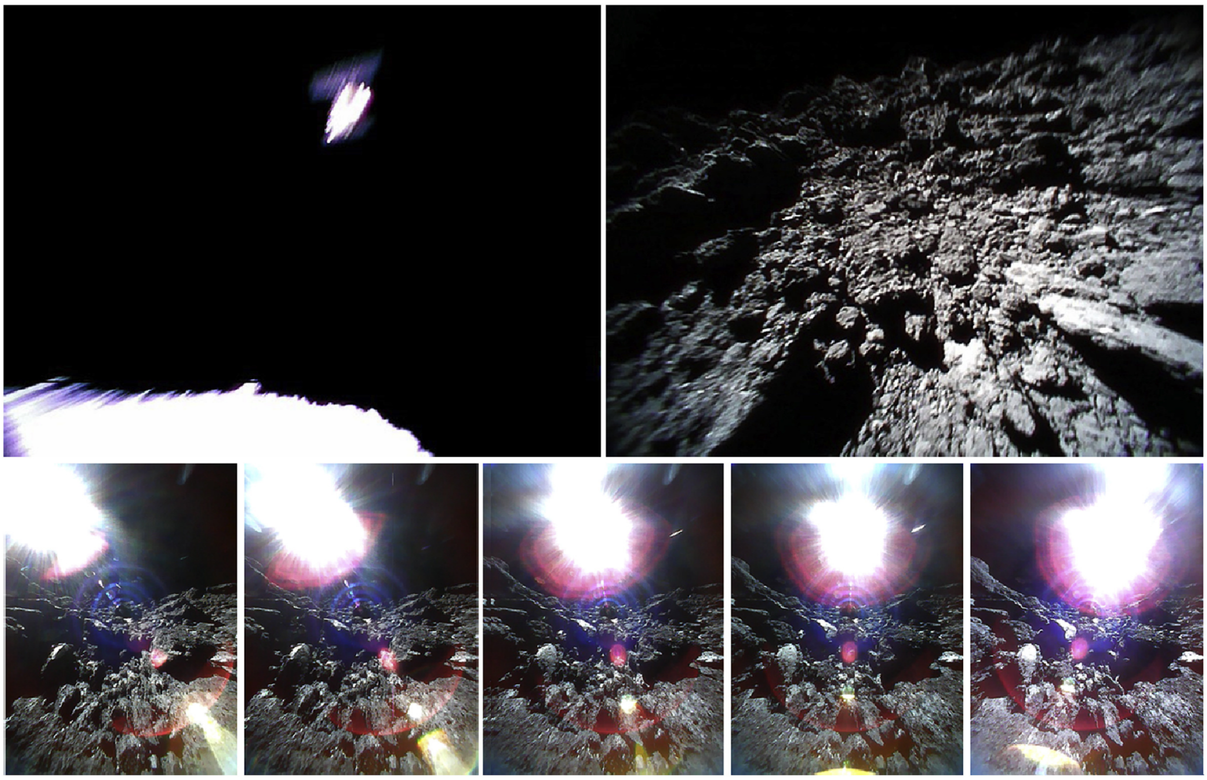

Figure 4. In the top left, image of Hayabusa2 captured by Rover-1A right after separation. Top right and bottom, images of Ryugu's very dark, low-albedo and fragile surface captured by Rover-1B.

From Fig. 4 we can indeed see large boulders across the surface which proved a challenge for locating suitable landing locations for Hayabusa2 [2] before taking samples. The dark surface further emphasises the low albedo and fragile nature of the carbonaceous material that supports the Earth based experiments.

4 Conclusion

As we have seen, Hayabusa2 utilised a very modular approach to its mission and achieved multiple important scientific and technological achievements as a result. The mutually exclusive experiments allowed for the findings to support each other in a single mission. Returning samples back to Earth has provided much more extensive analysis, not limited by the constraints of spacecraft operation, with the ability to review the samples over extended periods of time and in the future. Many further experiments can be conducted and comparisons can be made across past and future missions (e.g. a comparison against meteorites).

New achievements included the successful deployment of 2 MINERVA–II-1 rovers to Ryugu's surface that demonstrated the capabilities of remotely operated vehicles in microgravity environments. By taking near surface images the low albedo and fragile nature of the carbonaceous and fragile surface was able to visually support findings from both sensors on Hayabusa2 and Earth based experiments. The achievements not only play into improving our understanding of our early solar system but the new technology could also be considered as somewhat of a test and demonstration of the viability of asteroid mining missions.

Having looked at and sampled the dark, low-albedo surface of 162173 Ryugu (1999 JU3), Hayabusa2 is helping to unravel the origins of water and organic molecules that have been transferred to the area around the Earth. After completing its primary mission and releasing the sample back to Earth, Hayabusa2 performed a redirecting manoeuvre to rendezvous with a new target, 1998 KY26 [8]. This extension of the mission will allow for further observations of another Apollo-class asteroid using Hayabusa2's in-built scientific equipment.

References

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