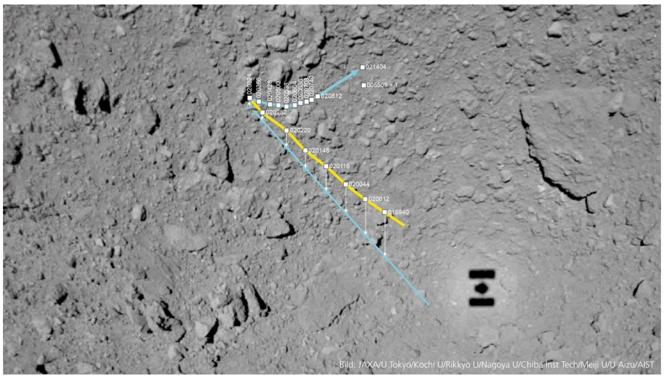
Numerous boulders, many rocks, no dust: MASCOT's zigzag course across the asteroid Ryugu

12 October 2018



MASCOT's approach to Ryugu and its path across the surface. Credit: German Aerospace Center

Six minutes of free fall, a gentle impact on the asteroid and then 11 minutes of rebounding until coming to rest. That is how, in the early hours of 3 October 2018, the journey of the MASCOT asteroid lander began on Asteroid Ryugu – a land full of wonder, mystery and challenges. Some 17 hours of scientific exploration followed this first 'stroll' on the almost 900-metre diameter asteroid. The lander was commanded and controlled from the MASCOT Control Centre at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) site in Cologne in the presence of scientific teams from Germany, France and Japan. MASCOT surpassed all expectations and performed its four experiments at several locations on the asteroid. Never before in the history of spaceflight has a Solar System body been explored in this way. It has now been possible to precisely trace MASCOT's path on Ryugu's surface on the basis of image data from the Japanese Hayabusa2 space probe and the lander's images and data.

"This success was possible thanks to state-of-the-art robotic technology, long-term planning and intensive international cooperation between the scientists and engineers of the three space nations Japan, France and Germany," says Hansjörg Dittus, DLR Executive Board Member for Space Research and Technology about this milestone in Solar System exploration. "We are proud of how MASCOT was able to master its way across the asteroid Ryugu over boulders and rocks and send so much data about its composition back to Earth," says DLR Chair Pascale Ehrenfreund.

MASCOT had no propulsion system and landed in free fall. Six minutes after separating from Hayabusa2, and following the end of a ballistic trajectory, the landing module made its first contact with asteroid Ryugu. On the surface, MASCOT moved through the activation of a tungsten swing arm accelerated and decelerated by a motor. This made it possible for MASCOT to be repositioned to the 'correct' side or even perform hops across the asteroid's surface. The gravitational attraction on Ryugu is just one 66,500th of the Earth's, so the little momentum provided was enough: a technological innovation for an unusual form of mobility on an asteroid surface used for the first time in the history of space travel as part of the Hayabusa2 mission.

Through a rock garden full of rough boulders and no flat surfaces

To reconstruct MASCOT's path across the surface of Ryugu, the cameras aboard the Hayabusa2 mother probe were aimed at the asteroid. The Optical Navigation Cameras (ONC) captured the lander's free fall in several images, detected its shadow on the ground during the flight phase, and finally identified MASCOT directly on the surface in several images. The pattern of the countless boulders distributed on the surface could also be seen in the direction of the respective horizon in oblique photographs of the lander's DLR MASCAM camera. The combination of this information unlocked the unique path traced by the lander.

After the first impact, MASCOT smoothly bounced off a large block, touched the ground about eight times, and then found itself in a resting position unfavourable for the measurements. After commanding and executing a specially prepared correction manoeuvre, MASCOT came to a second halt. The exact location of this second position is still being determined. There, the lander completed detailed measurements during one asteroid day and night. This was followed by a small 'mini-move' to provide the MicrOmega spectrometer with even better conditions for measuring the composition of the asteroid material.

Finally, MASCOT was set in motion one last time for a bigger jump. At the last location it carried out some more measurements before the third night on the asteroid began, and contact with Hayabusa2 was lost as the spaceship had moved out of line of sight. The last signal from MASCOT reached the mother probe at 21:04 CEST. The mission was over. "We were expecting less than 16 hours of battery life because of the cold night, says MASCOT project manager Tra-Mi Ho from the DLR Institute of Space Systems. "After all, we were able to operate MASCOT for more than one extra hour, even until the radio shadow began, which was a great success." During the mission, the team named MASCOT's landing site (MA-9) 'Alice's Wonderland', after the eponymous book by Lewis Carroll (1832-1898).

A true wonderland

Having reconstructed the events that took place on asteroid Ryugu, the scientists are now busy analysing the first results from the acquired data and images. "What we saw from a distance already gave us an idea of what it might look like on the surface," reports Ralf Jaumann from the DLR Institute of Planetary Research and scientific director of the MASCOT mission. "In fact, it is even crazier on the surface than expected. Everything is covered in rough blocks and strewn with boulders. How compact these blocks are and what they are composed of, we still do not know. But what was most surprising was that large accumulations of fine material are nowhere to be found – and we did not expect that. We have to investigate this in the next few weeks, because the cosmic weathering would actually have had to produce fine material," continues Jaumann.

"MASCOT has delivered exactly what we expected: an 'extension' of the space probe on the surface of Ryugu and direct measurements on site," says Tra-Mi Ho. Now there are measurements across the entire spectrum, from telescope light curves from Earth to remote sensing with Hayabusa2 through to the microscopic findings of MASCOT. "This will be of enormous importance for the characterisation of this class of asteroids," emphasises Jaumann.

Ryugu is a C-type asteroid – a carbon-rich representative of the oldest bodies of the four-and-a-half-billion year-old Solar System. It is a 'primordial' building block of planet formation, and one of 17,000 known Near-Earth asteroids.

On Earth, there are meteorites with a composition that could be similar to Ryugu's, which are found in the Murchison Range, Australia. However, Matthias Grott from the DLR Institute of Planetary Research and responsible for the radiometer experiment MARA is skeptical as to whether these meteorites are actually representative of Ryugu in terms of their physical properties: "Meteorites such as those found in Murchison are rather massive. However, our MARA data suggests the material on Ryugu is slightly more porous. The investigations are just beginning, but it is plausible to assume that small fragments of Ryugu would not survive the entry into the Earth's atmosphere intact."

About the Hayabusa2 mission and MASCOT

Hayabusa2 is a Japanese space agency (Japan Aerospace Exploration Agency; JAXA) mission to the near-Earth asteroid Ryugu. The German-French lander MASCOT on board Hayabusa2 was developed by the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) and built in close cooperation with the French space agency CNES (Centre National d'Etudes

Spatiales). DLR, the Institut d'Astrophysique Spatiale and the Technical University of Braunschweig have contributed the scientific experiments on board MASCOT. The MASCOT lander and its experiments are operated and controlled by DLR with support from CNES and in constant interaction with the Hayabusa2 team.

The DLR Institute of Space Systems in Bremen was responsible for developing and testing the lander together with CNES. The DLR Institute of Composite Structures and Adaptive Systems in Braunschweig was responsible for the stable structure of the lander. The DLR Robotics and Mechatronics Center in Oberpfaffenhofen developed the swing arm that allows MASCOT to hop on the asteroid. Das DLR Institute of Planetary Research in Berlin contributed the MASCAM camera and the MARA radiometer. The asteroid lander is monitored and operated from the MASCOT Control Center in the Microgravity User Support Center (MUSC) at the DLR site in Cologne.

Provided by German Aerospace Center