Outline of the operation of MINERVA-II2 (Rover 2) deployment

Sep. 24 (Tue) 2019

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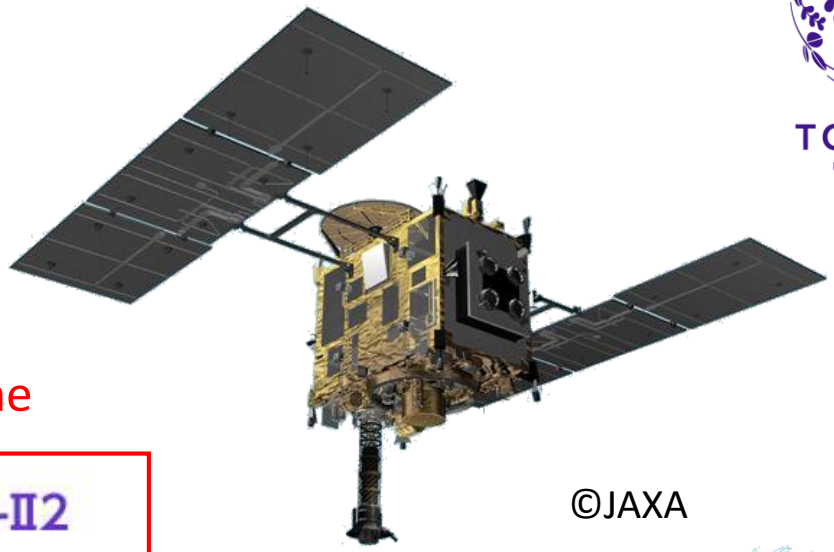
Micro-Rovers and Landers Onboard Hayabusa-2



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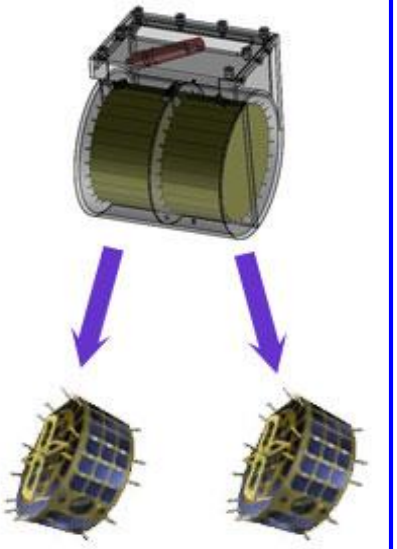
Deployed in Sep. 2018

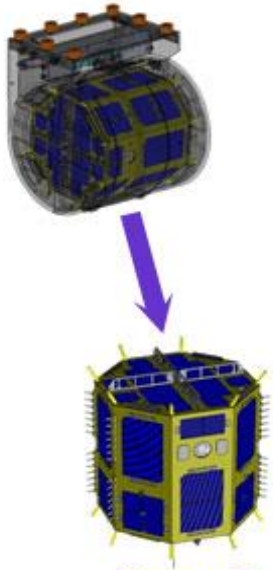
This time

MINERVA-II1



By JAXA

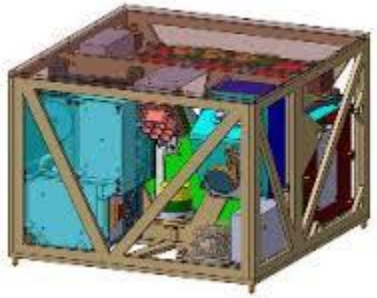
MINERVA-II2



By Univ. consortium

Deployed in Oct. 2018

MASCOT



By DLR/CNES

Status of Rovers 2 and Purpose of the deployment (update)

- In the onboard function tests, the communication system between Hayabusa 2 and Rover 2 can be established. However, the Rover 2 data processor cannot be booted normally. This situation is still the same since it was reported in November 2018.
- To obtain scientifically interesting/meaningful results from the rover 2 deployment, the Hayabusa 2 team, the University of Colorado in US, Kyushu Institute of Technology, and Tohoku University have discussed possible options.
- Instead of operating the rover 2 on the surface for the mobility and imaging missions, the idea was developed to release the rover at a higher altitude and put it into an orbit to go around Ryugu. If the orbital motion of rover 2 is observed by the optical cameras from Hayabusa 2, we will make a better understanding of the gravity field of Ryugu.

Goal of the Updated Rover 2 Operation

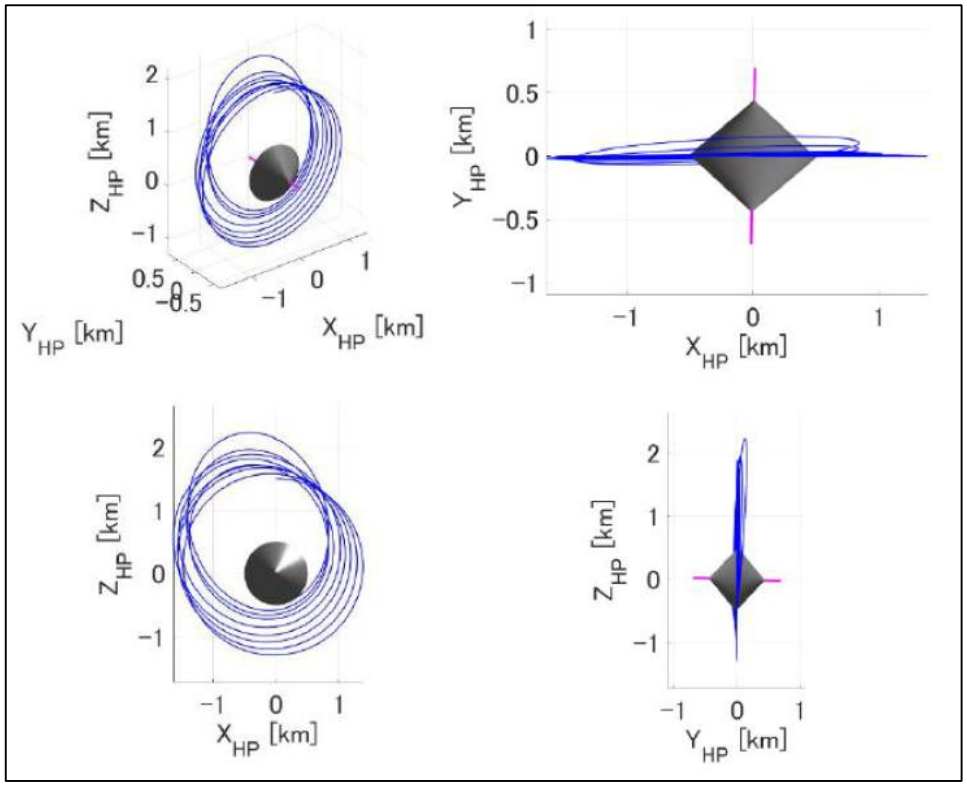
- Acquire the scientific data that contributes to improving the accuracy of Ryugu's gravity model.
- Accumulate the engineering experience for orbital maneuvering technology by orbiting a small artifact such as a CubeSat around an asteroid.

Operation Plan

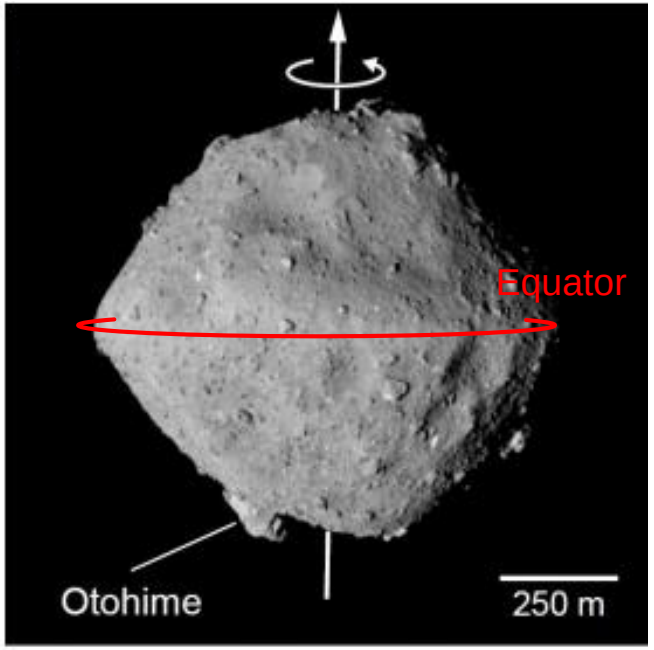
- Separate Rover 2 at an altitude of about 1km from the surface of Ryugu.
- Inject Rover 2 into an equatorial orbit toward the direction of the Ryugu’s rotation.
- Observe the motion/trajectory of Rover 2 optically with ONC-W1, W2, and ONC-T imagers.

Prediction of Orbit

item	Predicted value
Type of orbit	Around equator
Orbital life	5 days(±few days)
No. of revolution	8 times(±few times)
Orbital period (1st rev.)	17 hours(±few hours)



Expected Rover 2 orbit in the HP coordinate ©JAXA



Ryugu's rotation axis and equator ©JAXA

Expected Behavior of Rover 2

- The touch-down speed of Rover 2 on the surface of Ryugu will be about 0.5 m/s. This is the same level as dropping from a height of about 1.5cm on the 1G ground, then it is unlikely that the rover will be damaged by the touch-down impact.
- The following onboard instruments of Rover 2 will not be functioned unless the data processing system is restored.
  - Micro-hop movement with an eccentric motor (Tohoku Univ.)
  - Elastic-reaction movement using leaf springs (Osaka Univ.)
  - Impulsive movement using a permanent magnet (Tokyo Denki University)
  - MICAM imager (Tokyo University of Science)
- The elastic-reaction mechanism using bimetal springs (developed by Yamagata University) will react to the temperature changes due to the periodic sunlight and shade on Ryugu, then produce some hopping motions of the rover. However, it is difficult to observe the resulting movement.

MINERVA-II2 (in the original design)

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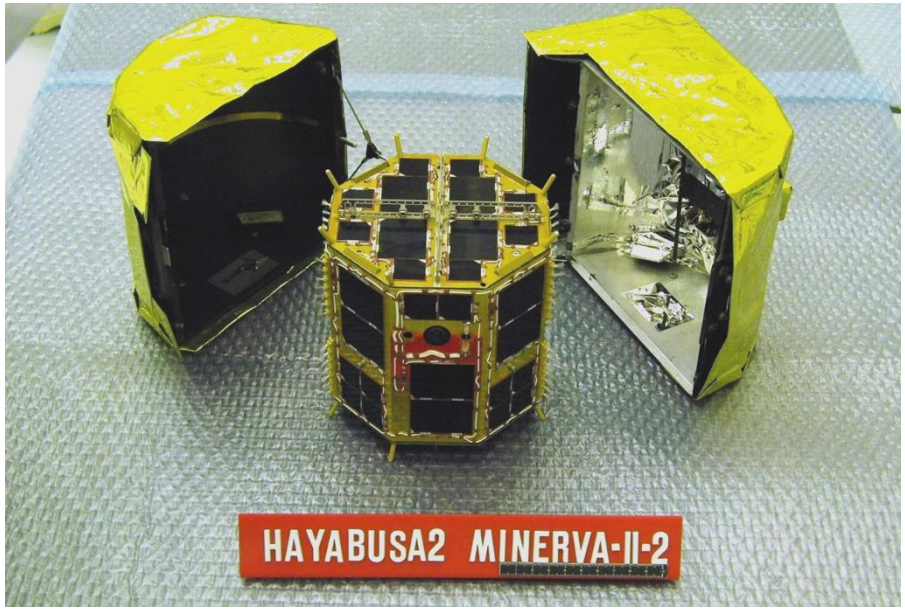

MINERVA-II2 ©JAXA

ROVER2 specification

- size: Φ15 [cm] ×14.5 [cm] (h)
- mass: 877 [g]
- power: 2 [W] in average
- mobility: multiple hopping modes
- mission: surface imaging

ROVER2 onboard actuators

- Micro-hopping by vibration of cilia
- Hopping by permanent magnet action
- Hopping by bi-metal action due to ambient temperature change
- Hopping with Leaf-Spring action

ROVER2 onboard sensors

- Micro-Camera (2): close-up imaging
- Temperature sensors (6)
- Accelerometers (2) : contact detection
- Photodiode (6) : sun-angle detection for attitude determination

Moving-mass actuators

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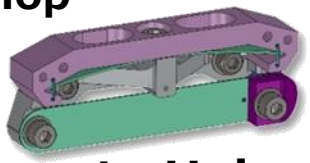
Bi-Metal

- **driven by temperature change**
- utilize bi-metal's buckling
- assembles 2-units -> **Hop**

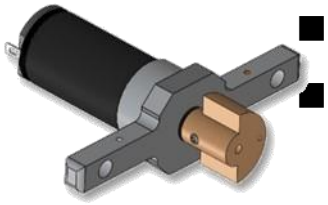


27.5 g

Yamagata Univ.

Eccentric Motor w/ Cilia

- **driven by DC-brushed motor**
- utilize centrifugal force
- utilize ex. cilia units -> **Micro-Hop**

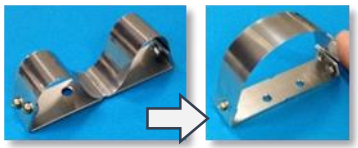


Tohoku Univ.

24.4 g

Leaf-Spring

- **driven by releasing compression leaf springs (2 units)**
- utilize spring's elastic energy -> **Hop**

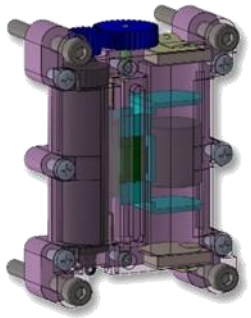


7.0 g

Osaka Univ.

Permanent Magnet

- **driven by DC-brushed motor**
- utilize magnetic force of permanent magnets -> **Hop**



Tokyo Denki Univ.

29.2 g

MICAM

(developed by
Science University of Tokyo)

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Specifications

- VGA/SXGA color images
- COTS CMOS imager
- Wide angle lens (H125.3° x V97.7°)
- Focal length: 10cm, 1cm
- Mass: 39g

(Fact Sheet) History of MINERVA-II2 (Rover 2) development

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1. Based on opinions from the external evaluation committee members in the mission review of the Hayabusa 2 pre-project (2007-2010), a framework was discussed to include university/non-JAXA members into the engineering challenge for the surface exploration robots, such as MINERVA that was previously developed for Hayabusa 1.
2. A consortium for the surface rover development was formed by university researchers who responded to a call sent to the Japan Society of Mechanical Engineers, Japanese robot researchers' mailing list, University Space Engineering Consortium (UNISEC), ISAS Engineering Committee Lunar Planetary Surface Exploration Technology (STEPS) working group, etc. in April 2011.
3. In 2012, at the approval review for move to a full-project, it was decided that MINERVA-II1 shall be developed by JAXA and MINERVA-II2 shall be developed by the University Consortium as an optional payload of Hayabusa 2.
4. In 2013, the substantial development of MINERVA-II2 (Rover 2) was started in the Consortium under the leadership of Tohoku University.
5. September 1, 2014, JAXA and Tohoku University signed an "Agreement on Mounting a Small Surface Exploration Robot (MINERVA-II2) on Hayabusa 2".
6. December 3, 2014, Hayabusa 2 was launched.

The Status of MINERVA-II2 (Rover 2)

(The press conference on November 8, 2018)

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1. After the launch of Hayabusa 2, the onboard status check procedures were performed for MINERVA-II2 in December 2014, June 2015, and October 2017, then the communication link was confirmed between Hayabusa 2 and Rover 2.
2. However, the telemetry data (including HK data) on the internal state of the rover 2 has not been obtained due to the booting anomaly of the rover 2 data processing system. The same symptom was observed in the pre-launch tests. Through the ground-based testing and analysis using the non-flight Engineering Model, the possibility of a fully functional rover operation is considered very low.
3. Under the collaboration with JAXA's Hayabusa 2 team, the Consortium is currently studying an operation plan that will produce meaningful results through the deployment of Rover 2 (which is scheduled around July 2019.)