Operation status for the asteroid explorer, Hayabusa2

September 27, 2018

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2 :

- MINERVA-Ⅱ1 newsflash
- MASCOT release operation
- Images of Ryugu

Contents

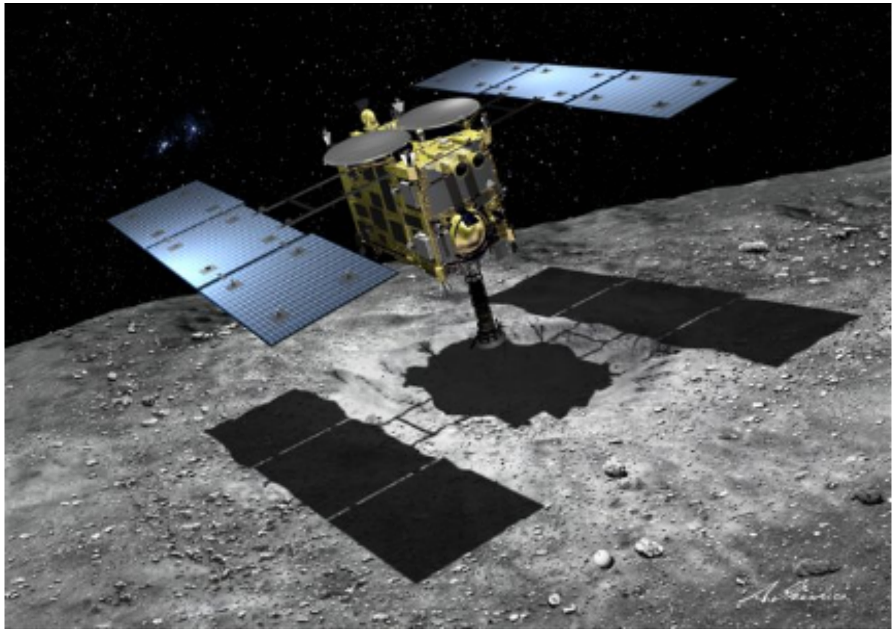
Overview of Hayabusa2

Objective
We will explore and sample the C-type asteroid Ryugu, which is a more primitive type than the S-type asteroid Itokawa that Hayabusa explored, and elucidate interactions between minerals, water, and organic matter in the primitive solar system. By doing so, we will learn about the origin and evolution of Earth, the oceans, and life, and maintain and develop the technologies for deep-space return exploration (as demonstrated with Hayabusa), a field in which Japan leads the world.

Expected results and effects
・By exploring a C-type asteroid, which is rich in water and organic materials, we will clarify interactions between the building blocks of Earth and the evolution of its oceans and life, thereby developing solar system science.
・ Japan will further its worldwide lead in this field by taking on the new challenge of obtaining samples from a crater produced by an impacting device.
・We will establish stable technologies for return exploration of solar-system bodies.

Features:
・World’s first sample return mission to a C-type asteroid.
・World’s first attempt at a rendezvous with an asteroid and performance of observation before and after projectile impact from an impactor.
・Comparison with results from Hayabusa will allow deeper understanding of the distribution, origins, and evolution of materials in the solar system.

International positioning：
・Japan is a leader in the field of primitive body exploration, and visiting a type-C asteroid marks a new accomplishment.
・This mission builds on the originality and successes of the Hayabusa mission. In addition to developing planetary science and solar system exploration technologies in Japan, this mission develops new frontiers in exploration of primitive heavenly bodies.
・NASA too is conducting an asteroid sample return mission, OSIRIS-REx (launch: 2016; asteroid arrival: 2018; Earth return: 2023). We will exchange samples and otherwise promote scientific exchange, and expect further scientific findings through comparison and investigation of the results from both missions.



(Illustration: Akihiro Ikeshita)

Hayabusa 2 primary specifications

Mass	Approx. 609 kg
Launch	3 Dec 2014
Mission	Asteroid return
Arrival	27 June 2018
Earth return	2020
Stay at asteroid	Approx. 18 months
Target body	Near-Earth asteroid Ryugu

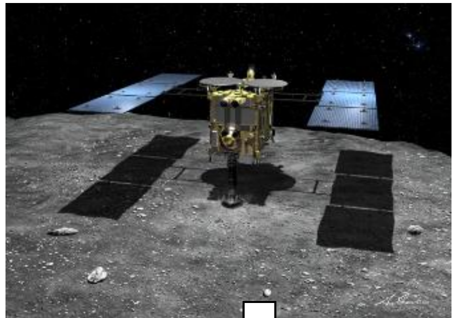
Primary instruments
Sampling mechanism, re-entry capsule, optical cameras, laser range-finder, scientific observation equipment (near-infrared, thermal infrared), impactor, miniature rovers.

Mission Flow

Launch
3 Dec 2014

Earth swing-by
3 Dec 2015

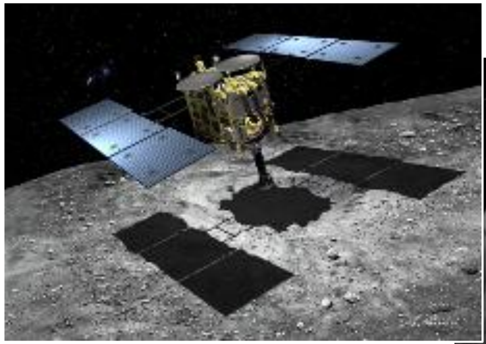
Arrival at asteroid
June 27, 2018



Examine the asteroid by remote sensing observations. Next, release a small lander and rover and also obtain samples from the surface.

Use an impactor to create an artificial crater on the asteroid's surface

Depart asteroid
Nov–Dec 2019



After confirming safety, touchdown within the crater and obtain subsurface samples

Earth return
late 2020

Sample analysis

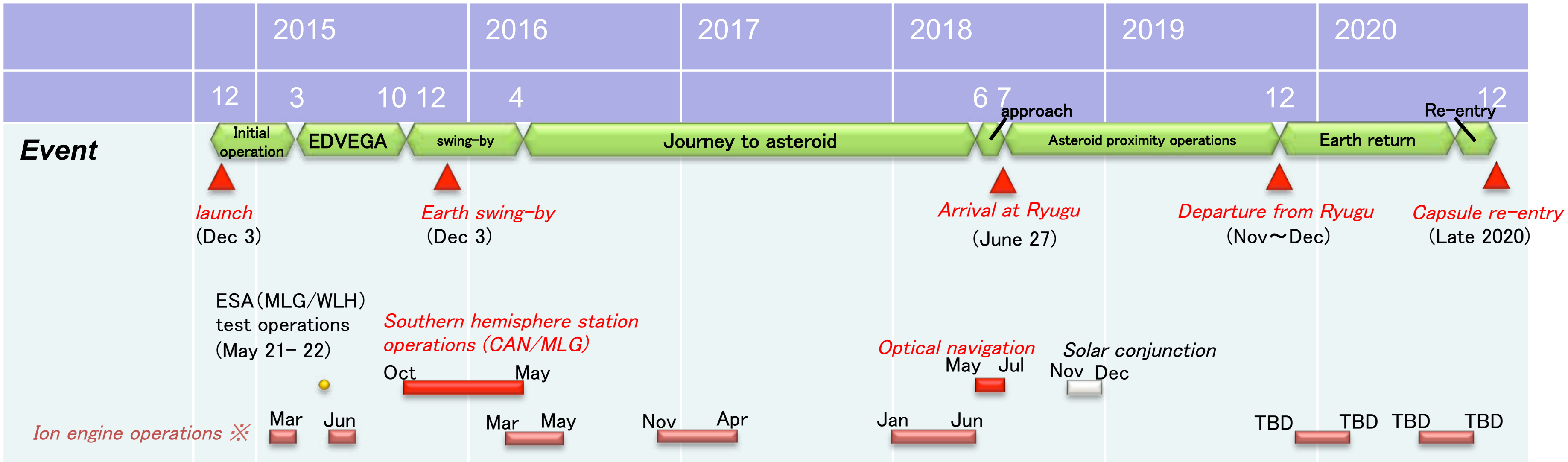
(Illustrations: Akihiro Ikeshita)

1. Current project status & schedule overview

Current status：

- September 19 – 21 was the MINERVA-II1 deployment operation, with MINERVA-II1 Rover-1A & Rover-1B separating from the spacecraft on September 21. The two rovers were later confirmed to have landed on the surface of Ryugu and are moving via hopping.
- September 30 – October 4 is the MASCOT deployment operation, including the preparatory period.

Schedule overview:



2. MINERVA-Ⅱ1 newsflash

History from deployment to present

- 9/21: 13:05JST separation from the Hayabusa2 spacecraft
- 9/21: Day 1 (Sol.1) Image data obtained after rover deployment
- 9/21: Day 2 (Sol.1) Rover ON confirmation, telemetry pending
- 9/22: Day 3 (Sol.3) Rover ON confirmation, telemetry pending
- 9/22: Day 4 (Sol.4)
  - Rover-1A confirm hopping
  - Rover-1B telemetry received, surface temperature measurement, hop preparation

・・・・・・・

- 9/23: Day 7 (Sol.7) Rover-1A, 1B telemetry received
  - Rover-1B confirm hopping

・・・・・・・

- 9/27: Day 20 (Sol.20)

2. MINERVA-II1 newsflash

Image taken immediately after separation

Image captured by Rover-1A on September 21 at around 13:08 JST. This is a color image taken immediately after separation from the spacecraft. Hayabusa2 is at the top and the surface of Ryugu is bottom. The image is blurred because the shot was taken while the rover was rotating. (Image credit: JAXA)

2. MINERVA-II1 newsflash

Image taken immediately after separation

Image captured by Rover-1B on September 21 at around 13:07 JST. This color image was taken immediately after separation from the spacecraft. The surface of Ryugu is in the lower right. The top left colored blur in the top left is due to the reflection of sunlight when the image was taken. (Image credit: JAXA) we deleted halation.

2. MINERVA-II1 newsflash

Image captured during hopping

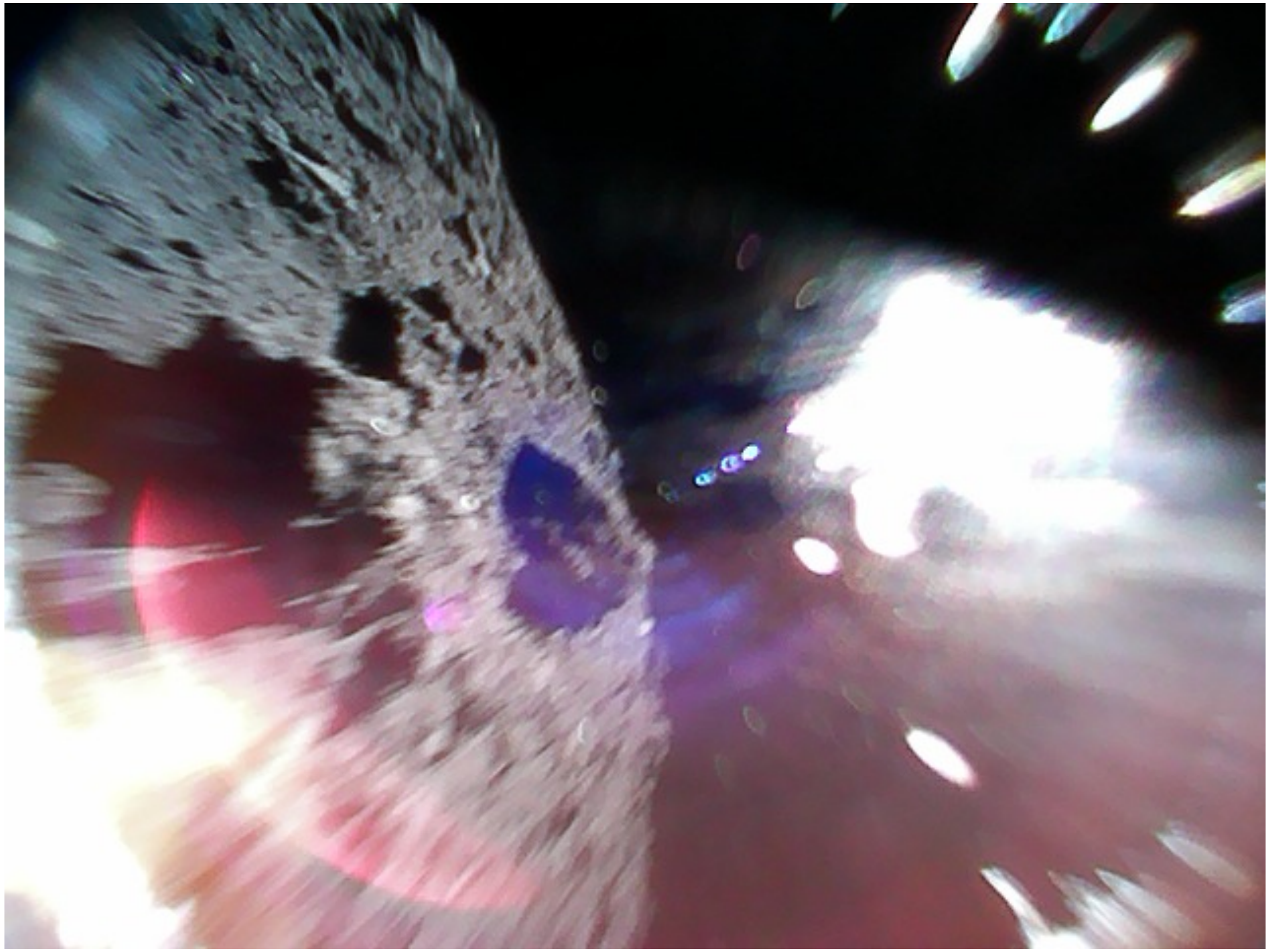


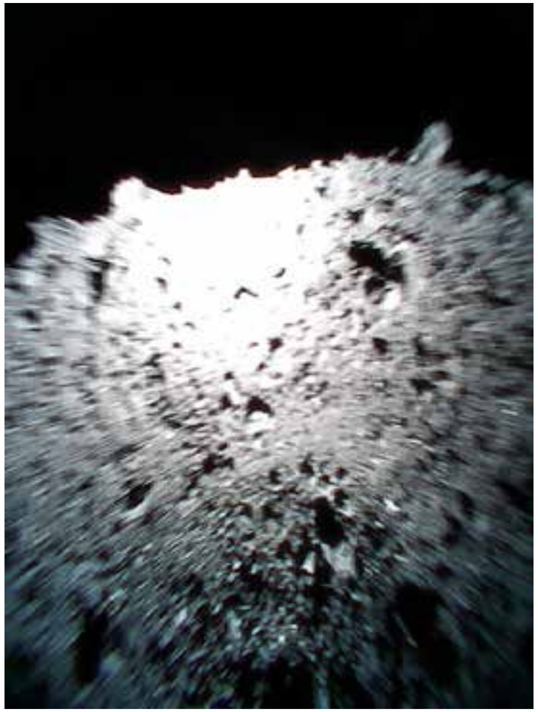
Image captured by Rover-1A on September 22 at around 11:44 JST. Color image captured while moving (during a hop) on the surface of Ryugu. The left-half of the image is the asteroid surface. The bright white region is due to sunlight. (Image credit: JAXA).

2. MINERVA-II1 newsflash

Images taken by Rover-1B

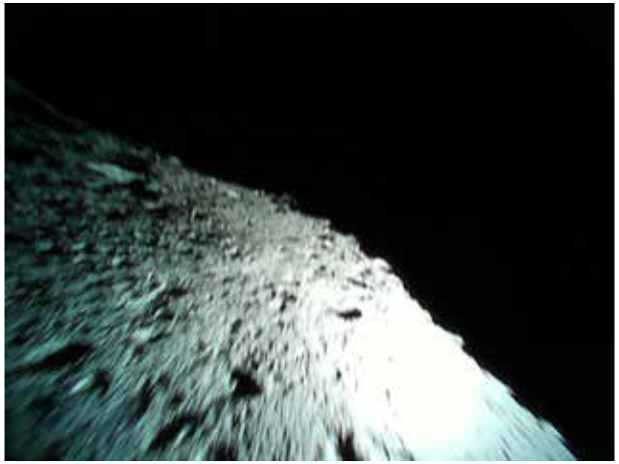
New

September 23, 2018: confirmation of Rover-1B hop



2018/09/23 09:50

2018/09/23 09:55



2018/09/23 10:00

(Image credit：JAXA)

2. MINERVA-II1 newsflash

New

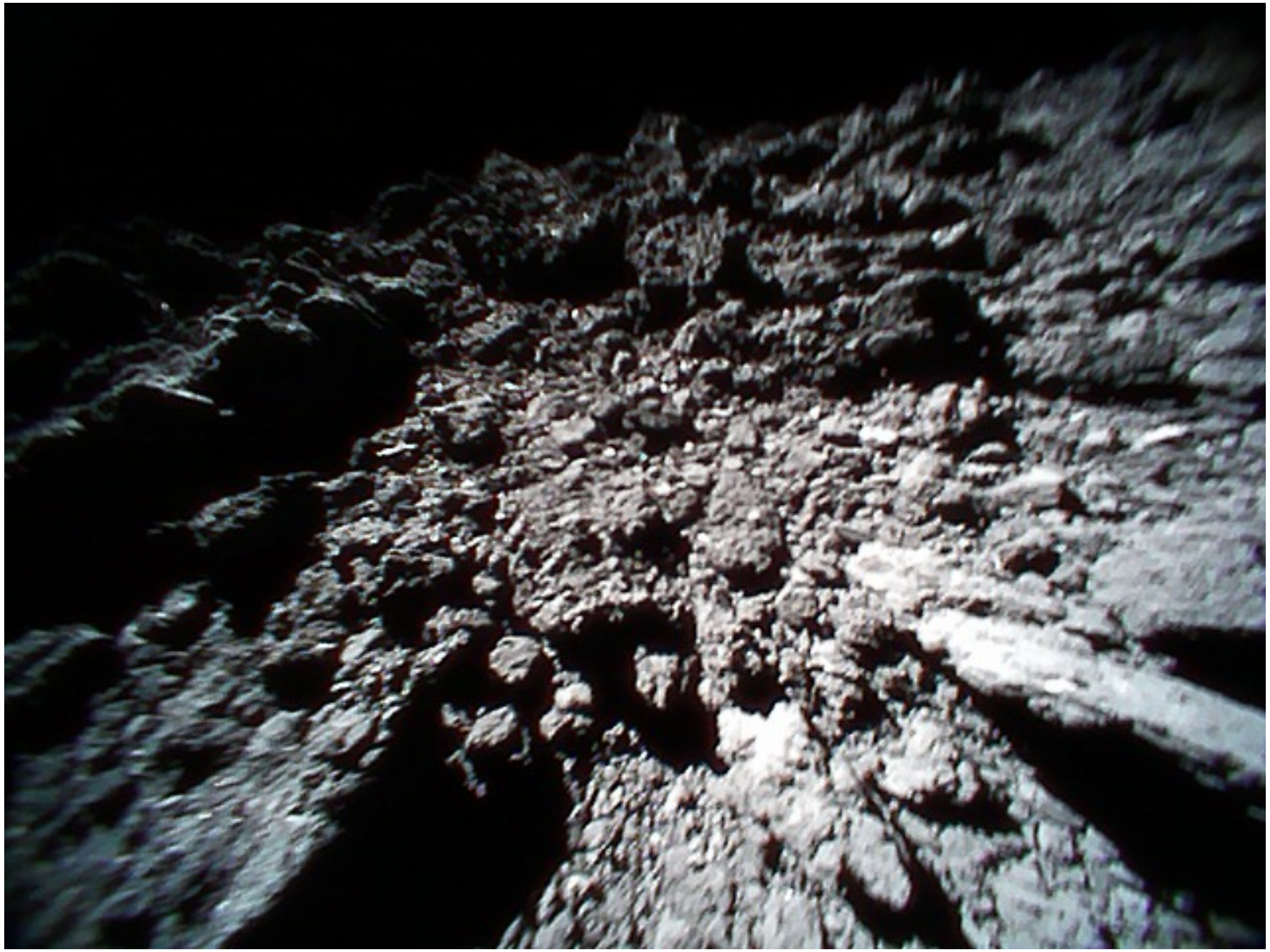
September 23, 2018: image captured immediately before hop of Rover-1B

（Image credit：JAXA）

2. MINERVA-II1 newsflash

New

September 23, 2018 at 10:10 JST: surface image from Rover-1B after landing



（Image credit：JAXA）

2. MINERVA-II1 newsflash

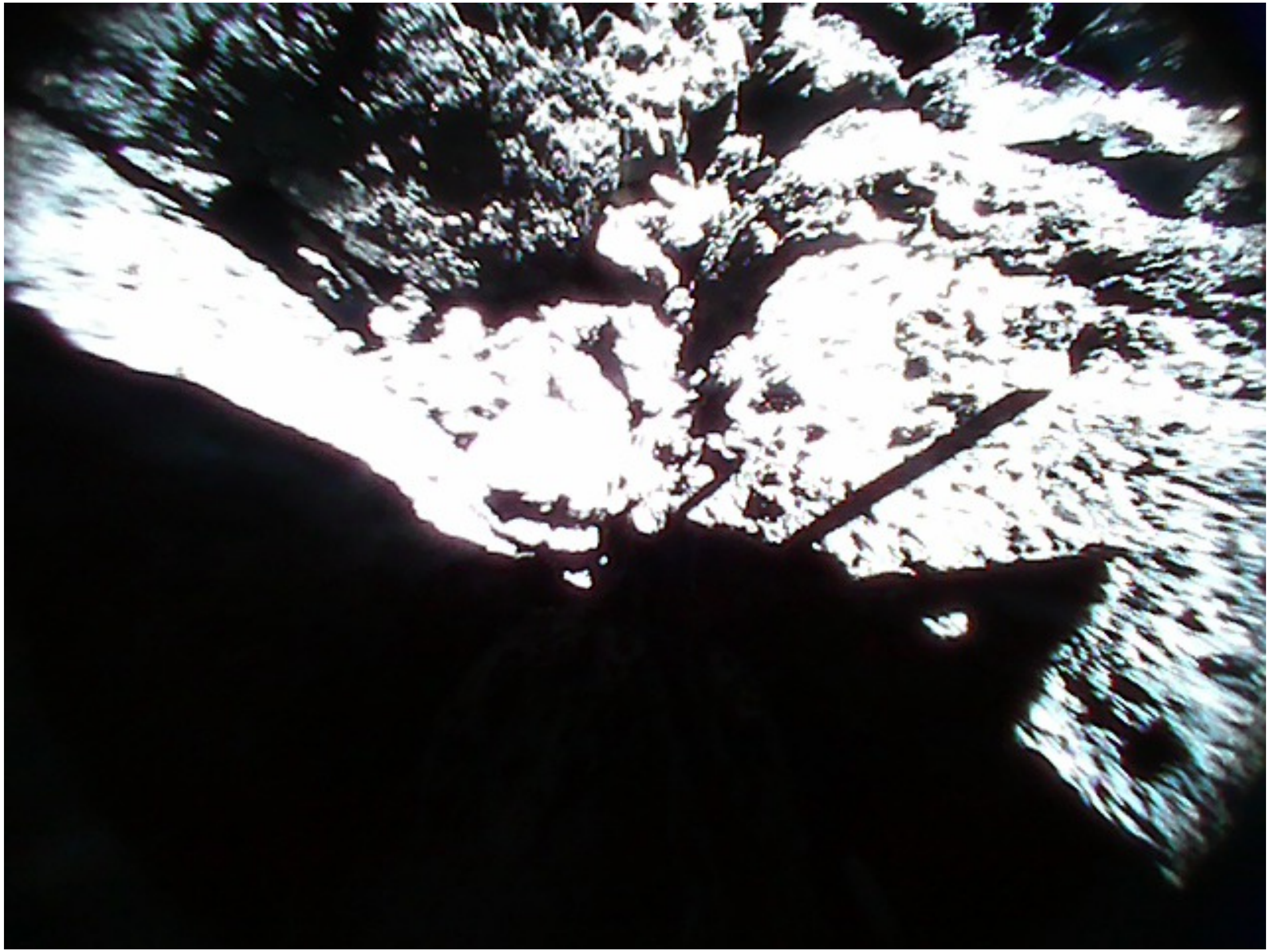
September 23, 2018 at 09:43 JST: surface image taken from Rover-1A

New

（Image credit：JAXA）

2. MINERVA-II1 newsflash

September 23, 2018 at 09:48 JST: surface image taken from Rover-1A



New

（Image credit：JAXA）

2. MINERVA-II1 newsflash

September 23, 2018 at 09:48 JST: surface image taken from Rover-1A

MINERVA-II1 successfully captured the shadow of its own antenna and pin

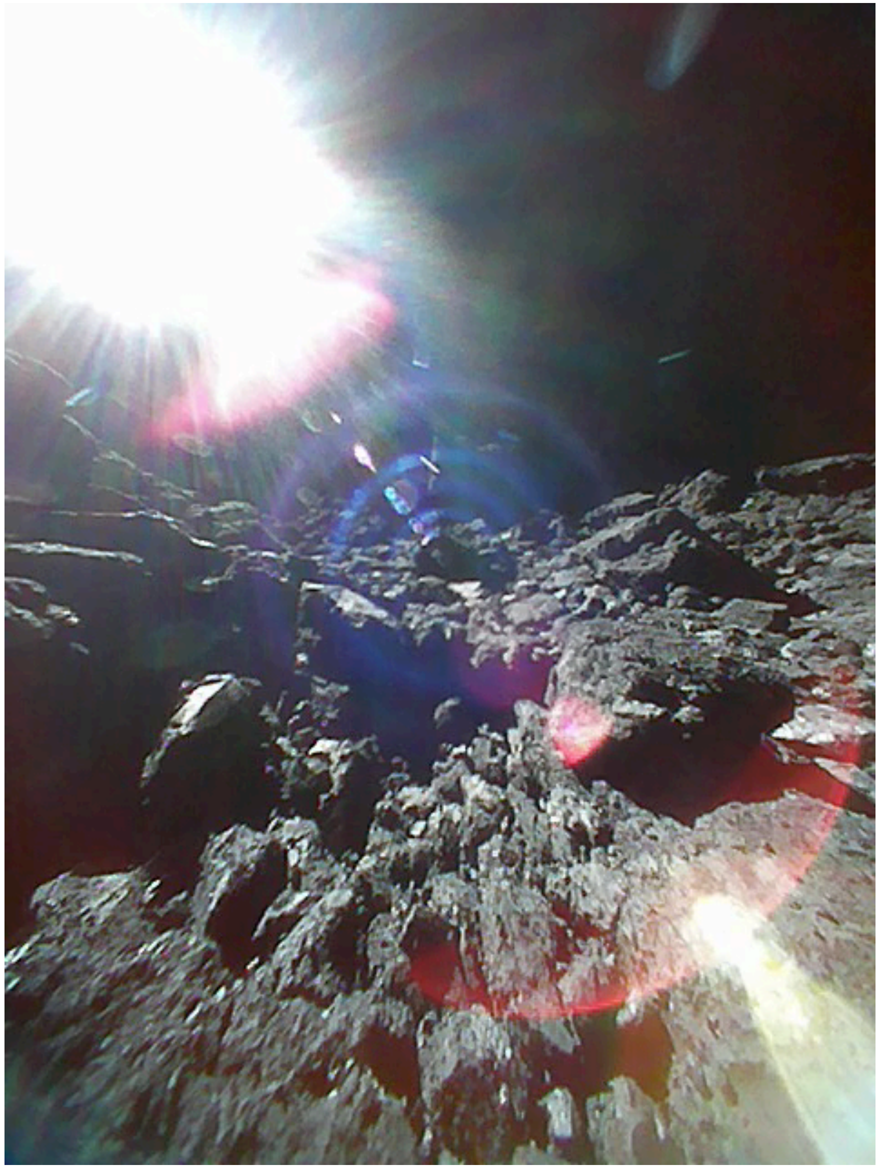
New

(Image credit：JAXA)

2. MINERVA-II1 newsflash

New

Rover-1B successfully shot a movie



15 frames captured on September 23, 2018 from 10:34 – 11:48 JST

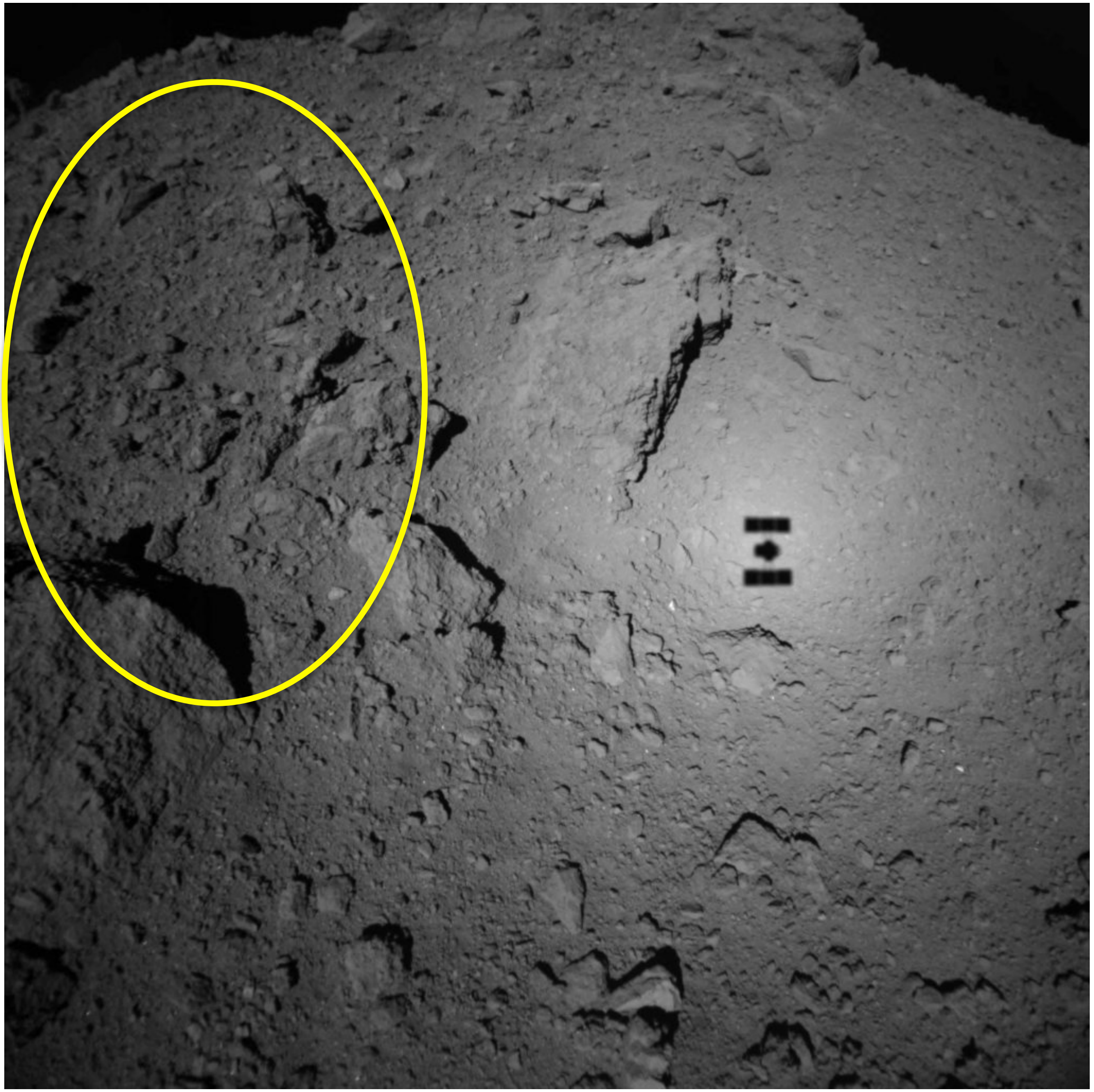
（animation）

（credit：JAXA）

2. MINERVA-II1 newsflash

September 21, 2018 at 13:02 JST: image from ONC-W1 at 70m altitude

Separation location of MINERVA-II1 (estimated)

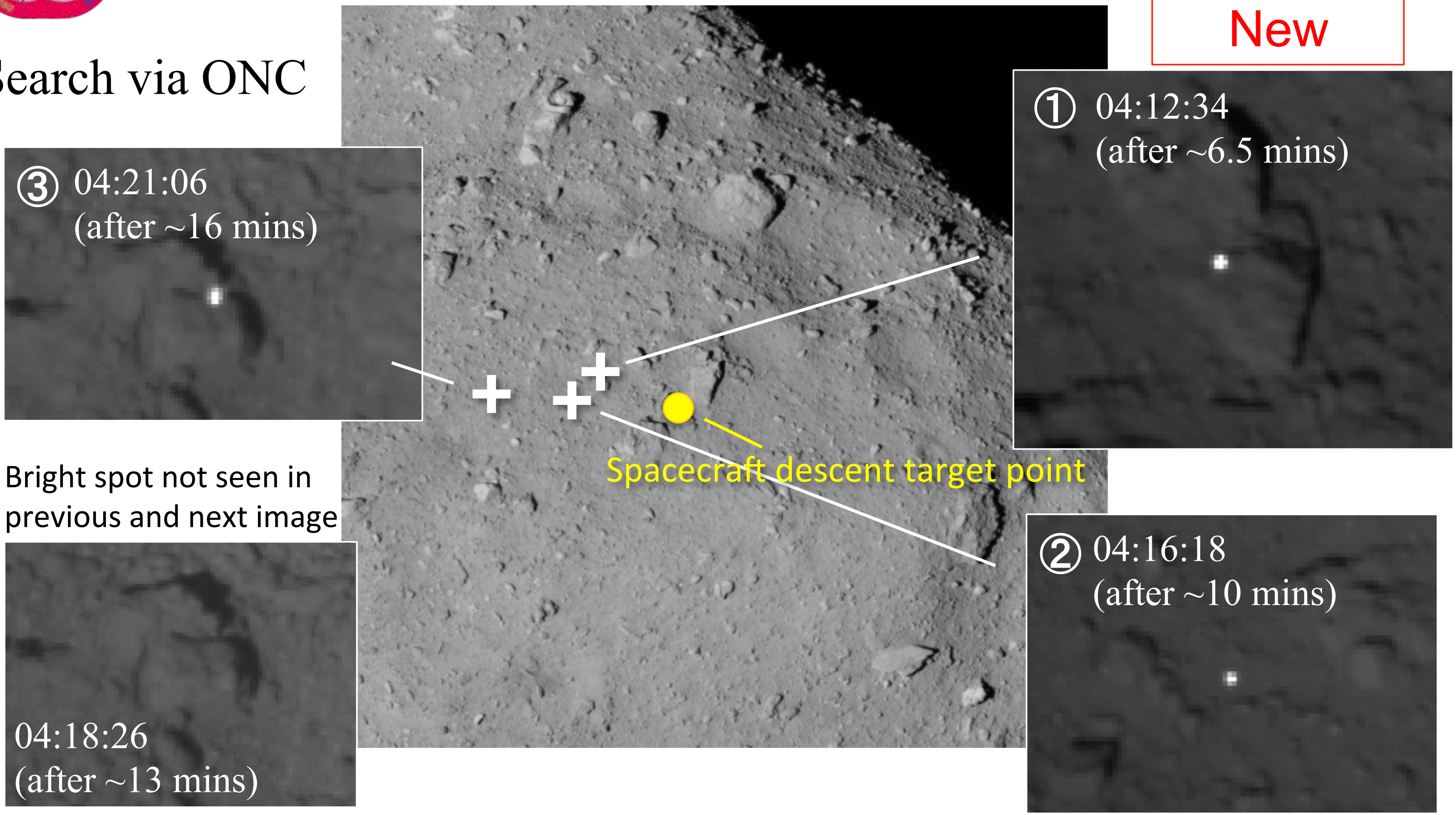


（Image credit：JAXA）

2. MINERVA-II1 newsflash

New

Search via ONC

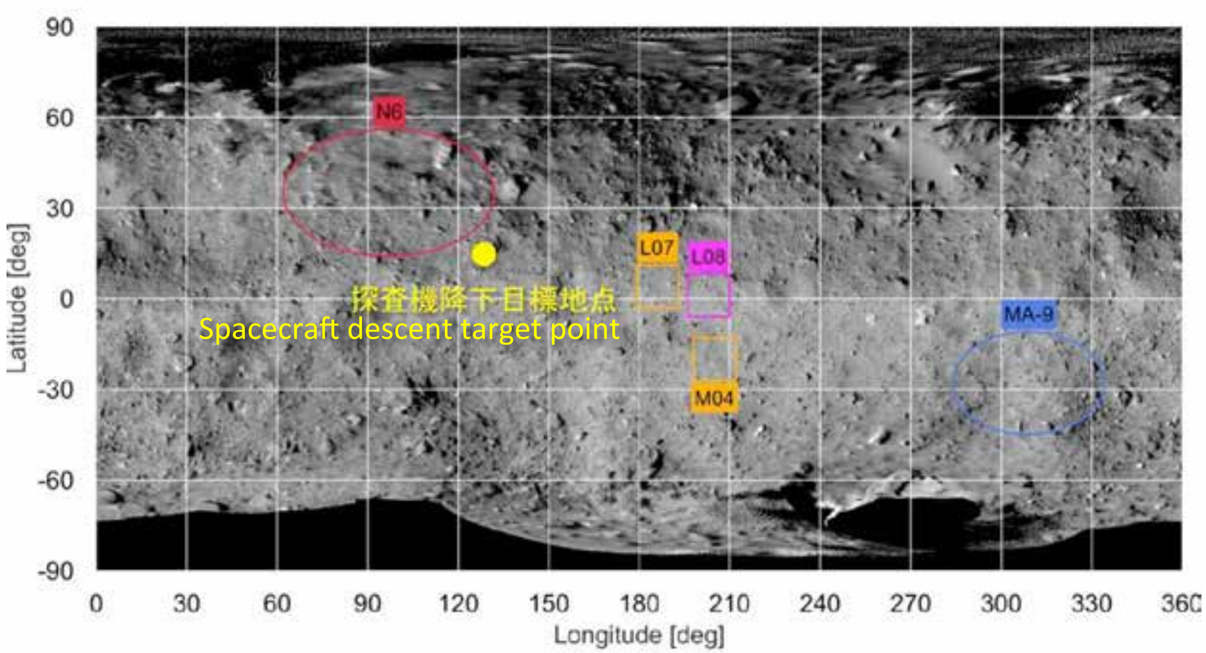


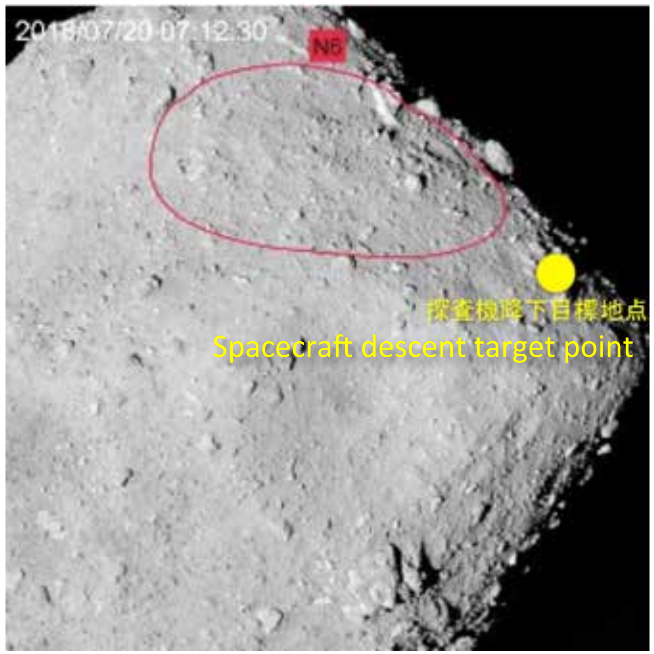
The bright point is confirmed as the MINERVA-II or the container cover moving across ①→②→③, (①, ②: ONC-W1, ③: ONC-T).

(**Image credit**: JAXA, AIST, U. Tokyo, Kochi U, Rikkyo U, Nagoya U, Chiba Institute of Tech, Meiji U, U. Aizu)

2. MINERVA-II1 newsflash

Reference：Location of landing site targets





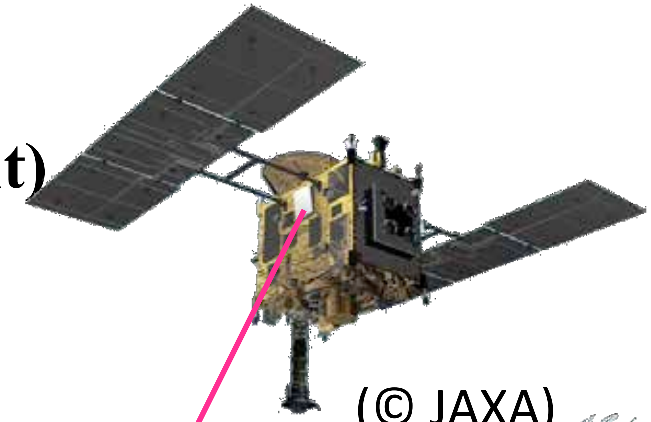
If MINERVA-II1 separated at the spacecraft descent target point, then post separation MINERVA-II1 should be within the area N6.

3. MASCOT release operation

MASCOT System Overview

MASCOT (Mobile Asteroid Surface Scout)

- Developed by DLR (German Aerospace Center) in close cooperation with CNES (French Space Agency)
- Agile, lightweight & compact landing platform for in-situ asteroid research
- Lander Module mass: ~9.8 kg
- Lander Module size: 0.275 x 0.290 x 0.195 m
- Carries Four Scientific Payloads: MASCAM, MicrOmega, MARA, and MASMAG


(© JAXA)

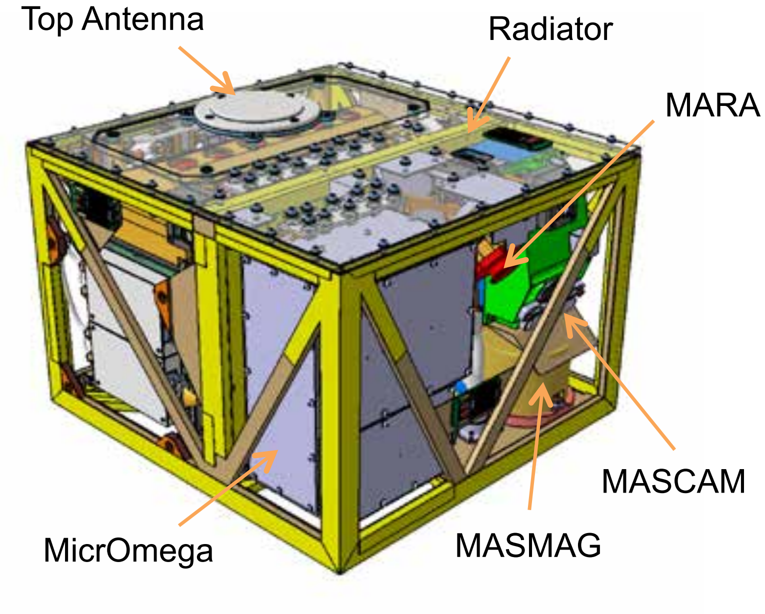

Flight Model (© DLR)

3. MASCOT release operation

MASCOT System Overview

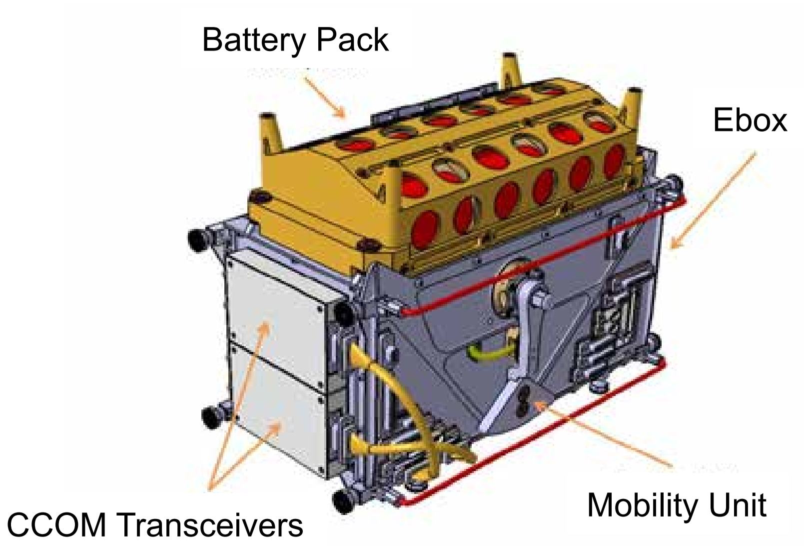
Scientific instruments aboard MASCOT

Device	Function
Wide-angle camera (MASCAM)	Imaging at multiple wavelengths
Spectroscopic microscope (MicrOmega)	Investigation of mineral composition and characteristics
Thermal radiometer (MARA)	Surface temperature measurements
Magnetrometer (MASMAG)	Magnetic field measurement



MASCOT Bus System

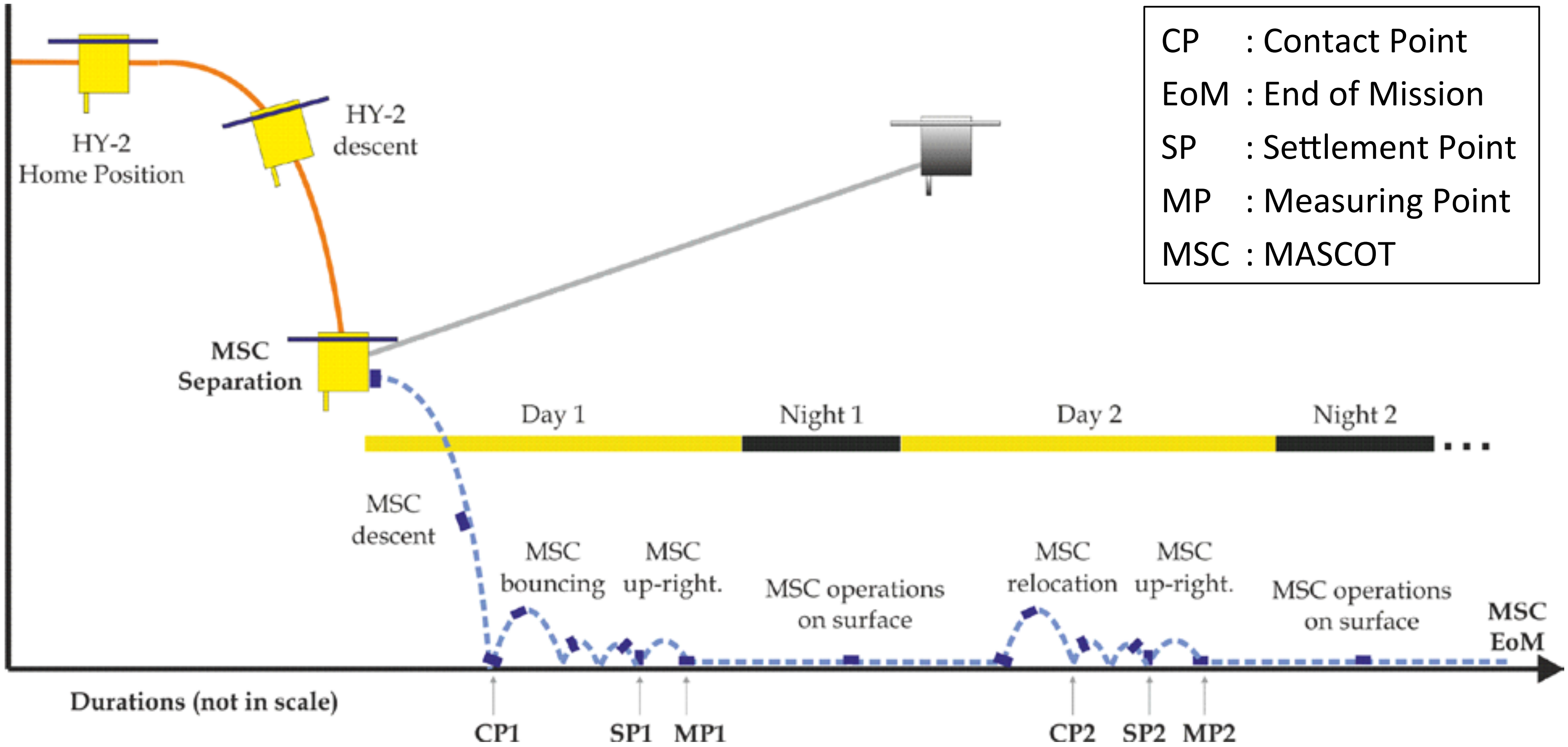
- Power: Primary lithium battery
- Communication: Communication system using transceivers same as Minerva-II rovers
- Mobility: Up-righting and hopping mechanism using motor and excenter mass
- GNC: MASCOT attitude determination using proximity sensors



3. MASCOT release operation

MASCOT On-Asteroid Operation

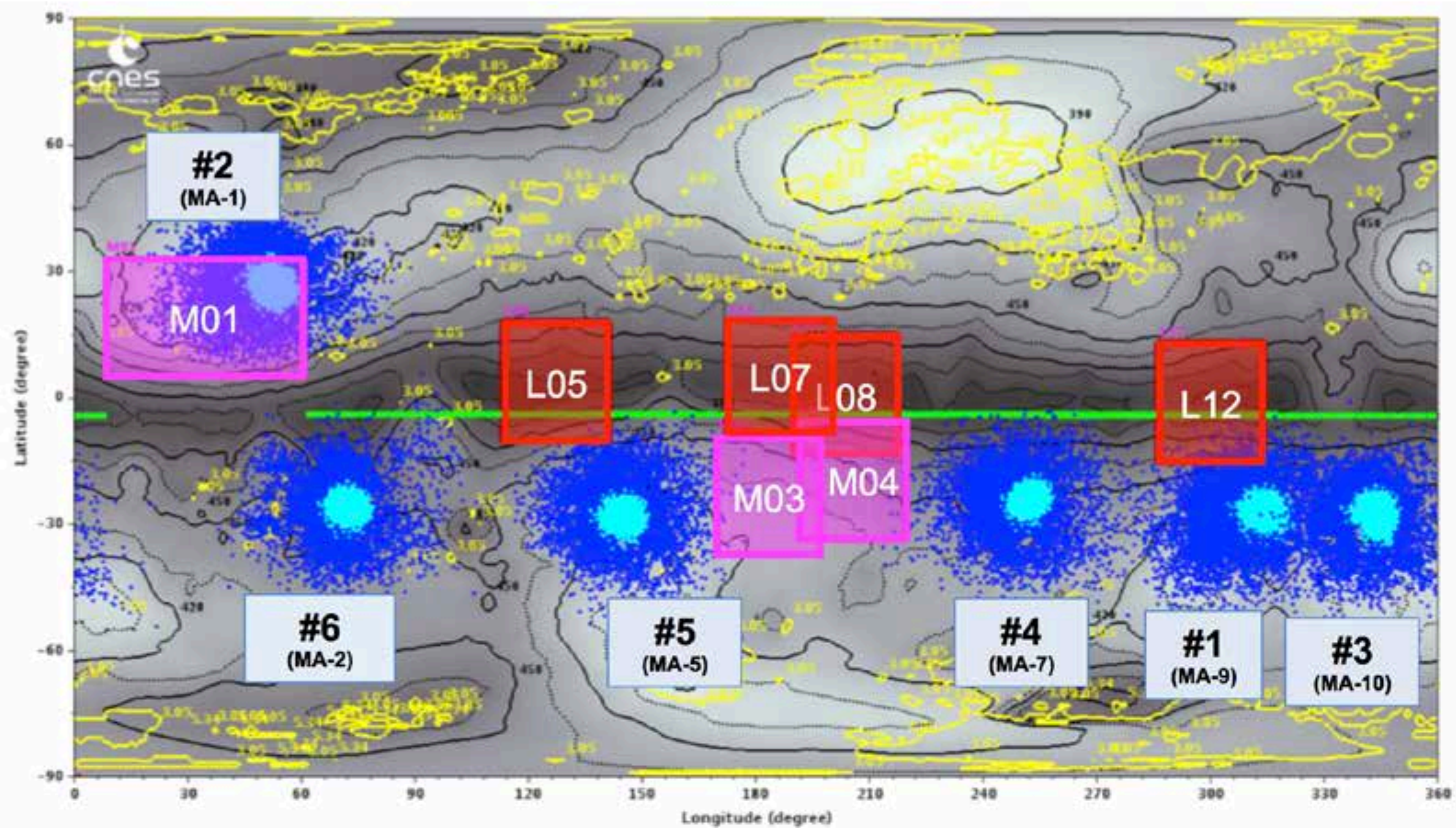
Baseline MASCOT Activities after the Separation



CP : Contact Point
EoM : End of Mission
SP : Settlement Point
MP : Measuring Point
MSC : MASCOT

3. MASCOT release operation

Landing site candidates for MASCOT：Selection from 10 candidates and the order of priority

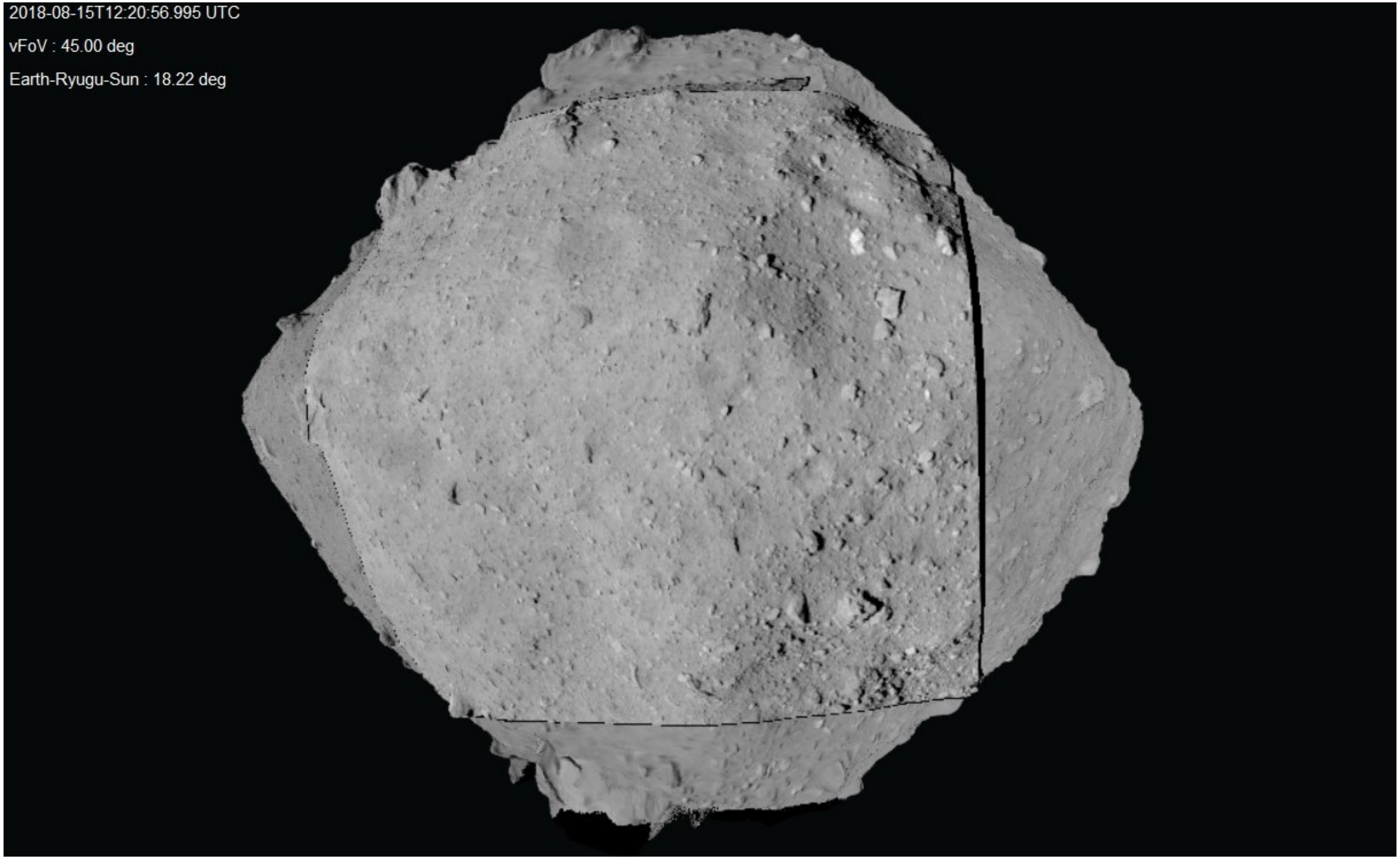


（©DLR,CNES）

Priority of landing site：MA-9 > MA-1 > MA-10 > MA-7 > MA-5 > MA-2

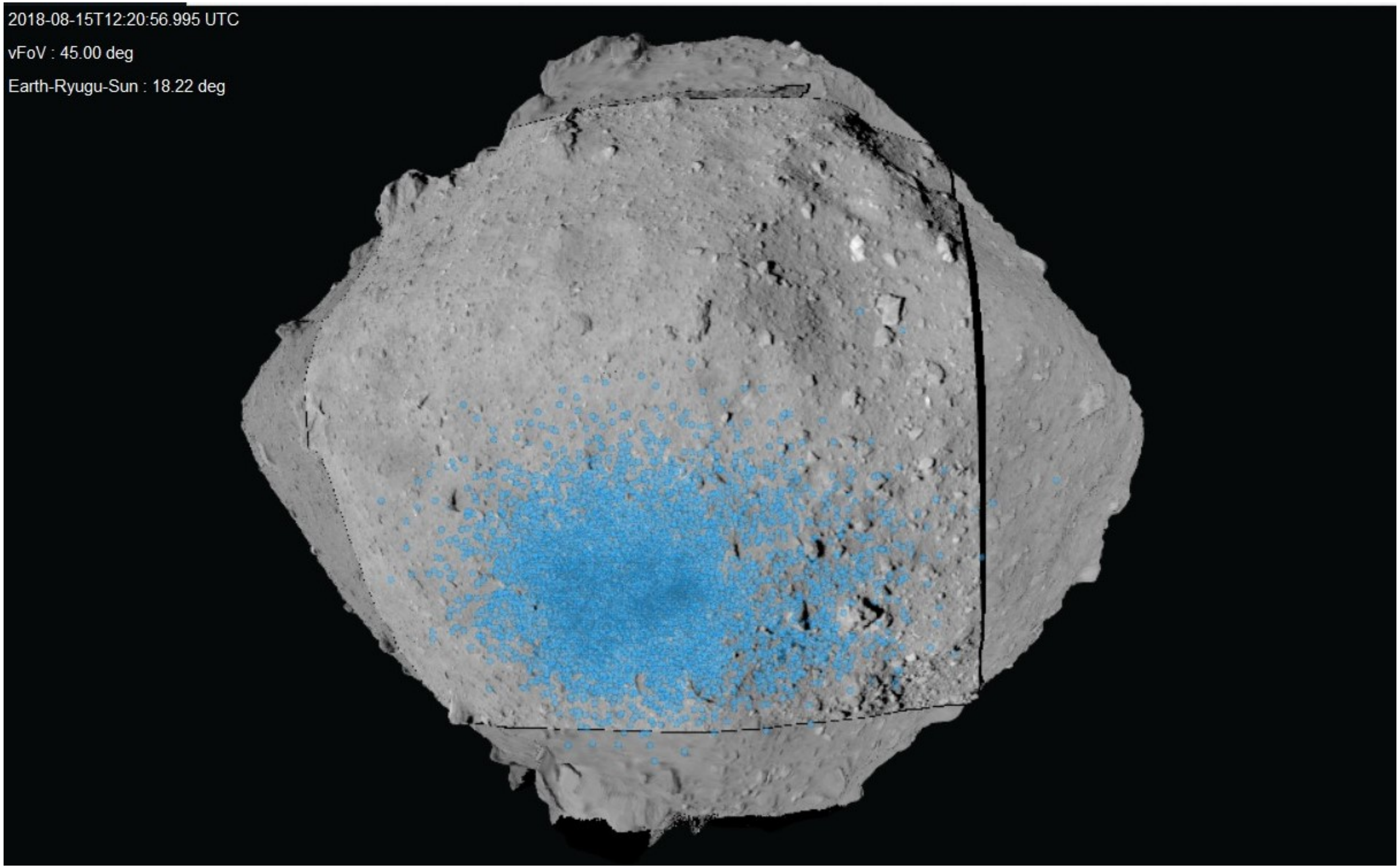
3. MASCOT release operation

MASCOT landing site



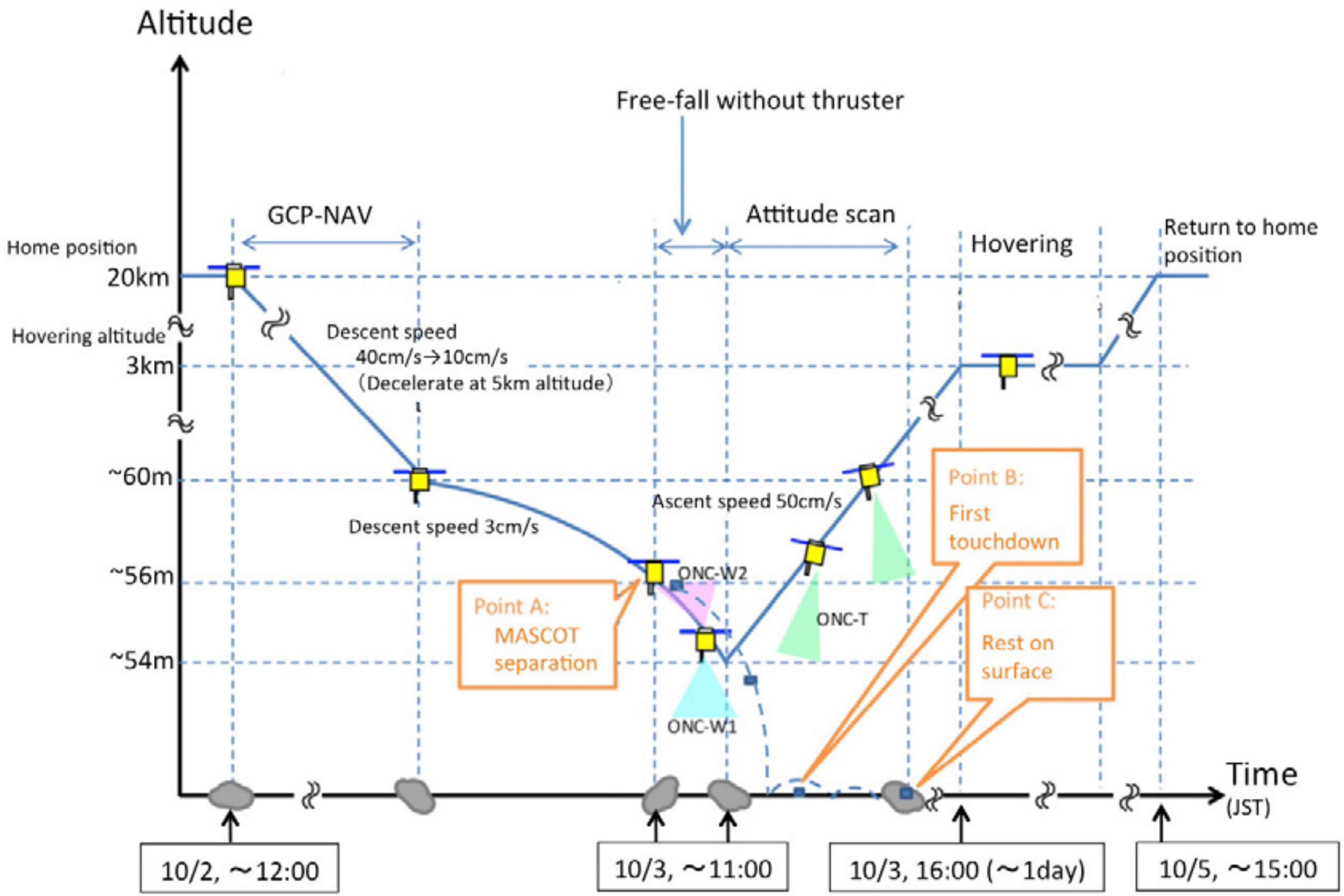
3. MASCOT release operation

MASCOT landing site



3. MASCOT release operation

Outline of MASCOT release operation sequence

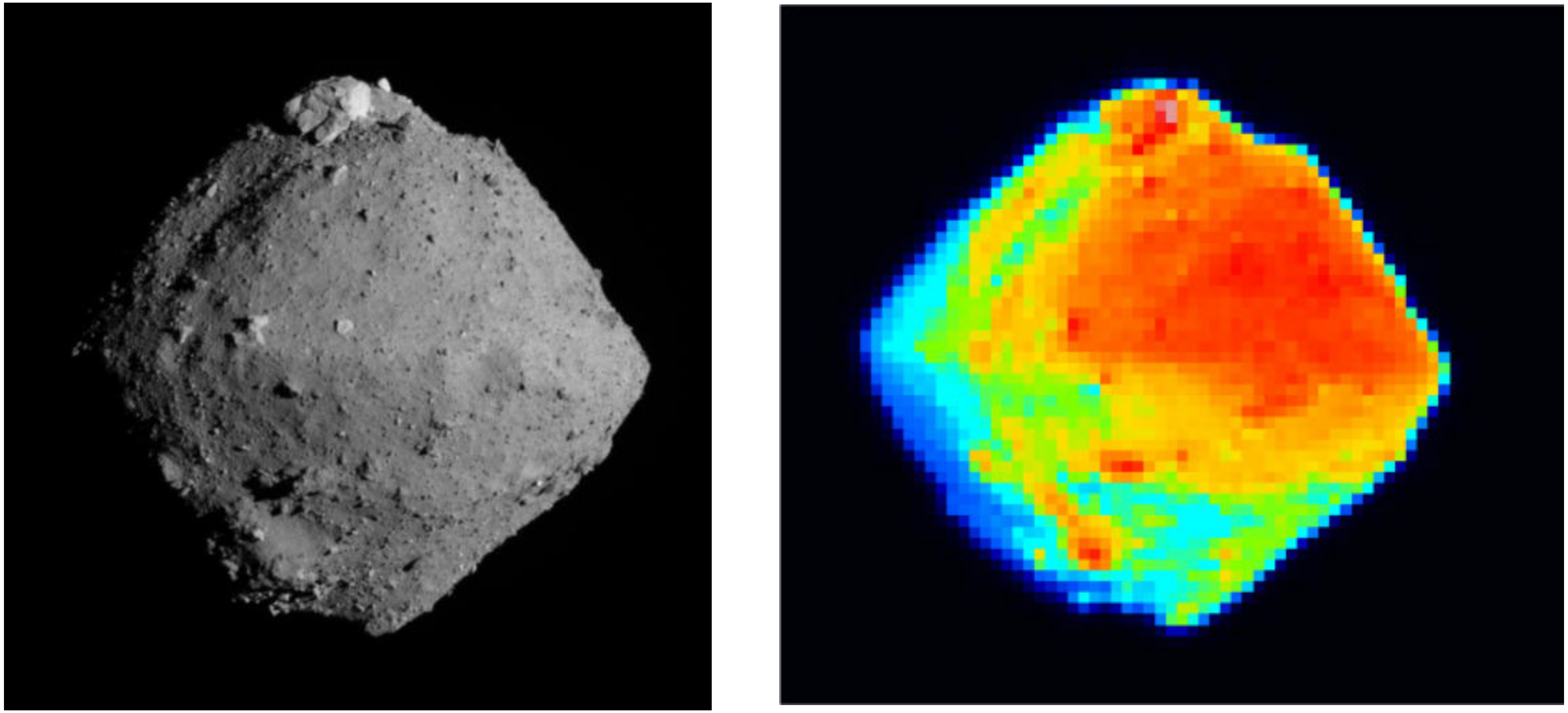


Note: Time indicates the scheduled time, but may change due to conditions during the actual operation.

4. Ryugu Images

New

Image in the evening direction during BOX-B operations



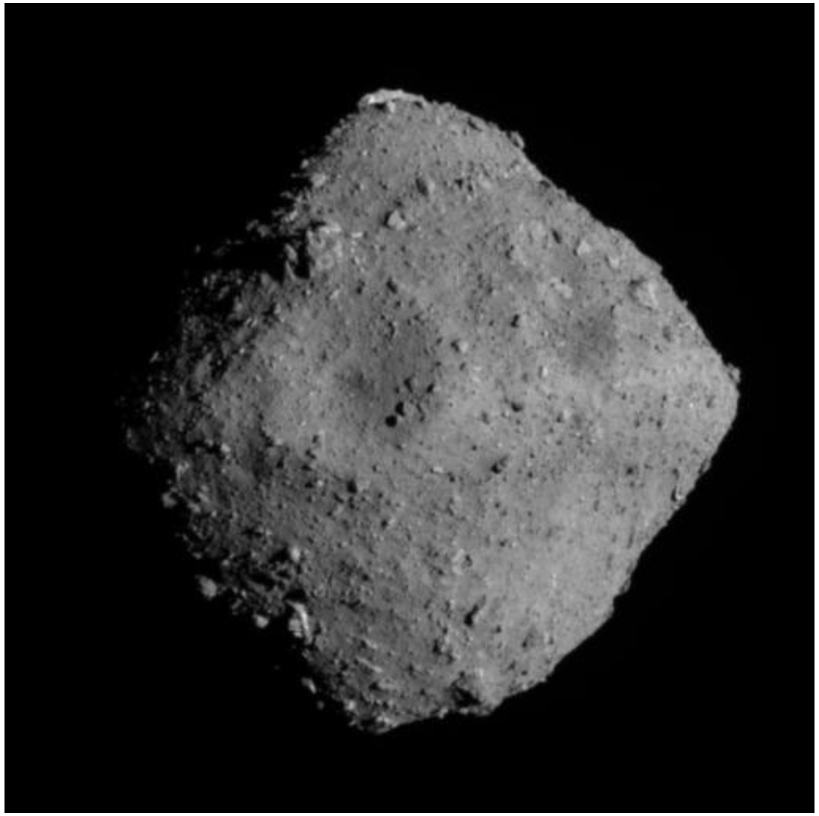
Images taken in the evening direction of Ryugu. Left is the photograph with the Optical Navigation Camera Telescopic (ONC-T) and on the right is the photograph from the Thermal Infrared Imager (TIR). The photographs were taken on August 31, 2018 at around 19:00 JST from a position of around -x = 9km.

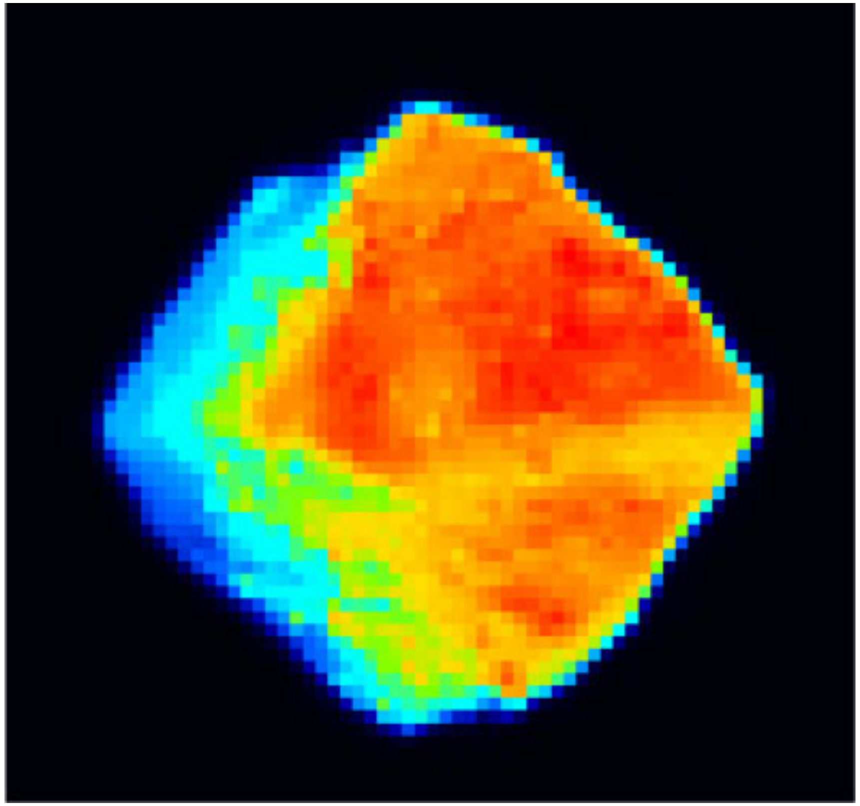
(Left image credit：JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST; Right image credit : JAXA, Ashikaga University, Rikkyo University, Chiba Institute of Technology, University of Aizu, Hokkaido University of Education, Hokkaido Kitami Hokuto High School, AIST, National Institute for Environmental Studies, University of Tokyo, German Aerospace Center (DLR), Max Planck Society for the Advancement of Science, Stirling University.)

4. Ryugu Images

New

Image in the evening direction during BOX-B operations





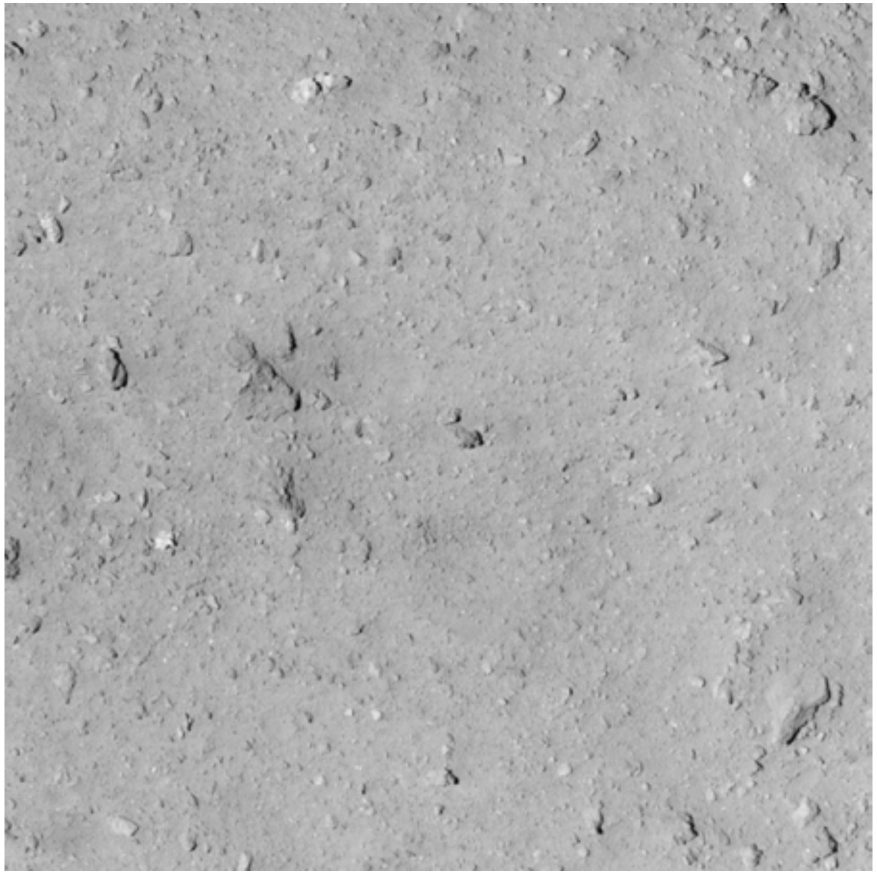
Images taken in the evening direction of Ryugu. Left is the photograph with the Optical Navigation Camera Telescopic (ONC-T) and on the right is the photograph from the Thermal Infrared Imager (TIR). The photographs were taken on August 31, 2018 at around 23:00 JST from a position of around -x = 9km.

(Left image credit：JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST; Right image credit: JAXA, Ashikaga University, Rikkyo University, Chiba Institute of Technology, University of Aizu, Hokkaido University of Education, Hokkaido Kitami Hokuto High School, AIST, National Institute for Environmental Studies, University of Tokyo, German Aerospace Center (DLR), Max Planck Society for the Advancement of Science, Stirling University.)

4. Ryugu Images

New

Images acquired during Touchdown 1 Rehearsal 1



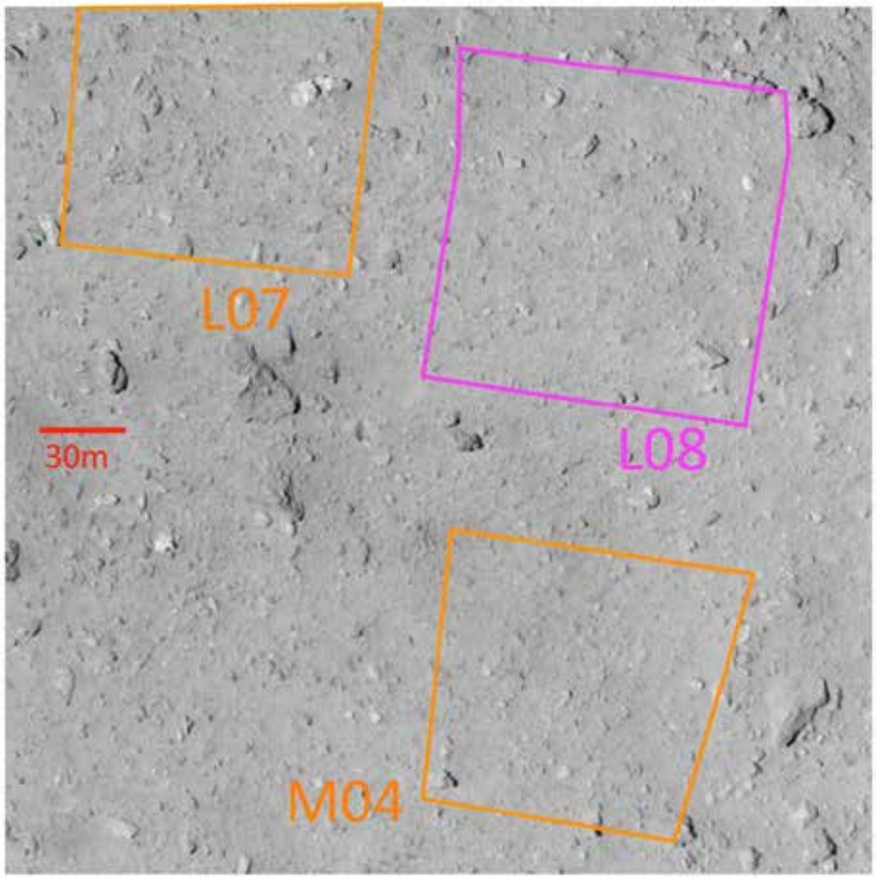


Image of the touchdown candidate sites taken from about 3km above the surface using the Optical Navigation Camera – Telescopic (ONC-T). The image was captured on September 12, 2018 at around 06:00 JST. In the right-hand image, the approximate areas of the touchdown candidate sites are marked out.

(Image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, Aizu University, AIST).

4. Ryugu Images

Image captured by ONC-W1 during the MINERVA-II1 separation operation

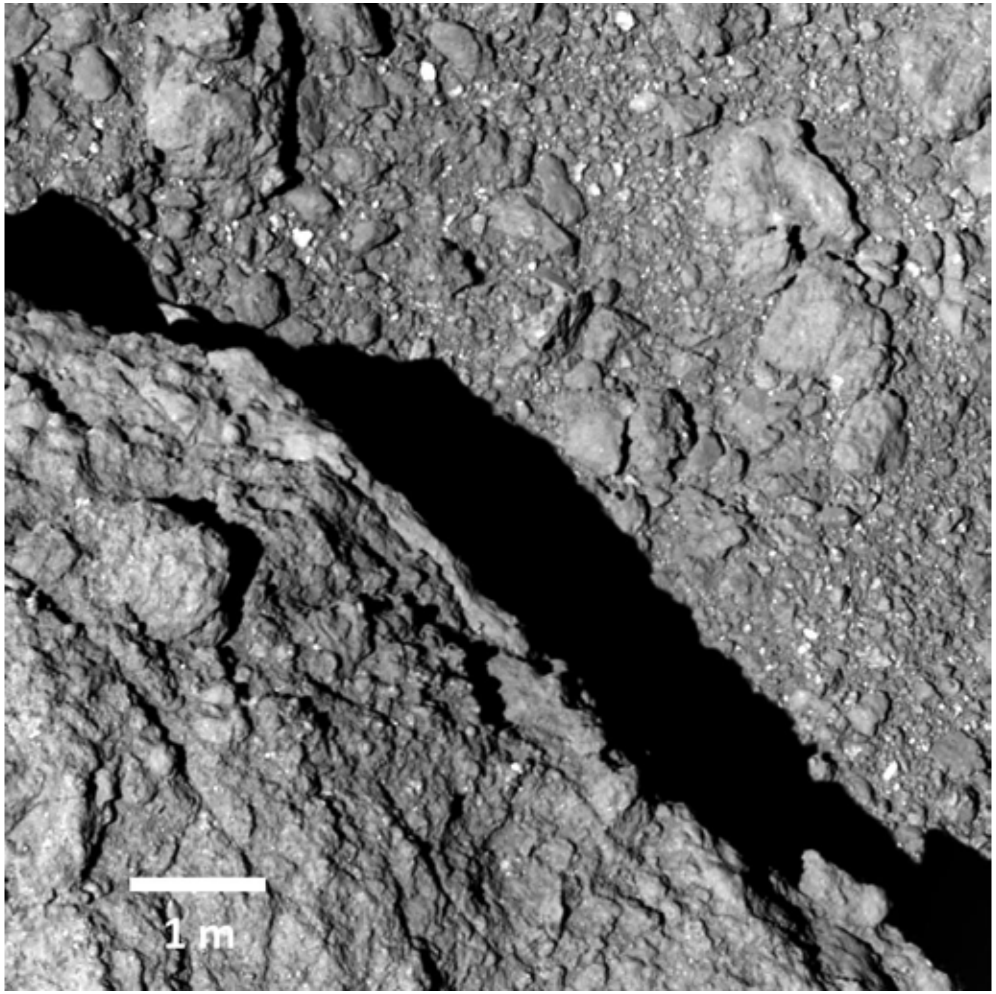
New

Note: This is the first image taken by ONC-W2.

Image of Ryugu captured with the ONC-W2 at an altitude of about 67m. Image was taken on September 21, 2018 at around 13:00 JST. This photograph of the horizon of Ryugu was taken diagonally downwards from where the W2 is installed on the spacecraft.
(Image credit: JAXA, U. Tokyo, Kochi U, Rikkyo U, Nagoya U, Chiba Institute of Tech, Meiji U, U. Aizu, AIST)

4. Ryugu Images

Image captured with ONC-T during the MINERVA-II1 separation operation

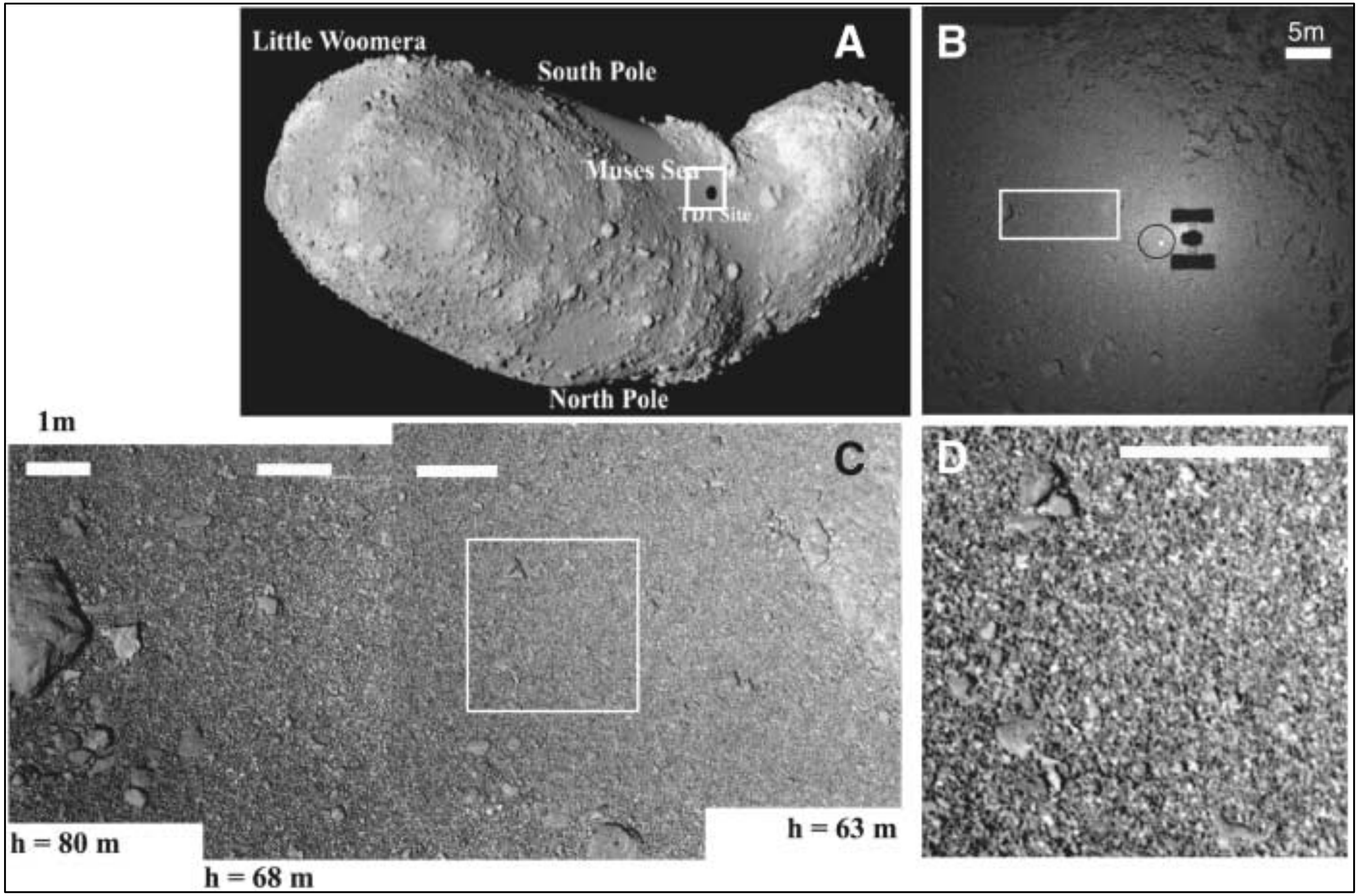


New

Image of Ryugu captured by the ONC-T at an altitude of about 64m. Image was taken on September 21, 2018 at around 13:04 JST.This is the highest resolution photograph obtained of the surface of Ryugu. Bottom left is a large boulder.

（Image credit: JAXA, U. Tokyo, Kochi U, Rikkyo U, Nagoya U, Chiba Institute of Tech, Meiji U, U. Aizu, AIST.）

Note：Highest resolution photograph obtained by Hayabusa



High resolution image of the surface of asteroid Itokawa photographed by Hayabusa. "D" is taken from an altitude of 63m. It is thought that the so-called "Muses Sea" (official name "MUSES-C Regio") is covered with a "gravel" of granules with diameters from a few mm to few cm. (From Yano et al, Science Vol 312 2, June 2006)

5. Other issues

■ On the “Imagining Ryugu” contest

▪Hayabusa2 Project nodes (organizations and institutes that gathered entries) must now each nominate works.

▪Final judgement will be at the end of the year.

6. Future Plans

■Operation schedule

- September 30 – October 4 ：MASCOT release operation (including preparatory period)

  MASCOT separation scheduled for October 3 at around 11:00 JST.
- Mid-October：Touchdown 1 Rehearsal 2
- Late October：Touchdown 1

■Press briefings and media events

- October 3（Wednesday） 9:30～18:30 Open press center@Sagamihara

  15:00～16:00 Press briefing

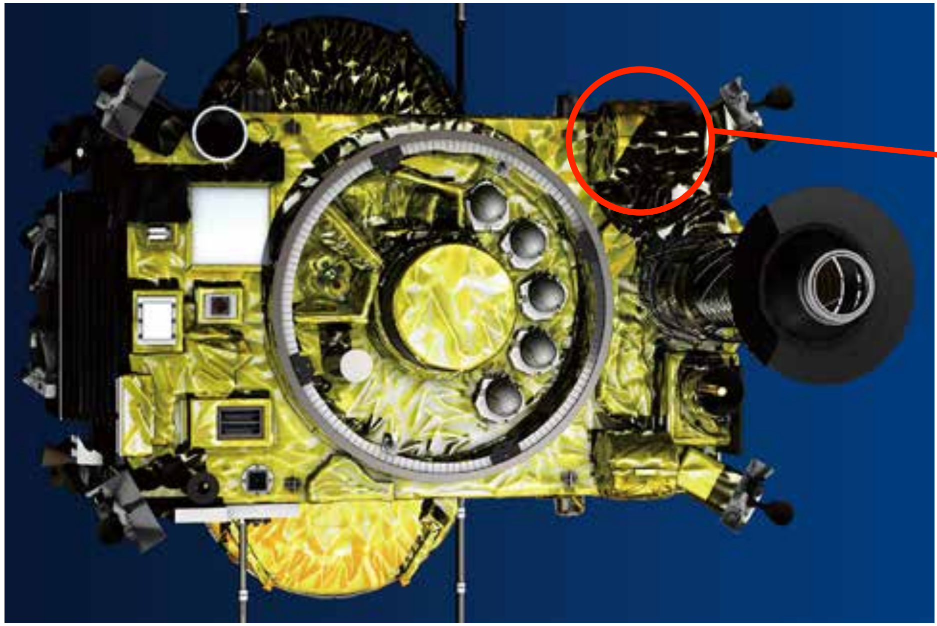
  17:00～18:00 MASCOT press conference transmission
- October 11（Thursday） 15:30～16:30 Press conf.＠Ochanomizu

Note: Time is in JST.

Reference

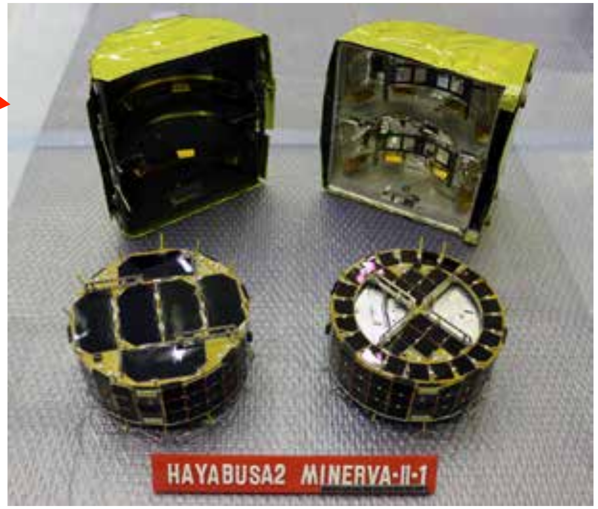
MINERVA-II1

MINERVA-II is the successor of MINERVA installed on the Hayabusa spacecraft.



(©JAXA)

MINERVA-II1 (Rover-1A, Rover-1B)



Produced at JAXA

< Collaborating manufacturers, universities and related organizations>

Aichi University of Technology, University of Aizu, Addnics corp., Antenna Giken Co., Ltd., ELNA , CesiaTechno, The University of Tokyo, Tokyo Denki University、Digital Spice Corp., Nittoh Inc., Maxon Japan, DLR, ZARM

- Weight (including deployment)

MIMERVA-II1 :2.5kg

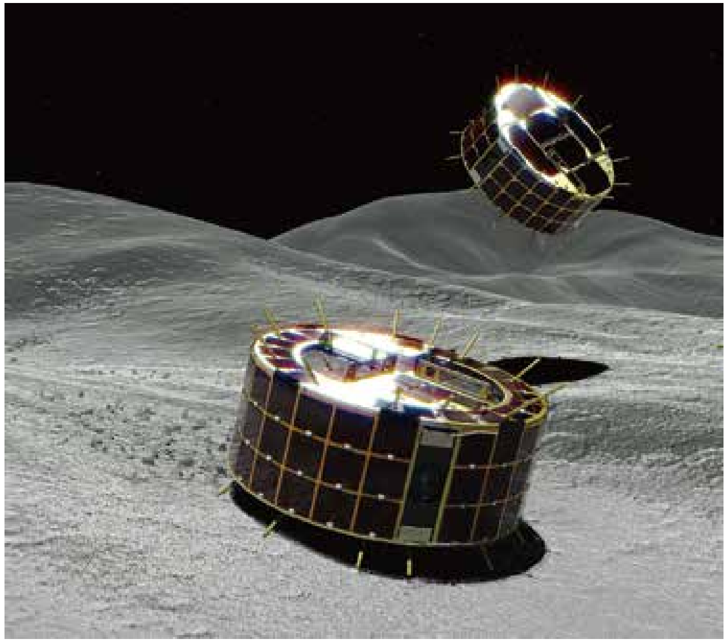
- MINERVA-II1

Twin rovers

MINERVA-II1

MIcro Nano Experimental Robot Vehicle for Asteroid, the Second Generation

- New hopping mobility
- Adaptation with AI
- Small, light-weight,
- Low power consumption
- Autonomous behavior
- Scientific observation （stereo sensing, thermometer)



(©JAXA)

MINERVA-II1

Specifications of Rover-1A, -1B

body size	Cylinder (hexadecagonal pole) Diameter: f180[mm] Height: 70[mm]
weight	1A:1151[g], 1B:1129[g]
actuators	DC motor
sensors	4 cameras(1A), 3 cameras(1B) photodiodes, accelerometer thermometers, gyro
com.	32k[bps](max)

Selection of landing site candidates for MINERVA-Ⅱ

Conditions for MINERVA-II landing site selection：

- □ Landing site does not overlap with spacecraft touchdown candidates.
- □ Landing site does not overlap with MASCOT landing site candidates.
- □ The altitude of the spacecraft after separation must not be lower than 30m.
- □ Ensure communication with ground station.
- ■ Ensure communication with Hayabusa2 spacecraft.
- ■ Not high temperature region, and fewer parts in shadow

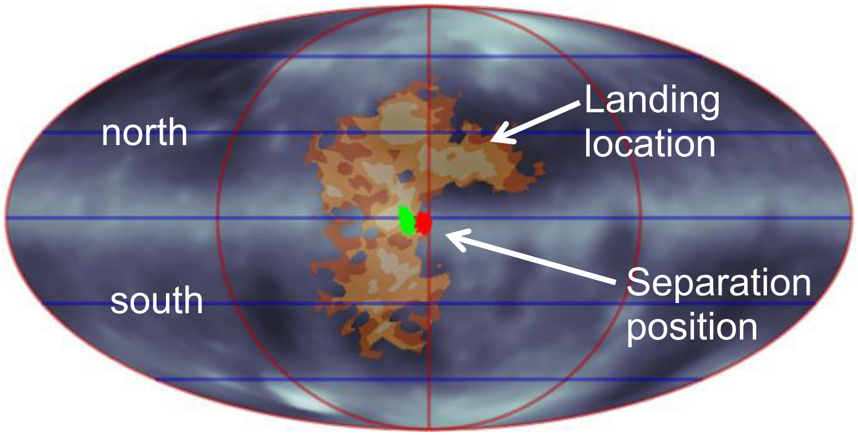
⇩

・Due to the equatorial ridge, separation near the equator results in widely spaced landing points to the north and south.

・Separating in the southern hemisphere may result in a spacecraft altitude below 30m.

⇩

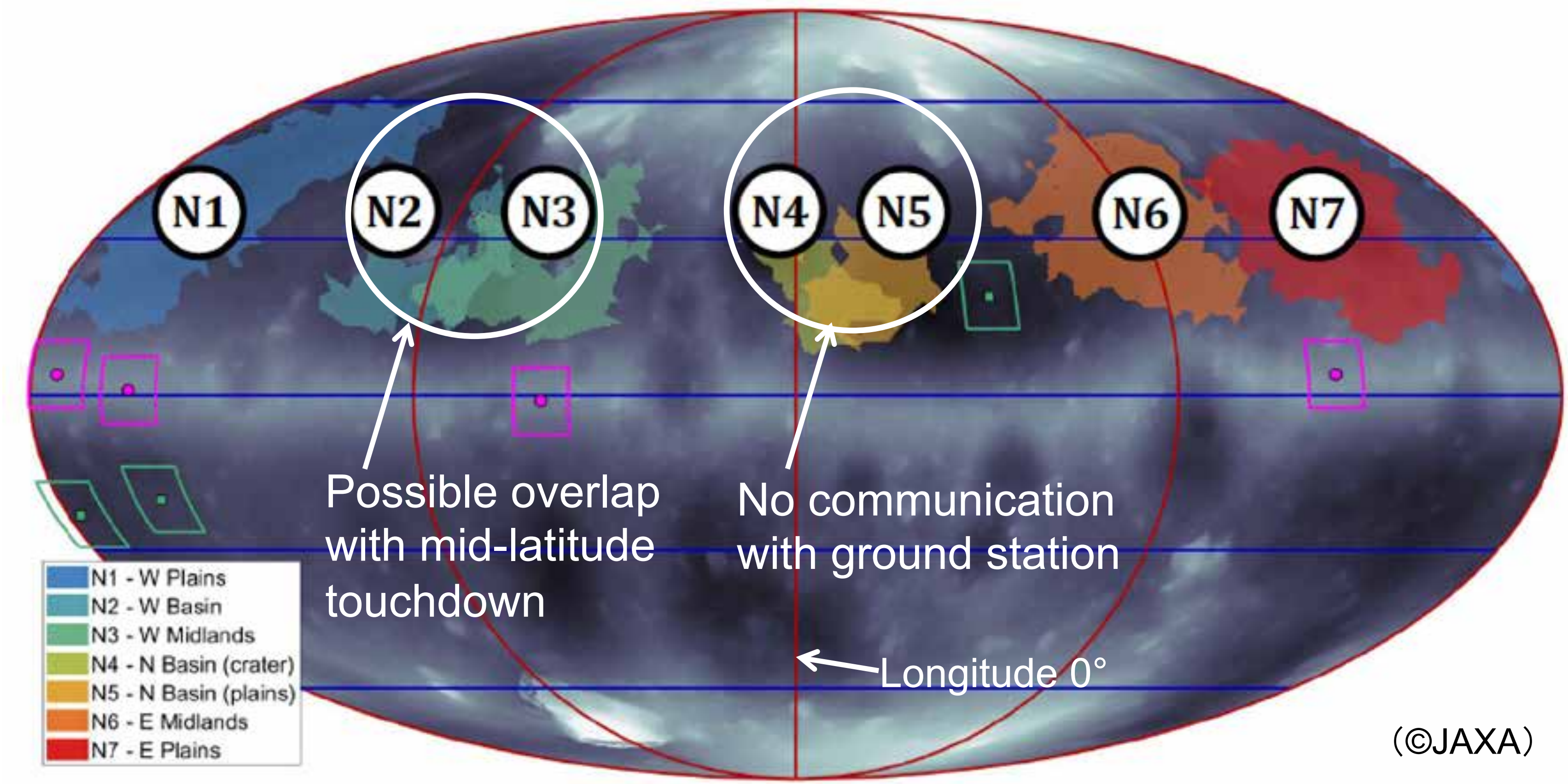
・Separate in northern hemisphere, more than 100m north of the equator.



(©JAXA) When separating near the equator, the landing position spread north and south.

Selection of landing site candidates for MINERVA-Ⅱ

Landing site candidates for MINERVA-II: northern hemisphere

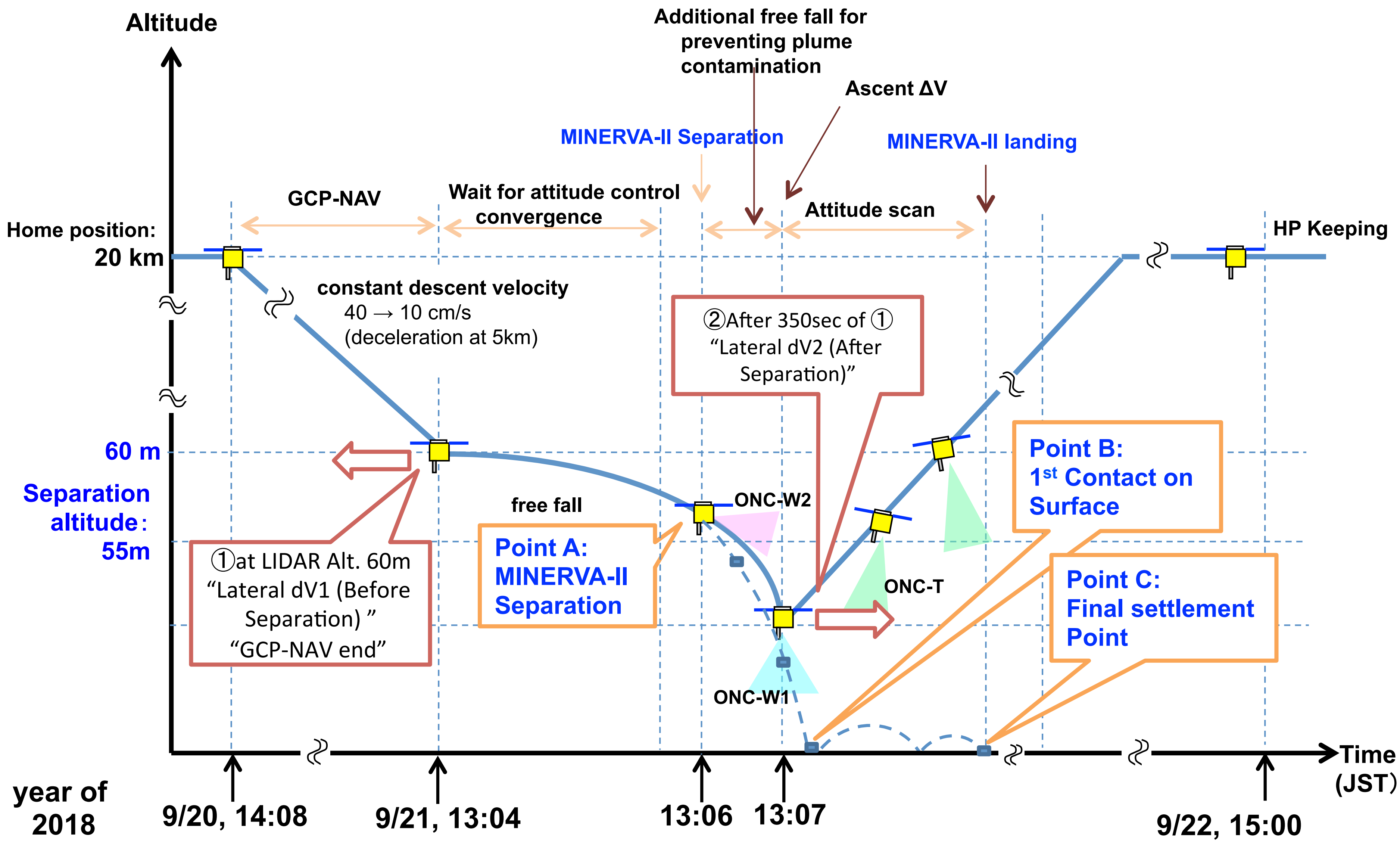


- Touchdown・confirm no overlap with MASCOT's landing site.
- Also consider observability etc. using the ONC-T camera.

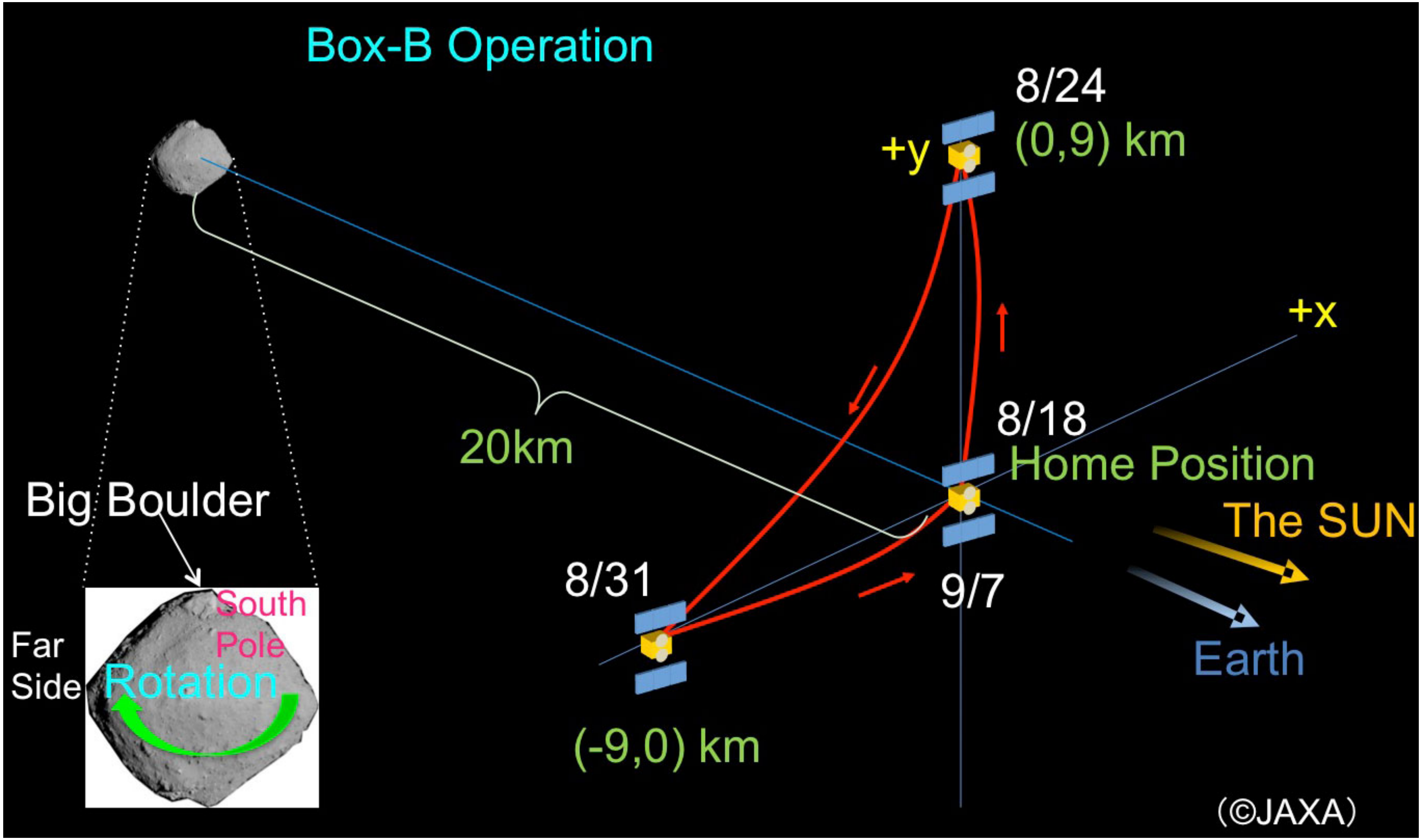
Candidate locations：
N6 > N1 > N7

MINERVA-II1

MINERVA-Ⅱ1 schematic showing the deployment operation sequence



BOX-B Operation



BOX-B operation images

Image of the south pole

Published

（but south pole is now at the image top）

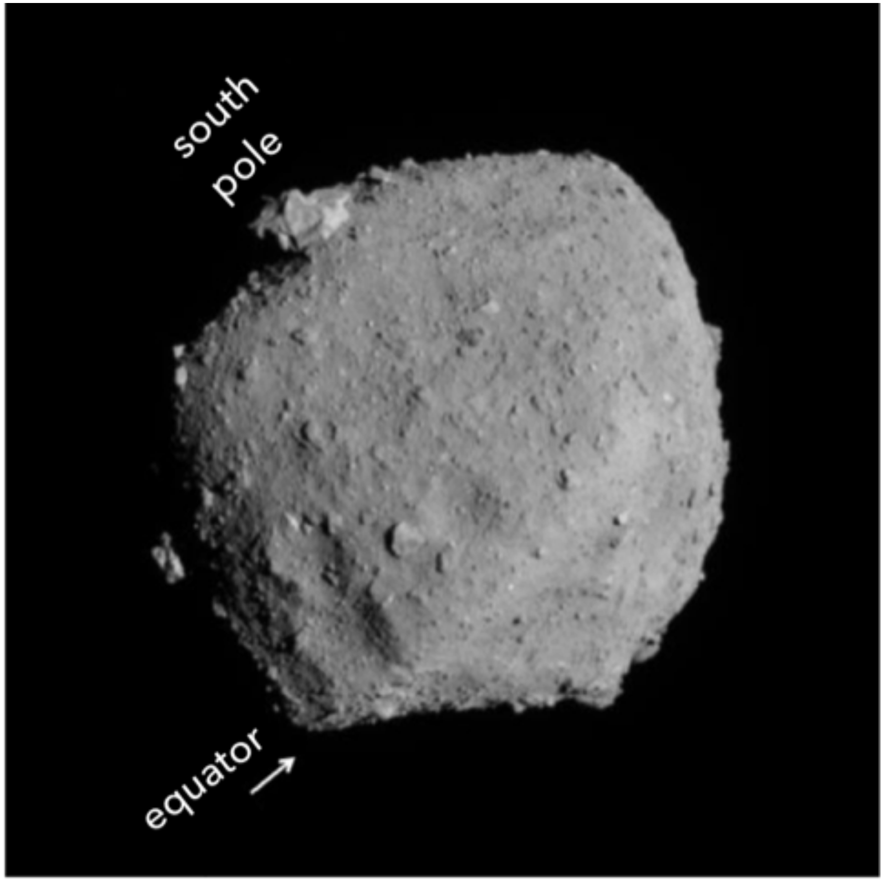


Image of Ryugu towards the asteroid’s south pole. Photograph taken with the Optical Navigation Camera Telescopic (ONC-T) on August 24, 2018 at around 17:00 JST. The image was captured from a position of around +y = 9 km. The distance to Ryugu was about 22 km.
(Image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

Touchdown 1 Rehearsal 1

TD1-R1 operation overview (Time is JST)

September 11, 2018

15:27　Start descent from home position (altitude 20km), descent speed 0.4m/s
20:20　Altitude approximately 10km

September 12

02:05　Descent slowed to 0.1m/s
10:40　Altitude approximately 1.5km
12:57　Descent cancelled at an altitude of about 600m※、began rising at 0.5m/s
16:30　Acceleration for return to home position

September 13

15:00　Return to home position

※ An automatic change was planned from the LIDAR long-distance mode to the short-distance mode. However, it was impossible to reach the required light intensity needed for the switch as the reflected light for distance measurement was too weak. The altitude measurement therefore became impossible and the spacecraft autonomously ceased descent and began to rise.