Operation status of the asteroid explorer, Hayabusa2

November 8, 2018

JAXA Hayabusa2 Project

Agenda

Regarding Hayabusa2、

- ▪Report on TD1-R3 operation
- ▪Report on BOX-C operation
- ▪Description of conjunction operations
- ▪Other topics (incl. DPS, Ryugu model)

Explanation of the Rover2 (MINERVA-II2) from Tohoku University, the representative of the university consortium.

Contents

TD1-R3 : Touchdown 1 Rehearsal 3 (equivalent to the third rehearsal)
BOX-C operation: operation to descend by hovering from the home position (about 20km altitude)
DPS: Division for Planetary Sciences of the American Astronomical Society (one of the world's largest meetings on planetary science)

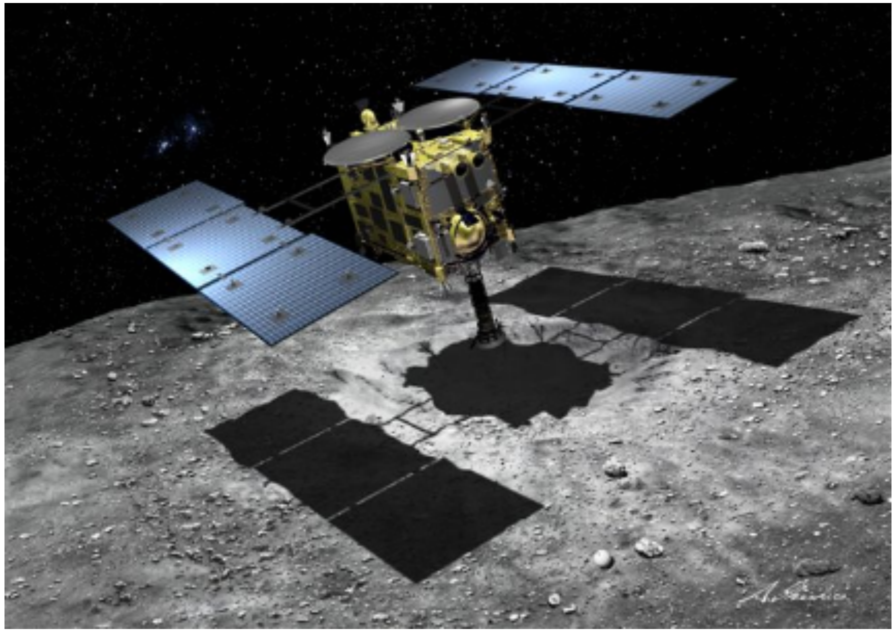
Overview of Hayabusa2

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

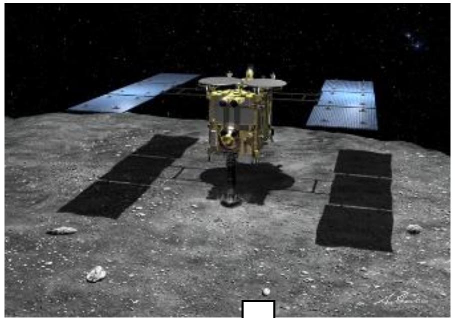
Primary instruments
Sampling mechanism, re-entry capsule, optical cameras, laser range-finder, scientific observation equipment (near-infrared, thermal infrared), impactor, miniature rovers.

Mission Flow

Launch
3 Dec 2014

Earth swing-by
3 Dec 2015

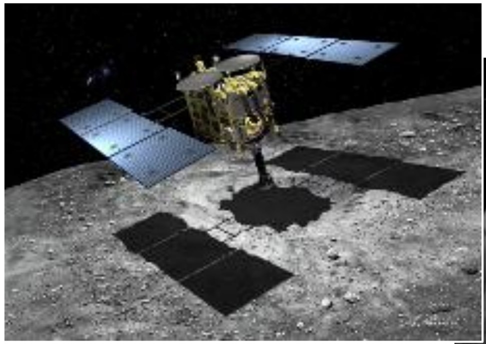
Arrival at asteroid
June 27, 2018



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)

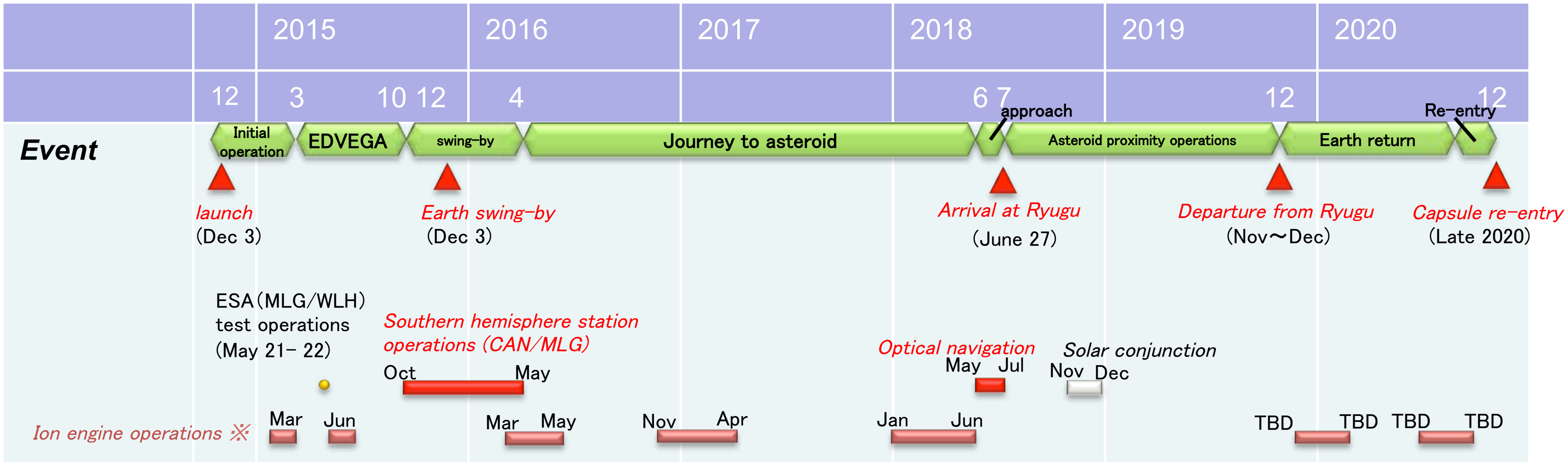
1. Current project status & schedule overview

Current status :

– Third rehearsal for touchdown, TD1-R3, was performed between October 23 – 25. On October 25, a target marker was deployed at an altitude of about 13m, Hayabusa2 descended to about 12m and the tracking of the target marker was confirmed.

– BOX-C operation was carried out between October 27 – November 5, with the spacecraft descending to an altitude of about 2.2km on November 1. Imaging the target marker was attempted successfully.

Schedule overview:



2. TD1-R3 operation report

Purpose

Operations to confirm the accuracy of the navigation guidance control at low altitude:

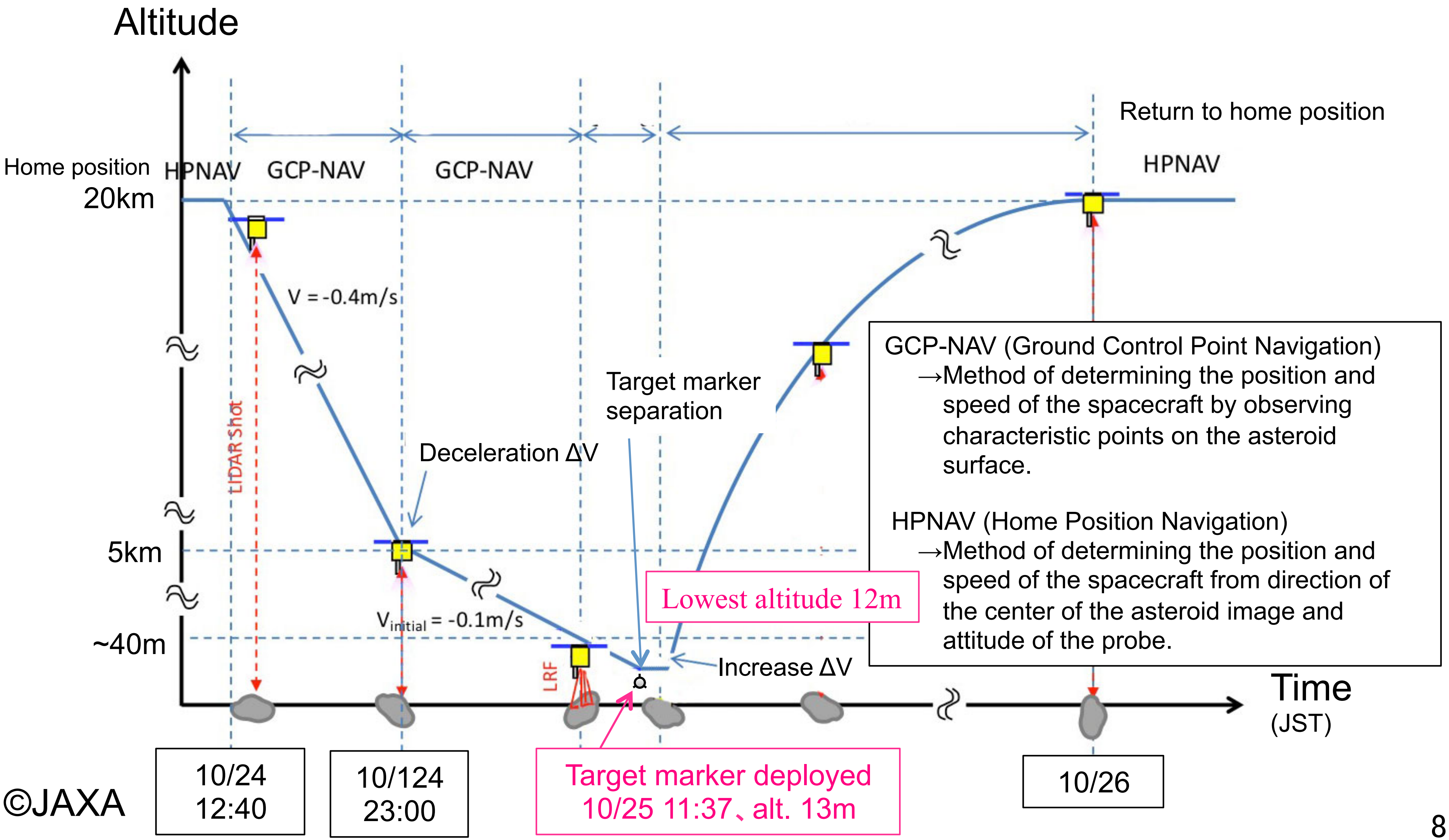
- Feedback the measured value from the LRF (Laser Range Finder) to control the spacecraft.
- If the conditions are satisfied, deploy a target marker.
- Track detached target marker.

Result

- Altitude reduced to 12m: accuracy of navigation guidance: 15.4 m.（The distances from the center of L08-B to the target marker）
- Successful control of six degrees of freedom by the LRF（Laser Range Finder).
- Successful target marker separation and tracking.

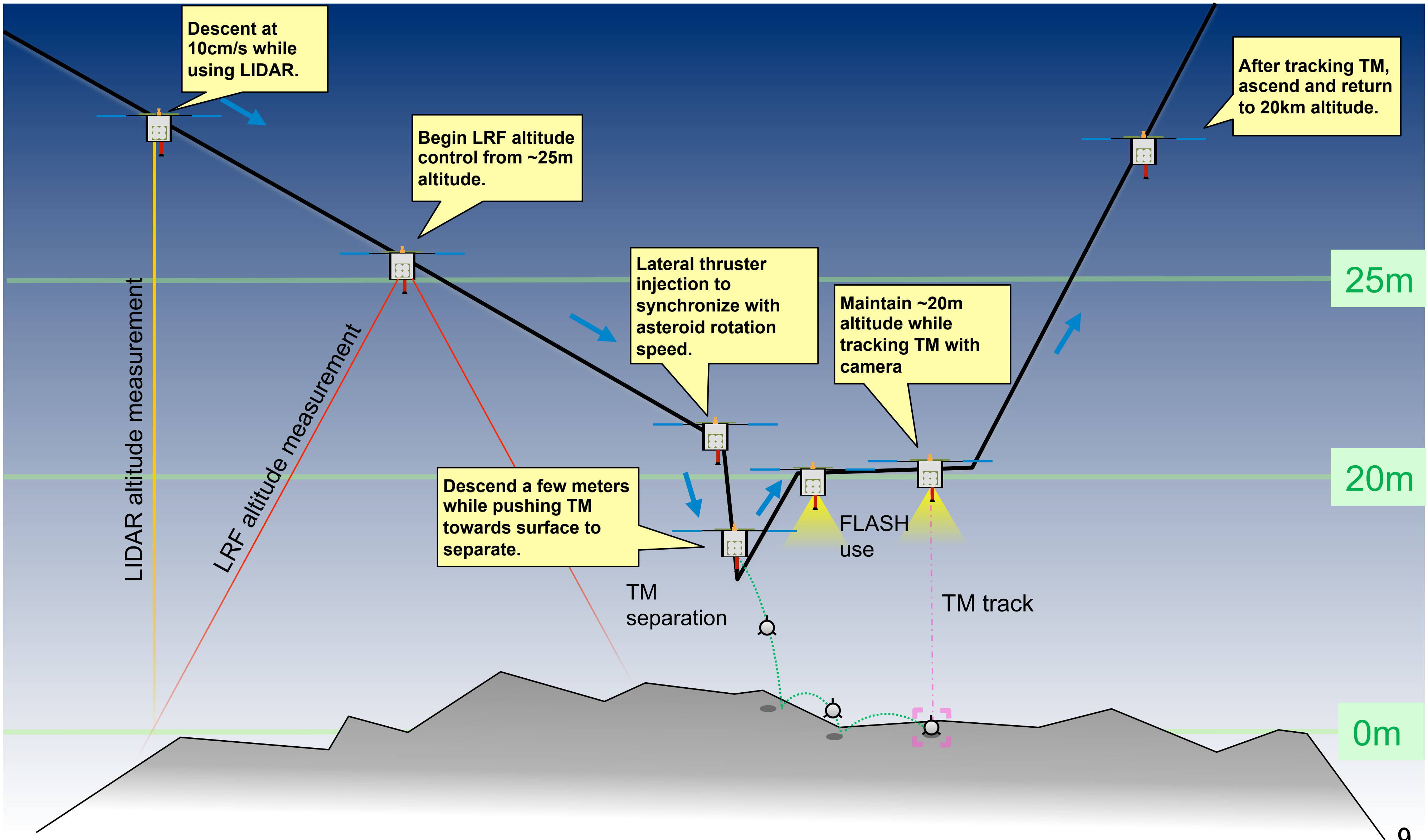
2. TD1-R3 operation report

TD1-R3 schedule



2. TD1-R3 operation report

TD1-R3 low altitude sequence



2. TD1-R3 operation report

The target marker resting on the surface of Ryugu

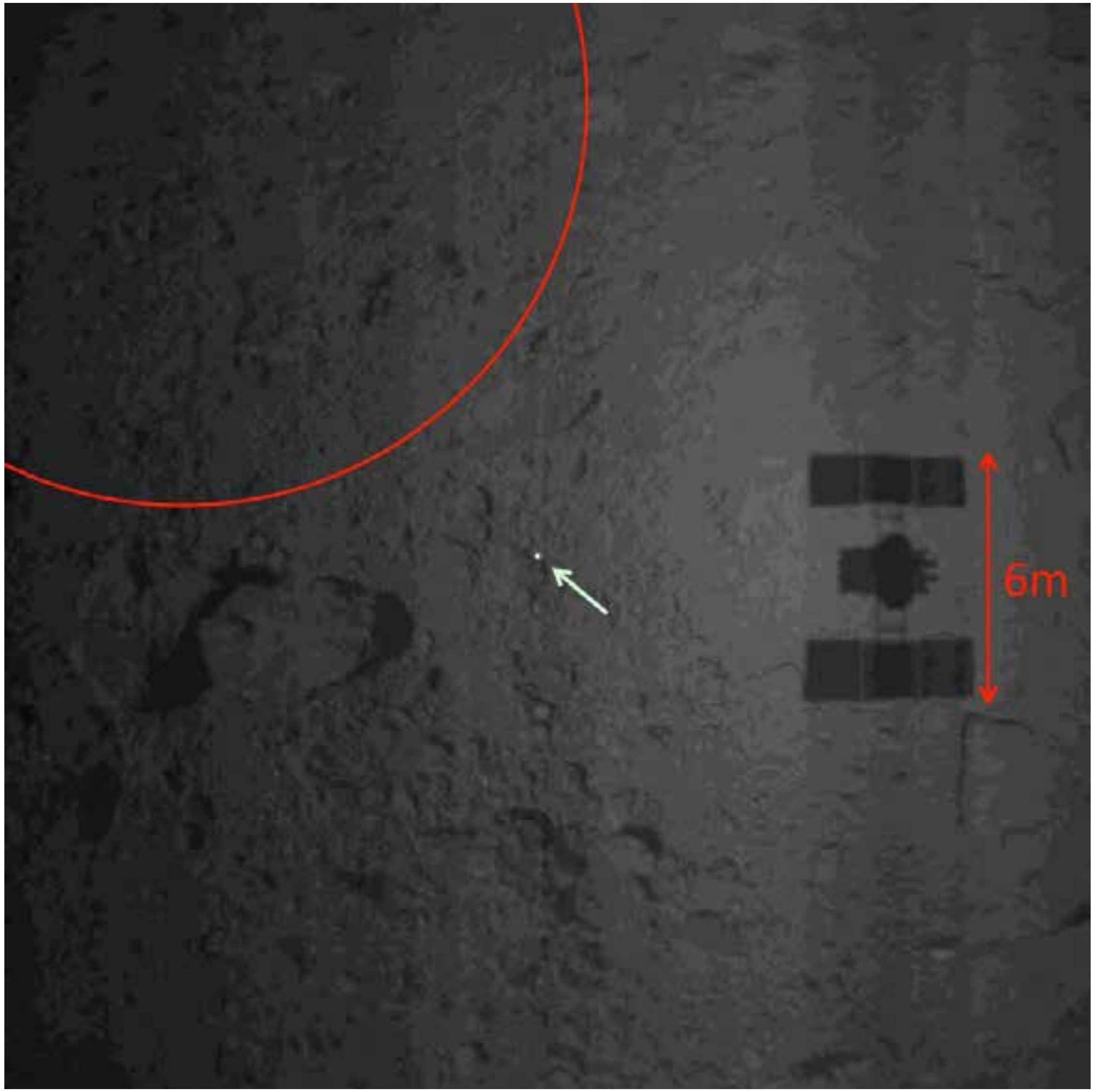


Image of the surface of Ryugu photographed by the Optical Navigation Camera – Wide angle (ONC-W1) during TD1-R3.
This image was captured after the target marker landed on the surface of Ryugu. The white point at the arrow tip is the target marker and the red circle indicates the touchdown candidate region L08-B (diameter about 20m).

Image date: October 25 at 11:47 JST.
Image altitude: approx. 20m
（Image credit：JAXA）

2. TD1-R3 operation report

Image of the target marker descending (captured with the ONC-W1)

New

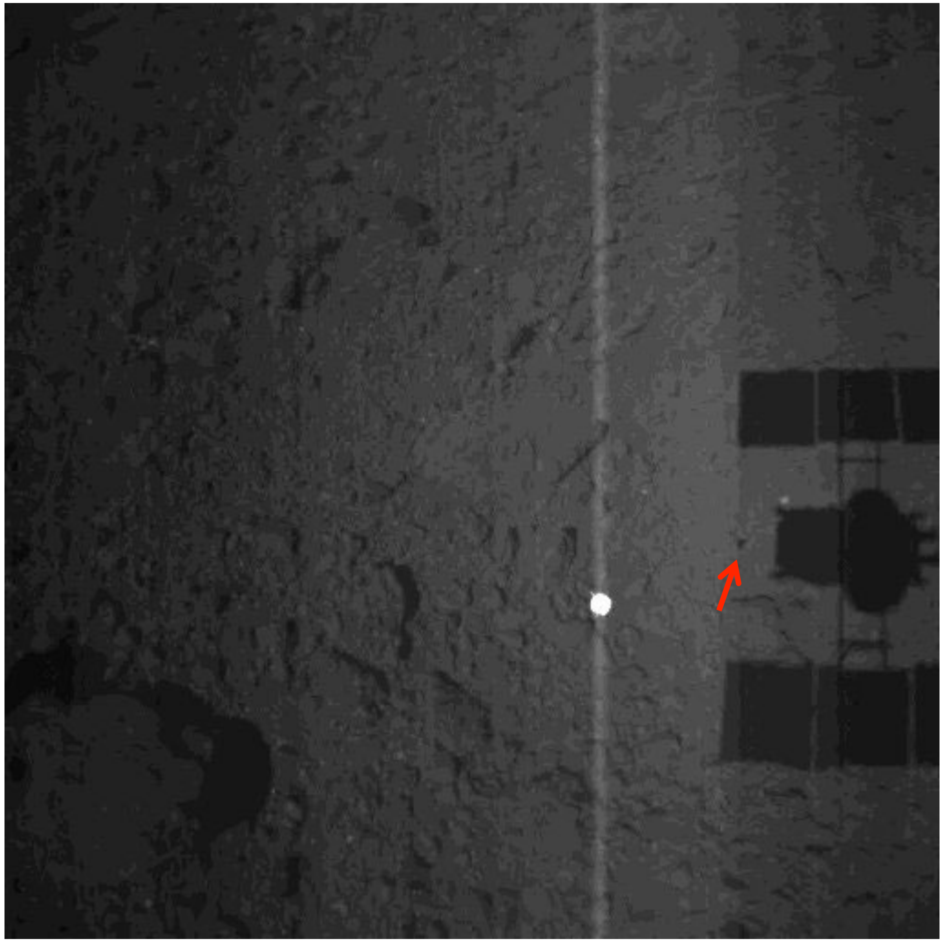


Image date: October 25 at 11:38 JST.
Image altitude：approx. 12m
（The black dot at the arrow tip is the shadow of the target marker)

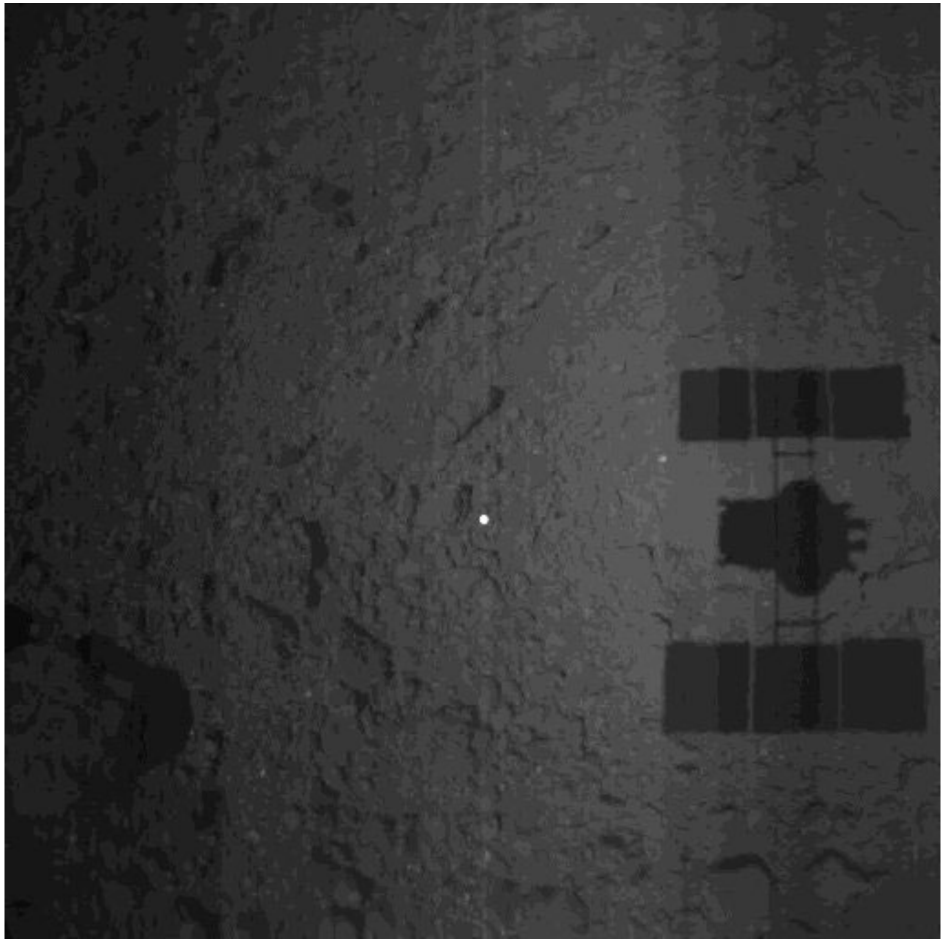


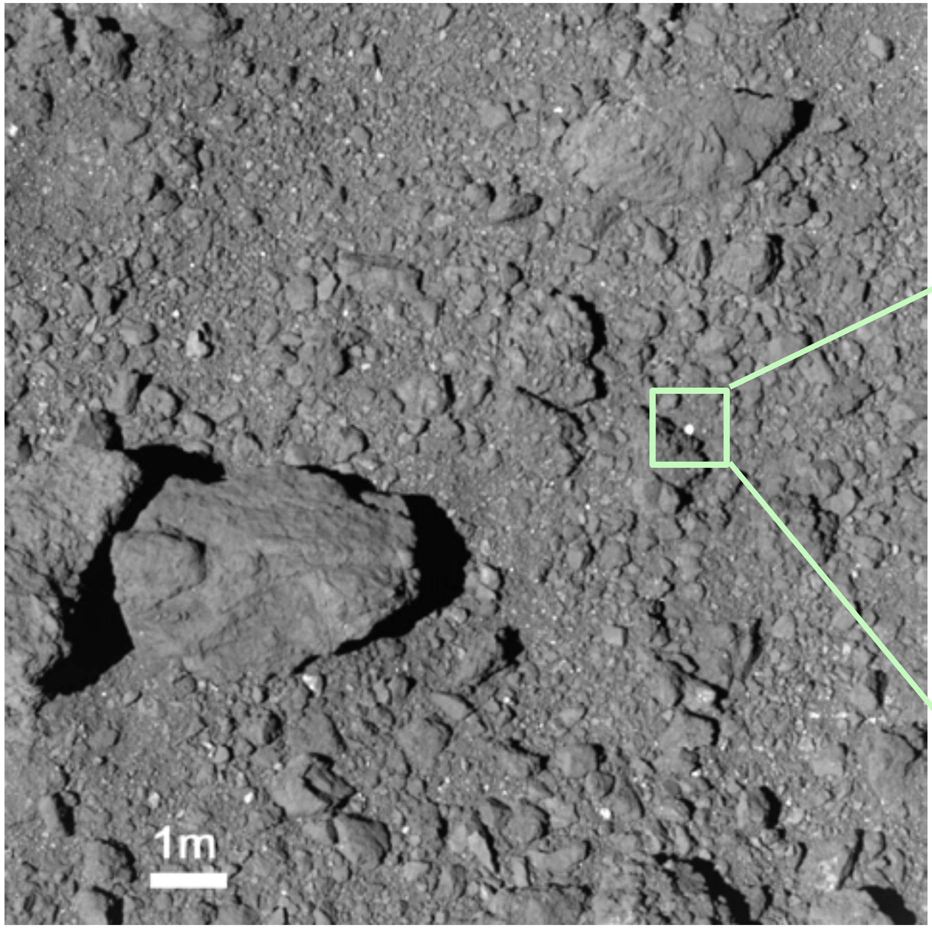
Image data: October 25 at 11:39 JST
Image altitude： approx12m

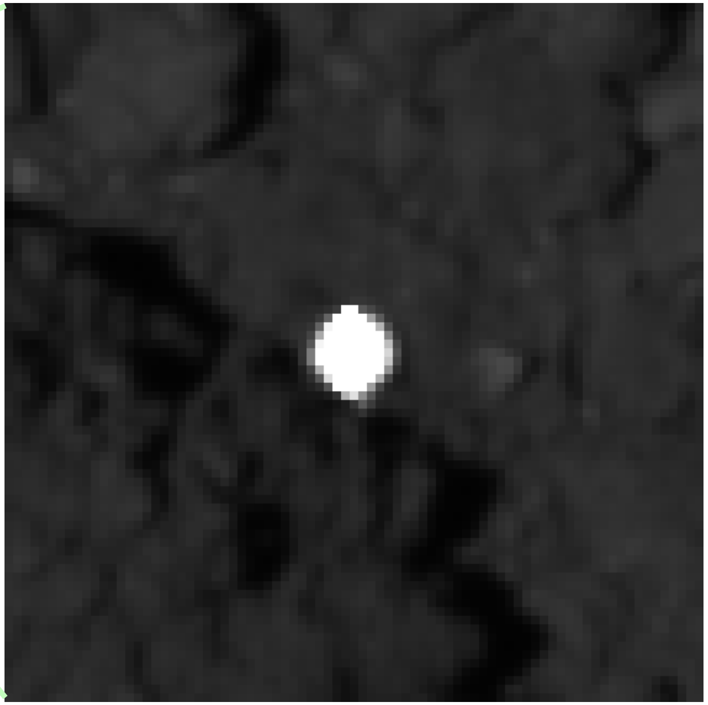
（Image credit：JAXA）

2. TD1-R3 operation report

Imaging the area around the target marker with the ONC-T

New



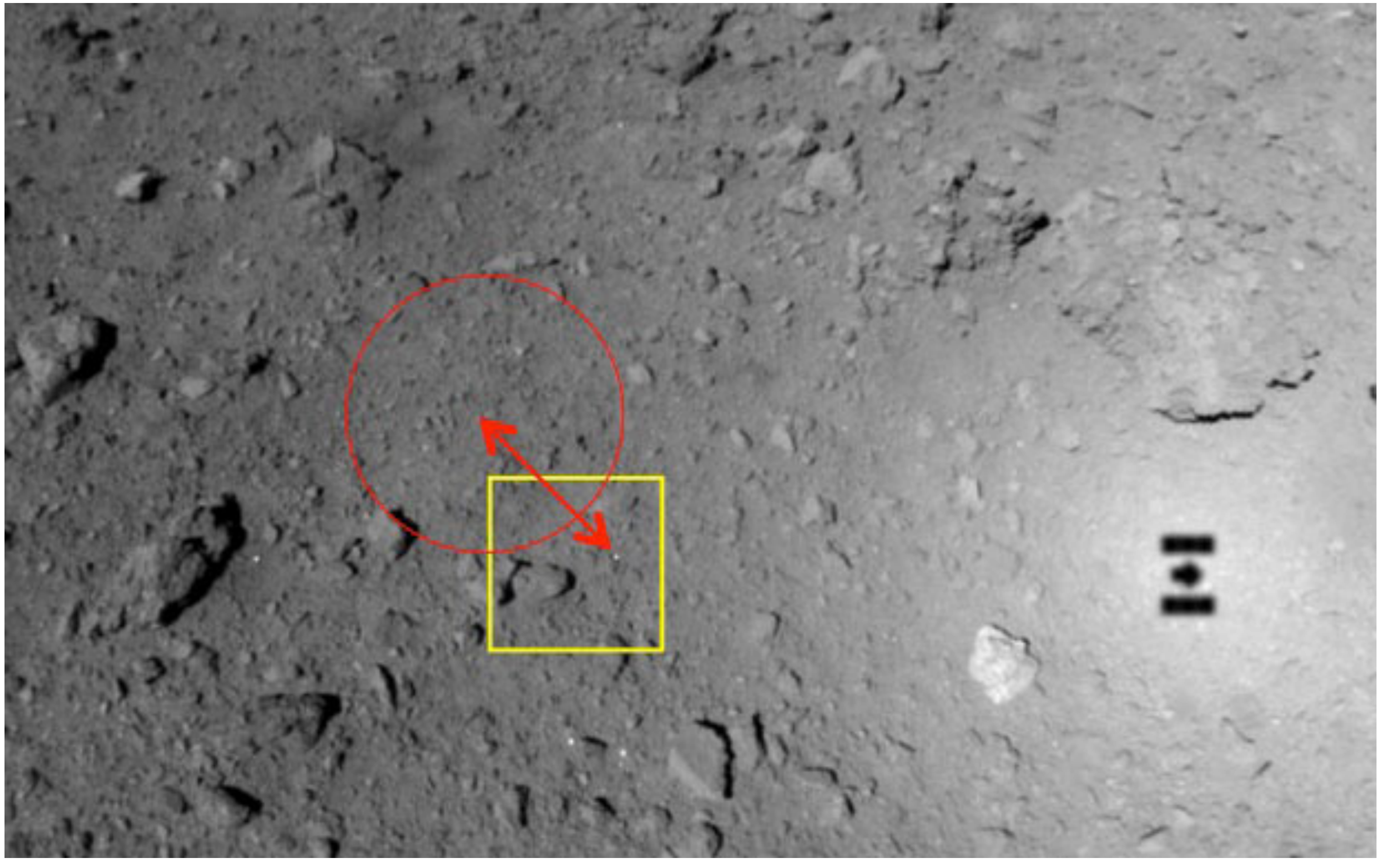


Region around the target marker captured by the Optical Navigation Camera – Telescopic (ONC-T). Image taken at an altitude around 100m on October 25, 2018 at about 11:50 JST.

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

2. TD1-R3 operation report

Imaging the area around the target marker with the ONC-W1



New

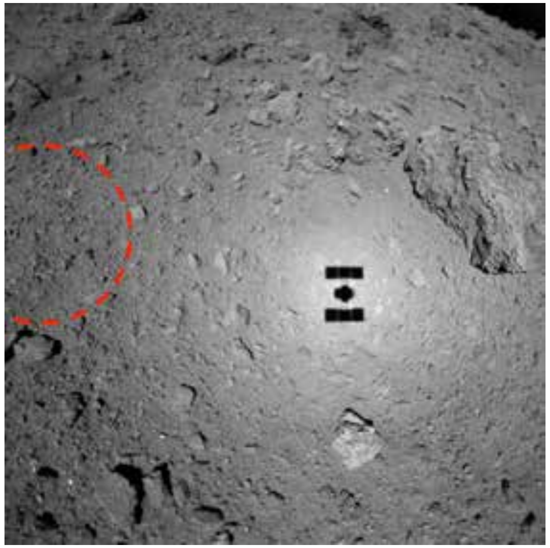
Area around the target marker captured with the Optical Navigation Camera – Wide angle (ONC-W1) from an altitude of around 100m on October 25, 2018 at about 11:50 JST. The yellow square indicates the region captured by the Optical Navigation Camera – Telescopic (ONC-T) on the previous slide, and the red circle is the area of L08-B. The distance from the center of L08-B to the target marker (length of arrow) is 15.4m.

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

2. TD1-R3 operation report

Reference：Similar to the L08-B area（taken during TD1-R1-A）

（movie）



↑ image with the Optical Navigation Camera-Wide angle (ONC-W1) at an altitude of about 47m. Time: October 15, 2018 at 22:45 JST

→ Sequential images of Ryugu imaged by the Optical Navigation Camera–Wide angle (ONC–W1). Image time October 15, 2018, 22:08 – 22:53 JST. The altitude in the first image is about 240m, lowest altitude is about 47m at 22:45 and final altitude is about 370,

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

2. TD1-R3 operation report

Let’s meet with the Le Petit Prince! Million Campaign 2

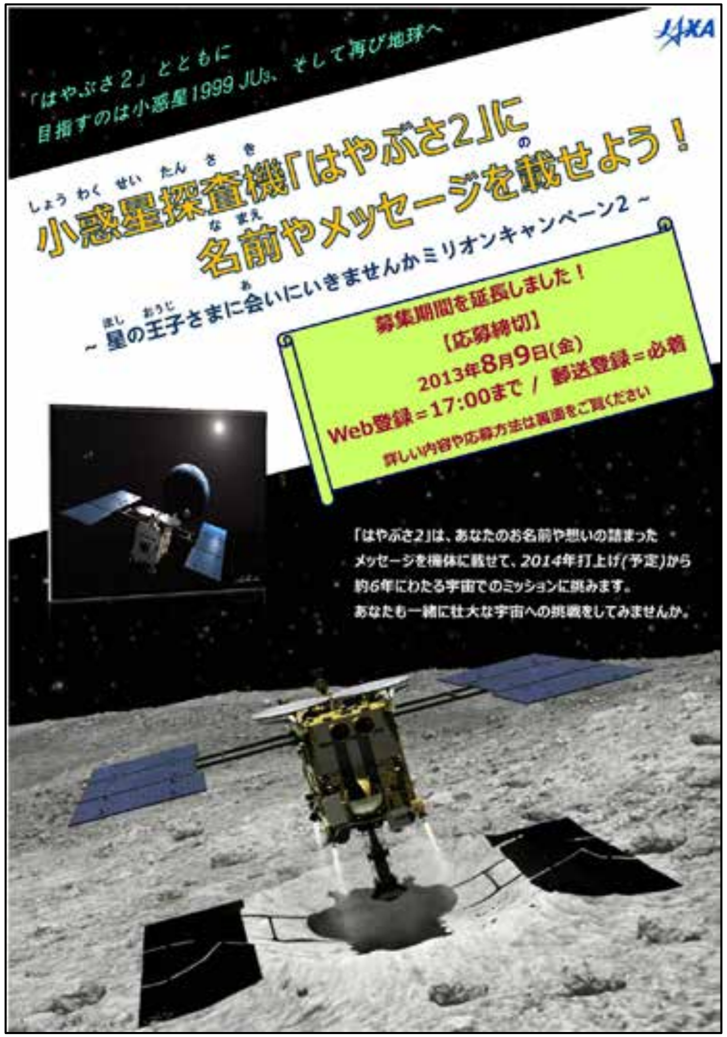
About the campaign:

Period : April 10, 2013 – August 9, 2013

Contents :

1. A sheet of names was placed within the target marker.
2. Names, messages, illustrations and photos were put on a memory chip within the re-entry capsule.

	Registration number	Breakdown by region	
		Japan	Other countries
Target marker	183,174	123,661	59,513
Re-entry capsule	226,800	170,279	56,521
Total	**409,974**	293,940	116,034



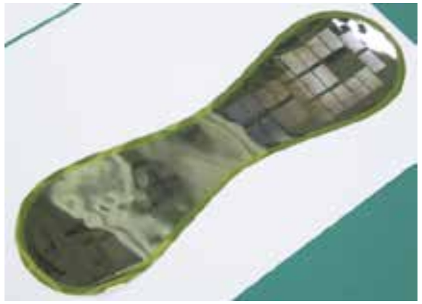
About 180,000 names were delivered to Ryugu

(Image credit JAXA)

2. TD1-R3 operation report

Process of mounting the name sheet within a target marker

①



The entered names are printed on film. The names are divided between two films of the same shape.

②

The films are wrapped around the ball-shaped core of the target marker.

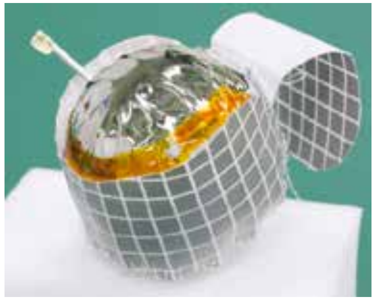
③

After wrapping the core in the two pieces of film, they are sealed with tape like the seams of a baseball.

④

The outer part of the target marker is a sheet of material that can reflect a flash.

⑤



The target marker is placed within the reflective sheet and sewn with yarn so there are no gaps.

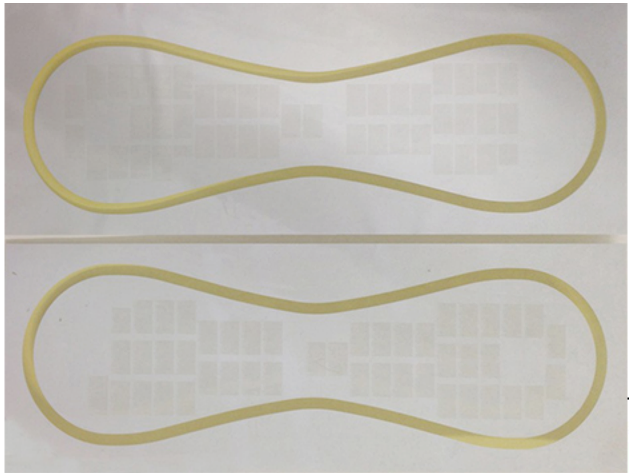
⑥

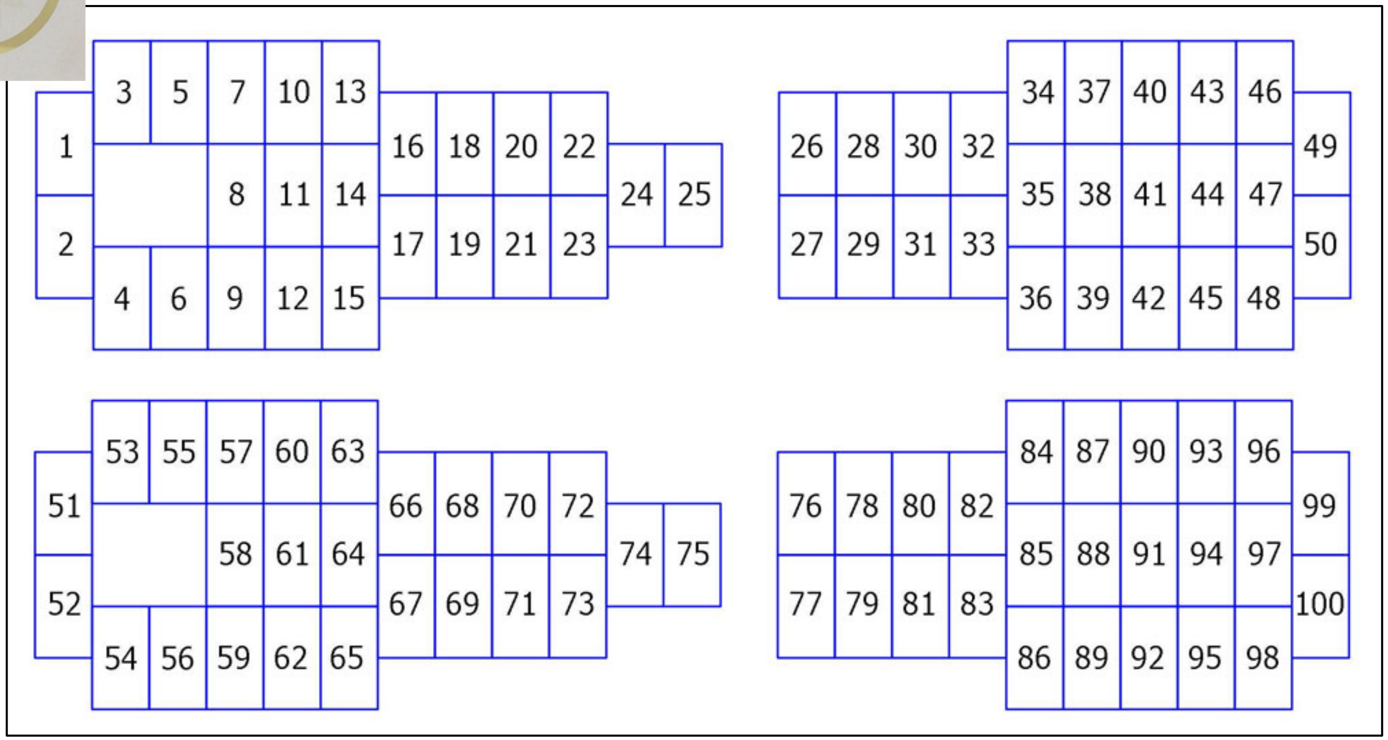
The finished product!
Hayabusa2 carries five target markers. All the names are printed inside each target marker in the same way.

(Image credit：JAXA、Assistance with photography：NEC)

2. TD1-R3 operation report

Name sheet within the target marker





（Image credit：JAXA）

2. TD1-R3 operation report

You can find the position of your name at:
https://www.haya2-campaign.jp/

Campaign entry page

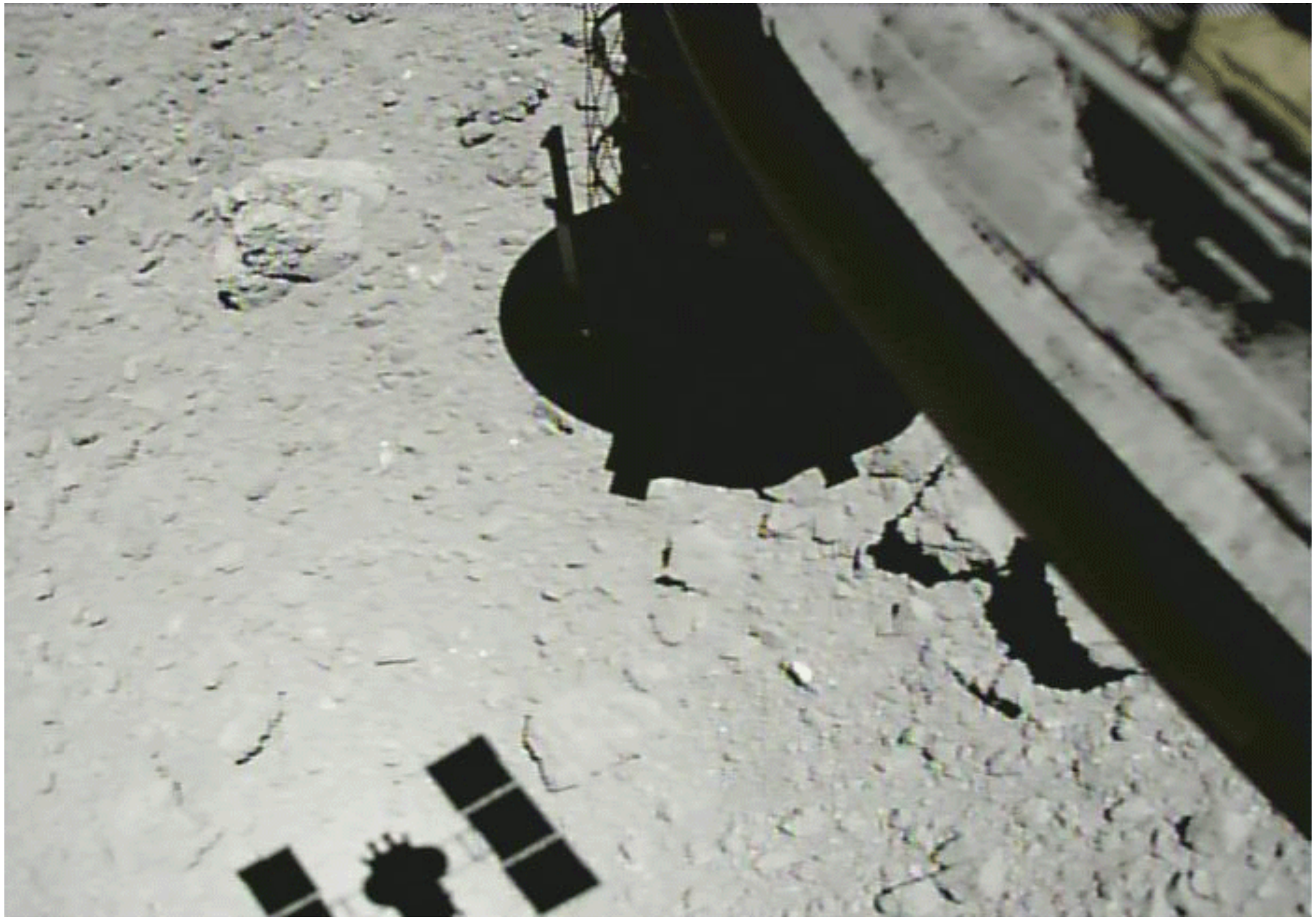
By entering your registration ID number or name, you can search for the block where your name is inscribed.

（Image credit：JAXA）

Note：Currently, this is available only for names in Japan
(location where their registration ID number was assigned)

3. TD1-R3 operation report

Images captured by the small monitor camera



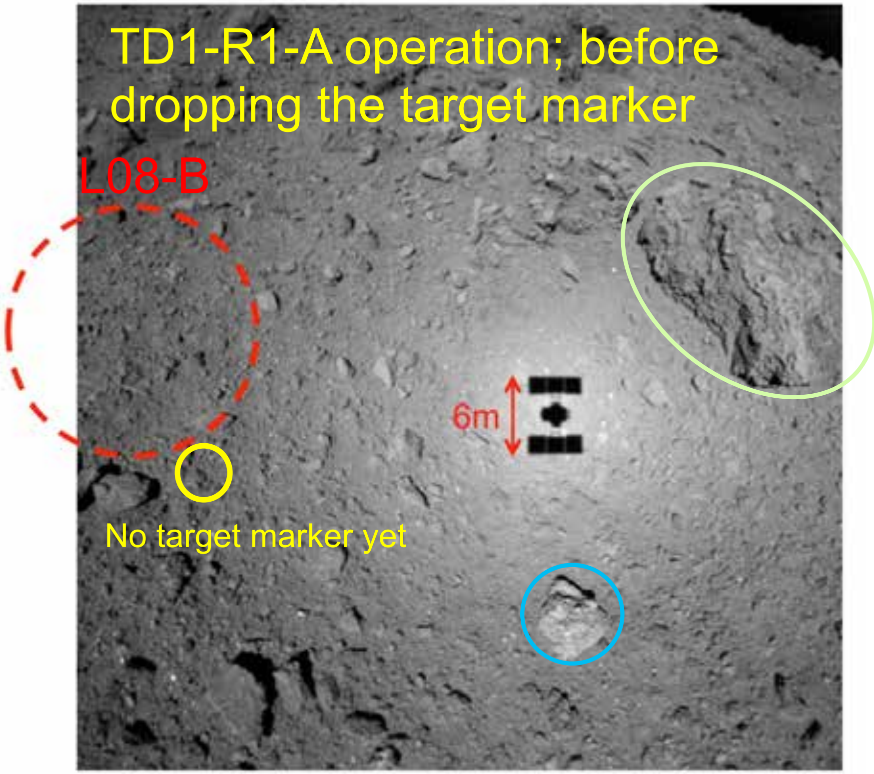
(animation)

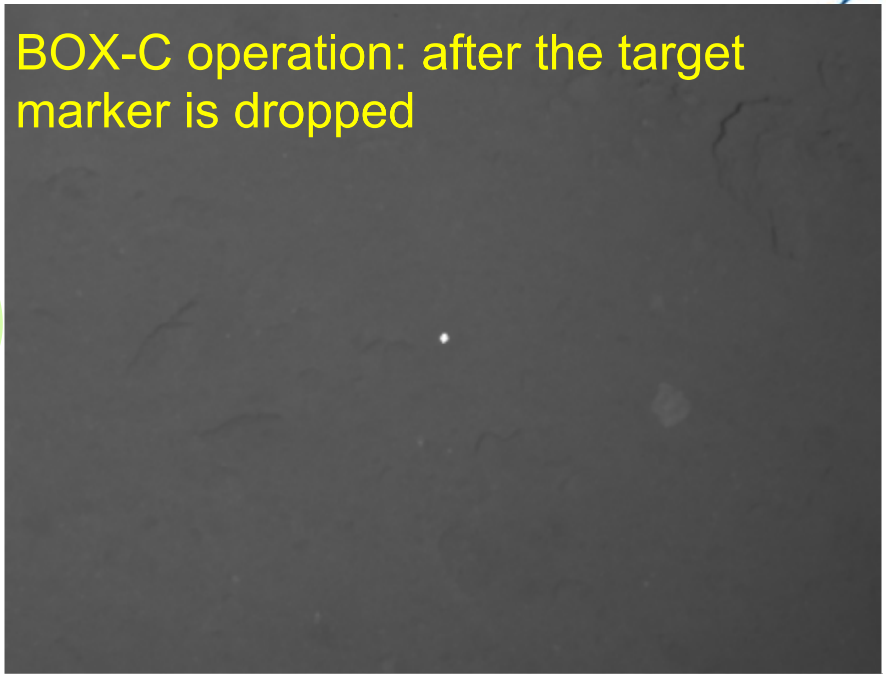
During TD1-R3, these images were taken with the small monitor camera (CAM-H). Images were shot every 5 seconds beginning immediately after rising to 11:47 JST on October 25, 2018 (altitude of about 21m). The ascending speed is about 52 cm/2. (Image credit: JAXA)

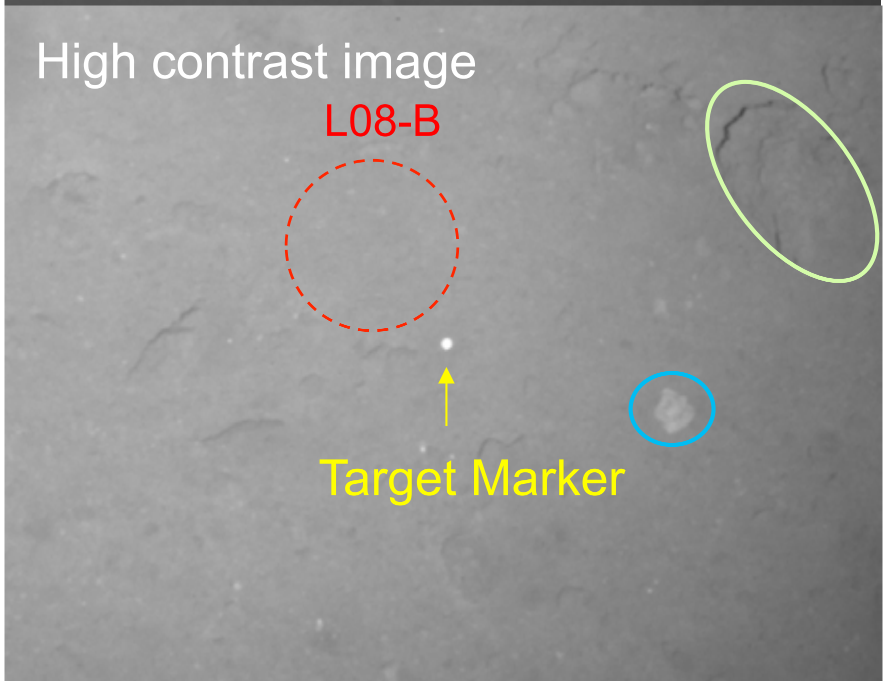
3. BOX-C operation

- Between October 27 – November 5, the hovering altitude of the spacecraft was reduced from the home position (about 20km altitude). This is the second BOX-C operation.
- On October 30, operation “BOX-C1” reduced the altitude of the the spacecraft to 5.1km and observations conducted with the laser altimeter and optical navigation cameras.
- On November 1, operation “BOX-C2” further reduced the altitude to about 2.2. km, where a successful attempt was made to image the target marker.

3. BOX-C operation







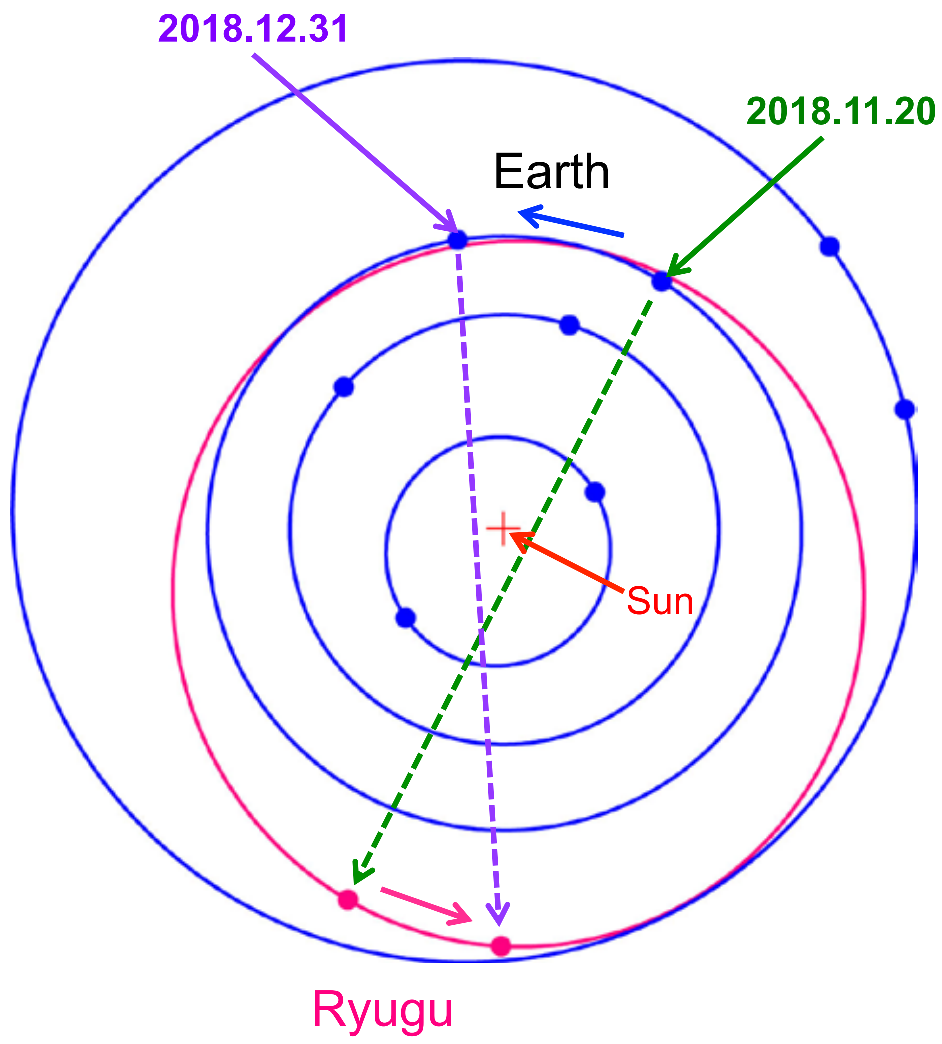
[Left] Image with the Optical Navigation Camera – Wide angle (ONC-W1) on 2018/10/15, 22:45 (JST)
Altitude: 47 m

[Right] Image with the Optical Navigation Camera – Telescopic (ONC-T) on 2018/11/01 11:17 (JST)
Altitude: 2.4 km

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

4. Conjunction operation

- "Conjunction" for spacecraft operation refers to the case where the spacecraft is in the direction that almost directly overlaps with the Sun when viewed from Earth.
- The alignment means that communication with the spacecraft is not secure due to radiowaves radiated by the Sun.
- In this period, critical operation is not carried out.
- For Hayabusa2, the duration of this period is from late November 2018 – end of December.



Positions of Ryugu and the Earth

4. Conjunction operation

Orbit and trajectory control during the operation

Orbit control

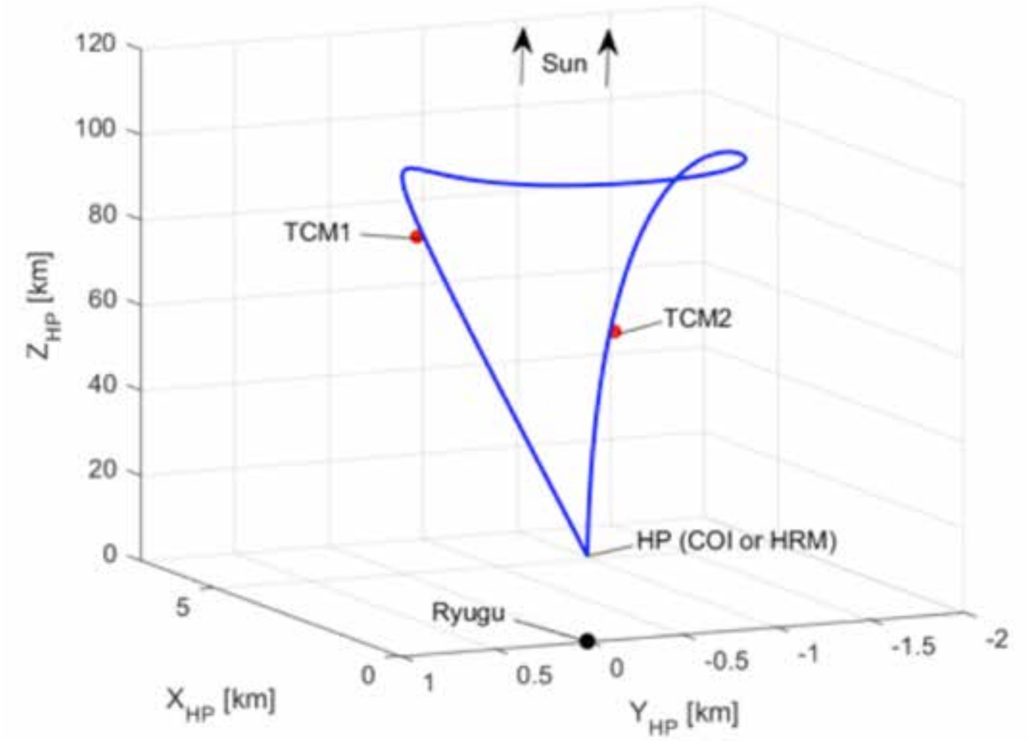
Name	Date
COI	2018/11/23
TCM1	2018/11/30
TCM2	2018/12/25
HPR	2018/12/29

COI : Conjunction Orbit Insertion

TCM : Trajectory Correction Maneuver

HPR : Home Position Recovery

Due to the influence from solar tidal forces, asteroid gravity and solar light pressure, the trajectory forms a complex shape.



Transition orbit during solar conjunction in the home position coordinate system

4. Conjunction operation

Operation details

(1) Preparation period（2018/11/18-2018/11/29）

On November 23, 2018, the spacecraft will be placed into the conjunction transition orbit at the COI point. As the SEP angle (angle formed by the Sun – Earth – spacecraft) decreases from six degrees to 3 degrees, communication will still be possible. Observations will be performed with the Optical Navigation Camera – Wide angle (ONC-W1) for two days before the orbit control maneuver (TCM1) on November 30, 2018. After conjunction, the positional relationship between the Sun, Earth and asteroid will be mirrored so a 180 degree attitude rotation will be performed before entering the conjunction period.

(2) Duration（2018/11/30-2018/12/21）

During this period, the SEP angle decreases below 3 degrees, making it difficult to communicate with spacecraft. No trajectory control is performed, but communication with the spacecraft is still attempted. This is a valuable opportunity to investigate the Sun’s environment.

(3) Reversion period（2018/12/22-2019/01/01）

In this period of return after conjunction there will be two days of observations after which the orbital control maneuver (TMC2) will be performed on December 25, 2018. Home Position Return control (HPR) maneuver will be performed on December 29, 2018 to return the spacecraft to the home position.

5. DPS press conference

DPS = Division for Planetary Sciences of the American Astronomical Society（one of the world's largest academic societies in planetary science, date/place： October 21 – 26, Knoxville, USA.

- Hayabusa2 press conference: October 25, 12:15 ~ 13:15 (October 26, 01:15 ~ 02:15 JST）
- Information：https://aas.org/meetings/dps50/2nd-media-advisory
- Title：Hayabusa2 Explores Asteroid Ryugu
- Presenters（titles omitted）：Masaki Fujimoto（JAXA）、Hikaru Yabuta（Hiroshima U.）, Eri Tatsumi（U. Tokyo）、Deborah Domingue (Planetary Science Institute)、Lucille Le Corre (Planetary Science Institute)、Ralf Jaumann (German Aerospace Center)

※ Hayabusa2 Special Session at DPS on October 25 (poster presentation #13), October 26 (oral announcement #9).

5. DPS press conference

Session outline (in order of presentation)

■Masaki Fujimoto：Hayabusa2 Project
  ･Outline of project progress and observations of Ryugu

■Ralf Jaumann：MASCOT: Decent, Landing and on-Asteroid Activity
  ･Introduction to ; landing and surface operations

■Tatsumi Eri：Ryugu's surface seen from Hayabusa2's remote-sensing observations
  ･Characteristics of Ryugu’s surface images by the optical navigation cameras.

■Deborah Domingue：Ryugu's surface seen from Hayabusa2's remote-sensing observations
  ･The rocky surface of Ryugu, with no regolith like the Moon.

■Lucille Le Corre：Asteroid Ryugu imaged at high resolution
  ･Detailed topographical model of the surface of Ryugu

■Hikaru Yabuta：Landing site selection to provide key scientific and engineering findings from proximal operations and material sampling
  ･Landing site selection process and results.

5. DPS press conference

Photograph from the press conference

October 25, 2018@Knoxville

6. Ryugu shape model

- JAXA Space Exploration Innovation Hub unveils a simple version of the shape model.
- The Hayabusa2 Science Team is developing a precise shape model for Ryugu.
- Schedule for release with the publication of the associated paper.

6. Ryugu shape model

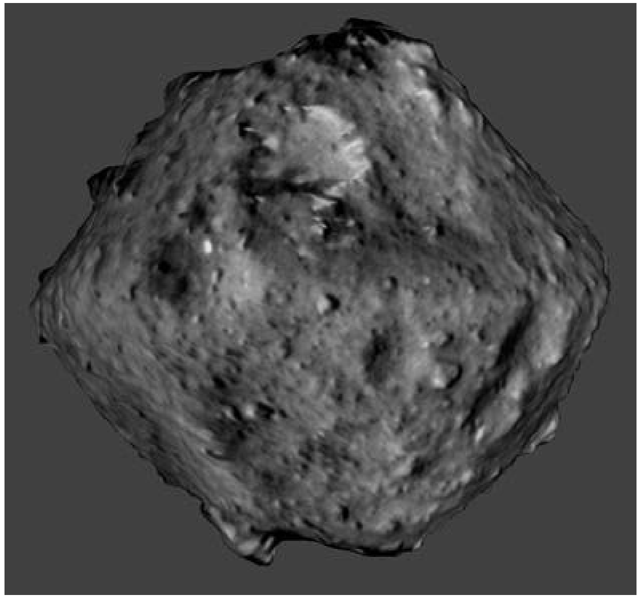
Data release of the Ryugu simple shape model by JAXA Space Exploration Innovation Hub

- Through collaborative research at the Space Exploration Innovation Hub (Task name: autonomous location estimation and environmental map creation from exploration robot images, 2 pairs of 2 companies: Qoncept, Morpho, Ivis, ViewPLUS), the three-dimensional shape of Ryugu was constructed using only image information.

- The three-dimensional model of Ryugu obtained by this method is described as a “simplified shape model” and available as a data file. (Because it is a simple model, this cannot be used for science or engineering purposes)

【Public URL (Website of the Space Exploration Innovation Hub)】
http://www.ihub-tansa.jaxa.jp/ryugu_mokei.html

- The simplified shape model uses the animation from the article on the Hayabusa2 home page entitled “This is Ryugu – a global image in 3D” taken with the Optical Navigation Camera – Telescopic (ONC-T) on 6/23 at an altitude of about 40km.



Ryugu simple shape model
Number of vertices : 157,500
Number of triangular patches : 52,600
File size : 4MB、FBX format

Cooperation : Hayabusa2 Project

Credit : JAXA Space Exploration Innovation Hub / Qoncept, Morpho, Ivis, ViewPLUS

※ Data files can be views with a 3D display tool or the model output to a 3D printer.

7. Other

■Place names on Ryugu

- A proposal for naming regions of Ryugu was submitted to the IAU (International Astronomical Union) Working Group for Planetary System Nomenclature. We are currently awaiting the results of their consideration.

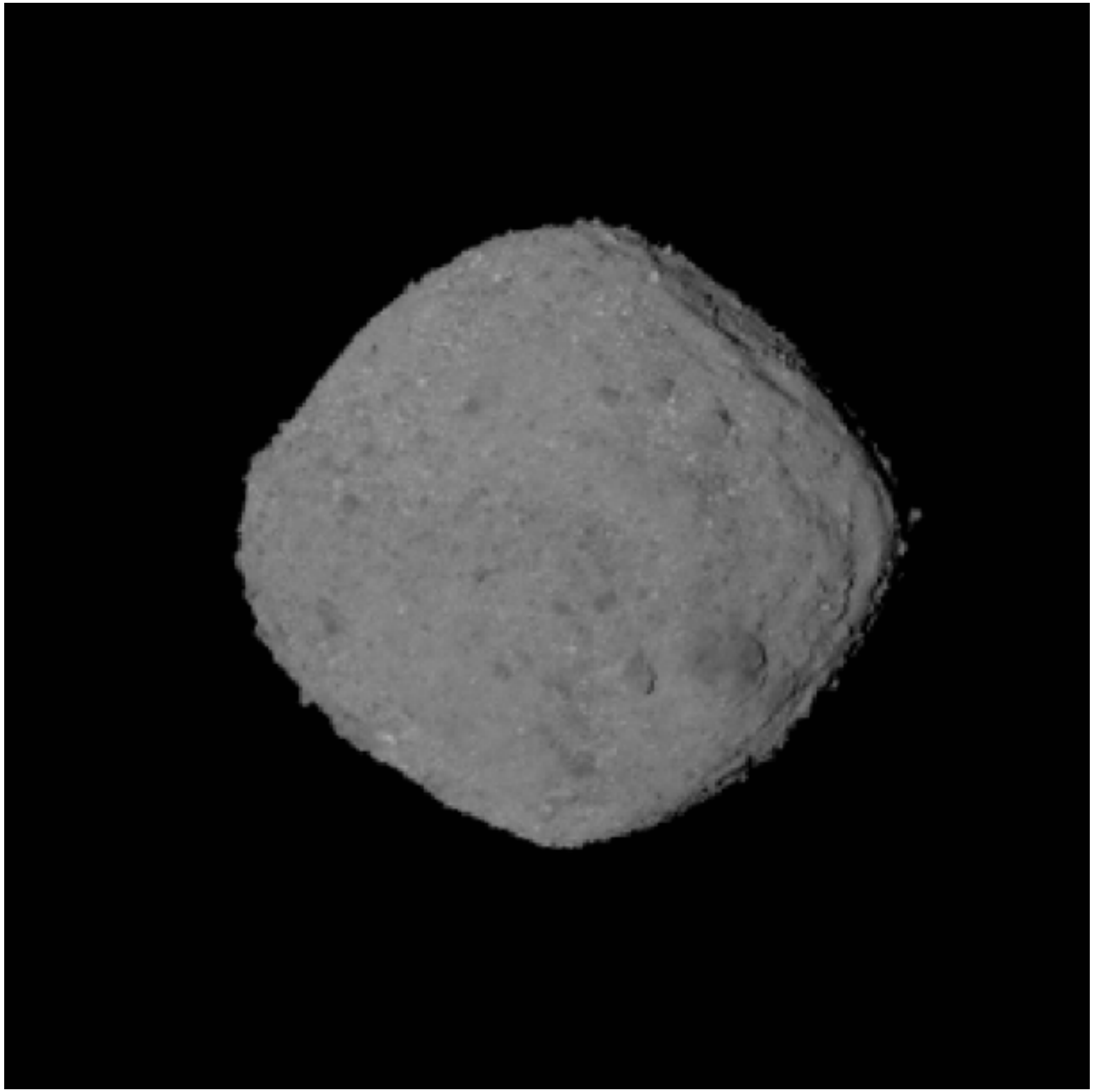
■OSIRIS-Rex captures image of asteroid Bennu

- OSIRIS-Rex successfully photographed asteroid Bennu, whose shape was shown to be similar to Ryugu.

7. Other

（animation）

Reference：Asteroid Bennu



Bennu Full Rotation at 200 Pixels

- Rotation period: 4 hours 11 minutes.
- November 2, 2018
- PolyCam camera
- Shot every 10 degrees
- Distance: 122 miles (197 km)
- Credit: NASA/ Goddard/ University of Arizona

8. Future plans

■Scheduled operations

- Late November ～December：solar conjunction

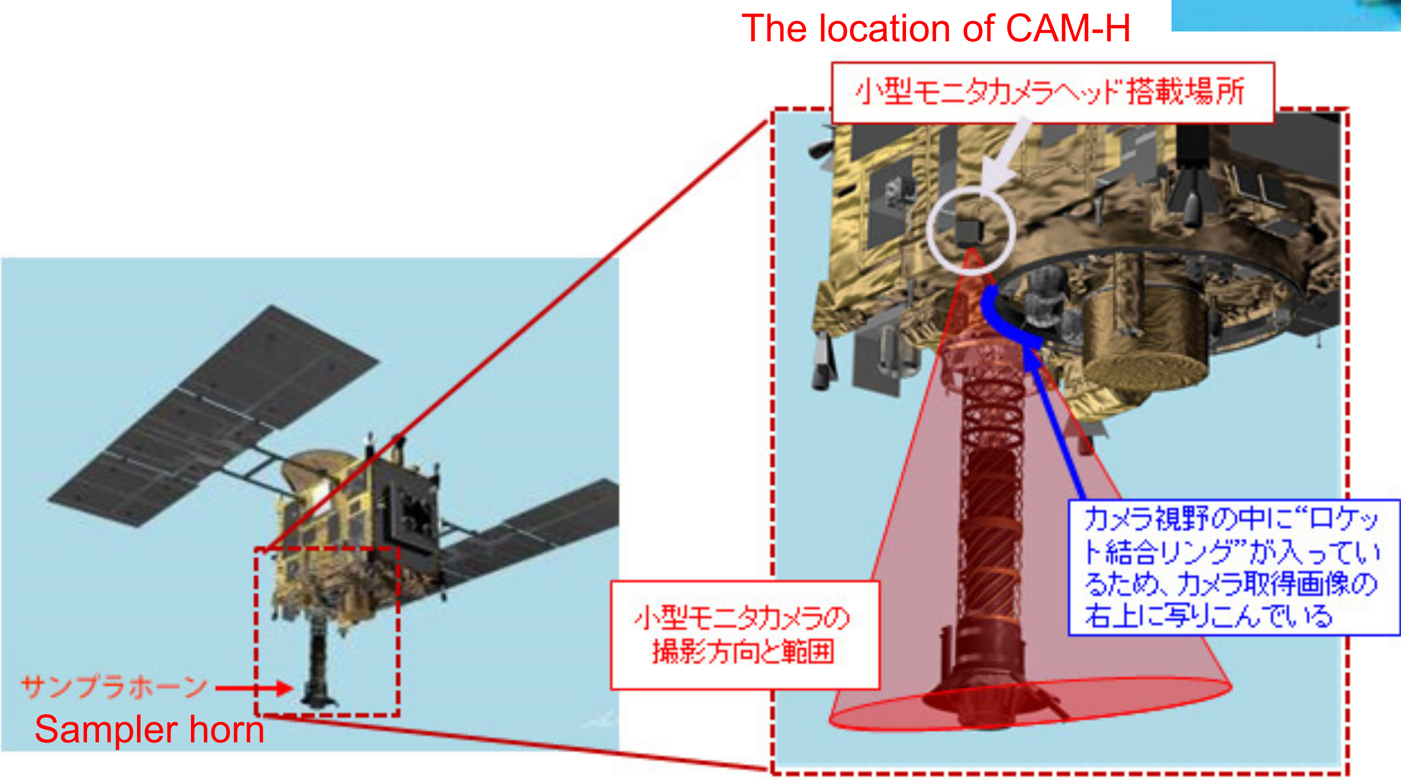
■Media and press briefings

- December 6（Thursday） 13:30～16:00（guideline）
  Reporters' conference @ Sagimihara
- December 13（Thursday） 11:00～ Reporters' briefing @ Ochanomizu

Reference material

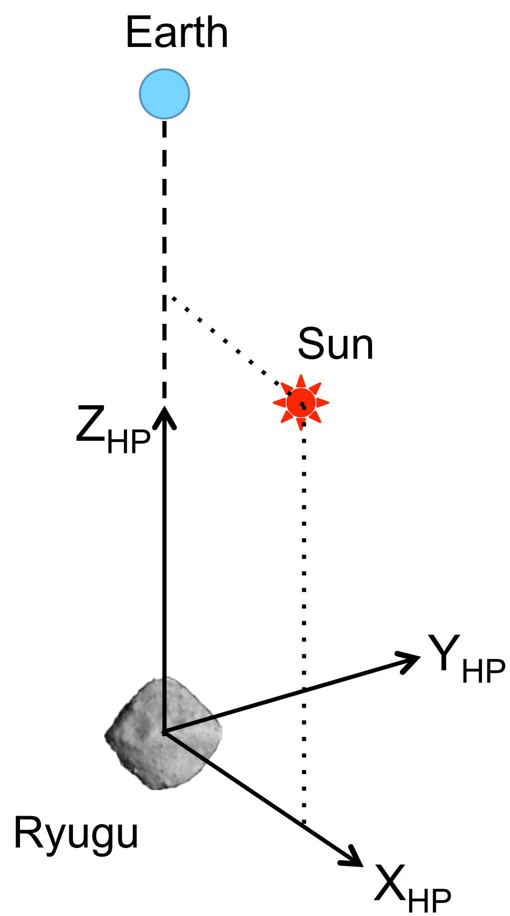
Small Monitor Camera（CAM−H）

- Camera built & mounted from donation funds.
- View down sampler horn.

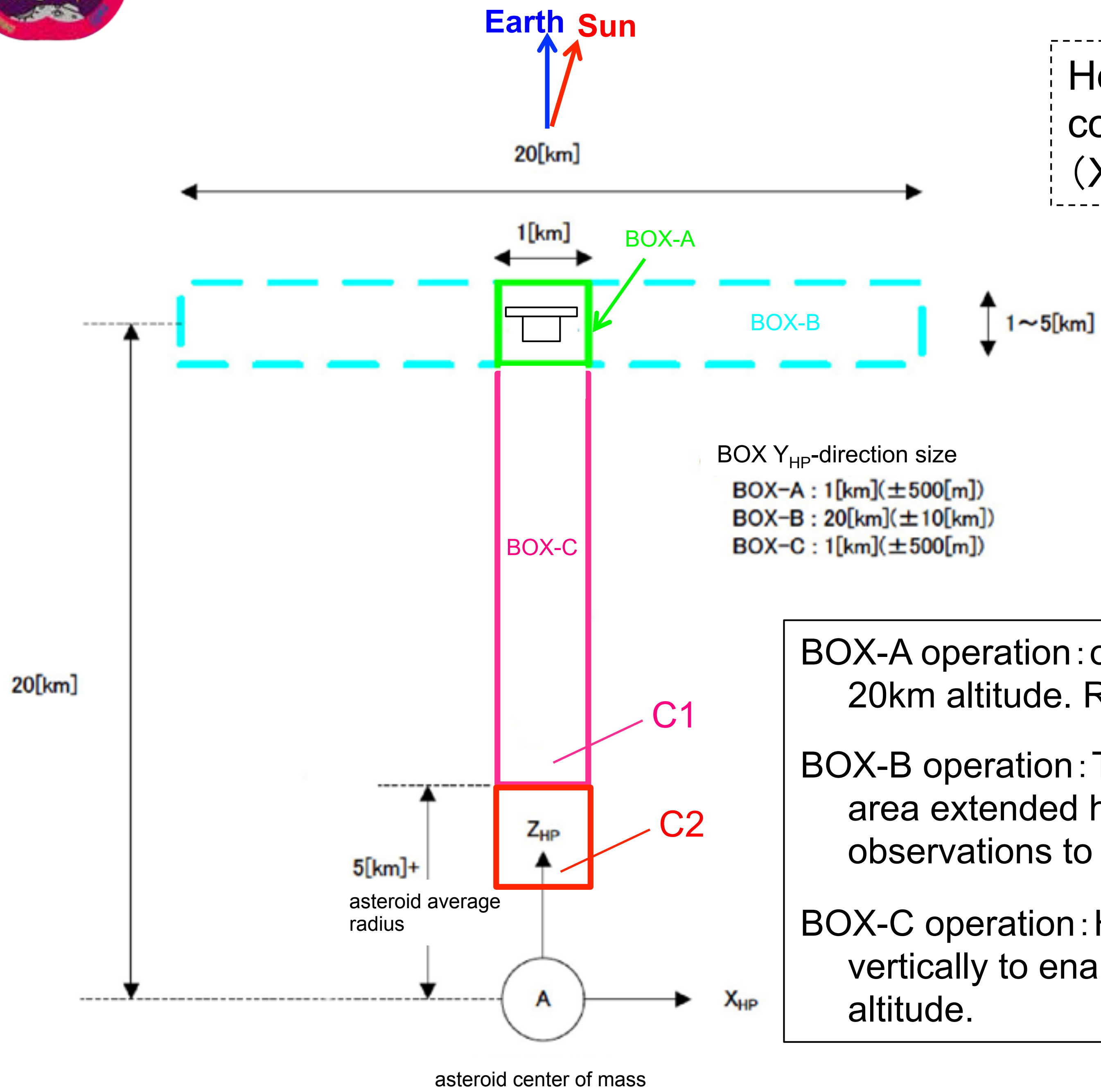


（©JAXA）

Home Position Coordinate System



BOX definition



Home position coordinate system (X_{HP}, Y_{HP}, Z_{HP})

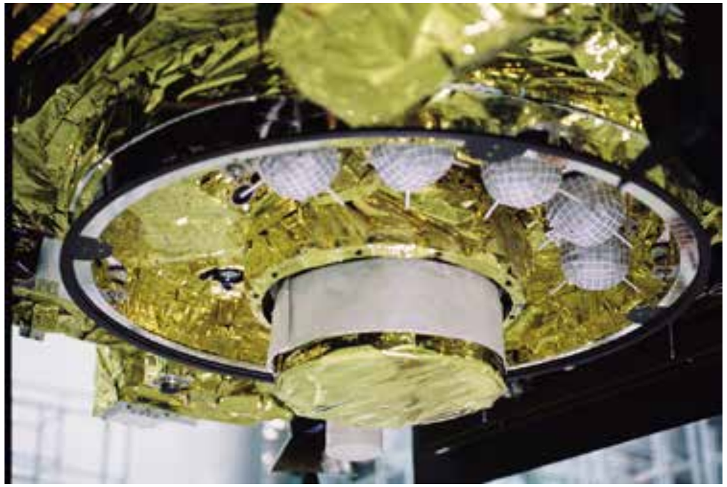
（Reference material）

BOX-A operation : operations while hovering at 20km altitude. Regular operation standard.

BOX-B operation : Tour observation. Hovering area extended horizontally to enable observations to either side of the asteroid.

BOX-C operation : Hovering area extended vertically to enable observations at low altitude.

Target Marker



- Size of body (ball): about 10cm
- Retroreflective film
- 4 bars：rolling prevention
- Inside contains many polyimide globules

- First to separate：B
- Order of separation : B→A→E→C→D
- On the inside of the target marker is a sheet on which is written the names of members from the general public.