Asteroid explorer, Hayabusa2, reporter briefing

June 11, 2019

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2,

・ Results from the low altitude descent observation operation（PPTD-TM1A）

・ Plan for the low altitude descent observation operation （PPTD-TM1B）

・Future operations

・Science results

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

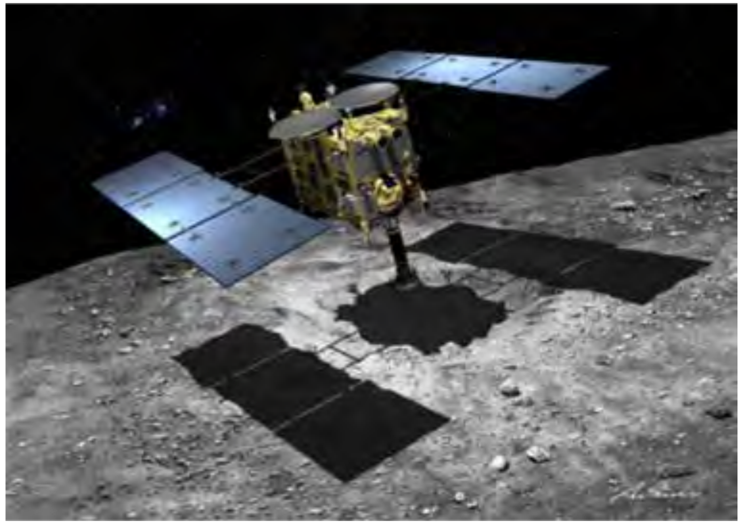
- By exploring a C-type asteroid, which is rich in water and organic materials, we will clarify interactions between the building blocks of Earth and the evolution of its oceans and life, thereby developing solar system science.
- Japan will further its worldwide lead in this field by taking on the new 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

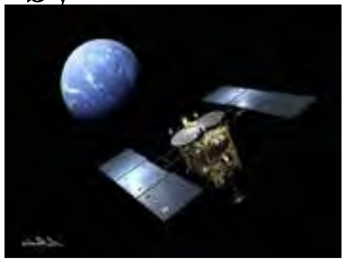
Primary instruments

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

Mission flow

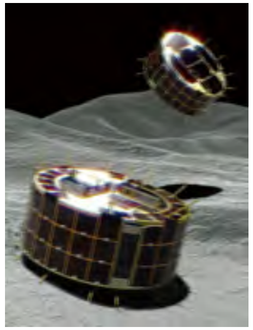
Launch
Dec 3, 2014

Earth swing-by
Dec 3, 2015



Ryugu arrival
June 27, 2018

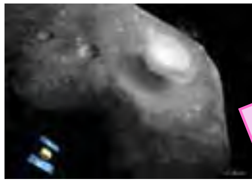
MINERVA-II-1 separation
Sep 21, 2018



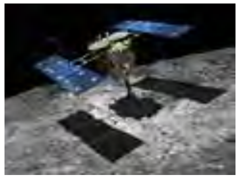
MASCOT separation
March 10, 2018

Feb 22, 2019

completed → **First touchdown**



Impactor (SCI)
5 April, 2019



After confirming safety, touchdown at or near crater area to collect subsurface material.

Ryugu departure
Nov〜Dec, 2019

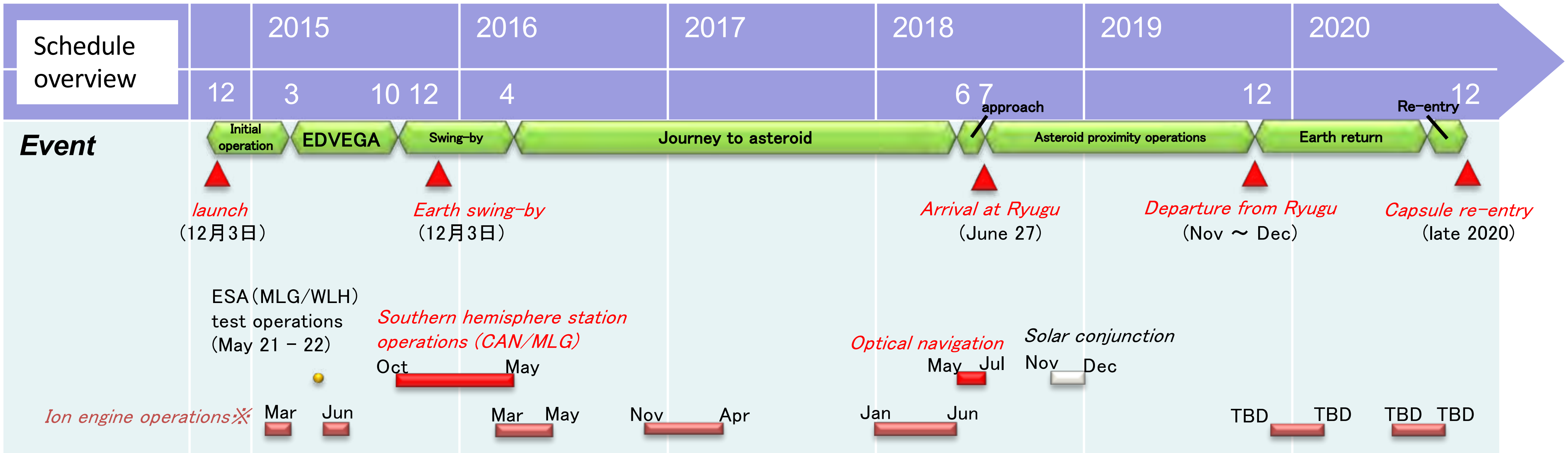
Earth return
End of 2020

(image credit: illustrations including spacecraft by Akihiro Ikeshita, others by JAXA)

1. Current project status & schedule overview

Current status :

- From May 28 ~ 30, the low altitude descent observation operation (PPTM-TM1A) was performed. A target marker was dropped in the C01 region and low altitude observations were performed.
- From June 11 ~ 13, the low altitude descent observation operation (PPTM-TM1B) will be performed. Today (6/11) we are preparing for the descent.

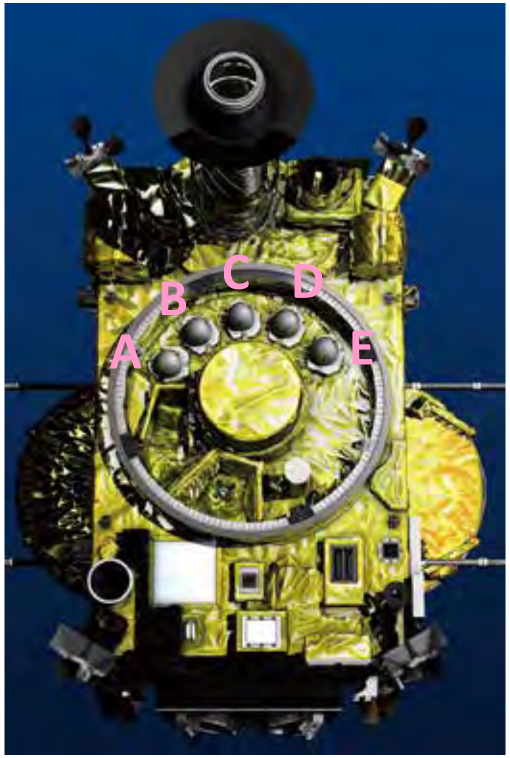


2. Low altitude descent observation operation (PPTD-TM1A) results

- The low altitude descent observation operation (PPTD-TM1) was performed between May 28 ～30.
- Preparations were made for the descent (May 28) which began on May 29 12:06 JST (on-board time) and reached an altitude of about 35m on May 30 at 11:00 JST. The spacecraft then hovered around this altitude.
- The spacecraft began to descend again at 11:09, and the target marker was separated at 11:18 at an altitude of about 9m. Then the spacecraft began to rise. The lowest altitude reached was about 8m.
- The spacecraft returned to the home position on May 31.
- The target marker was dropped about 3m away from the target point.
- We were able to get the characteristics of the measurement data for the Laser Altimeter (LIDAR) and Laser Range Finder (LRF) at low altitude, as well as characteristics of the images of the target marker captured by Optical Navigation Camera – Wide angle (ONC-W1) .

2. Low altitude descent observation operation (PPTD-TM1A) results

Second target marker dropped successfully!

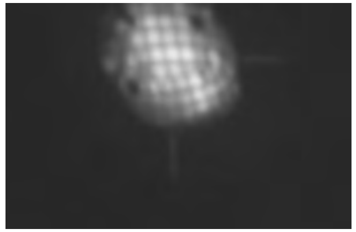


This time A was separated. B is already separated.（Separation order：B→A→E→C→D）

<u>Target marker</u>

- Body (ball) size：about10cm diameter
- Retroreflective film on the surface
- 4 bars rolling prevention
- Many polyimide small balls inside
- All five target markers contain a sheet with the names of members of the general public.
- Total number of names listed：183,174.

You can search for the location of a name here：
https://www.haya2-campaign.jp/

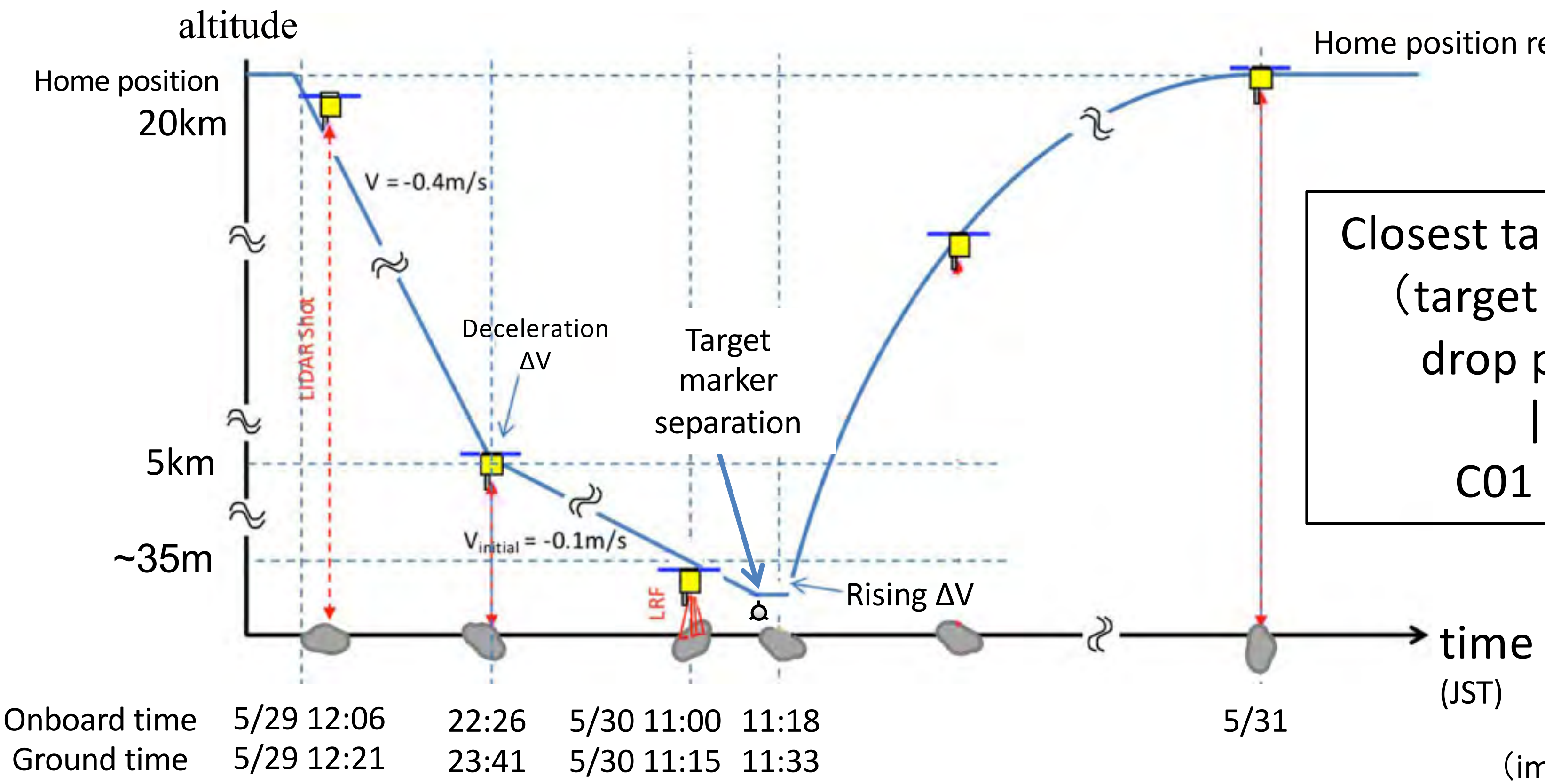


Target marker A separated.

Sheet of names

2. Low altitude descent observation operation (PPTD-TM1A) results

PPTD-TM1A operation (actual)



Closest target point
（target marker drop point）
||
C01 area

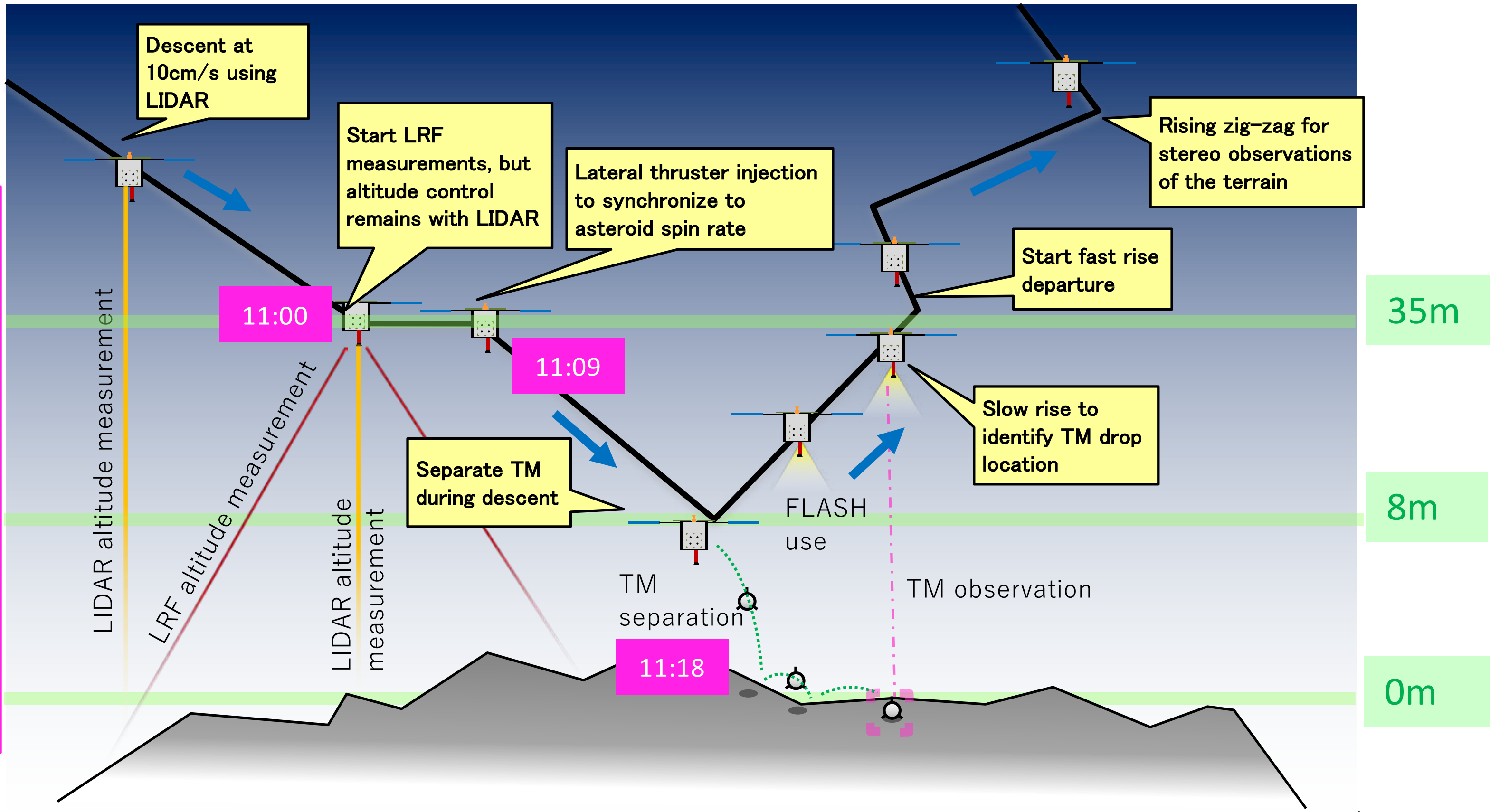
（image credit: JAXA）

2. Low altitude descent observation operation (PPTD-TM1A) results

Low altitude sequence during PPTD-TM1A operation (actual)

※Time is JST ground time on May 30, 2019。

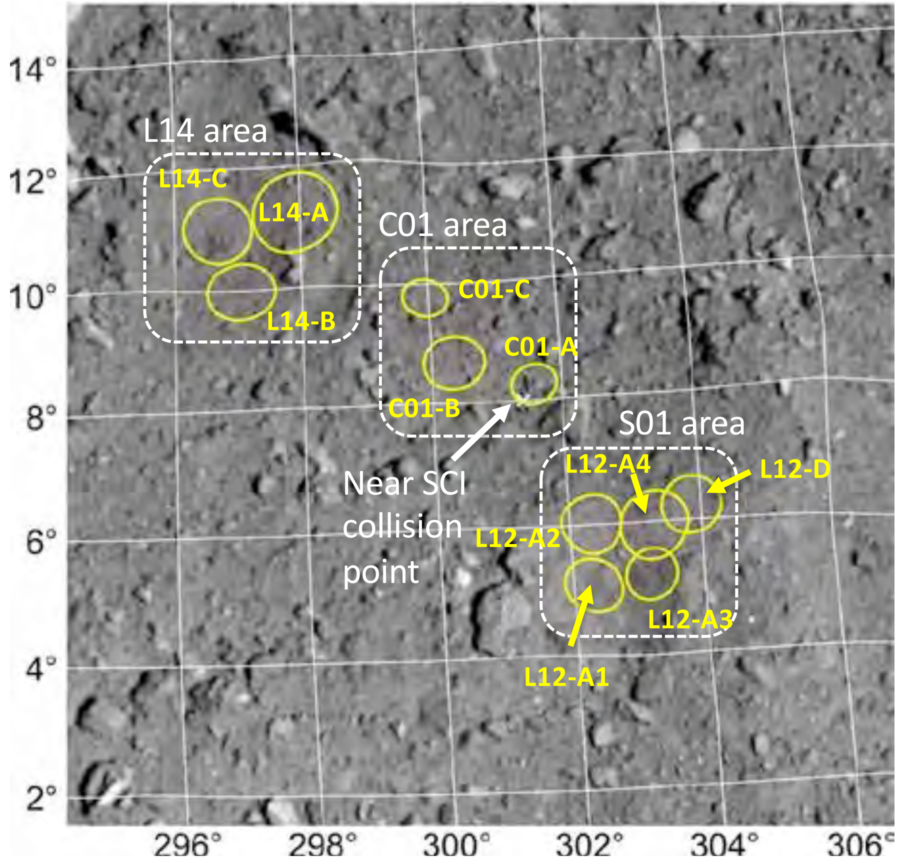
11:00 Time when altitude reached about 35m.
11:09 Time when descent began.
11:18 Time when the TM separated and rise began

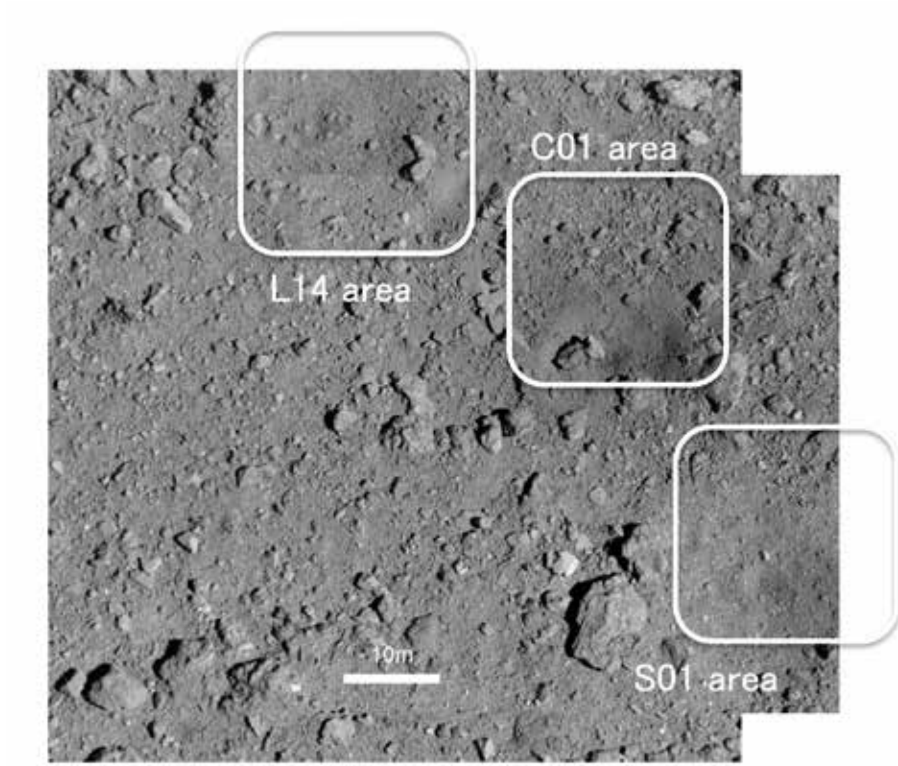


(image credit: JAXA)

2. Low altitude descent observation operationn (PPTD-TM1A) results

Touchdown candidate sites





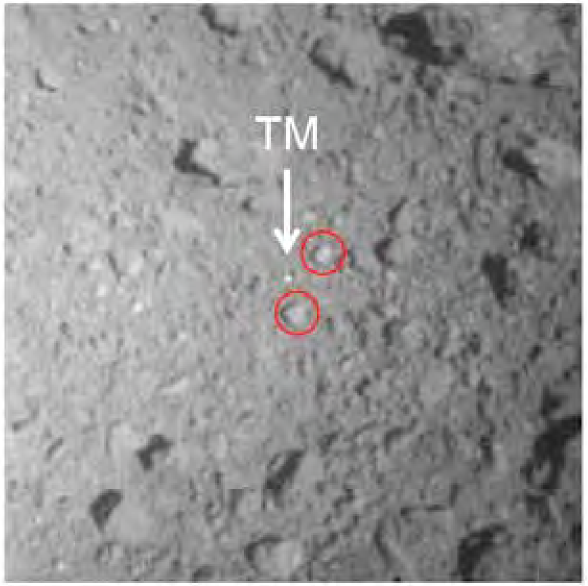
(image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

2. Low altitude descent observation operation (PPTD-TM1A) results

Target marker drop results

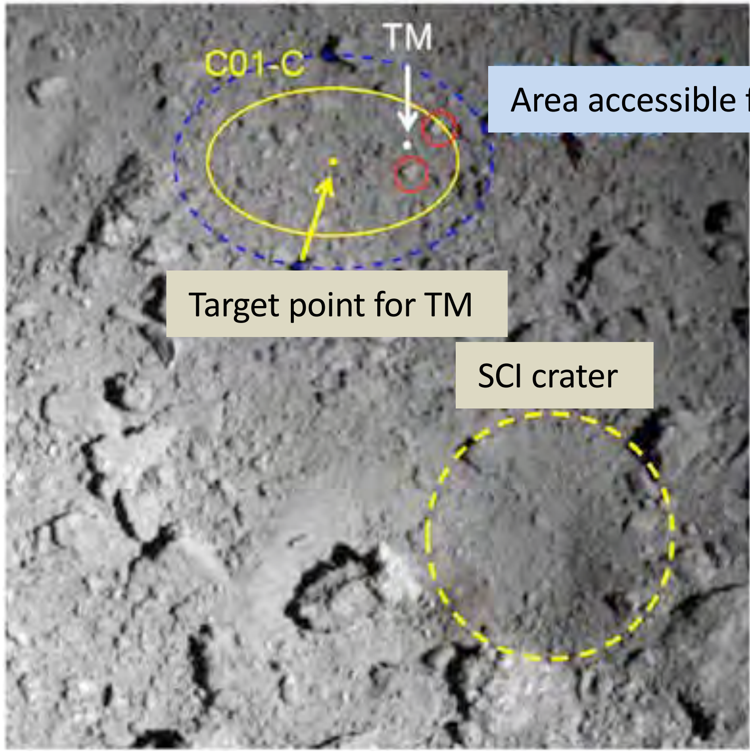
- Succeeded in dropping TM into “area accessible for TD”.

New



（TM：
Target Marker）

Image taken by ONC-W1 on May 30 at 11:23 JST (ground time). Image altitude about 35m.



（Explanatory diagram: actual and planned TM location are plotted.）

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

2. Low altitude descent observation operation (PPTD-TM1A) results

Separation image of the target marker (by ONC-W1)

Composition of continuous sequence of images from ONC-W1 taken on May 30 between 11:18 – 11:26 JST (onboard time). Spacecraft altitude is from 8m – 68m. Images taken with flash. （Credit: JAXA、Chiba Inst. of Tech.）

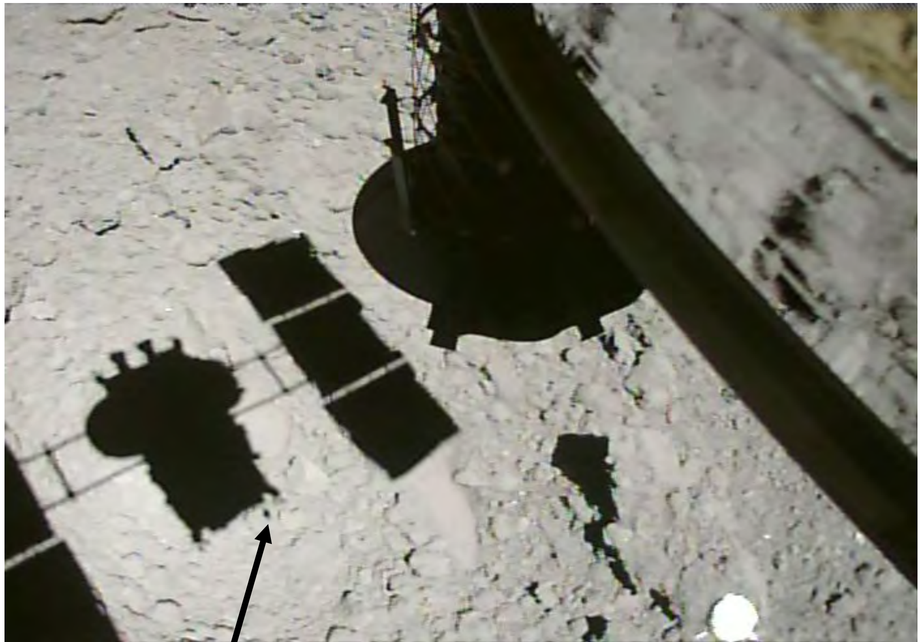
New

（animation）

Animation over roughly the same time period as image on left. Shot with flash.（Credit: JAXA）

2. Low altitude descent observation operation (PPTD-TM1A) results

Separation image of the target marker (by CAM-H)



Target marker shadow Target marker

Image taken by CAM-H on May 30, 2019 at 11:18 JST (onboard). The spacecraft altitude is about 8m.

Images taken by CAM-H on May 30, 2019 from 11:18 JST. The altitude rose from about 8m to about 15m.

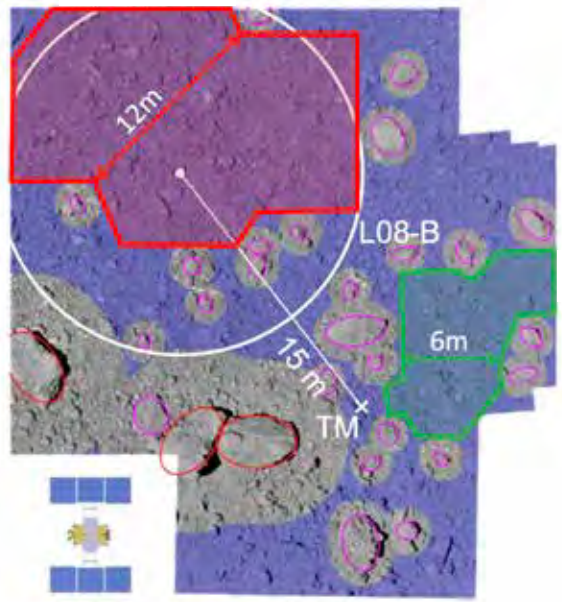
(animation 10x speed)

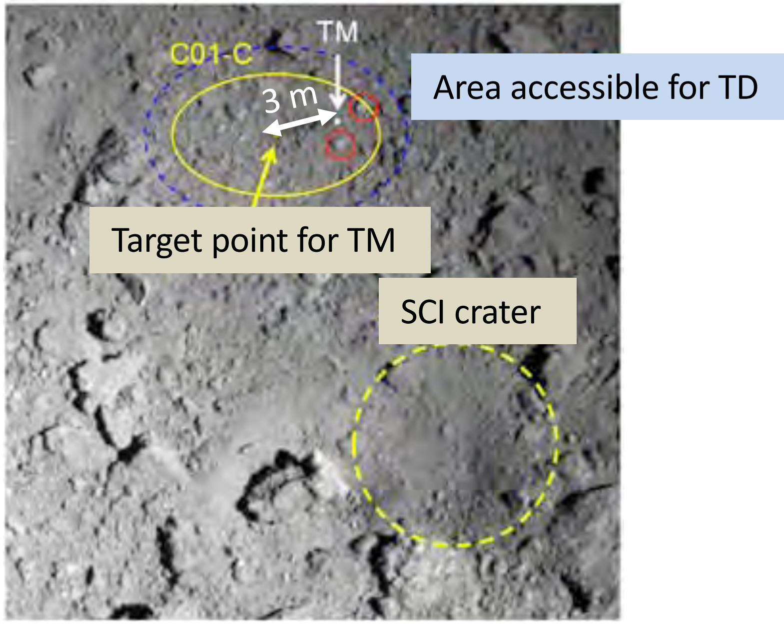
（Image credit: JAXA）

2. Low altitude descent observation operation (PPTD-TM1A) results

Comparison with the first target marker drop (TD1-R3)

- The error in the target marker position (distance from the target point) was 15m for TD1-R3 but reduced to 3m for PPTD-TM1A.

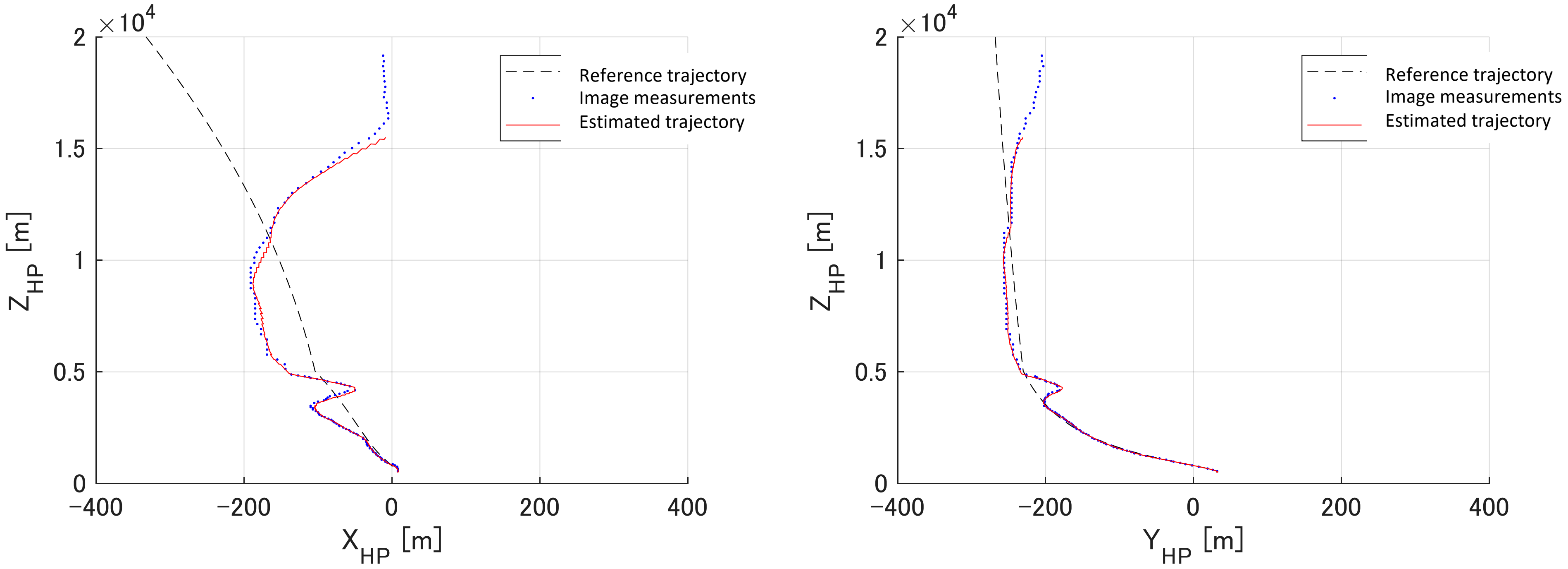




(image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

2. Low altitude descent observation operation (PPTD-TM1A) results

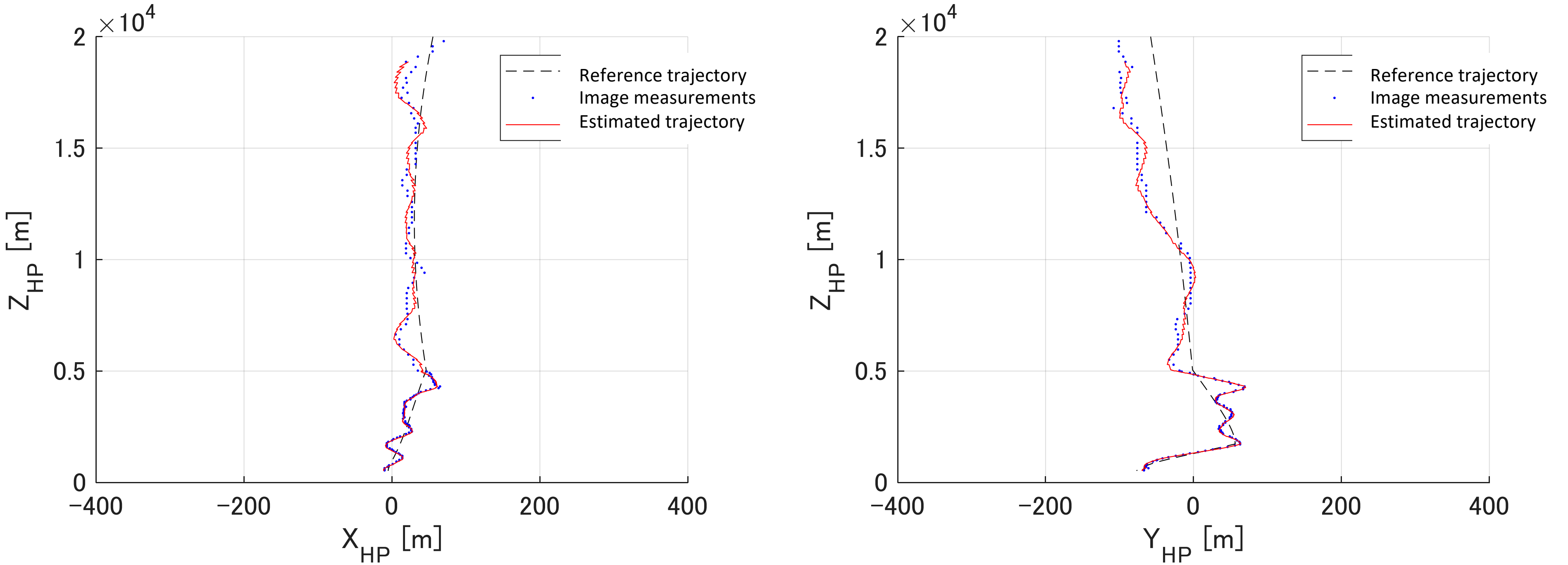
Descent orbit（PPTD-TM1A）



The descent followed the reference trajectory

2. Low altitude descent observation operation (PPTD-TM1A) results

Reference: Descent orbit for TD-R3 operation on Oct 25, 2018



Movement was back-and-forth past the reference trajectory

2. Low altitude descent observation operation (PPTD-TM1A) results

Accuracy improvement factors

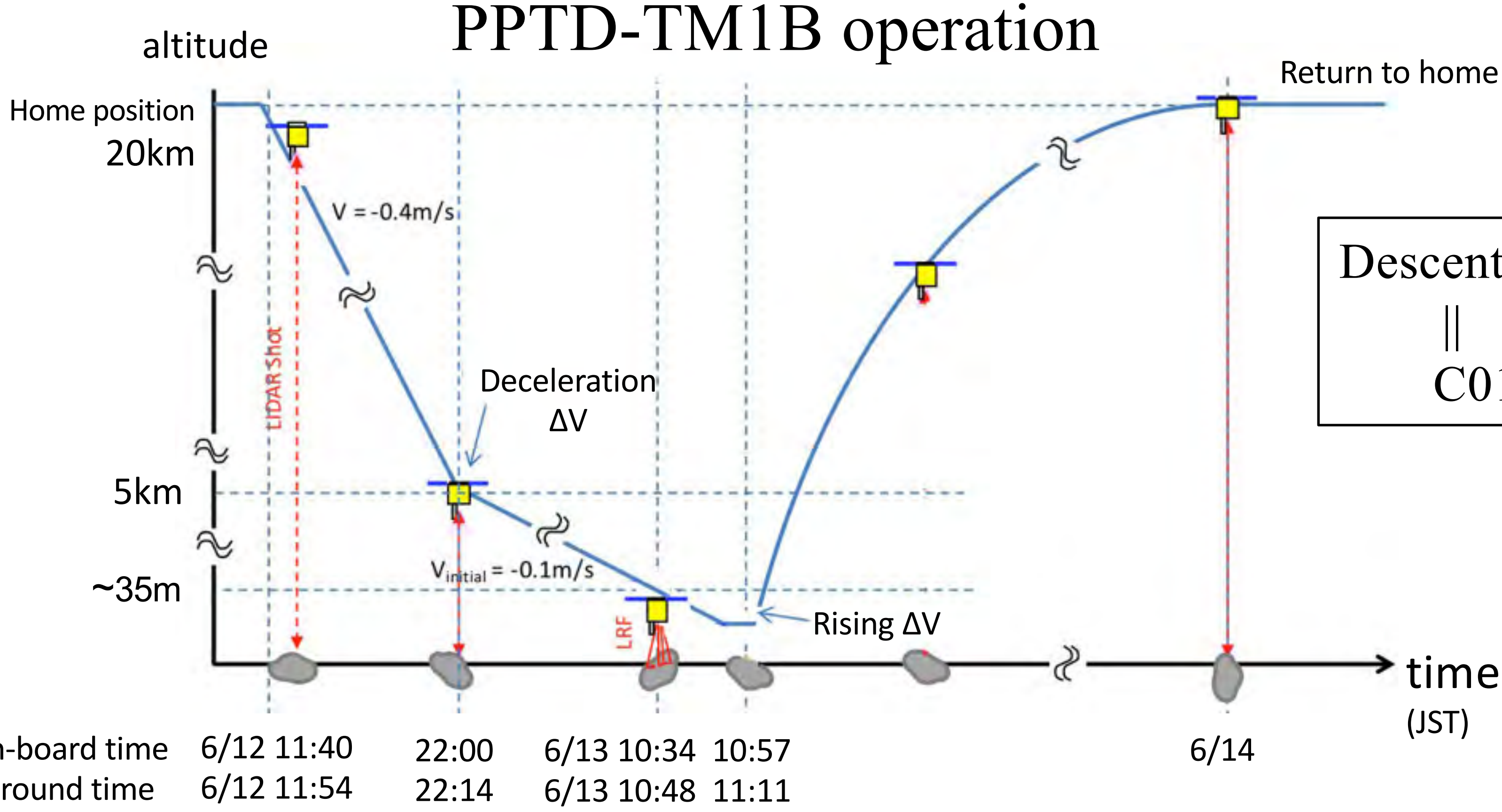
- Design of navigation guidance control system
  - Parameters that make difficult to pass the reference orbit.
- Asteroid gravity model update
  - Improved consideration of the asteroid shape
- Operation sequence change
  - Target marker dropped from hovering.

3. Plan for low altitude descent observation operation (PPTD-TM1B)

- Spacecraft operation from June 11 – 13, 2019.
- Descend to the C01 region and observe the artificial crater.
- Acquire and store data for low-altitude spacecraft operation checks.
- No new target marker will be dropped.

3. Plan for low altitude descent observation operation (PPTD-TM1B)

PPTD-TM1B operation



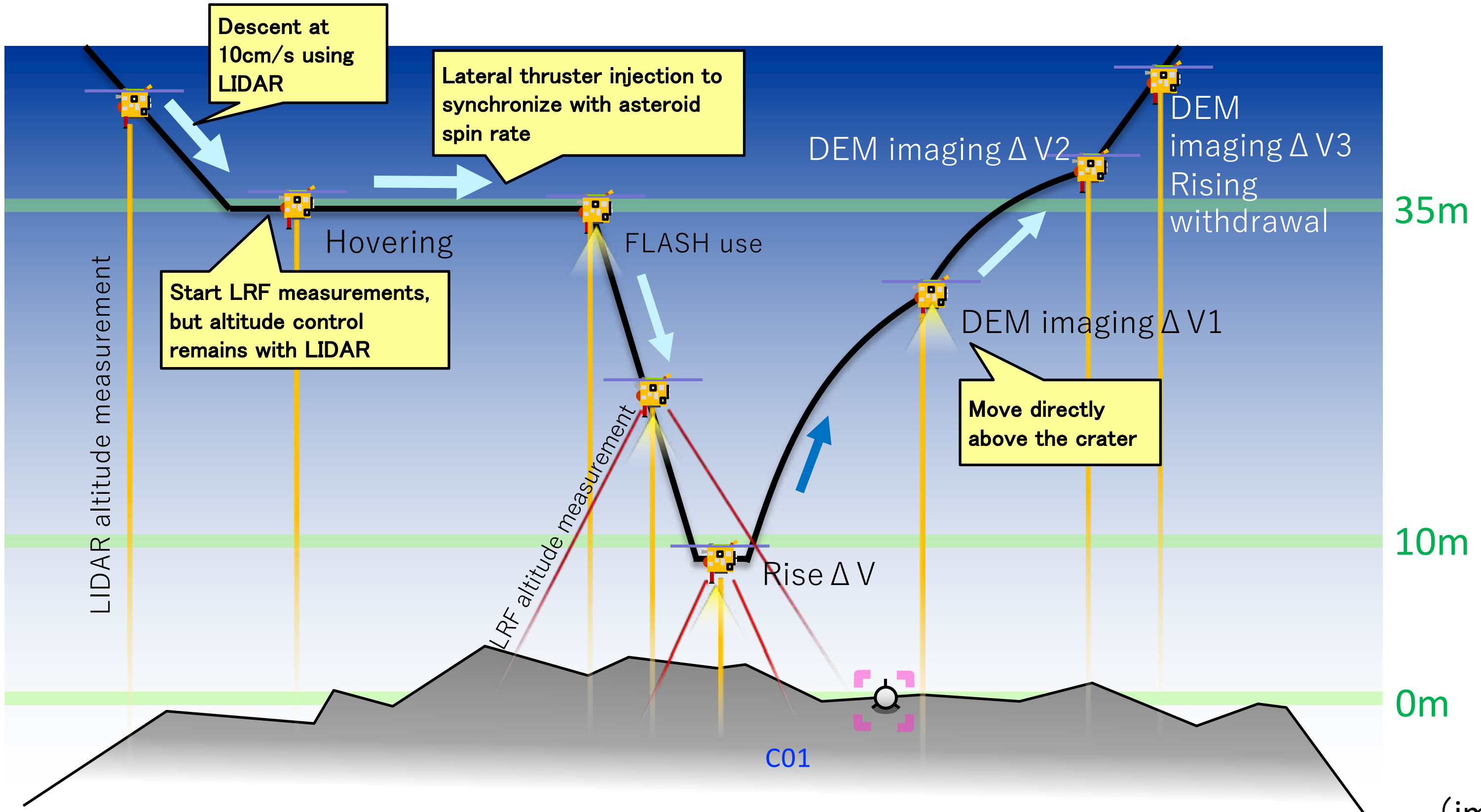
Descent target point
||
C01

※Times in actual operation may vary.

(image credit: JAXA)

3. Plan for low altitude descent observation operation (PPTD-TM1B)

Low altitude sequence for PPTD-TM1B



(image credit: JAXA)

4. Future operation plans

■ Operation plan concept from May ~ July (updated information)

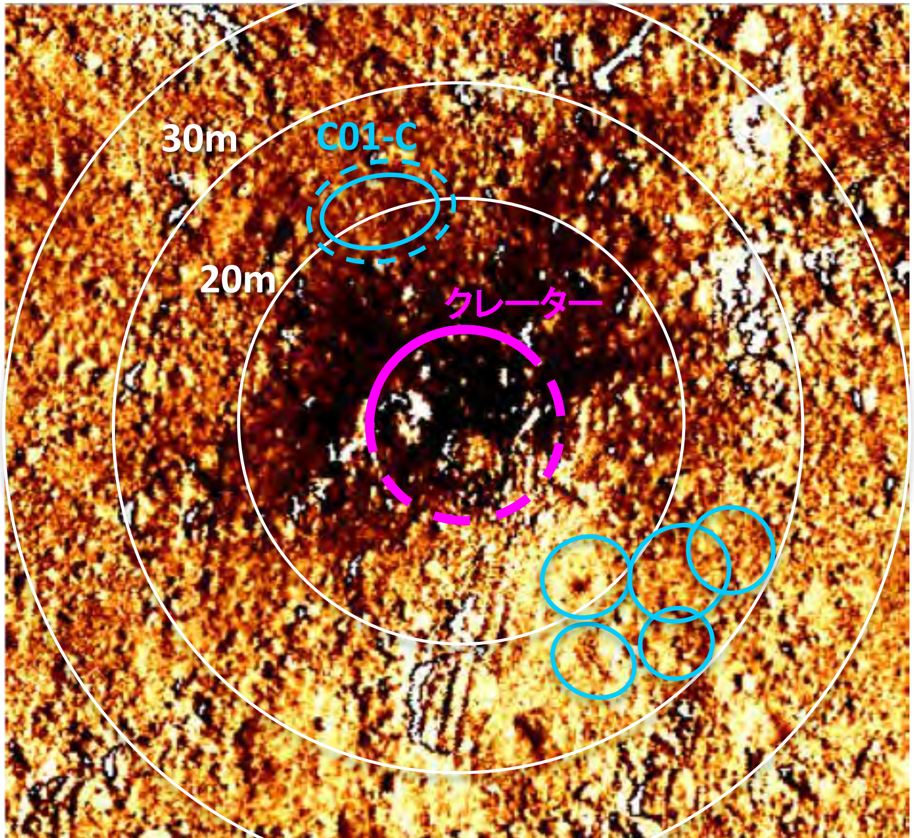
- Currently, Ryugu is approaching the Sun (perihelion in September). It will only be possible to land on Ryugu until the start of July, after which the asteroid temperature will rise.
- By the middle of June, the crater and state of the spacecraft will have been examined and it will then be decided if a second touchdown operation will be performed between the end of June and start of July.
  - Target point: Area where there is ejected material from the artificial crater.
  - Operation name: "Pinpoint touchdown" (PPTD).
- 2 or 3 low altitude descent observations will be performed in May and June before the PPTD operation. While performing detailed topographical observations of the landing point candidates, a target marker will be dropped as a guide for landing in this region.
  - 1st: 5/14〜5/16 Operation name: PPTD-TM1 → target marker could not be dropped
  - 2nd: 5/28〜5/30 Operation name: PPTD-TM1A → target marker dropped successfully
  - 3rd: 6/11〜6/13 Operation name: PPTD-TM1B → target marker not dropped
- During PPTD-TM1A operation, a target marker was dropped in CO1-C. Currently, we are investigating the possibility of touchdown in CO1-C.

4. Future operation plans

Project judgement for whether to perform the second touchdown operation

	Judgement items	Current status	Judged
Scientific and engineering value	Is there a high probability in collecting artificial crater ejecta?	For sites is close to the artificial crater, it is very likely ejecta is on the surface.	○
	Is the scientific value high enough?	Subsurface collection, multiple collection and increased collected volume are all very valuable.	○
	Is the engineering value high enough?	There is high engineering significance in demonstrating the world's first multi-sampling and subsurface sampling.	○
Operation feasibility	Do we have the terrain information needed for touchdown?	Terrain information necessary for touchdown was obtained from PPTD-TM1 and PPTD-TM1A.	○
	Proximity of the target marker to the touchdown target point.	Target marker landed 3m from the center of C01-C.	○
	Can we design a sufficiently safe touchdown sequence?	Under consideration.	
Spacecraft status	Is there any problem with the optical system where the amount of light received has decreased due to dust in the first touchdown?	Under consideration.	

4. Future operation plans



Change in reflectance before and after SCI impact（CRA1 → CRA2）. Contrast emphasized. Black areas darkened after collision.

Ejecta from the SCI crater near C01

- Ejecta from the SCI crater (darker colors than the surroudings) is distributed all over the PPTD candidate site, C01-C.
- The average thickness of the ejecta in C01-C is estimated at about 1cm, based on the spatial distribution of the darkening.
- The C01-C ejecta is thought to be a mix of excavated material from depths of 0m to about 1m. ※ Layers of several 10s cm or more are predicted from space weathering, solar heating and cosmic rays.

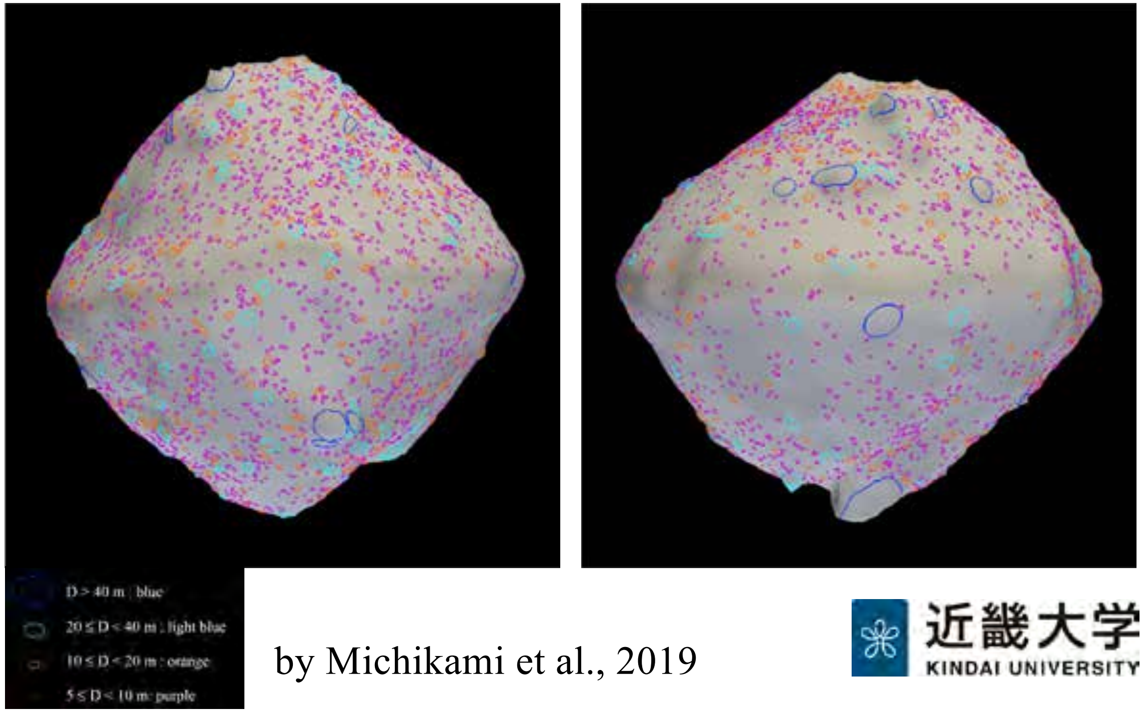
New

Terrain created by adjusting lighting conditions in the ONC image. (JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

5. Science results

Paper published In Icarus：by Tatsuhiro Michikami (Kindai University)

- Michikami, T (Kindai Univ)., and 35 colleagues, 2019. “Boulder size and shape distributions on asteroid Ryugu.” Icarus 331, 179-191. https://doi.org/10.1016/j.icarus.2019.05.019 Published：2019/5/21



by Michikami et al., 2019

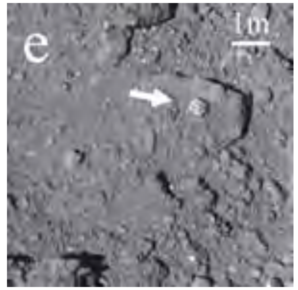
- The size and shape of more than 10,000 boulders were measured across asteroid Ryugu. There are about 4400 boulders larger than 5m and they have a shape consisted with collision fragments. This suggests most of the boulders are fragments formed in the collisional destruction of Ryugu’s parent body.
- The number of boulders (per unit area) over 10m is larger than any asteroid explored so far.

5. Science results

Michikami, et al. 2019: main conclusioms

① Boulder distribution (global) [above 5m]

The number density of boulders above 10m is higher than that of other asteroids, but the power of the size distribution is relatively gentle at -2.65 (meaning that there are relatively few smaller boulders for each large boulder) → Rubble pile object that has experienced an intense collision. Small rocks are buried.



buried boulders
(Michikami et al., 2019より)

② Number density of rocks by longitude & latitude

Overall, uniform. Slight differences in the east-west direction. The number density of boulders near the equator is small. → Many boulders near the equator are buried.

③ Size distribution of boulders in close-up images (2cm – several m)

The smaller the boulders, the smaller the slope of the power-law.

→ The smaller the boulder, the more are buried.

④ Shape of boulders (bi-axial ratio)

Smaller boulders or those closer to the equator have an average axial ratio (b/z) that is closer to the collision debris shape. → these have moved more.

6. Other topics

Award winner!

COOL JAPAN Conference

- Winner of「COOL JAPAN AWARD 2019」
- For Hayabusa & Hayabusa2
- Award ceremony：5/27, Kyoto Gyoen National Garden

AIRBUS

- Received the “Hayabusa2 Special Award” from Airbus Space Day
- Award ceremony: 6/4、Tokyo Conference Center (Shinagawa)
- AIRBUS was involved in the equipment for the MASCOT lander.

7. Upcoming events

■Operation plans:

- June 11～13：Low altitude descent observation operation (PPTD-TM1B)

■Press & media briefings

- June 25 15:00～： Press briefing session @ Tokyo Office

Press briefing session, part II
（Individual Q & A）

～Investigation and preparation for the second touchdown～

Hayabusa2 Mission Success Criteria

Mission goal	Minimum success	Full success	Extra success
【Science goal 1】 Investigate the material characteristics of C-type asteroids. In particular, clarify the interaction between minerals, water and organic matter.	Provide new insights on the surface material of C-type asteroids by observations in the vicinity of the asteroid.	Obtain new findings on mineral-water-organic interactions by the initial analysis of the collected samples.	Integrate astronomical & microscale information to create new scientific results regarding materials for Earth, sea and life.
【Science goal 2】 Investigate the formation process of asteroids by direct exploration of the asteroid's reaccumulation process, internal structure and subsurface material.	Provide insights on the internal structure of the asteroid by observations in the vicinity of the asteroid.	Obtain new knowledge on the internal structure and subsurface material of the asteroid by observing the phenomena caused by collisions with an impacting body.	・Present scientific results on asteroid formation based on new findings regarding the collision destruction & reaccumulation process. ・New scientific results from the exploration robots on the surface environment of asteroids.
【Engineering goal 1】 Improve robustness, accuracy and operability of the new technology implemented in Hayabusa, and mature it as a technology.	Rendezvous with a target orbit using ion engines for deep space propulsion.	・Drop the exploration robot to the asteroid surface. ・Take a sample of the asteroid surface. ・Collect the re-entry capsule on Earth.	N/A
【Engineering goal 2】 Demonstrate impact object colliding with a celestial body.	Construct a system to allow an impact device to collide with the target object and perform that collision with the asteroid.	Make the impact device collide in a specified area.	Collect a sample of asteroid subsurface material exposed during the collision.

Achieved

Awaiting achievement confirmation

Current aim

Conditions for execution of the 2nd touchdown

Project judgement for whether to perform the second touchdown operation

	Judgement items	Current status	Judged
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	Can we design a sufficiently safe touchdown sequence?	Under consideration.	
Spacecraft status	Is there any problem with the optical system where the amount of light received has decreased due to dust in the first touchdown?	Under consideration.	

Engineering value

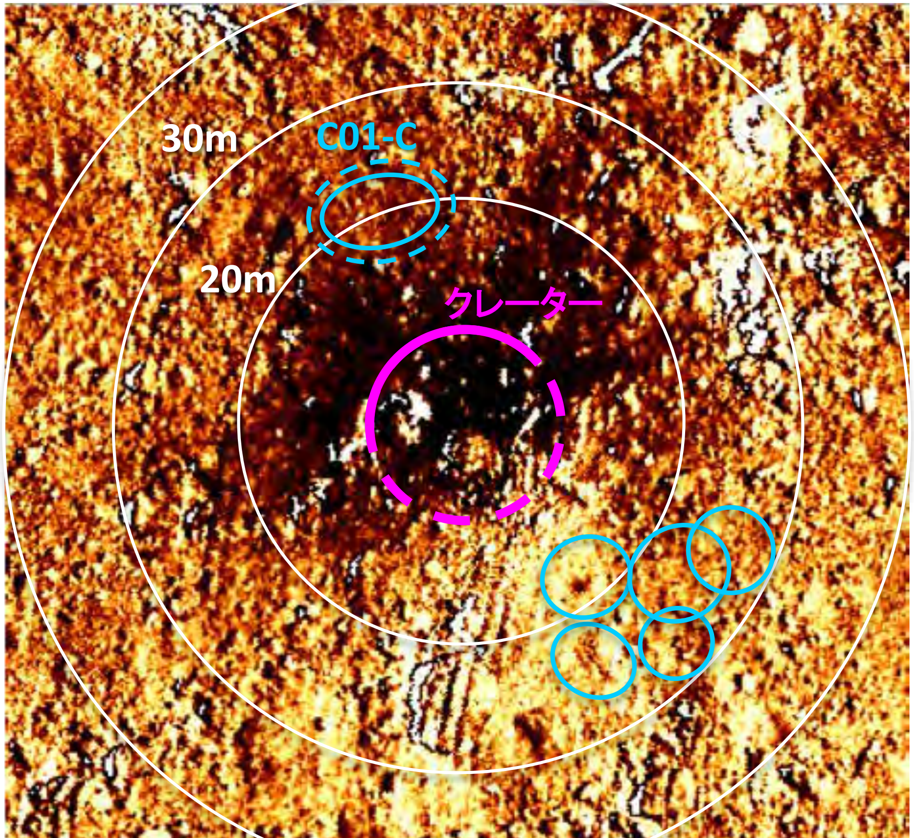
- Multi-sampling (sampling from multiple points on one celestial body) and subsurface sampling (collection of artificial crater ejecta) are challenges that humanity has not yet achieved. It is a technology that can dramatically increases the freedom of space exploration.
- The main technologies related to sample return (electric propulsion navigation, optical navigation, sampling, re-entry) were achieved by Hayabusa, but multi-sampling and subsurface sampling are unexplored technologies that were planned with Hayabusa2, along with artificial crater generation.
- Multi-sampling is an operation that requires comprehensive reliability and technology accumulation, including hardware and software reliability for the spacecraft and operation technology (human skill).

Science value (by Sei‘ichiro Watanabe)

- The second planned touchdown point (C01-C) is close to the SCI crater and there is a high possibility that subsurface material excavated from the crater has been deposited on the surface.
- Subsurface material is a valuable sample as through comparison with the first surface sample collected, it can be used to evaluate the impact of the solar wind and cosmic ray generation on the asteroid surface.
- If degeneration is weak, information regarding the formation period of the Solar System should be acquired in detail. Subsurface materials are particularly valuable for sensitive organics.
- The mixing process and its timescale on the asteroid surface can be constrained.
- The extend of regional heterogeneity of celestial bodies can be clarified from the comparison of multiple point samples.
- OSIRIS-REx excels at sample volume, but only from a single point. If Hayabusa2 can obtain samples from multiple points, it will be an qualitatively unmatched outcome.
- This can be expected to be a valuable sample that will be the key to directly connected Hayabusa2 science (remote observation, collision experiment, returned sample analysis).
- Collecting several samples successfully will prove that the sampling operation of Hayabusa2 has been established with high reliability.

Ejecta from the SCI near C01

(by Seiji Sugita)



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Terrain created by adjusting lighting conditions in the ONC image. (JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST)

New

Expectation for the second touchdown from material analysis science （by Hikaru Yubata）

■ Reveal the cause of the “black substance” characteristic of Ryugu

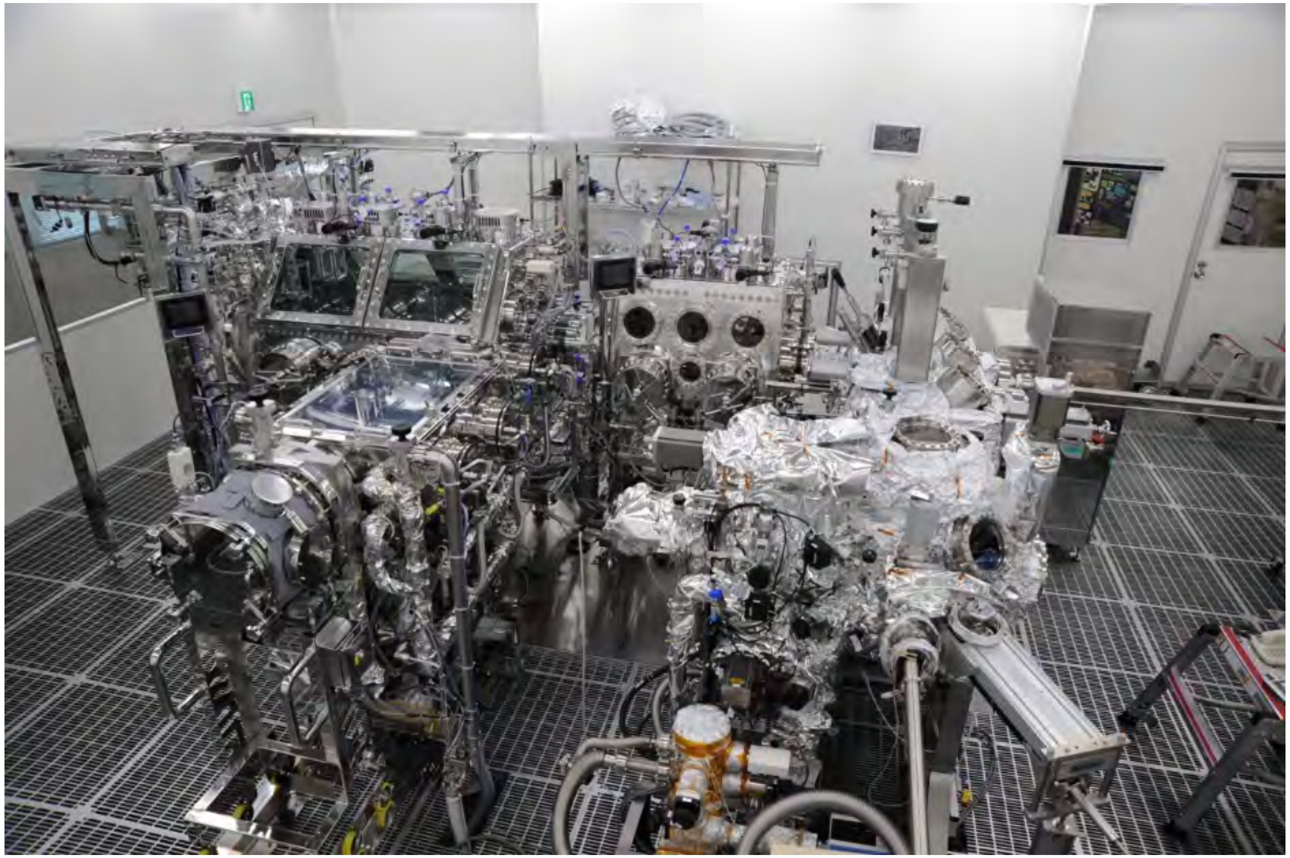
- The reflectance of the Ryugu surface is lower than that of any known meteorite and various possibilities have been speculated as to its origin (organic carbon composition, iron sulphide / iron oxide composition, modification by heat and space weathering, particle size etc). The fact that the reflectivity is lower in the artificial crater than at the surface suggests that the black material may be a component before being subjected to surface modification, or it may be a product of the SCI collision experiment. Chemical analysis of a second sample is essential to clarify the cause.

■ High quantity of (possibly) organic chemical information

- Amino acids, carboxylic acids, hydrocarbons, nucelobases etc, are hardly detected (reported in the 80-90s) in carbonaceous meteorites that that undergone heating (similar in spectrum to the surface material of Ryugu). In addition to this, thermal decomposition and carbonization of insoluble high molecular weight organic compounds occur. Therefore, if a weakly modified sample can be collected during a second touchdown, the type and quantity of organic molecules obtained will increase, and the acquisition of clues to clarify the origin of the Solar System and life will be overwhelmingly improved.
- From the surface sample collecting in the first touchdown, we may discover new kinds of organic molecules that can be synthesized (not only decomposed) by solar heating and space weathering. Analysis of a subsurface sample will be very important as a comparison to understand the formation process.
- During observations, organic matter has not been identified. For Hayabusa2, sample analysis is the only means of organic matter characterization.

Hayabusa2 clean chamber for receiving the returned sample

（by Masanao Abe）



（credit: JAXA）