Asteroid explorer, Hayabusa2, reporter briefing

June 25, 2019

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2,

- Results from the low altitude descent observation operation（PPTD-TM1B）
- Decision on the 2nd touchdown operation
- The 2nd touchdown operation

Contents

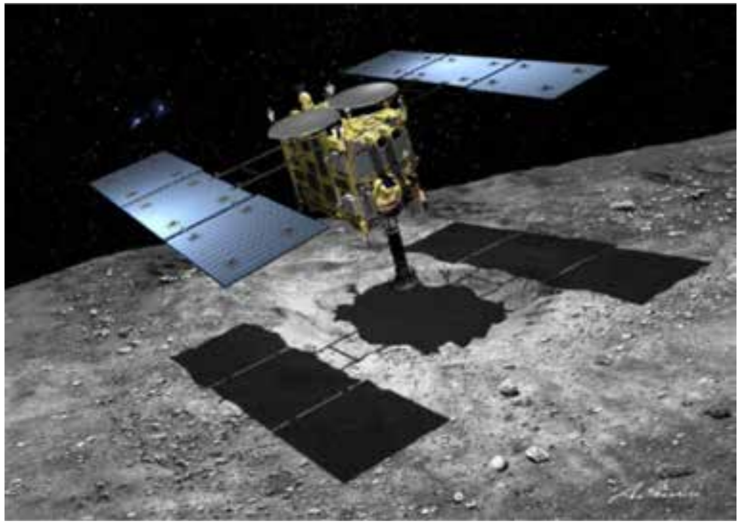
Overview of Hayabusa2

<u>Objective</u>
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.

<u>Expected results and effects</u>
- 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.

<u>Features:</u>
- 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.

<u>International positioning:</u>
- 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)

<u>Hayabusa 2 primary specifications</u>

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.

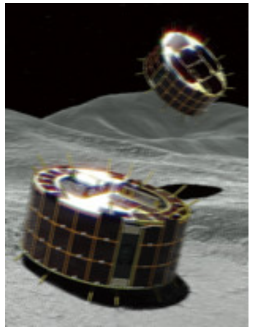
Mission flow

Launch
Dec 3, 2014

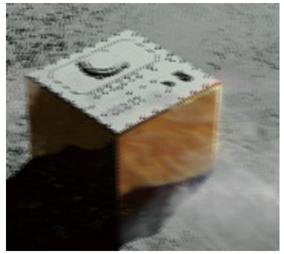
Earth swing-by
Dec 3, 2015

Ryugu arrival
June 27, 2018

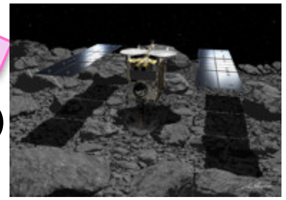
MINERVA-II-1 separation
Sep 21, 2018



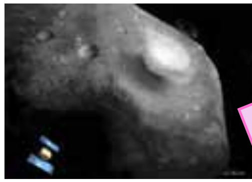
MASCOT separation
March 10, 2018



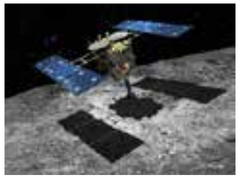
Feb 22, 2019



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

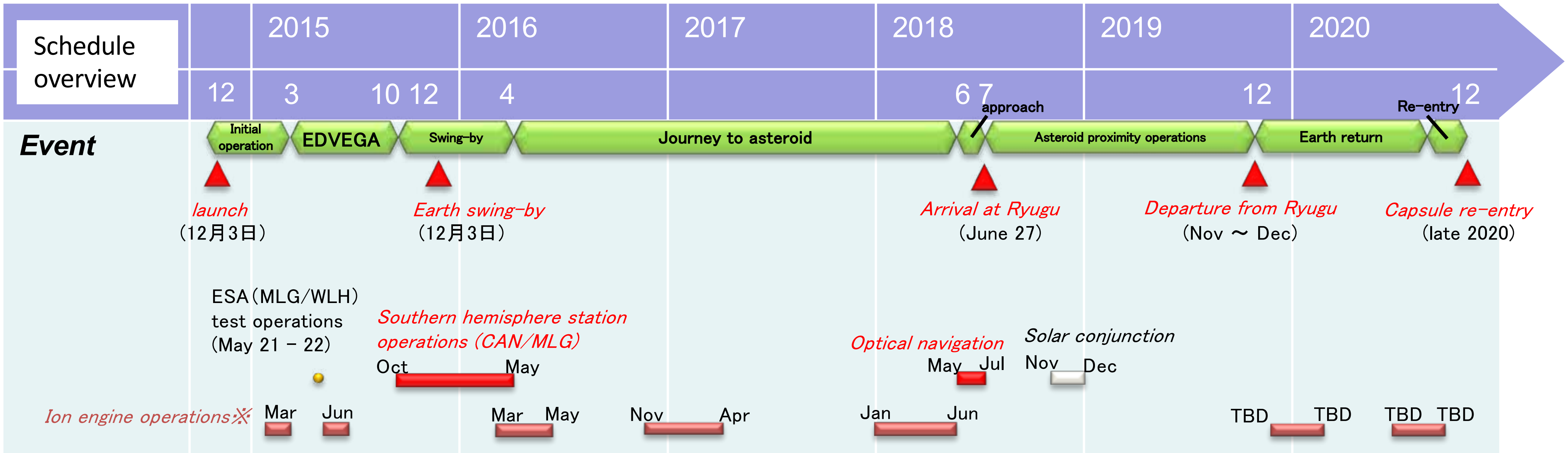
Earth return
End of 2020

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

1. Current project status & schedule overview

Current status :

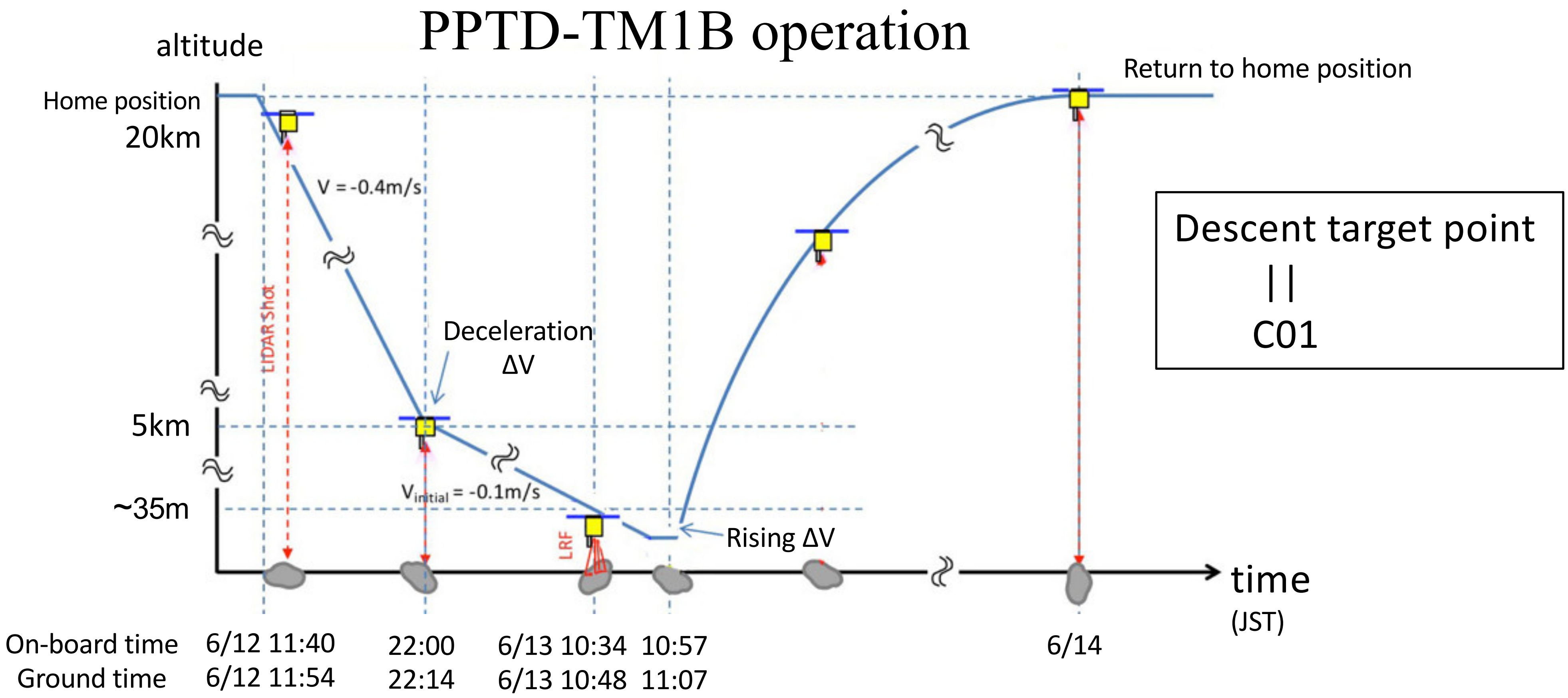
- From June 11 ~ 13, the low altitude descent observation operation (PPTM-TM1B) was performed.
- The spacecraft descended to an altitude of about 9m above the CO1 area, and observed the surface of Ryugu.
- Preparation is now underway for the second touchdown.



2. Low altitude descent observation operation (PPTD-TM1B) results

- The low altitude descent observation operation (PPTD-TM1) was performed between June 11 ～13.
- Preparations were made for the descent (June 11) which began on June 12 11:40 JST (on-board time) and reached an altitude of about 35m on June 13 at 10:34 JST. The spacecraft then hovered around this altitude.
- The descent began again at 10:43 JST and reached an altitude of 9m at 10:53 JST, after which the spacecraft began to rise (PPTD-TM1B did not separate a target marker).
- The spacecraft returned to the home position on June 14.
- In this operation, we observed near the area CO1 and the crater generated with the SCI.
- We also acquired data for the spacecraft operation checks at low-altitude.

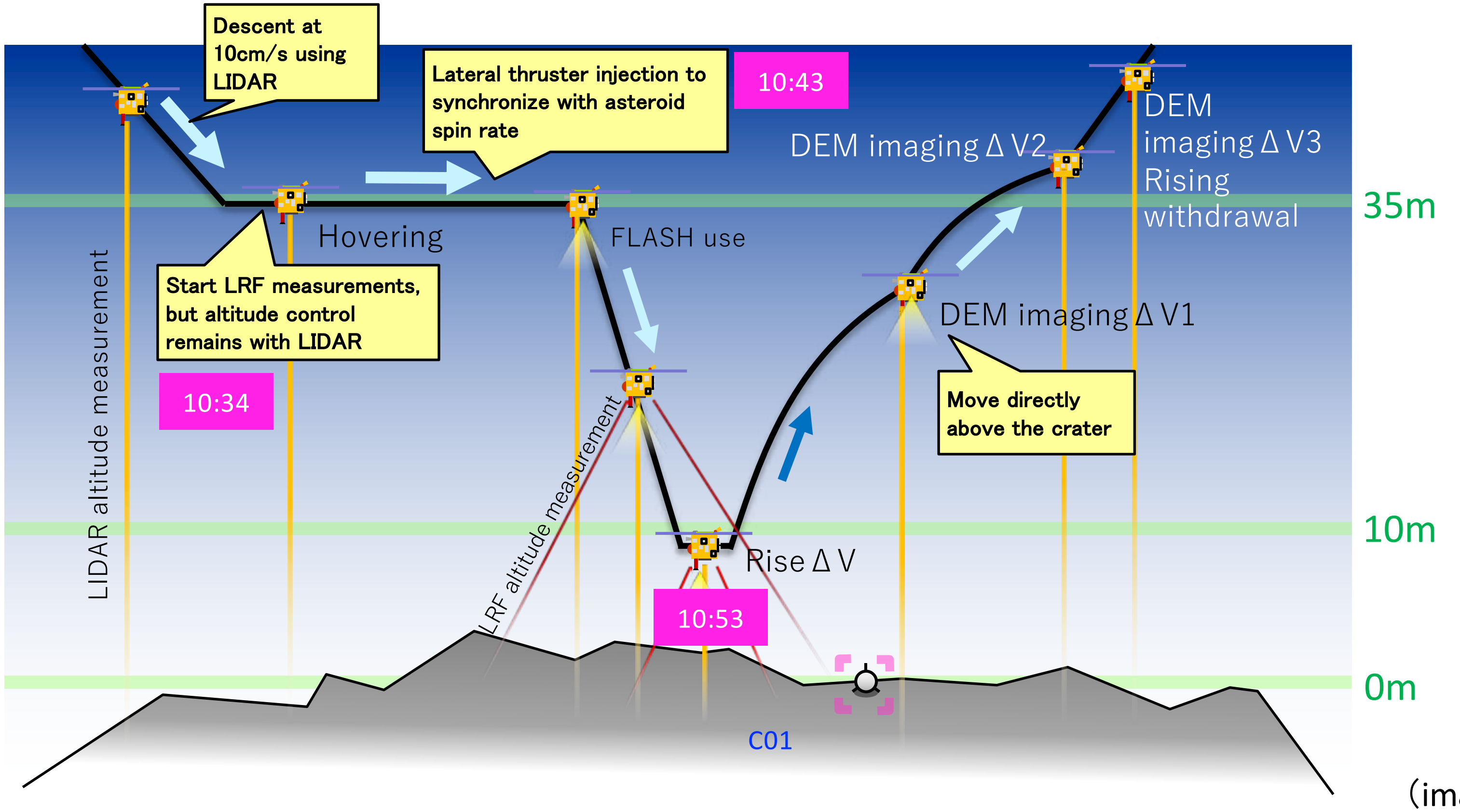
2. Low altitude descent observation operation (PPTD-TM1B) results



(image credit: JAXA)

2. Low altitude descent observation operation (PPTD-TM1B) results

Low altitude sequence for PPTD-TM1B



※Time is the onboard time on June 13, 2019 in JST

(image credit: JAXA)

2. Low altitude descent observation operation (PPTD-TM1B) results

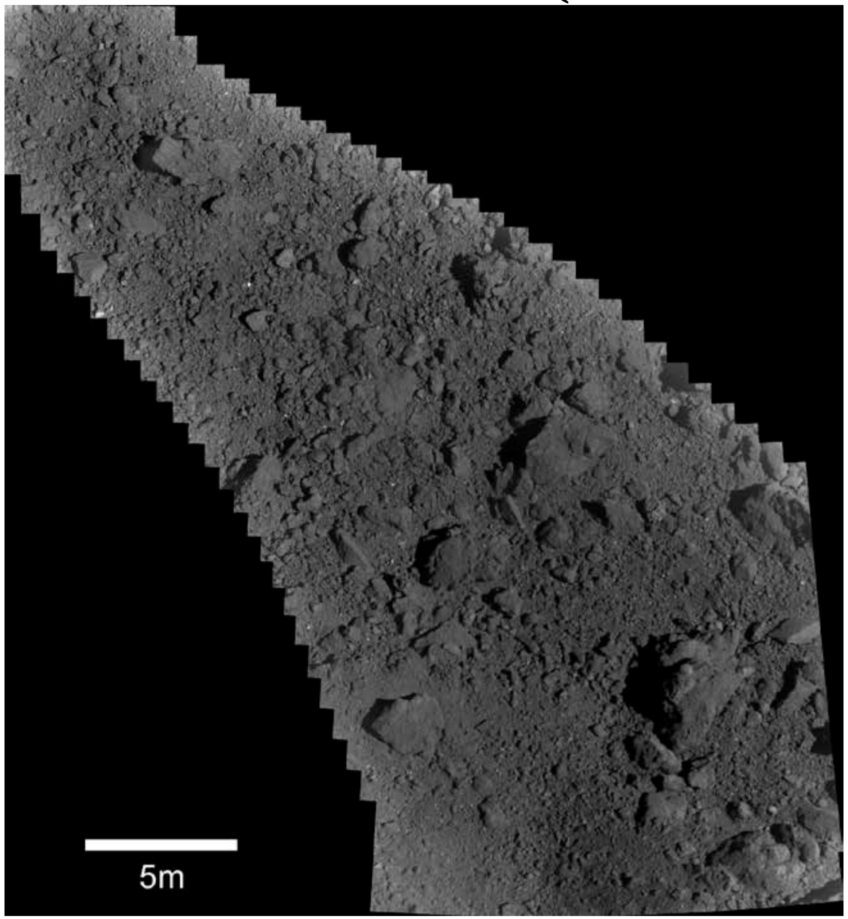


Image taken on June 13, 2019 during the PPTD-TM1B operation. This is a composite of 28 images taken at 7 second intervals from 10:58 JST, on-board time (upper left) to 11:01 (lower right) using the Optical Navigation Camera – Telescopic (ONC-T). The altitude is about 52m at the beginning of the composite and 108 at the end. The white point in the upper-left-center is the target marker. This shows detailed images can be acquired continuously from the target marker to the edge of the artificial crater in the lower right of the screen.

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

3. Decision on the 2nd touchdown

- Based on the detailed study of the results from the Hayabusa2 project, JAXA/ISAS have decided to conduct the second touchdown.
- Touchdown operation will be performed from July 9 〜11 (touchdown on July 11).
- The back-up week for the touchdown operation will be the week of July 22 (Note 1).
- Judgement considerations for touchdown:
  - ➢ High scientific value of a subsurface sample collection
  - ➢ Confirmation of the feasibility of a sufficiently safe touchdown operation by the spacecraft in its current condition.
  - ➢ Confirmation that there is no hindrance to subsequent operations even if the amount of light received by the optical system is further reduced during the second touchdown.

Note 1）The temperature conditions on the asteroid were investigated in detail, particularly at the touchdown point. It was determined that touchdown was possible for solar distances more than 1au (about 150 million km) → touchdown is possible until the end of July.

3. Decision on the 2nd touchdown

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?	Confirm that a sufficiently safe touchdown sequence can be designed ※	○※
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?	Confirm that the reduction in received light in the optical system does not affect touchdown operation ※	○※

※Update from last press briefing (6/11)

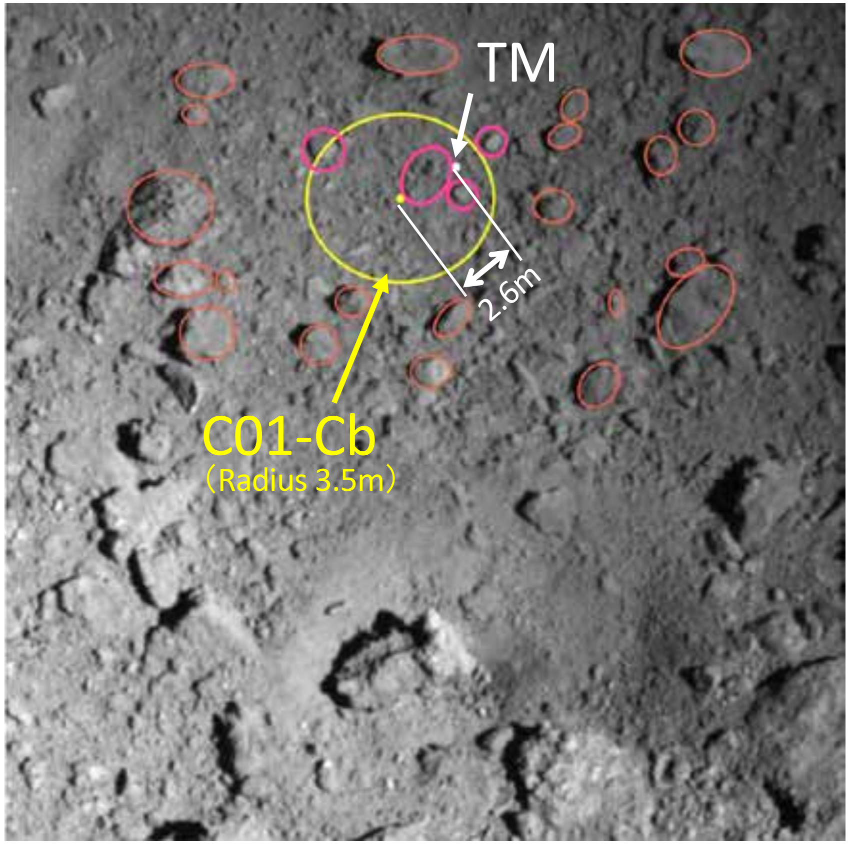
4. The 2nd touchdown operation

- 2nd touchdown operation： July 9～11
- Touchdown date: July 11、around 11 JST
- Touchdown location：C01-Cb（target marker drop area）

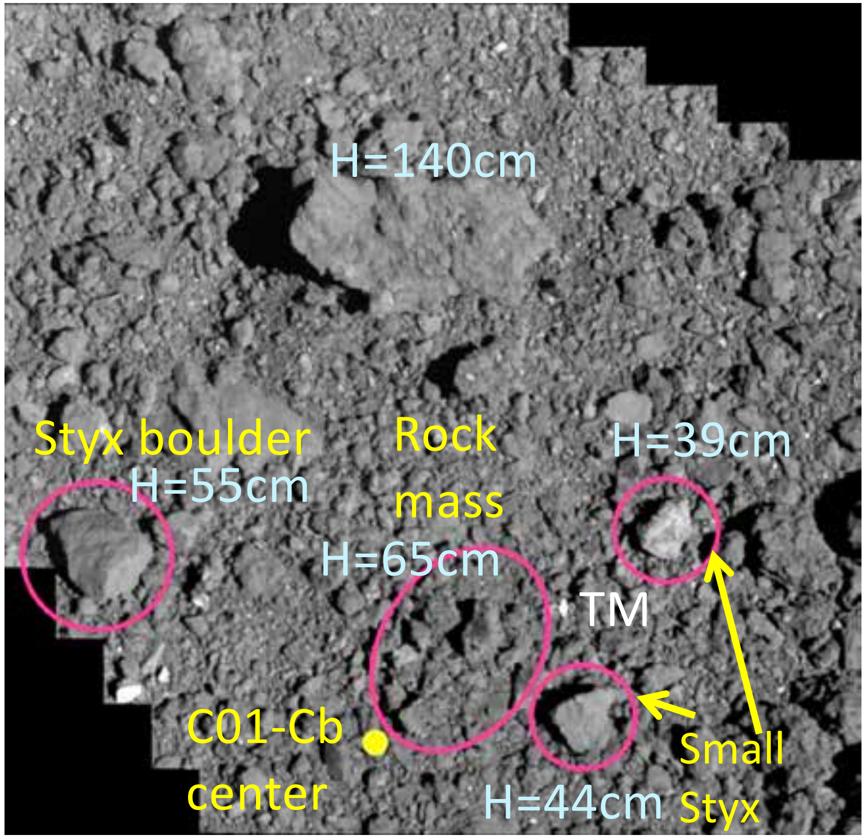
※ We refer to this as the ”2nd touchdown” but the operation is denoted PPTD.

4. The 2nd touchdown operation

PPTD-TM1 image



PPTD-TM1B image



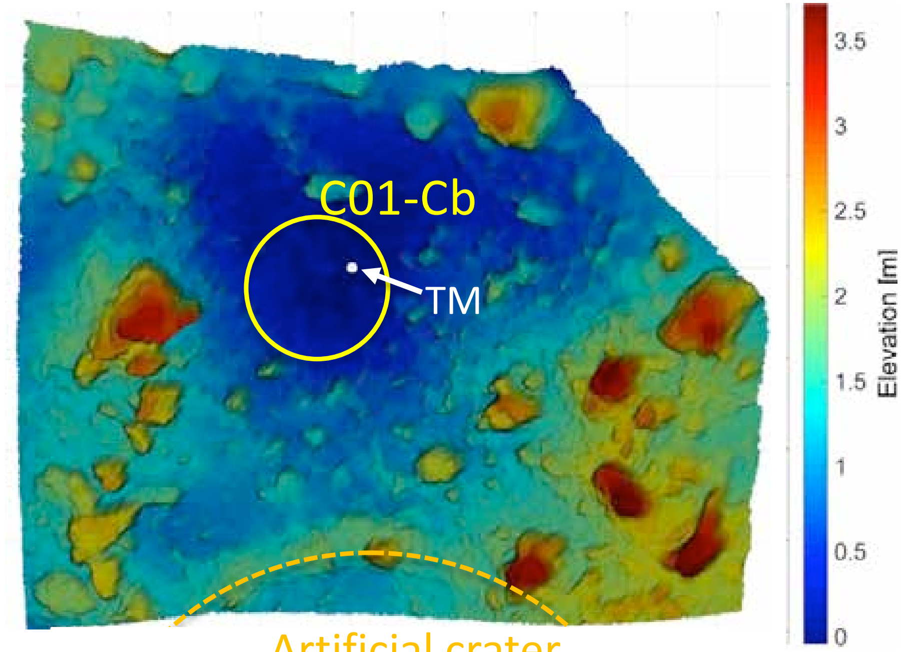
H is the highest estimated height value (worst scenario)

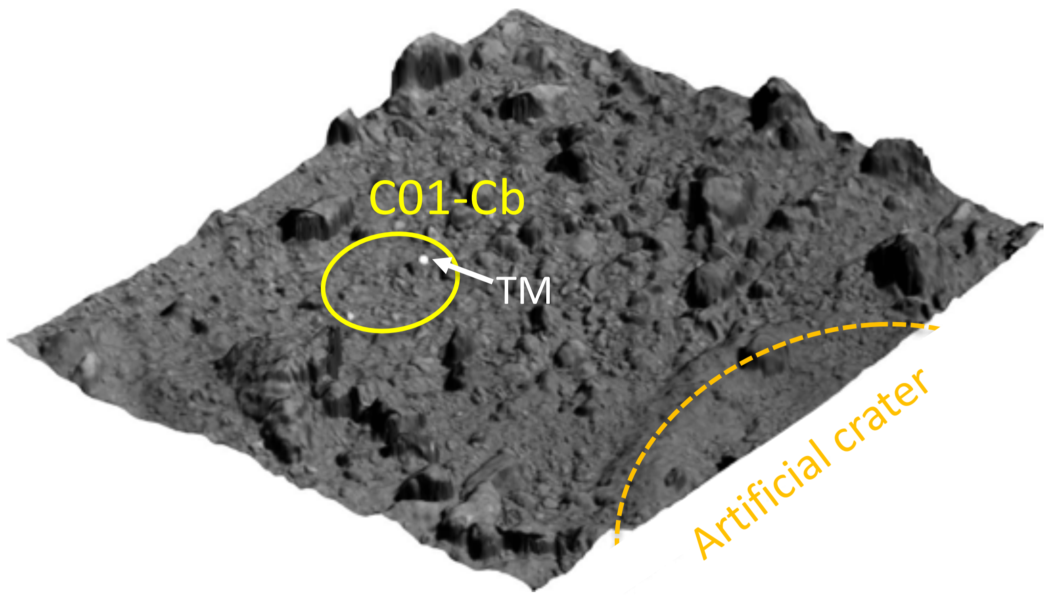
※ Boulder names are nicknames, not official names

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

4. The 2nd touchdown operation

C01-Cb area





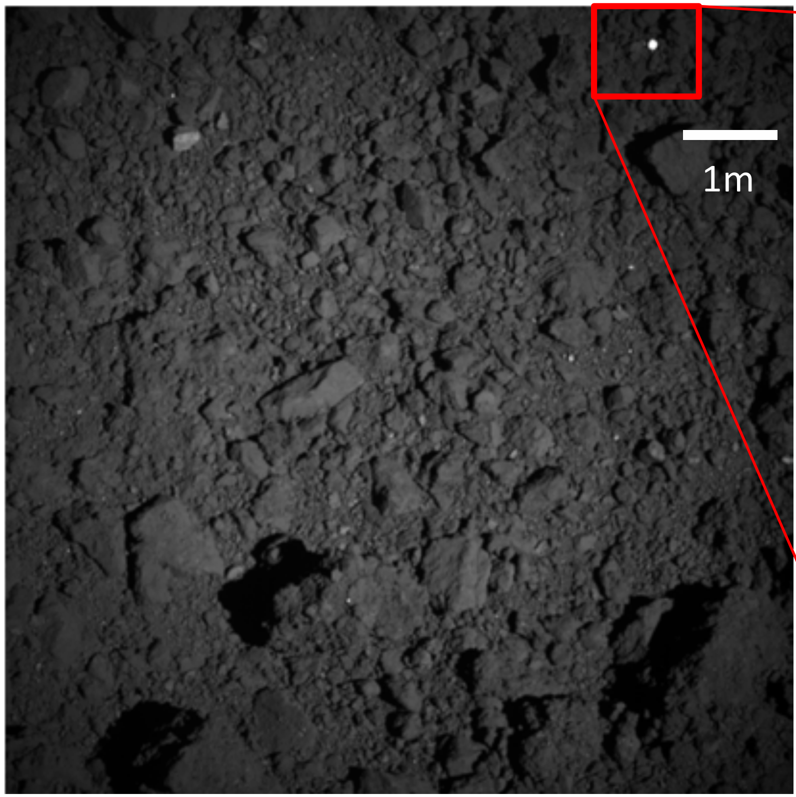
DEM（Digital Elevation Map）near the touchdown candidate point

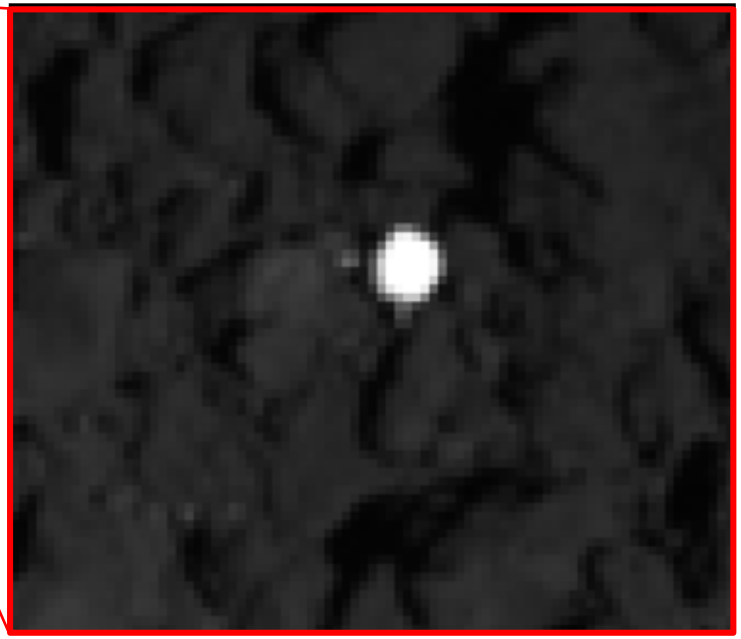
（image credit：JAXA）

4. The 2nd touchdown operation

Images taken with the ONC-T while rising during PPTD-TM1A

New

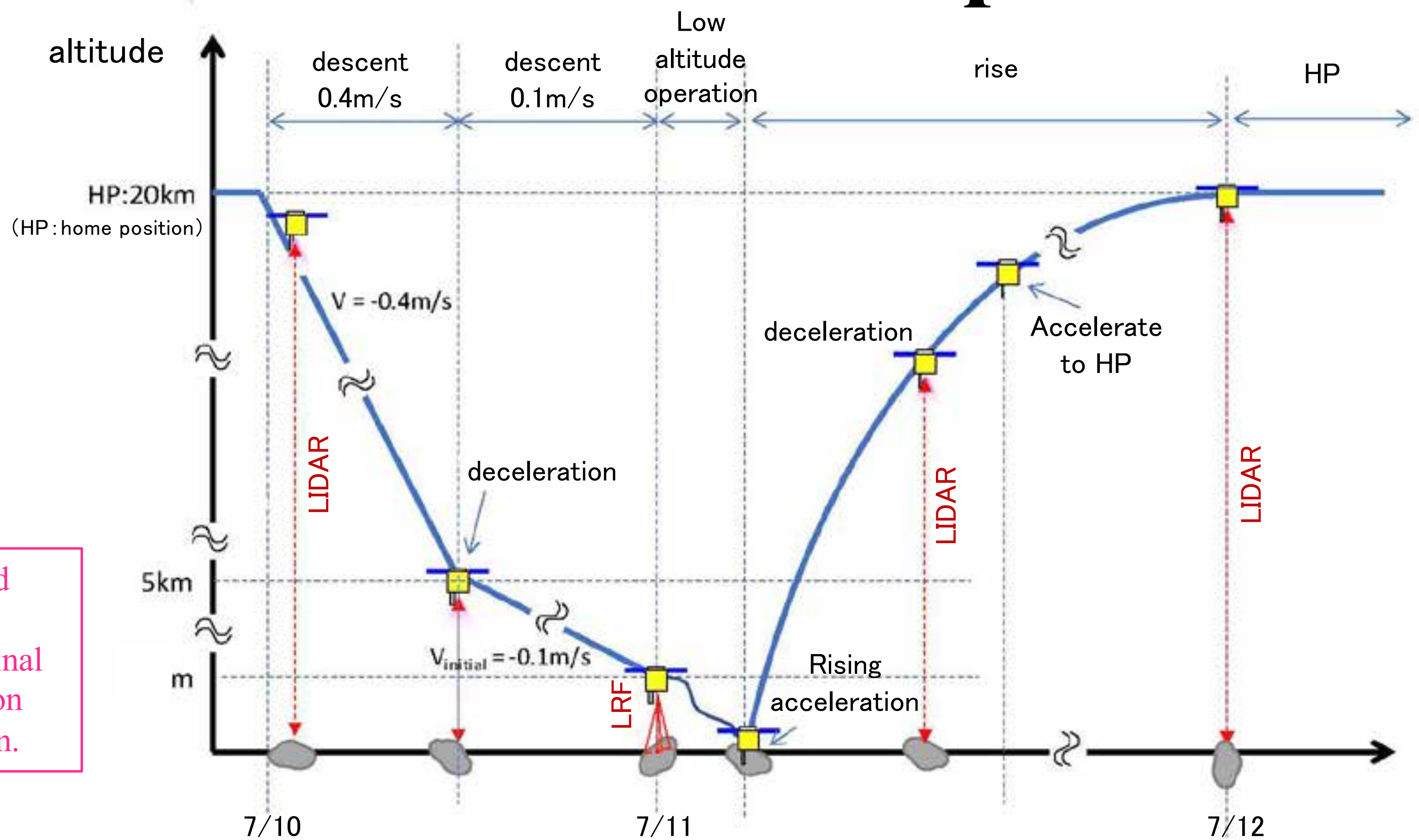




2019/05/30 11:26 JST (onboard time)
Altitude: 71 ～72m

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

4. The 2nd touchdown operation



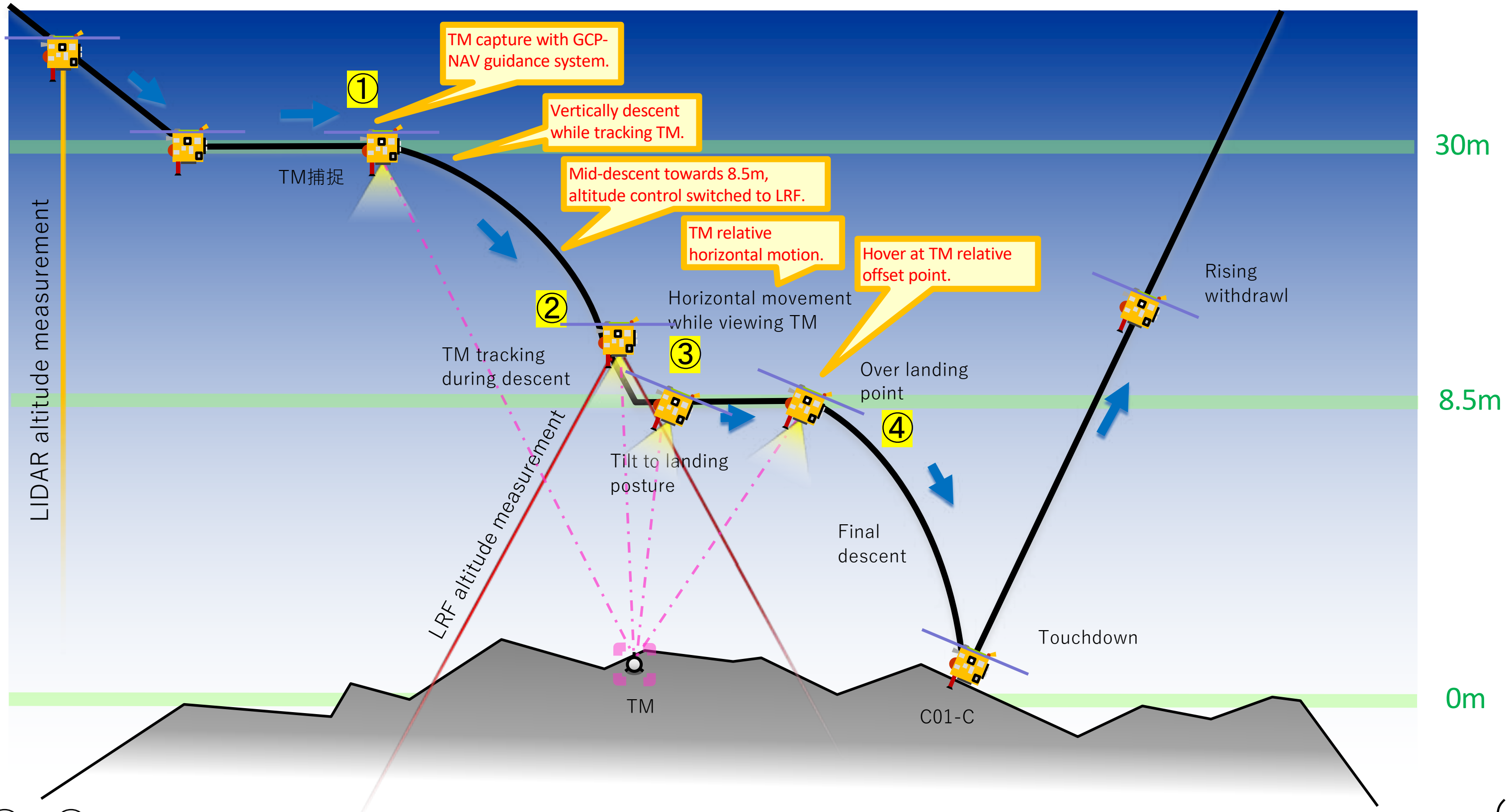
※Times are not fixed and may change depending on the final plan and situation on the day of operation.

Date & time:	On-board time Ground time	~10:00	~20:00	~11:00

(image credit : JAXA)

4. The 2nd touchdown operation

Low altitude sequence



※①～④ checkpoints for autonomous judgements as to whether Hayabusa2 continues to the next sequence.

（image credit：JAXA）

4. The 2nd touchdown operation

Changes from the 1st touchdown sequence

- To counter the cloudiness of the optical system at the base of the spacecraft, the altitudes to begin tracking the TM and using LRF were set lower than in TD1.
  - The safety design either maintains or strengthens the level of TD1. As a result, the sampling achievement probability is slightly reduced.
- To shorten the sequence, the spacecraft attitude will switch to tail-up immediately after reaching an altitude of 8.5.
  - This is streamlined based on experience from TD1. In TD1, tail-up was just before the final descent.
- As the TM and landing point are very close this time, the final descent for touchdown will be a vertical descent.
  - This improves landing accuracy. As the TM was further away during TD1, the final descent had to be diagonally downwards.

For other touchdown sequence design highlights, please refer to press briefings before the 1st touchdown (February 6 & 20, 2019)
http://www.hayabusa2.jaxa.jp/en/enjoy/material/

5. Upcoming events

■Operation plans

- July 9～11：2^{nd} touchdown operation

■Press & media briefings

- July 9：Regular press briefing @ Tokyo office
- July 11: Press Center Opened @ Sagamihara Campus

Reference material

Hayabusa2 Mission Success Criteria

Mission goal	Minimum success	Full success	Extra success
【Science goal 1】 Investigate the material science 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 from 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

Engineering value

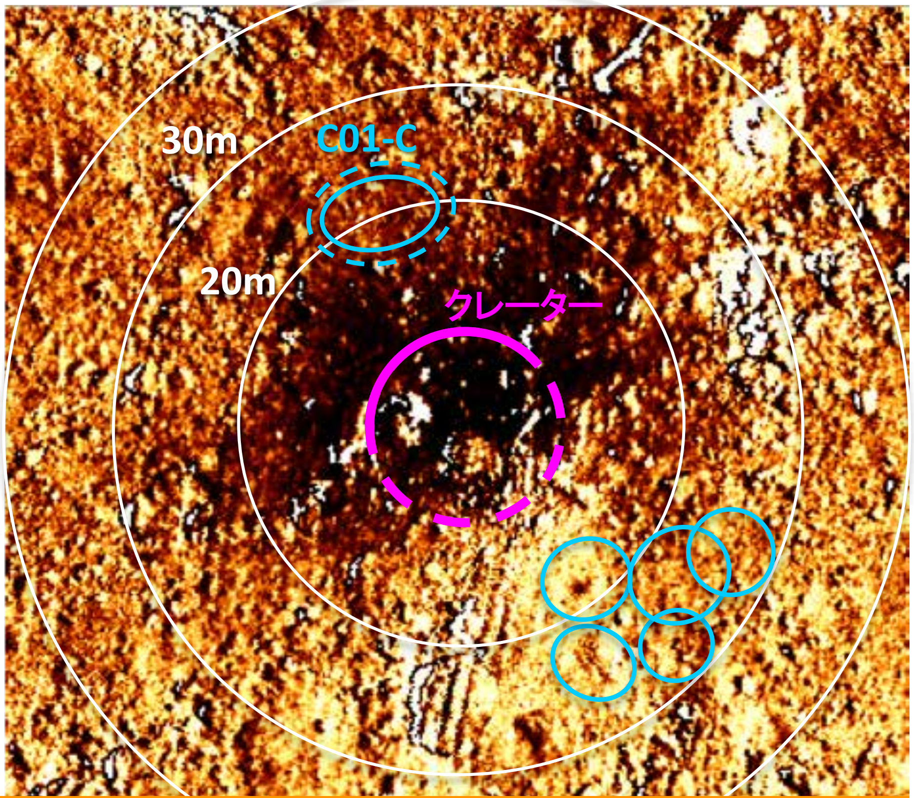
- Multi-sampling (sampling from multiple points on one celestial body) and subsurface sampling (collection of artificial crater ejecta) are challenges that humanity has not yet achieved. It is a technology that can dramatically increases the freedom of space exploration.
- The main technologies related 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

- The second planned touchdown point (C01-C) is close to the SCI crater and there is a high possibility that subsurface material excavated by 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 can 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.

（by Sei'ichro Watanabe）

Ejecta from the SCI near C01



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

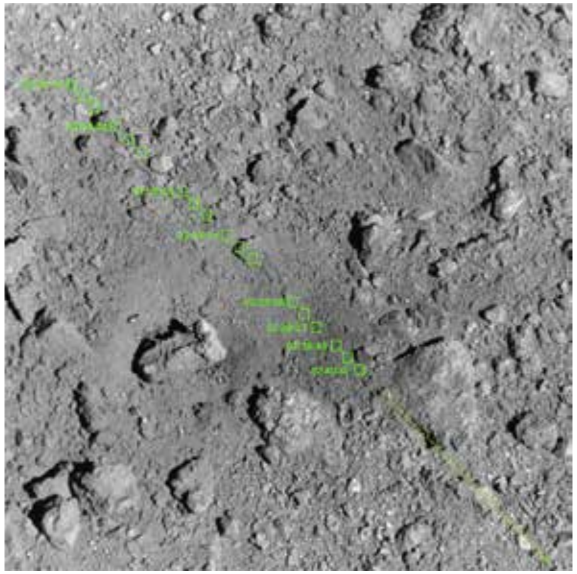
- Ejecta from the SCI crater (darker colors than the surface) is distributed all over the PPTD candidate site, C01-C.
- The average thickness of the ejecta in C01-C is estimated at about 1cm, based on the spatial distribution of the darkening. C
- The C01-C ejecta is thought to be a mix of excavated 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.

（by Seiji Sugita ）

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)

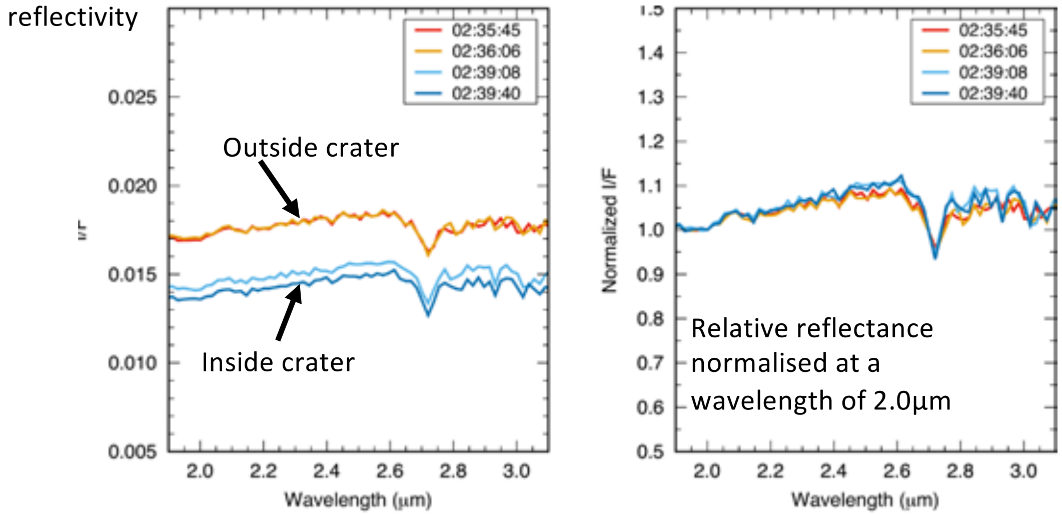
SCI crater observation by NIRS3

New



NIRS3 footprint（PPTD-TM1A)

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



NIRS3 reflection spectrum inside and outside the SCI crater (data from TM1A) （image credit：JAXA、University of Aizu）

- Part of the SCI crater was successfully observed at high resolution during the PPTD-TM1A/B operations.
- Similar to with the ONC, the reflectivity of the crater tends to be lower than the surroundings.
- No significant difference in the characteristics of the 2.7µm absorption, which indicates the presence of hydrated minerals, inside and outside the crater.

（by Kohei Kitazato)

Expectation for the second touchdown from material analysis science

■ Reveal the cause of the "black substance" characteristic of Ryugu

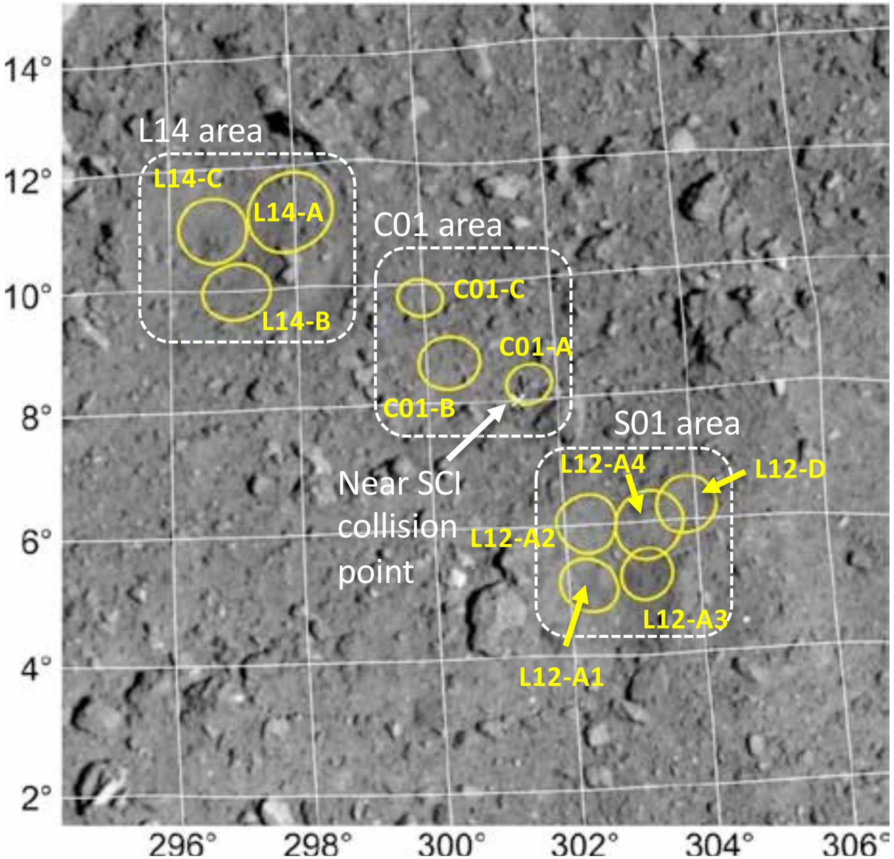
- The reflectance of the Ryugu surface is lower than that of any known meteorite and various possibilities have been speculated as to its origin (organic carbon composition, iron sulphide / iron oxide composition, modification by heat and space weathering, particle size etc). The fact that the reflectivity 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.

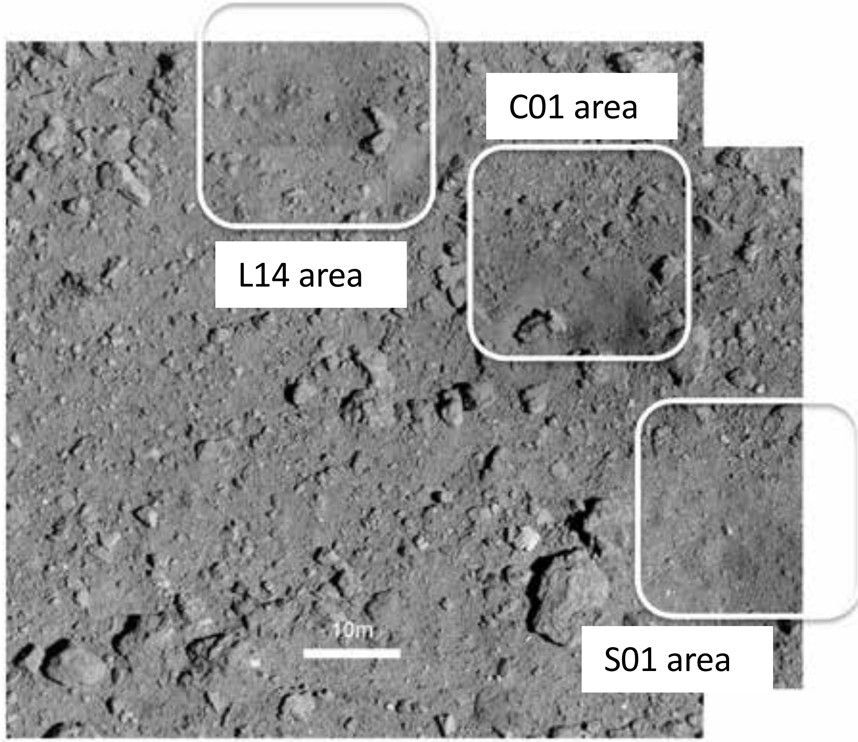
■ High quantity of (possibly) organic chemical information

- 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). This is in addition to thermal decomposition and carbonization of insoluble high molecular weight organic compounds. 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.

(by Hikaru Yubata)

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)