Asteroid explorer, Hayabusa2, reporter briefing

February 20, 2019

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2:

- Touchdown operation plan
- Images from the BOX-B operation (first release)

Since the content presented today is nearly the same as for the press briefing on February 6, today we will focus on Q&A. We hope you find this useful for coverage on February 22nd.

Contents

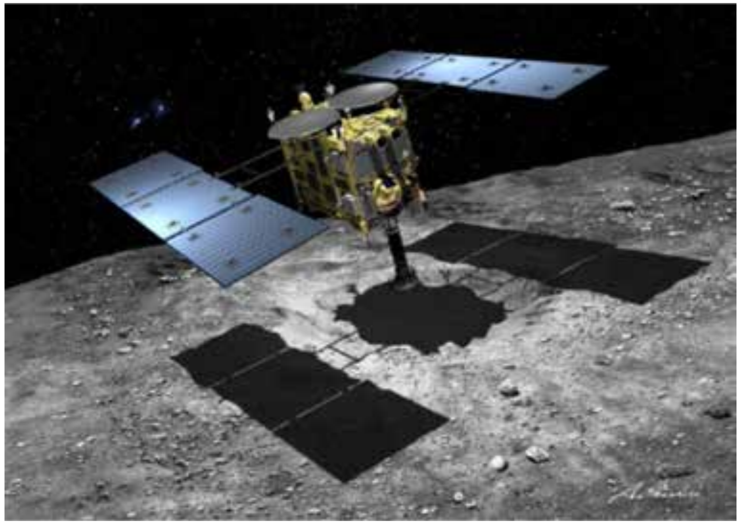
Overview of Hayabusa2

<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

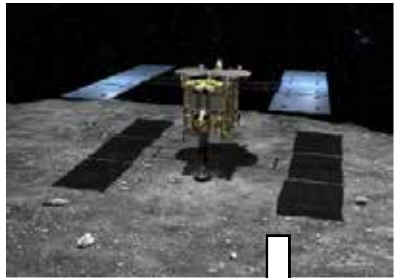
Launch → Arrival at asteroid

3 Dec 2014

Earth swing-by
3 Dec 2015

June 27, 2018

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

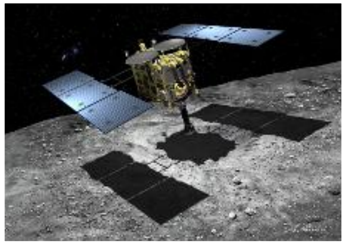


Earth return ← Depart asteroid

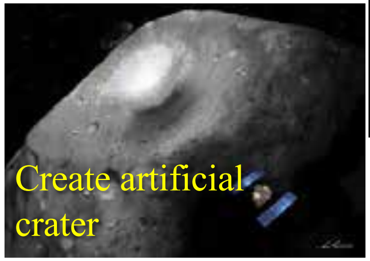
late 2020

Nov–Dec 2019

Sample analysis



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



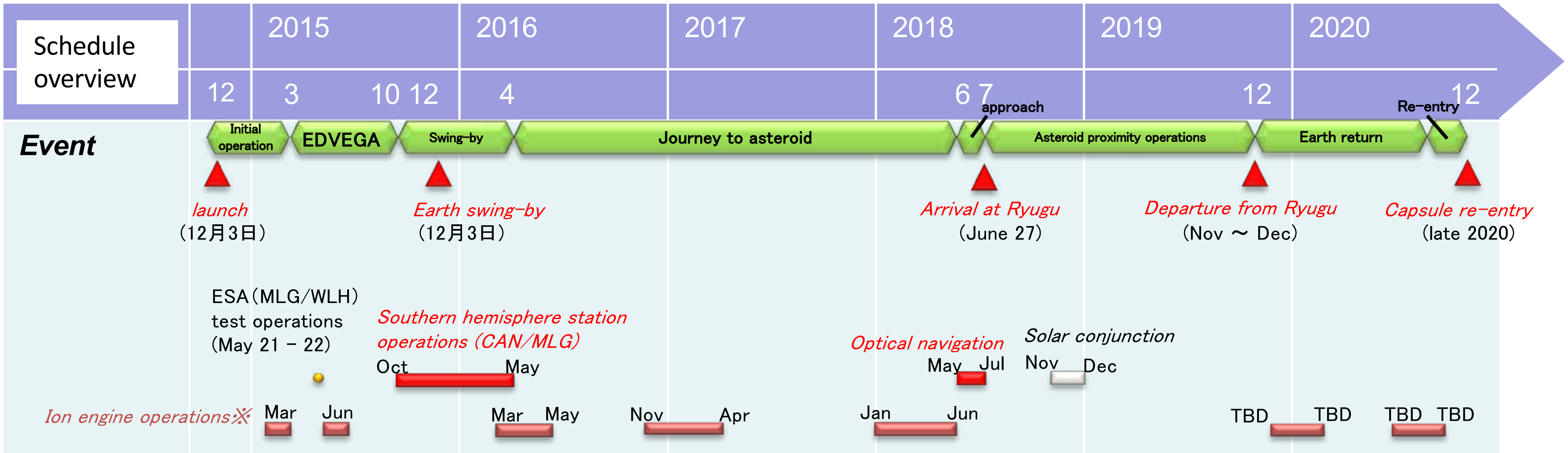
Use an impactor to create an artificial crater on the asteroid's surface

(Illustrations: Akihiro Ikeshita)

1. Current project status & schedule overview

Current status :

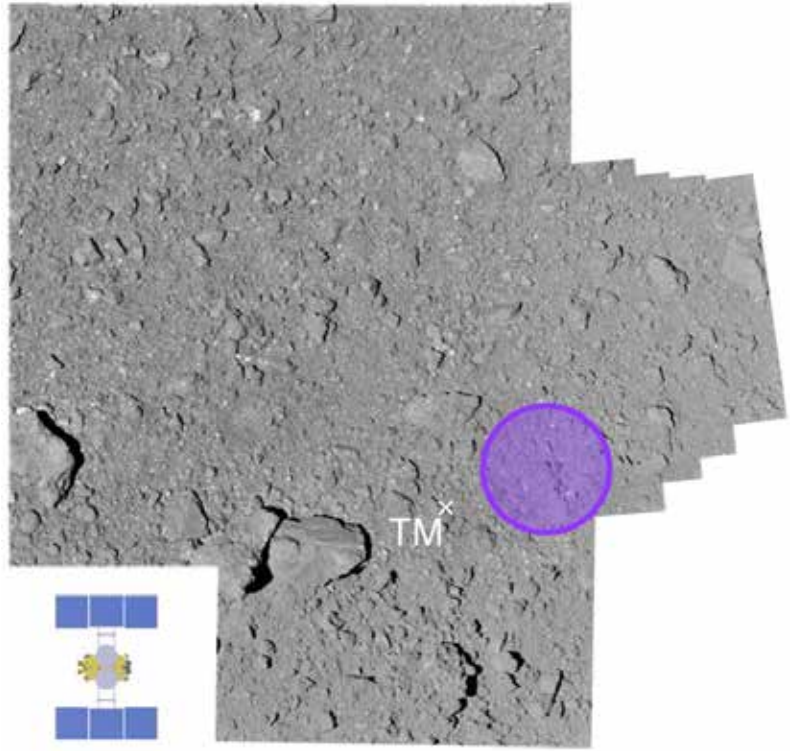
- Preparation for the descent operation for touchdown.
- Touchdown operation will be from February 20 ~ 22 (start of the touchdown operation is from today).



2. Touchdown operation plan

outline

- Touchdown (TD) date & time
  Feb 22, 2019 about 8am
- Touchdown operation
  Feb 20 ～ 22, 2019
  （Begin descent：2/21 ～ 8am）
  （All times are in JST）
- Touchdown location
  In the circle (radius 3m) in L08-E1
- Target marker (TM)
  Use pinpoint touchdown method with TM-B that is already dropped.



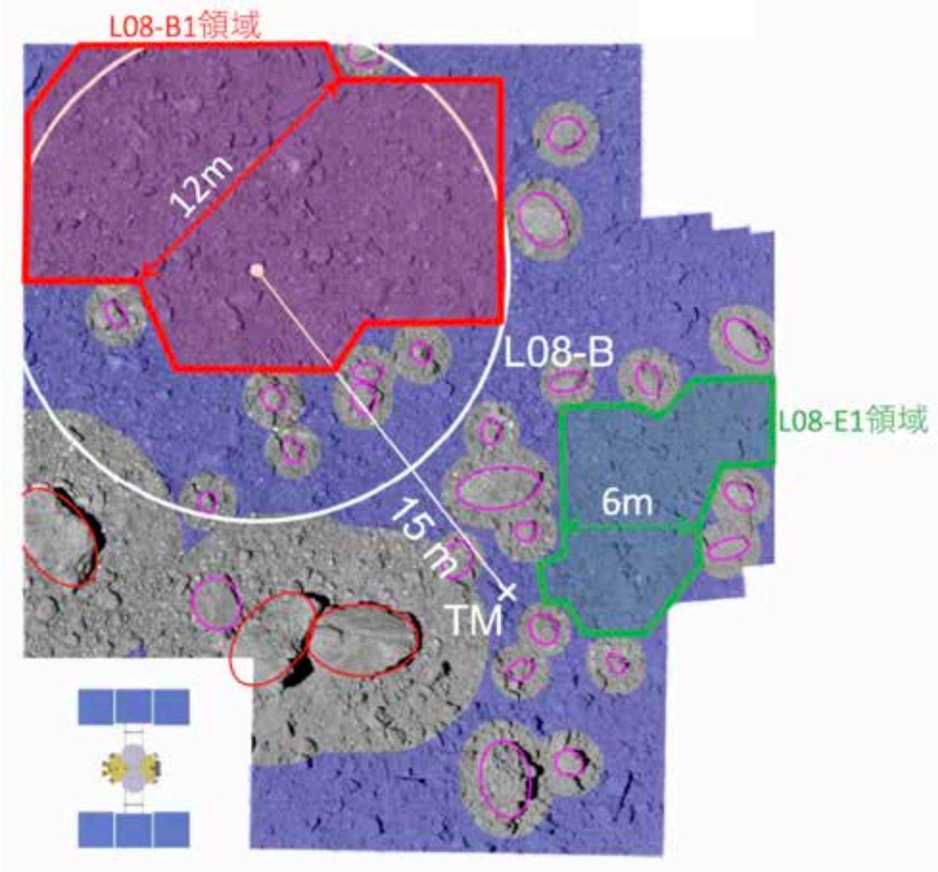
Touchdown candidate site. TM indicates the position of the target marker.

（Image credit：JAXA）

2. Touchdown operation plan

The region around the target maker

L08-B1 and L08-E1 were selected as the touchdown candidate site.

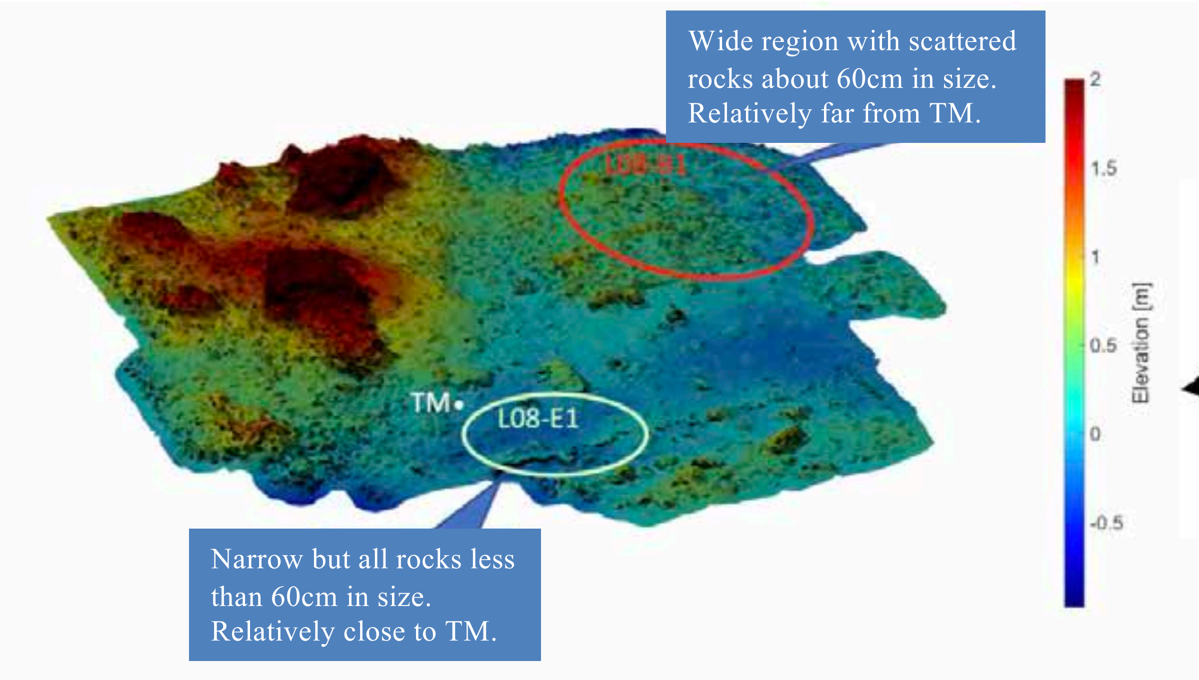


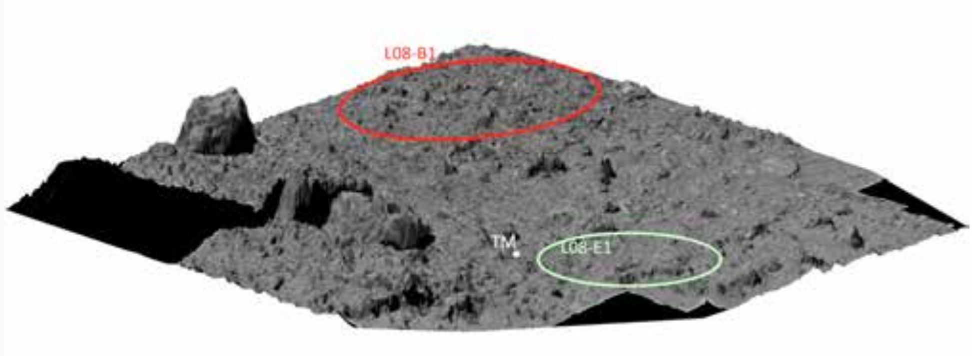
TM-B position and touchdown candidate site

（Image credit：JAXA）

2. Touchdown operation plan

L08-E1 area

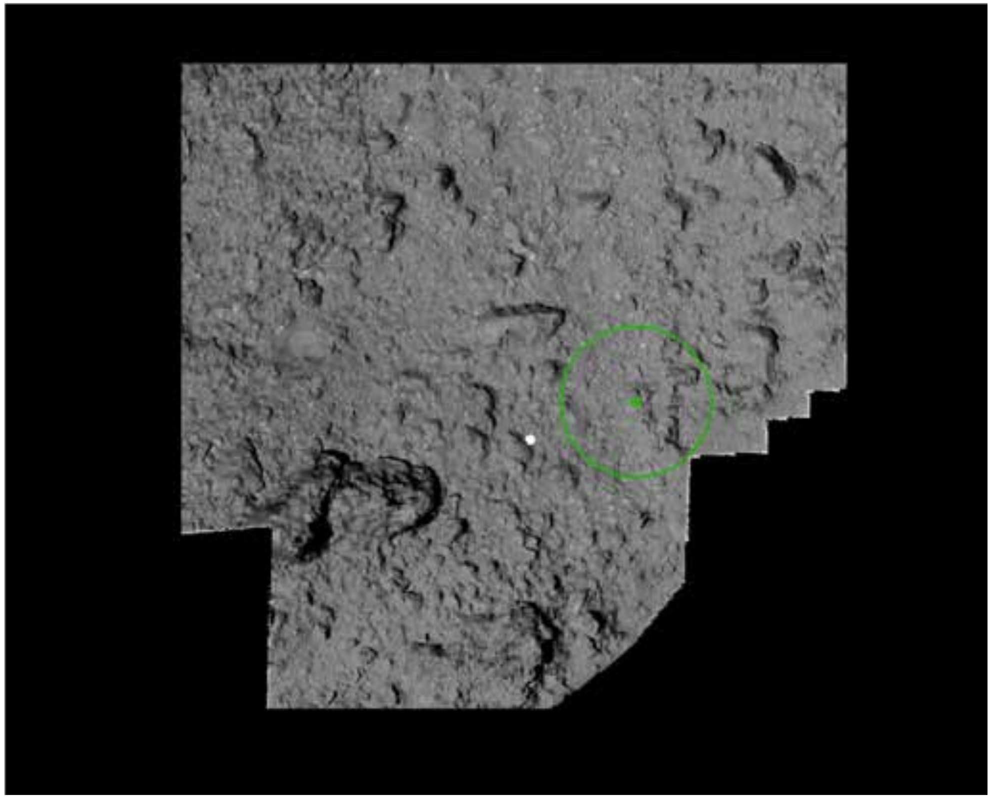




A DEM（Digital Elevation Map）near the touchdown candidate site （image credit：JAXA）

2. Touchdown operation plan

L08-E1 area

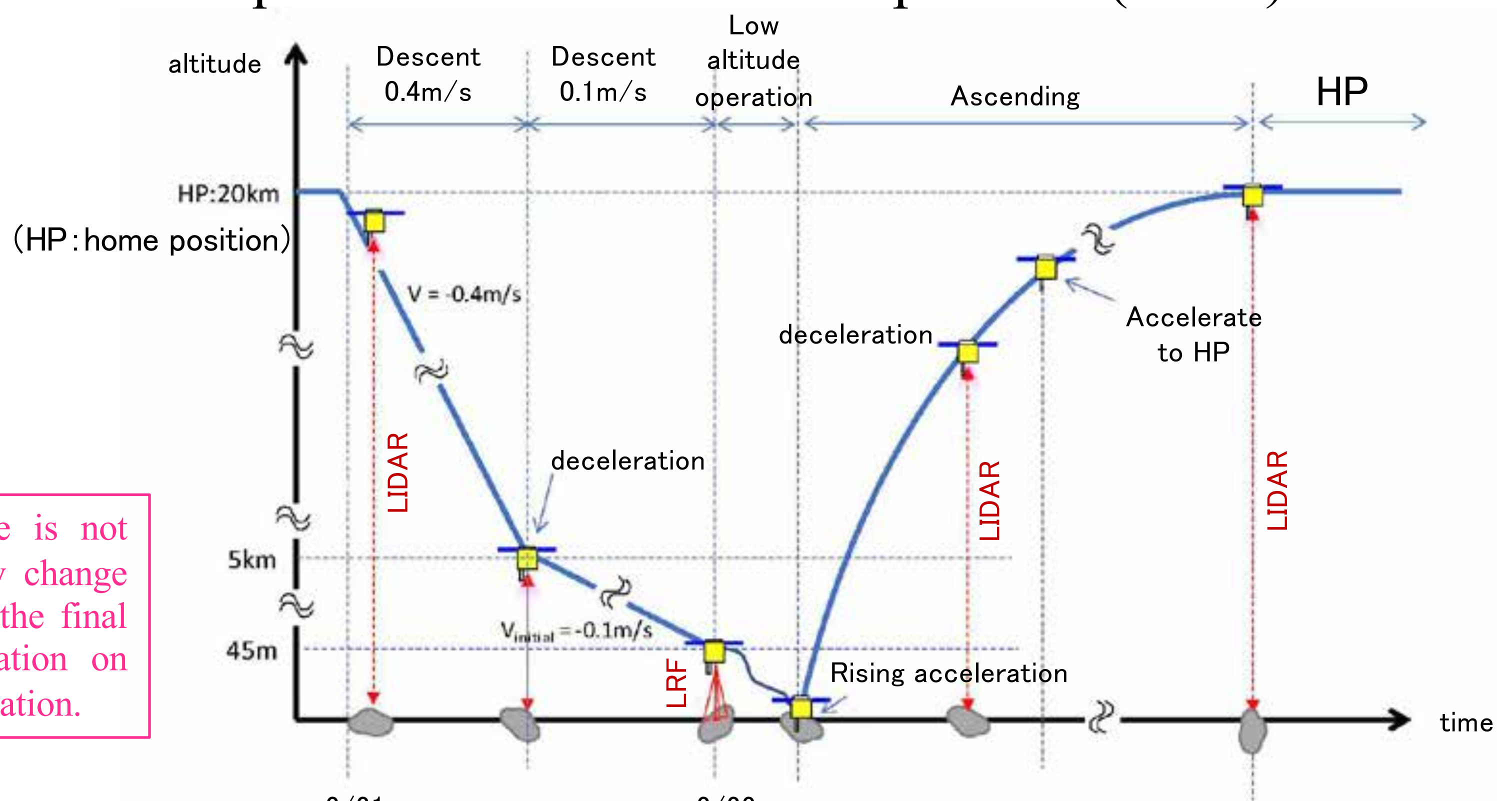


（animation）

A DEM（Digital Elevation Map） near the touchdown candidate site （image credit：JAXA）

2. Touchdown operation plan

Sequence of the touchdown operation (entire)



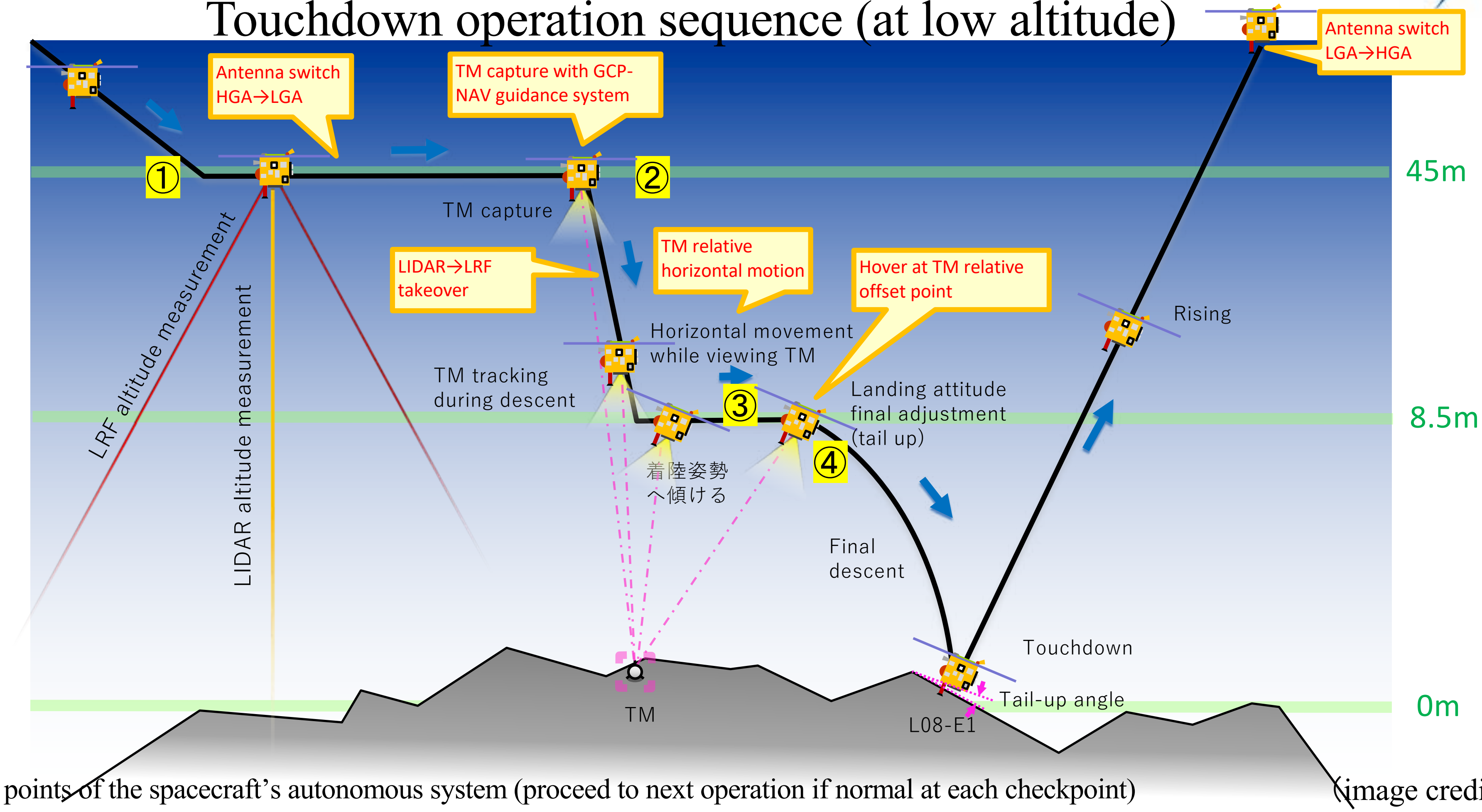
※Indicated time is not fixed and may change depending on the final plan and situation on the day of operation.

Time		2/21		2/22			
	On-board time	08:13	18:33	07:08	08:06	11:08	19:18
	Ground time	08:32	18:52	07:27	08:25	11:27	19:37

(image credit: JAXA)

2. Touchdown operation plan

Touchdown operation sequence (at low altitude)

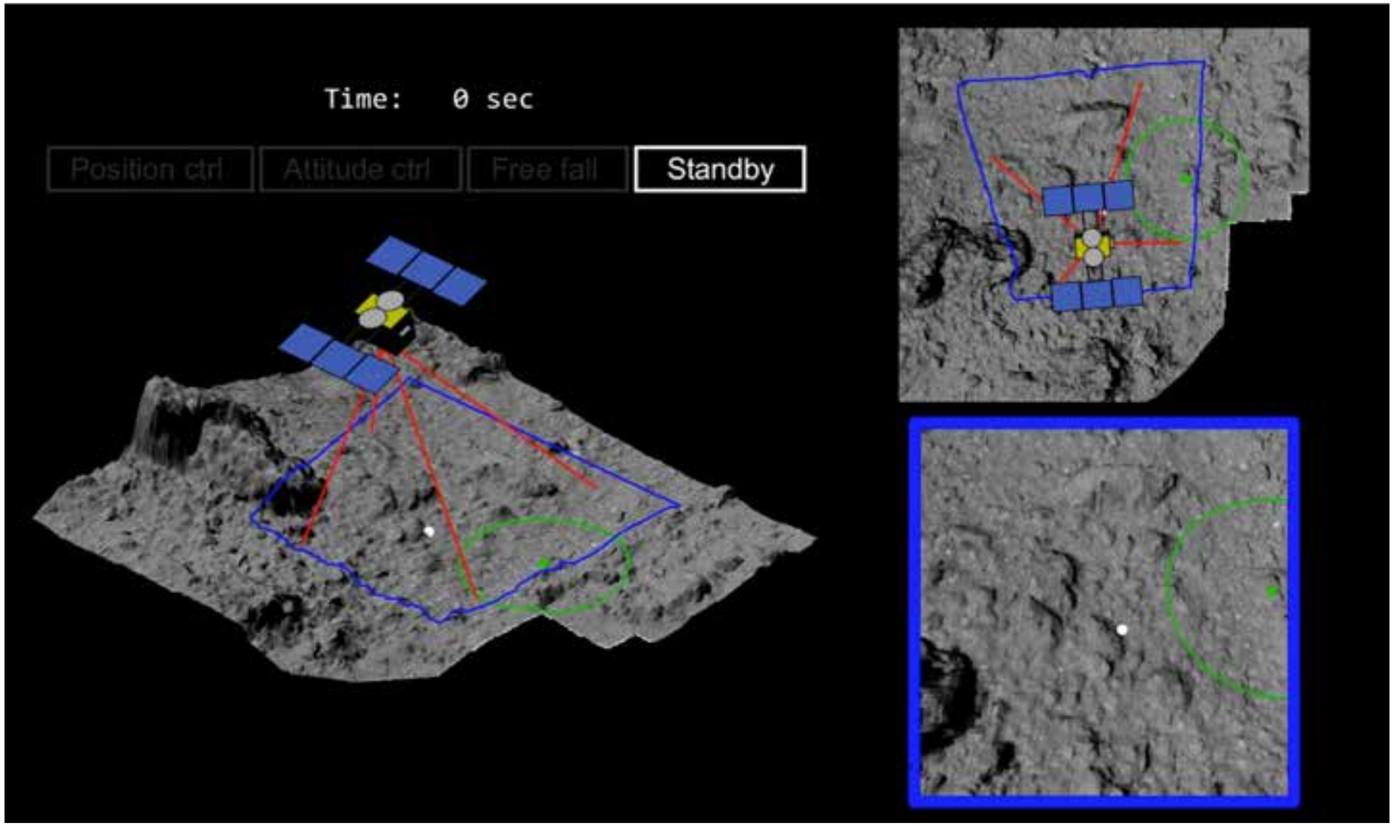


①~④:Check points of the spacecraft's autonomous system (proceed to next operation if normal at each checkpoint)

(image credit:JAXA)

2. Touchdown operation plan

Motion of the spacecraft directly before touchdown (animation, speed x10)

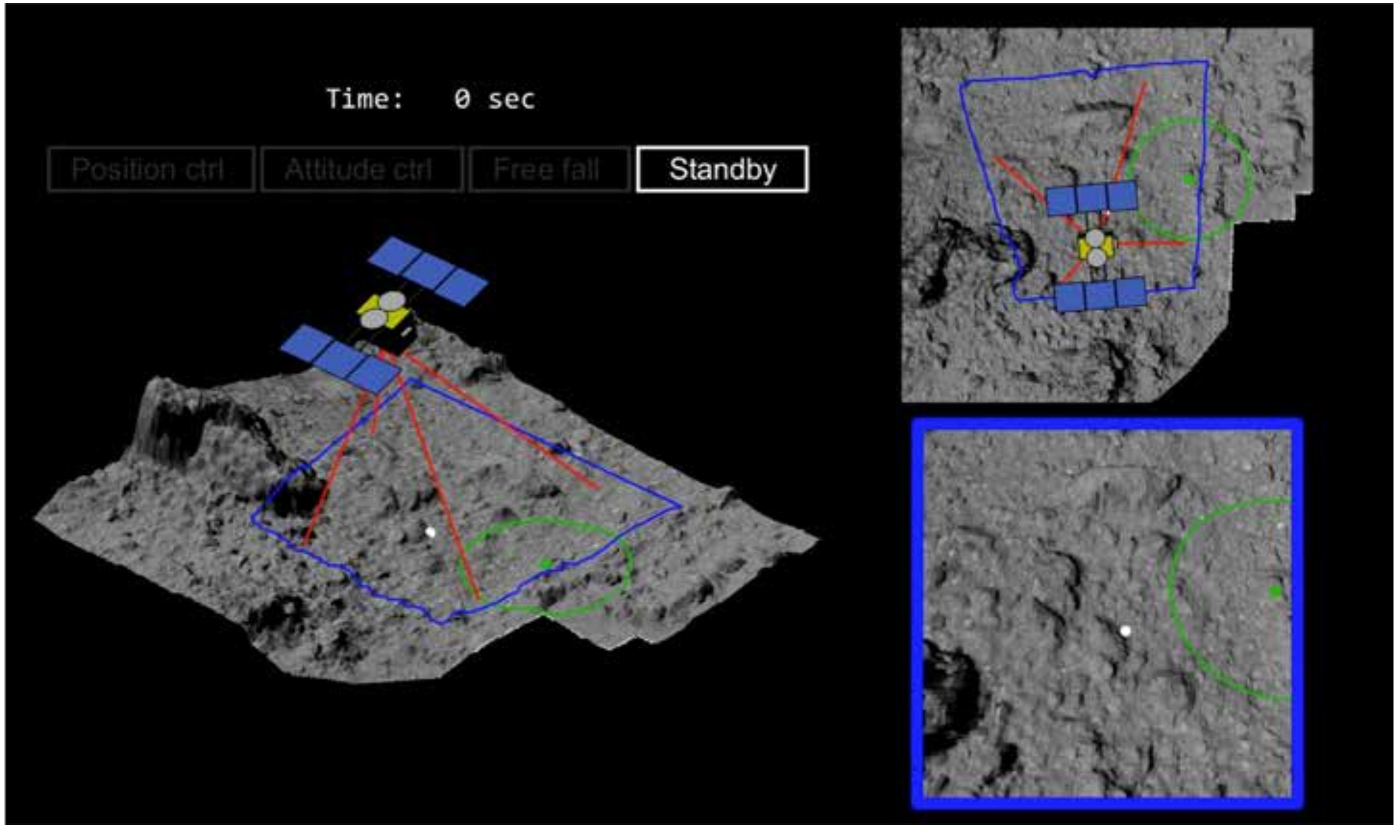


※Since we are currently tuning the position and posture, these will change in the future.

(image credit：JAXA)

2. Touchdown operation plan

Motion of the spacecraft directly before touchdown (animation, speed x1)



※Since we are currently tuning the position and posture, these will change in the future.

(image credit: JAXA)

2. Touchdown operation plan

Touchdown operation points

Initial plan:

→ Assumed $100m^2$ possible touchdown area

- Hayabusa touchdown method
- Target marker is used to adjust the horizontal component of the spacecraft's motion to the velocity of the asteroid surface.
- In addition to measuring the altitude with the LRF, the spacecraft attitude will be rotated parallel to the asteroid surface by the measurement of LRF.

⇒

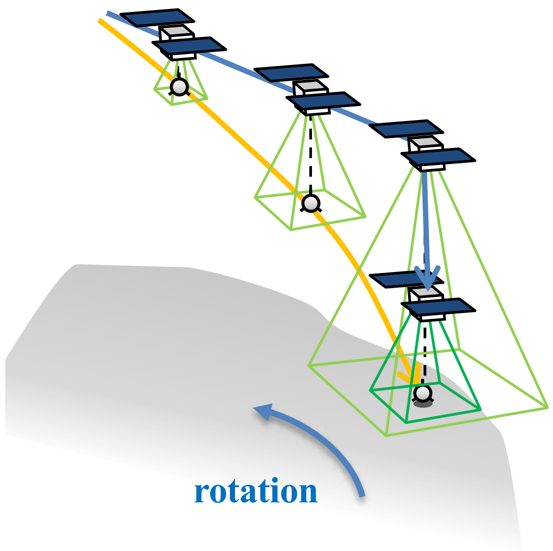
Reality:

→ For a touchdown area about 6m wide

- Pinpoint touchdown method
- Control the spacecraft relative to the position of the target marker on the asteroid surface.
- LRF is used for altitude measurement and safety confirmation but not for attitude control.
- Attitude set based on planned values.

2. Touchdown operation plan

Hayabusa2 pinpoint touchdown feature

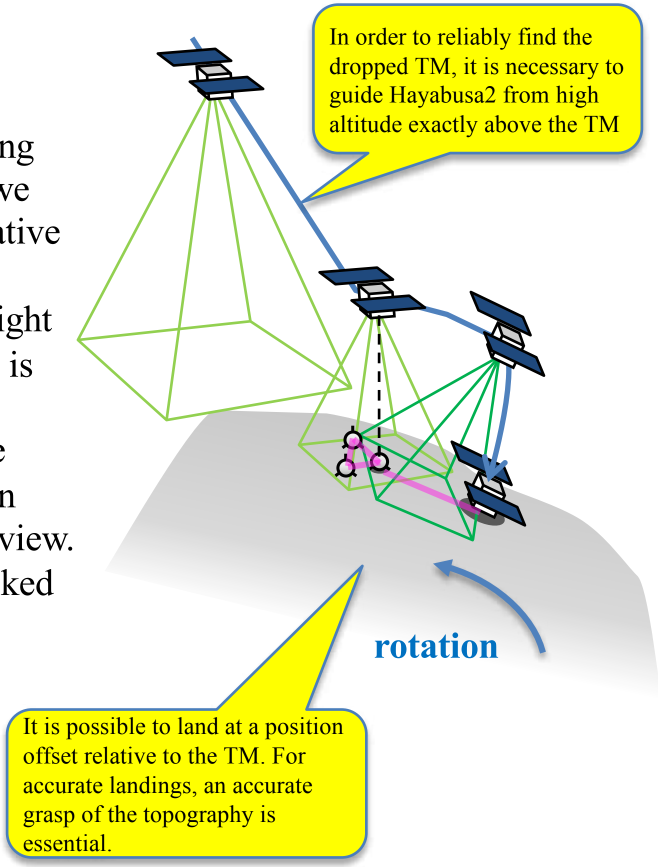


“Hayabusa” method

- By tracking the descending TM after its separation, we can land with a zero ‘relative speed’ to the ground.
- By recognising the TM right after separation, tracking is relatively easy.
- Altitude is lowered while always keeping the TM in the center of the field of view.
- Only one TM can be tracked at a time.

⇩

- Landing accuracy is determined by the TM dropping accuracy. .



“Pinpoint touchdown” method

- Capture the already dropped TM and land at position specified relative to this TM (it is possible to offset the TM from the screen center)
- It is possible to recognise the arrangement of multiple TMs.

⇩

- The landing point can be specific regardless of TM dropping accuracy.
- In this touchdown, pinpoint touchdown using one TM will be carried out.

※TM : target marker

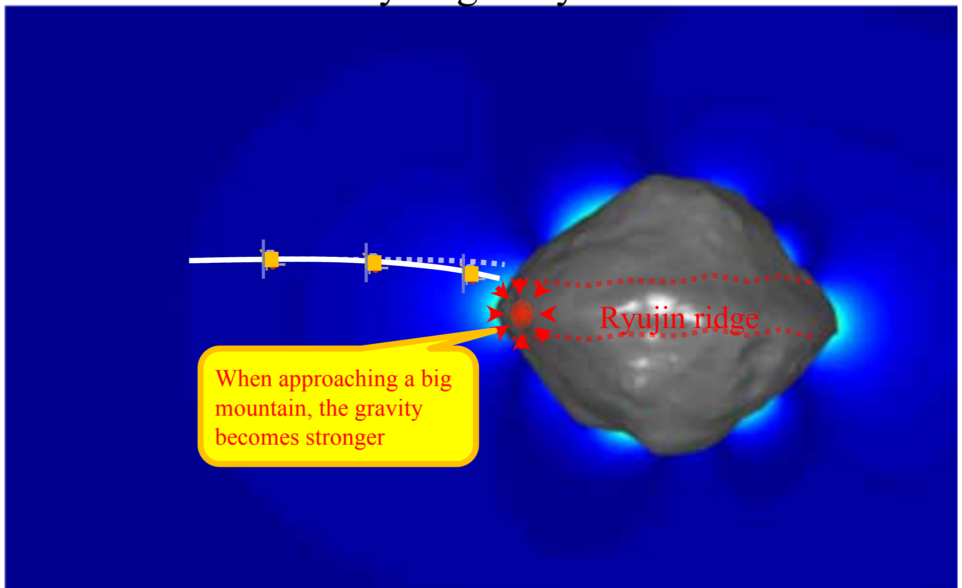
2. Touchdown operation plan

Measures implemented to achieve high precision landing

① High accuracy of asteroid model, ② Tuning of autonomous controls, ③ Expansion of landing safety margin

One example

Accuracy of gravity model

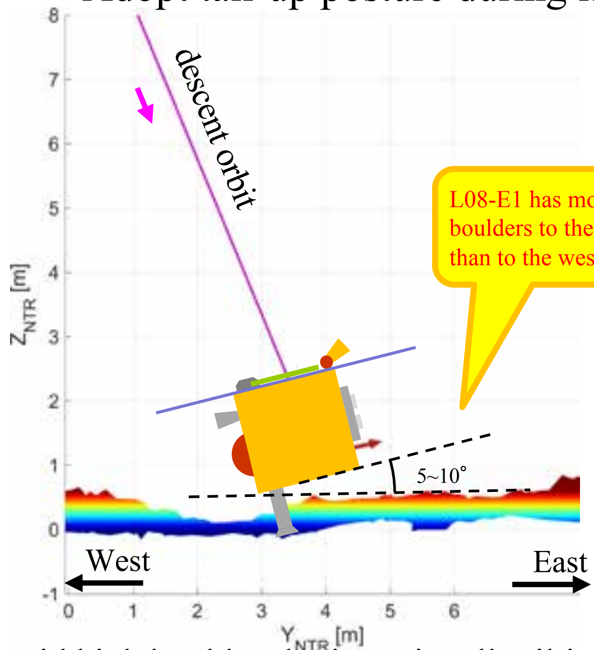


※White areas = places where gravity is stronger or weaker than normal

As Ryugu is not spherical, the effect of orbital bending due to the mass concentration at the equatorial edge is considered.

One example

Adopt tail-up posture during landing



Avoid high boulders by intentionally tilting slightly rather than keeping a straight-down landing posture.

2. Touchdown operation plan

Decision points during operation

item	Ground time: JST () onboard time	Decision item
Gate 1	2/21 07:13	Decision on start of descent
Gate 2	2/21 18:52	Start confirming whether to continue descent
Gate 3	2/22 06:02	Start final decent judgement (GO/NOGO)
HGA→LGA	2/22 07:27 (07:08)	Antenna switching
TD	2/22 08:25 (08:06)	Touchdown
Gate 4	2/22 08:25	Start rising check
LGA→HGA	2/22 08:44 (08:25)	Antenna switch
Gate 5	2/22 08:44	Start check of the state of the spacecraft
Gate 6	2/22 18:37	Start confirmation of ΔV to return to home position.

Transmission of information

Gate 1 – Gate 3:
- Ryugu images from ONC-W1
- Advanced data from LIDAR

HGA→LGA – LGA→HGA:
- Confirm the probe speed with Doppler data.

Gate 5 – Gate 6:
- Check with telemetry

※ The indicated time is not fixed and may change depending on the final plan and situation on the day of operation. The time written by the Gate is the time to start judgment, and it may take some time for the final result to be determined.

2. Touchdown operation plan

Touchdown operation plan concept

- During the landing sequence, the spacecraft autonomously monitors whether the sequence is progressing normally. If it is judged as abnormal, abort (urgent rise) is performed automatically.
- If abort occurs, the safely of the spacecraft is ensured.
- The design of this touchdown operation strictly sets the abort condition to not impair safety (in particular, monitoring at check points ①～④ in the low altitude sequence).
- If an abort occurs, the back-up period will be used to re-execute the touchdown operation.

Touchdown operation plan = a series of operation groups up to the completion of touchdown, including re-implementation.

4. Scientific importance of the touchdown

Touchdown = sample collection

⇩

Science can be done over a wide range of scales (12 orders of magnitude)

⇩

- History of asteroid Ryugu
- Origin & early evolution of the Solar System
- Earth composition（body, water, life）
- The environment 4.6 billion years ago in the 13.8 billion year history of the Universe.

4. Scientific importance of the touchdown

science on different scales

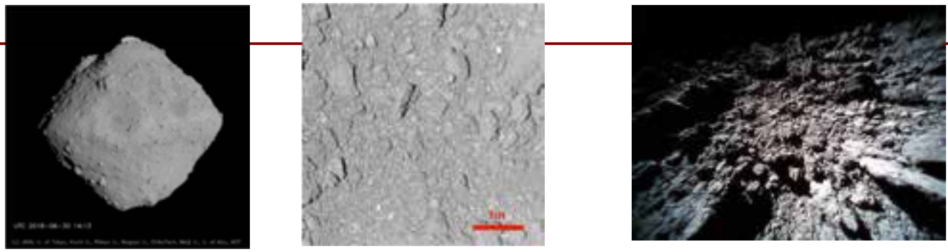
Km — m — mm — µm — nm

1 | 100 10 1 | 100 10 1 | 100 10 1 | 100 10 1

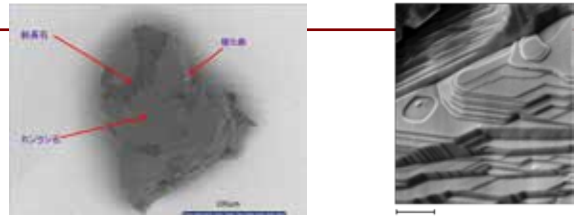
Remote sensing observations from the spacecraft
ONC (T, W1, W2), LIDAR, NIRS3, TIR, DCAM3

Rover & lander observations
MASCOT, MINERVA-II (1A, 1B, 2)

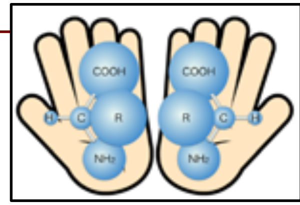
Sample analysis
Sampler, ground analyzer



Ryugu（©JAXA、University of Tokyo & collaborators）

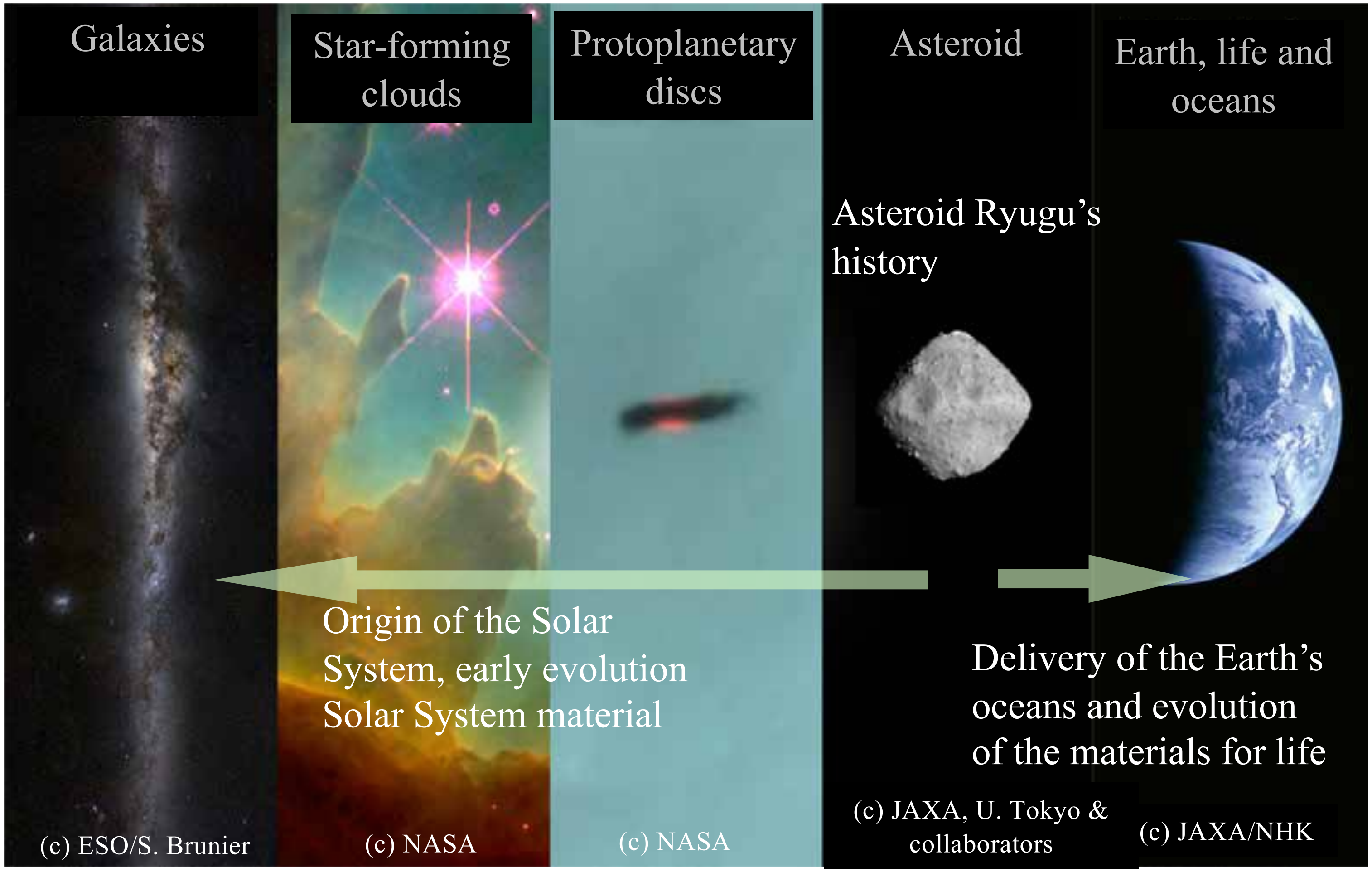


e.g. Itokawa particles（©JAXA）



Molecular structure

4. Scientific importance of the touchdown



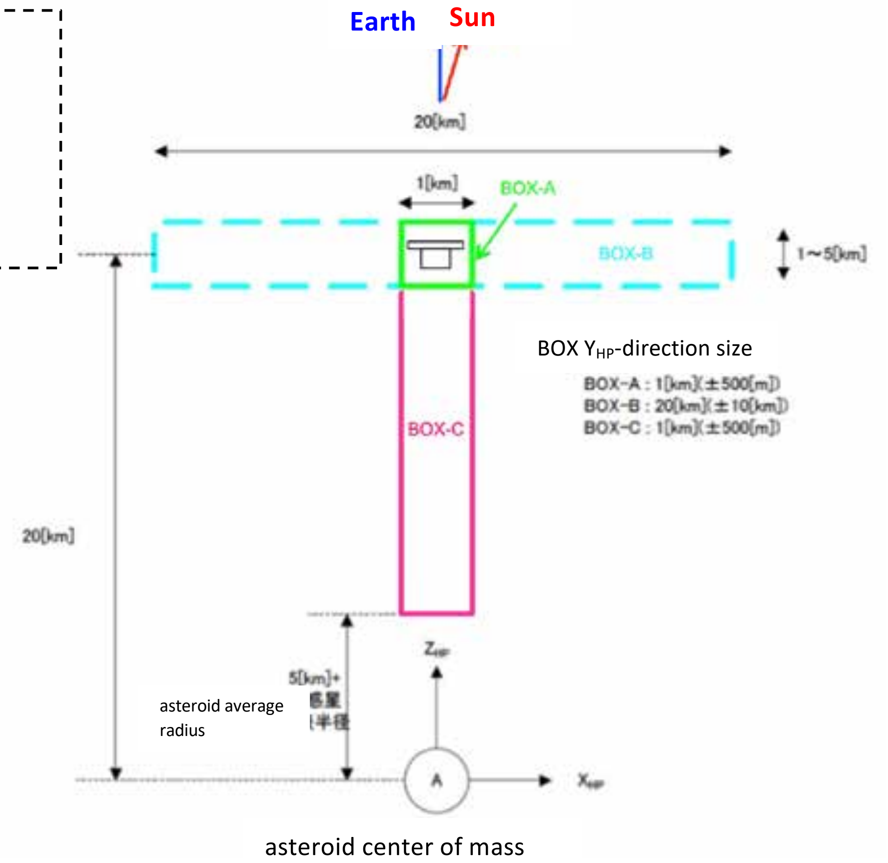
4. Images from the BOX-B operation

BOX-B :
- ･Distance (altitude) from the asteroid remains about 20 km.
- ･Move about 10km in the north-south direction & east-west direction of the asteroid.

■ BOX-B operation was previous carried out from August – September 2018.
- ･Images captured in the direction of Ryugu's south pole.
- ･Images on the evening side of Ryugu

Now

■ BOX-B operation in January 2019
- ･Images in solar opposition (January 8, 2019)
- ･Images towards the direction of Ryugu's north pole (January 24, 2019)



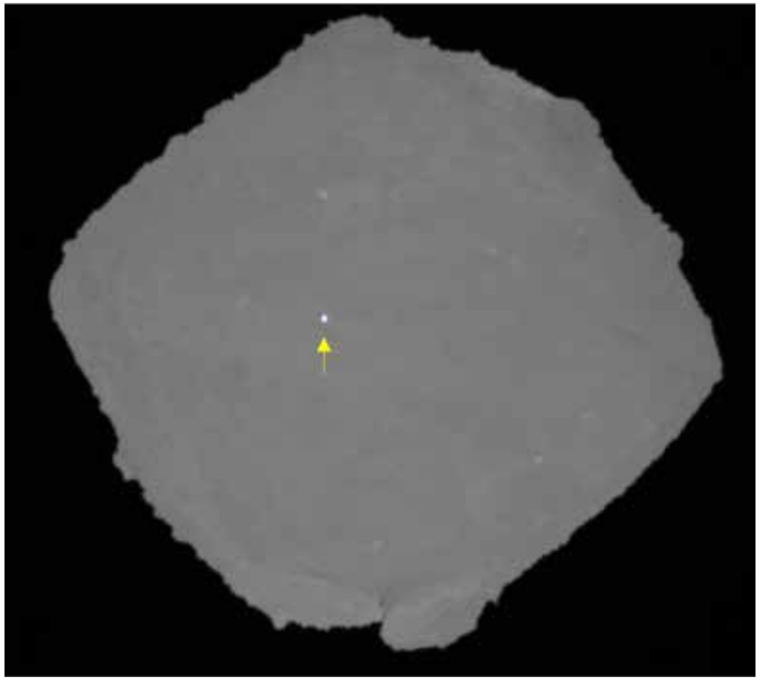
BOX Description

(image credit：JAXA)

4. Images from the BOX-B operation

Images in solar opposition

New



Ryugu images from the direction of opposition. The photograph was captured at around 19:12 JST on January 8, 2019, using the Optical Navigation Camera – Telescopic (ONC-T). The white dot at the arrow tip is the target marker. The distance to Ryugu is about 20 km.

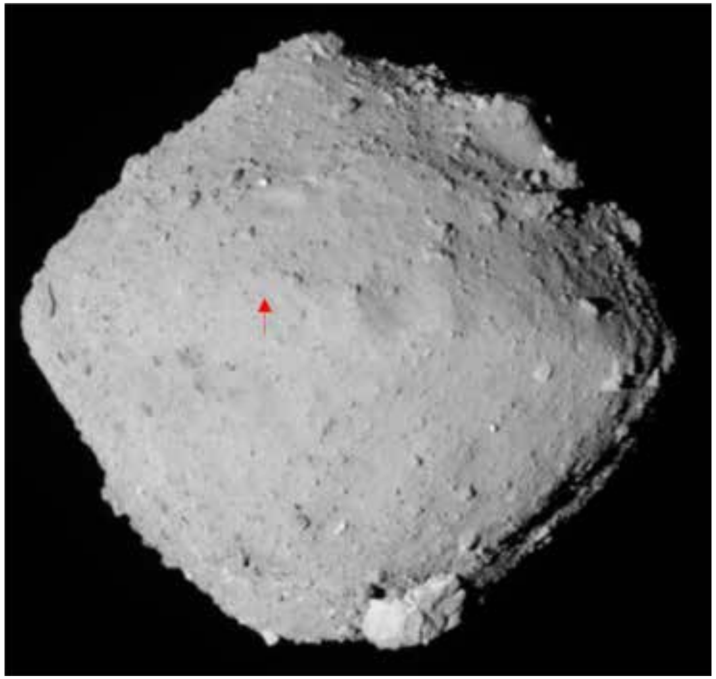
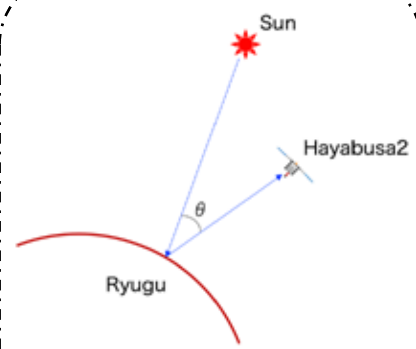


Image captured when not in opposition (captured from approximately the same direction as in Figure 2). The photograph was taken with the Optical Navigation Camera – Telescopic (ONC-T) on July 12, 2018. The phase angle when this image was taken was about 19 degrees. The arrow tip marks the planned touchdown point.



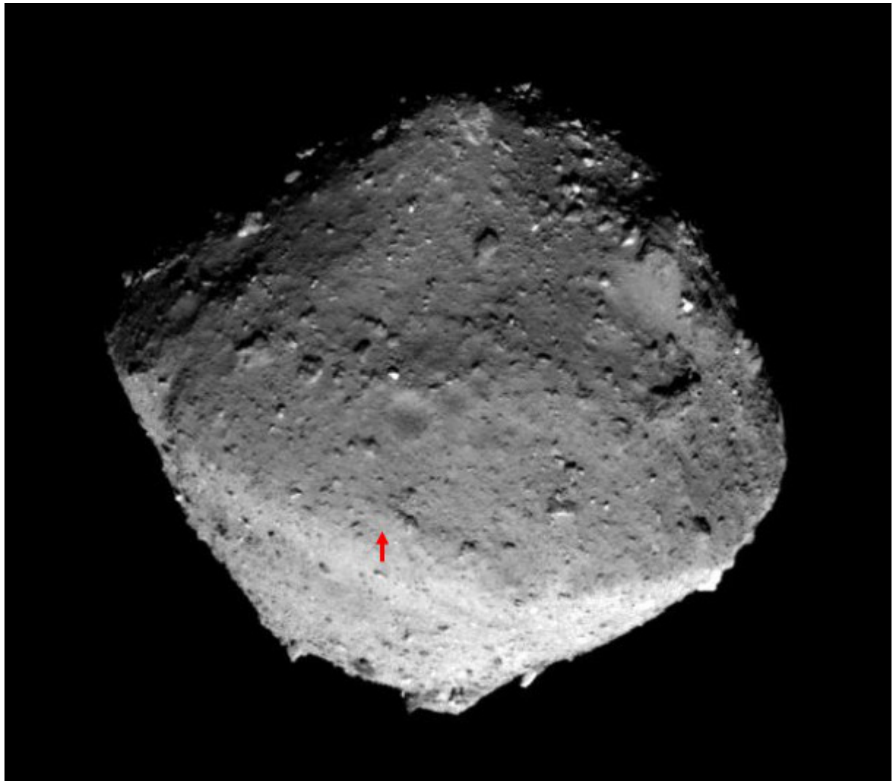
θ : Phase angle

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

4. Images from the BOX-B operation

New

Images towards the direction of Ryugu's north pole



Ryugu photographed with the Optical Navigation Camera – Telescopic (ONC-T) at around 16:33 JST on January 24, 2019. The northern hemisphere of Ryugu fills most of the image. The tip of the arrow indicates the intended touchdown point.

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

5. Future plans

■ Scheduled operations

- Dependent on touchdown results

■ Press briefings and media events

- February 22 5:30～14:30 Press center opened @ Sagamihara Campus
- February 22 11:00～12:00 Press conference on touchdown implementation @ Sagamihara Campus

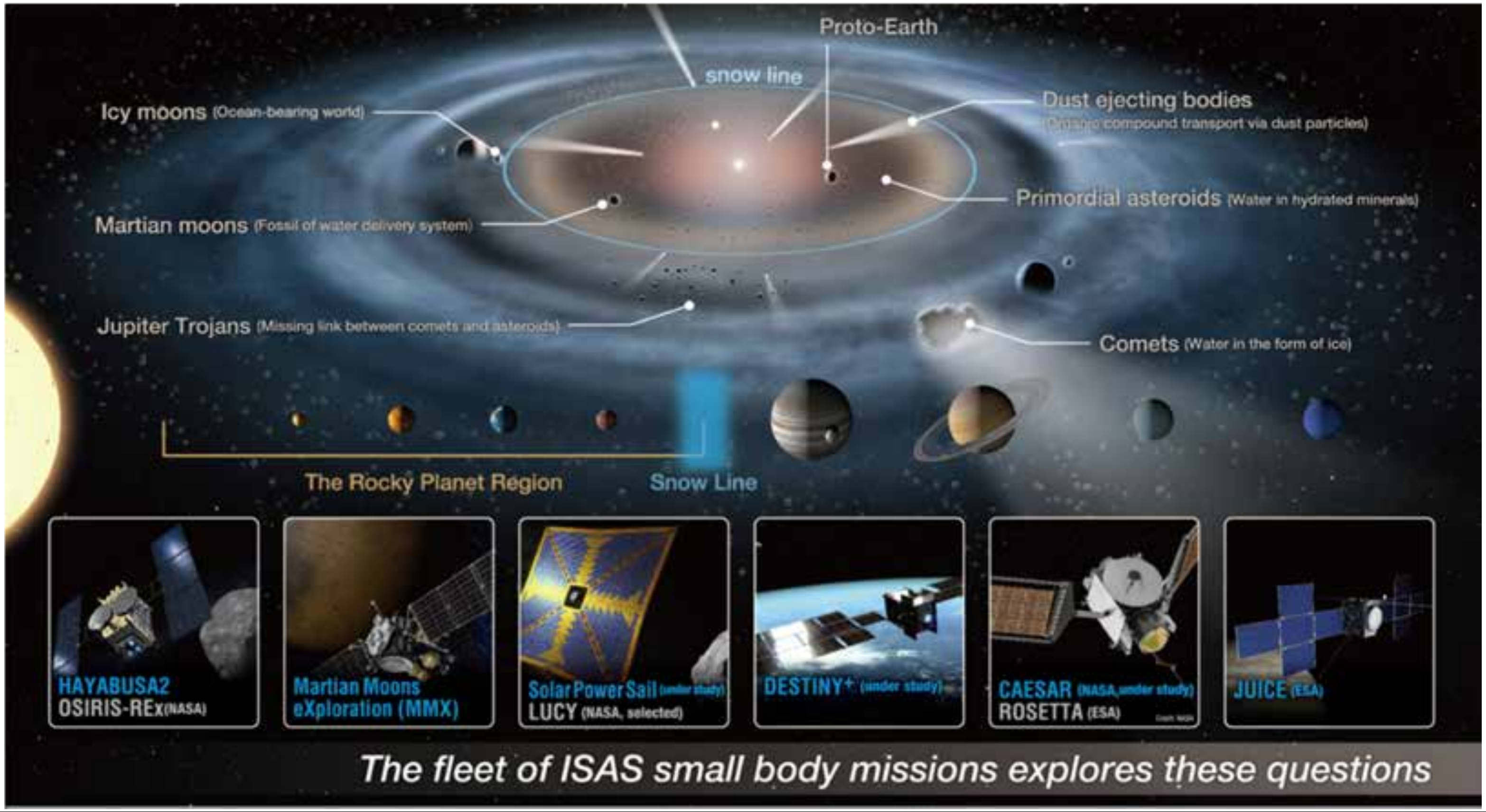
（Applications to participate in the press conference at the press center were closed on February 18)

February 22 6:30～14:30: There will be a secondary location for media at the presentation room in our Tokyo office. This location will connect to the press conference at the press center from 11:00am via video conference. Questions from this secondary venue will also be possible. The application deadline for participation from the secondary venue is February 21 at 17:00. If you wish to participate, please contact the JAXA Public Relations Department.

Reference material

Small Body Exploration Strategy

How did the Earth become rich in water and life? What is needed to maintain these conditions?



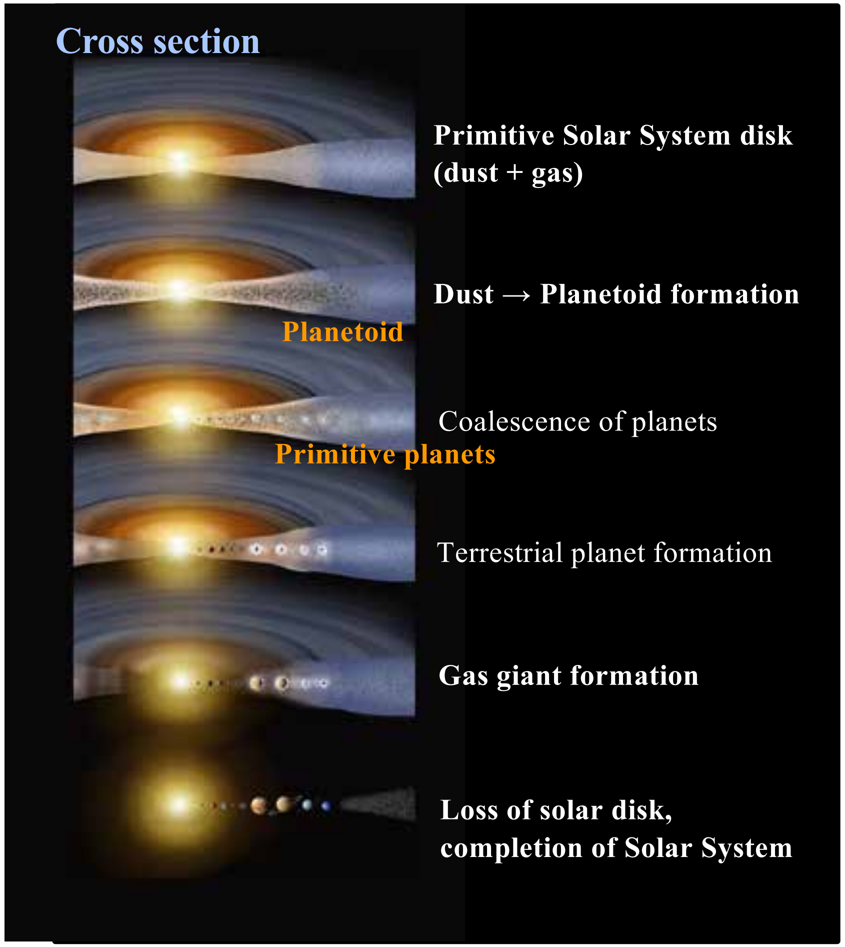
・Small bodies born outside the snowline are initially balls of icy mud (primitive comets) but can evolve into a variety of forms (e.g. primitive asteroid).

・Transport of volatiles such as water and organics to the terrestrial planet region is thought to be essential for life.

・When, which stage of evolution of these celestial bodies, and how water and organic matter was brought to the primitive Earth is explored in the following missions:

- HAYABUSA2 (asteroid)
- MMX (Martian moons)
- DESTINY+ (asteroid・cosmic dust)
- CAESAR (comet)
- OKEANOS (Jupiter Trojans)
- JUICE (Jupiter), etc.

Science of Hayabusa2: birth & evolution of the Solar System



Subjects

① Investigate the materials that formed the planets

> What materials existed in the primitive Solar System disk and how did it change before the planets were born?

② Investigating the formation process of the planets

> How do celestial bodies grow from planetoids to planets?

① Investigating the materials that formed the planets

- The Universe is thought to have begun 13.8 billion years ago. After this, numerous elements were created during the evolution of stars and were dispersed into outer space. About 4.6 billion years ago, the Solar System was born and our goal is to clarify the types of material in space at that time.
- We aim to clarify the substance distribution in the original Solar System disk.
- After the initial celestial bodies were formed, we seek to clarify how materials evolved on these bodies.

↓

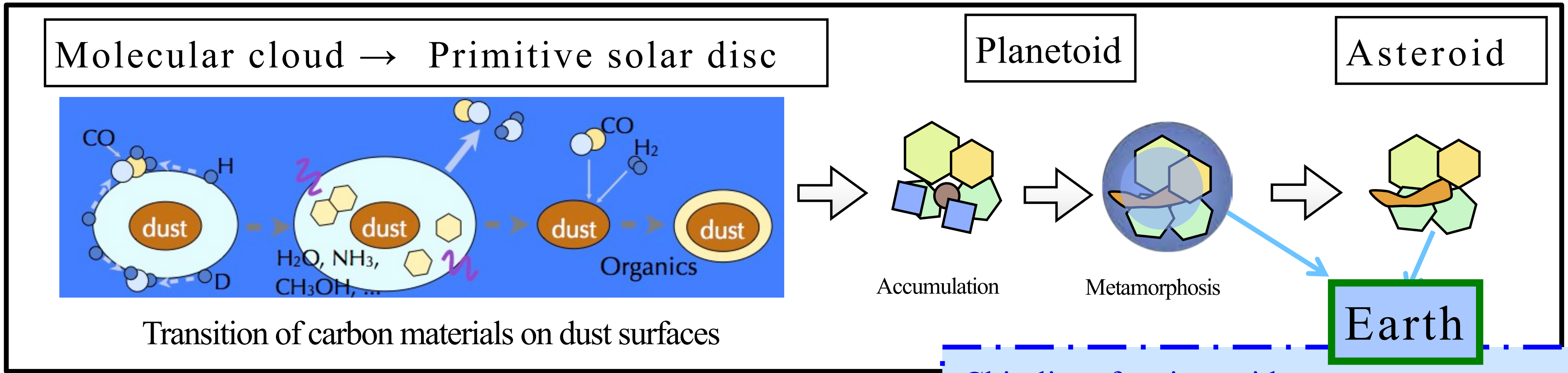
Revealing the materials that eventually became the planetary body, sea and life

Keywords :

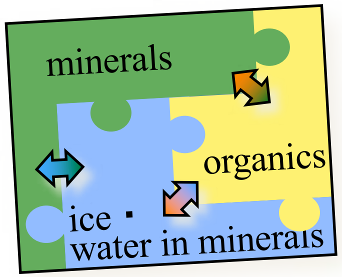
- Pre-solar particles : Particles inherited from the interstellar molecular cloud that are in the Solar System.
- White inclusions（CAI）: Substances that record the initial high temperature state of the Solar System.
- Mineral-water-organic matter interaction : Diversification of organic matter in the original birthplace.
- Thermal metamorphism・space weathering : Changes of materials in the celestial body after its initial formation.

Elucidation of organics by Hayabusa2

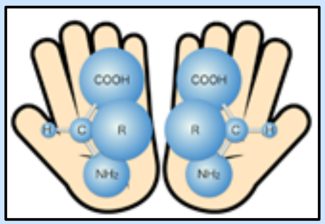
Volatile substances, such as water and organic matter, form on dust surfaces in molecular clouds. It is thought that these change due to aqueous metamorphism and thermal denaturation in primitive solar system discs and planetoids, eventually accumulating on Earth and providing materials for life. We will clarify what kinds of substance existed during this process.



Interactions between materials, water, and organics



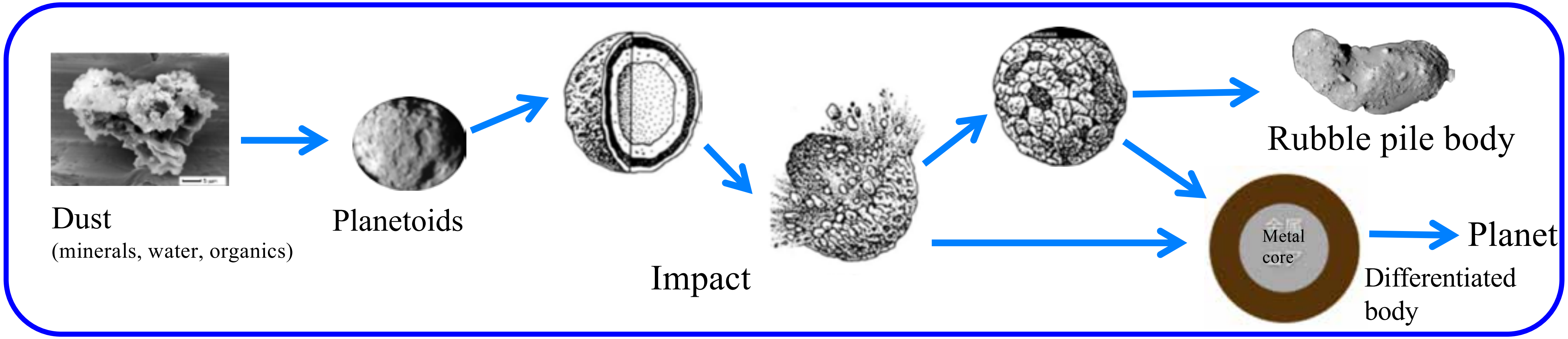
Chirality of amino acids



Life on Earth almost exclusively uses left-handed amino acids. But why?

Left-handed (L-configuration) and right-handed (D-configuration) amino acids

② Investigating Planetary Formation



- Elucidate the structure of planetoids that eventually became planets.
- Elucidate what processes occurred during the collisions, coalescence, and accumulation of celestial bodies.

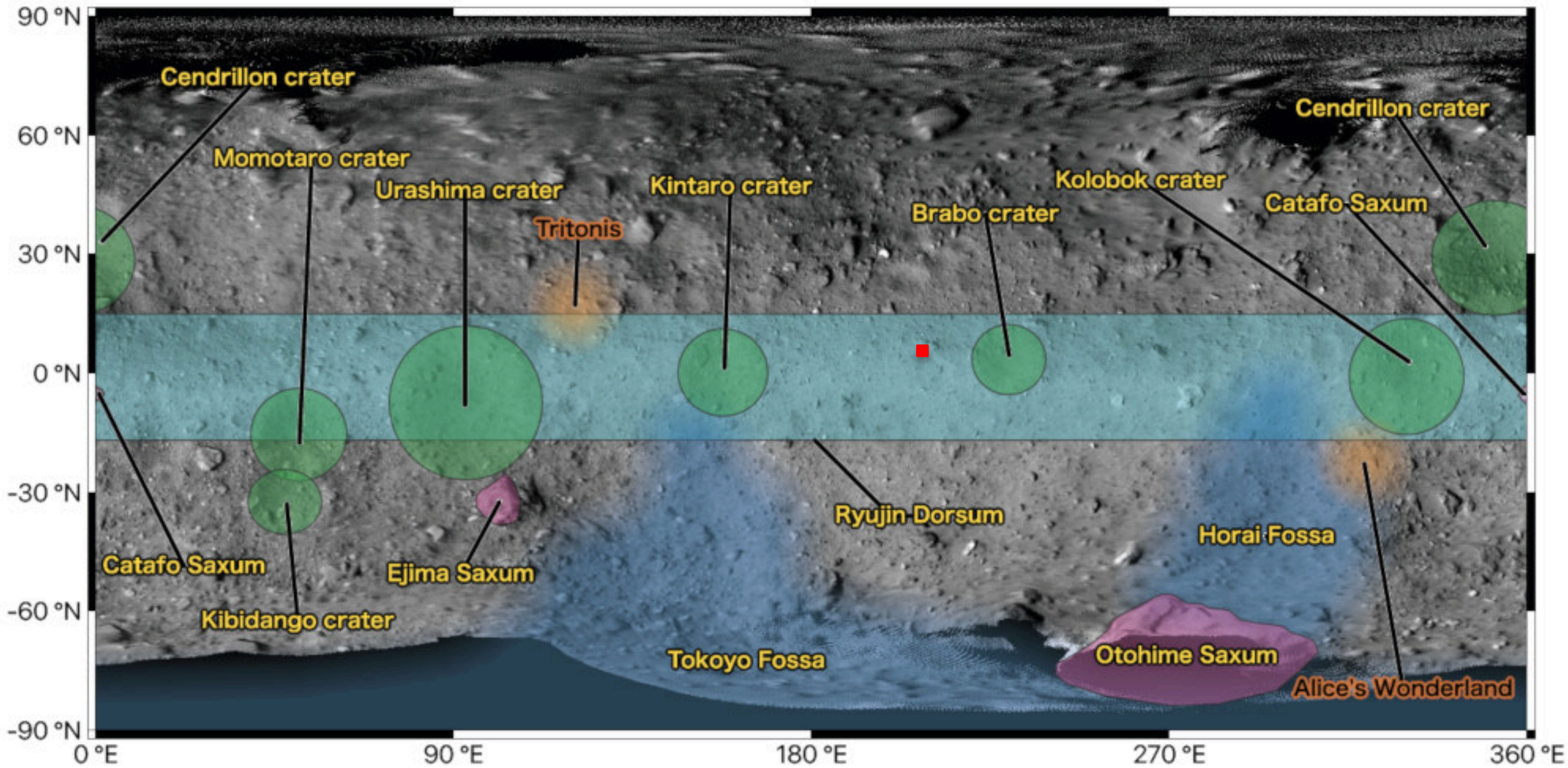
↓

Elucidate formation processes from planetoid to planet

Keywords:
- Rubble pile body: A celestial body formed from accumulated rubble
- Impact fragment and coalescence: When celestial bodies collide, the resulting fragments can combine to form a new body
- Re-accumulation: Accumulation of fragments resulting from a collision via the force of gravity

Touchdown Position

The approximate position of touchdown will be the red square（■）in the figure below.



（image credit：JAXA）

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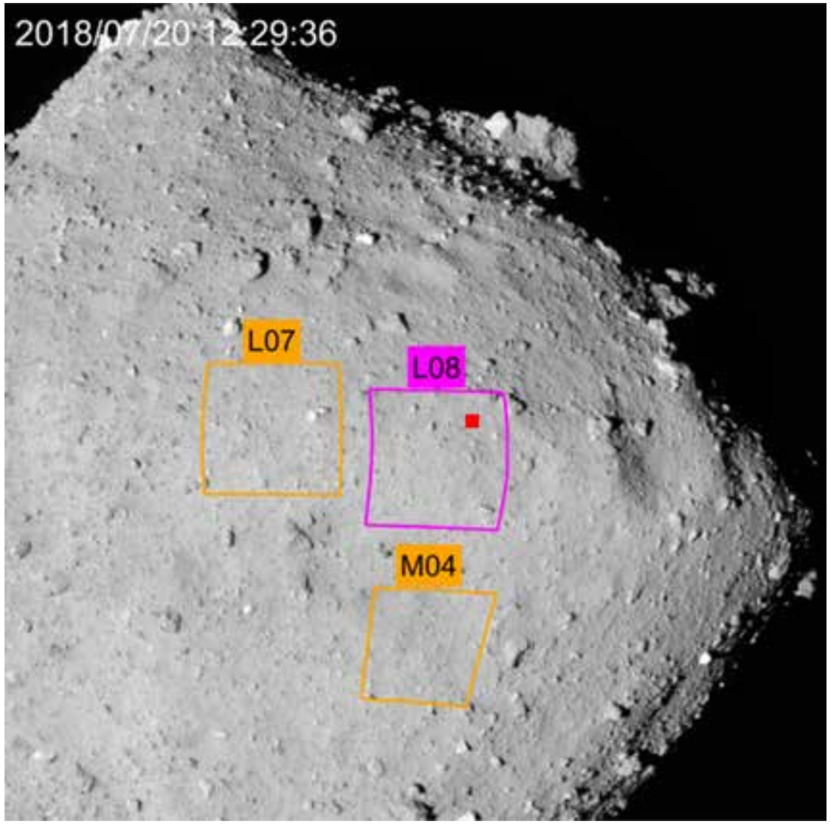
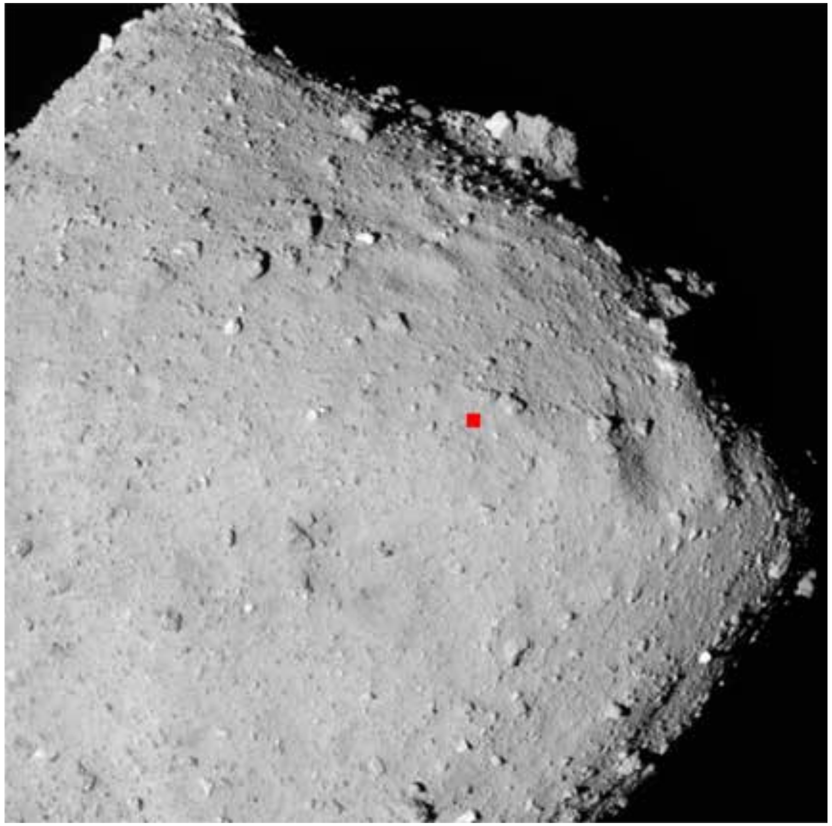
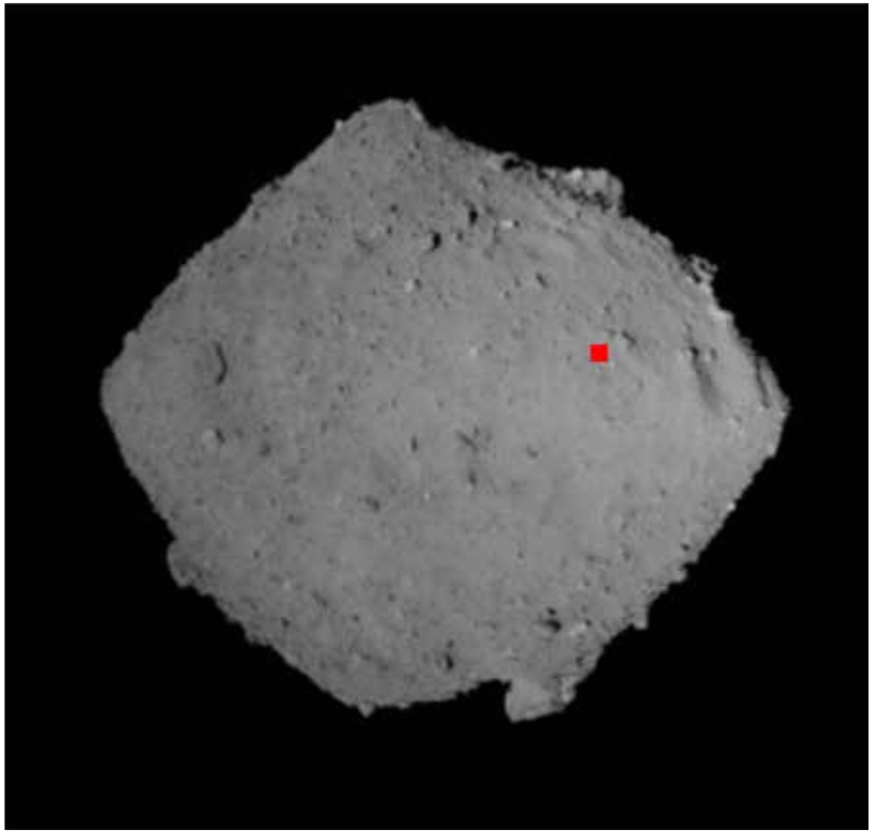




（image credit：JAXA / University of Tokyo / Koichi University / Rikkyo University / Nagoya University / Chiba Institute of Technology / Meiji University / University of Aizu / AIST)

Touchdown Position

The approximate position of touchdown will be the red square (■) in the figure below.



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