Asteroid explorer, Hayabusa2, reporter briefing

February 6, 2019

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2:

- Touchdown operation plan
- Touchdown related information

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

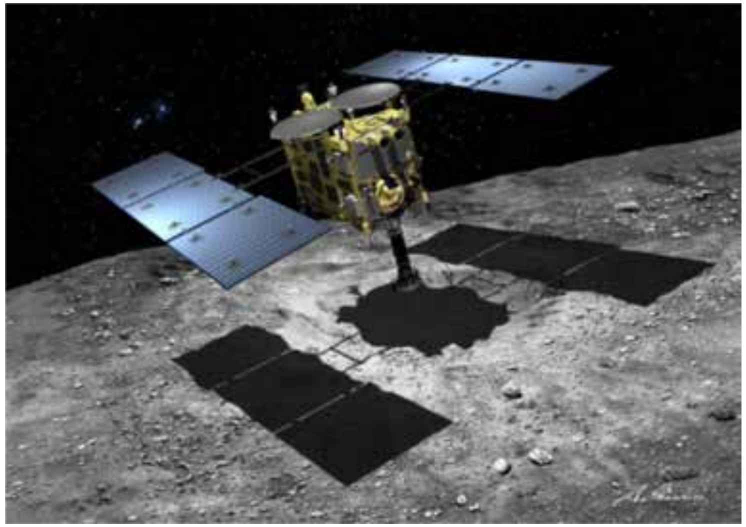
- By exploring a C-type asteroid, which is rich in water and organic materials, we will clarify interactions between the building blocks of Earth and the evolution of its oceans and life, thereby developing solar system science.
- Japan will further its worldwide lead in this field by taking on the new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

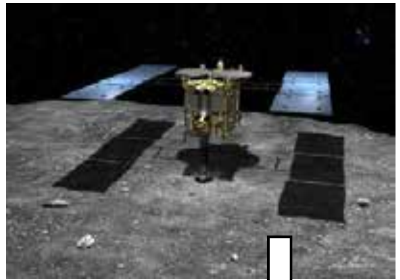
3 Dec 2014

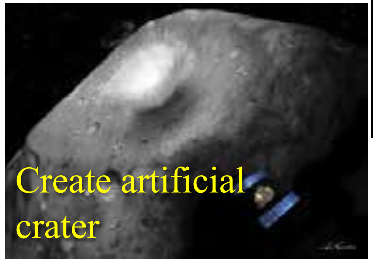
▲ Earth swing-by

3 Dec 2015

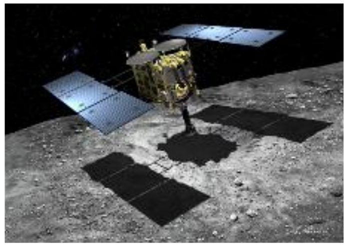
June 27, 2018

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





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



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

Depart asteroid

Nov–Dec 2019

Earth return

late 2020

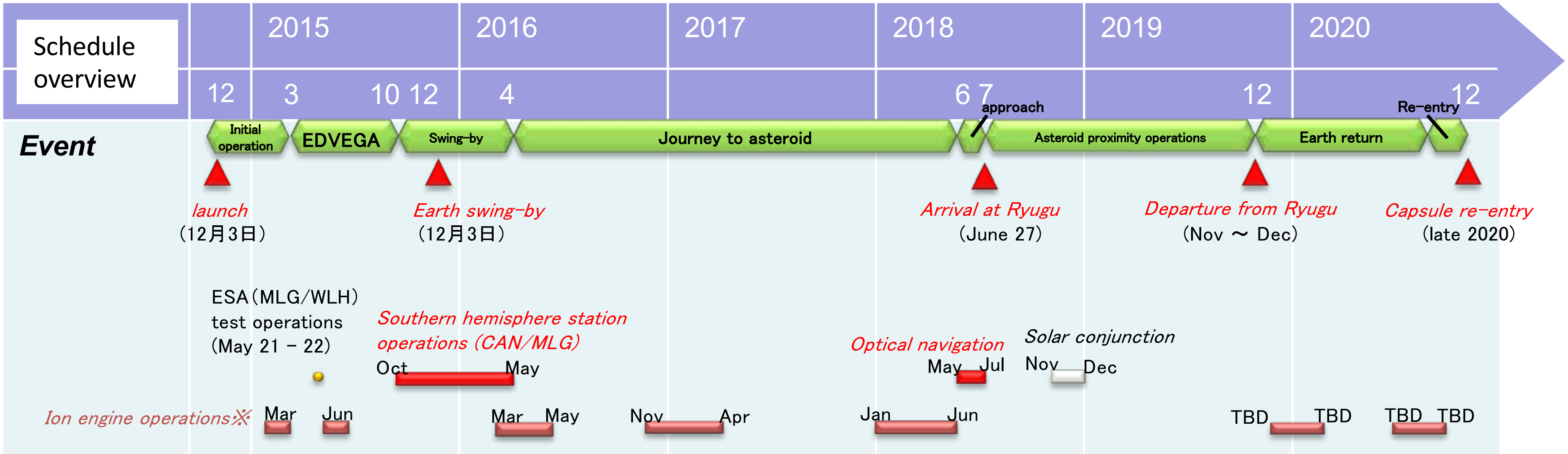
Sample analysis

(Illustrations: Akihiro Ikeshita)

1. Current project status & schedule overview

Current status :

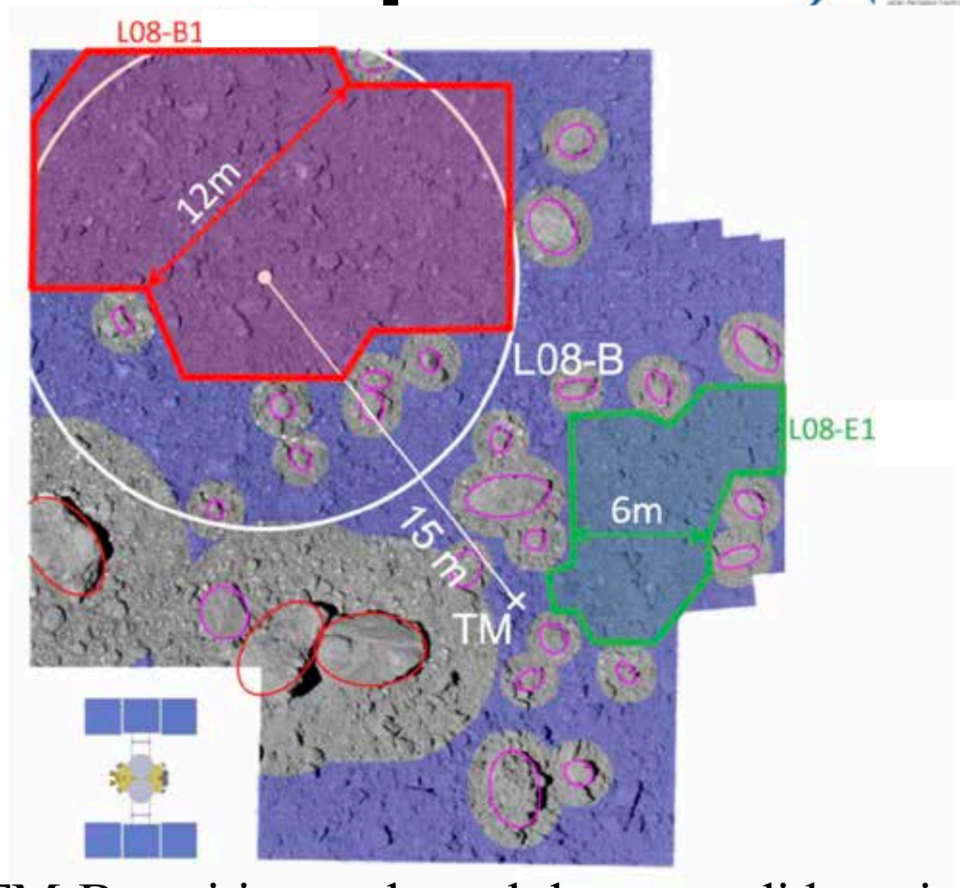
- BOX-B observations were performed between January 8 – 9 and data from opposition (the direction towards the Sun as seen from Ryugu) was acquired.
- BOX-B observations were also conducted on January 25 to make observations around the north pole of Ryugu



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
  L08-E1
- Target marker (TM)
  Use pinpoint touchdown method with TM-B that is already dropped.

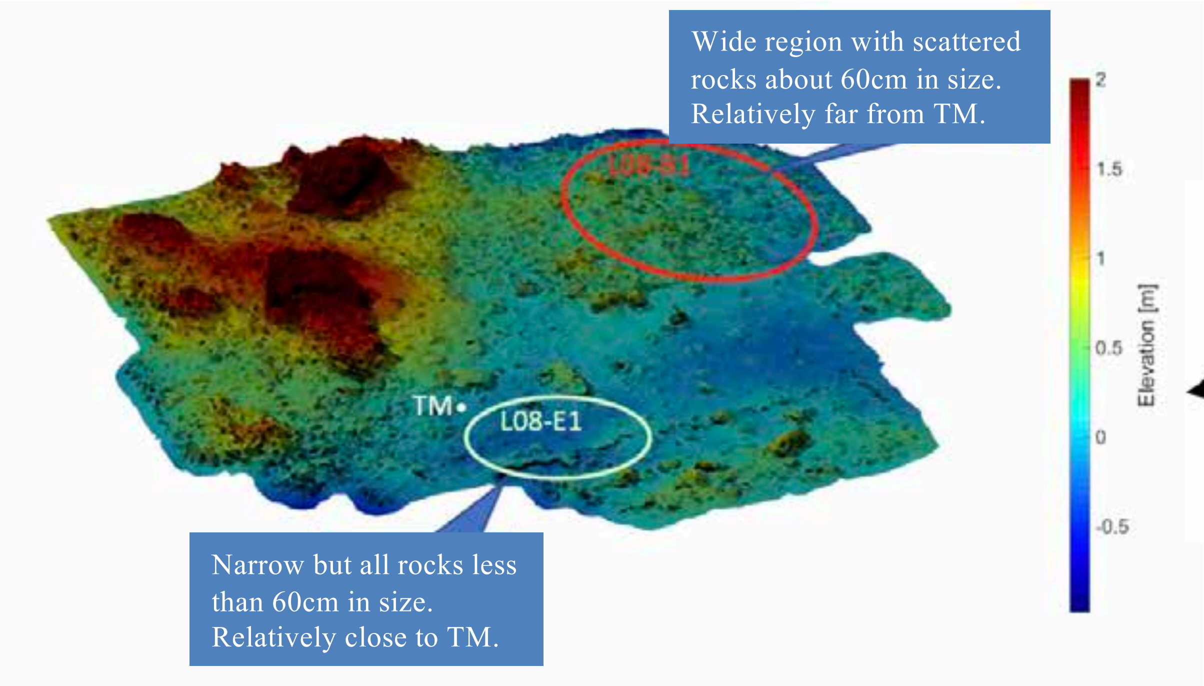


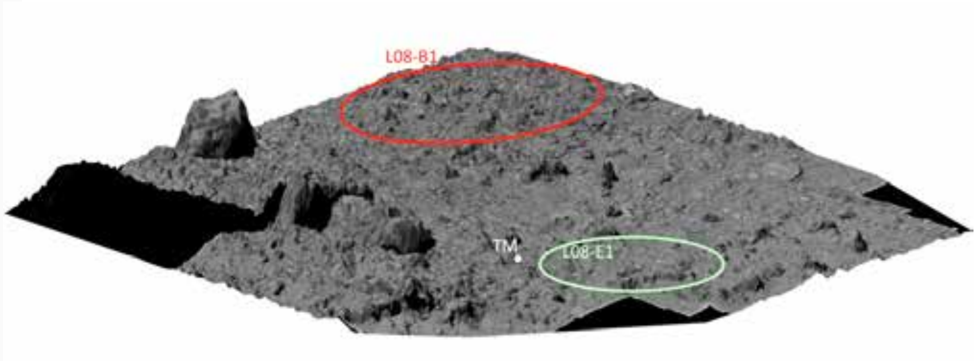
TM-B position and touchdown candidate site

（Image credit：JAXA）

2. Touchdown operation plan

L08-E1 area

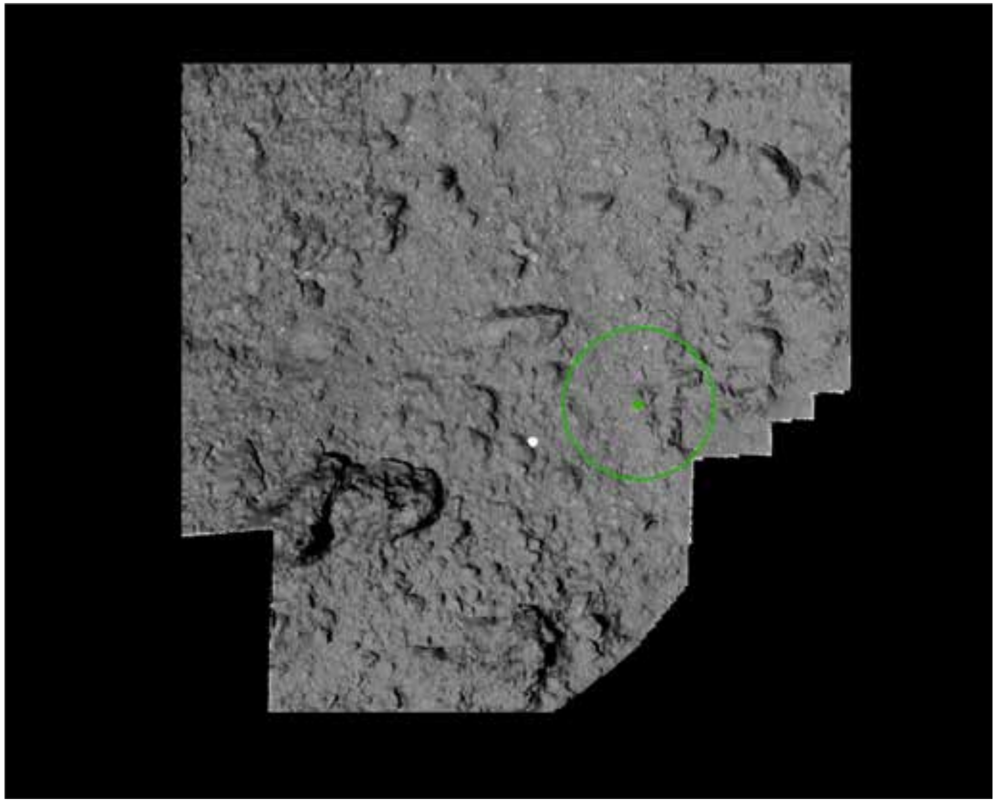




A DEM（Digital Elevation Map）near the touchdown candidate site （image credit：JAXA）

2. Touchdown operation plan

L08-E1 area

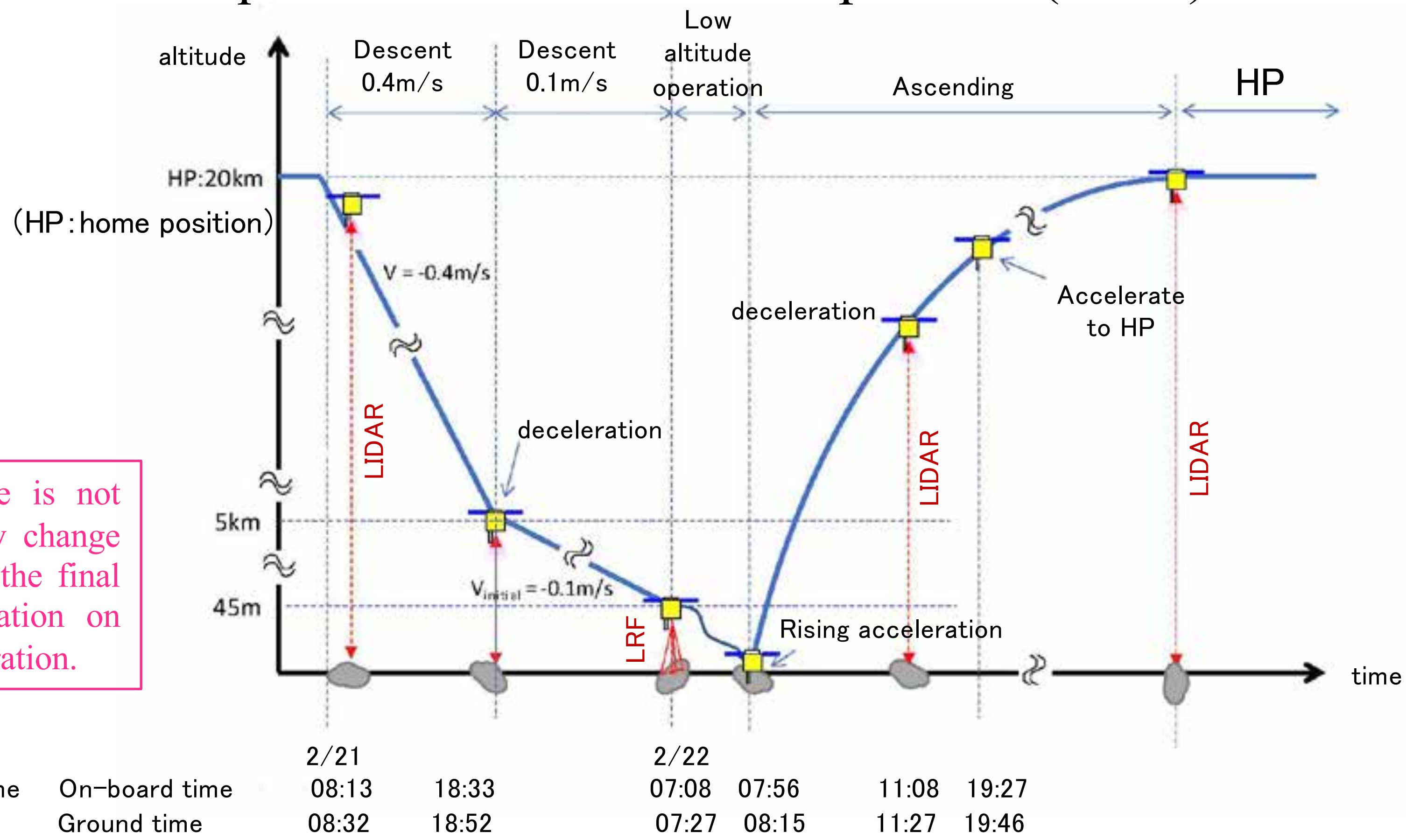


(animation)

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

2. Touchdown operation plan

Sequence of the touchdown operation (entire)

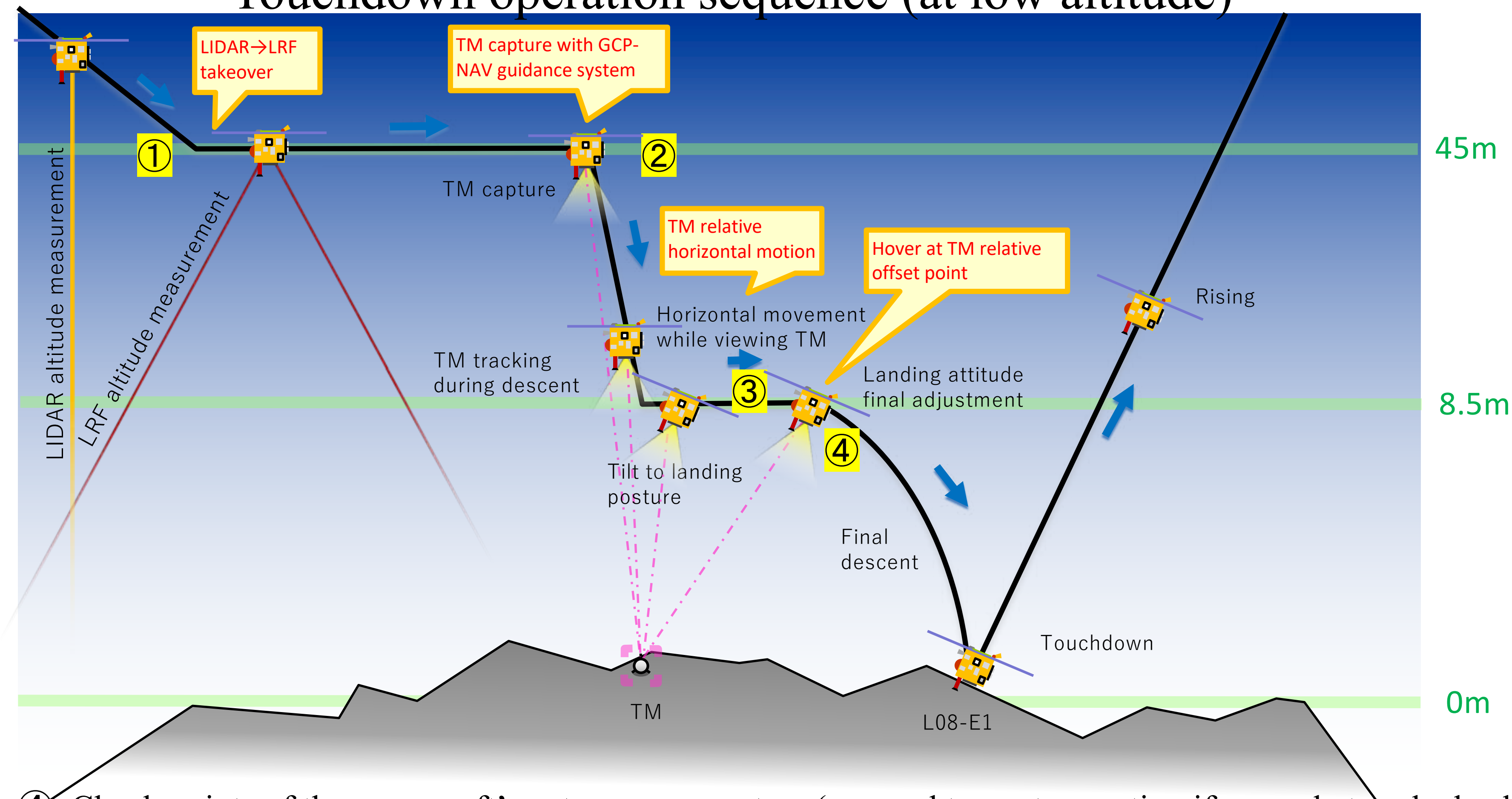


※Indicated time is not fixed and may change depending on the final plan and situation on the day of operation.

(image credit: JAXA)

2. Touchdown operation plan

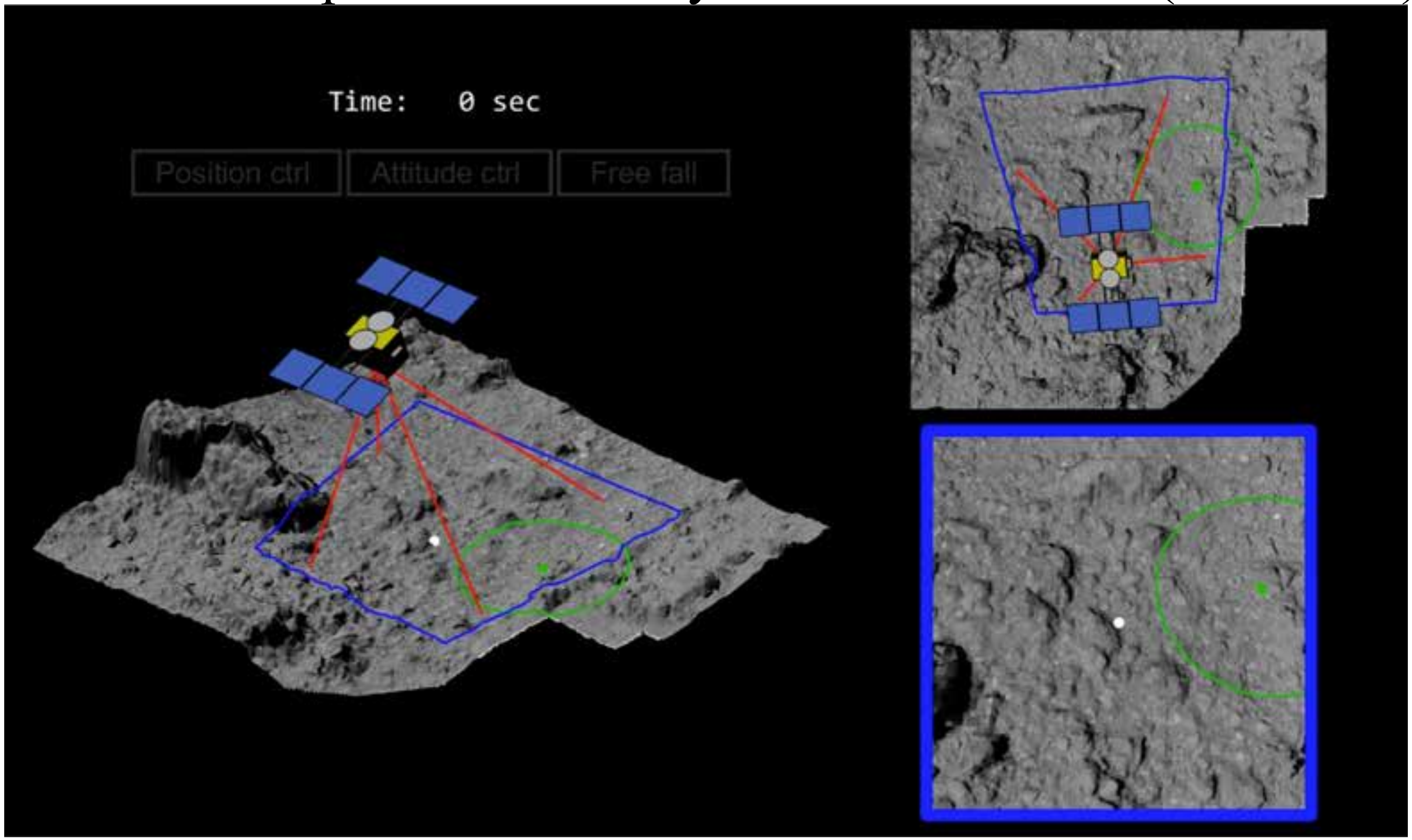
Touchdown operation sequence (at low altitude)



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

2. Touchdown operation plan

Motion of the spacecraft directly before touchdown (animation)



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

(image credit：JAXA)

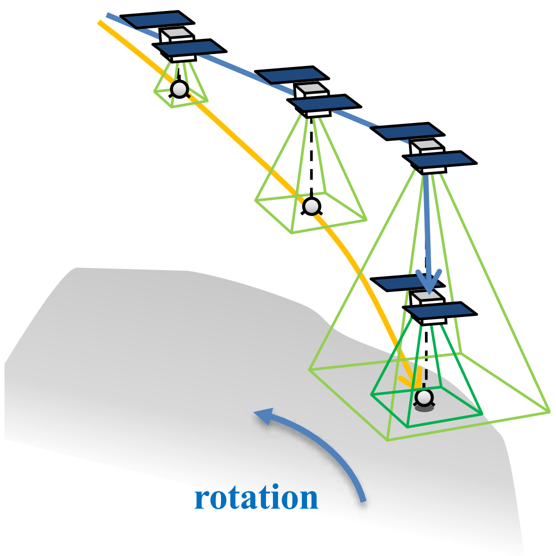
2. Touchdown operation plan

Touchdown operation points

Initial plan：	Reality：
→ Assumed 100m^2 possible touchdown area	→ For a touchdown area about 6m wide
● 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.	● 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

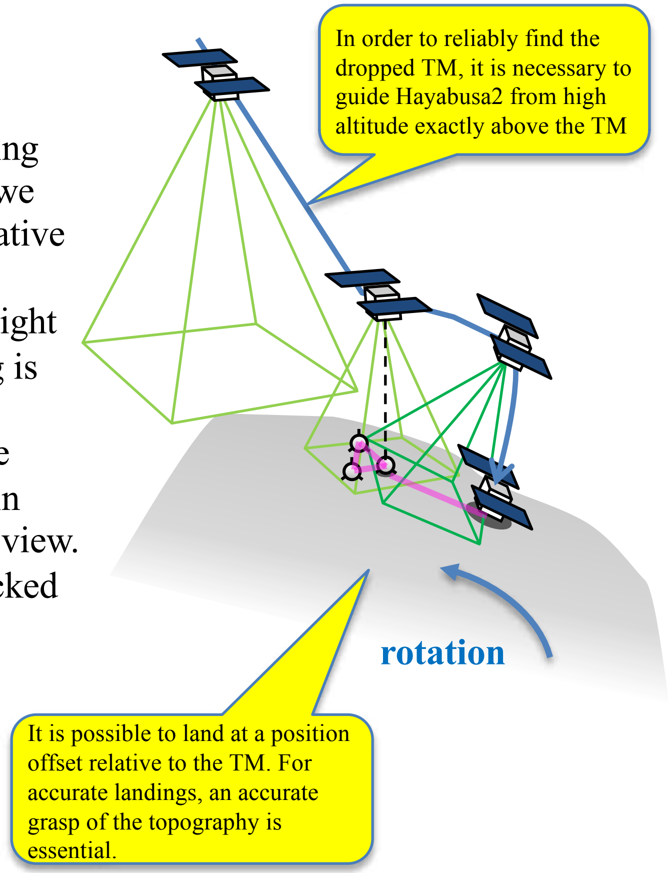
Hayabusa2 pinpoint touchdown feature



"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

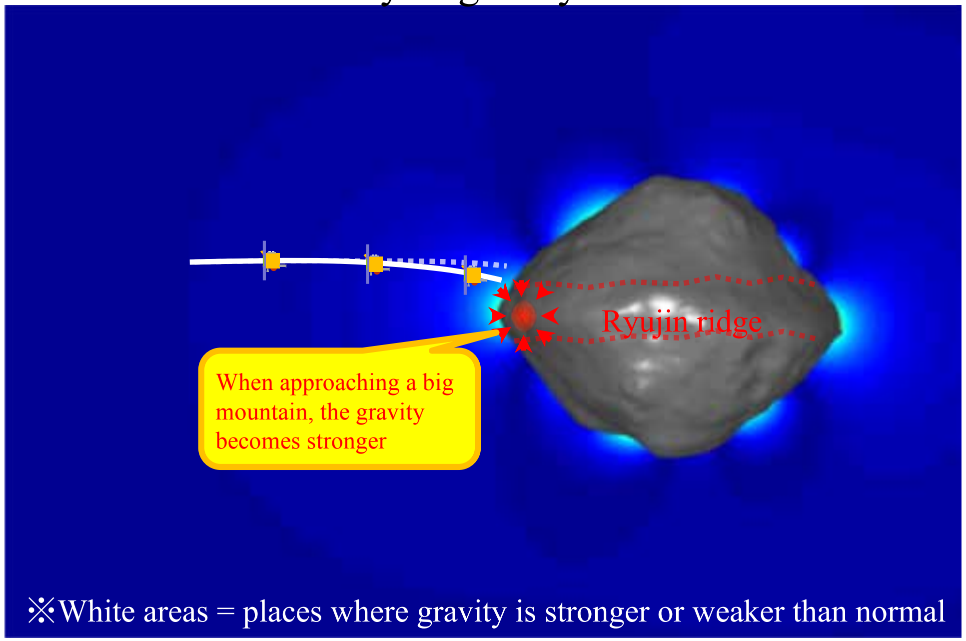
2. Touchdown operation plan

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

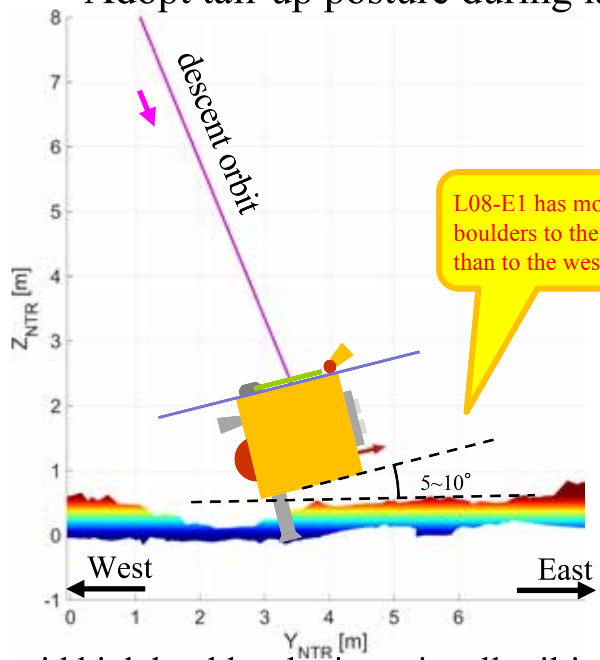
Accuracy of gravity model



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 08:15 (07:56)	Touchdown
Gate 4	2/22 08:15	Start rising check
LGA→HGA	2/22 08:22 (08:03)	Antenna switch
Gate 5	2/22 08:22	Start check of the state of the spacecraft
Gate 6	2/22 18:27	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

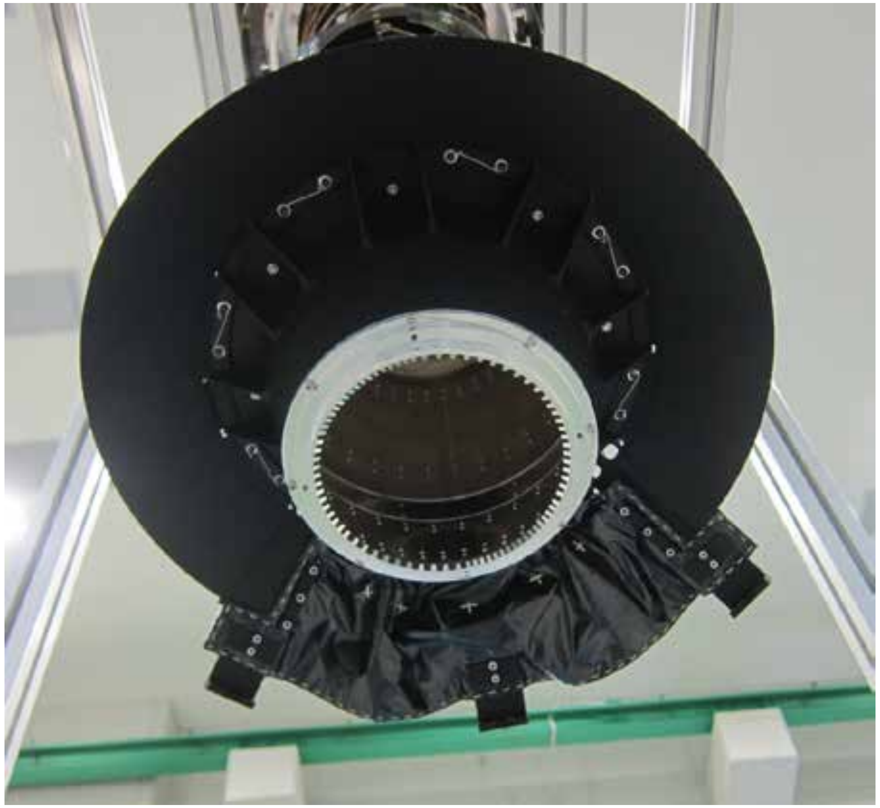
- During the landing sequence, the spacecraft autonomously monitors whether the sequence is progressing normally. If it is judged as abnormal, abort (urgent rise) is performed automatically.
- If abort occurs, the safely of the spacecraft is ensured.
- The design of this touchdown operation strictly 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.

3. Projectile firing experiment

Sampler horn

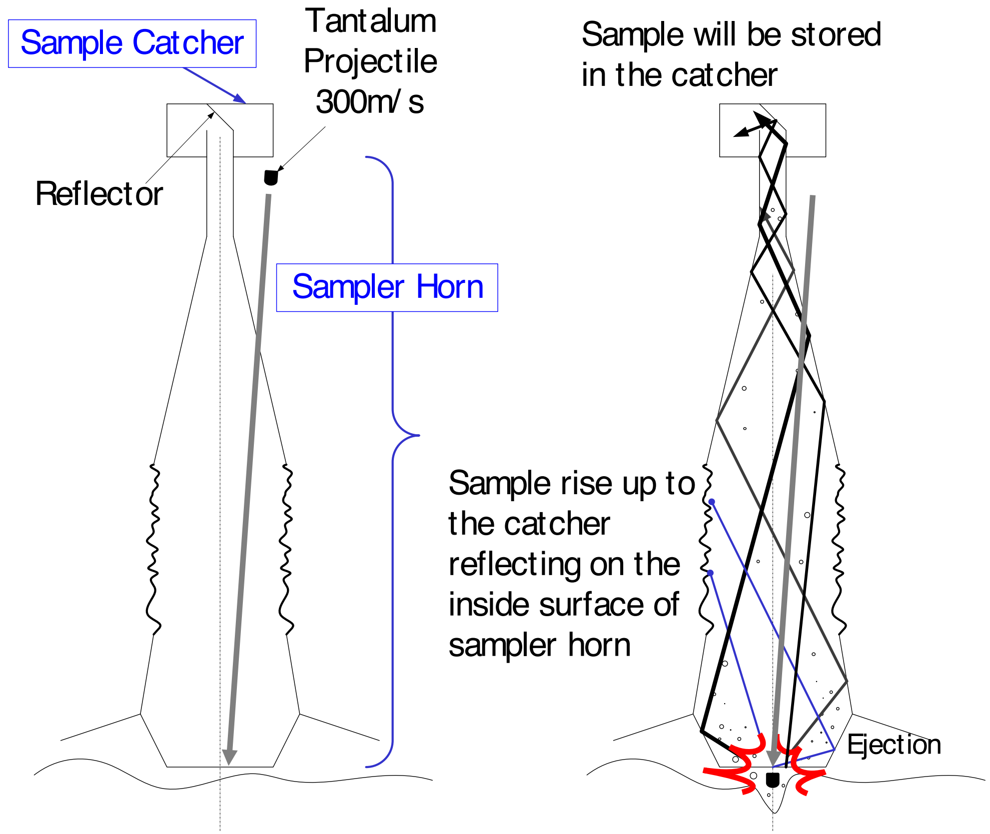
entire



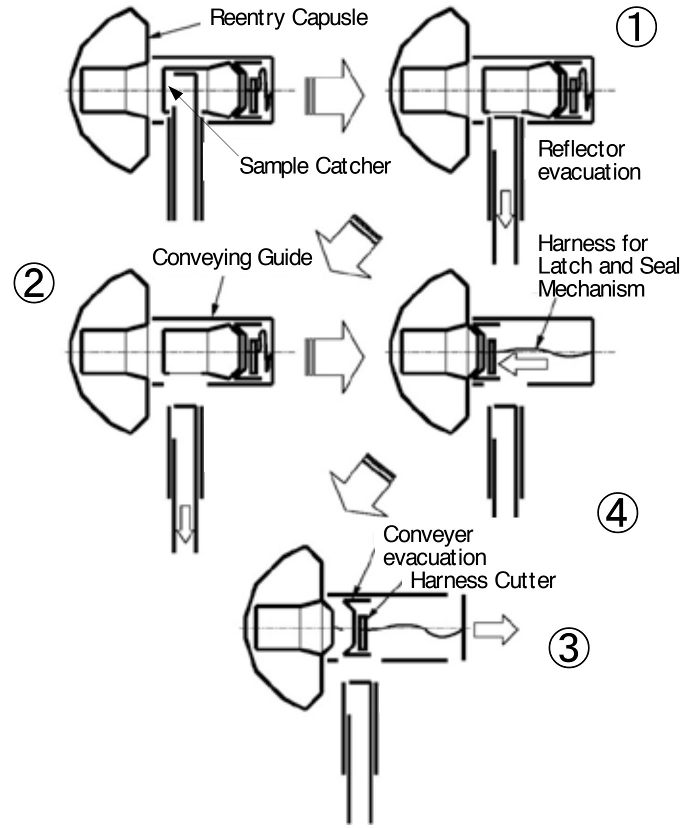
tip

（image credit：JAXA）

3. Projectile firing experiment



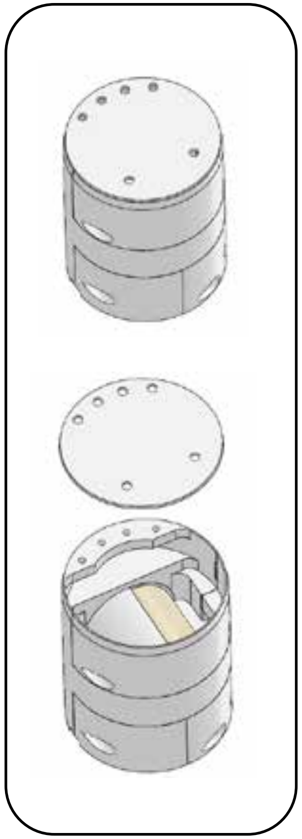
Sampler horn

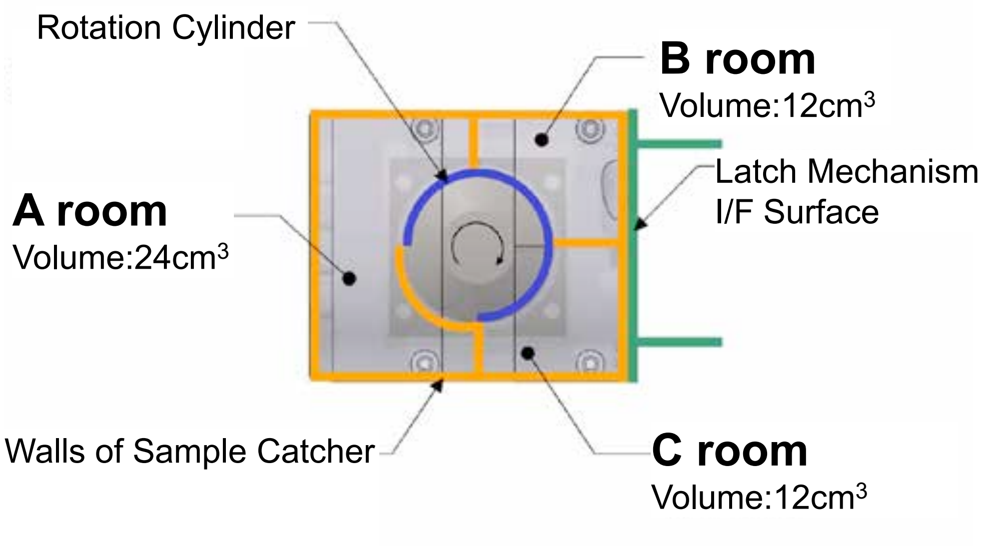


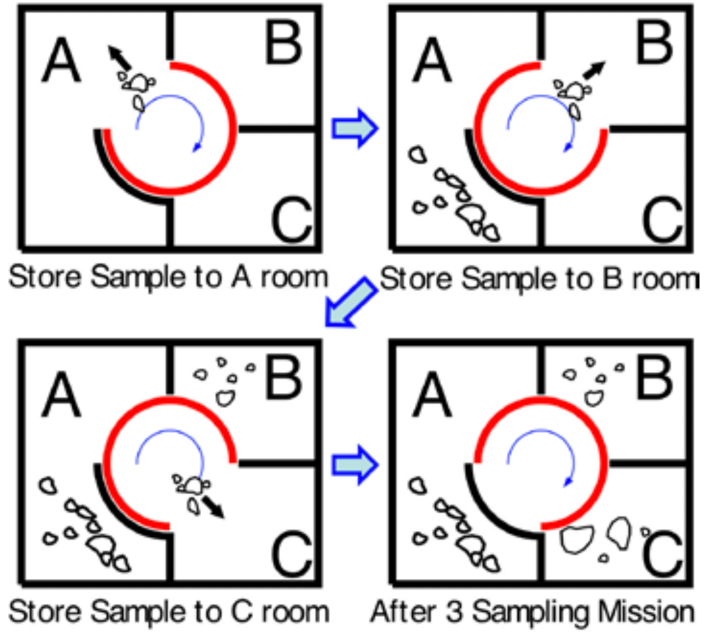
Transport mechanism

(image credit：JAXA)

3. Projectile firing experiment







Structure of sample catcher

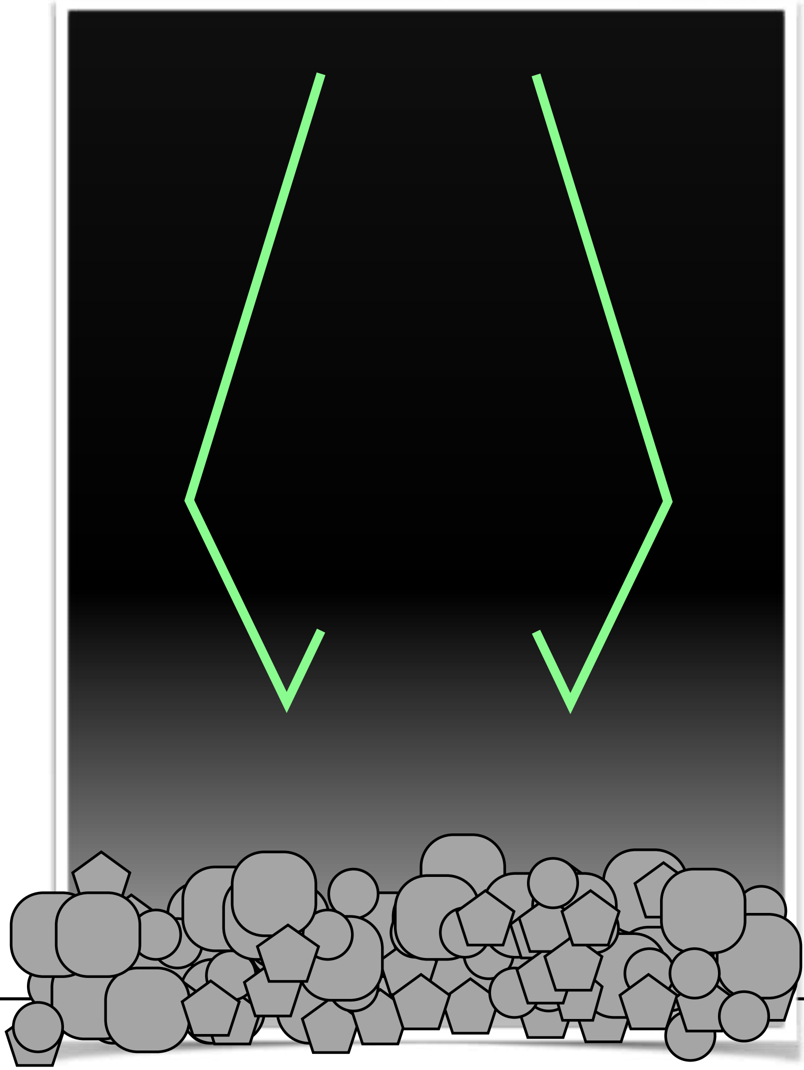
(image credit: JAXA)

3. Projectile firing experiment

<u>Folded tip of the sampler horn</u>

Surface material caught on the folded edge of the tip has the possibility of entering the sample catcher during the ascent of the spacecraft.

Before launch, we made a device simulating the folded tip and confirmed the functionality in a microgravity experiment. See JAXA archive:
http://jda.jaxa.jp/result.php?lang=j&id=8e3fa0b26882c50c19b007f2b878ac64



（image credit：JAXA）

（animation）

3. Projectile firing experiment

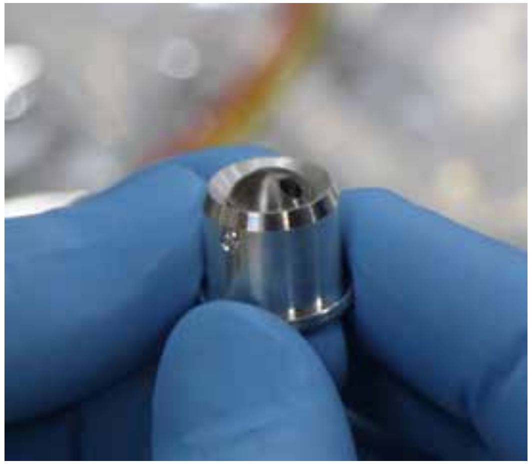
Experiment: Hayabusa2 sampler projector FM-equivalent ignition operation test.
Date: 2018/12/28
Place: JAXA Institute of Space and Astronautical Sciences (ISAS)
Implementing group: Hayabusa2 Project Sampler Team

Purpose: By using an equivalent projector as that onboard the spacecraft (FM-equivalent: manufactured in the same batch as the flight mode equipment), confirm that after a storage period of four years, ignition and planned function can occur normally.
Shoot into a target simulating Ryugu and check the resultant behavior, such as the ejector released from the impact.

Method:
(1) Create a simulated target of the surface of Ryugu based on information acquired during previous exploration.
・Destroy artificial rocks created by simulating the composition and density of carbonaceous chondrite meteorites and create targets for the gravel layer that reproduce the distribution of gravel and stones on the surface of Ryugu that was confirmed by the landers.
(2) Execute bullet firing test under vacuum conditions
・Ignite Hayabusa2 sampler projector in a vacuum chamber, aiming at one pebble.
・5g metal bullet injected at a speed of about 300 m/s
・High-speed video captured of gravel crushing where the bullet landed and the surrounding gravel ejection.

3. Projectile firing experiment

Target simulating the surface of Ryugu.
(image credit：JAXA、University of Tokyo）



Projector (barrel) and projectile (bullet) used: as these are flight spares, the shape, material etc are the same as those onboard Hayabusa2.（image credit：JAXA）

3. Projectile firing experiment

(movie)

Image taken during the experiment. This is recorded at the normal video rate. (image credit：JAXA)

3. Projectile firing experiment

(movie)

Image taken during the experiment. The true frame rate is 420 images per second, and this is slowed to about 14 times longer than actual time. (image credit：JAXA））

3. Projectile firing experiment

Results：

- FM equivalent projector works normally.
- Bullets were injected and the target gravel was crushed.
- Confirmed that adjacent pieces are also crushed and both small and fine particles are released.
- A large quantity of crushed gravel and particles are released even in Earth's gravity, confirming that a crater was formed.

Discussion：

- Similar behaviour is assumed for sample collection during the actual touchdown.
- Since the surface of Ryugu experiences microgravity, more debris is expected to be discharged and enter the sampler horn than during the ground experiment.

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

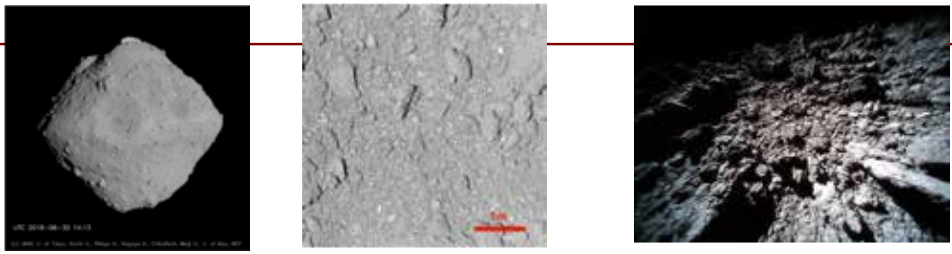
science on different scales

Km		m			mm			µm			nm	
1	100	10	1	100	10	1	100	10	1	100	10	1

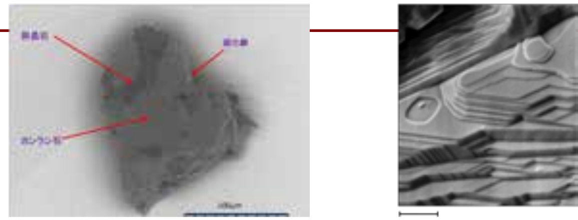
Remote sensing observations from the spacecraft
ONC (T, W1, W2), LIDAR, NIRS3, TIR, DCAM3

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

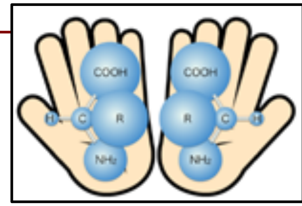
Sample analysis
Sampler, ground analyzer



Ryugu（©JAXA、University of Tokyo & collaborators）

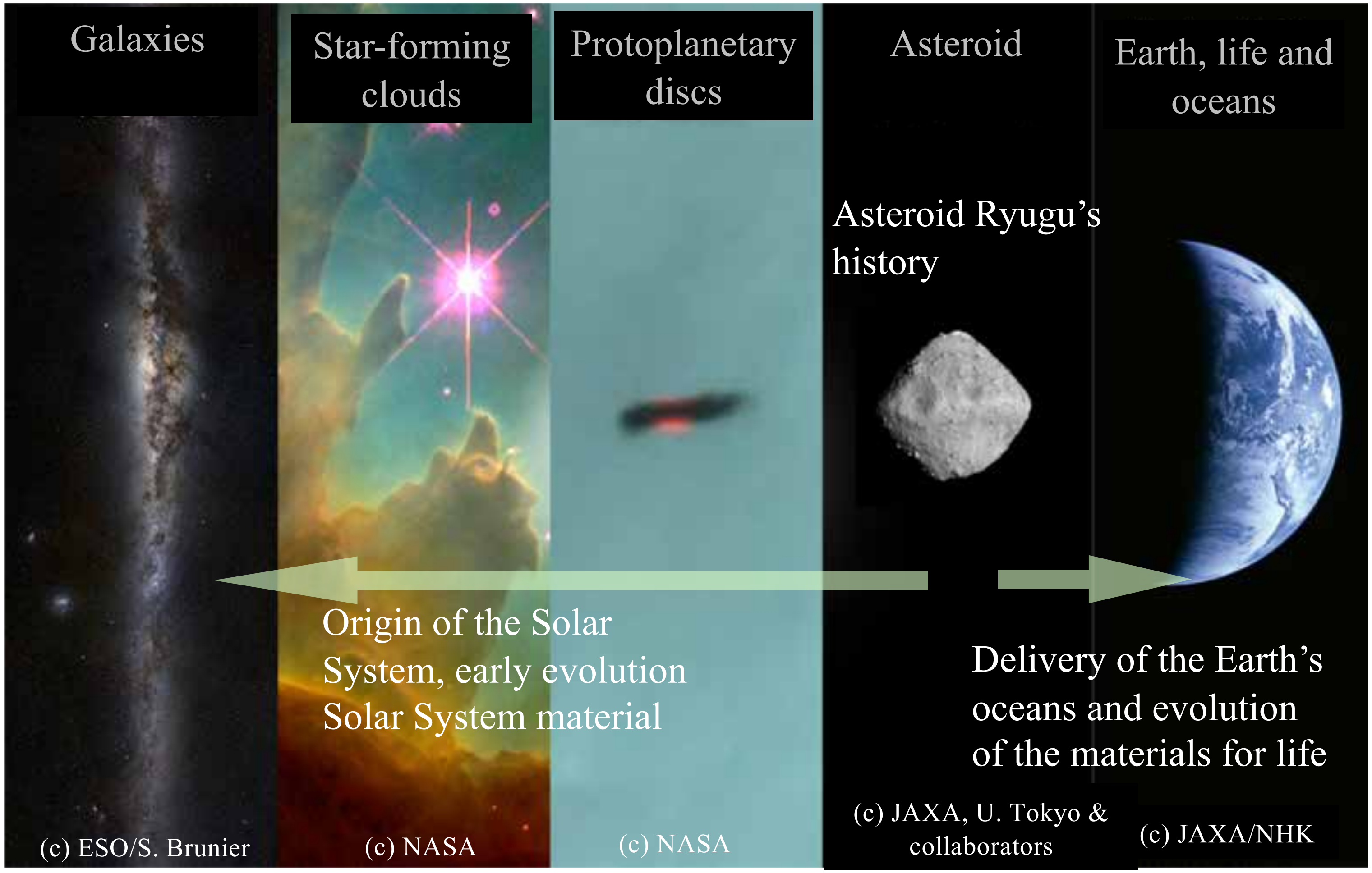


e.g. Itokawa particles（©JAXA）



Molecular structure

4. Scientific importance of the touchdown



5. Future plans

■Scheduled operations

- Touchdown：2/22日（Friday）

Web broadcast scheduled for about one hour before and after touchdown (English translation provided)

■Press and media briefings

- 2/20（Wed.） 15:00～ Press briefing @ JAXA Ochanomizo Office
- 2/22（Thurs.） 05:30～ Press center @ JAXA Sagamihara campus（※）

（※）Due to limited capacity, media participation in the press center will be via a pre-registration system. Notice for related information, such as the application method, will be distributed at a later date.

Correction

MINERVA-II1: correction to the landing site name

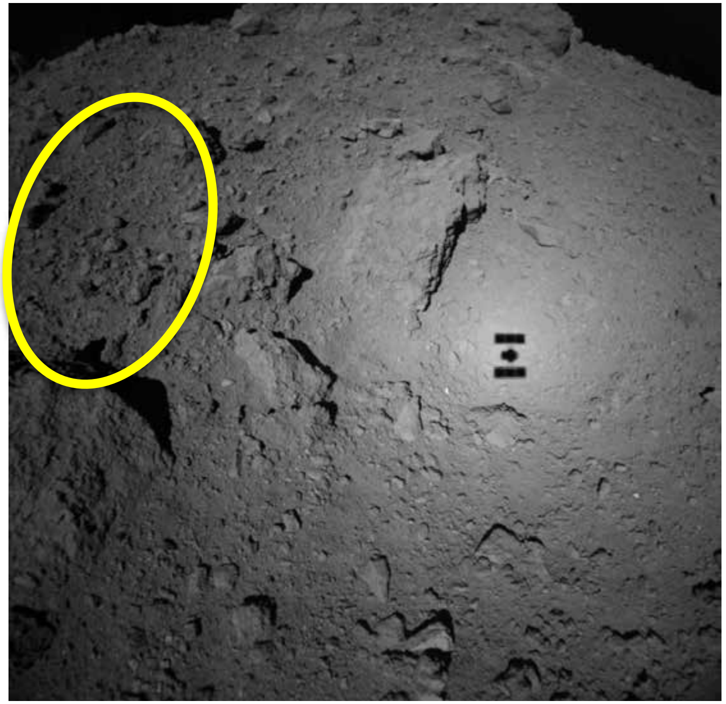
At the press briefing on December 13, 2018, we announced the landing site of the MINERVA-II1 rovers as “Trinitas, the birthplace of the goddess, Minerva”. This is actually an error and the correct name should be “Tritonis”.

incorrect）「トリニトス（Trinitas）」 → correct）「トリトニス（Tritonis）」

MINERVA-II1: correction to the landing site name

revised

MINERVA-II1 rover landing site



2018/9/21 at 13:02 JST
Altitude 70m、with the ONC-W1

Nickname for the landing site for the MINERVA-II1 rovers.

Tritonis

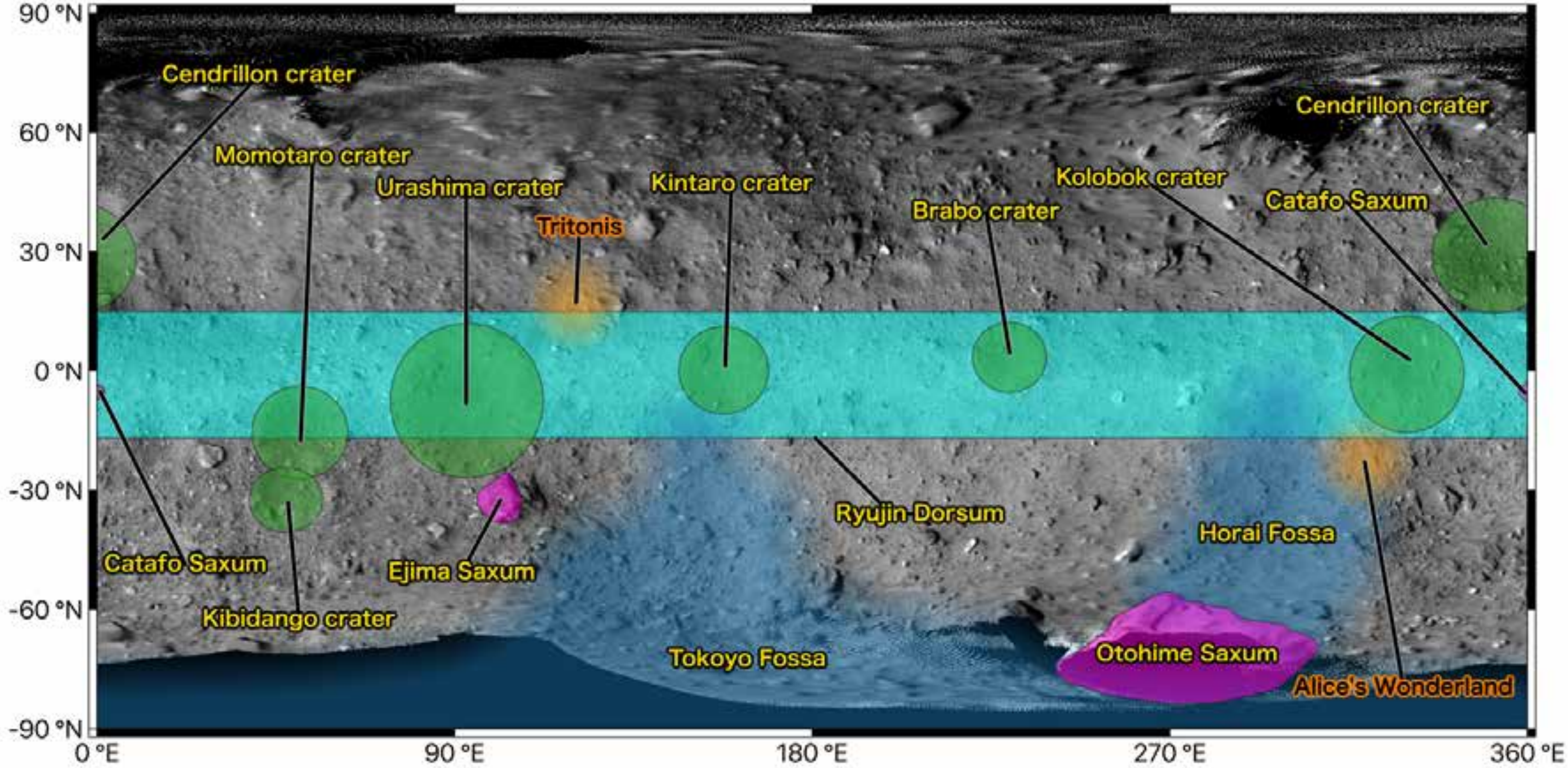
Tritonis, birthplace of the goddess, Minerva

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

MINERVA-II1: correction to the landing site name

Revised

Official names



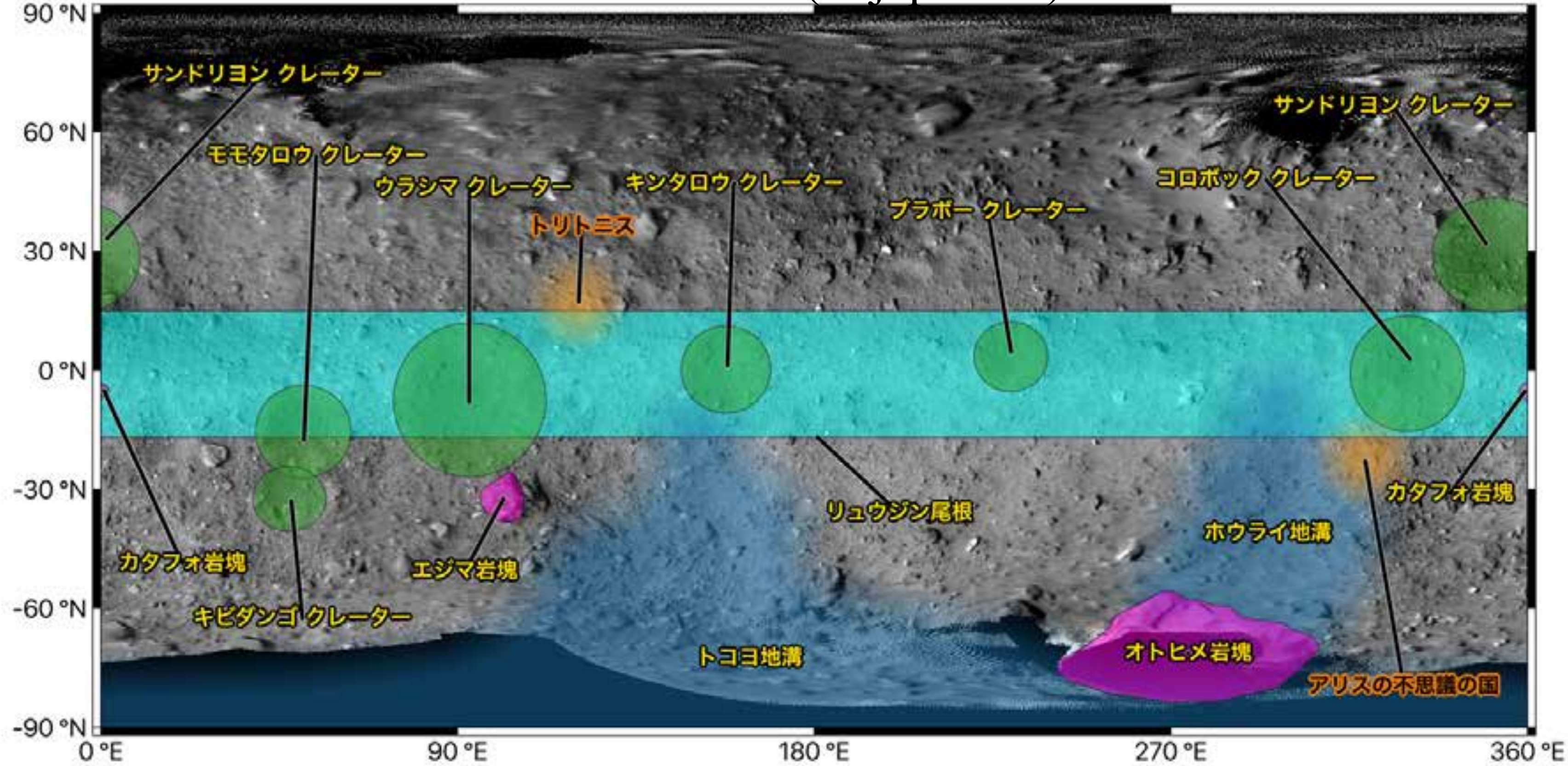
Note：Tritonis & Alice's Wonderland are nicknames for the MINERVA-II1 and MASCOT landing sites, respectively, and not place names recognized by the IAU.

（image credit：JAXA）

Revised

MINERVA-II1:
correction to the landing site name

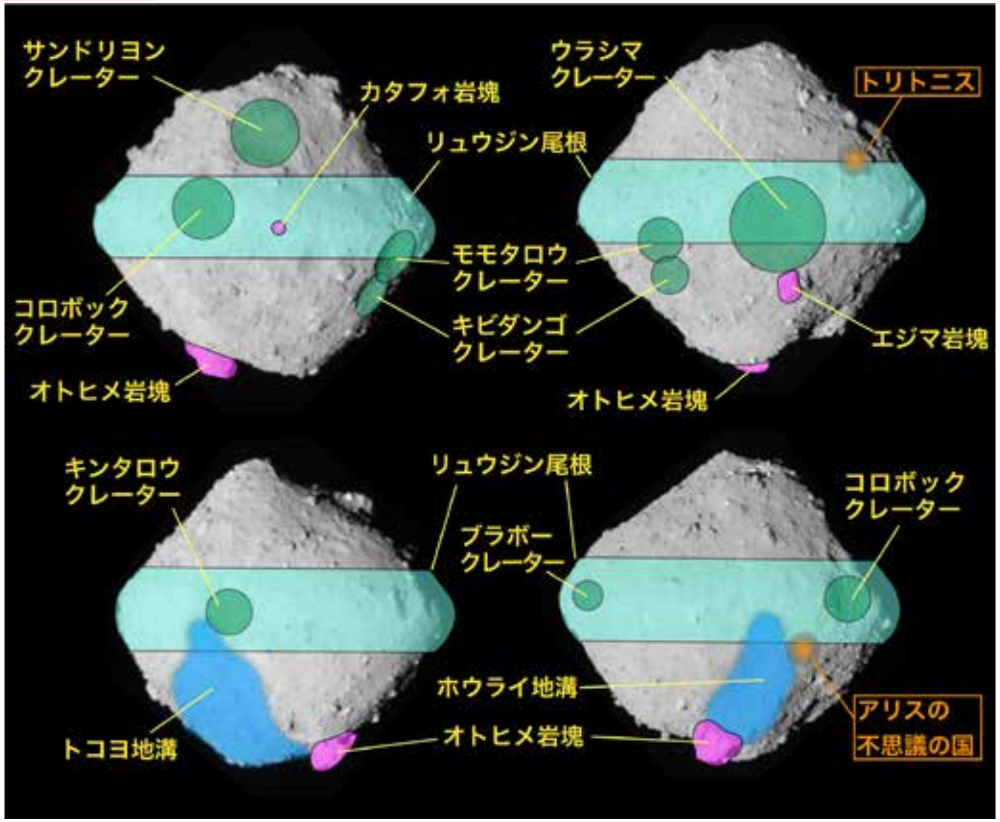
Official names (in japanese)

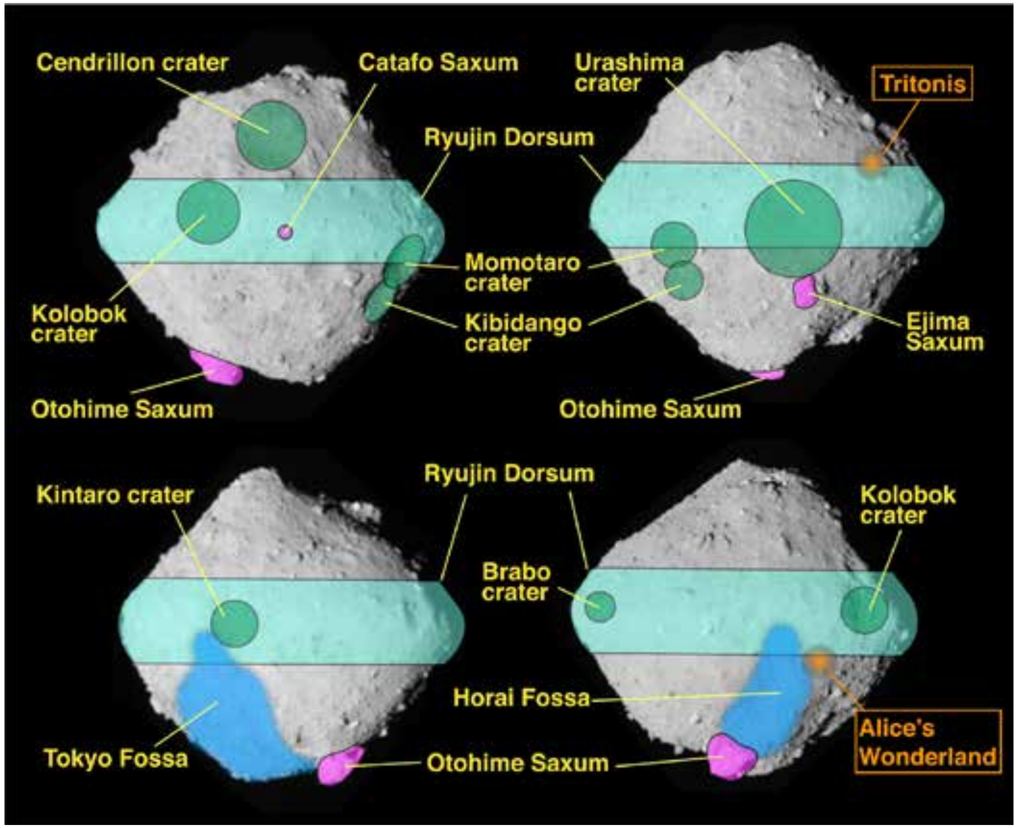


注：トリトニスとアリスの不思議の国は、それぞれMINERVA-II1とMASCOT着陸地点のニックネームで、IAUに認められた地名ではない。　（画像のクレジット：JAXA）

Revised

MINERVA-II1: correction to the landing site name





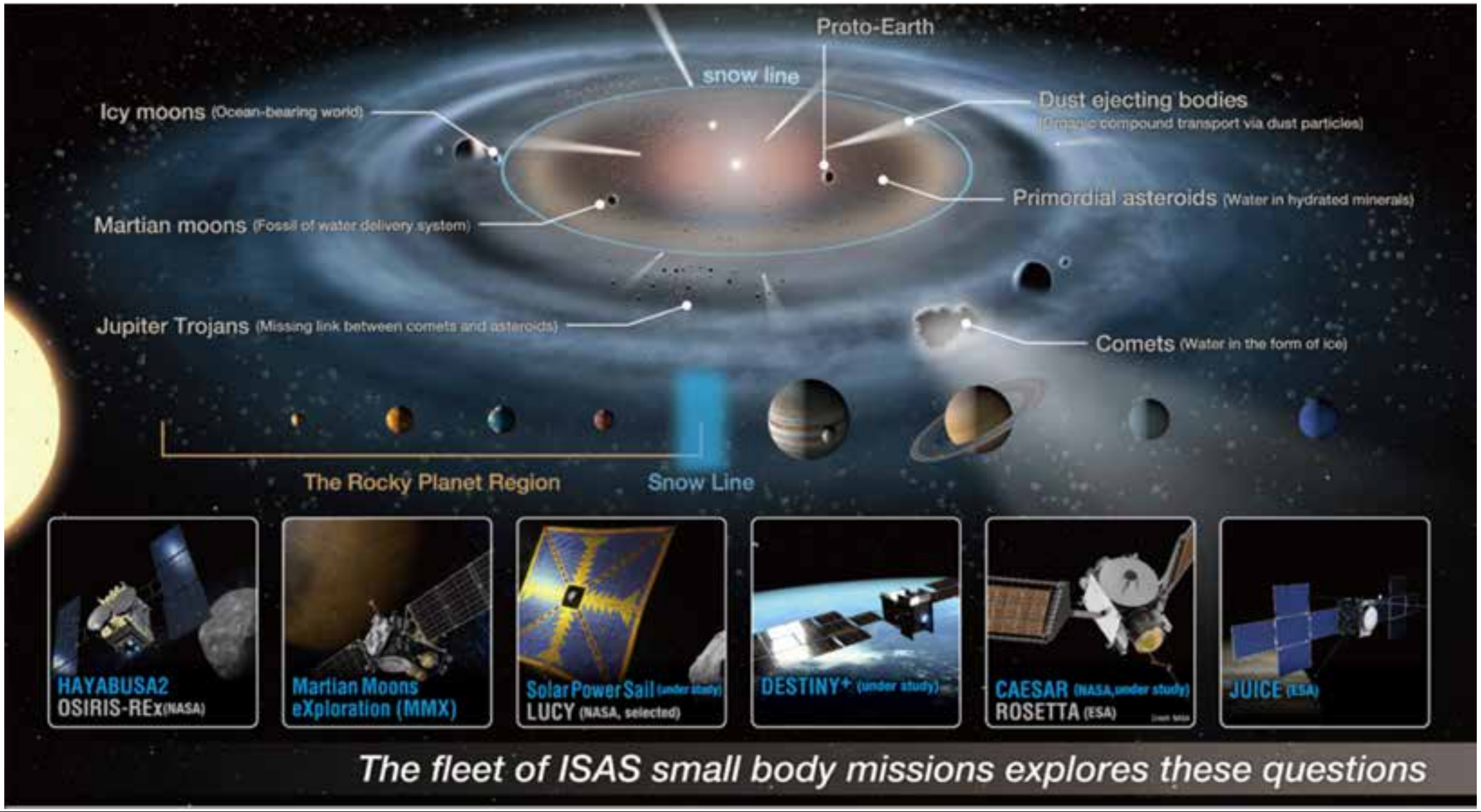
Note : Tritonis & Alice's Wonderland are nicknames for the MINERVA-II1 and MASCOT landing sites, respectively, and not place names recognized by the IAU.

（Image credit : JAXA）

Reference material

Small Body Exploration Strategy

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



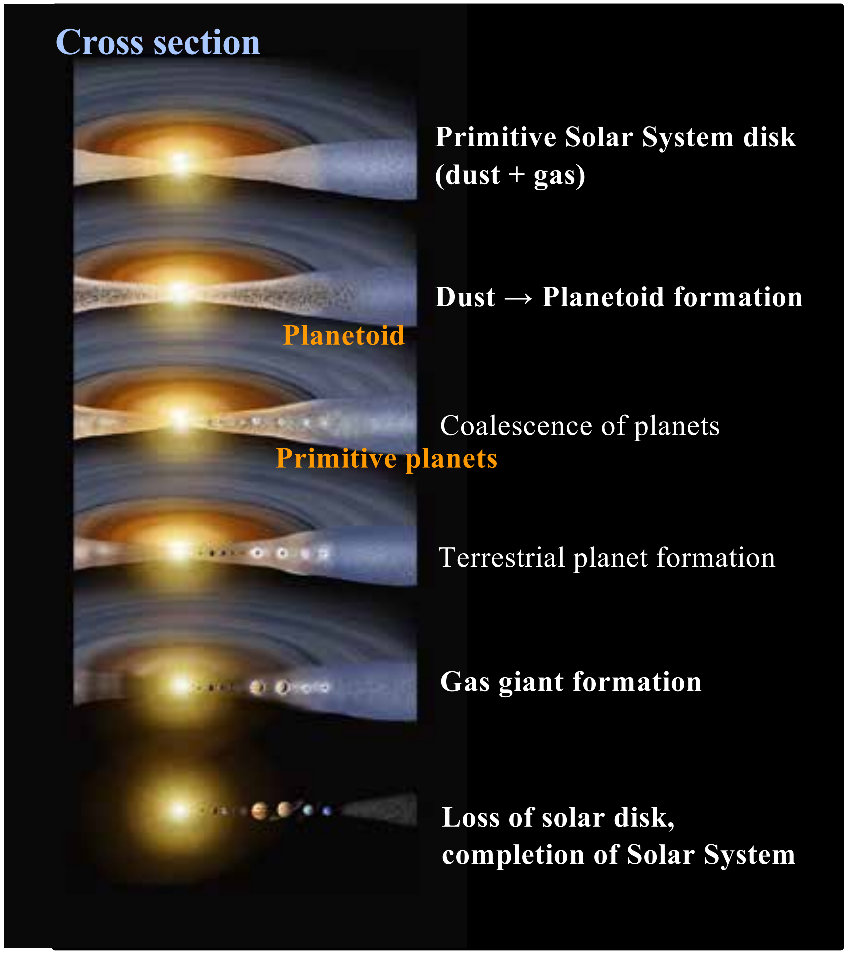
・Small bodies born outside the snowline are initially balls of icy mud (primitive comets) but can evolve into a variety of forms (e.g. primitive asteroid).

・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.

↓

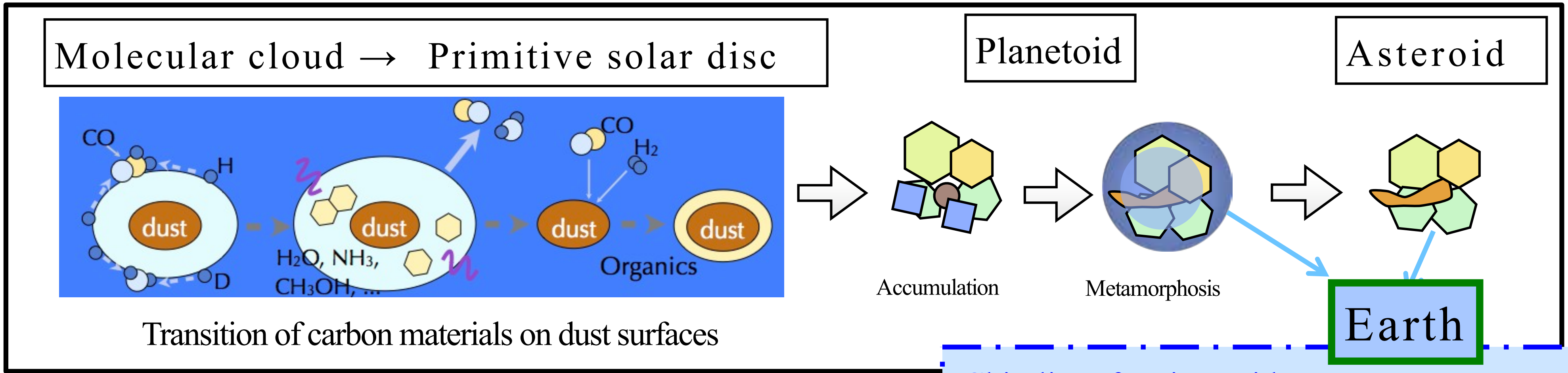
Revealing the materials that eventually became the planetary body, sea and life

Keywords :

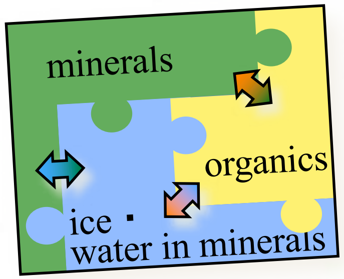
- Pre-solar particles : Particles inherited from the interstellar molecular cloud that are in the Solar System.
- White inclusions（CAI）: Substances that record the initial high temperature state of the Solar System.
- Mineral-water-organic matter interaction : Diversification of organic matter in the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

Elucidation of organics by Hayabusa2

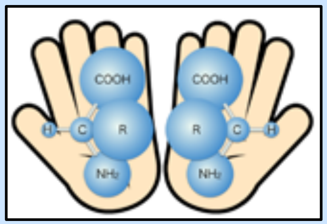
Volatile substances, such as water and organic matter, form on dust surfaces in molecular clouds. It is thought that these change due to aqueous metamorphism and thermal denaturation in primitive solar system discs and planetoids, eventually accumulating on Earth and providing materials for life. We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



Interactions between materials, water, and organics



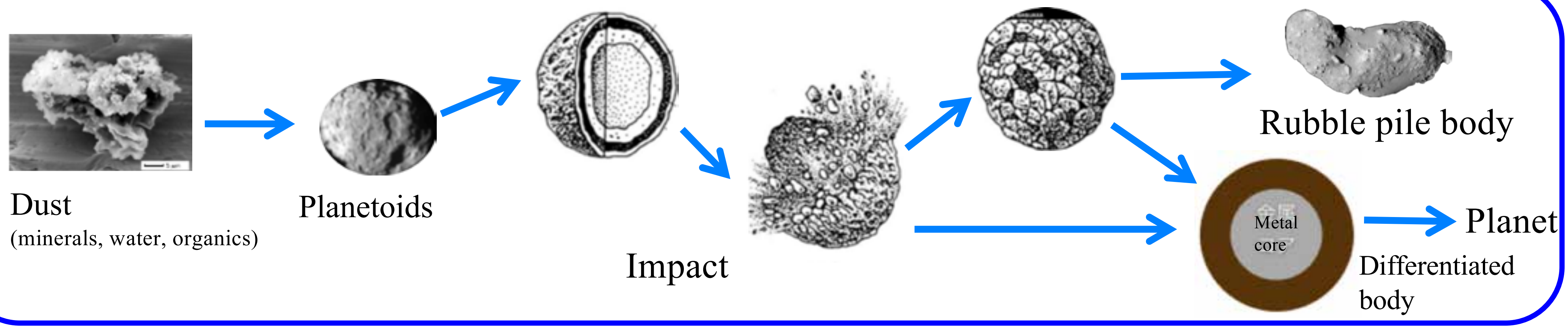
Chirality of amino acids



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.

↓

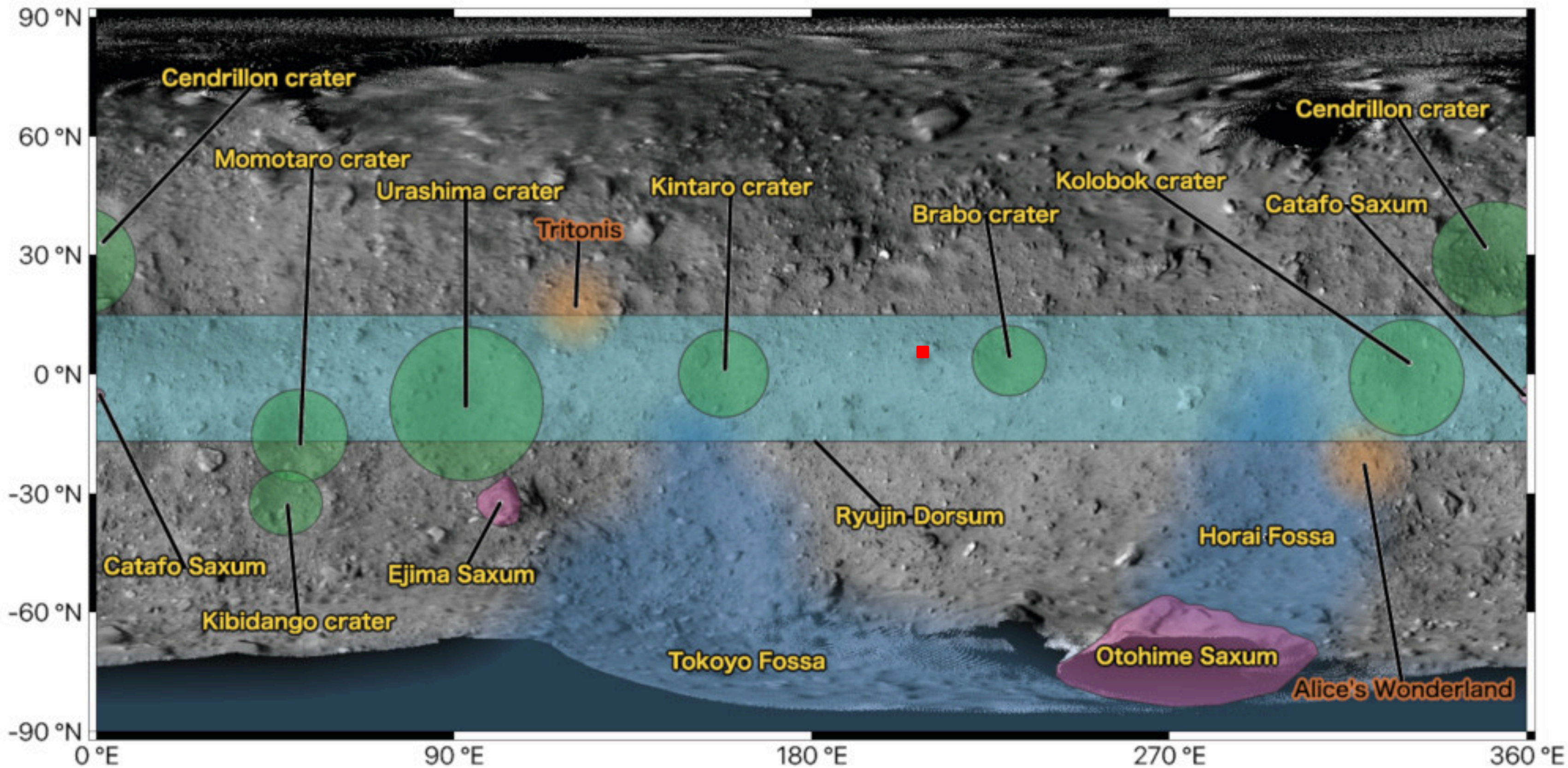
Elucidate formation processes from planetoid to planet

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

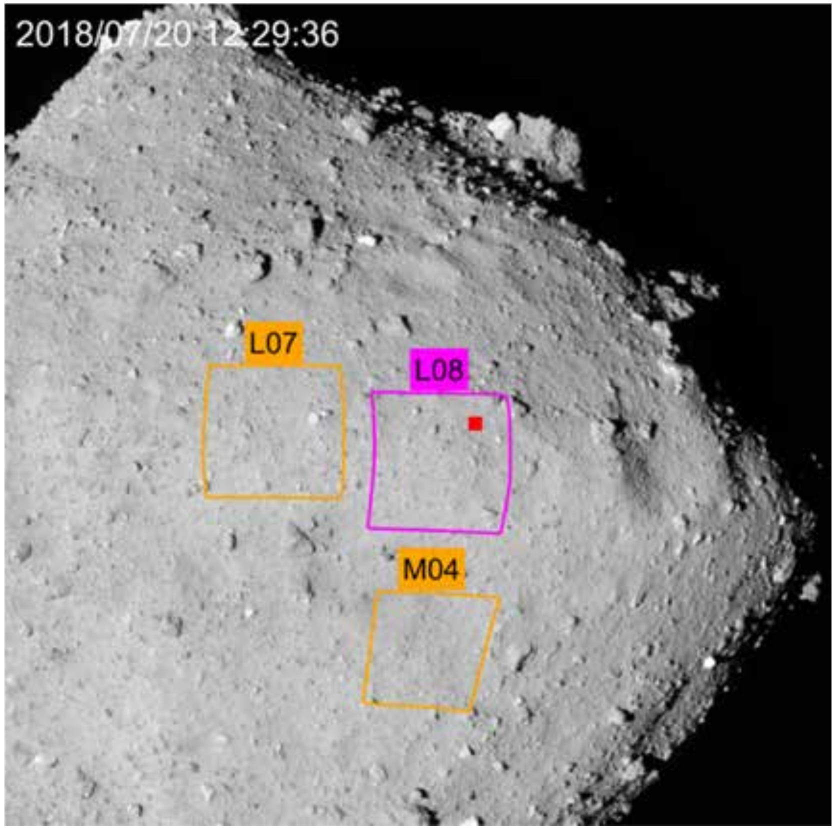
The approximate position of touchdown will be the red square (■) in the figure below.

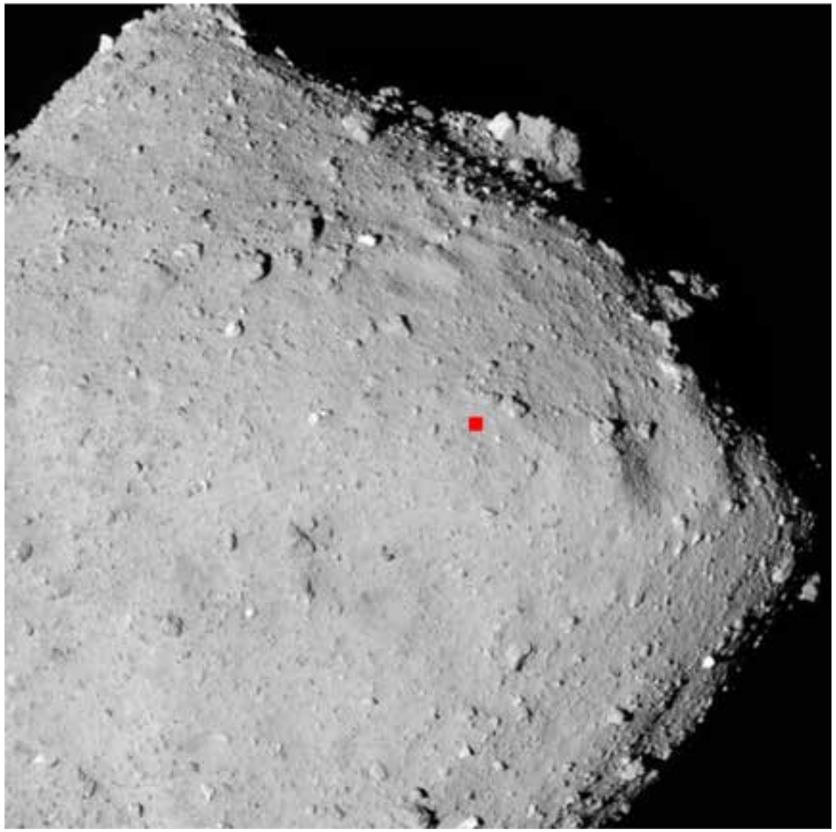


(image credit: JAXA)

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)