Asteroid explorer, Hayabusa2, reporter briefing

March 5, 2019

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2:

- Future operations objective
- Result of the touchdown operation

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

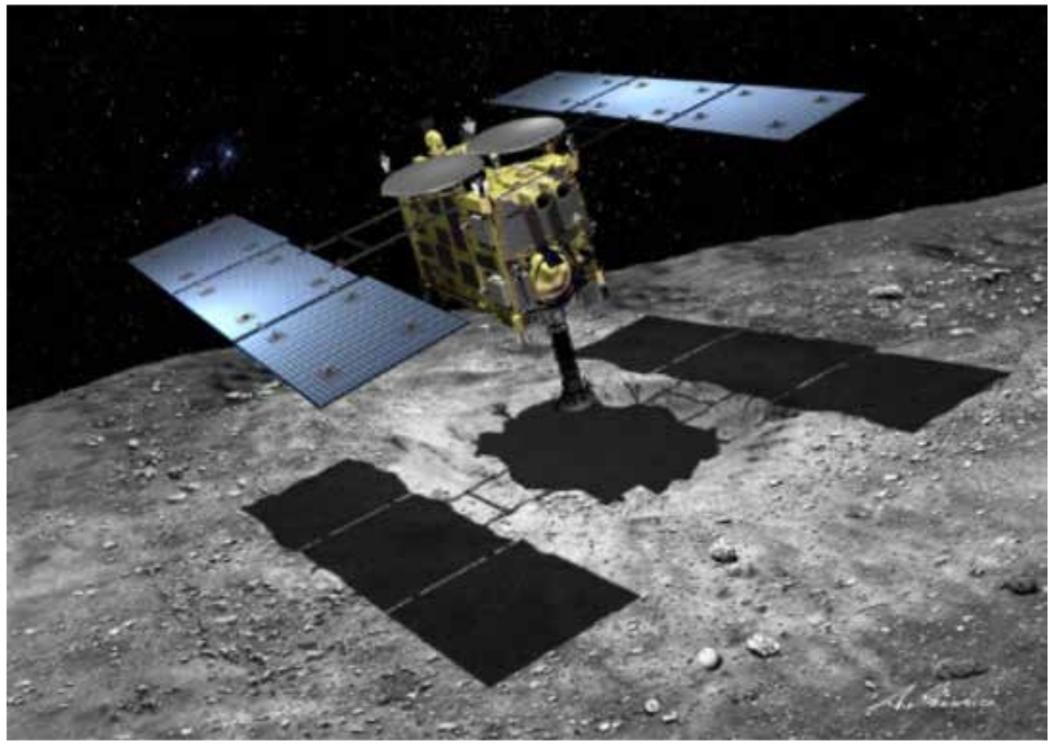
- By exploring a C-type asteroid, which is rich in water and organic materials, we will clarify interactions between the building blocks of Earth and the evolution of its oceans and life, thereby developing solar system science.
- Japan will further its worldwide lead in this field by taking on the new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

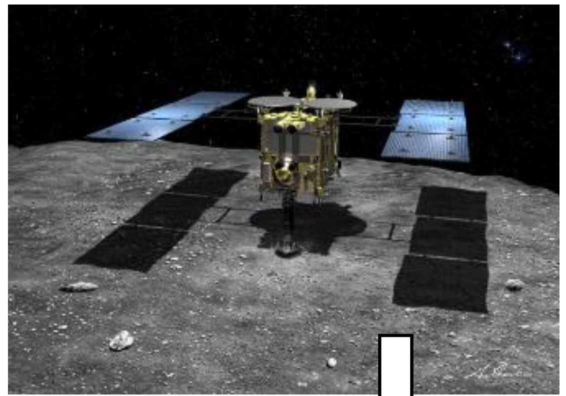
Launch → Arrival at asteroid

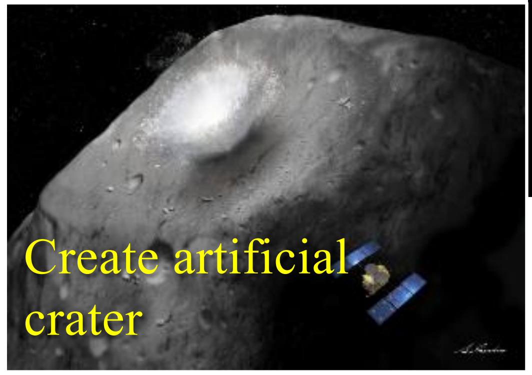
3 Dec 2014

Earth swing-by
3 Dec 2015

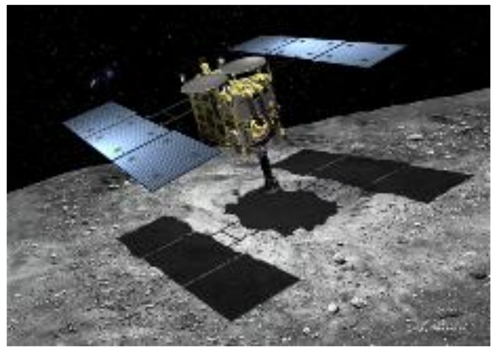
June 27, 2018

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

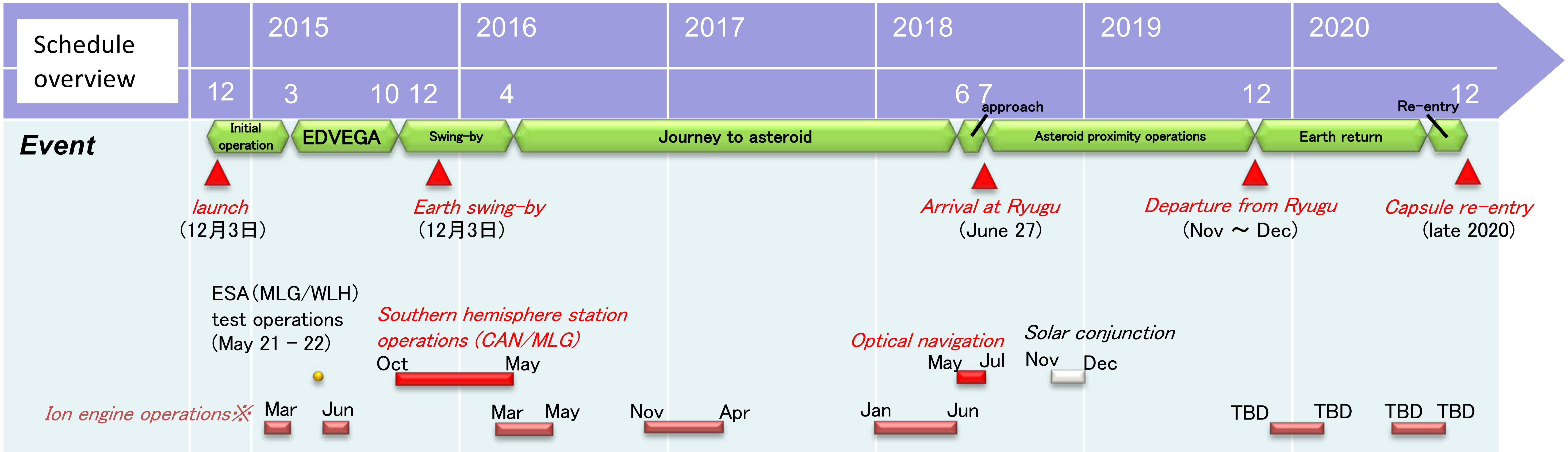
Sample analysis

(Illustrations: Akihiro Ikeshita)

1. Current project status & schedule overview

Current status :

- Touchdown operation was performed from February 20 – 22. Touchdown was successful.
- In the week beginning February 28, BOX-C observations were carried out that included observations from an altitude of about 5km.
- In the week beginning March 4, we will conduct a survey descent operation to observe the region around S01.



2. Future operation policy

Following the success of the first touchdown operation (TD1-L08E1), the future operation policy will be as follows:

- The next event is the experiment to form an artificial crater using the Small Carry-on Impactor (SCI).
- The second touchdown will be done inside or outside the artificial crater formed with the SCI. Alternative sites at a different location will also be considered. (It will be decided after the SCI operation whether we will actually execute the second touchdown or not.)
- There is a high probability that a third touchdown will not be performed.

※Reasons for prioritizing the SCI collision experiment

- The first touchdown has been judged to have collected a sufficient sample.
- During the first touchdown, some of the optical sensors in the spacecraft base received a reduced amount of light. There is no problem during normal operations, but this effect means that careful preliminary investigation is necessary ahead of touchdown operations. As this preparation takes time, the SCI operation will be performed first.

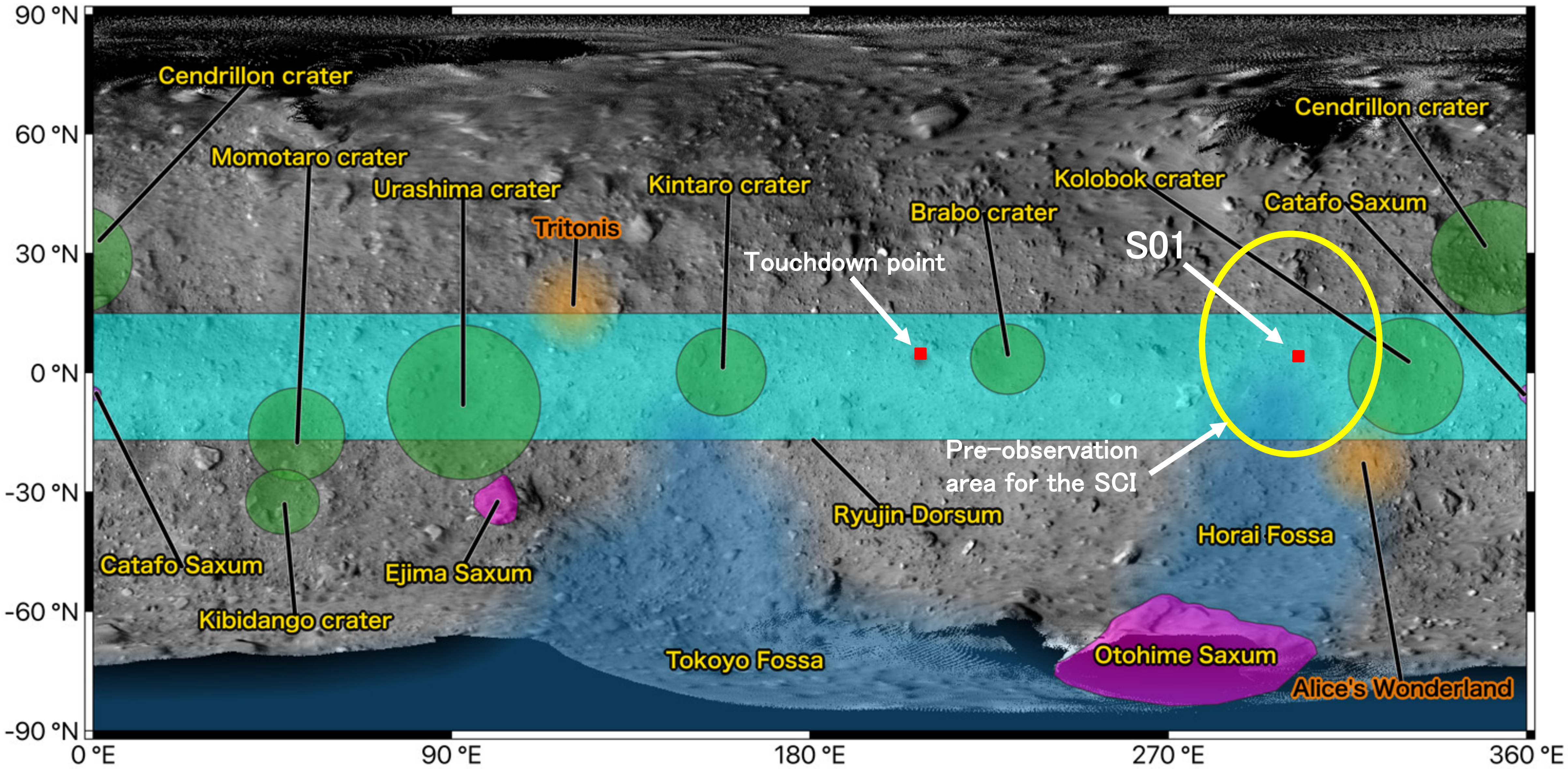
2. Future operation policy

Future Schedule

Date & time	Operation	Event
Mar. 6～8	Descent operation（DO-S01）	Acquire information for touchdown at this new location.
Mar. 20～22	Descent operation（CRA1）	Preliminary observations near the planned crater formation site with the SCI.
Apr. week of 1st	SCI operation	Crater formation experiment with the SCI
Apr. week of 22nd	Descent operation（CRA2）	Observation of the crater created by the SCI.
After May	2^{nd} touchdown	Sampling
After July	MINERVA-II2 separation operation	MINERVA-II2 operation
Nov. ～ Dec.	Depart Ryugu	
End of 2020	Earth return	

2. Future operation policy

Region S01: site of the SCI operation



(Image credit：JAXA）

3. Results of the touchdown operation

Summary

- Touchdown operation
  February 20 〜 22, 2019
- Touchdown time
  February 22, 2019, 07:29:10
  （Time is JST、onboard time）
- Touchdown location
  L08-E1, within a circle of radius 3m
  Accuracy of guidance control : 1m
  Sample collection point also identified
- Method
  Pinpoint touchdown method using the dropped TM-B.

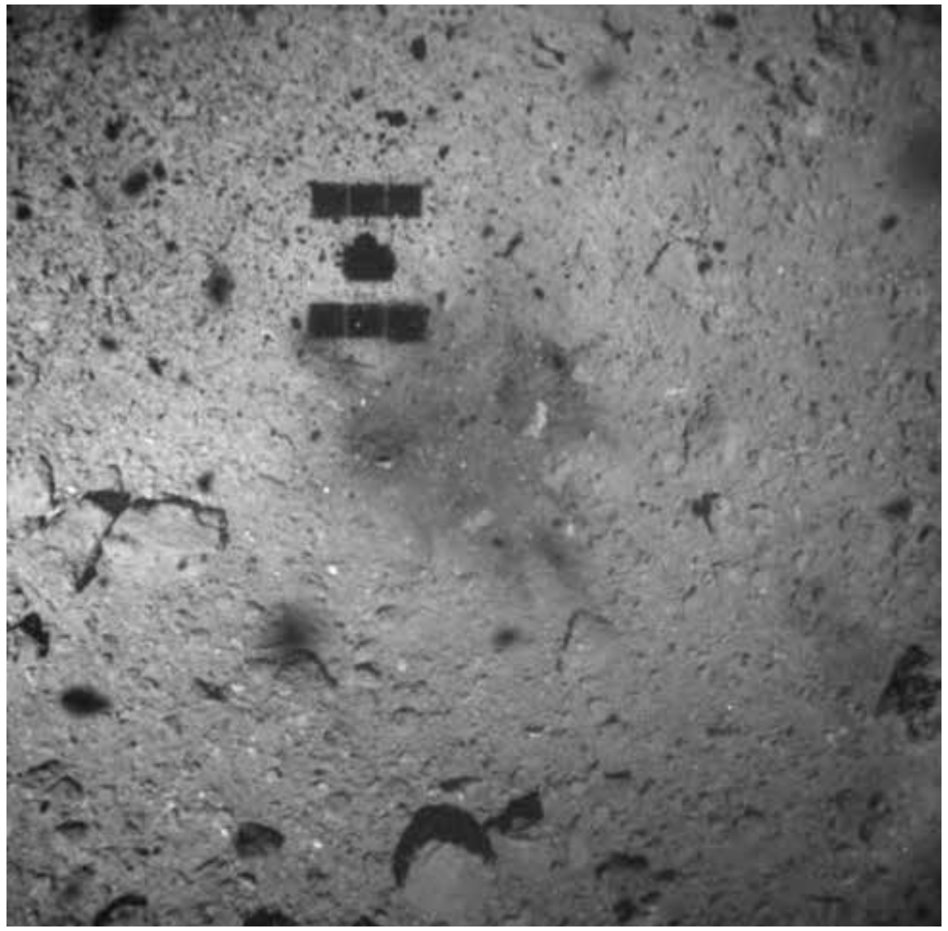
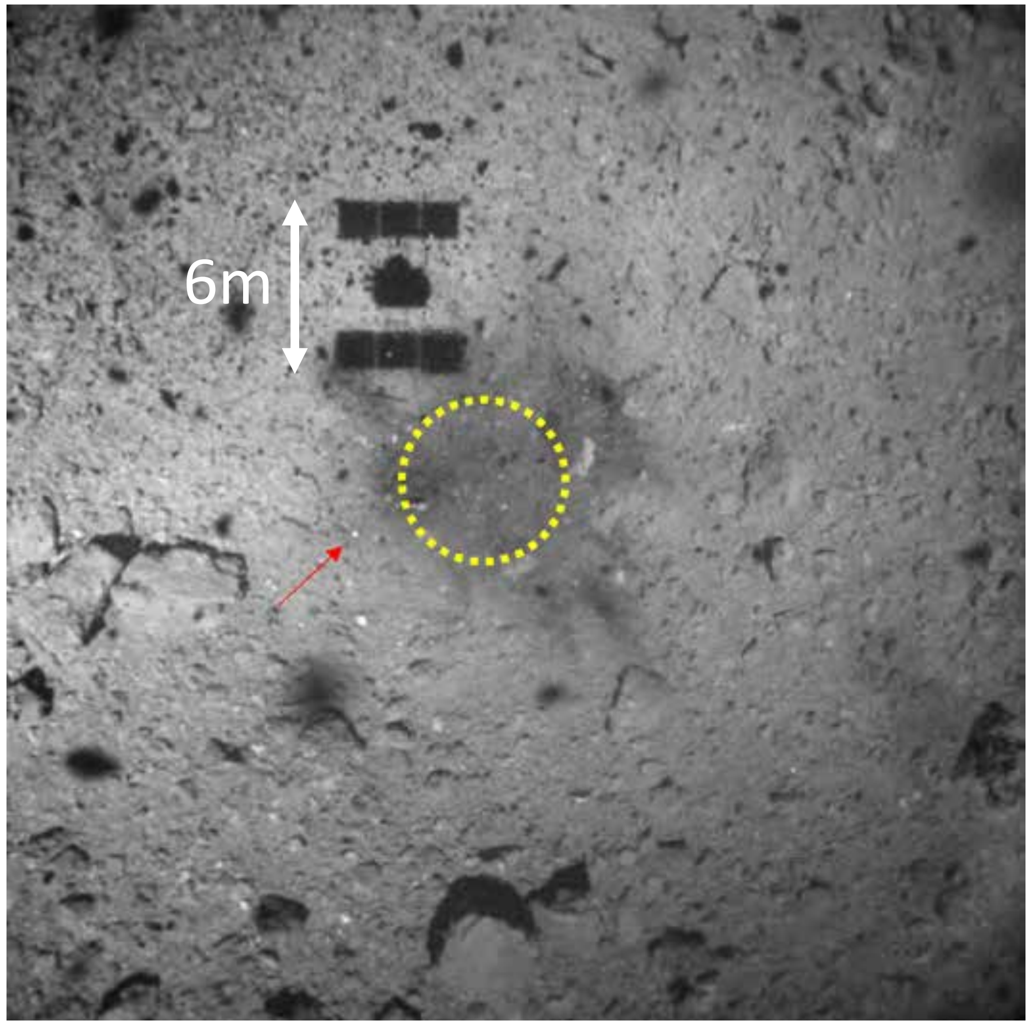


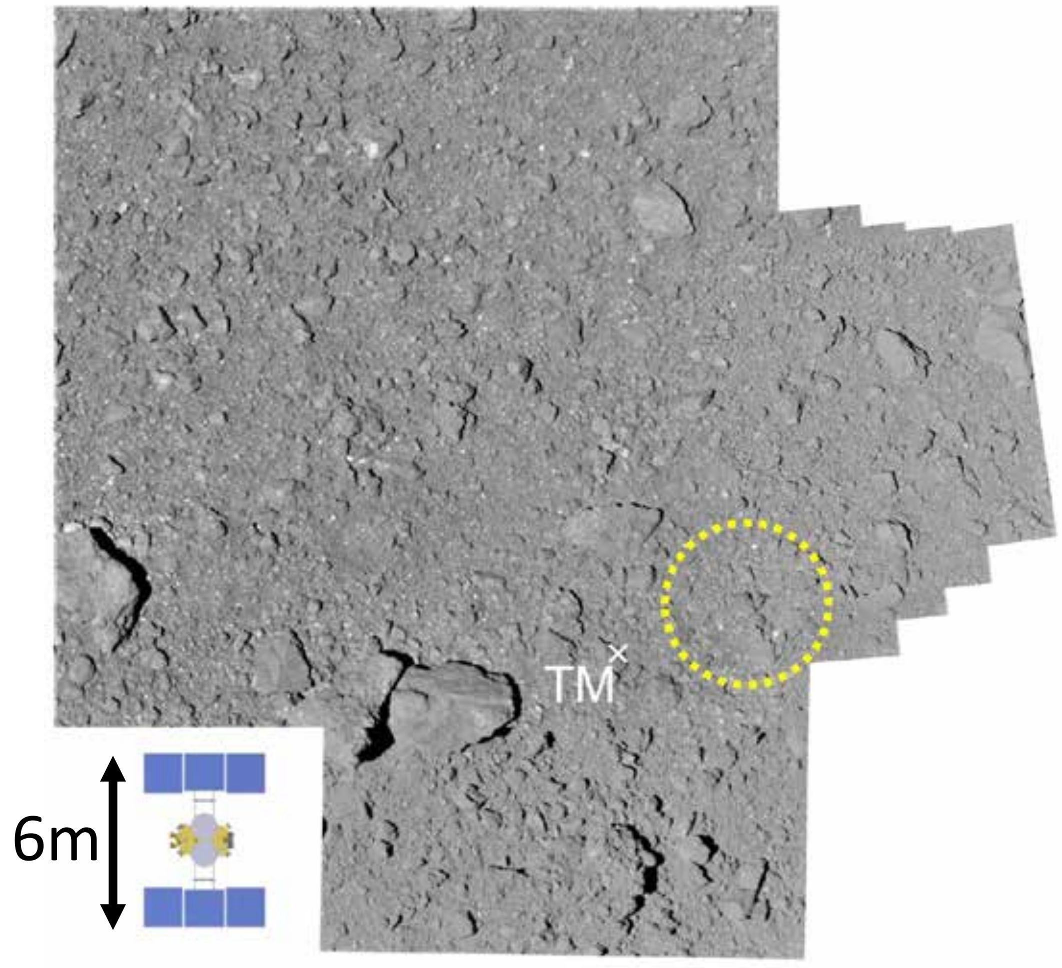
Image captured around the touchdown point at approximately 07:30 JST (onboard time) on February 22, 2019 immediately after touchdown. Taken with Optical Navigation Camera – Wide angle (ONC-W1), at an altitude of about 25m.

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

3. Results of the touchdown operation



The planned touchdown point (circle diameter 6m) superimposed on the image captured immediately after touchdown. The white dot at the arrow tip is the target marker.

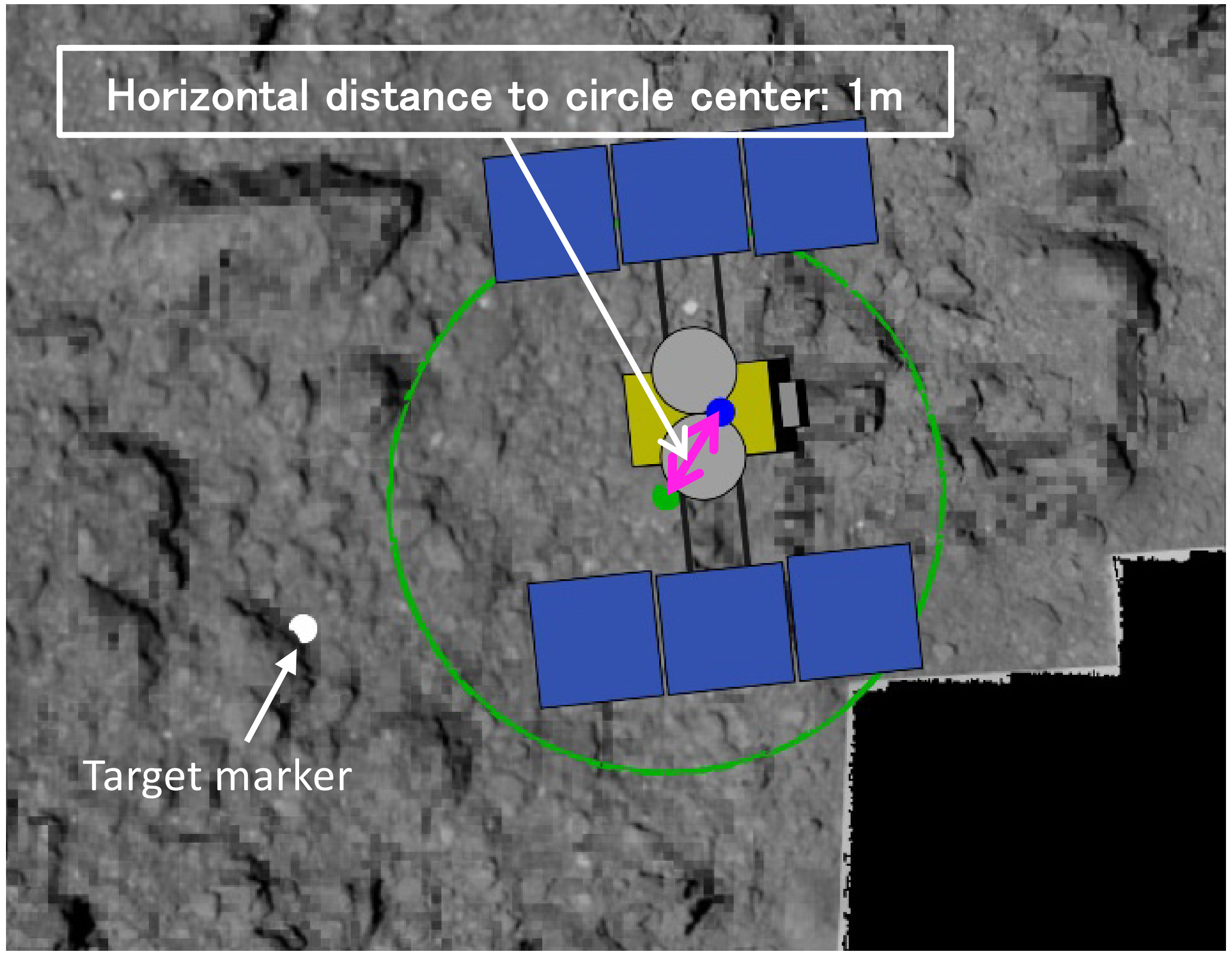


For comparison, this is an image taken before touchdown. The circle at the planned touchdown point is 6m in diameter. X indicated the position of the target marker. The size of the spacecraft picture is on the same sclae as this image.

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

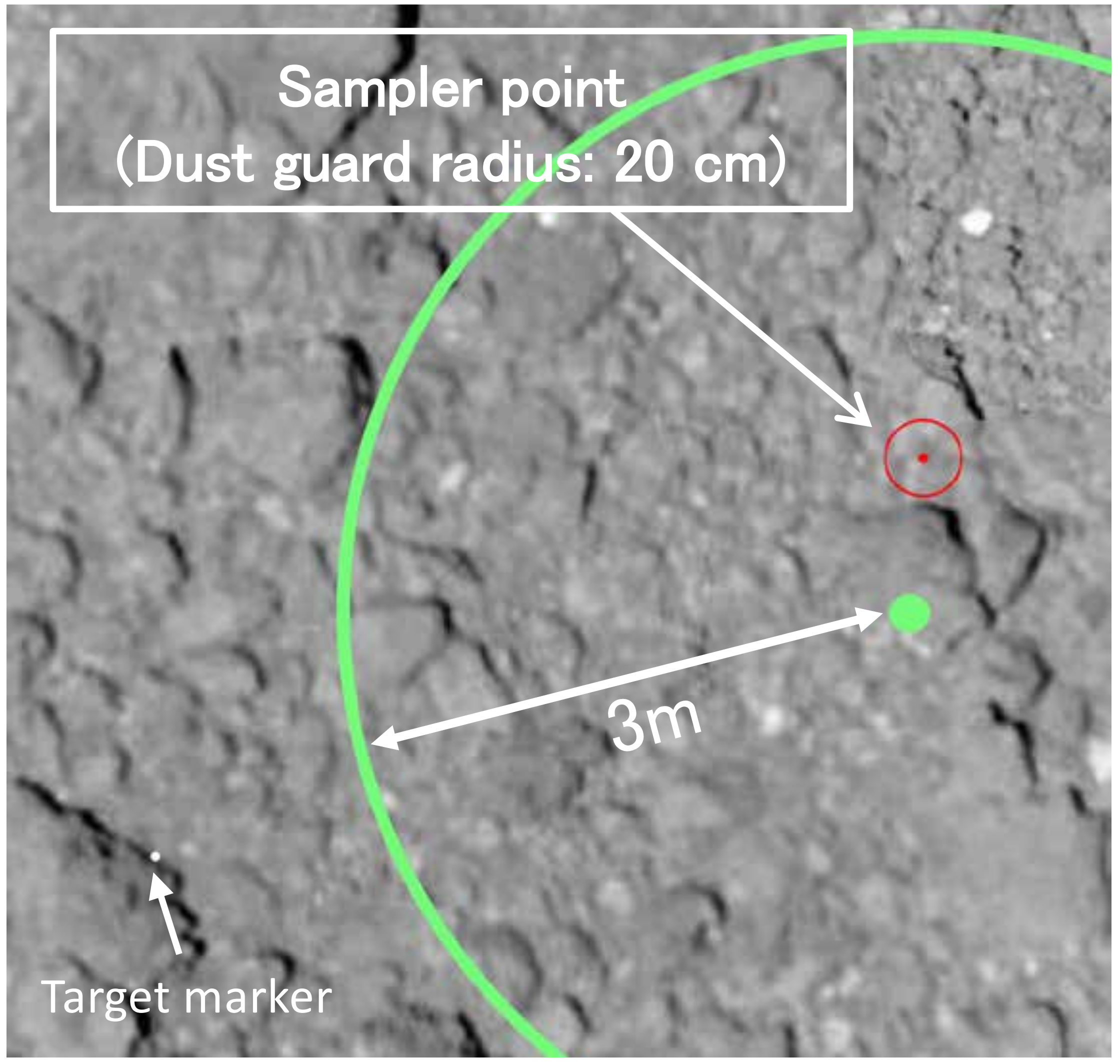
3. Results of the touchdown operation

Touchdown point



Green circle is the planned touchdown point. The deviation from the circle center to the center of the spacecraft (blue dot) is 1m (Background is from the shape model).

Sampling point

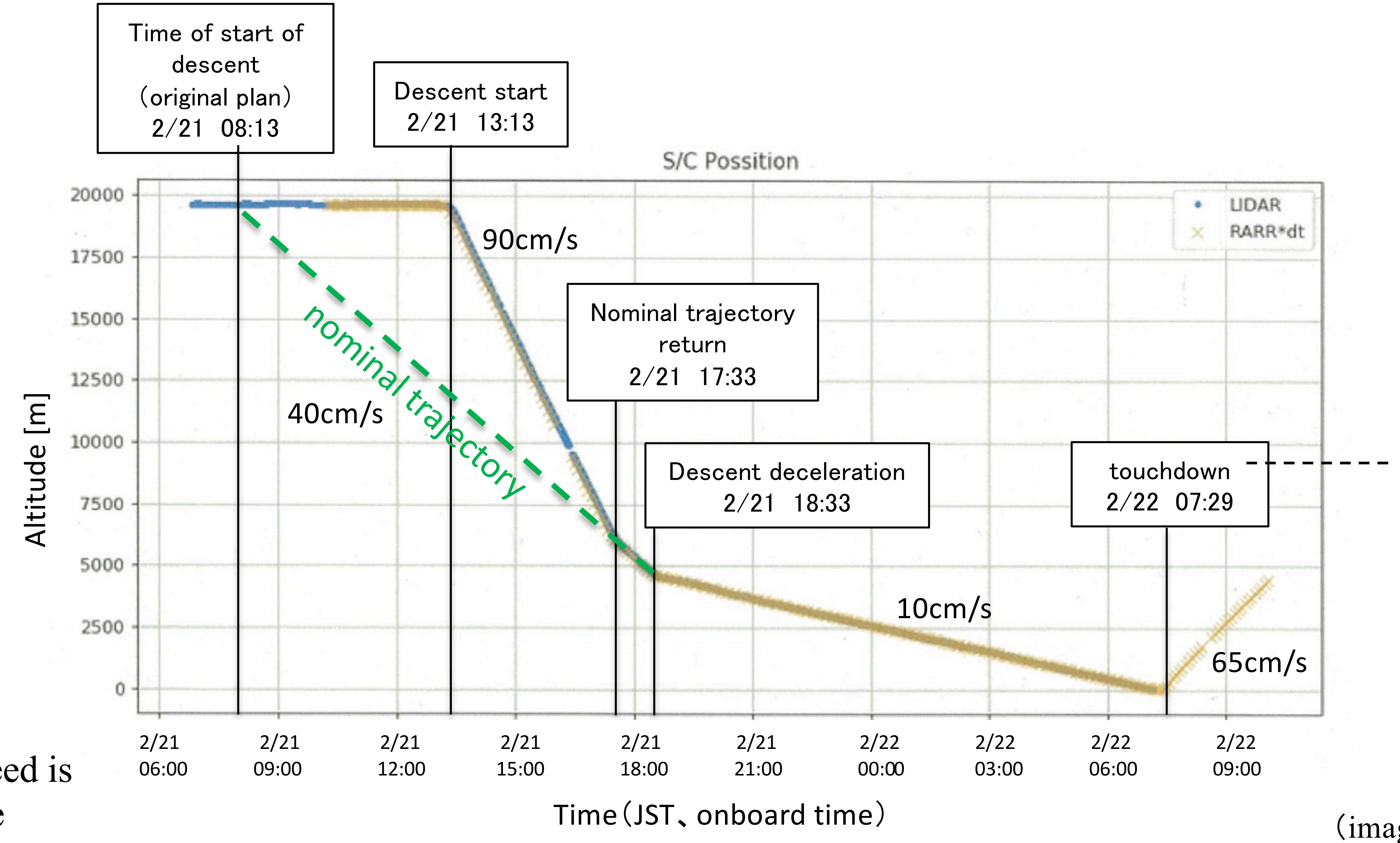


(©JAXA)

Red circle is where the sampler horn is thought to have touched the surface. Green circle is the planned touchdown site. Background is a real image of Ryugu.

3. Results of the touchdown operation

During descent



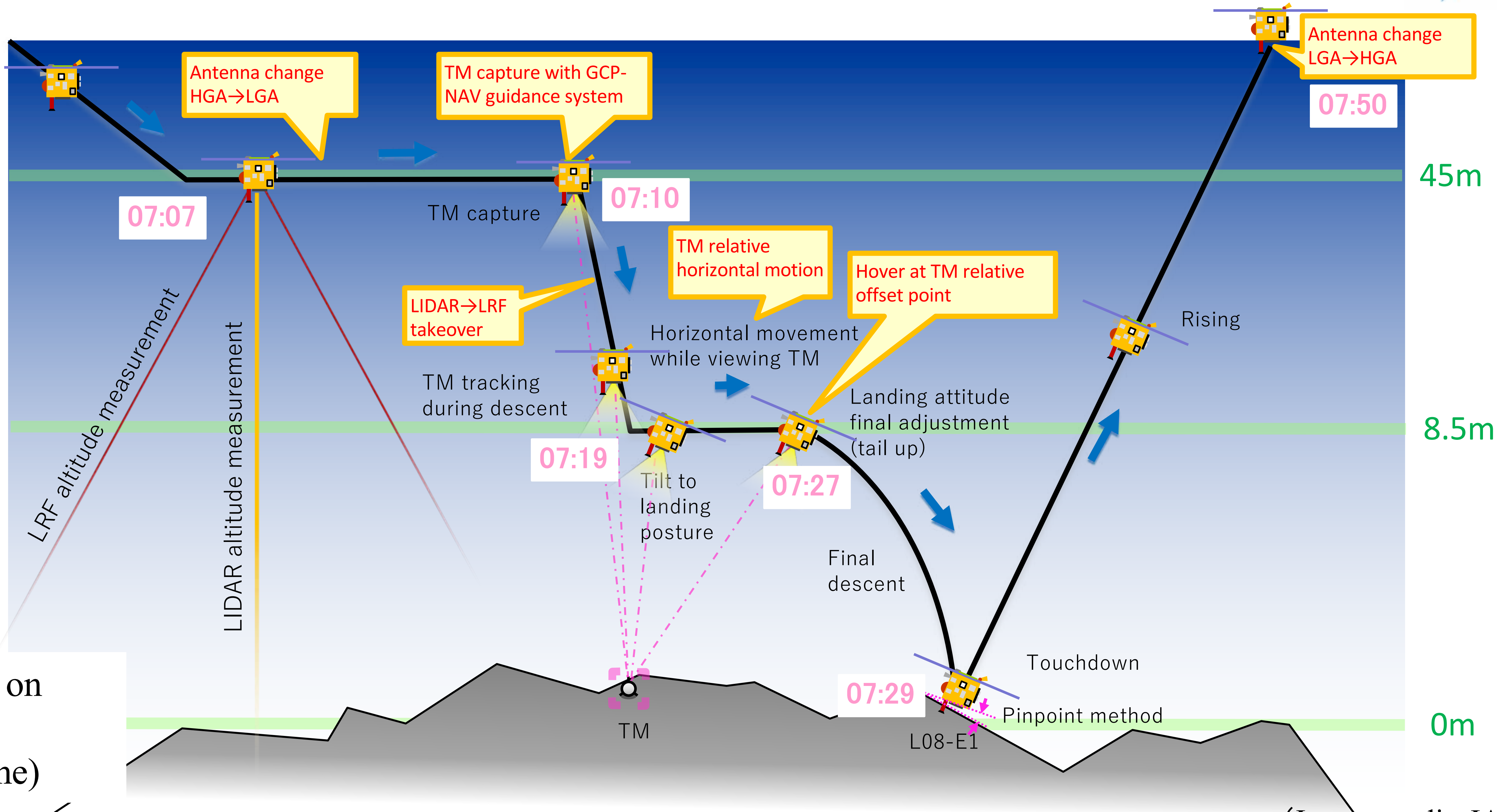
Note）Touchdown detected by change in attitude.

Value of speed is approximate

（image credit：JAXA）

3. Results of the touchdown operation

Low altitude



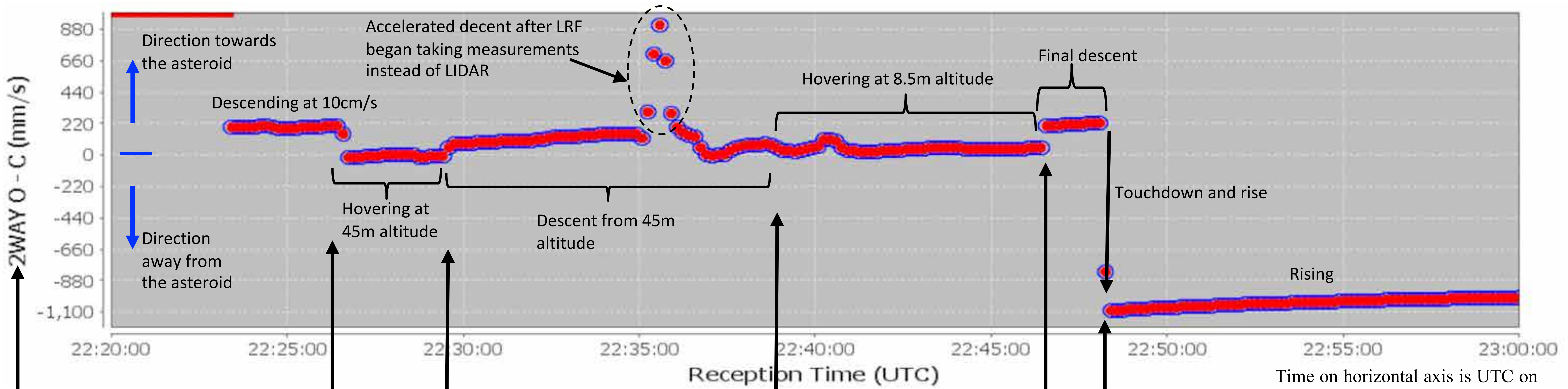
Time is JST on February 22 (onboard time)

(Image credit: JAXA)

3. Results of the touchdown operation

Low altitude

Doppler data



Twice the value of the line-of-sight velocity of the spacecraft, relative to the asteroid

07:07

07:10:31

07:19:44

07:27:29

07:29:10

Time on horizontal axis is UTC on the ground (February 21).

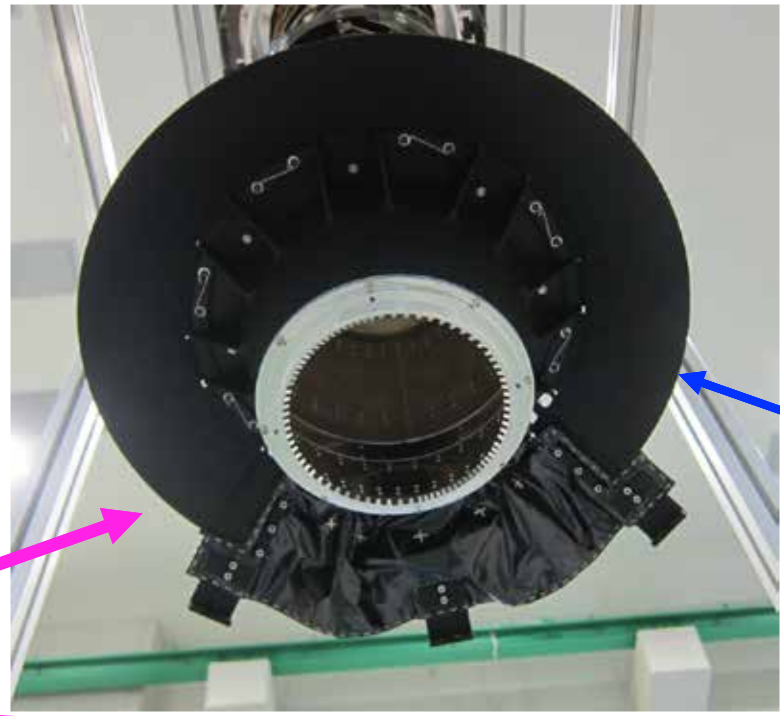
（Times with underlines are the onboard time in JST）

（Image credit：JAXA）

3. Results of the touchdown operation

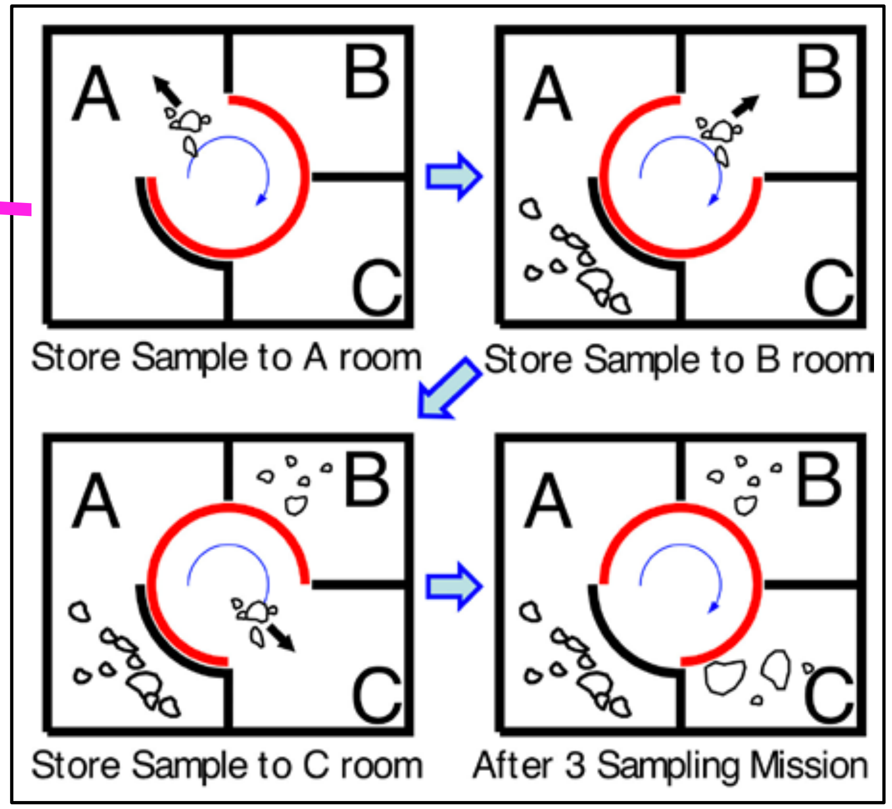
During ascent

Event	Onboard time (JST)
Touchdown	2/22 07:29
LGA→HGA	2/22 07:50
Deceleration ΔV	2/22 10:40
Catcher A chamber closed	2/22 11:20
Attitude : solar orientation	2/22 13:00
Return to HP ΔV	2/22 13:30
Attitude : Earth orientation	2/22 13:40
HP return	2/23 12:00



By suddenly reducing the speed of the spacecraft, material caught on the teeth at the tip of the sampler horn is transferred into the catcher.

dust guard



Rotating cylinder (red part in right-hand figure) was turned to close chamber A and open chamber B.

(image credit : JAXA)

3. Results of the touchdown operation

About sampling

After ascending after touchdown and checking the telemetry on the ground, it was confirmed from the status and temperature change of the projector that the projectile had been fired.

In order to float the sample that was collected in the inverted horn tip upwards, a ΔV of -1cm/s was applied at 10:40.

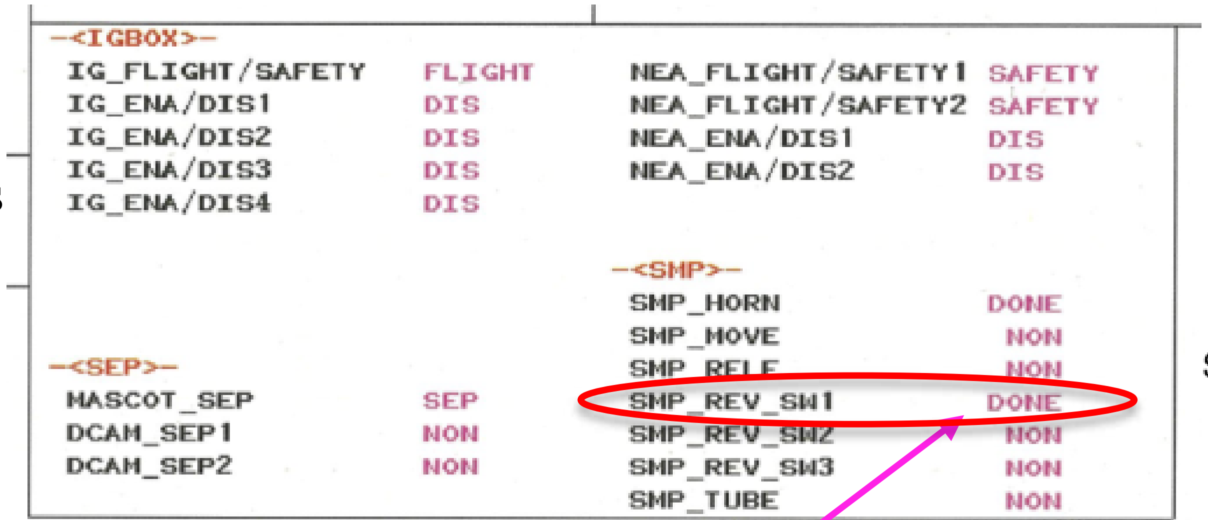
To allow time for the floating sample to enter the catcher and settle in the chamber, the rotation mechanism of the catcher was employed 40 minutes later at 11:20 and the lid of chamber A was closed. The change of status confirmed that the rotation mechanism was performed normally.

(Time: JST, onboard time on Feb. 22)

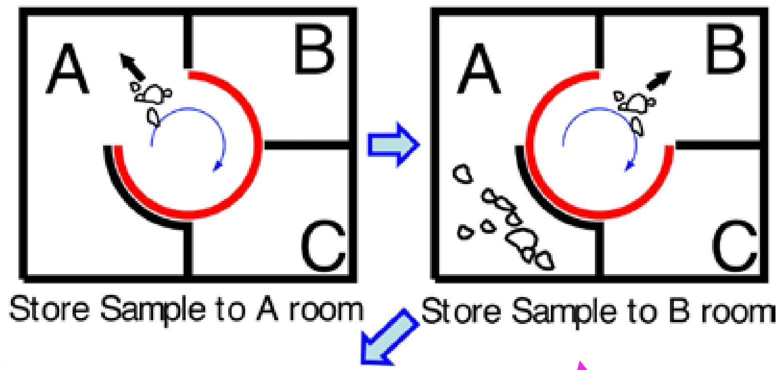
(image credit: JAXA)

Projector temperature sensor position

Confirm temperature rise from 07:29



Confirm the rotation mechanism operated normally and becomes "Done"



Current state

3. Results of the touchdown operation

Reason for the delay in the descent start time:

- On February 21 at around 07:15 JST, when the descent preparation process for the spacecraft began the Gate 1 check, it was found that the position information recognized by the spacecraft differed from the assumed position.
- Therefore, we delayed the judgement of whether to begin the descent to check the situation, confirming that the spacecraft condition was normal. It was found that this event was due to slight difference in the operation timing of the descent guidance program.
- We adjusted the timing and confirmed that the descent sequence could operate without problems.
- Procedures such as delaying the descent start time and generating a new descent trajectory at the Gate 1 check are part of the training. The new descent plan was ready and confirmed in about 5 hours.
- Since the touchdown time had been decided, we decided to increase the descent speed. As previous ground training had used a descent speed of about 1 m/s down to an altitude of several kilometres, this was no problem.

3. Results of the touchdown operation

<u>The nickname for the touchdown point:</u>

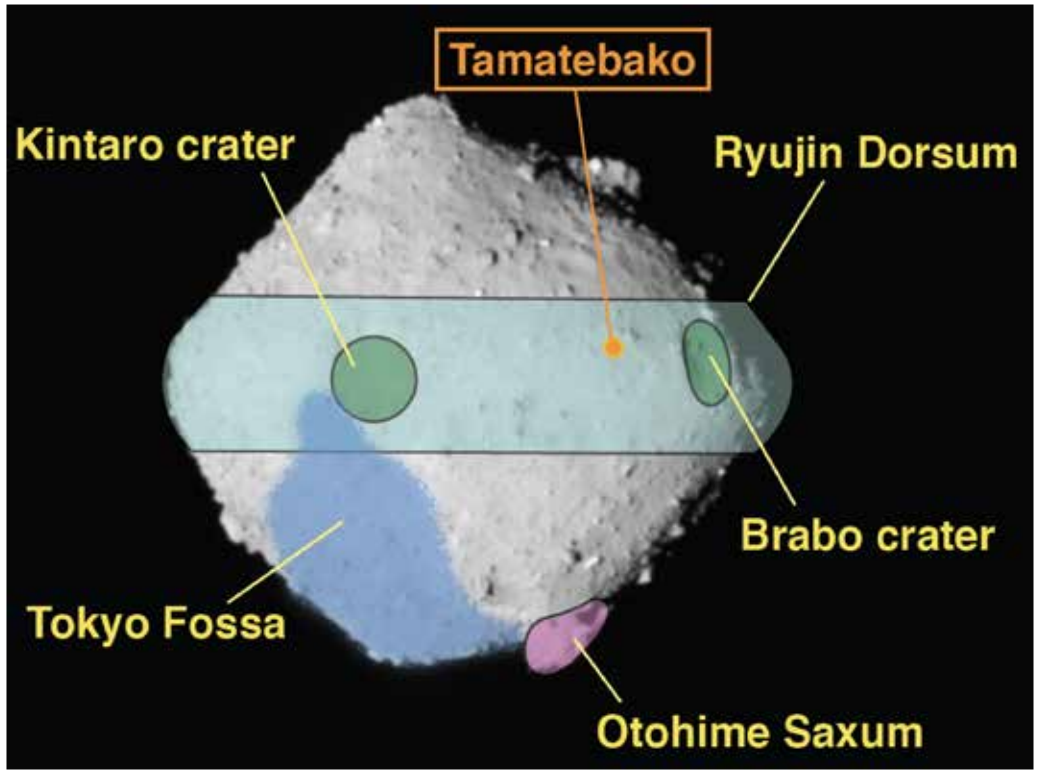
The point of the Hayabusa2 touchdown has been named

“Tamatebako”

This is a nickname, not an official name.

Reason:

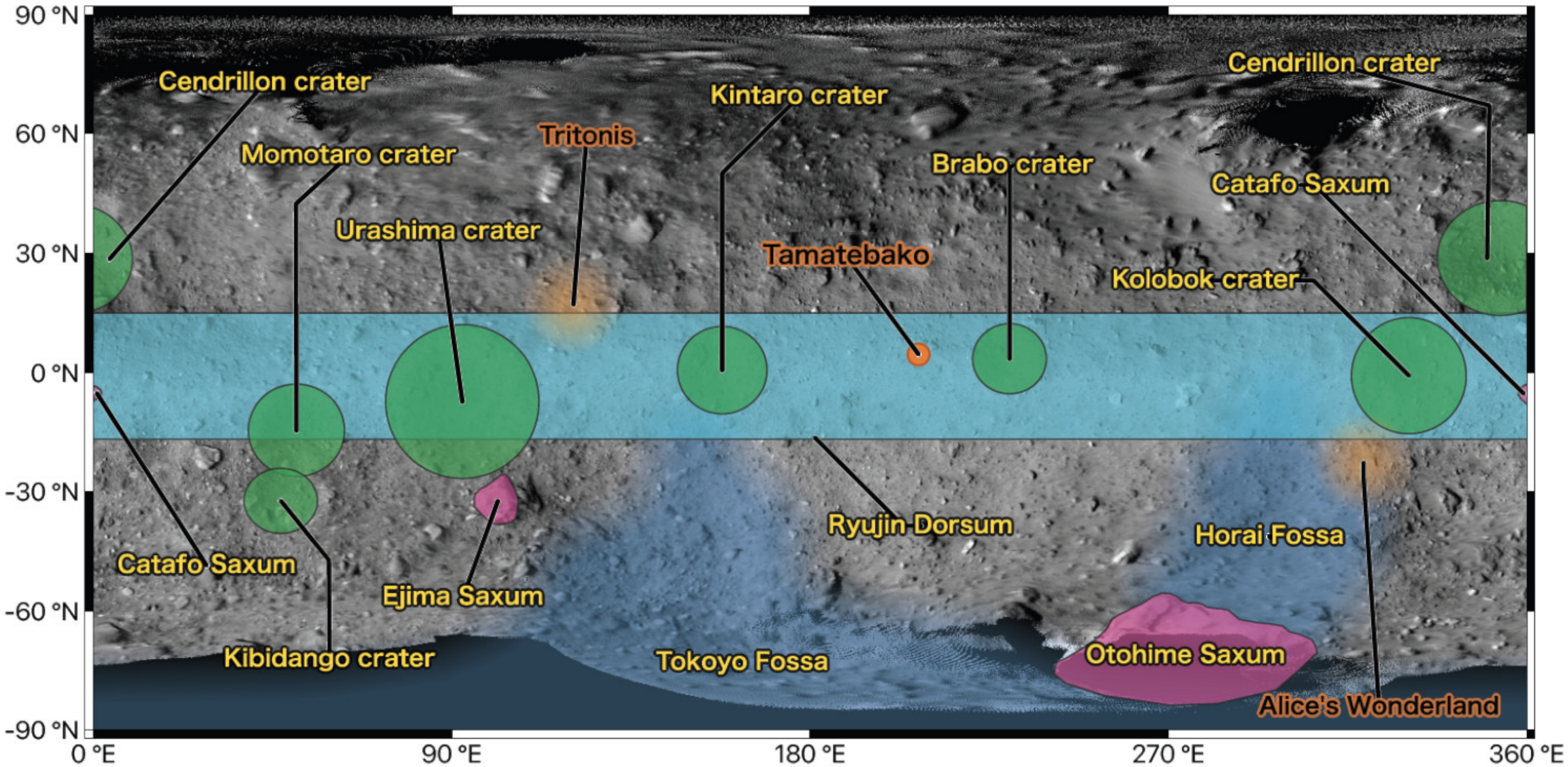
- Proposed name was the most popular suggestion when requesting names from Project Members.
- In the story of Urashima Taro (where Ryugu takes its name), smoke emerges from the tamatebako (treasure box) which is like the ejector flying upwards at touchdown.
- Also because this is the point where the sample (= treasure of Ryugu) was collected.



(image credit: JAXA)

3. Results of the touchdown operation

Place names on Ryugu (updated)

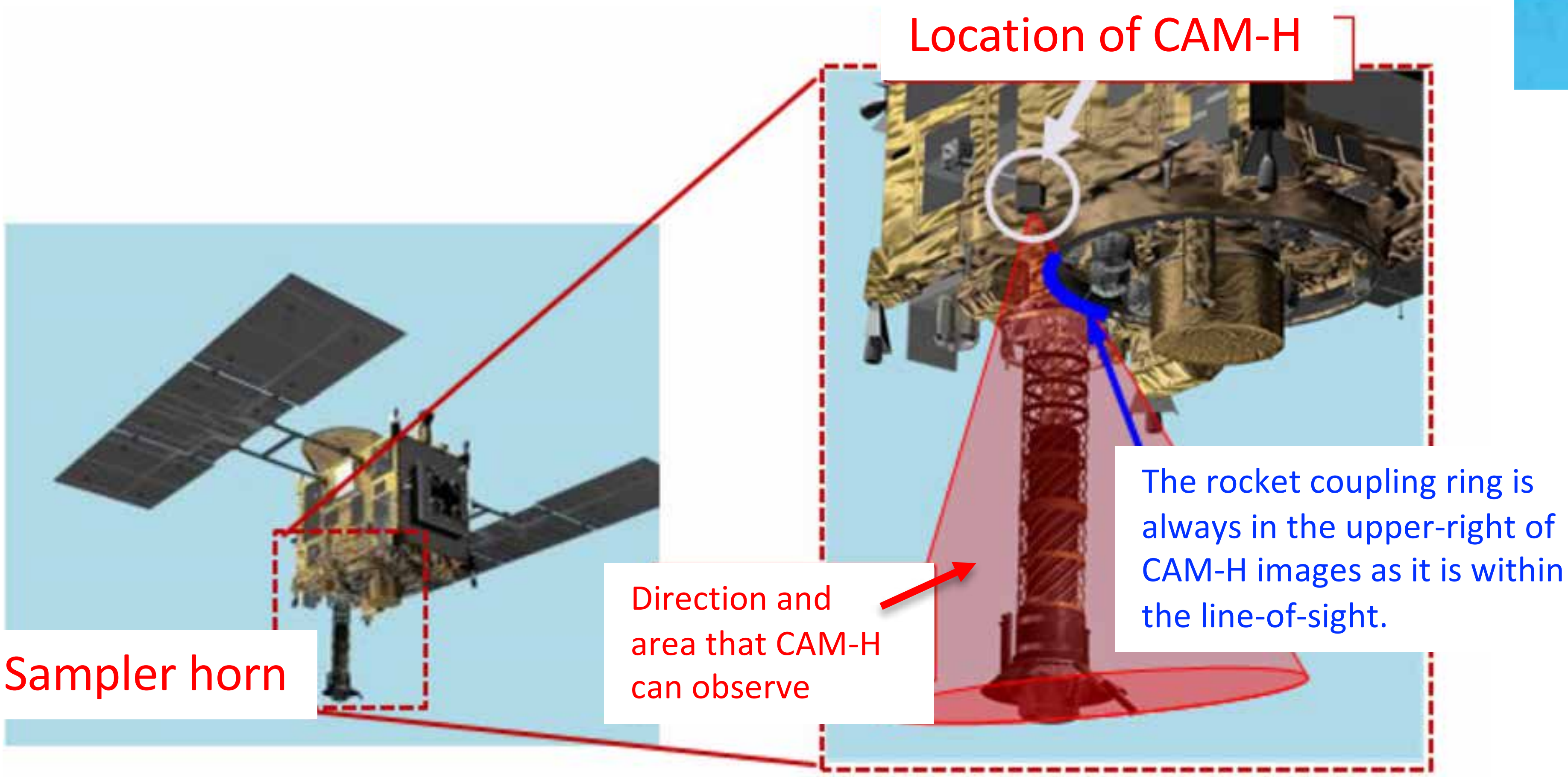


Note: Tritonis (landing site for MINERVA-II1), Alice's Wonderland (MASCOT landing site), Tamatebako (first touchdown point) are nicknames and not recognised by the International Astronomical Union (IAU). Other places names are official names recognised by the IAU.

(image credit: JAXA)

4. Images from CAM-H

CAM-H（small monitor camera）
- Camera built and mounted using money from donations.
- Images the sampler horn



（Image credit：JAXA）

4. Images from CAM-H

Continuous image sequence plan with CAM-H

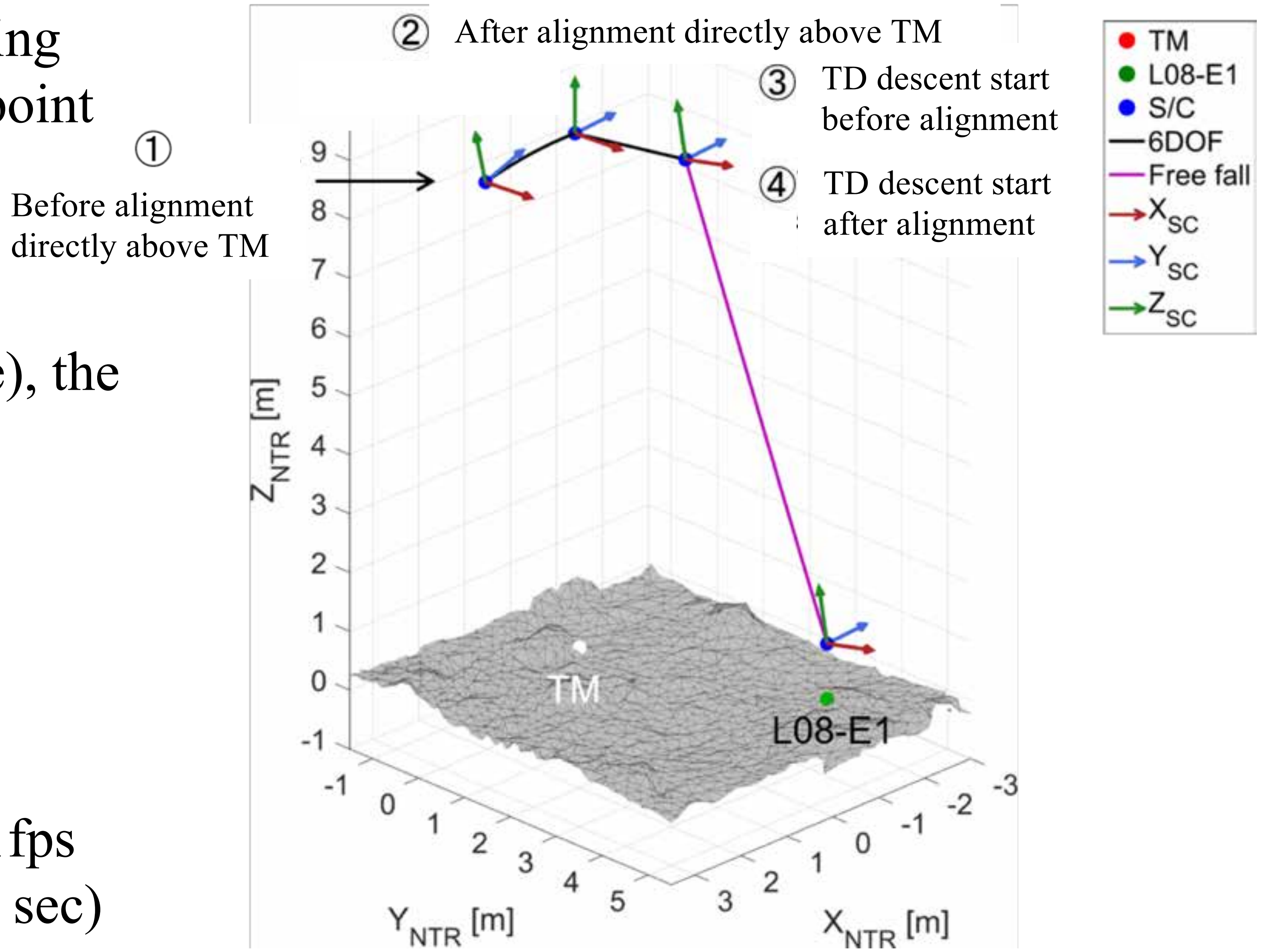
- Hayabusa2 moves to the final descent position using the TM, while maintaining the immediate below point altitude of 8.5m. (①⇒②⇒③)

- At the final descent position, after changing the attitude of the spacecraft (tail up) (④ in the figure), the final descent ⊿V (about 7cm/s downwards) is performed, then free-fall to touchdown.

- Continuous imaging with CAM-H starts from 59s before the final descent ⊿V.

- Automatic sequence capture at 0.2fps (85 sec) ⇒1fps (86 sec)⇒2fps (25 sec)⇒1fps (64 sec)⇒0.2fps(85 sec)

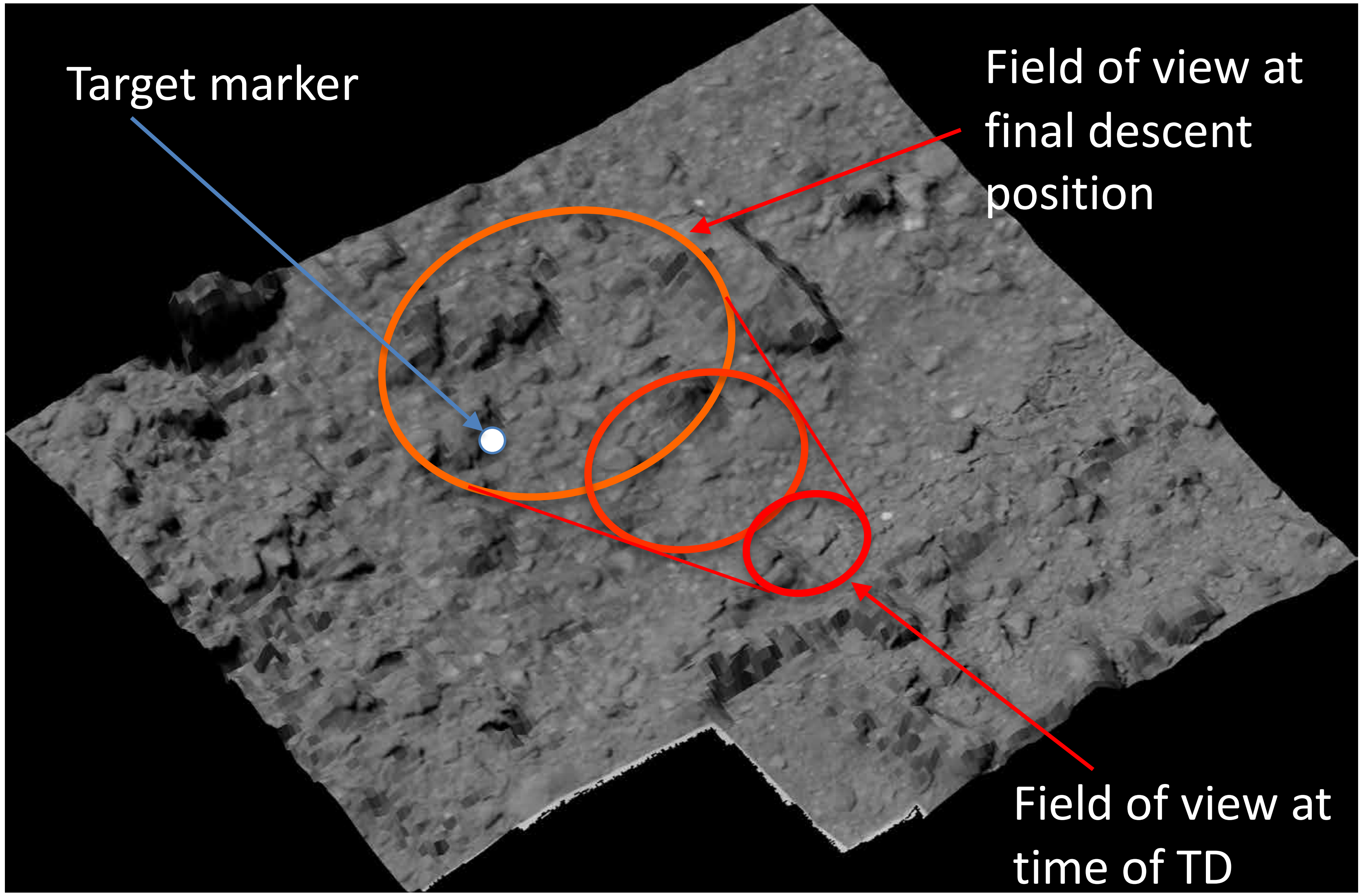
fps = frame per second



(Image credit：JAXA)

4. Images from CAM-H

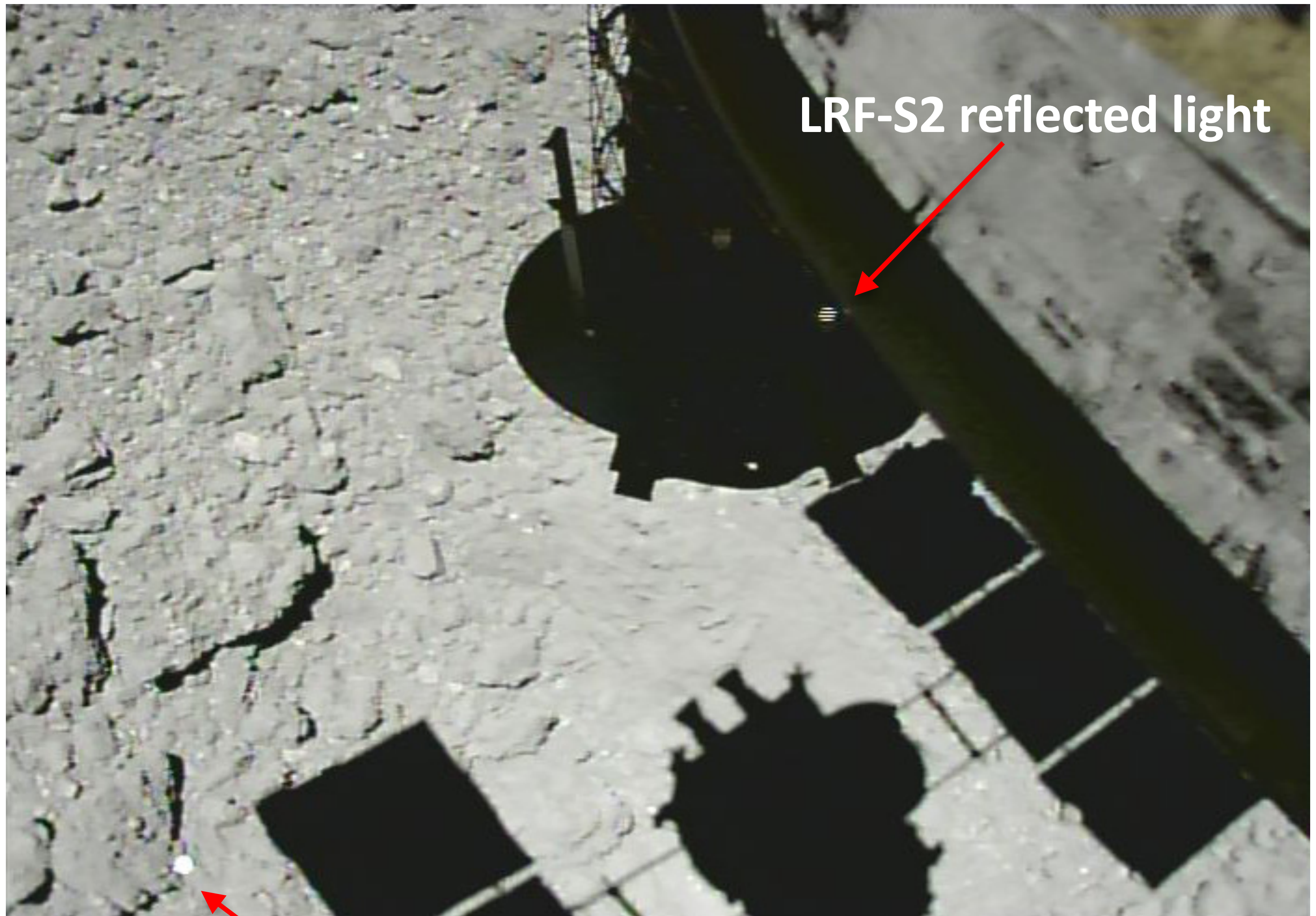
Prediction of the view from continuous imaging with CAM-H at touchdown



（Image credit：JAXA）

4. Images from CAM-H

Successful imagining before and after touchdown with CAM-H



Target Marker

(image credit: JAXA)

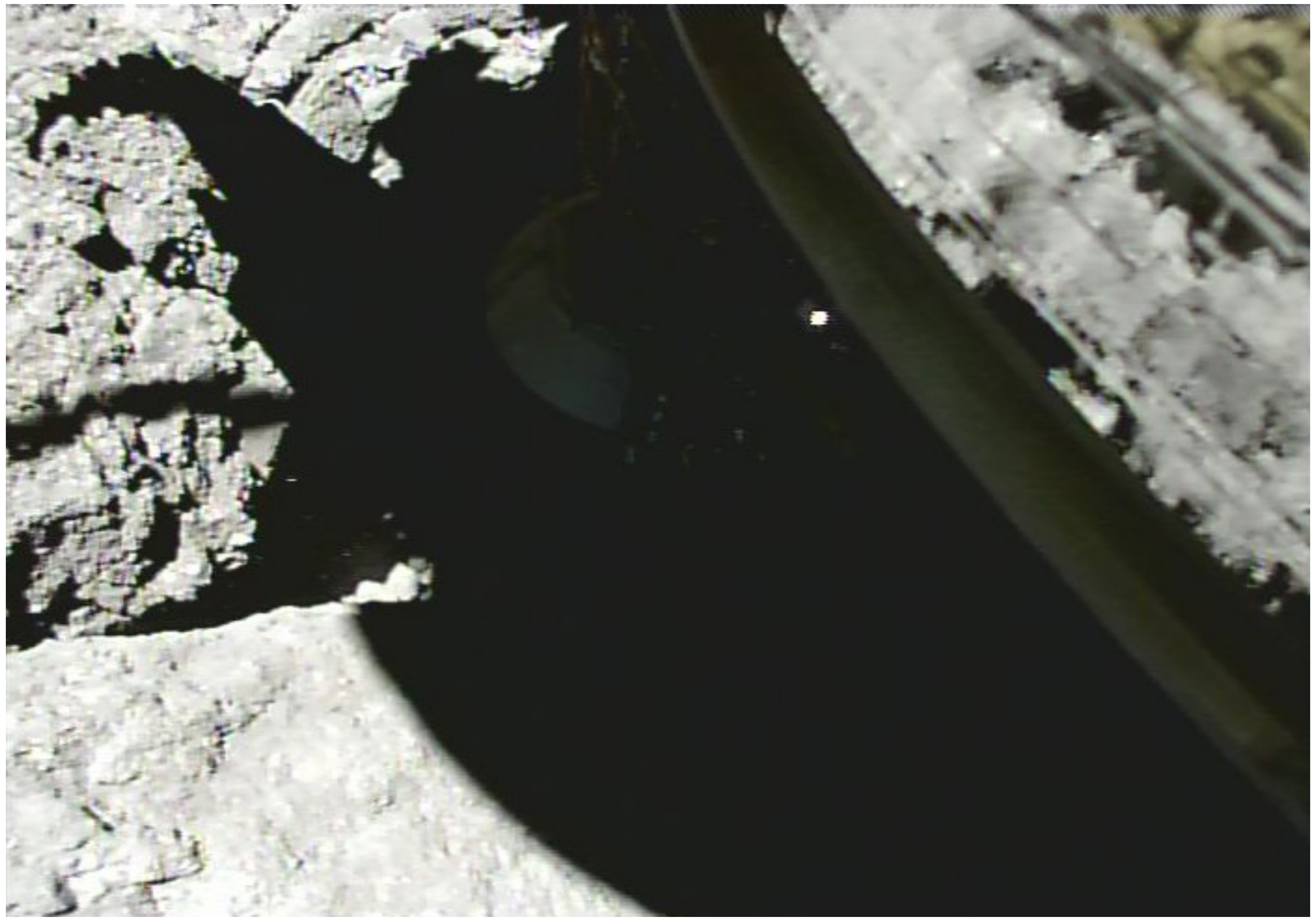
Before final descent: during hovering
Time: 2/22 07:26
Altitude: approx. 8.5m

(Time: onborad, JST)

During descent
Time: 2/22 07:28
Altitude: approx. 4.1m

4. Images from CAM-H

Successful imagining before and after touchdown with CAM-H



Moment of touchdown
Time：2/22 07:29
Altitude： approx. 1.0m

Immediately after the rise ⊿V
Time：2/22 07:29
Altitude： approx. 2.9m

(Time: onborad, JST)

（image credit：JAXA）

4. Images from CAM-H

Successful imagining before and after touchdown with CAM-H

During ascent
Time：2/22 07:29
Altitude：approx. 8.0m

During ascent
Time：2/22 07:30
Altitude：approx. 49.6m

（Image credit：JAXA）

(Time: onborad, JST)

4. Images from CAM-H

Successful imagining before and after touchdown with CAM-H (animation)

- Continuous imaging began from 59 seconds before the final descent and images were taken for 5 minutes and 40 seconds while varying the imaging frequency.
- TD moment captured at 1 fps timing.
- Final altitude is about 117m

(Animation plays at 5x speed)

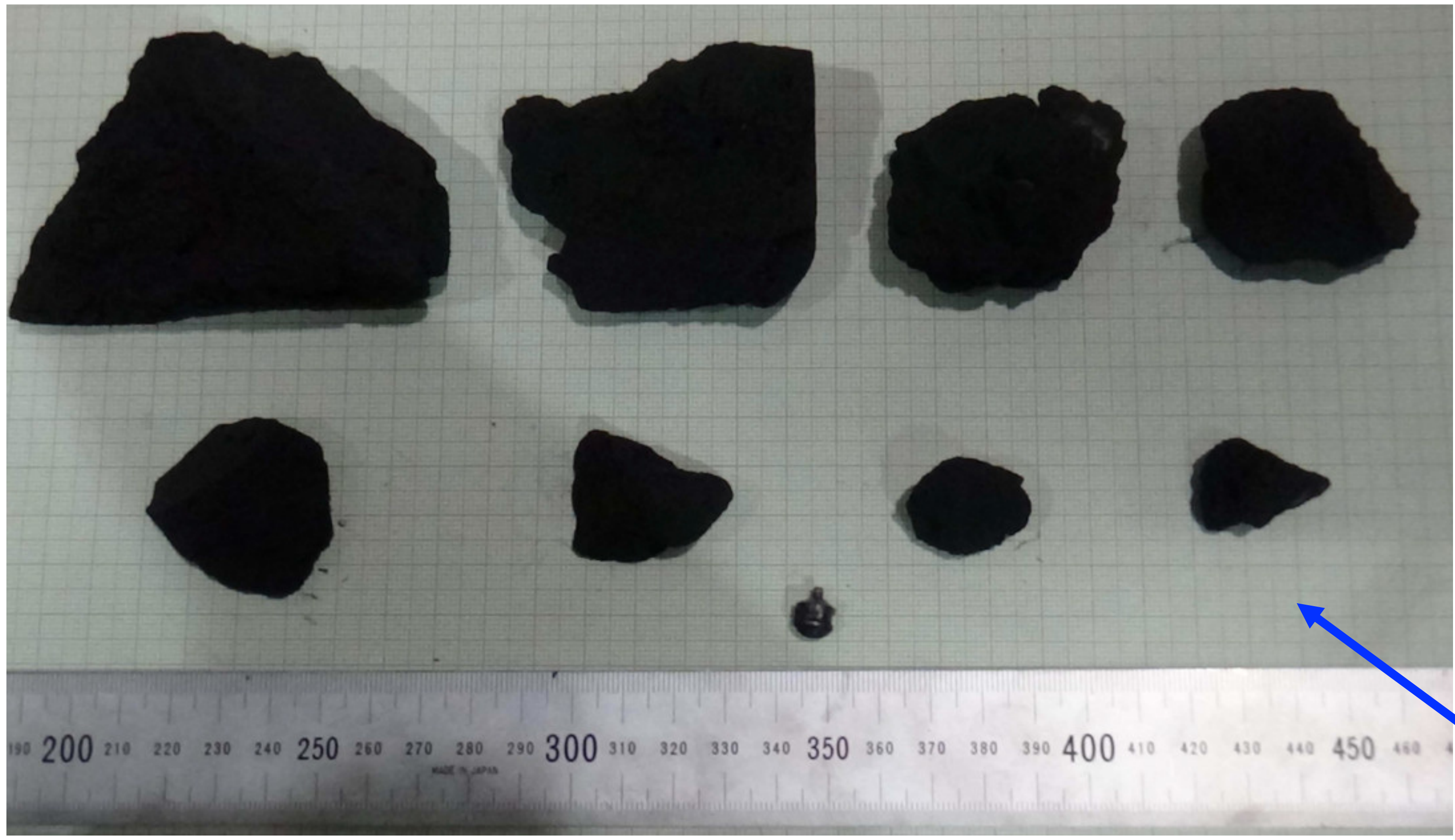
(Image credit：JAXA)

4. Images from CAM-H

Reference：Ryugu-simulant target and the projectile in the experiment to simulate the results of the projectile firing. （From the projectile firing experiment carried out on December 28, 2018）

Simulated Ryugu gravel target after the projectile fired.

※Simulated Ryugu gravel is created at the University of Tokyo & TeNQ



Examples of the Ryugu simulated gravel after fragmentation by the projectile.

Is the shape similar to gravel on the surface of Ryugu?

Fired projectile

（Image credit：JAXA、University of Tokyo）

5. Science comment on the touchdown

- Scientific analysis is in progress, but the following describes initial impressions from the images.
- ONC-W1 images immediately following touchdown
  - There seems to be an area containing a lot of debris / particle scattering / floating material just above the surface.
  - There also seems to be abrasions on the ground made with the sampling bullet and thruster firing.
  - A large quantity of scattered particles / debris can be seen: the potential for sample collection is high.
  - Fine particles may have adhered to the lens of the ONC-W1 camera.
- Images from CAM-H
  - The sampler horn seemed able to make contact with the ground without striking any large rocks.
  - Surface images are similar to those captured by the landers: the surface is covered with rocks of average size about 10cm.
  - After touchdown, rocks reaching sizes of several tens of centimetres in diameter were ejected.
  - Many chips of this released debris are flattened plate-shaped and appear to reach quite a high altitude.

6. Future plans

■Scheduled operations

- Mar. 6～8：Descent operation（DO-S01）
- Mar. 20～22：Descent operation（CRA1）
- Apr. week beginning 1st ：Small Carry-on Impactor（SCI）operation

■Overseas presentations

- LPSC（The 50th Lunar and Planetary Science Conference）：Mar. 18～22, Texas, USA. There will be a Hayabusa2 session and an explanatory meeting for local media is planned.

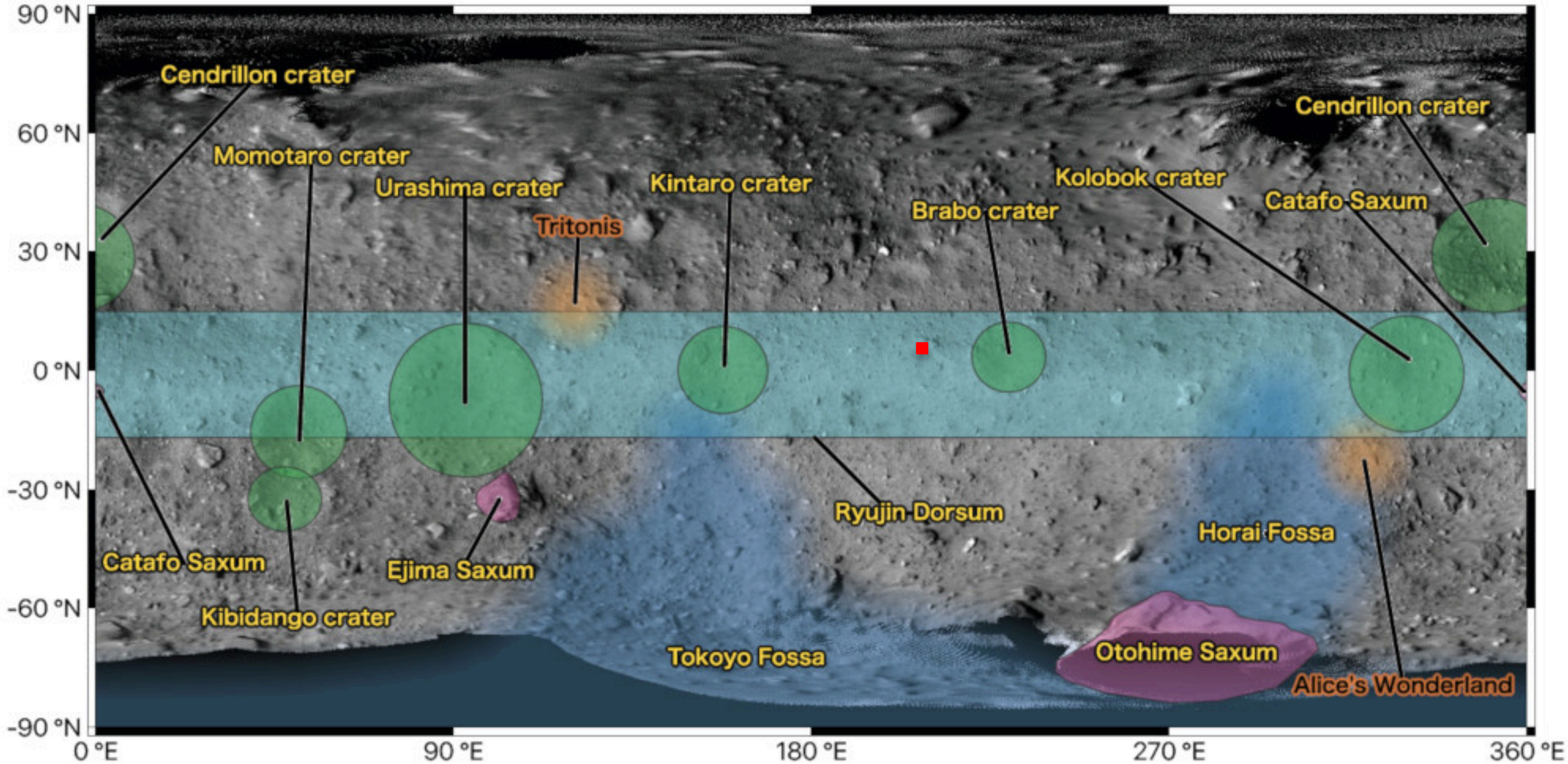
■Press and media briefings

- Mar.18 15:00～16:00 regular press briefing session @ JAXA Tokyo Office

Reference material

Touchdown Position

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



（image credit：JAXA）

Touchdown Position

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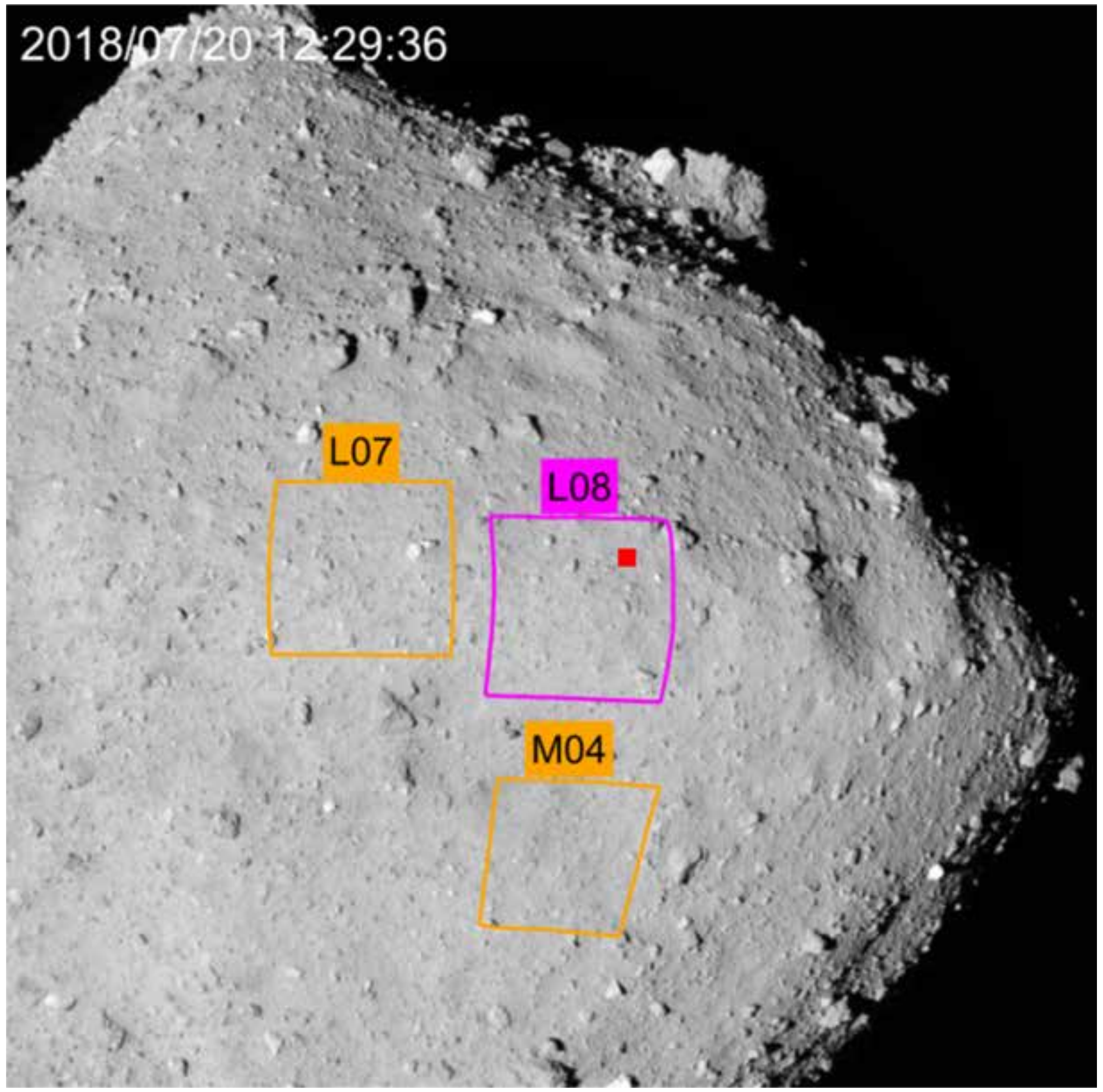

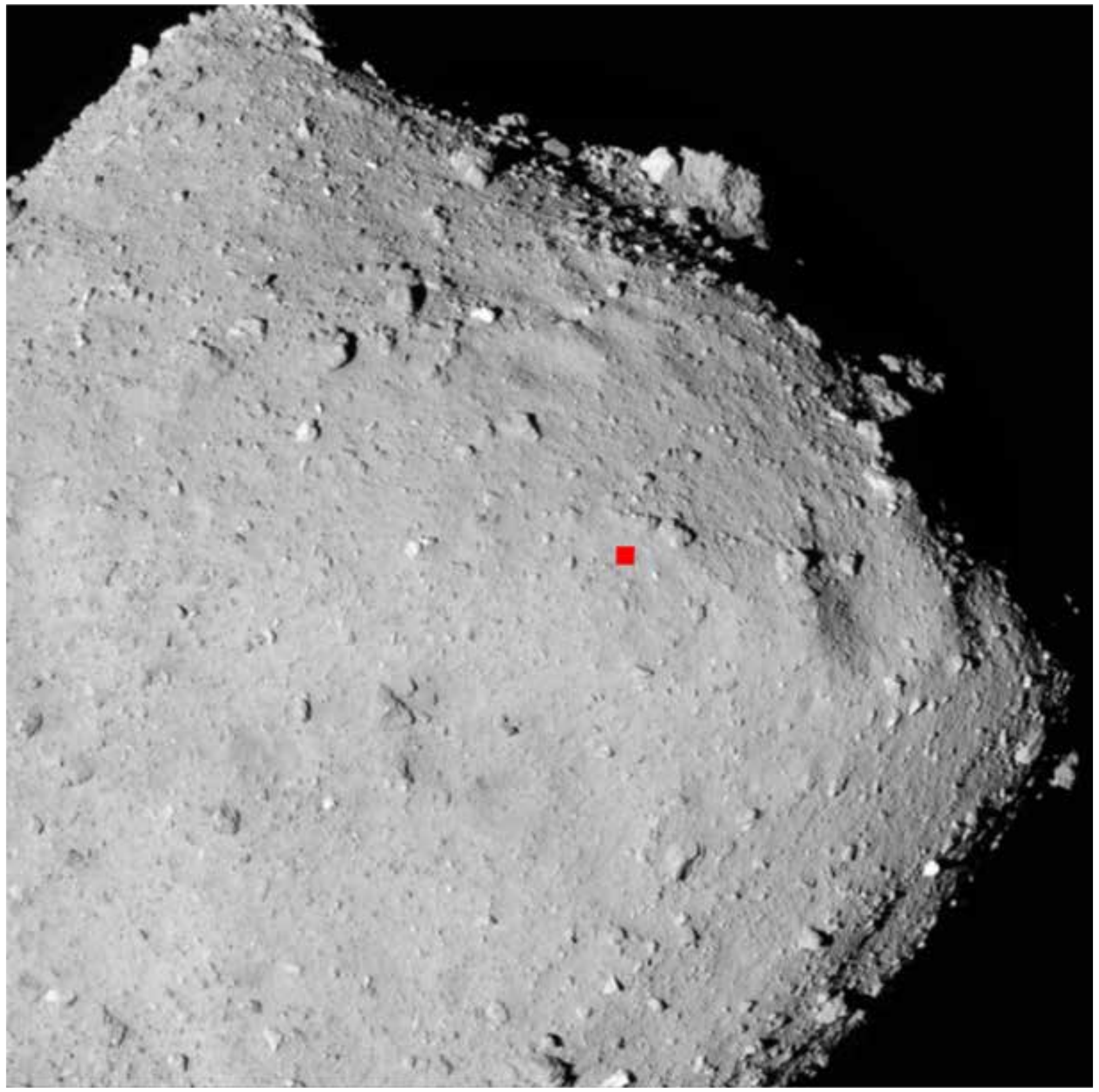

(image credit: JAXA / University of Tokyo / Koichi University / Rikkyo University / Nagoya University / Chiba Institute of Technology / Meiji University / University of Aizu / AIST)

Touchdown Position

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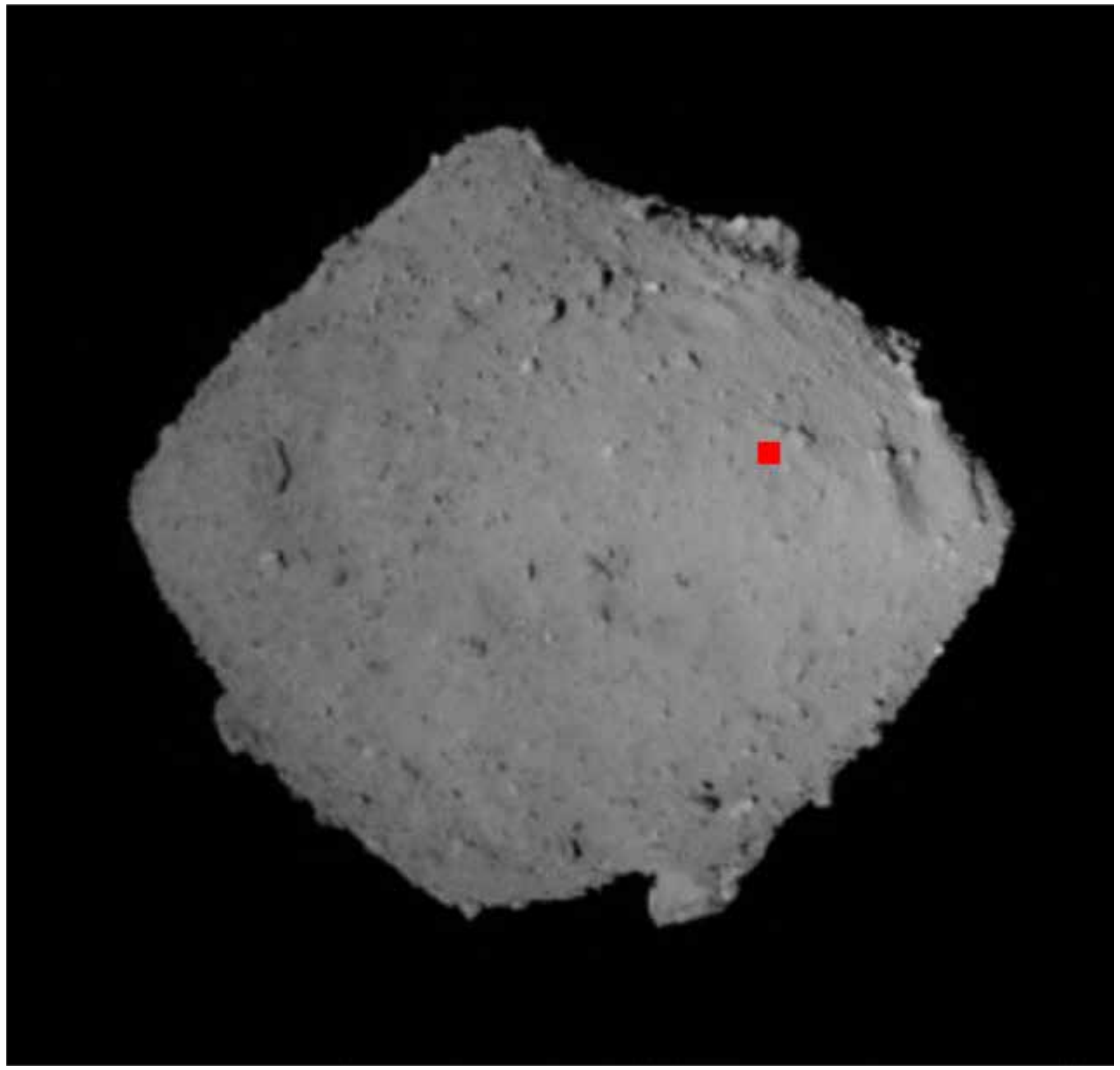


(image credit: JAXA / University of Tokyo / Koichi University / Rikkyo University / Nagoya University / Chiba Institute of Technology / Meiji University / University of Aizu / AIST)

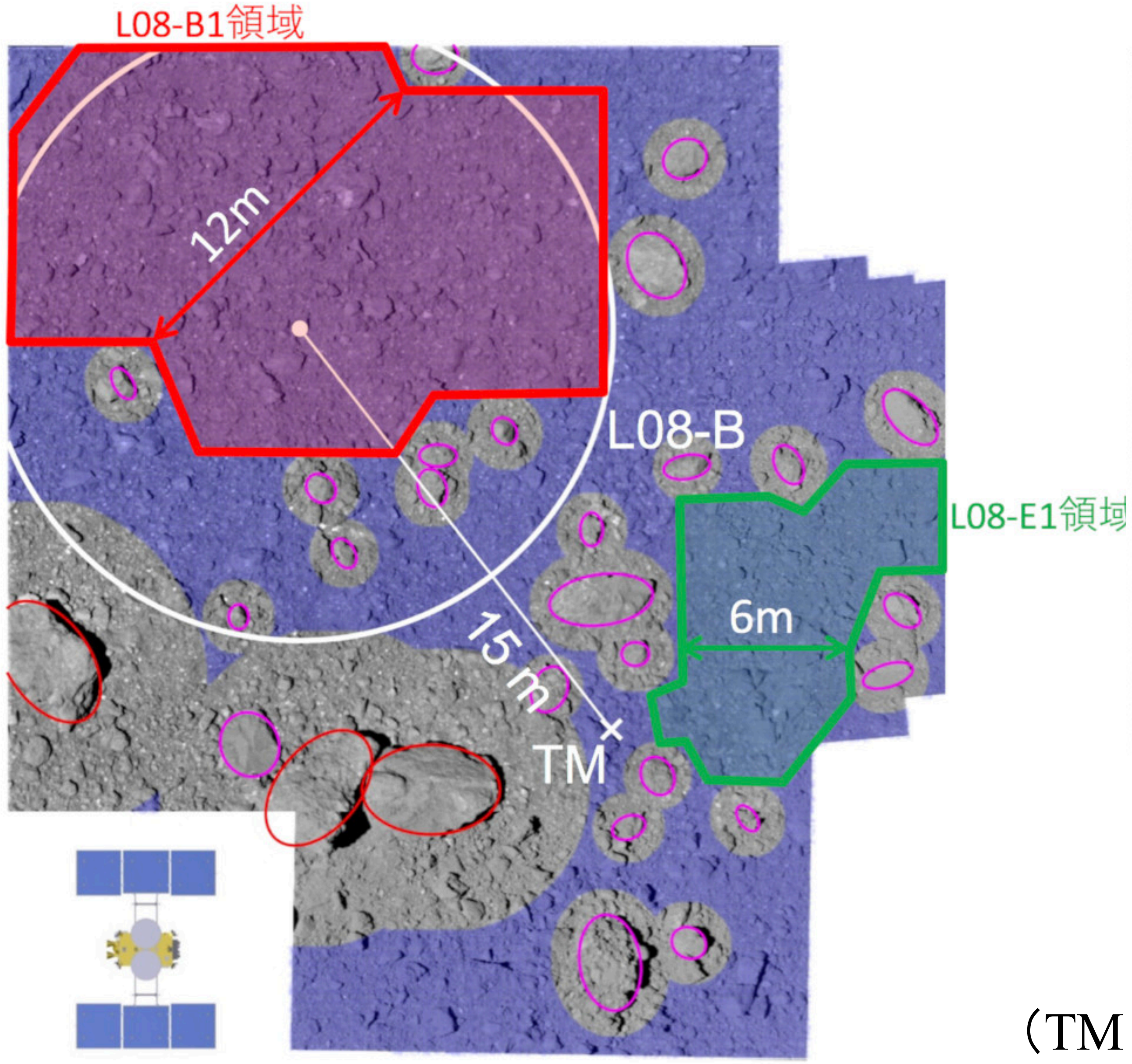
Touchdown Position

Area around the target marker

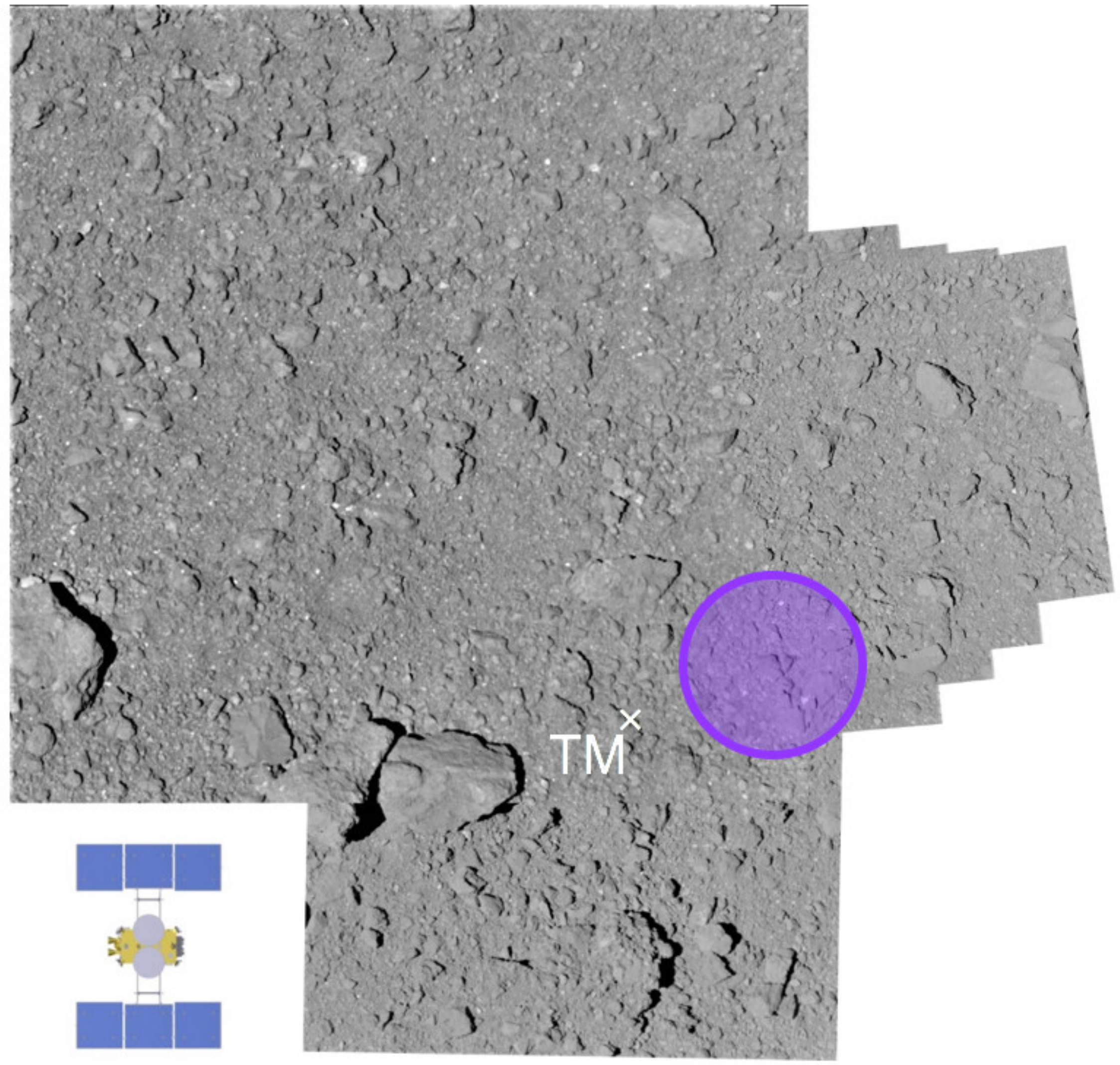
L08-B1 and L08-E1 were selected as candidates for touchdown.

↓

Finally L08-E1 was selected.



TM-B position and touchdown candidate site.



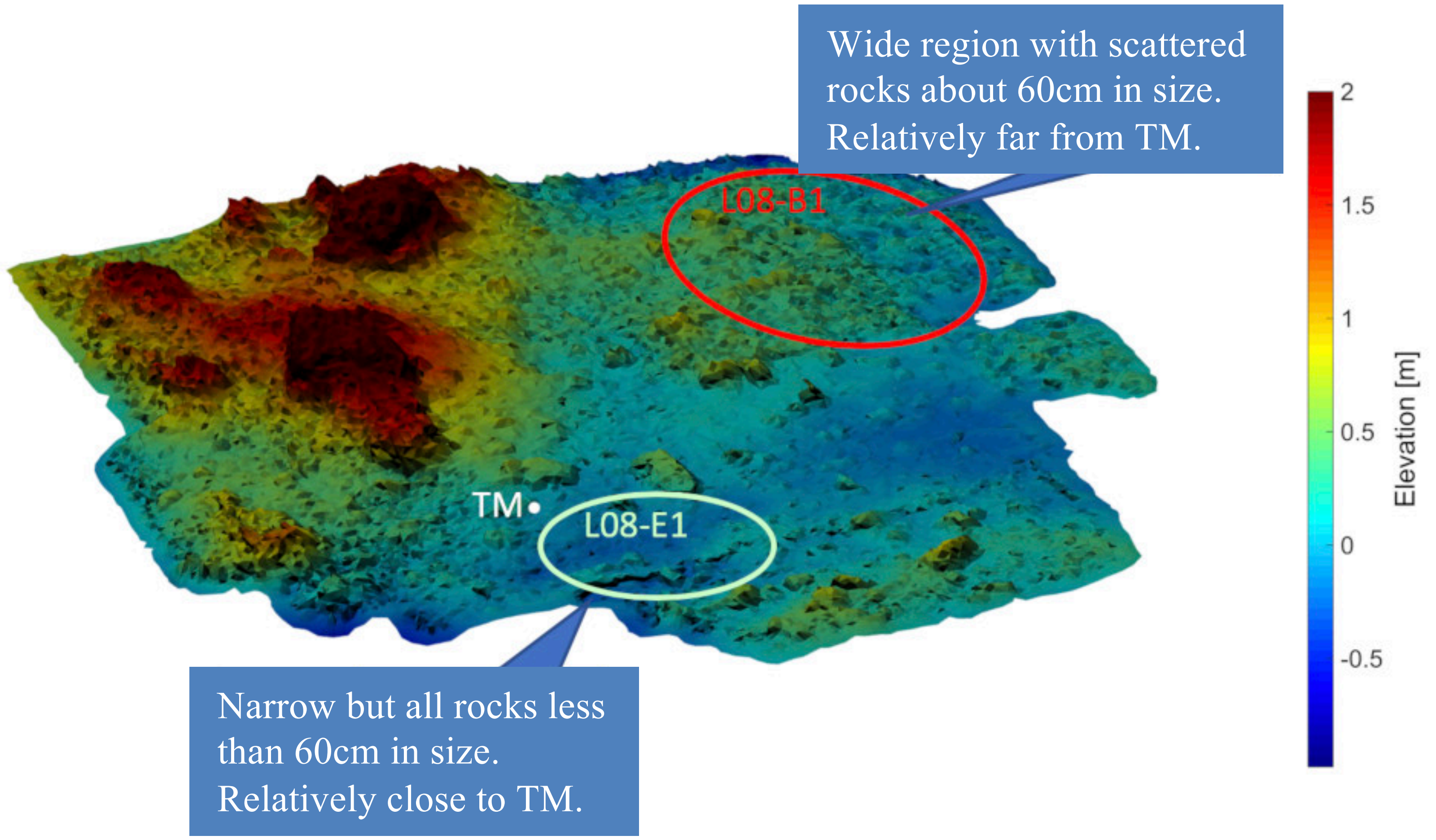
（TM indicates the position of the target marker）

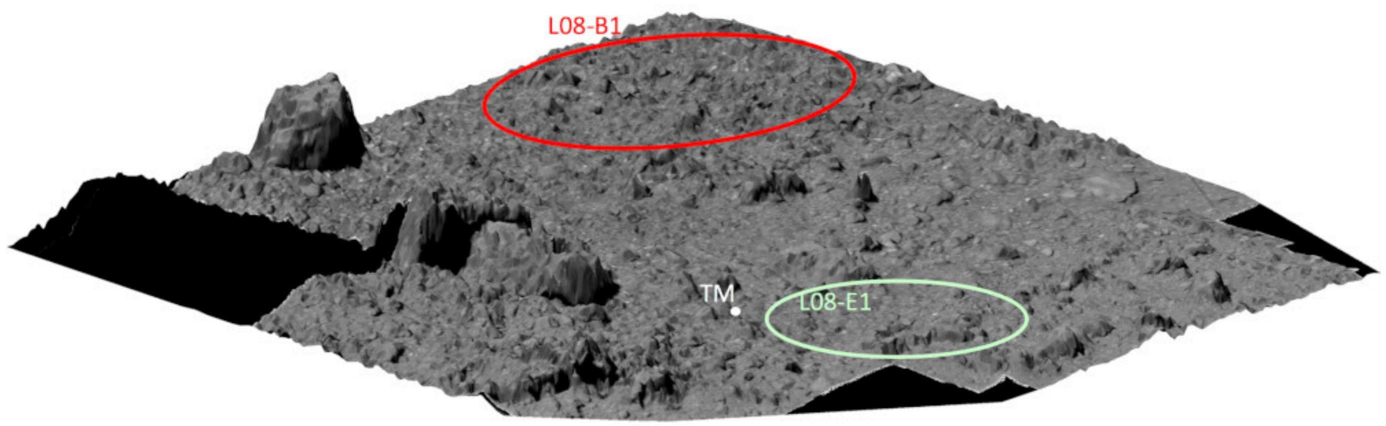
Touchdown planned area

（Image credit：JAXA）

Touchdown operation plan

L08-E1 area

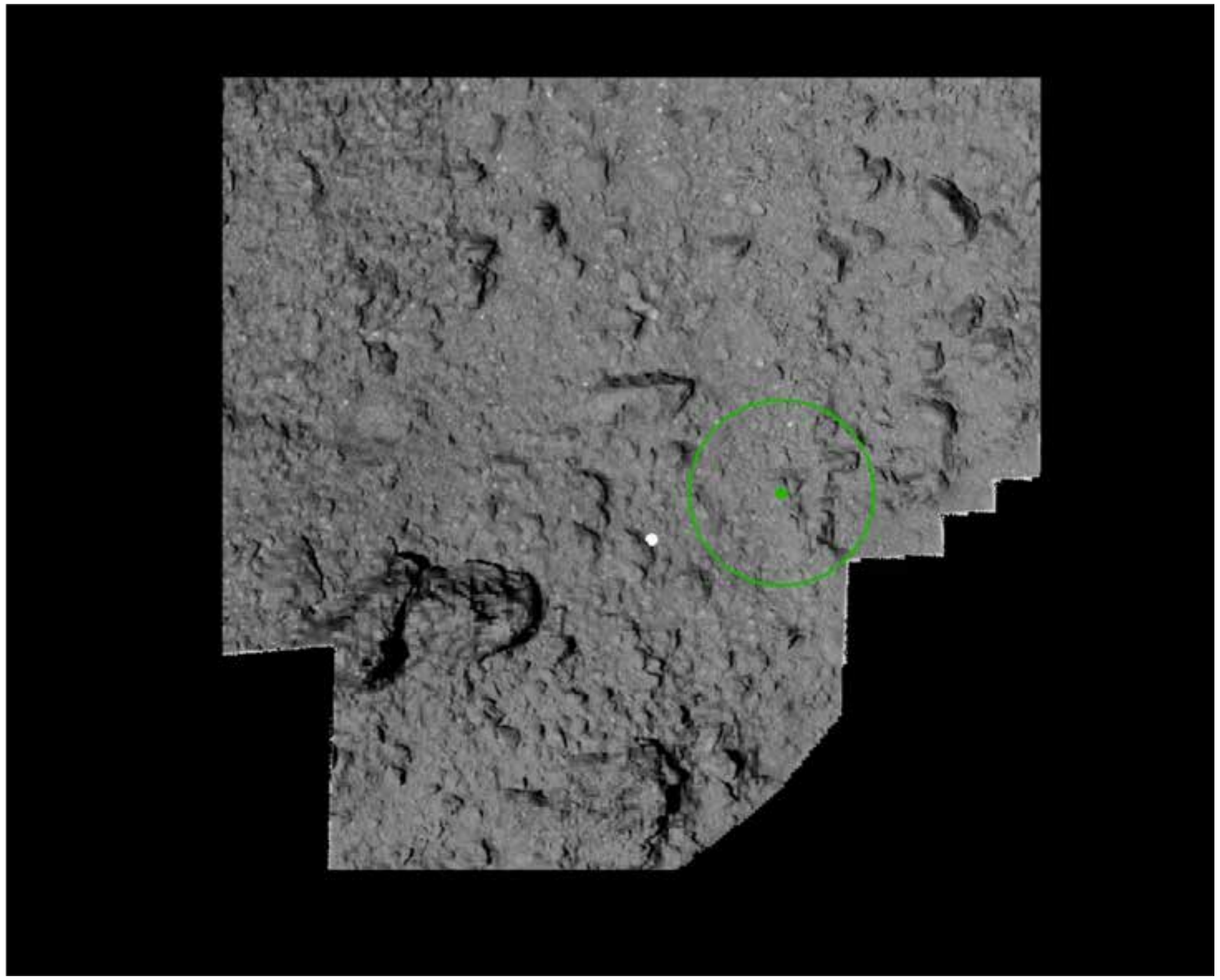




A DEM（Digital Elevation Map）near the touchdown candidate site （image credit：JAXA）

Touchdown operation plan

L08-E1 area



（animation）

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

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.

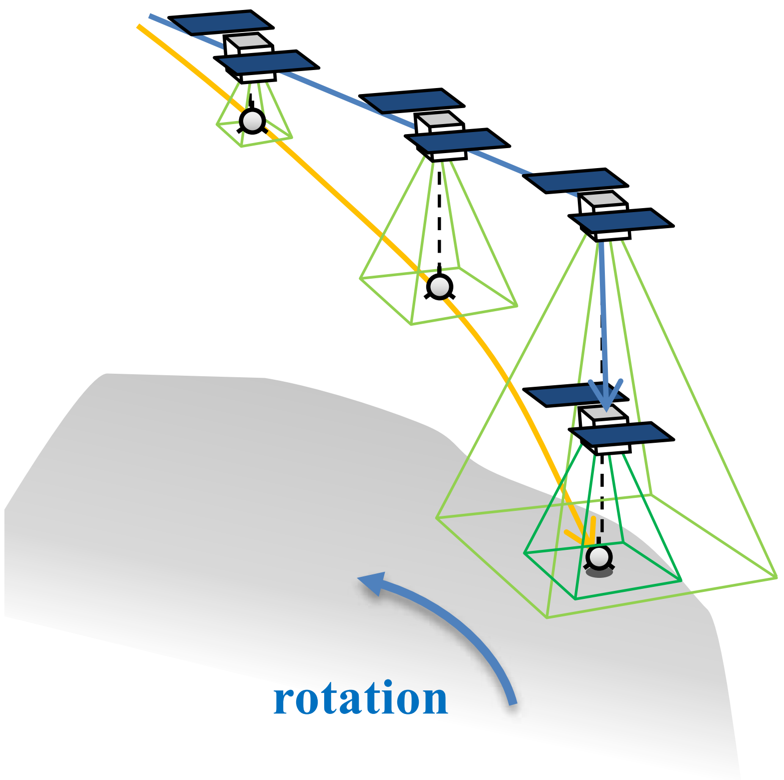
Touchdown operation plan

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.

Touchdown operation plan

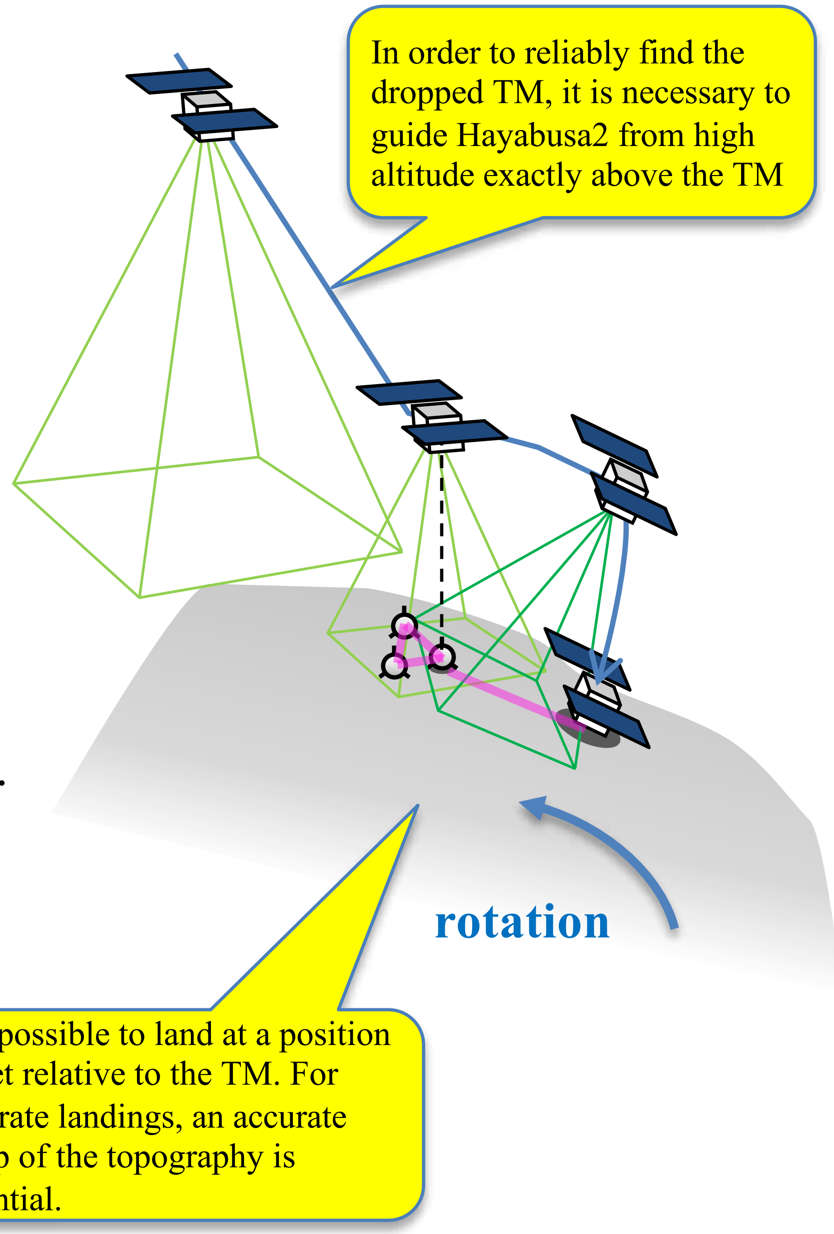
Hayabusa2 pinpoint touchdown feature



"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

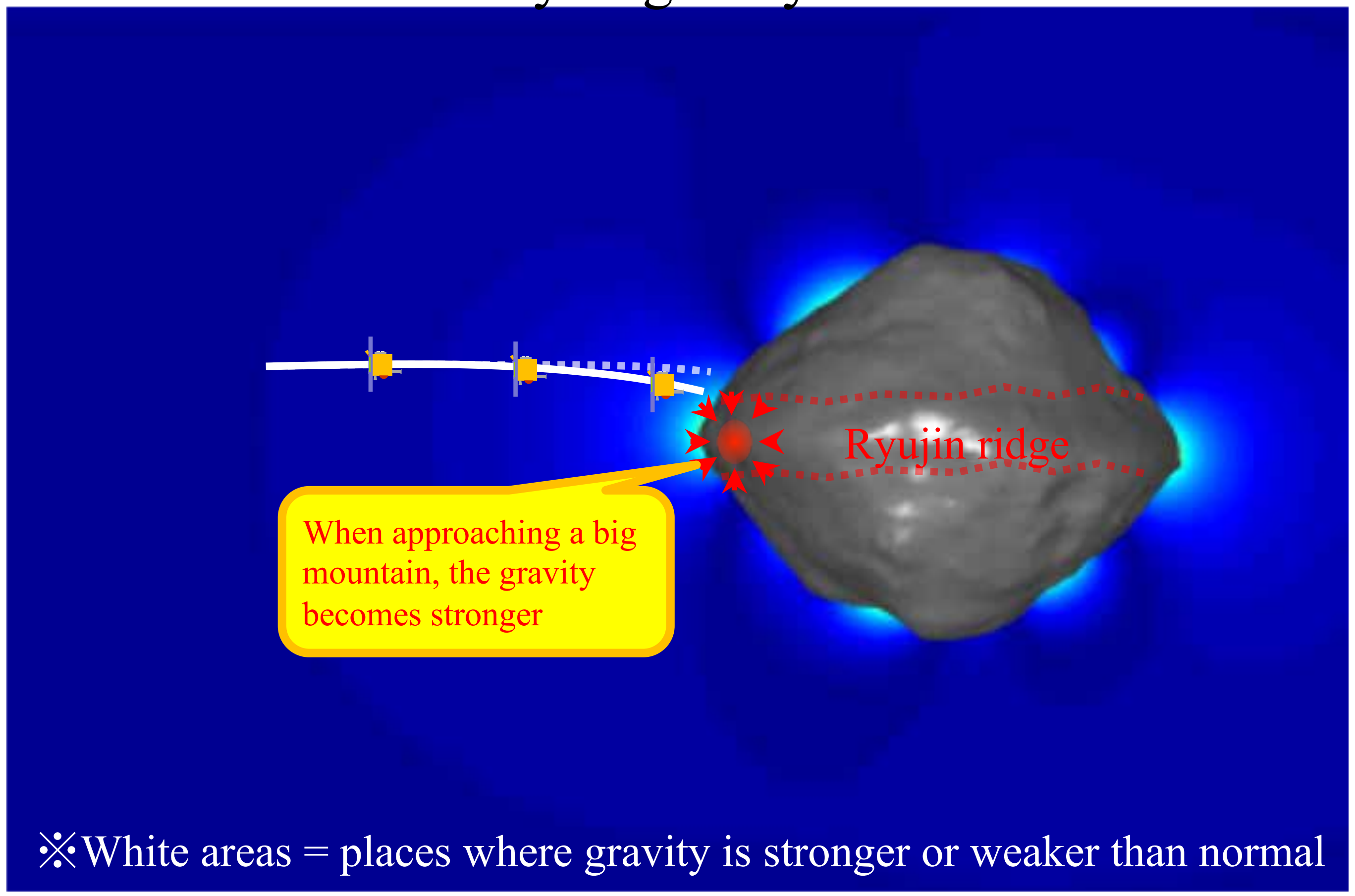
Touchdown operation plan

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

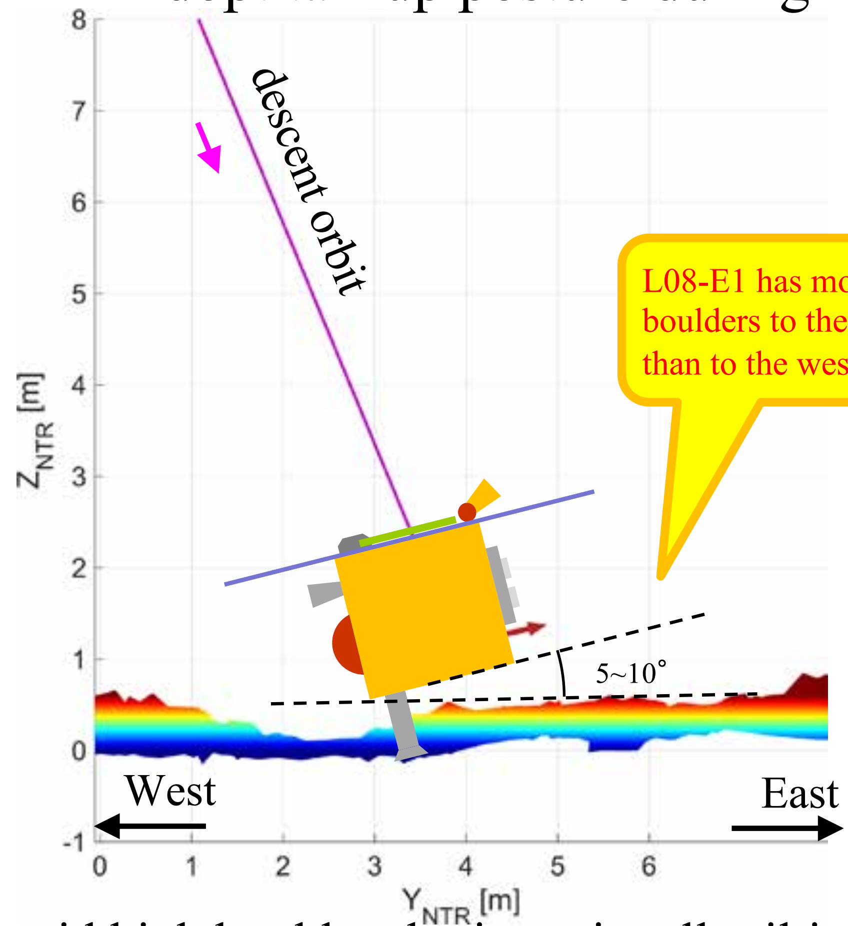
Accuracy of gravity model



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

One example

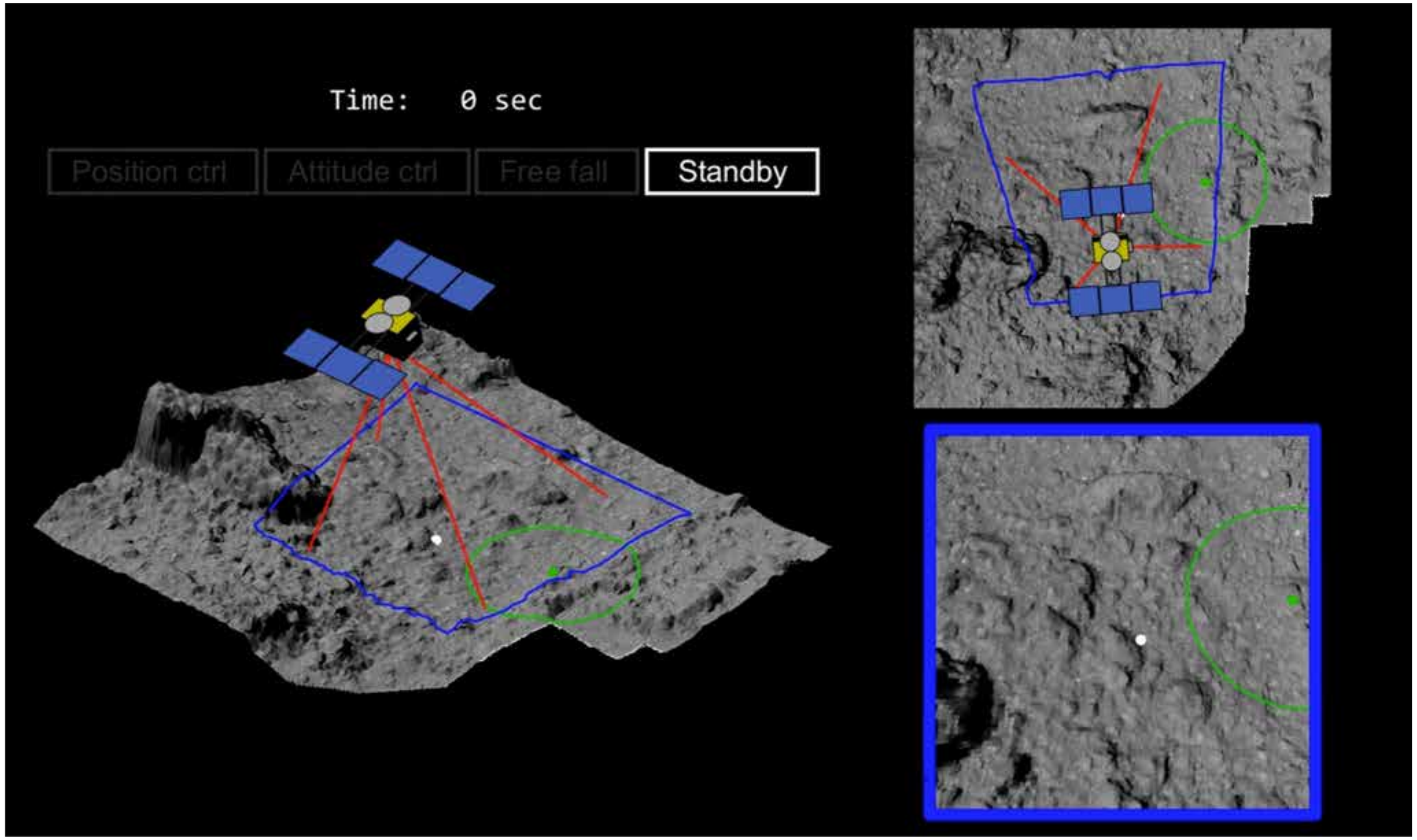
Adopt tail-up posture during landing



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

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)