Hayabusa2: Successful Touchdown and Scientific Findings for Ryugu

Hayabusa2 Project Team

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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

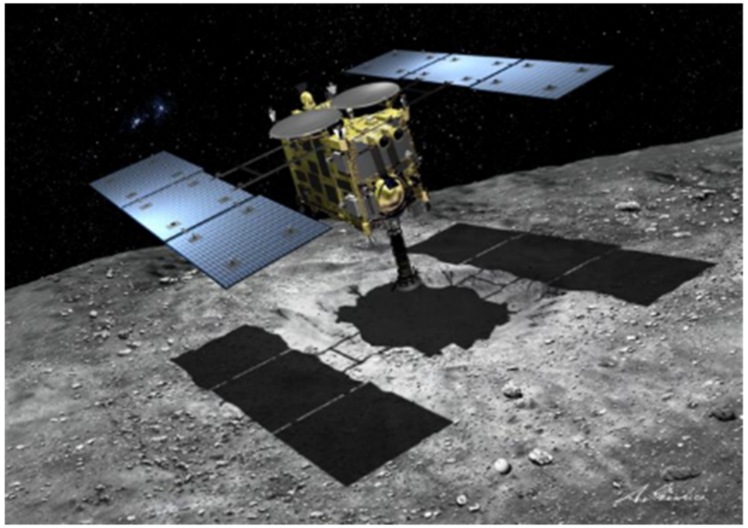
・By exploring a C-type asteroid, which is rich in water and organic materials, we will clarify interactions between the building blocks of Earth and the evolution of its oceans and life, thereby developing solar system science.
・ Japan will further its worldwide lead in this field by taking on the new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

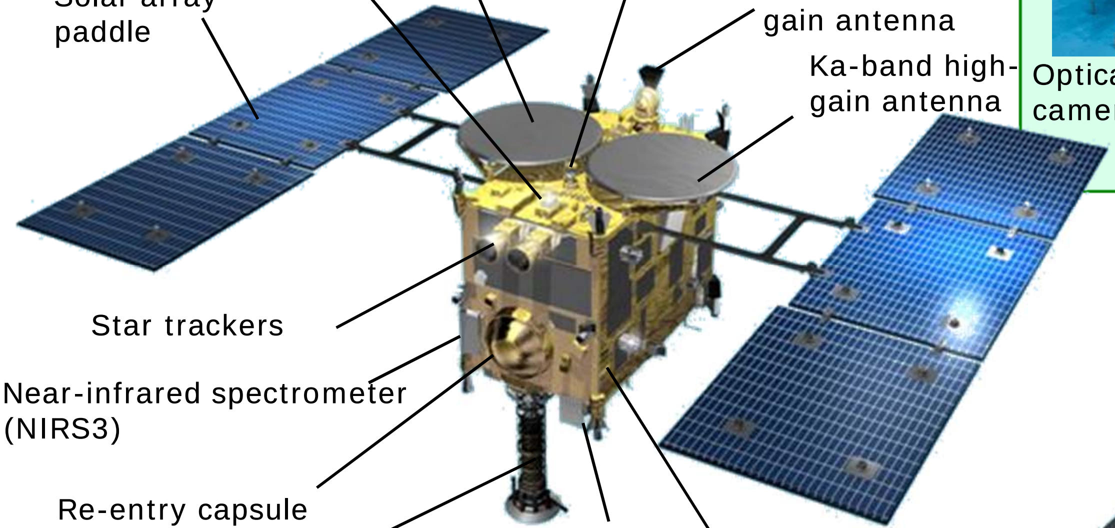
Hayabusa 2 primary specifications

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

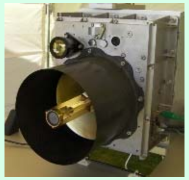
Primary instruments

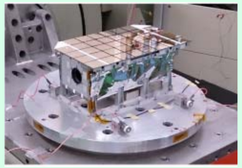
Sampling mechanism, re-entry capsule, optical cameras, laser range-finder, scientific observation equipment (near-infrared, thermal infrared), impactor, miniature rovers.

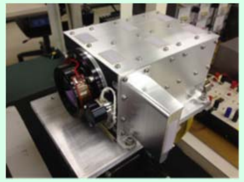
Spacecraft Overview



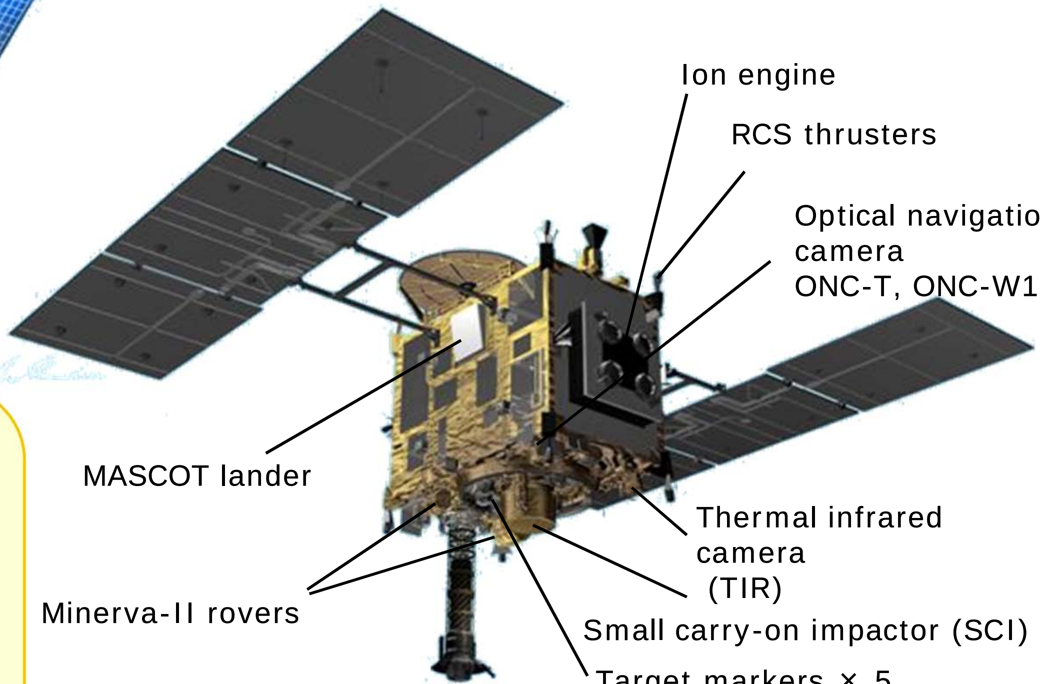

Optical navigation camera, ONC-T


Laser altimeter, LIDAR


Near-infrared spectrometer, NIRS3


Thermal infrared camera, TIR

Scientific observation equipment



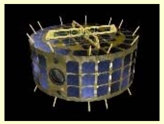
Small lander & rovers

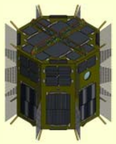
MASCOT

Built by DLR and CNES

Minerva 2


II-1A


II-1B


II-2

II-1: By the JAXA Minerva-II team

II-2: By Tohoku Univ. & the Minerva-II Consortium

Size: 1 ×1. 6×1. 25 m (main body)
Solar paddle deployed width 6 m
Mass : 609 kg (incl. fuel)

Mission Flow

Launch

3 Dec 2014

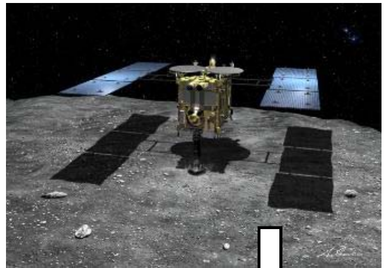
Earth swing-by

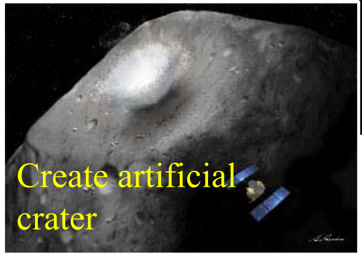
3 Dec 2015

Arrival at asteroid

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

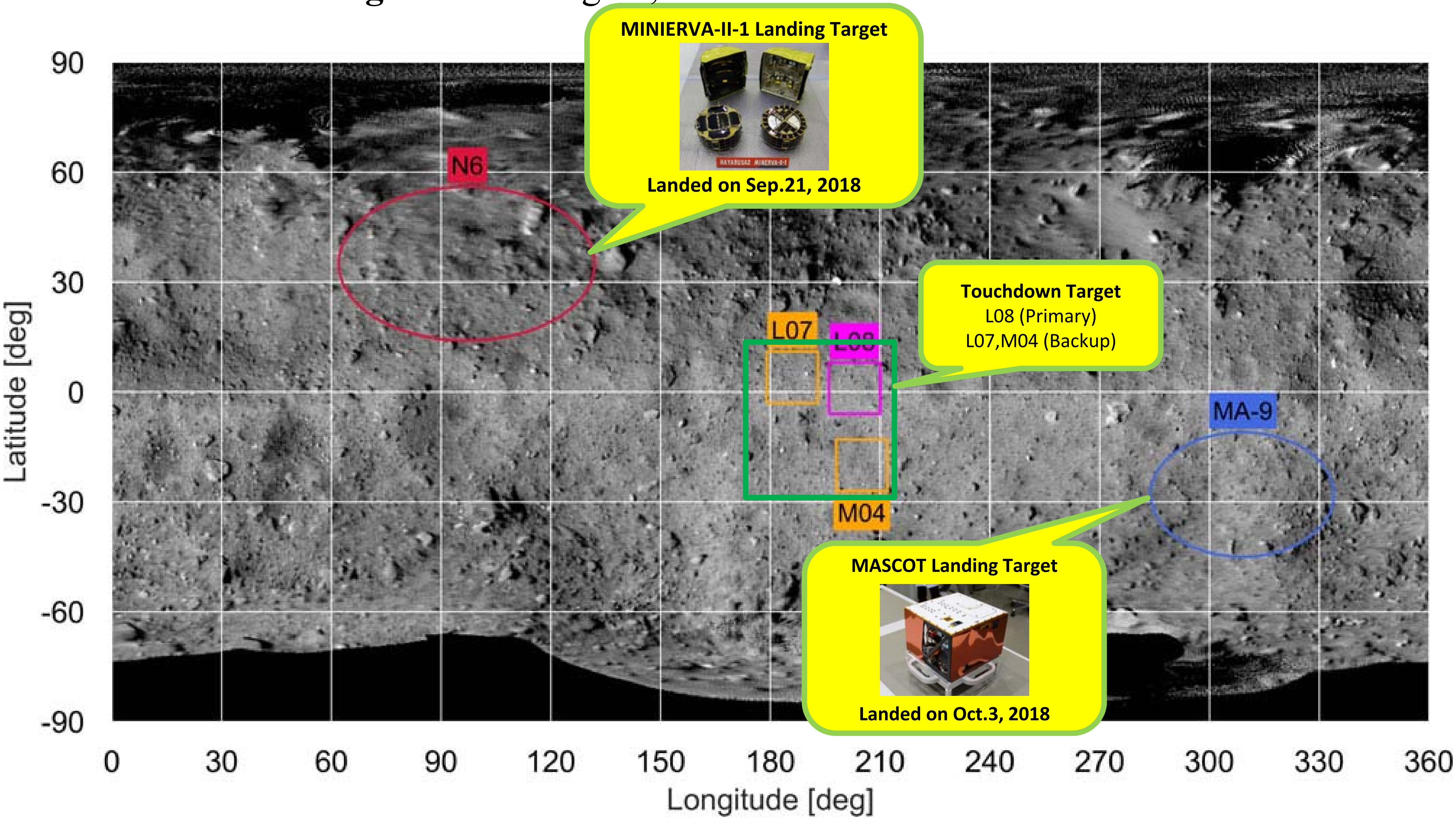
(Illustrations: Akihiro Ikeshita)

Ryugu

- 300 million km distant from the Earth (20 min by the speed of light)
- Top shape
- Size ~900m in diameter
- Very dark surface
- Low gravity
- Upright and retrograde rotation
- Numerous boulders (very bumpy!)

Decided Landing Sites and Accomplishments

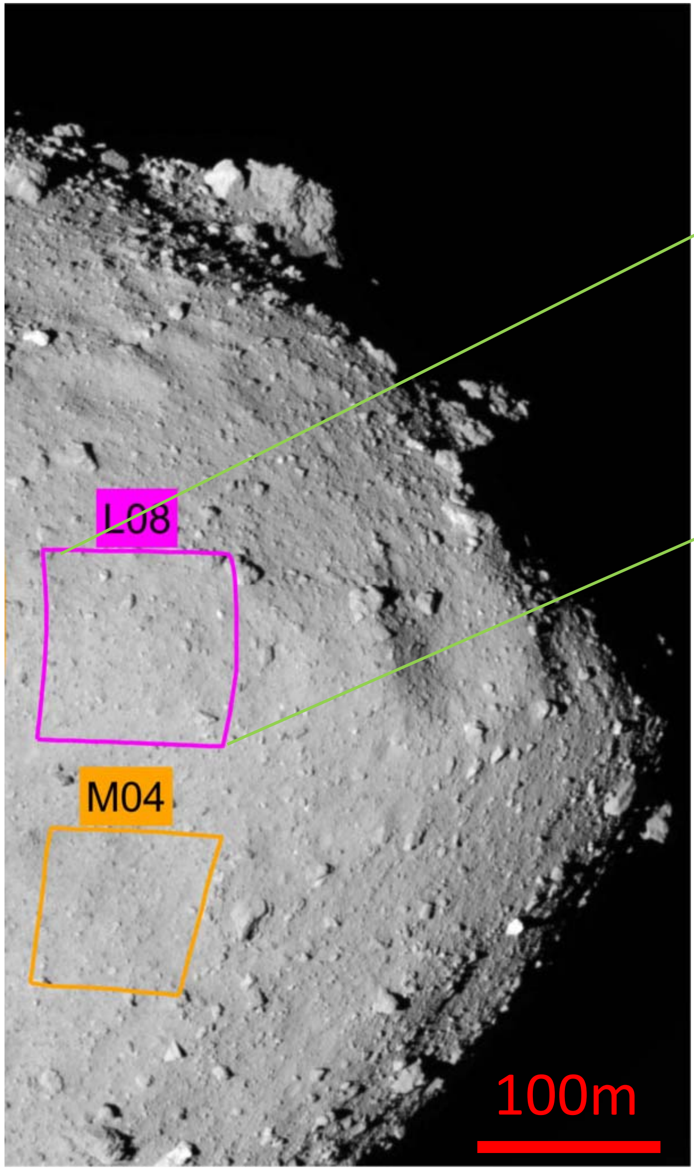
The three landing targets were decided at the project-wide **“Landing Site Selection Decision meeting”** held on Aug.17, 2018.

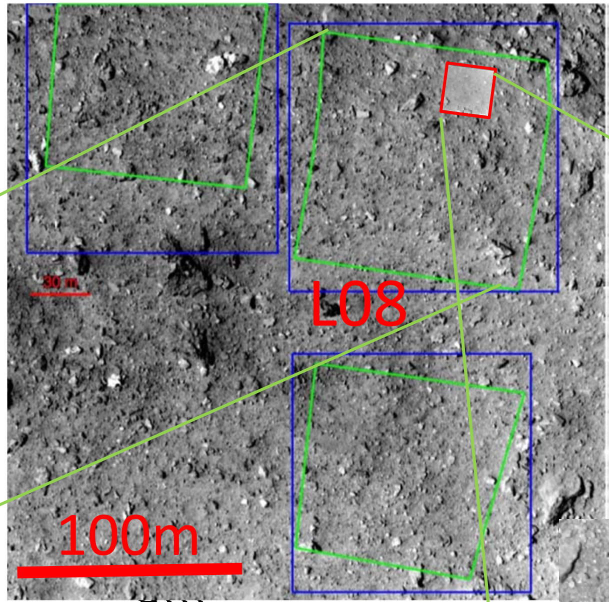


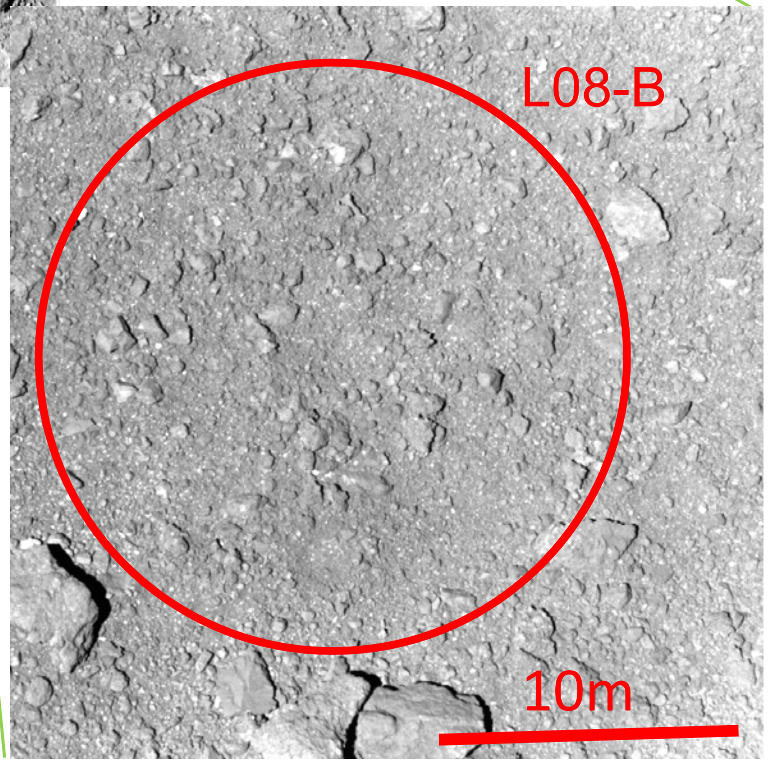
(Image Credit : JAXA/UTokyo/Kochi U/Rikkyo U/Nagoya U/Chiba Inst Tech/Meiji U/U Aizu/AIST)

Landing/Sampling Site Selection

TM: Target Marker



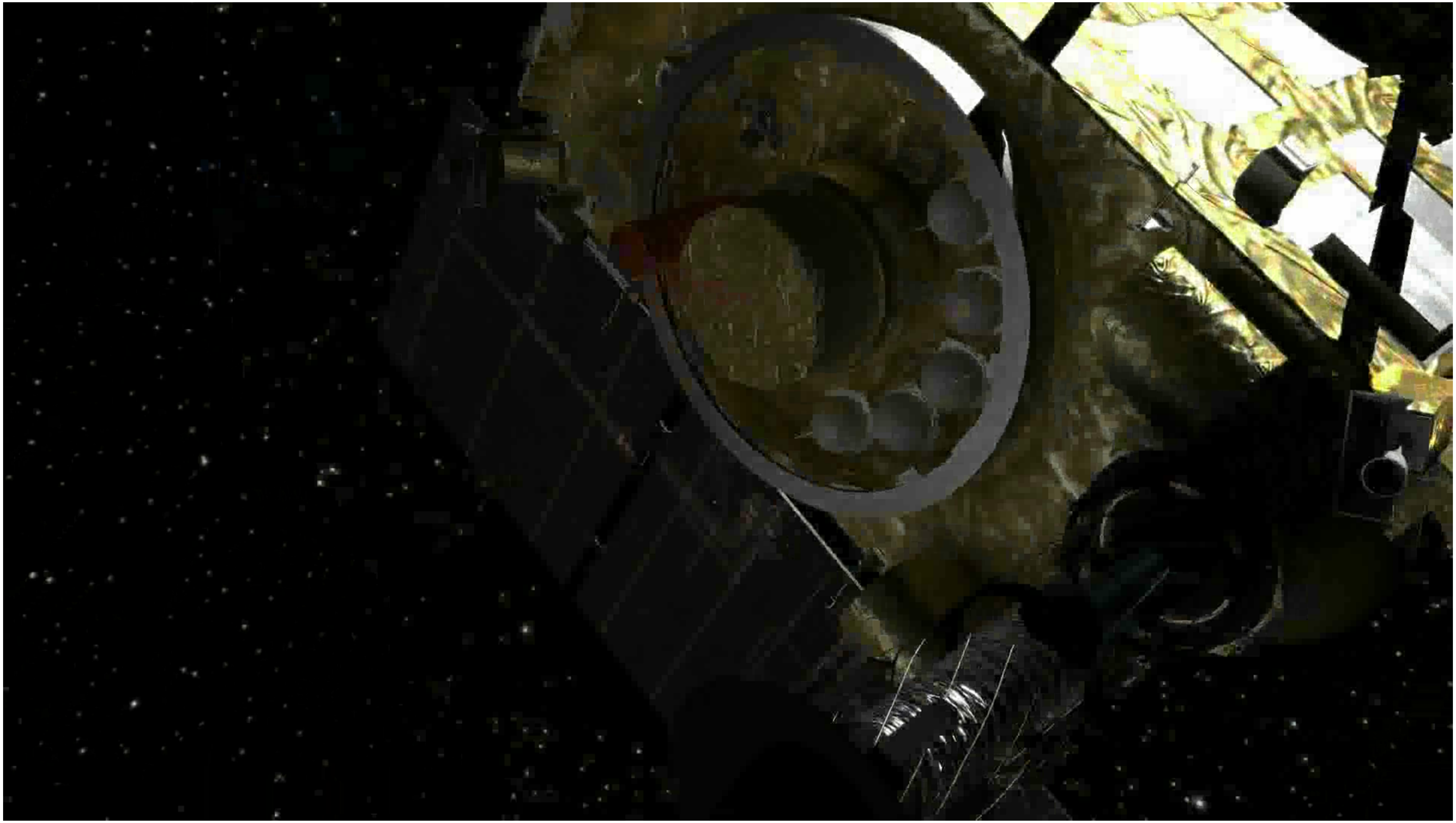




Within originally selected L08 site, L08-B was targeted for landing practice.

(Image Credit : JAXA/UTokyo/Kochi U/Rikkyo U/Nagoya U/ Chiba Inst Tech/Meiji U/U Aizu/AIST)

Target Marker Release Operation(TD1-R3), Oct.25, 2018



Movie credit: JAXA

Strategy Change for Touchdown

※TM: Target Marker

Before TM Drop (Original Plan)

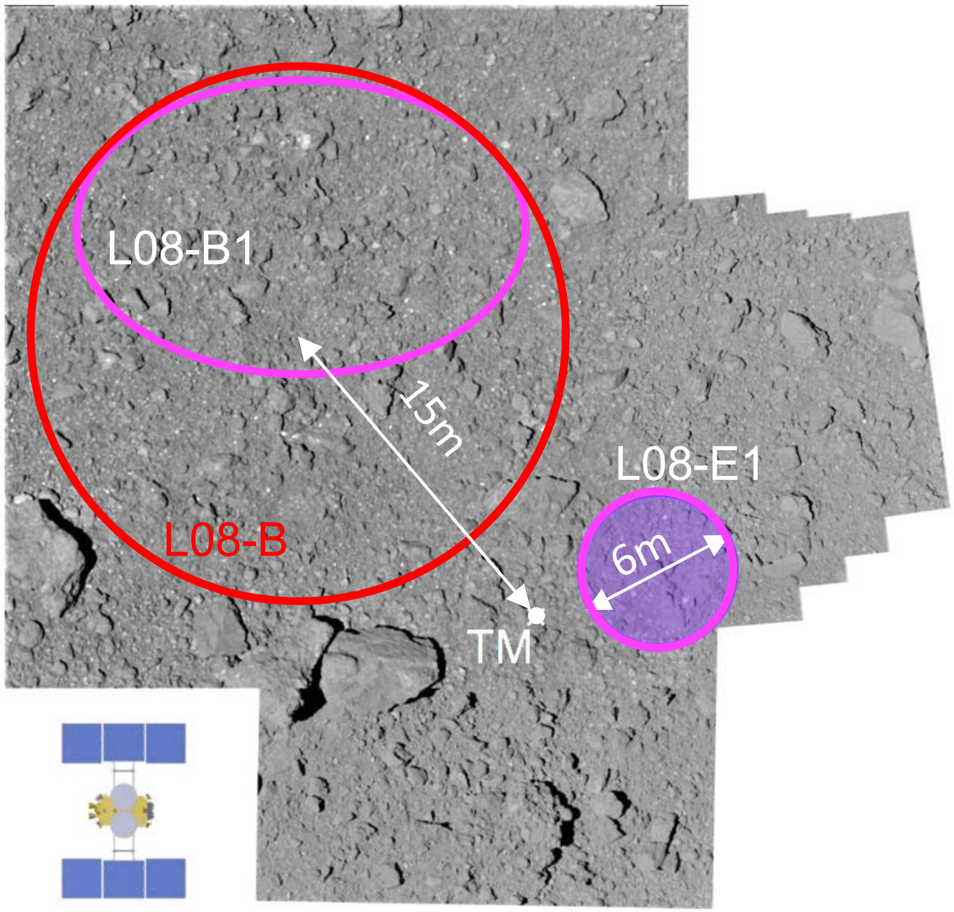
- The original design assumes a touchdown accuracy of 50m.
- L08 area (100x100m width) has been selected as the target landing site in the Landing Site Selection Decision meeting on Aug.17, 2018.
- Further observations revealed that even L08 only has safe areas with size less than 10m.
- The project has decided to postpone the original landing planned in October 2018, and add a landing rehearsal operation to deploy the Target Marker (TM) first to precisely evaluate the terrain-relative navigation & guidance performance.

After TM Drop (Modified Plan)

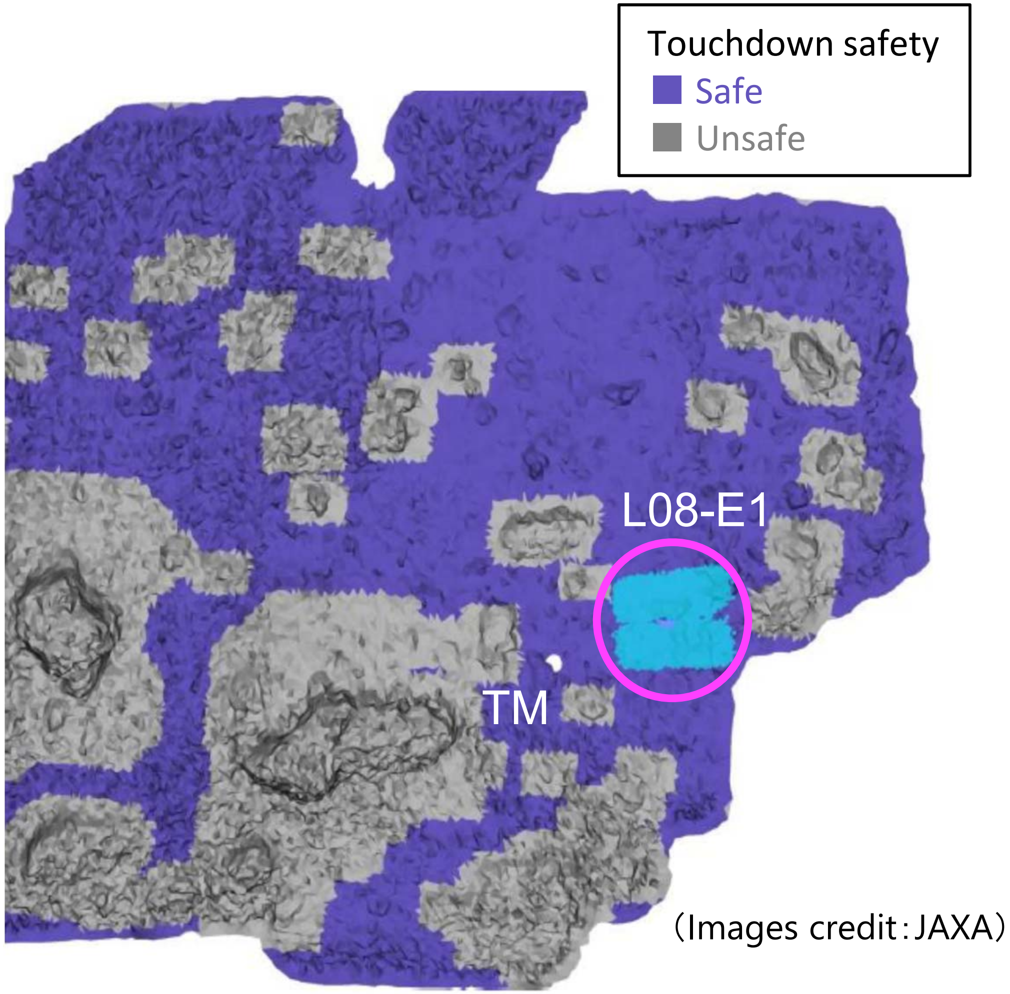
- Based on the result from this TM drop (landing rehearsal) operation, the project defined the larding target L08-E1, which requires a landing with a precision of 3m and with an offset of 4m from the dropped TM.
- The project decided to apply the “pin-point touchdown” method to perform the 3m precision landing.

Landing/Sampling Target (After TM drop)

TM: Target Marker



Location of Target Marker (TM) and landing target L08-E1



Digital Elevation Map and Landing Error (Monte-Carlo) Simulation in Planning Phase

Integrated Scientific Activity Toward Touchdown

◆Laboratory Experiment

Ryugu's stimulant fragmented after firing a high-speed projectile.

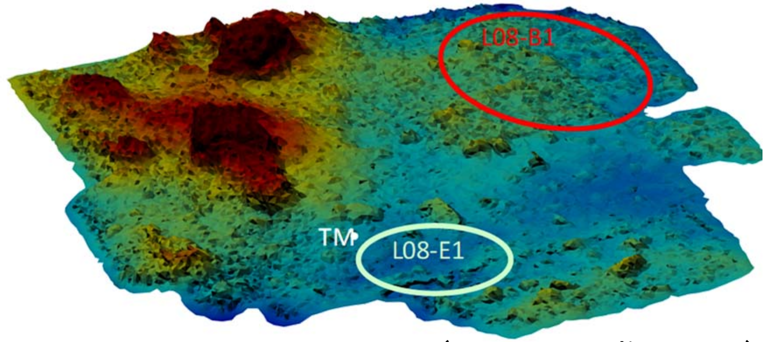
※Ryugu's stimulant is created at the University of Tokyo & TeNQ

Fired projectile

(Image credit：JAXA, U of Tokyo)

◆Accurate Terrain Modeling

<10cm accuracy 3 dimensional digital elevation map (DEM) has been created



(Image credit：JAXA)

◆In-Situ Observation Data from MINERVA-II, MASCOT and ONC-T/W1

(Image credit：JAXA)

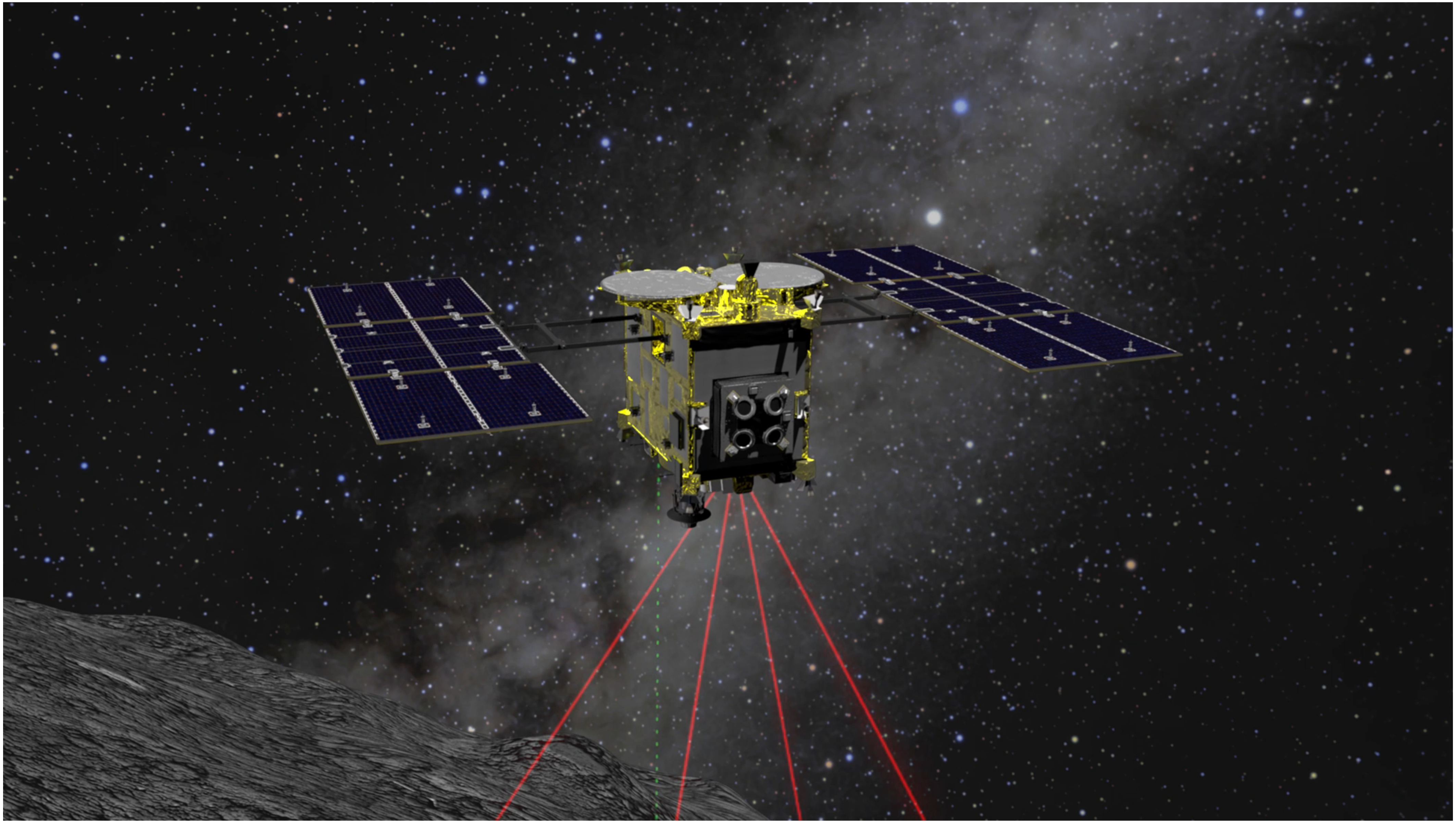
Sep. 23, 2018, 10:10 JST: image by MINERVA-II-1B

Achievable Landing Accuracy

Original: 50m

Improved: 2.7m

Autonomous Pin-Point Touchdown Sequence



（Movie credit：JAXA）

Target Marker Tracking Movie (Smoothed)

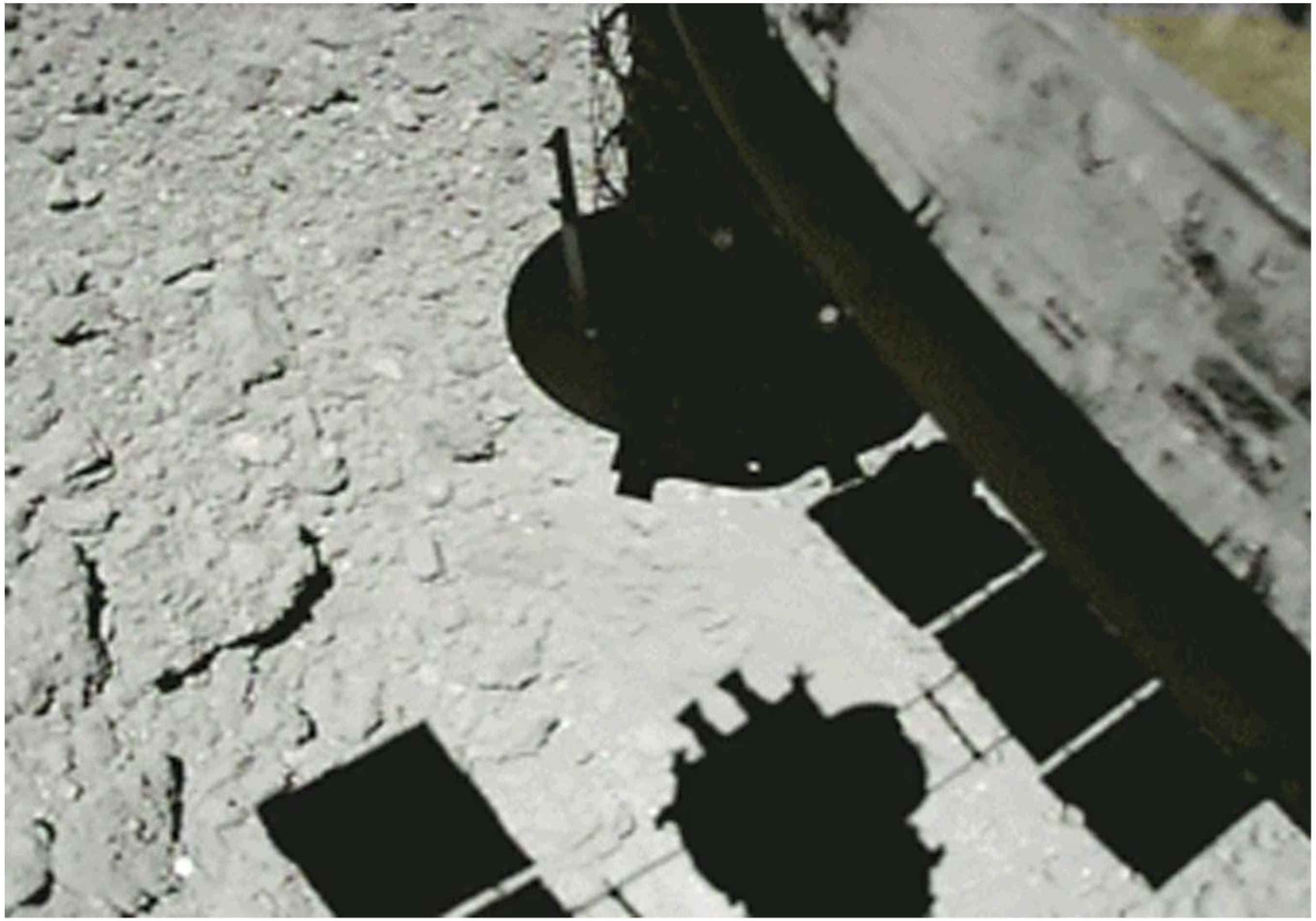
New Release

Movie credit: JAXA

CAM-H (Sampler Horn Monitor Camera) Movie

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



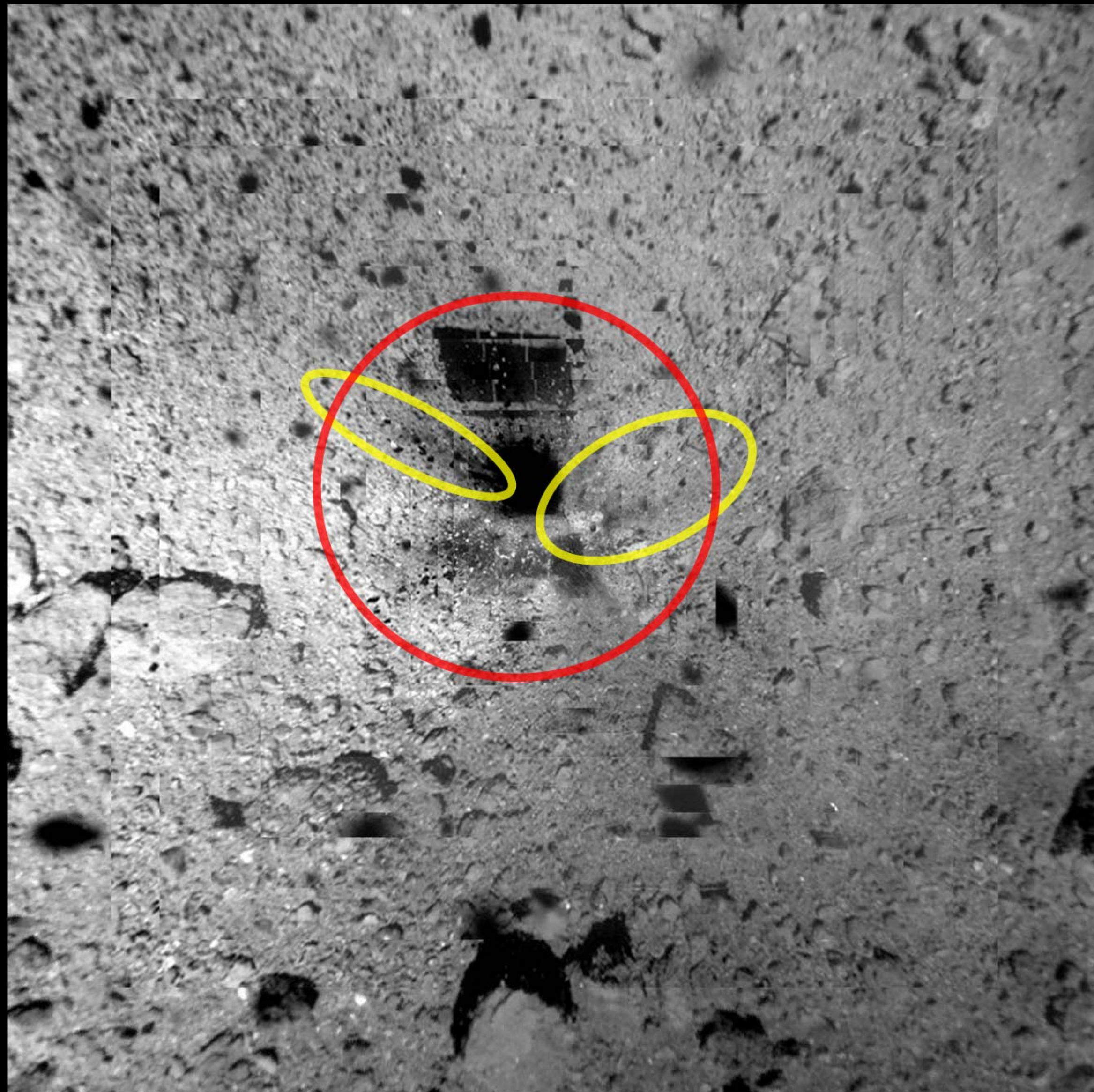
(Animation plays at 5x speed) （Movie credit：JAXA）

Movie taken by ONC-W1 at the first touchdown

New Release

A motion picture taken by Hayabusa2's nadir-viewing wide-angle optical navigation camera (ONC-W1) soon after the touchdown (TD) from 7:29 am on Feb. 22, 2019 (JST) at altitudes from about 6 to 25m. Individual images were pasted on each other after projected to the perspective from infinity.

The motions of surface materials induced by TD are seen. The time between adjacent frames is 2 or 4 seconds; 34 seconds of motion pictures during the ascent are shown here. A variety of moving objects can be found in this motion picture. The shadow that moves from the central part of the frame to lower right is the shadow of Hayabusa2. Many fast-moving black shadows with diffuse boundaries are pebbles just underneath Hayabusa2. They look black because they are flying in the shadow of Hayabusa2. Bright moving objects with sharp boundaries are boulders moving on or near the Ryugu surface. Dark rays that have diffuse boundaries and extend radially from where the Hayabusa2 shadow is seen in the beginning of the motion picture is estimated to be materials ejected from the TD site.

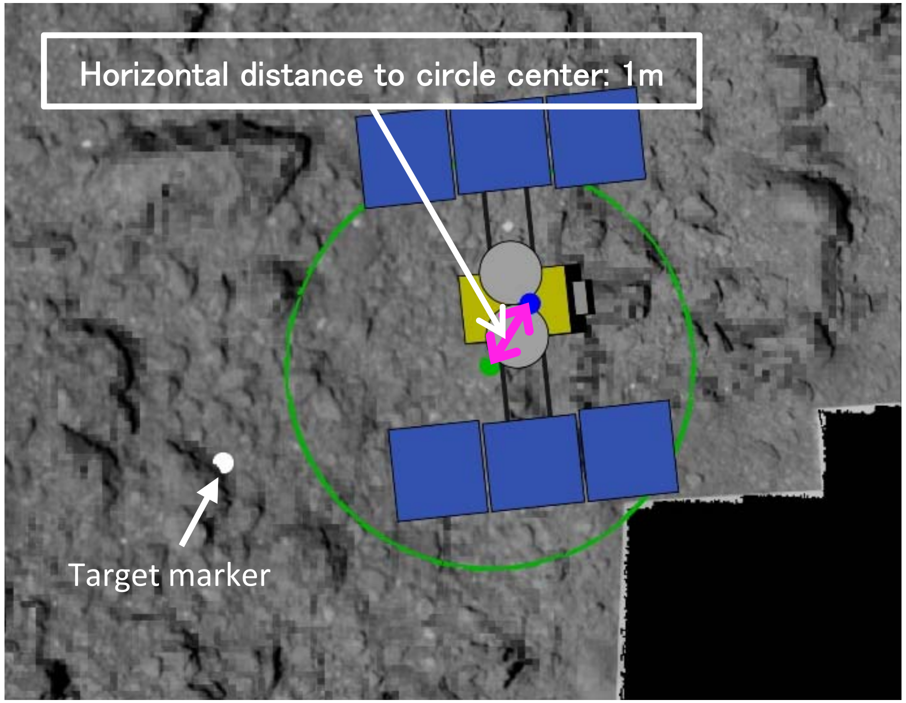


(Image Credit : JAXA/ Meiji U/UTokyo/Kochi U/Rikkyo U/Nagoya U/Chiba Inst Tech/ U Aizu/AIST)

Achieved Landing Accuracy and Sample Point

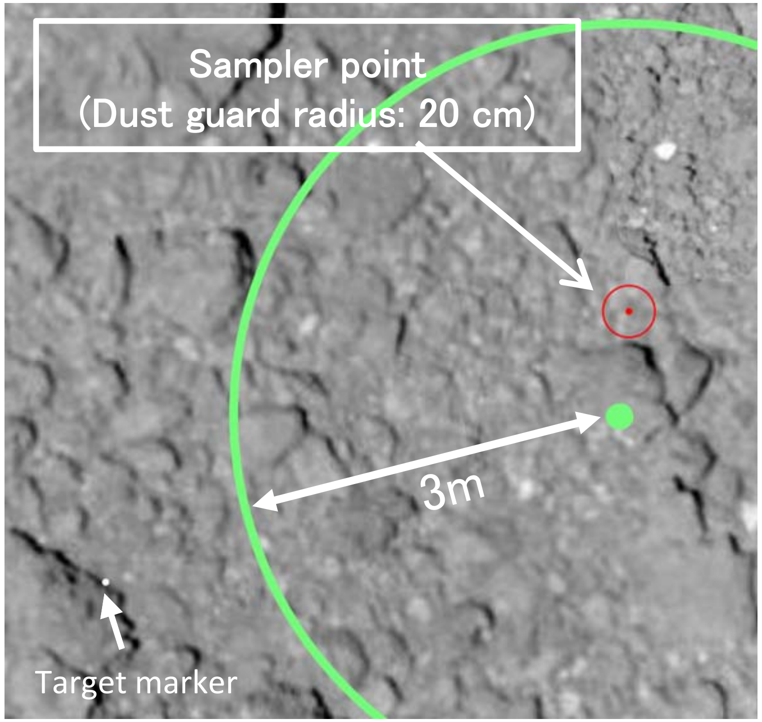
1m precision landing has been achieved!

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



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.

Summary

- Hayabusa2 succeeded in touchdown on Ryugu at Feb. 22, 2019, 07:29:10 (JST).
- The achieved landing accuracy was 1m.
- The sample chamber A (one of three chambers) was closed 4 hrs after TD, and the collected sample has been secured.
- Hayabusa2 will perform a kinetic impact experiment (artificial crater forming) on April 5, leave Ryugu in Nov/Dec 2019, and return to the Earth in Nov/Dec 2020.

The movies presented in this material can be downloaded from:
http://www.jaxa.jp/press/kit/hayabusa2/td/