Asteroid explorer, Hayabusa2, reporter briefing

February 4, 2021

JAXA Hayabusa2 Project

Topics

Overview

1. Operation status of the spacecraft
2. Curation work
3. Results from the LIDAR optical link experiment
4. Introduction to the NIRS3 journal paper
5. Introduction to the LIDAR journal paper
6. Future plans

Overview of current status

■Spacecraft operation

- The ion engine operation for the Extended Mission began on January 5. Powered navigation time so far is 577 hours.

■Curation work

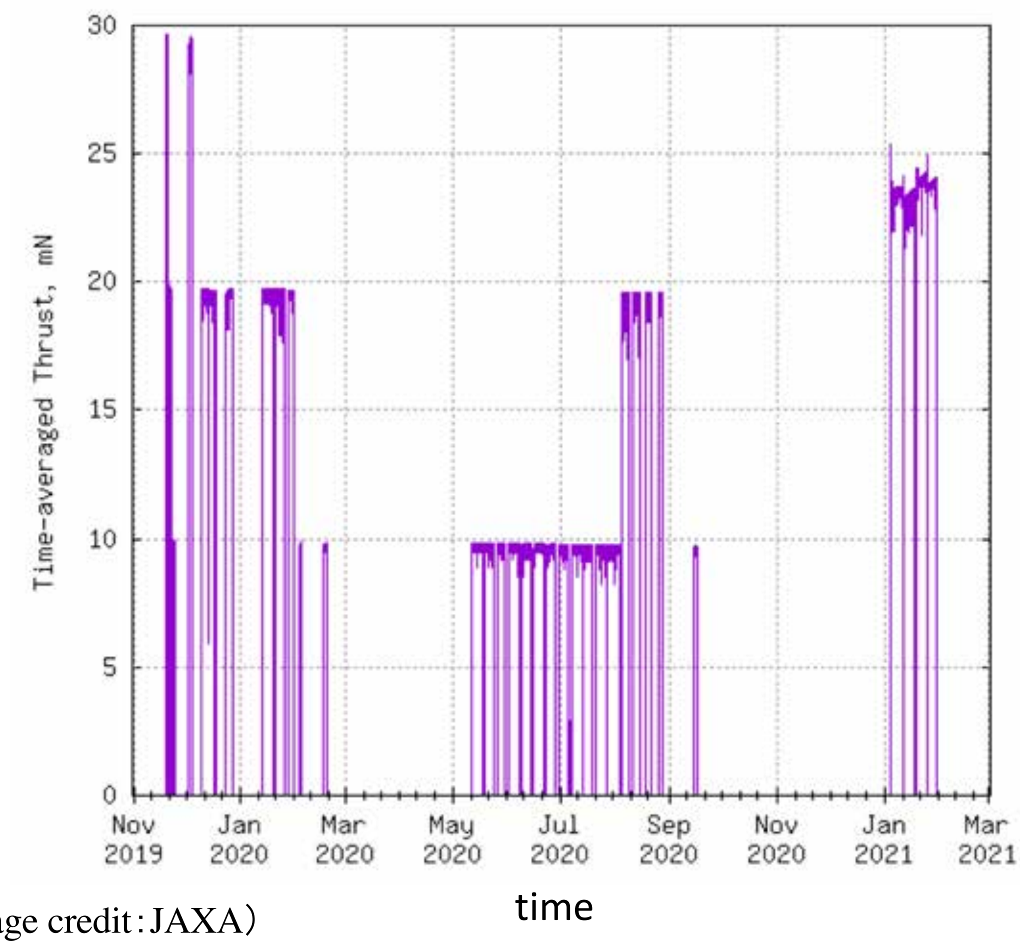
- The sample of particles and bulk powder returned from Ryugu have been moved to observation containers, and high-definition optical microscope images are being acquired, along with measurements of the weight.

1. Operation status of the spacecraft

- Ion engine operations resumed on January 5.
- The cumulative powered navigation time was 9,514 hours before returning to Earth, but exceeded 10,000 hours on January 26 (10,091 hours on January 31st)
- To save propellent, priority was given to high efficiency (specific impulse) and three engines were operated with a modest thrust of about 8 mN/engine. (This corresponds to the maximum thrust at the time of Hayabusa.)
- The mission record for the shortest solar distance is now updated; it was 0.853 au (astronomical units) when ion engine operations stopped on January 30. This is slightly below the shortest solar distance of 0.86 au experienced during the ion engine operations of Hayabusa.
- The powered navigation time from January 5th to January 31st was 577 hours.

1. Operation status of the spacecraft

- On January 5, 2021, the operation began with 3 ion engines, B･C･D
- Deceleration direction with respect to orbit
- Cumulative operation time for the ion engines (as of January 31, 2021)
  A: 6705 hours
  B: 611 hours
  C: 8652 hours
  D: 8106 hours
  IES (powered navigation) : 10091 hours
- Intermittent operation until around November, then pause for a time.



(image credit：JAXA)

2. Curation work

- The sample in chamber A was placed in observation containers (3 dishes in total: see figure below), and the weight measurement and optical microscope observations were started.

＊weight (below) is the weight of the sample in each observation container. The weight of the separated pieces is not included.

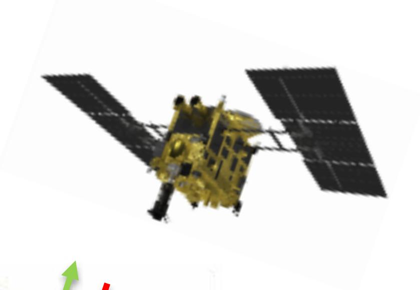
Container inner diameter is 21 mm

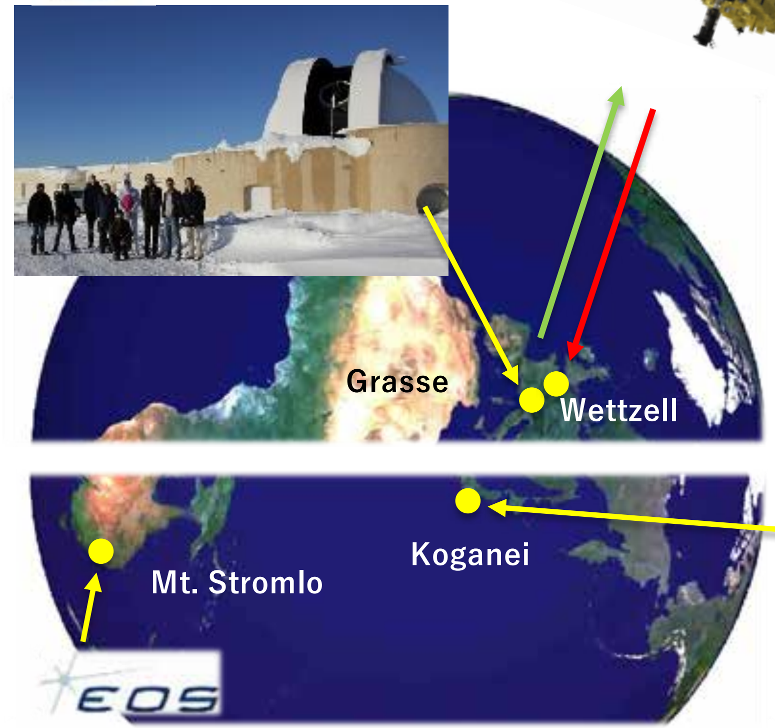
（image credit：JAXA）

3. Result of the laser ranging experiment

A 2-way laser link between Hayabusa2 and ground stations was successful using the echo transponder method.

University of Cote d'Azur, France
CNRS Cote d'Azur Observatory





Australia
EOS Space Systems Pty Ltd
Mt. Stromlo Satellite Laser Ranging facility

The Cote d'Azur Observatory in France received the downlink signal from the Hayabusa2 LIDAR and successfully established the 2-way link.

Dec. 9, 2020: 1 million km
Dec. 21, 2020 : 6 million km

The signals detected by other stations are under analysis.

Germany
Technical University of Munich,
Wettzell Observatory

国立研究開発法人 情報通信研究機構

Telecommunications
JPL/NASA
Deep Space Network
Canberra, Madrid

National Astronomical Observatory of Japan

Chiba Inst. Tech.
PREC

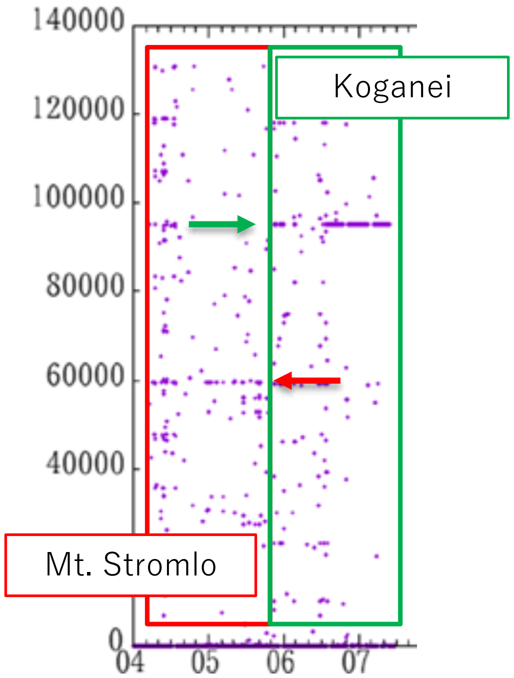
Hitotsubashi Univ.
Geoscience Lab.

LIDAR

3. Result of the laser ranging experiment

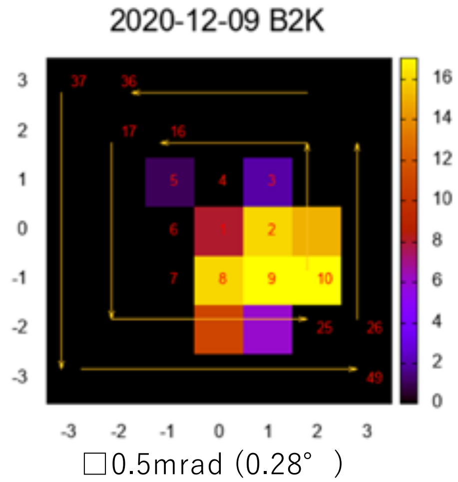
Uplink

Three stations (Koganei, Mt.Stromlo, Grasse) successful.



Laser pulse intervals measured by LIDAR from NICT Koganei station and EOS Stromlo station.

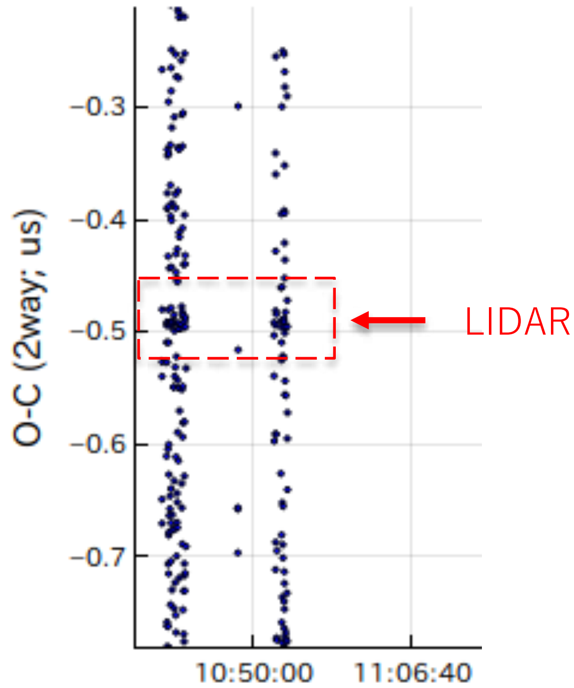
Frequency distribution of Uplink detection from Koganei



The result of measuring the field of view range of LIDAR by scanning Hayabusa2's attitude in a spiral pattern. In this figure, attitude positions with high frequency of signal detection by LIDAR are shown in bright colors.

Downlink

Grasse station successful.



Timing of the signal received by the CNRS Côte d'Azur Observatory.
The random scatter is noise caused by sunlight and heat from the detector. Signals with constant timing can be seen in the red dashed frame.

3. Result of the laser ranging experiment

Example of a successful laser link between a planetary explorer and ground stations

2005 Messenger 24million km Asynchronous 2-Way
2005 Mars Global Surveyor 80million km 1-Way
2009 Lunar Reconnaissance Orbiter 0.385million km 2-Way
2013 Lunar Laser Communication Demonstration 0.385million km 622Mbps
2015 Hayabusa2 6.6million km 1-Way
2020 Hayabusa2 6million km Synchronous 2-Way

The 2-way link between Hayabusa2 and the Earth station is rare success example that could be achieved in cooperation with foreign institutions.

Results and Significance

- One station succeeded in 2-way link and three stations succeeded in 1-way link.
- First example of 2-way link between a planetary probe and a ground station by a echo transponder.
- Successful downlink detection in daytime when there is a lot of noise from the Sun.
- Measurement of LIDAR's field-of-view by the stable uplink.
- Technology accumulation for future deep space laser ranging and high precision orbit determination.
- The successes was achieved by cooperation with foreign laser stations.

4. NIRS3 paper introduction

Overview

- A paper on the research results from direct observations of subsurface material on asteroid Ryugu using the Near-Infrared Spectrometer (NIRS3) was published in the British online journal, Nature Astronomy, on January 4, 2021 (January 5 JST).
- The research reports that the subsurface material on Ryugu has undergone partial dehydration due to heating, similar to the surface material. However, it is water-rich compared to that of the surface. Heating would therefore have occurred on the parent body that is the predecessor of Ryugu.

4. NIRS3 paper introduction

Paper details

Title: Thermally altered subsurface material of asteroid (162173) Ryugu

Authors: Kohei Kitazato[1★], Ralph Milliken[2], Takahiro Iwata[3,4], Masanori Abe[3,4], Makiko Ohtake[1]
96 other authors

★Corresponding author, [1]University of Aizu, [2]Brown University, [3]JAXA, [4]Graduate University for Advanced Studies (SOKENDAI), 32 other institutes

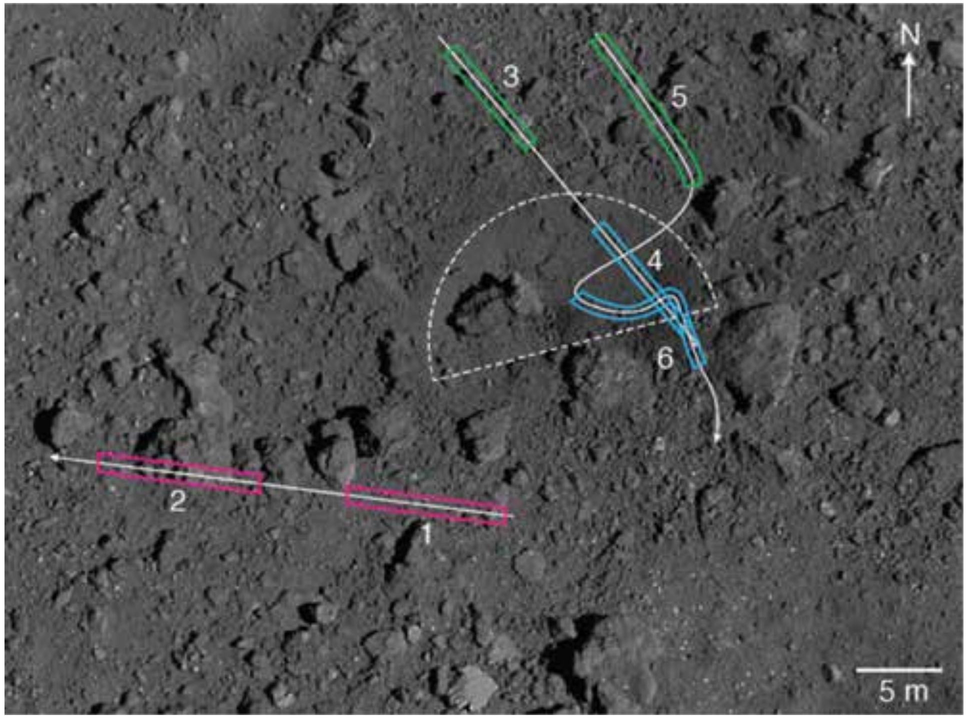
Journal: Nature Astronomy

Publication date: 2021/1/4（1/5 JST）

DOI: https://doi.org/10.1038/s41550-020-01271-2

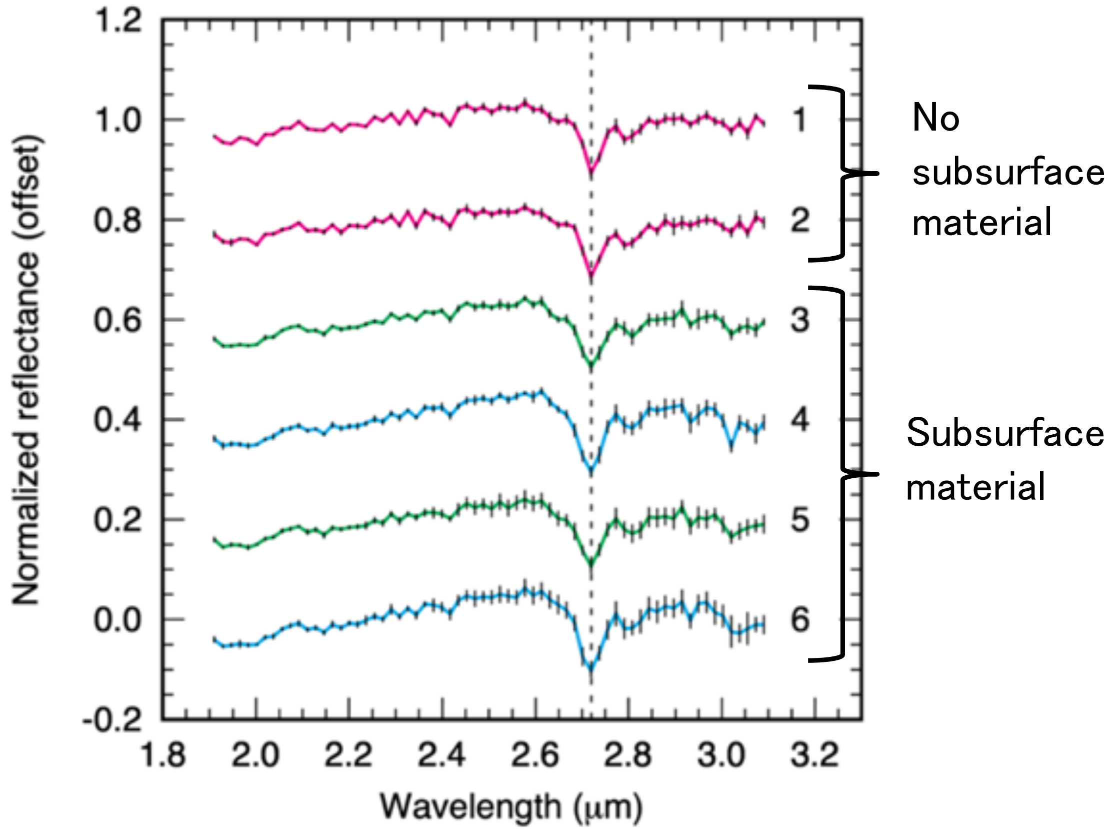
4. NIRS3 paper introduction

SCI crater observations by NIRS3



SCI crater (dotted line) and
NIRS3 observation line (arrow curve)
(image credit: University of Aizu、JAXA)

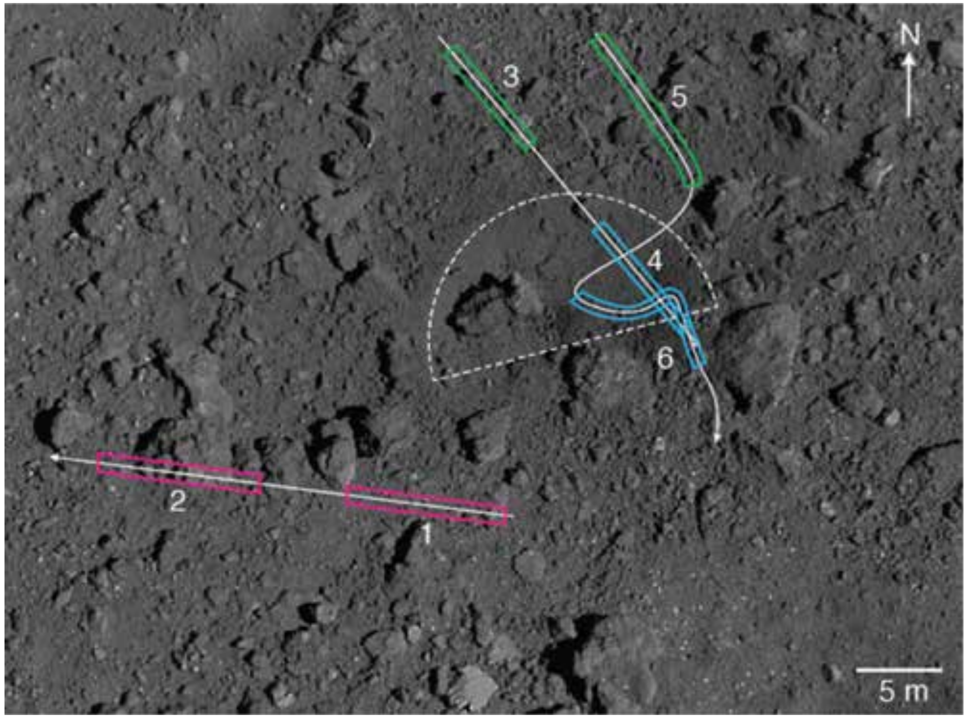
(from Kitazato et al. (2021))



NIRS3 spectra. The absorption near 2.7μm is by OH.

4. NIRS3 paper introduction

SCI crater observations by NIRS3



SCI crater (dotted line) and
NIRS3 observation line (arrow curve)
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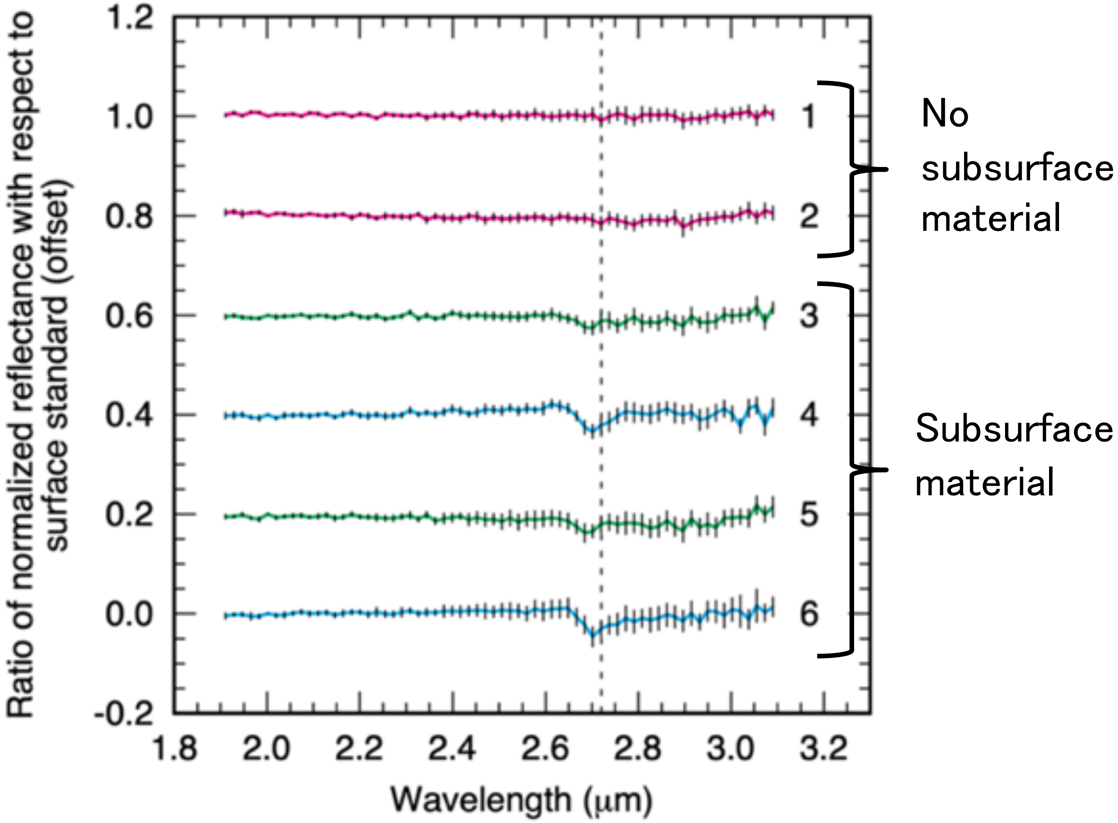


Subsurface absorption slightly deeper than surface

4. NIRS3 paper introduction

Summary of observation results & interpretation

subsurface・surface	Observation results	Interpretation
Difference	Subsurface material has slightly deeper absorption for the hydroxyl groups than the surface, indicating water rich.	After the formation of Ryugu, a part of surface water was lost through heating in sunlight or space weathering.
Similarity	Both the subsurface and surface material have a narrow absorption width for the hydroxyl groups, indicated partial dehydration at temperatures above 300˚C	Even if Ryugu once orbited closer to the Sun than at present, temperatures of subsurface material would only have reached 200˚C from sunlight heating＊. Ryugu material has been thermally metamorphosed by internal heating or impact heating of the parent body.

＊Paper shows this via numerical calculation

5. LIDAR paper introduction

- The following 3 papers have been released by the Laser Altimeter (LIDAR) team.
- By making full use of the distance data collected in the vicinity of the asteroid using the laser altimeter, the orbit of the spacecraft could be accurately determined. This was used in the analysis of the camera images and forms the bases for developing useful technology for the up-coming Martian Moons eXploration (MMX) mission.

Matsumoto（NAOJ） et al. Icarus, 2020/3

Yamamoto（NAOJ） et al. EPS 2020/6

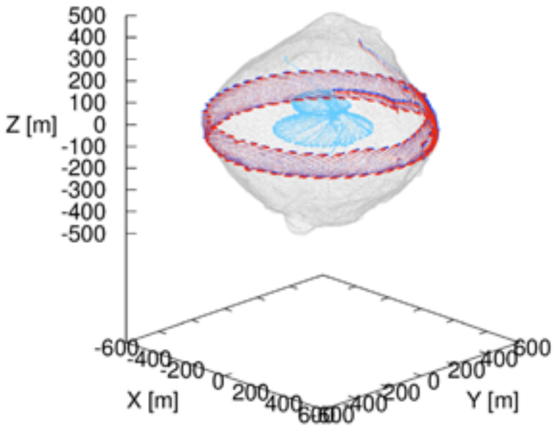
Noda（NAOJ） et al. EPS 2021/1

5. LIDAR paper introduction #1

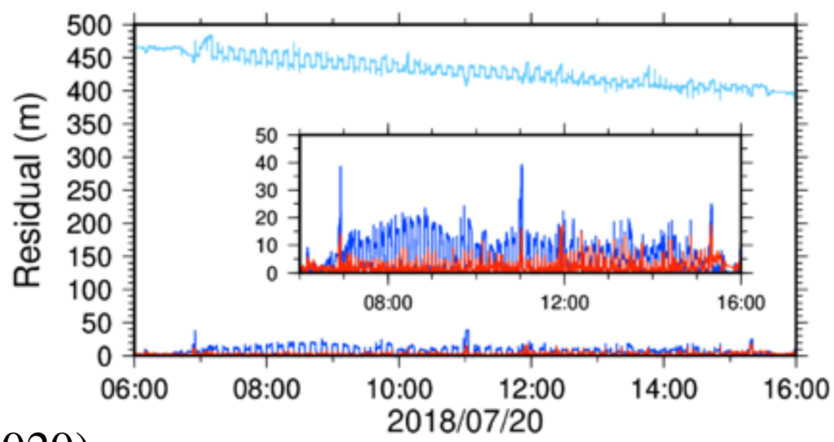
Matsumoto, K., and 39 colleagues, "Improving Hayabusa2 trajectory by combining LIDAR data and a shape model", Icarus, 338, 113574, https://doi.org/10.1016/j.icarus.2019.113574, Publication date: 2020/3/1

- The orbit of the spacecraft was improved by fitting the time series for the topographical information from the LIDAR ranging data to the shape model.
- Orbit estimation is possible even during a period when there is no Doppler tracking or image data.
- The improved spacecraft trajectory was also used for the data analysis from other observational instruments.

LIDAR Footprint



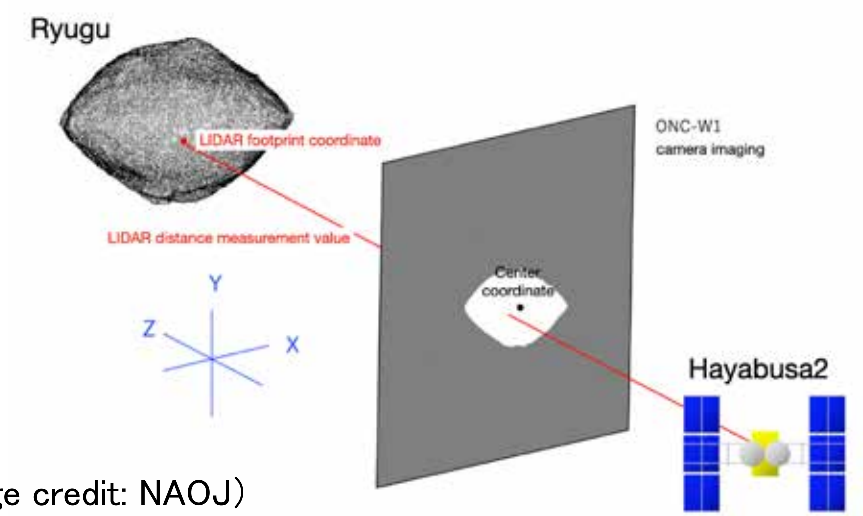
Residual time series



From Matsumoto et al. (2020)

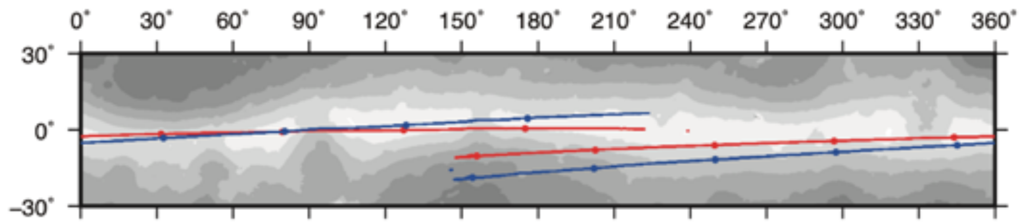
5. LIDAR paper introduction #2

- Yamamoto, K. and 37 colleagues, "Dynamic precise orbit determination of Hayabusa2 using laser altimeter (LIDAR) and image tracking data sets", Earth Planets and Space (2020) 72: 85, https://doi.org/10.1186/s40623-020-01213-2, Publication date 2020/6/12
- The orbit of the spacecraft geometrically determined through terrain fitting was improved by using the distance measurement data obtained from the LIDAR laser altimeter and the image center data from the ONC-W1 camera.
- This is expected to be useful not only for the Hayabusa2 mission, but also for future missions to small celestial bodies as a method for obtaining precise orbits.



(image credit: NAOJ)

https://www.miz.nao.ac.jp/rise/c/reading/paper-detail-20200706



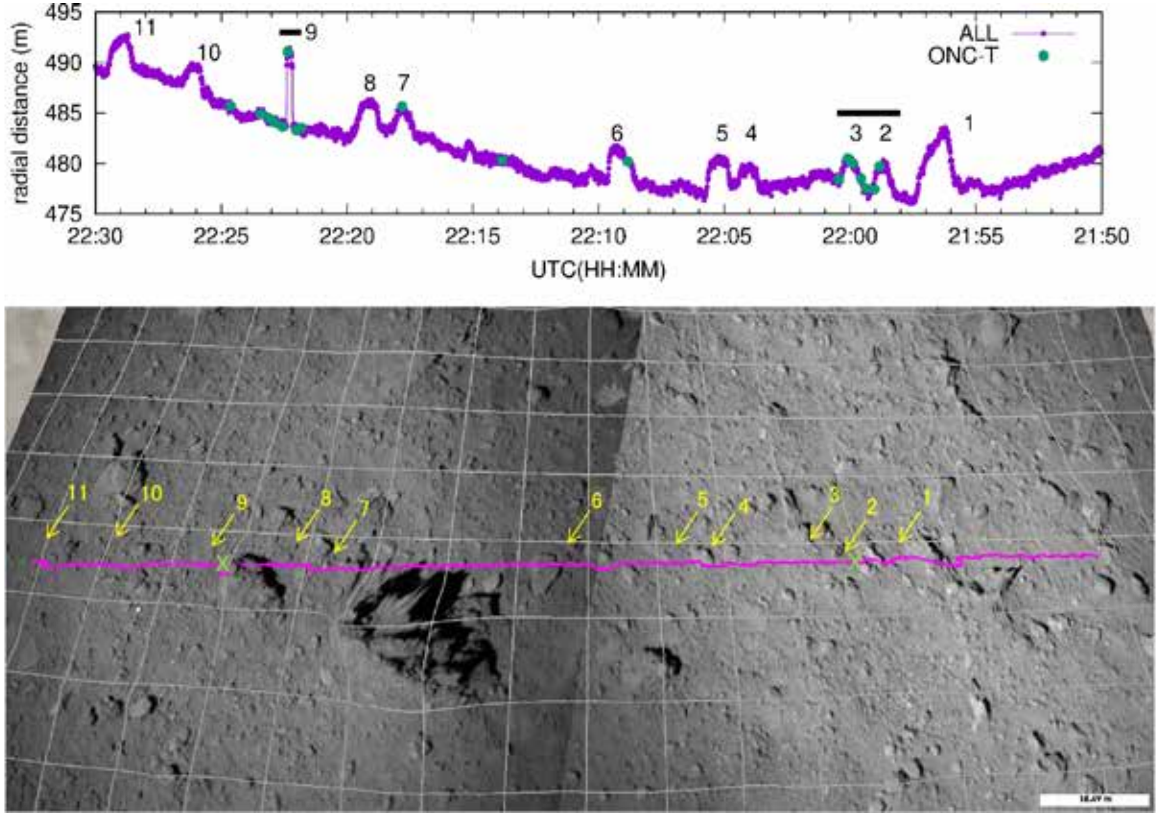
Red : LIDAR footprint position calculated from terrain fitting trajectory
Blue : LIDAR footprint position calculated using the orbit of this study.

From Yamamoto et al. (2020)

5. LIDAR paper introduction #3

- Noda, H., and 51 colleagues, "Alignment determination of the Hayabusa2 laser altimeter (LIDAR)", Earth, Planets and Space volume 73, Article number: 21 (2021), https://doi.org/10.1186/s40623-020-01342-8, Publication date 2021/1/20

- The LIDAR time series data was compared with the ONC-T images to accurately determine the orientation of the LIDAR instrument. This contributes to the refinement of the spacecraft trajectory estimated from the LIDAR data.



From Noda et al., 2021

6. Future plans

■Operation Schedule

2021/2-3 Ion engine operation test
（when the solar distance is small）

■Press and media briefings

2021/2 or 3 TBD Press briefing @ online

Reference

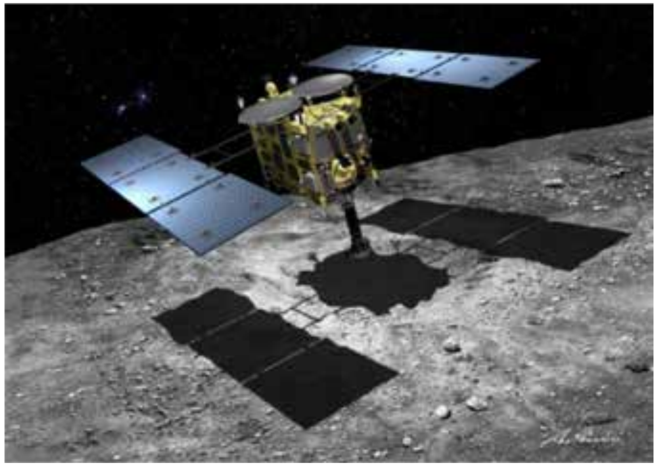
Overview of Hayabusa2

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.



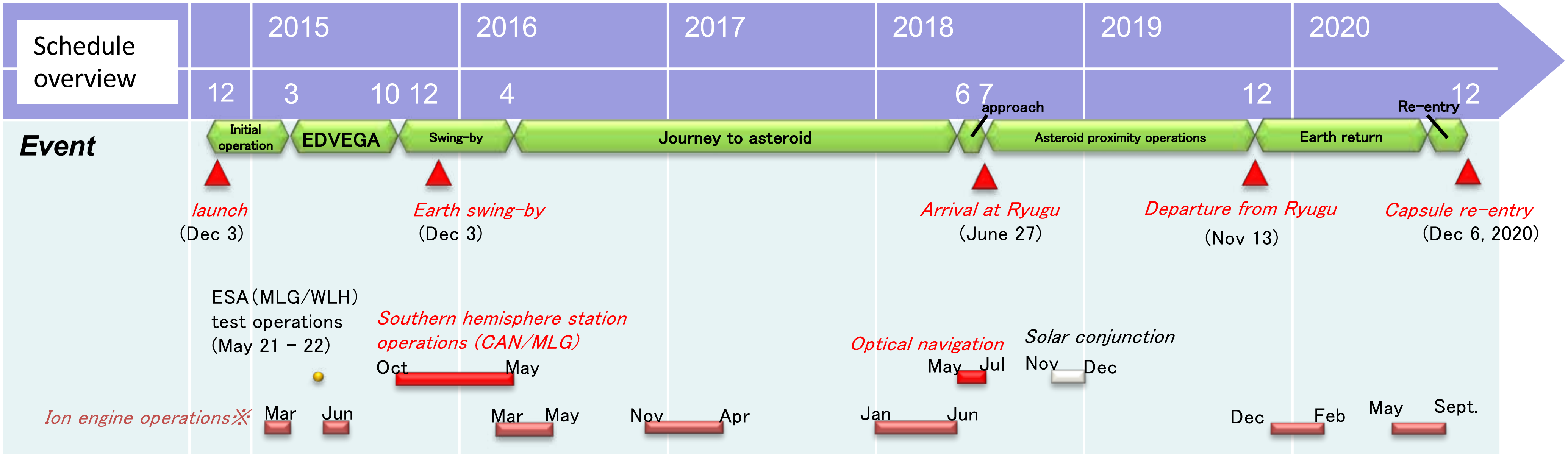
(Illustration: Akihiro Ikeshita)

Hayabusa 2 primary specifications

Mass	Approx. 609 kg
Launch	3 Dec 2014
Mission	Asteroid return
Arrival	27 June 2018
Deoarture	13 Mov 2019
Earth return	6 Dec 2020 (plan)
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.

1. Current project status & schedule overview



(image credit：JAXA)

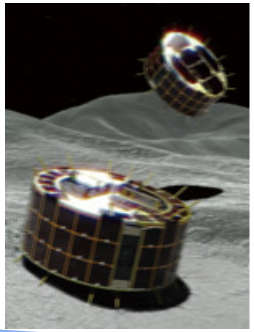
Mission flow

Launch
Dec 3, 2014

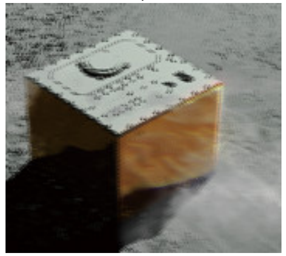
Earth swing-by
Dec 3, 2015

Ryugu arrival
June 27, 2018

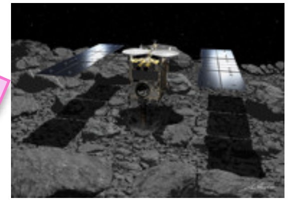
MINERVA-II1 separation
Sep 21, 2018



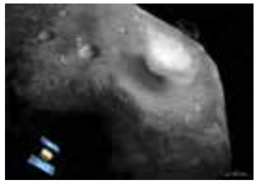
MASCOT separation
Oct 3, 2018



Target marker separation
Oct 25, 2018

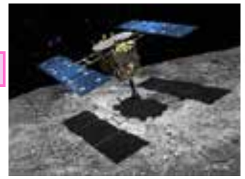


First touchdown
Feb 22, 2019

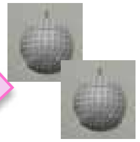


Impactor (SCI)
5 April, 2019

Target marker separation
May 30, 2019



Second touchdown
July 11, 2019



Target marker separation
Sept. 17, 2019

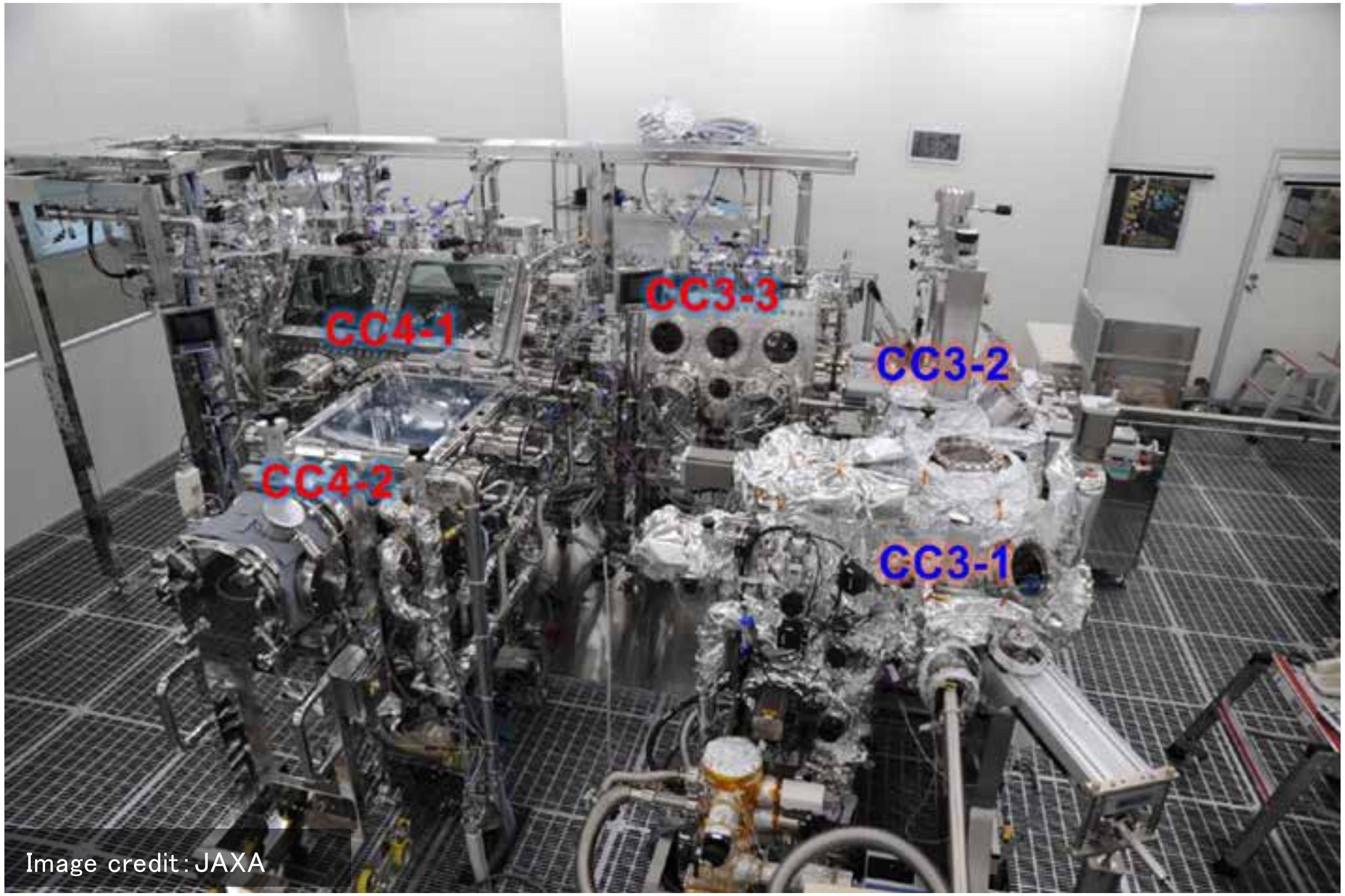
MINERVA-II2 separation
Oct. 3, 2019

Ryugu departure
Nov 13, 2019

Earth return
Dec. 6, 2020

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

Clean chamber overview



CC3-1 ：
Opening the sample container under vacuum environment

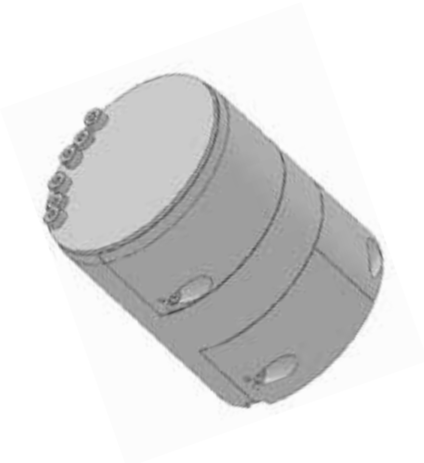
CC3-2 ：
Sample collection under vacuum

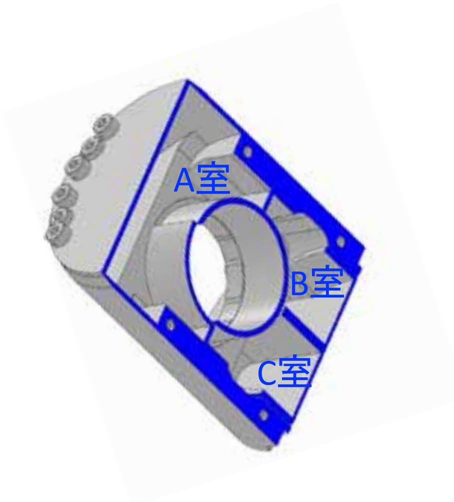
CC3-3 ：
Transition from vacuum to nitrogen environment

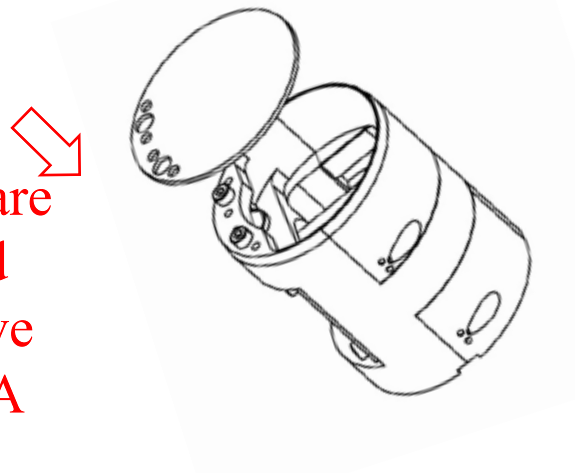
CC4-1 ：
Handling of submillimeter-sized particles

CC4-2 ：
Handling / observation / sorting of relatively large particles (> mm)

Reference: Catcher opening operation







- The sample catcher was moved to clean chamber CC3-2, and the lid of sample catcher chamber A was opened in vacuum conditions.
- Many particles are confirmed to be in chamber A. This is thought to be the sample collected during Touchdown #1 on Ryugu.
- Part of the sample was picked up in Chamber A to be stored in vacuum in its present condition.
- From here, we will move to chamber CC3-3, remove the samples from chamber A in a nitrogen environment, and open chambers B and C.

(image credit：JAXA)

Reference：Observation container