Asteroid explorer, Hayabusa2, reporter briefing

October 29, 2020

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2,

- Results of TCM-1
- Preparation status for capsule collection
- Ground observations of Ryugu
- Outreach

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1. Current status and overall schedule of the project
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6. Outreach / public relations
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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

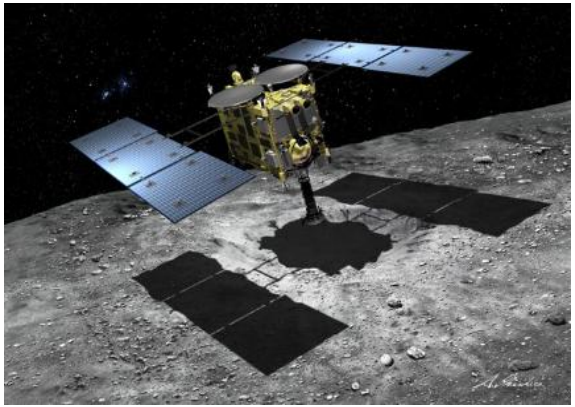
- By exploring a C-type asteroid, which is rich in water and organic materials, we will clarify interactions between the building blocks of Earth and the evolution of its oceans and life, thereby developing solar system science.
- Japan will further its worldwide lead in this field by taking on the new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

Mission flow

Launch
Dec 3, 2014

Earth swing-by
Dec 3, 2015

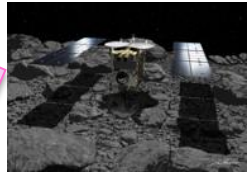
Ryugu arrival
June 27, 2018

MINERVA-II1 separation
Sep 21, 2018

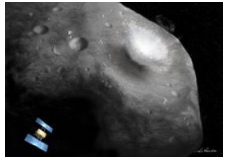
MASCOT separation
Oct 3, 2018

Target marker separation
Oct 25, 2018

First touchdown
Feb 22, 2019



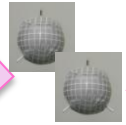
Impactor (SCI)
5 April, 2019



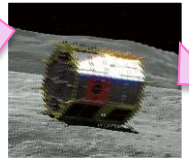
Target marker separation
May 30, 2019

Second touchdown
July 11, 2019

Target marker separation
Sept. 17, 2019



MINERVA-II2 separation
Oct. 3, 2019



Ryugu departure
Nov 13, 2019

complete

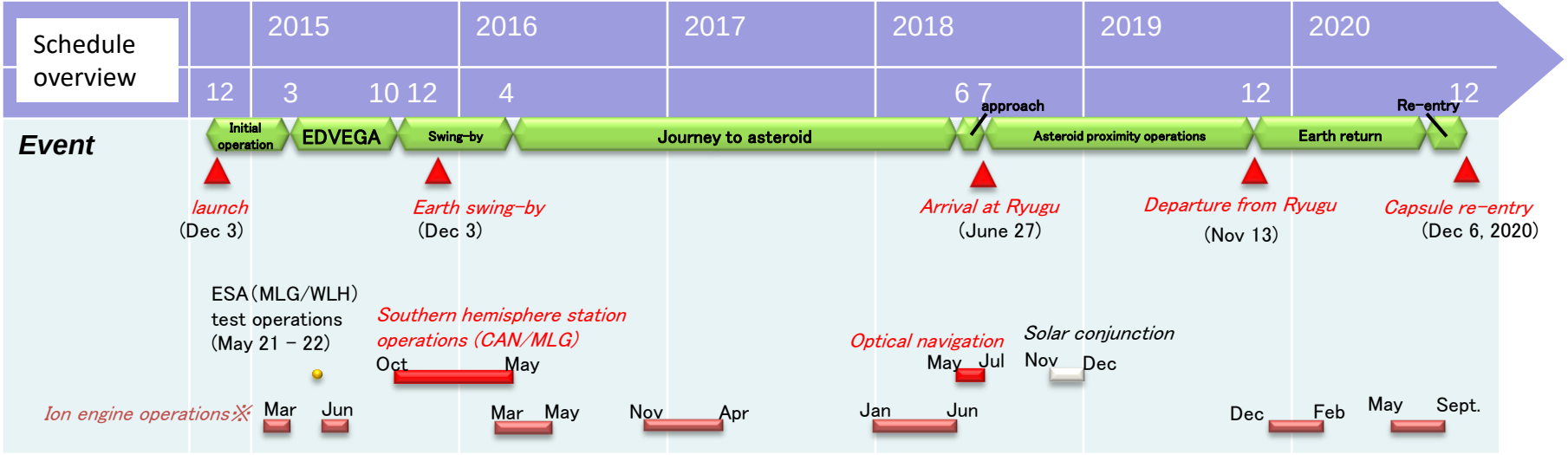
Earth return
Dec. 6, 2020

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

1. Current project status & schedule overview

Current status:

- The final guidance phase began in October, and TCM-1 was performed on October 22, which corrected the orbit as planned.
- Part of the capsule recovery team have begun domestic quarantine ahead of the move to Australia.



(image credit: JAXA)

2. Results of TCM-1

- The first orbit control for the final re-entry guidance phase, TCM-1, was performed on October 22, and the orbit correction was achieved as planned（TCM: Trajectory Correction Maneuver）.
- The orbit correction was made by the chemical engines (RCS) at around 18:00 JST. At around 19:00, an acceleration correction (trim ΔV) was performed.
- The orbit control amount was about 15cm/s. The closest altitude to the Earth has changed from about 400 km to about 330 km.
- The spacecraft condition is normal.

3. Preparation status for capsule collection

Spacecraft operation rehearsal

The CPSL operation

- As with the critical operations near the asteroid, real-time operation training using the Hayabusa2 simulator (HIL) and rehearsals with the actual spacecraft are planned.
- On September 26, real-time operation training using HIL was conducted covering the CPSL separation to TCM-5, including response to contingency cases. Based on the training results, we are updating the procedure manual.
- A CPSL separation operation rehearsal using the actual spacecraft is scheduled for November 4, and the procedure is currently being prepared.

The TCM operation

- From September 28, a dry run of the series of work from orbit determination to orbit correction (ΔV) procedure creation was carried out as the TCM rehearsal. This confirmed the procedure and preparation status from offline work to operation.
- TCM-1 was carried out without any delays on October 22.

3. Preparation status for capsule collection

Preparation status of the capsule recovery team

- Start the move towards capsule collection.
- Capsule collection team: 73 people in total (preliminary team (14 people) and main team (59 people)).
- The coronavirus situation in Australia is calm. However, depending on the situation, interstate travel may require two weeks of quarantine, so we will travel directly to Adelaide, south Australia by charter plane.

- Preliminary team:
  10/24: Domestic quarantine began
  11/1: Departure (Haneda → Adelaide)
  until 11/15: 2 weeks quarantine in Adelaide
  11/16: Woomera arrival, preparations begin.

- Main team:
  11/1: Domestic quarantine began
  11/9: Departure (Haneda → Adelaide)
  until 11/23: 2 weeks quarantine in Adelaide
  11/24: Arrive at Woomera and begin work

4. Ground observations of Ryugu

Overview:

October – December 2020 is an opportunity to observe Ryugu at a large phase angle (Fig. 4-1, 4-2).

Dark asteroids such as Ryugu are expected to show a high degree of polarization when observed at a phase angle of 90 – 100 degrees, but there are few observations of similar objects (Fig. 4-3).

The polarization of Bennu has been measured, but only for a phase angle of just 57 degrees (Cellino+2018).

The ground observation subgroup is planning polarized imaging observations of Ryugu using four telescopes in Japan and overseas (Hiroshima University, University of Hyogo, Hokkaido University and Bohyunsan Optical Astronomy Observatory. If we miss this opportunity, we have to wait 13 years for next time.

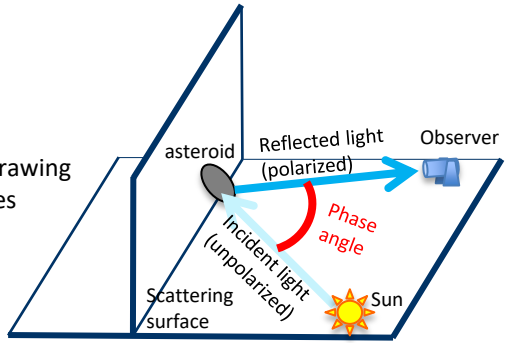


Figure 4-1
Explanatory drawing of phase angles
(Credit: Kyoto University)

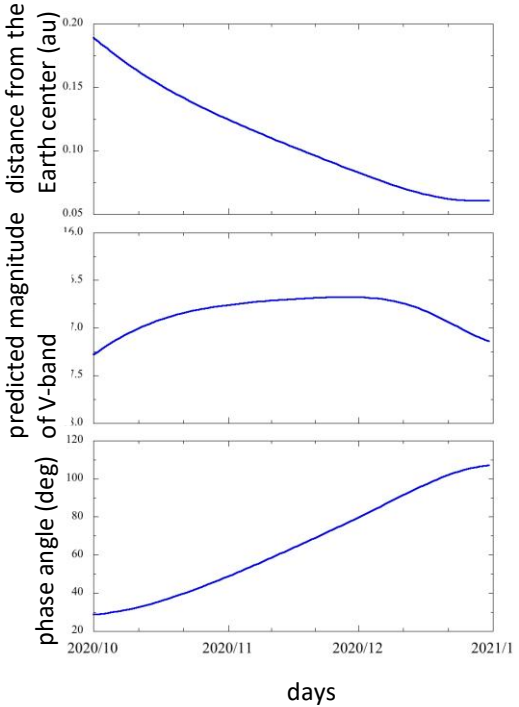


Figure 4-2
Ryugu phase angle, magnitude, geocentric distance (credit: Kyoto University)

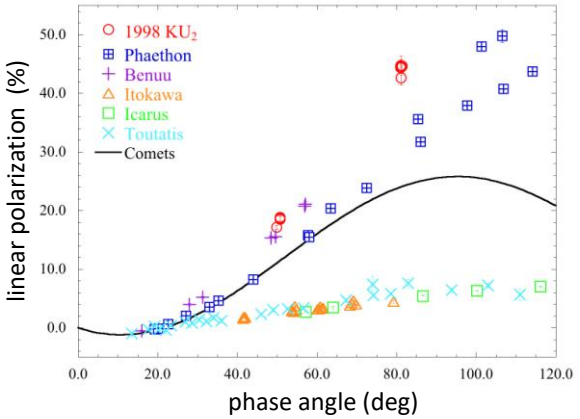


Figure 4-3
Asteroid phase angle – polarization plot. Data from Kuroda+2018; Ito+2018; Shinnaka+2018; Cellino+2018; Cellino+2005; Ishiguro+2017; Ishiguro+1997; Mukai+1997; Kiselev+2005.
(Credit: Kyoto University)

4. Ground observations of Ryugu

Expected result:

・Do dark (low albedo) asteroids **truly show high polarization?**

Preliminary predictions suggest Ryugu will exhibit a degree of polarization of over 30%.

・It may be possible to clarify the mechanism of polarization that occurs on the surface of asteroids.

From previous studies, there is an expected close relationship between the degree of polarization and the surface particle size. Ryugu is the optimal and essential target to verify this, as the surface conditions have been well investigated. It may be possible confirm the presence of smaller particles that were not visible in close-up images of Ryugu (Fig. 4-4) (suggested by Morota+2020).

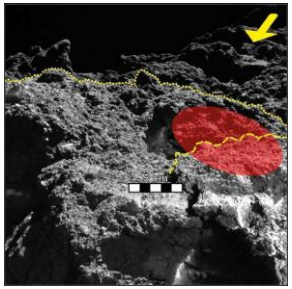


Figure 4-4
DLR camera MASCAM on MASCOT (Grott+2019)
(Credit: MASCOT/DLR/JAXA)

Progress:

In October 2020, polarized imaging data was acquired at the observatories of three universities in Japan (Fig. 4-5). Observations will continue in November and December, with the final results expected after the end of 2020.

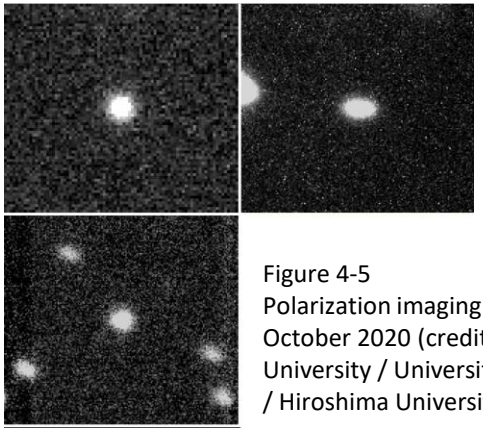


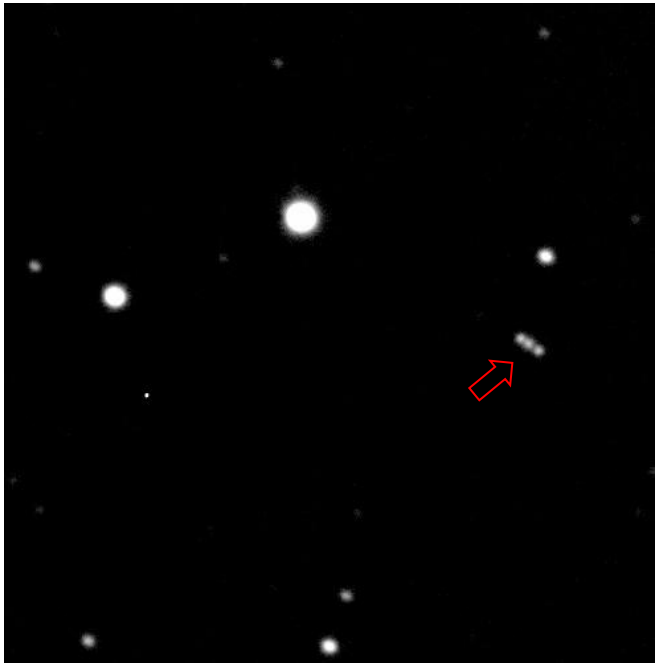
Figure 4-5
Polarization imaging data for October 2020 (credit Hokkaido University / University of Hyogo / Hiroshima University)

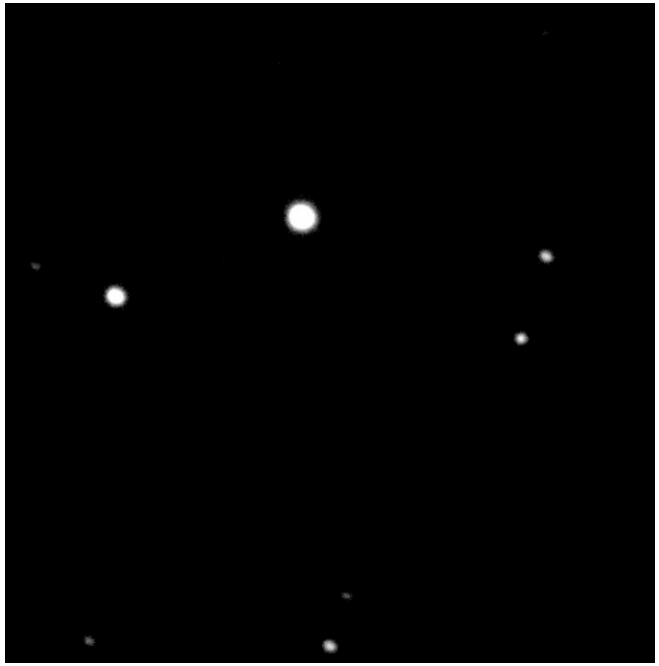
Collaborators:

Daisuke Kuroda (Kyoto University), Sunao Hasegawa, Makoto Yoshikawa (JAXA), Masateru Ishiguro (Seoul National University), Hiroshi Akitaya, Koji Kawabata (Hiroshima University), Jun Takahashi, Miyako Tozuka, ASoi Kawakami (University of Hyogo), Hiroyuki Naito (Nayoro Observatory), Tomohiko Sekiguchi, Koki Takahashi (Hokkaido University of Education), Seiko Takagi, Kiyoshi Kuramoto (Hokkaido University)

4. Ground observations of Ryugu

Recent images to Ryugu





(animation)

Observation date & time: October 18, 2020, 19:53 – 19:58 JST (exposure time: 60 seconds x 3)
Observation site : Hokkaido University Astronomical Observatory (Nayoro City, Hokkaido)
Location : Near Pegasus

(Credit: Hokkaido University / Kyoto University)

5. Open call for re-entry observations

・We held an open call for participants to observe the re-entry capsule and joint research agreements are signed for the following 7 cases.
・However, the novel coronavirus made it difficult to execute observations for these joint researches.
・To the extent possible, collaborative research with Australian researchers or proxy observations by project members will be performed.

Research title	Representative (affiliation)	How to do
GNSS observations of ionospheric disturbances generated by the re-entry of Hayabusa2	ITO Takeko (Nagoya University) Phil R. Cummins (Australian National University)	Australia collaborative project
VLF Observation of the Hayabusa-2 Sample Return Capsule Re-entry	KOBAYASHI Miki (Nippon Meteor Society)	JAXA proxy observation
Spectroscopic observation of meteors using a grating	MINO Shotaro/SAITO Koichiro (Furukawa Reimei High School)	JAXA proxy observation
NUV-VIS Spectroscopy of Meteor Train and Afterglow Plasma caused by Hayabusa2 Reentry Capsule	ABE Shinsuke (Nihon University)	JAXA proxy observation
The project to receiving the message of Hayabusa2 ! ～Research of Meteor Bursts Caused by Atmospheric Re-entry Objects～	KAWACHI Kohei (Chubu University) TANAKA Kouki (University of Tokyo) KAWAMURA Tomoya (Aichi Institute of Technology) NAKAYAMA Nao (Doshisha University)	JAXA proxy observation
Measurement of plasma size of the re-entry capsule by high magnification video observation	IIYAMA Ohmi (Osaka science museum)	Not implemented
Detailed observation of overpressure (infrasonic) and induced seismic waves generated by shock waves on HAYABUSA 2 earth-reentry and its trajectory determination	YAMAMOTO Masa-yuki (Kochi University of Technology)	Australia collaborative project

6. Outreach & public relations

Ryugu & Hayabusa2 return observation campaign

- Currently, there is an opportunity to observe Ryugu (brightness of Ryugu: about 17 mag).

※ This is the second Ryugu observation campaign (previous campaign was conducted in 2016).

- Immediately before re-entry, there is the possibility to observe the Hayabusa2 spacecraft.
- Organizer: Hayabusa2 Project, Japan Public Observatory Association (JAPOS), The Planetary Society of Japan (TPSJ)
- Observers recruited from November 1
- Campaign URLs:

JAPOS https://www.city.himeji.lg.jp/atom/planet/info/campaign/haya2return/index.html

TPSJ http://planetary.jp/Haya2-Special/projects/hayabusa2-serv.html

7. Future plans

■Schedule of operation

2020/11/2～19　　TCM-2

2020/11/25～29　　TCM-3

2020/12/6　　Re-entry

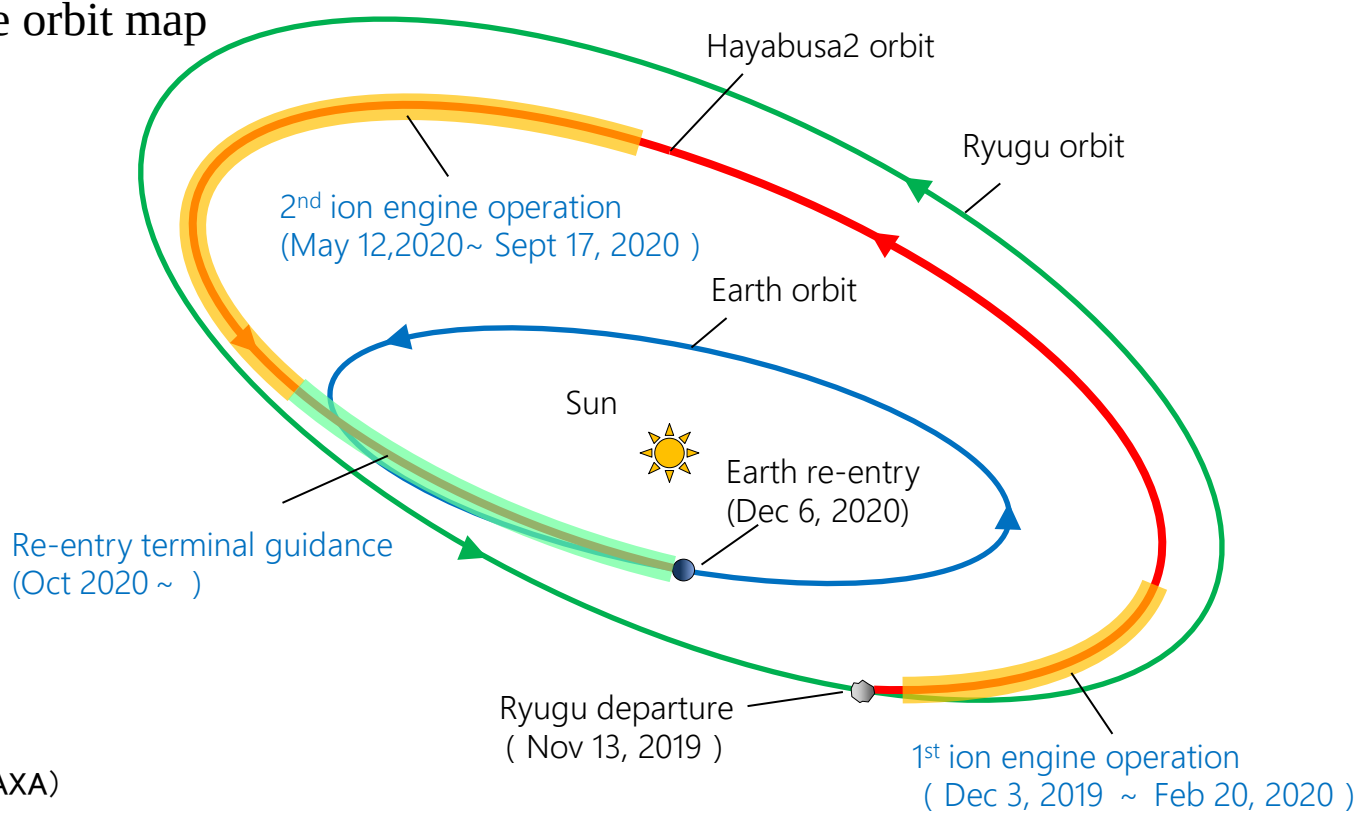
■Press and media briefings

2020/11（TBD）　　Press briefing @ online（TBD）

Reference material

Return cruise operation plan

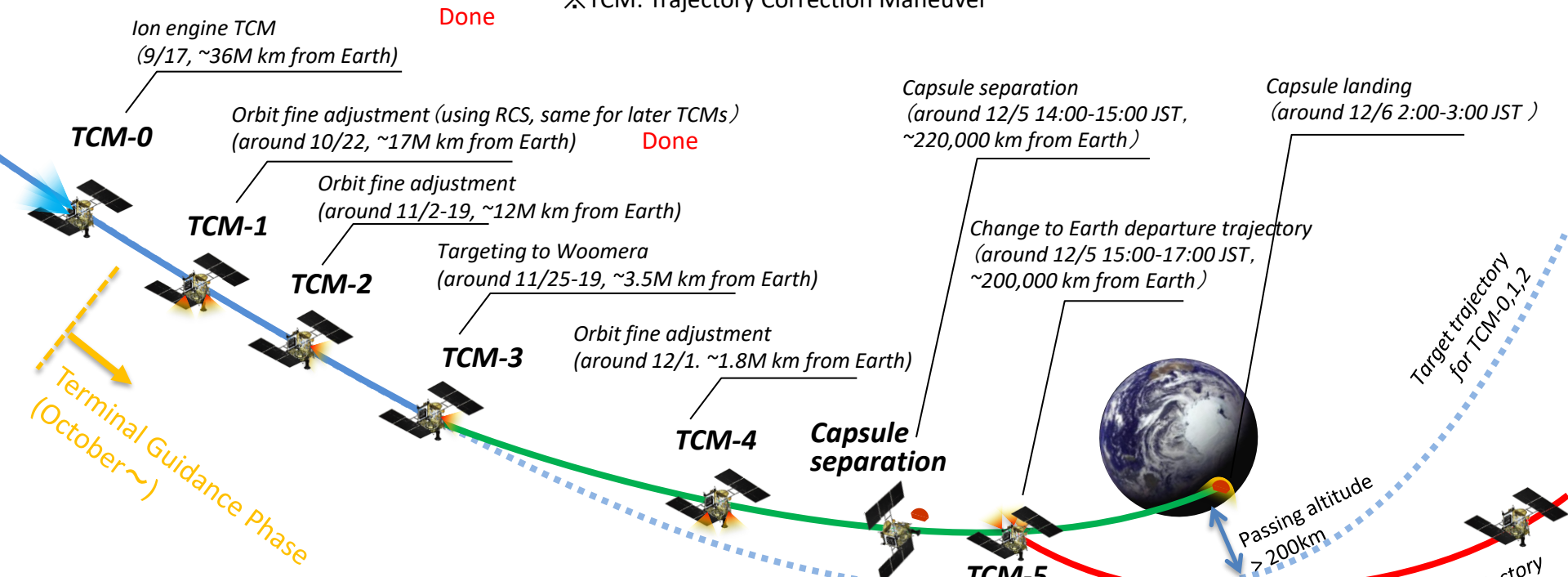
Return phase orbit map



（image credit：JAXA）

Operation plan for re-entry terminal guidance

※TCM: Trajectory Correction Maneuver



- May change depending on conditions.
- At TCM-0,1,2, the spacecraft will enter an orbit that passes more than 200 km away from the Earth.
- After capsule separation, the spacecraft will divert from the reentry trajectory by TCM-5.

(Image credit：JAXA)

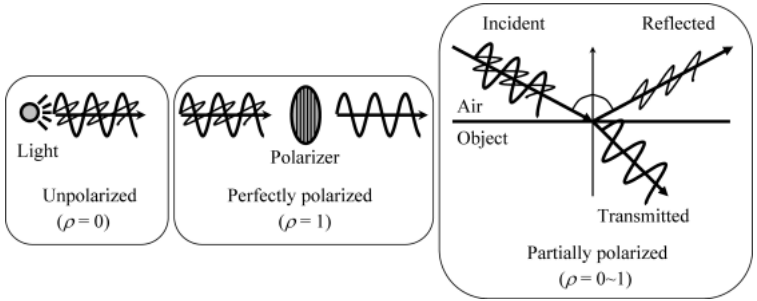
Supplementary information on polarization observation

What is polarized light?
Light (electromagnetic waves) is a transverse wave that travels due to electric and magnetic fields vibrating (changing) on a planet perpendicular to the direction of travel. The vector magnitude and direction bias of the electric field oscillations in this vertical plane is the polarization. There are linearly polarized light and circular and elliptical polarized light depending on how the electric field vibrates.

What is the degree of polarization?
The degree of polarization is the ratio of the polarized states, where one completely polarized state (fully polarized) is 1 and unpolarized is 0. States in between are referred to as partial polarization, and the degree is indicated by a value between 0 and 1. Unpolarized light (natural light) is randomly polarized and the polarized state is unknown.

Typical example
When light is reflected or refracted, the vibrational direction does not change but in order to change the direction of travel, only the vertical component remains. This can suppress reflection intensities such as for polarized sunglasses.

Polarization observation
The intensity of the light collected by the telescope is measured by separating the polarizing components using a polarizing element. High-precision polarized light observations often use a wave plate and polarizing element to measure two components of the polarized light at the same time.

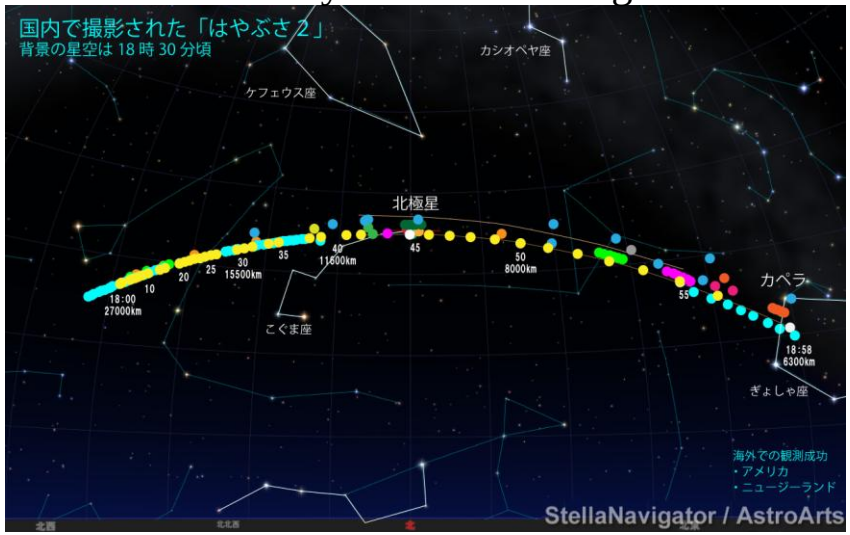


Explanatory diagram of polarized light
Credit (Miyazaki & Ikeuchi, 2008, IPSJ Journal 64-72)

Observations during Earth swing-by on 2015/12/3

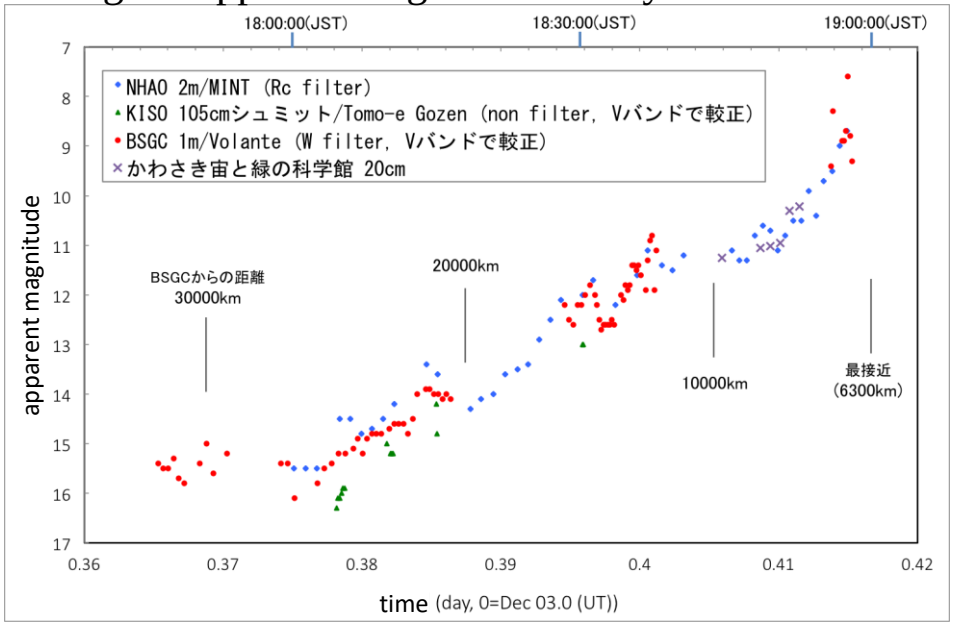
Observations of Hayabusa2's Earth swing-by with ground-based telescopes → observations reported from a total of 39 locations in Japan and overseas.

Position where Hayabusa2 was imaged



Plots of the observed positions of Hayabusa2. Hayabusa2 moves from left to right across the figure. At 18:48, Hayabusa2 entered the shadow of the Earth and could not be observed.

Change in apparent magnitude of Hayabusa2



(image credit：JAXA, JAPOS, TPSJ)