Asteroid explorer, Hayabusa2, reporter briefing

September 15, 2020

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2,

- Extended mission selection

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

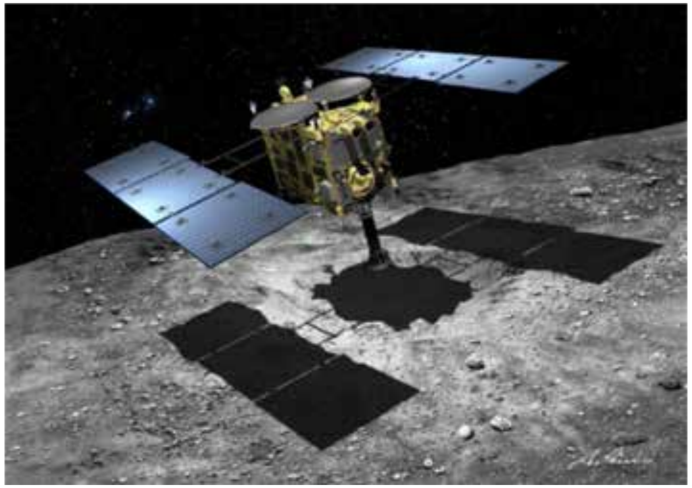
- By exploring a C-type asteroid, which is rich in water and organic materials, we will clarify interactions between the building blocks of Earth and the evolution of its oceans and life, thereby developing solar system science.
- Japan will further its worldwide lead in this field by taking on the new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

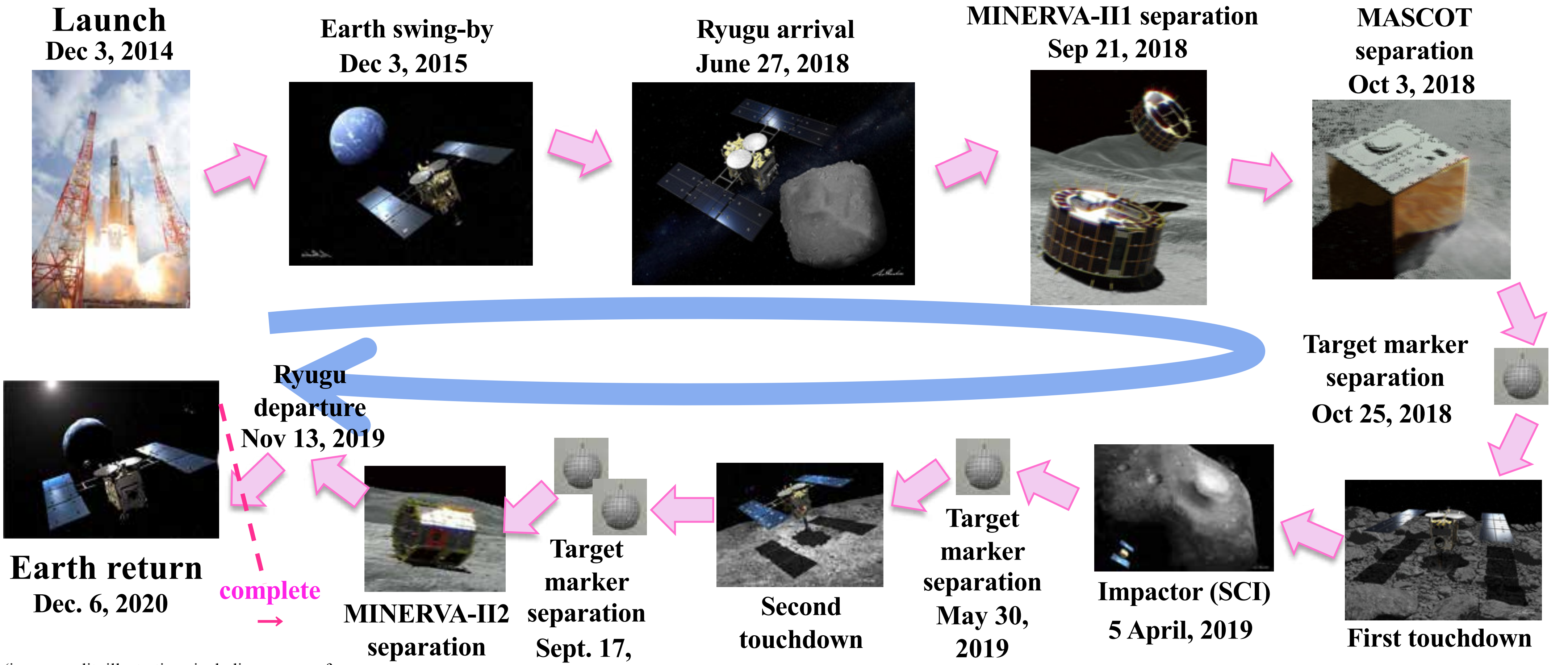
Hayabusa 2 primary specifications

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

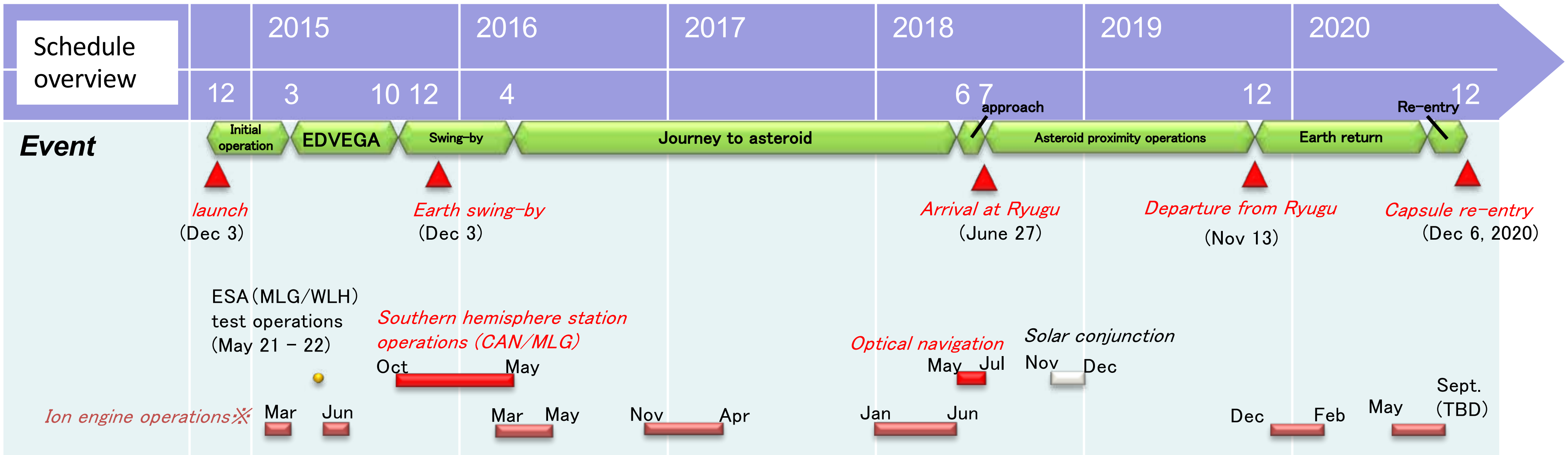


(image credit: illustrations including spacecraft by Akihiro Ikeshita, others by JAXA)

1. Current project status & schedule overview

Current status :

- Precise estimate of the orbit of the spacecraft was made and from today (September 15), the fine correction (TCM-0) of the orbit by the ion engine is planned.
- Narrowed down the extended mission
- Continue preparation for recovery work



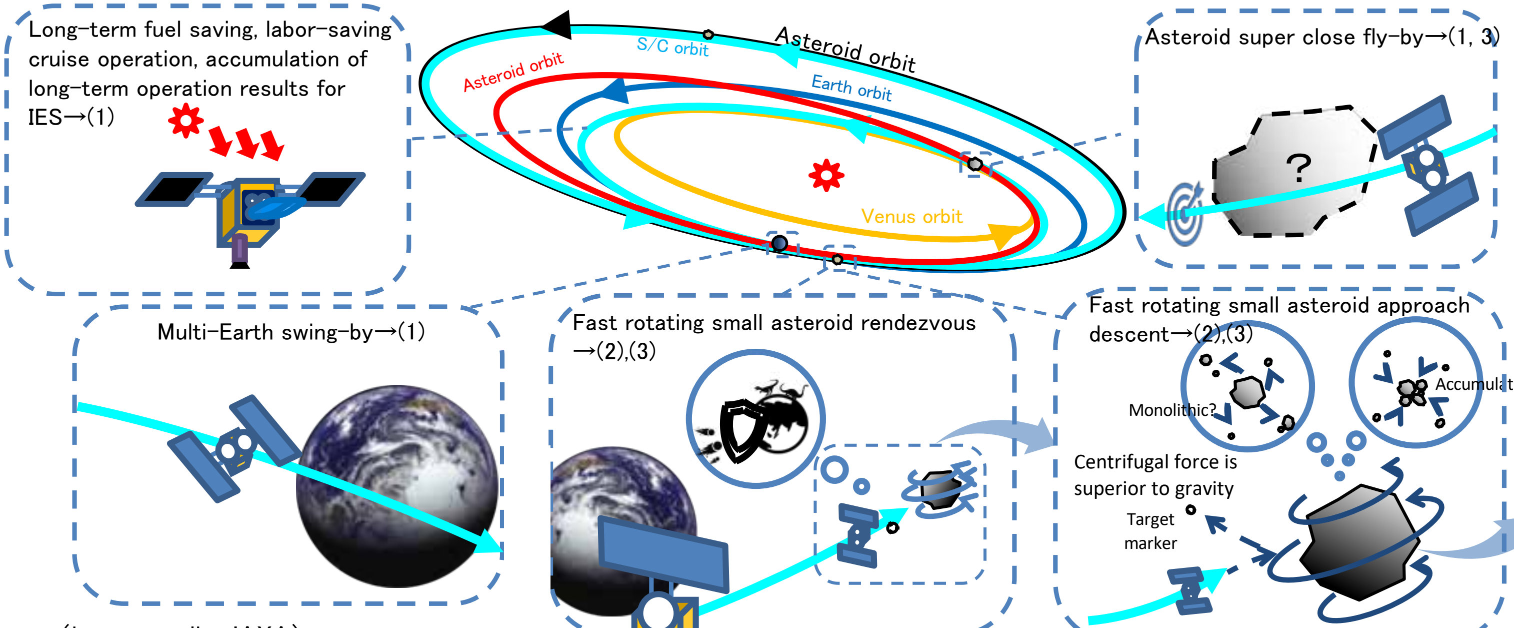
(image credit:JAXA)

2. Extended mission selection

Scenario selection result

- There were 2 candidates for the Hayabusa2 extended mission and we planned to select one scenario after confirming the technical feasibility
- After examination, the EAEEA scenario has been selected.（The final target celestial body is 1998 KY26）

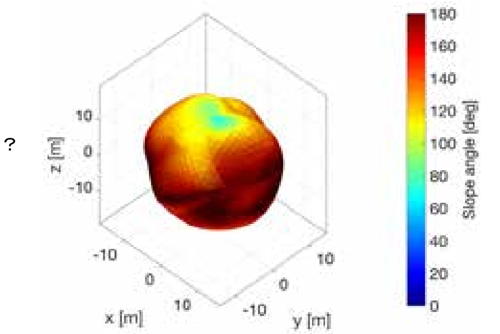
Mission significance： (1) Advancement in long-term navigation within the Solar System (2) fast-rotating small asteroid exploration (3) Acquisition of science and technology for planetary defense.



（image credit：JAXA）

＜1998 KY26 properties＞

Shape	Spherical (from radar obs.)
Av. Diameter	About 30 m
Spin period	10.7 min (0.178hr)
Tumbling motion	No short-term variability detected
Spectral type	Possible carbonaceous asteroid



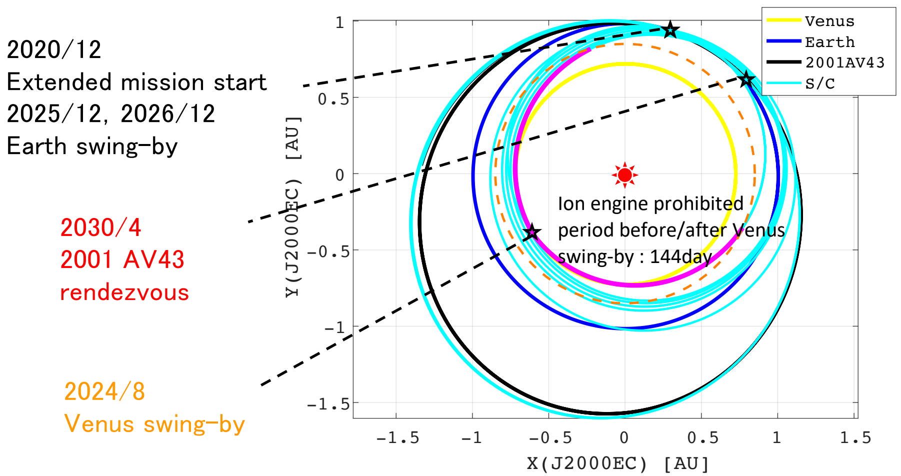
（image credit：Auburn University, JAXA）

2. Extended mission selection

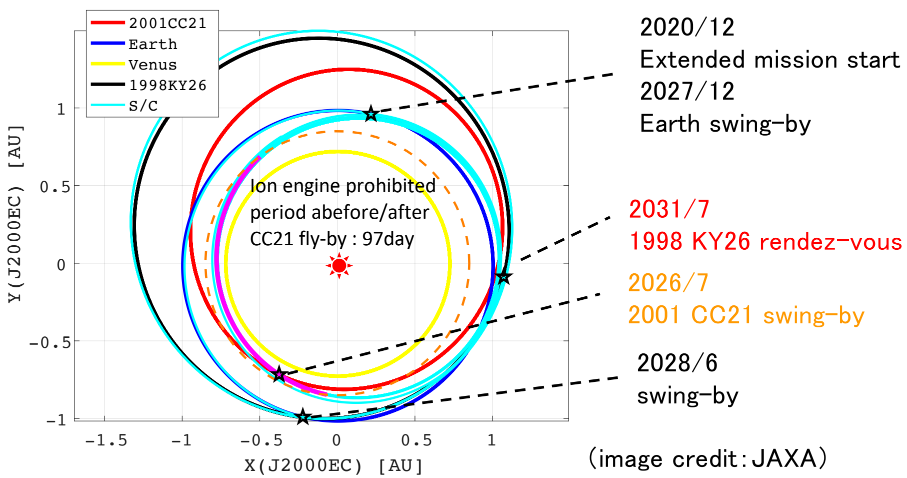
Background

- Originally, the spacecraft was designed on the assumption that the solar distance is in the range 0.85 – 1.41 au. But in both scenarios, the solar distance will deviate from the design premise.
  - EVEEA Sun distance range： 0.71～1.64au
  - EAEEA Sun distance range： 0.77～1.52au
- Further analysis and the conducted examination highlighted further specific issues:
  - Deviation from the allowable temperature range of the onboard equipment near the Venus orbit (0.71 au) (0.77 au is no problem)
  - Operation restrictions for the ion engines in a high temperature environment (3 engines can be operated up to 0.85 au but even 1 engine is difficult to operate at 0.77 au)

EVEEA（Earth->Venus->Earth->Earth->Asteroid）



EAEEA（Earth->Asteroid->Earth->Earth->Asteroid）



（image credit：JAXA）

2. Extended mission selection

Scenario comparison and selection

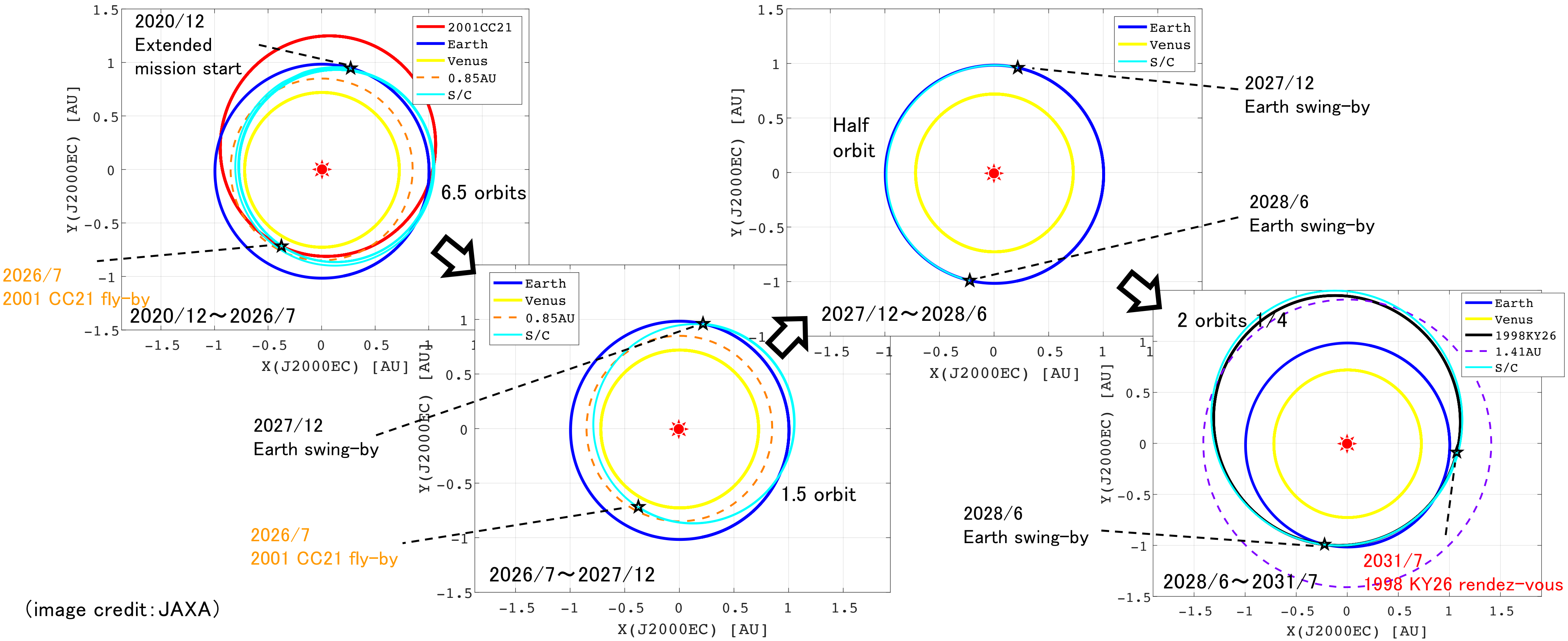
Evaluation	EVEEA	Eval.	EAEEA
Thermal feasibility	When attitude is changed for observing Venus, the temperature range for onboard eqipnebts exceed the nomal range. (Max. Sun distance: 1.64 au)	≪	Even at minimum solar distance (0.77 au), the temperature range for onboard equipment does not exceed the mormal range. (Max. Sun distance: 1.52 au)
Ion engine conditions	Ion engine cannot be used for about 140 days before/after Venus swing-by (0.71 au)	<	Ion engine cannot be used for about 100 days before/after asteroid fly-by (0.77 au)
Scenario feasibility	If trouble occurs during the Venus swing-by, the orbit plan for the asteroid cannot be achieved (critical operation required in a high-risk environment)	≪	Even if the asteroid fly-by cannot be implemented, there is no problem with the subsequent Earth swing-by and no major changes to the orbit plan are required.

- The difference between the minimum solar distance of 0.71au and 0.77au, as well as the timing of the mission implementation make a big difference to the mission feasibility, and EAEEA is generally more feasible.
- In addition to the thermal analysis here, the model uncertainty cannot be determined because we have no experiences. This results in a latent risk that should be supressed by minimising the deviation from the initial solar distance range.

- Conclusion:
  From a comprehensive judgement and evaluation from these situations, the EAEEA scenario with less deviation from the design premise for the solar distance range was selected in order to reduce risk.

2. Extended mission selection

EAEEA scenario orbit sequence



(image credit: JAXA)

2. Extended mission selection

EAEEA scenario mission sequence

time	Event	Engineering achievements	Science achievements
2021～26/7	Cruise operation	Acquisition of long-term fuel saving / labor saving cruise operation technology	・Zodiacal light observation ・Exoplanet observation
2026/7	Asteroid（2001 CC21） Fly-by	・Acquisition of asteroid proximity high-speed flyby technology ・Acquisition of technology that contributes to Planetary Defense	Observation of L-type asteroids by close-range high-speed flyby.
2027/12	Earth swing-by 1	・Multi (3rd) Earth swing-by achieved	Calibration of on-board equipment through lunar observations during Earth swing-by
2028/6	Earth swing-by 2	・Multi (4th) Earth swing-by achieved	Calibration of on-board equipment through lunar observations during Earth swing-by
2031/7	Target body（1998 KY26）rendezvous	・Progress of long-term deep space navigation (completion of the final phase) ・Acquisition of fast rotator exploration technology ・Acquisition of knowledge contributing to Planetary Defense technology	・Elucidation of the formation and evolution of fast rotating asteroids ・Acquisition of science that contributes to Planetary Defense

3. Scientific significance of the extended mission

The great challenges of sending Hayabusa2 to an unplanned destination

- Long cruise over 10 years
  - Deterioration due to radiation of the optical system for the observation equipment and sensors.
    - Evaluation of equipment through stellar observations and those of the Moon during the Earth swing-by.
  - Zodiacal light and exoplanet observations can take advantage of the long cruise.
- Proximity high-speed fly-by observations of small asteroids
  - Challenging observations for equipment not designed for a fly-by, such as the fixed cameras.
- The world‘s first rendezvous with a fast rotating micro-asteroid.
  - Can we rendezvous and observe a small celestial body about 1/30 the size of Ryugu?
  - Rotation period is about 10 minutes. The centrifugal force > force due to gravity, so target markers cannot be used.

3. Scientific significance of the extended mission

Scheduled scientific observations and expected outcomes

Mission phase	Expected scientific observations：Expected outcomes
Cruising	・Zodiacal light observation*：Long-term observation constrains the spatial distribution of interplanetary dust ・Exoplanet observation*：Follow-up of exoplanet search projects
Asteroid 2001 CC21 fly-by	・Observations of L-type asteroids by proximity high-speed fly-by: an unexplored spectral type object, determining similarity to white inclusions (CAI) found in primitive meteorites.
Earth swing-by	・Moon observation：Calibration of on-board equipment and examination of any changes during long-term navigation.
Asteroid 1998 KY26 rendezvous	・Visible light observation: Elucidation of the characteristics of asteroids with a diameter of several tens of meters. ・Near/mid-infrared observation: Elucidation of physical and thermal properties of rapidly rotating objects. ・Comparative observation with Ryugu: Details comparison using the same observation equipment. ・ Acquisition of information useful for Planetary Defense.

（* see p. 20 and p. 21 for zodiacal light observations and exoplanet observations)

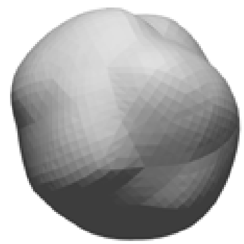
3. Scientific significance of the extended mission

Characteristics of the asteroid to be explored

From JPL Small-Body Database

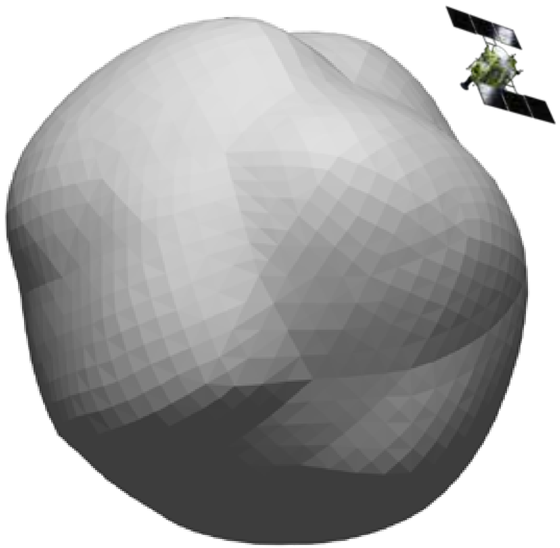
- (98943) 2001 CC21（fly-by）
  - Semi-major axis 1.032 au, eccentricity 0.219, orbital inclination 4.81°, orbital period 383 days.
  - Absolute magnitude 18.4 mag, rotation period 5.02 hours, diameter 700m（assuming albedo 0.15）, shape unknown, L-type [R. P. Binzel et al. 2004, *Meteor. Planet. Sci.* **39,** 351]
- 1998 KY26（rendezvous）
  - Semi-major axis 1.233 au, eccentricity 0.202, orbital inclination 1.48°, orbital period 500 days.
  - Absolute magnitude 25.5 mag, rotation period 10.7 minutes, diameter 30 ±10 m [S.J. Ostro et al. 1999, *Science* **285**, 557], close to spherical（lower right figure）, possibly carbonaceous (radar / visible albedo is slightly low and there are signs of water presence).
  - Passed Earth at a distance of 806,000 km on June 8, 1998. At this time, the shape etc was observed with the Goldstone X-band radar in the USA.

（image credit：Auburn University, JAXA）

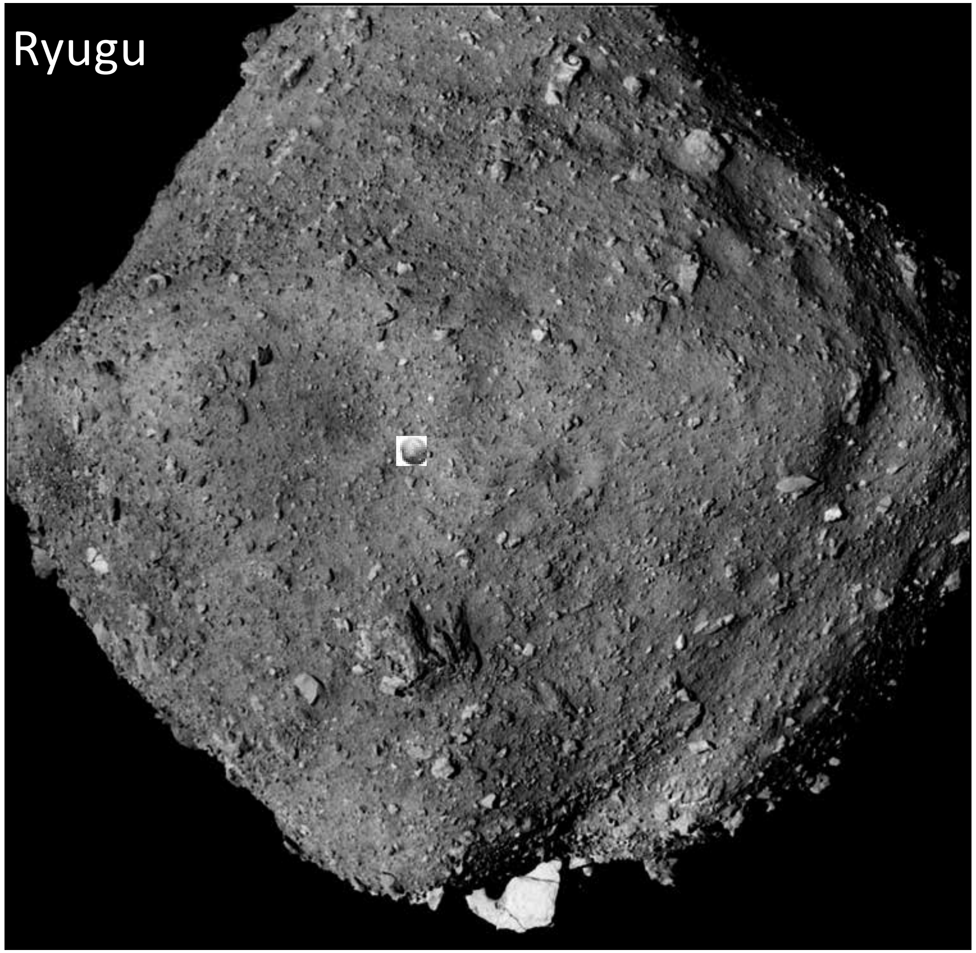


3. Scientific significance of the extended mission

1998 KY26



■ Image credit
left：Auburn University, JAXA
right, Ryugu image：JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST.
right、1998 KY26 image：Auburn University, JAXA



3. Scientific significance of the extended mission

From the perspective of Earth history and Planetary Defense

- If a celestial body with a diameter of several tens of meters collides with the Earth, great damage is expected to occur locally.
  - The Chelyabinsk meteorite that fell on the Ural region of Russia on February 15, 2013, and injured nearly 1,500 people, is thought to have had a diameter of 17m when it entered the atmosphere.
  - The frequency of impacts with meteorites with a dimeter of more than 30m is thought to be about once every several hundred years.
- However, the mechanical properties such as the strength of micro-asteroids, the rotation state and physical properties are not well understood.
- The role of collisions with micro-asteroids on the Earth's history is not well understood.
- It is expected that the world's first proximity observation of celestial bodies less than 100m in diameter will provide useful information, not only for elucidating the history of the Earth but also for Planetary Defense.

4. Future plans

■Operation schedule

Around 2020/9/15～16	Fine orbit correction with the ion engines (TCM-0)
2020/10～	Final re-entry guidance
2020/12/6	Re-entry

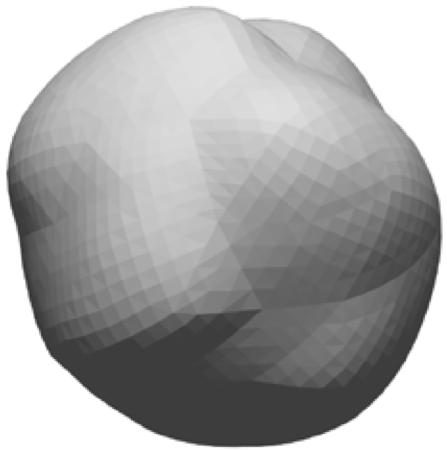
■Press and media briefings

2020/10（TBD）	Press briefing @ online（TBD）

Reference material

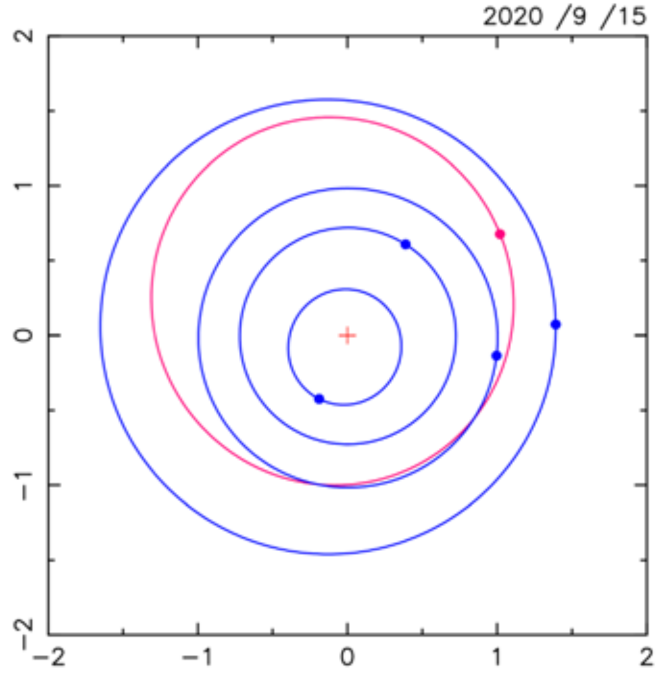
About 1998 KY26

- Discovered by the US Spacewatch Project on May 28, 1999 (the closest distance to Earth at the time was about 800,000 km)
- Radar observations made in June, 1998（by S. Ostro）.
- Approximately 30m in size, rotation period 0.1784 hours（10.7 minutes）
- Semi-major axis：1.23au, orbital period：1.37 years（500days）



Shape model:

Image credit: Auburn University, JAXA
1998 KY26 original data for the shape model：
Ostro et al. (1999), Radar and optical observations of asteroid 1998 KY26, Science, 285, 5,427, 557-559.



Track map：

Red is the orbit of 1998 KY26, blue is the orbit of planets (Mercury, Venus, Earth and Mars from inside to out). The position of the celestial bodies are of September 15, 2020. (Image credit: JAXA)

About zodiacal light observations

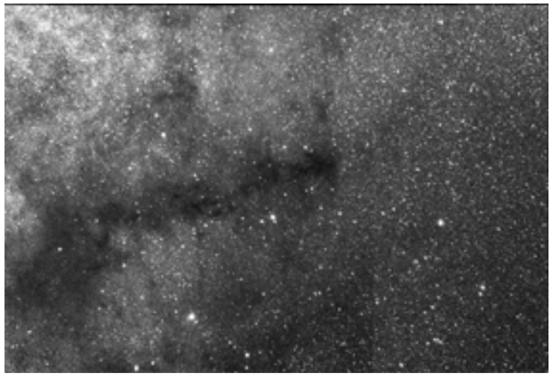
What is zodiacal light?:

- Scattering sunlight by solid particles (interplanetary dust) with sizes about 0.1- 100 micrometeres floating in interplanetary space.
- It is important to explore the distribution and origin of interplanetary dust through observations of zodiacal light in order to understand the whole picture of material transport through the Solar System: the scientific goal of Hayabusa2.
- Zodiacal light observations in interplanetary space beyond the Earth's orbit have not been observed since the Pioneer spacecraft in the 1970s

Provided by: Koji Onishi

Observations from Hayabusa2:

- We aim to clarify the density and structure of interplanetary dust near the Earth by observing zodiacal light at multiple points away from the Earth.
- The brightness of the zodiacal light will be determined by regularly conducting observations with the ONC-T and measuring the 'brightness of outer space' where celestial bodies such as stars are not visible.



Test observations were conducted during the return trip, confirming that zodiacal light could be detected with the required accuracy.

Test observation of the Milky Way
Image credit: JAXA, AIST, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu.

About exoplanet observations

Purpose:

- Accurate observations of the diameter and transit time of exoplanets around bright stars that will be targets for high-precision spectroscopic observations in the future.
- Development of exoplanet observation technology using satellite-mounted photodetectors.

Background:

- Expected to be the first exoplanet observation by Japanese satellites/spacecraft.
- High-precision telescopes have large apertures, so they are not well suited for observing bright stars.
- In orbit, Hayabusa2 can take stable observations regardless of weather or temperature. Since the ONC has a small aperture, it is suitable for observing bright stars.

Method: Transit technique

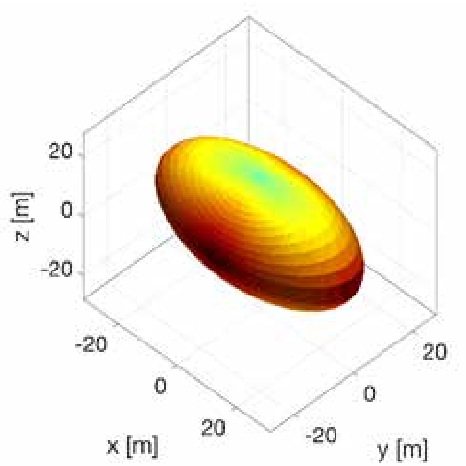
- **Principal:** Measure the size of the planet and the distance to the host star by identifying the dimming of the host star due to the planet passing in front of the host star.
- **Specific method**: The same star is imaged multiple times over a long period (often 3 – 10 hours) to examine the temporal change in light. Basically the same as Ryugu observations during the approach phase.

2 celestial bodies in the final candidate selection for the extended mission

＜Characteristics of 2001 AV43＞

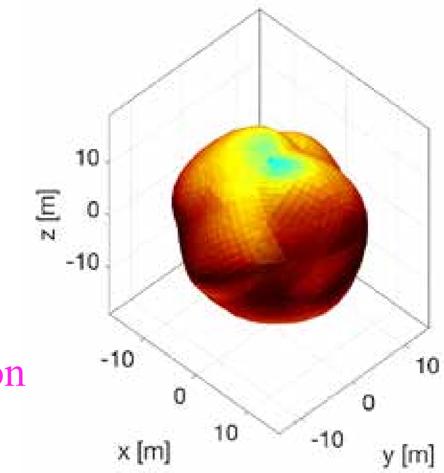
＜ Characteristics of 1998 KY26＞

・small（30～40m）
・rapid rotation（spin period: about 10 minutes）
↓
Is this a rubble pile or monolithic?



Earth approach at a distance of approximately 300,000km on 2029/11/11 ← Hayabusa2 rendezvous at the time of this approach

Shape	Elongated, aspect ratio: ~0.5 (from light curve observation)
Av. diameter	About 40m
Spin period	10.2 min (0.17hr)
Tumbling motion	No short-term variability detected
Spectral type	Possible S-type, uncertain

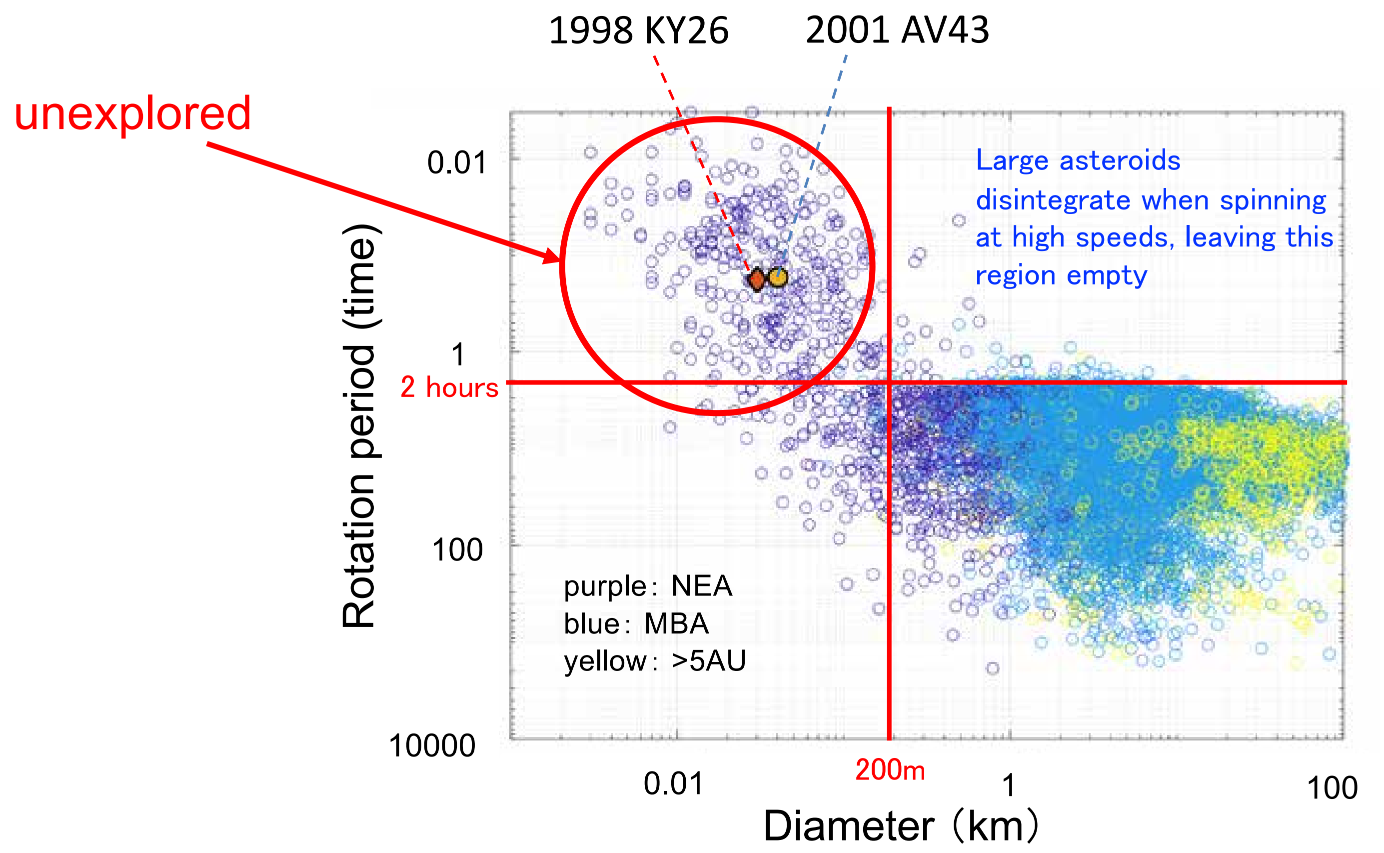


Possible C-type asteroid, offering interesting comparison with Ryugu and Bennu

Shape	Spherical (from radar observation)
Av. diameter	About 30m
Spin period	10.7 min (0.178hr)
Tumbling motion	No short-term variability detected
Spectral type	Possible carbonaceous asteroid

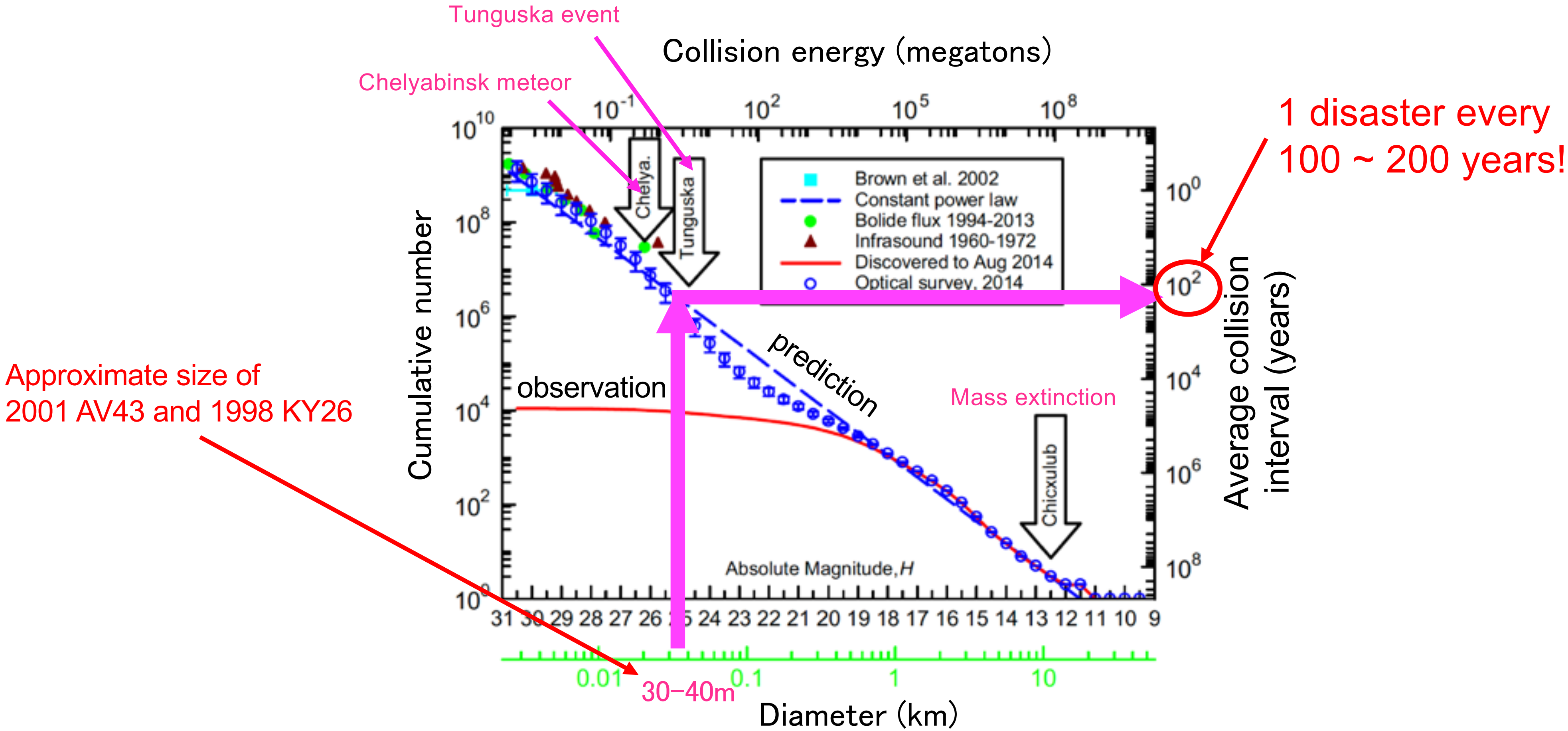
（Image credit：Auburn University, JAXA）

Relationship between asteroid diameter and rotation period



(© Auburn University, JAXA)

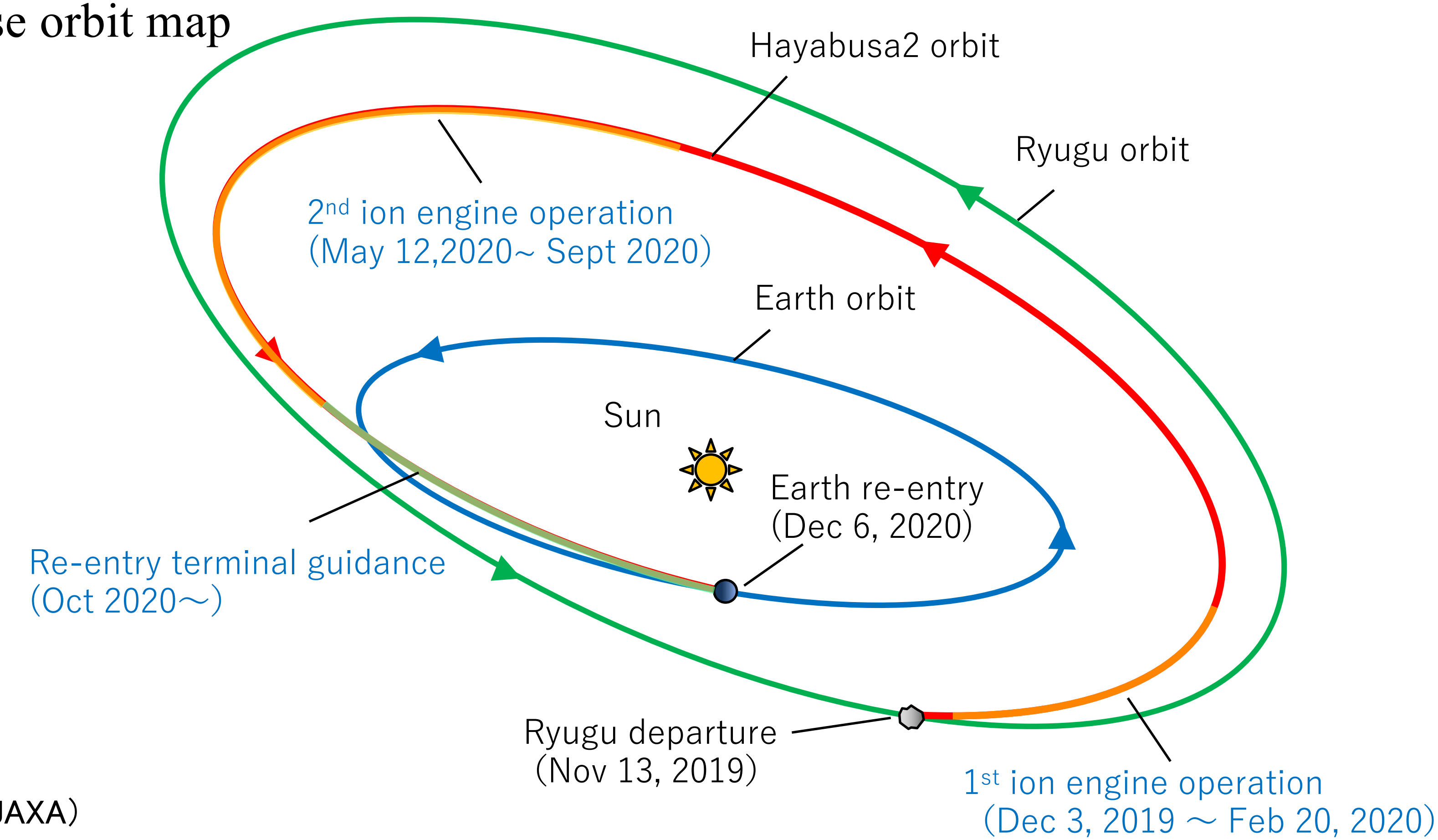
Prediction of asteroid collision frequency



(Original figure from Harris and D'Abramo, Icarus 257 (2015) 302–312)

Return cruise operation plan

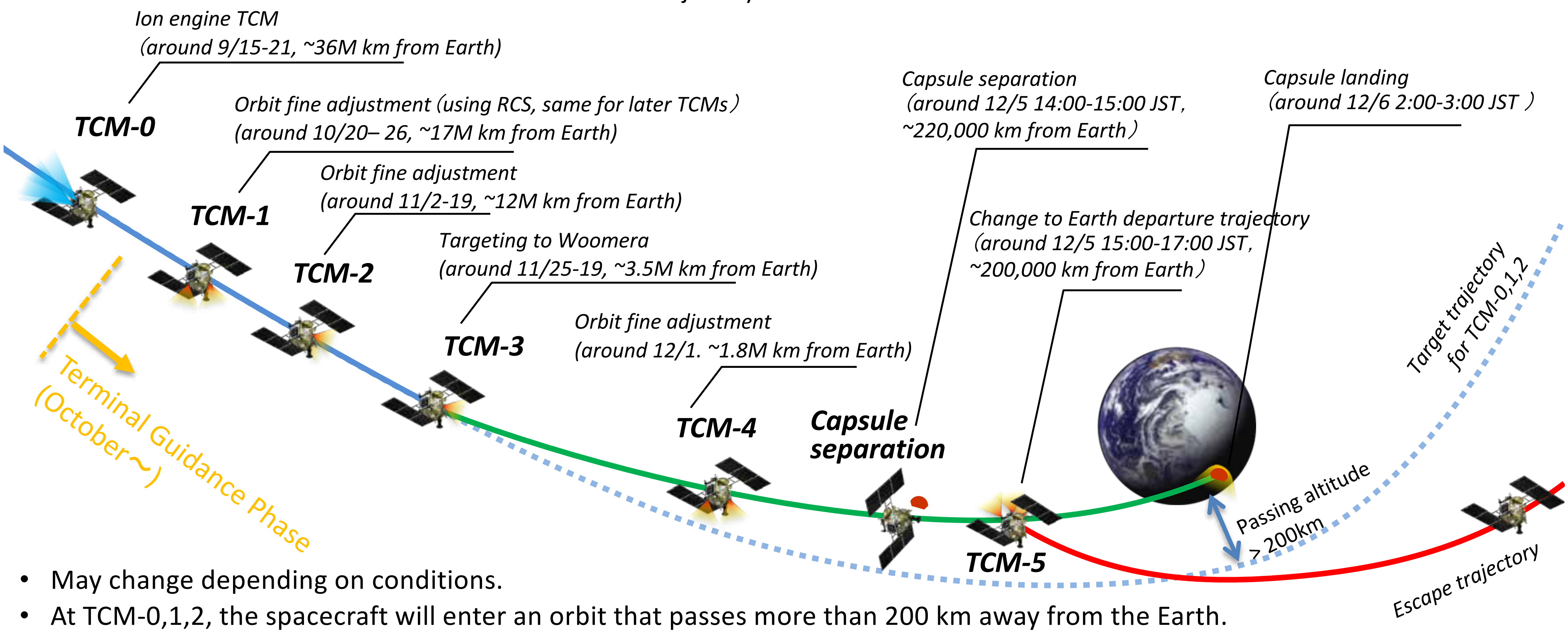
Return phase orbit map



(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)