Asteroid explorer, Hayabusa2, reporter briefing

July 22, 2020

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2,

- Extended mission

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1. Current status and overall schedule of the project
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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.

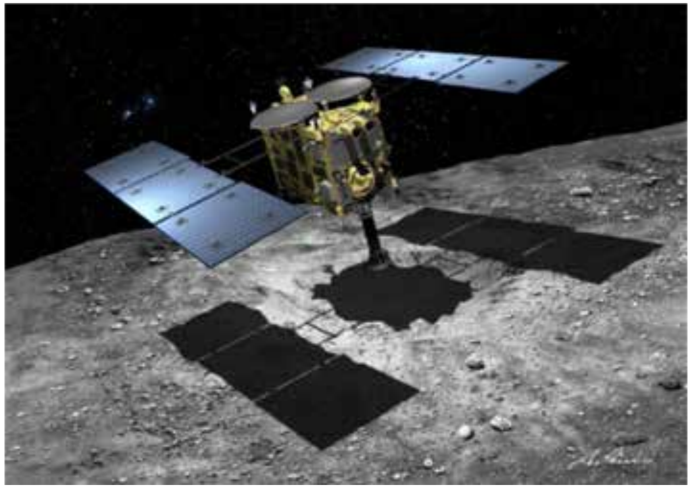
・Comparison with results from Hayabusa will allow deeper understanding of the distribution, origins, and evolution of materials in the solar system.

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)

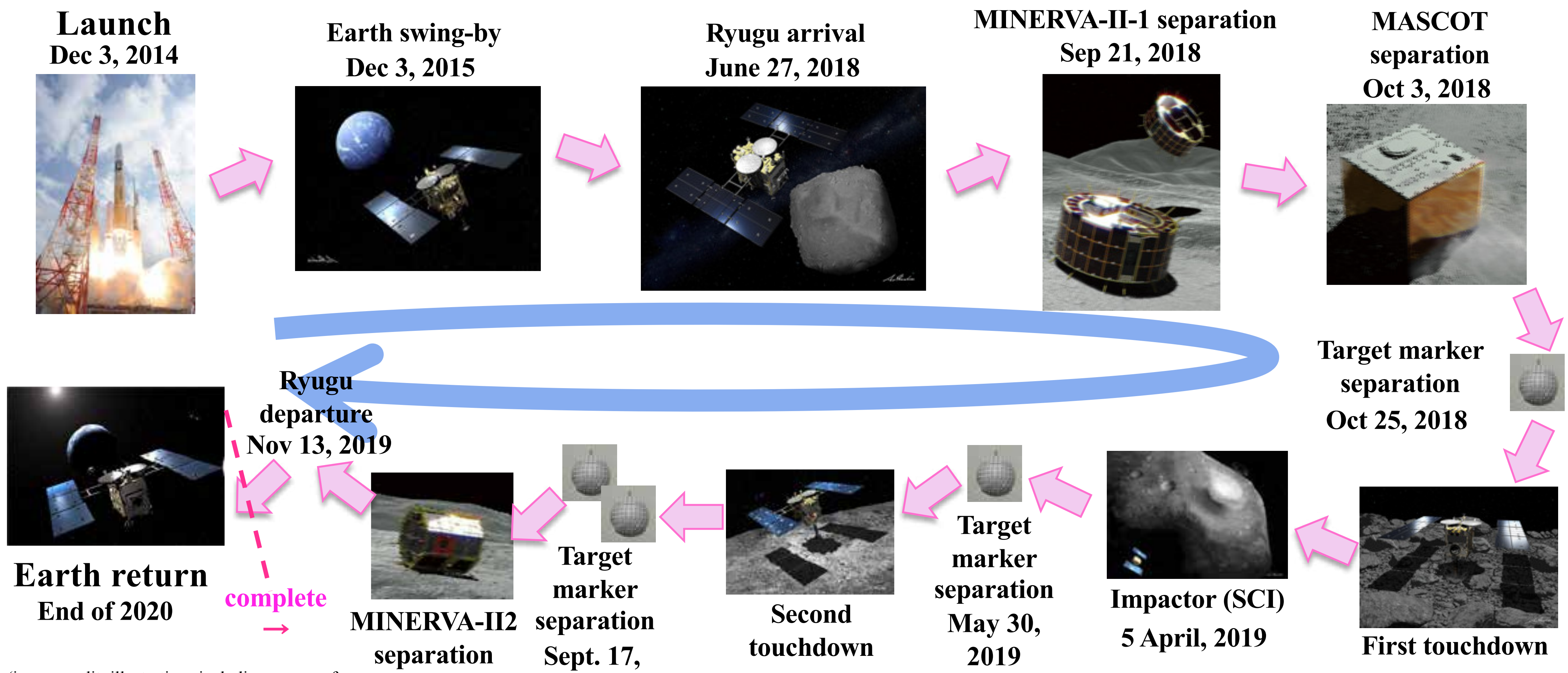
Hayabusa 2 primary specifications

Mass	Approx. 609 kg
Launch	3 Dec 2014
Mission	Asteroid return
Arrival	27 June 2018
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

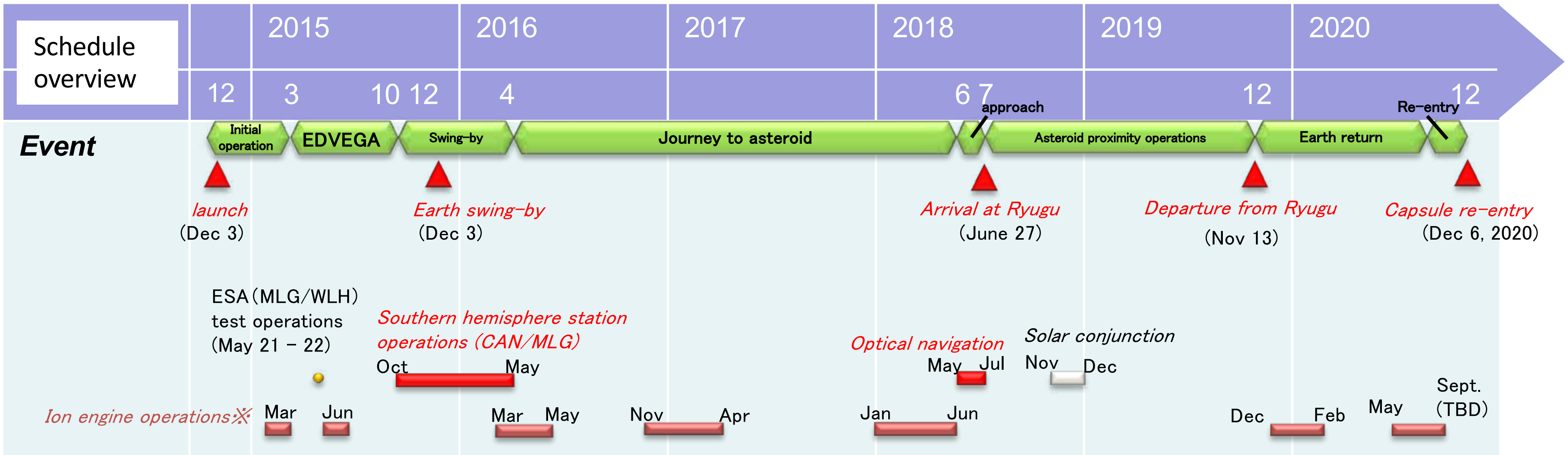


(image credit: illustrations including spacecraft by Akihiro Ikeshita, others by JAXA)

1. Current project status & schedule overview

Current status:

- The 2nd ion engine operation and work for the return of the re-entry capsule to Earth is ongoing.
- Discussion and consideration for an extended mission.
- Scientific papers have been submitted and published.

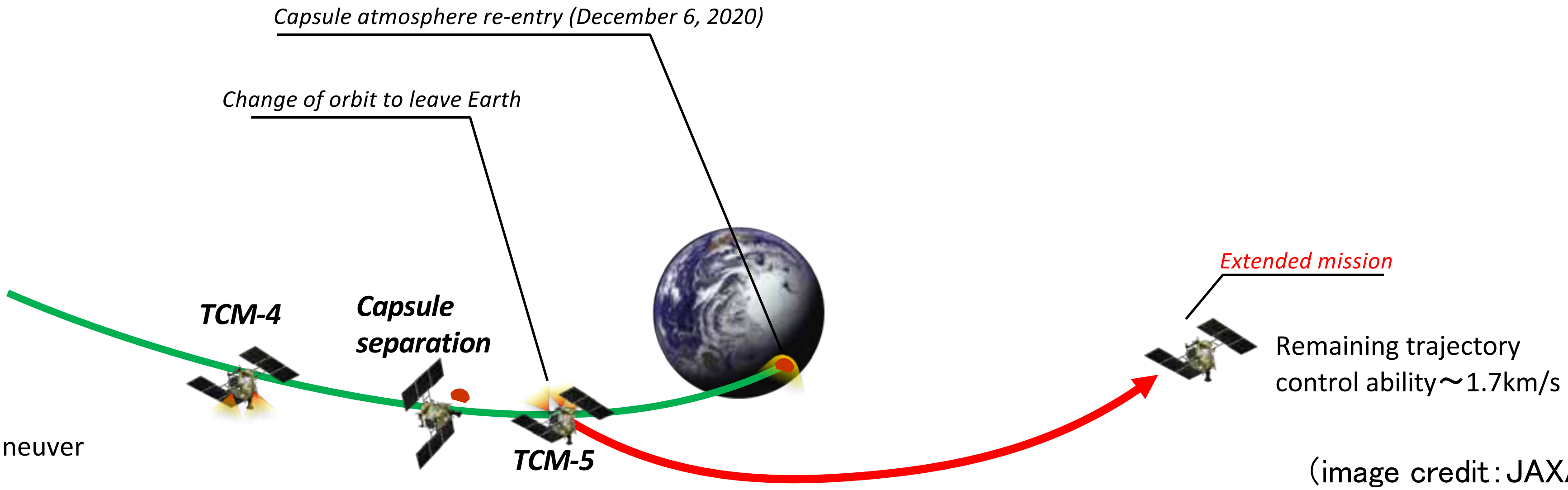


(image credit：JAXA)

2. Extended mission proposal: background

- After leaving the Earth, Hayabusa2 can continue deep space flight with an orbit control capability equivalent to 1.7 km/s.
- All initial objectives of the mission will have been meet, and extended operation would provide a rare opportunity to hone challenging on-orbit operation techniques.
- When aiming for another celestial body, it is possible to reach new scientific achievements at much better cost performance than when designing a new mission.

Propose a mission after leaving Earth (“extended mission”)



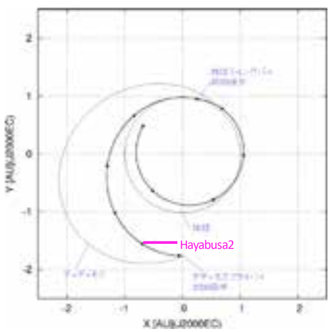
※TCM: Trajectory Correction Maneuver

（image credit：JAXA）

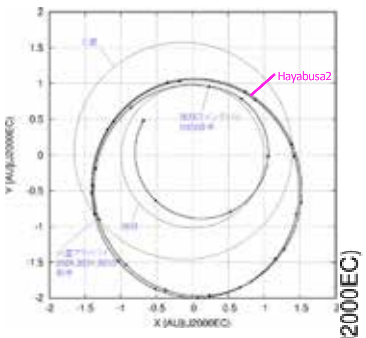
3. Extended mission: review process

Examples from the study of orbits after Earth departure.

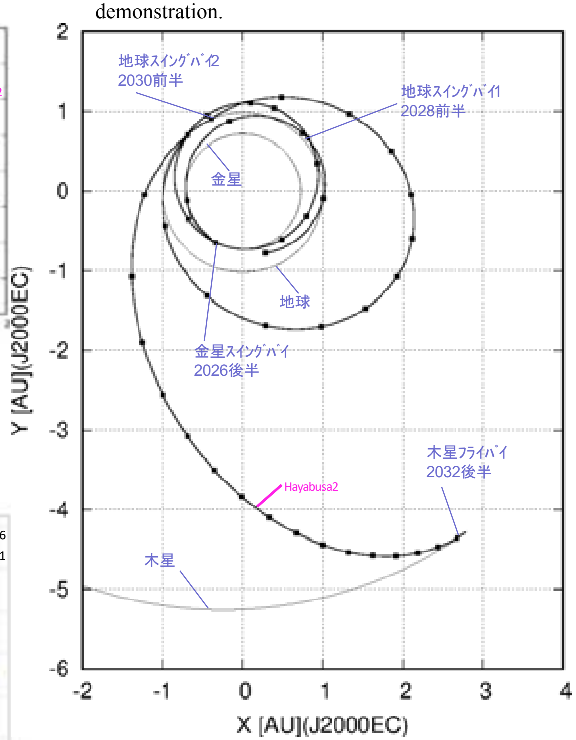
Earth→Earth→Asteroid
(Asteroid flyby/impact)



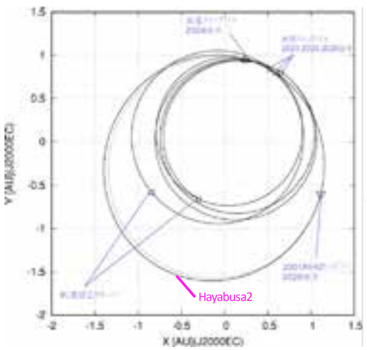
Earth→Earth→Mars→Mars→Mars・・・
Mars multi-flyby



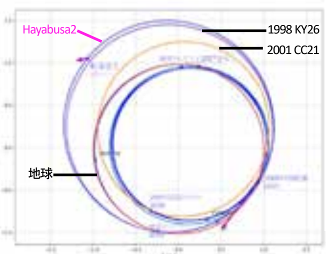
Earth→Venus→Earth→Earth→towards Jupiter
Venus flyby observations and distant flight demonstration.



Earth→Venus→Earth→Earth→Asteroid
(Venus flyby + asteroid rendezvous)



Earth→Asteroid→Earth→Earth
→Asteroid
(Asteroid flyby and asteroid rendezvous)



(image credit：JAXA)

- First, we searched for potential orbits from the viewpoint of orbit feasibility (celestial mechanics) with the residue orbit control capability of Hayabusa2.
- Hayabusa2 enters into an orbit between Venus and the Earth due to the influence of the Earth's gravity (swing-by effect) after leaving the Earth.
- After that, celestial bodies were identified that could be reached with the ion engines and planetary swing-bys (Earth, Venus etc.).

◆Search for target celestial bodies

Venus, Earth, Mars, asteroids, comets (Hayabusa2 solar cells can operate up to Mars distance)

◆Mission type

Fly-by exploration： Passing by celestial bodies at high speed. Trajectory design is relatively easy.

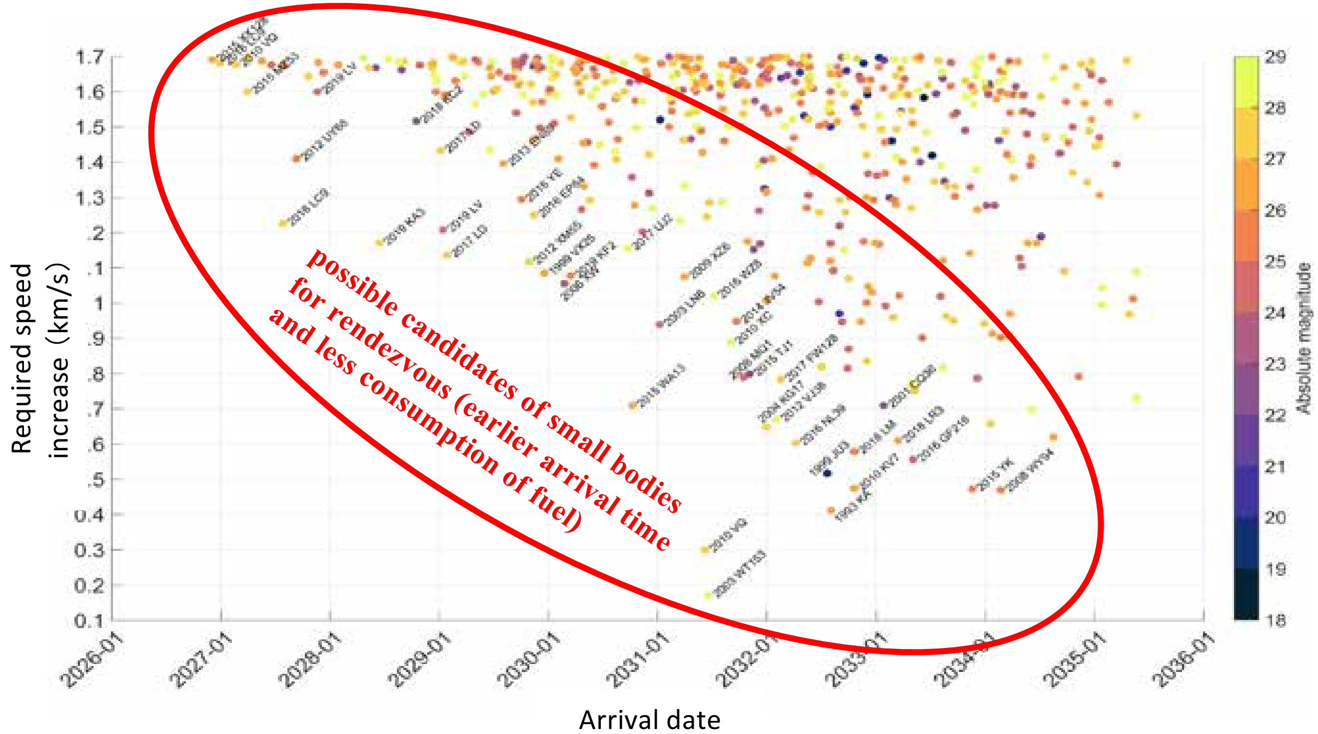
Rendezvous exploration： Arrives and stays at the celestial body. Trajectory design is difficult.

◆Planets vs small bodies（asteroids・comets）

- Only fly-by is possible for planets. Planets can be used for swing-by, but arrival & orbit is not possible with Hayabusa2's ability.
- Fly-by, impact & rendezvous are possible for small celestial bodies.

3. Extended mission: review process

Search for possible small bodies (asteroids / comets) for rendezvous



Search for candidate bodies

- Search for asteroids/comets that can be reached with fuel speeds of 1.7 km/s or less from the 18002 celestial bodies that pass through the Earth's orbit.
- "Rendezvous" has a priority over "fly-by" in the search.

Total reachable celestial bodies：354

Items	No
Absolute magnitude less than 22 deg (Approximate diameter : larger than 140m)	17
Rader observation	30
After the departure from the Earth : arrives within 6 years arrives within 7 years arrives within 8 years	2 13 31
Binary	0
Quasi-satellite, mini-moon	0
Known spin period	23
Rader observation is possible in future	6
Reachable via Venus	1

✓ There are no celestial bodies (planets or small bodies) that can be reached within a short period (1 ~ 5 years)

✓ We found many rendezvous candidate asteroids around 10 year travel via an Earth or Venus swing-by in 4 ~ 10 years after Re-entry.

✓ These candidates were further narrowed down from the viewpoint of operation feasibility and scientific value.

（image credit：JAXA）

3. Extended mission: review process

- The top two celestial bodies were selected by narrowing down the asteroids that satisfy the following constraints and have a high score from the viewpoint of engineering and science.

Constraints

- Arrival date: before 2031/12/31
- ΔV: below 1.6 km/s
- Sun distance is not too far at arrival date.
- Trajectory is well understood.

Engineering feasibility	Science value
Certainty of asteroid orbit	size
Observability from ground	Spin rate
Trajectory plan feasibility	Shape
Feasibility of spacecraft operation	Type

(comprehensive evaluation)

⋮

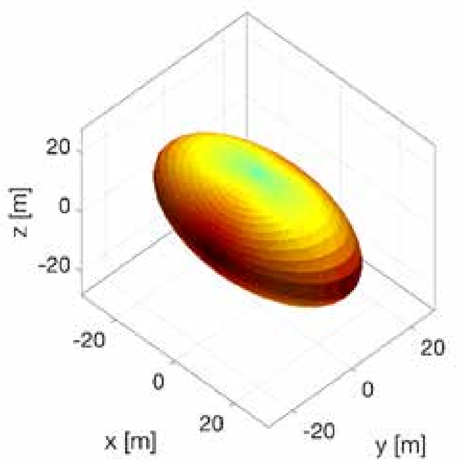
4. Extended mission: plan outline

About the 2 candidate celestial bodies

＜Characteristics of 2001 AV43＞

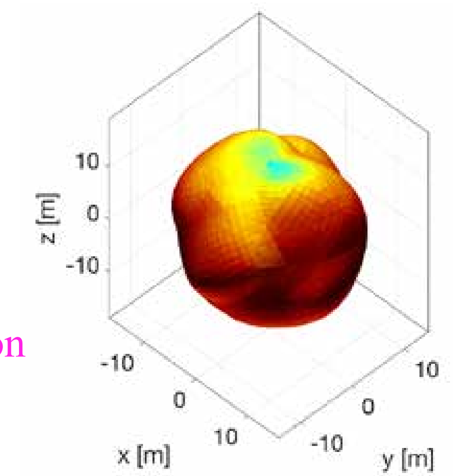
＜ Characteristics of 1998 KY26＞

・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）

4. Extended mission: plan outline

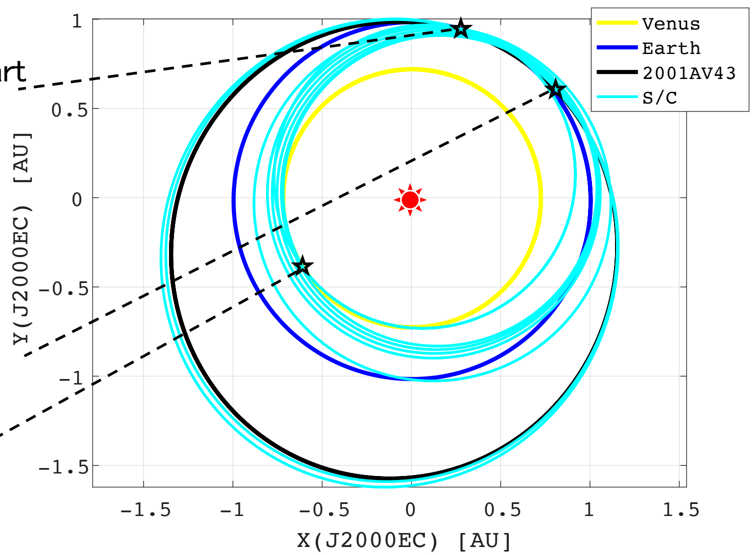
- Created mission plans for 2001 AV43 and 1998 KY26
- Finally choose one of these two

EVEEA scenario Total acceleration 1.25km/s
(Earth->Venus->Earth->Earth->Asteroid)

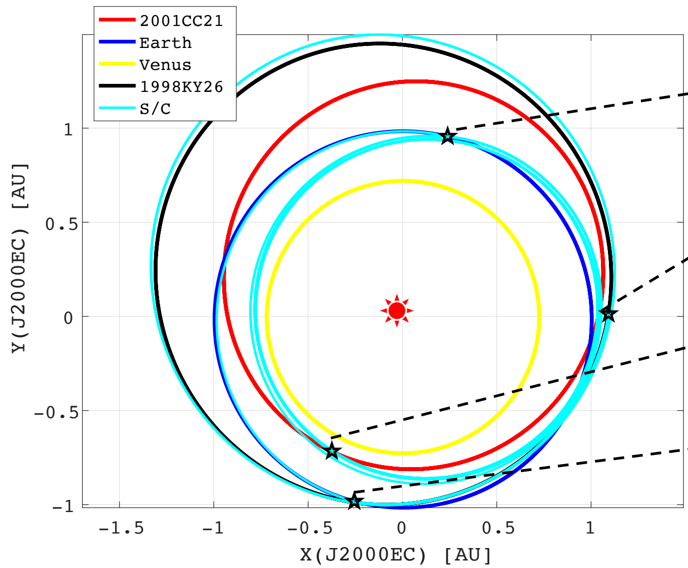
2020/12
Extended mission start
2025/12, 2026/12
Earth swing-by

2029/11
2001AV43
rendezvous

2024/8
Venus swing-by



EAEEA scenario Total acceleration 1.19km/s
(Earth->Asteroid->Earth->Earth->Asteroid)



2020/12
Extended mission start
2027/12
Earth swing-by

2031/7
1998 KY26
rendezvous

2026/7
2001CC21 fly-by

2028/6
Earth swing-by

(Image credit: JAXA)

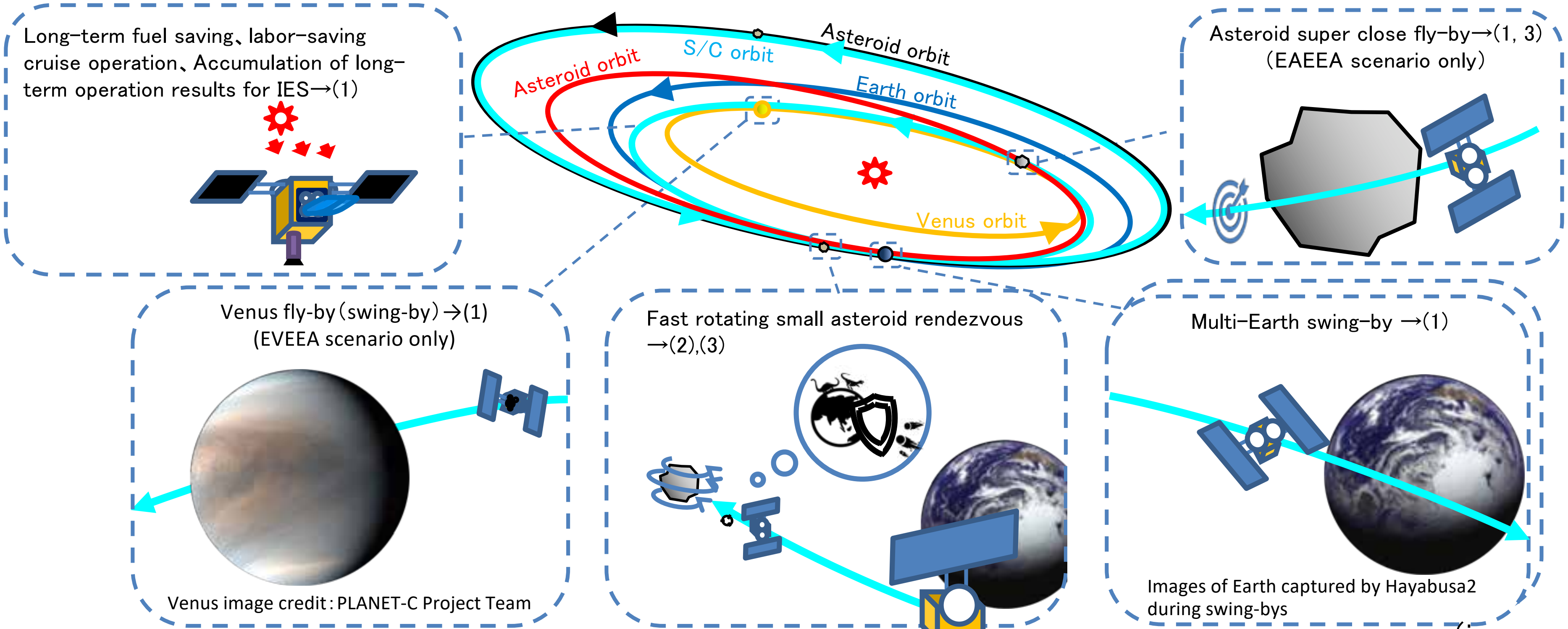
4. Extended mission: plan outline

Significance of targets 2001 AV43 and 1998 KY26

(1) Progress in long-term navigation technology within the Solar System

(2) Realisation of fast rotating small asteroid exploration

(3) Acquisition of science and technology for planetary defense



(image credit：JAXA)

4. Extended mission: plan outline

Significance：(1) Progress in long-term navigation technology within the Solar System

- Acquire operation technology necessary for more flexible exploration at greater distances, based on engineering achievements until Earth-return.
  - Ultra-low fuel consumption operation and ultra long-term maintenance technology for spacecraft system .
  - Experience of ion engine operation technology, acquisition of long-term performance.
  - Navigation technology for Solar System multi-flyby with ion engines.

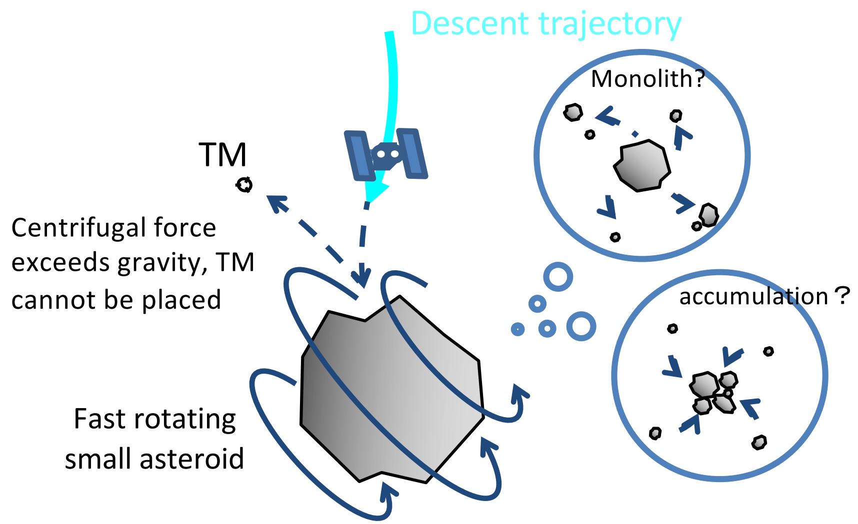
- Perform scientific observation during long-term navigation and at fly-by.
  - Observation of zodiacal light and exoplanets
  - Observations during Venus fly-by（EVEEA scenario）
  - Observations during asteroid fly-by（EAEEA scenario）
  - Moon observations during Earth fly-by

（image credit：JAXA）

4. Extended mission: plan outline

Significance：(2) Fast rotating small asteroid exploration

- This is an unexplored system that has never been visited so far, making an extremely attractive exploration target.
  - How such asteroids form is a mystery (they could be monolithic, but an rubble pile is also possible)
  - On the surface of such asteroids, the centrifugal force should dominate gravity.



（image credit：JAXA）

- Comparative observations with Ryugu can further deepen the scientific knowledge obtained from Ryugu.
- New asteroid exploration technology can be expected to be acquired due to the approach in a special dynamic environment.

4. Extended mission: plan outline

Significance：(3) Acquisition of science and technology that contribute to Planetary Defense

What is Planetary Defense：
- Activities to prevent disasters caused by celestial bodies colliding with the Earth （also called ‘spaceguard’）.
- The collision between the Earth and a small celestial body about 10km is regarded as a possible cause for the extinction of many species including the dinosaurs about 66 million years ago.
- Even below the scale of the dinosaur extinction, the collision of a celestial body with a size of 10s of meters will cause great damage locally (e.g. Tunguska event in 1908, Chelyabinsk Meteor in 2013).
- The frequency of collision with celestial bodies several 10s of meters in size is about 1 every 100 – several 100 years.

Illustration: Akihiro Ikeshita

Extended mission：
- Investigate the characteristics of asteroids with a size of 10s of meters that are capable of causing great regional damage (world first).
- Refining exploration technology in the vicinity of an asteroids with size 10s m obtains knowledge to contribute to Planetary Defense technology. (world first)
- In the EAEEA scenario, ultra-close fly-by/impact technology will also be acquired.

4. Extended mission: plan outline

Conclusion (summary)

- Built a scientific scenario based on criteria that "celestial bodies that are reachable" and "celestial bodies that are high-value".
- Key points:
  - Acquisition of Solar System navigation technology utilizing ion engines + swing-by.
  - Fast Rotator
  - Science and technology related to asteroids approaching the Earth
    = Planetary Defense
- Based on consideration of "operational feasibility" and "scientific significance", we narrowed down the candidates to two asteroids.
  - A mission plan was prepared for each of the two scenarios.
  - Currently, we are finalizing the two scenarios from the standpoint of their feasibility. We plan to select one of these by the end of this fall, whereupon it will become the final plan.
- Since this will be a long-term mission of about 10 years, the policy will be to gradually accumulate results during flight.

5. Future plans

■Operation plans

2020/5/12～9	Continuation of 2nd ion engine operation until around September.
2020/10～	Re-entry precision guidance
2020/12/6	Re-entry

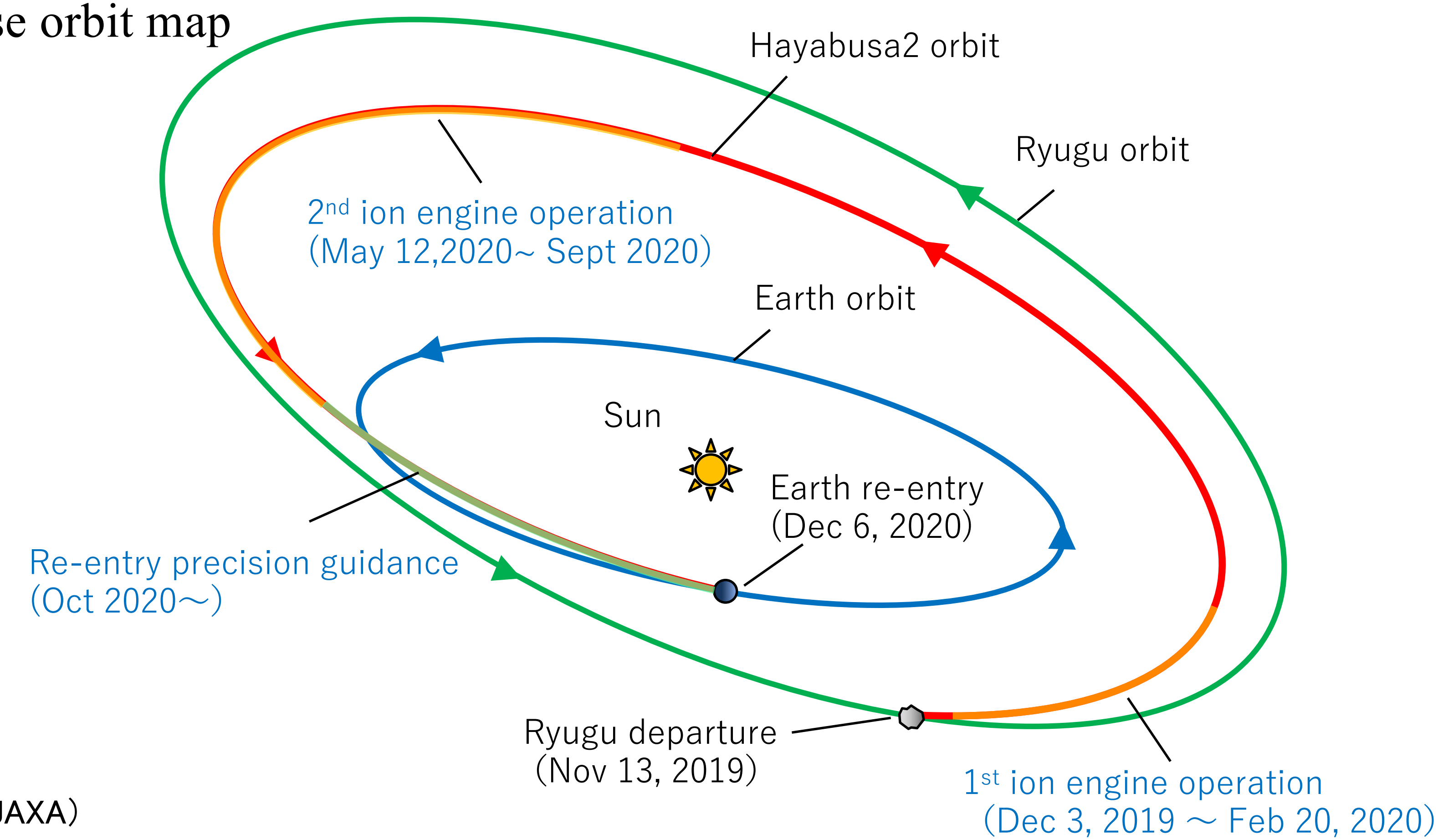
■Press and media briefings

2020/8（TBD）	Press briefing @ online（TBD）

Reference

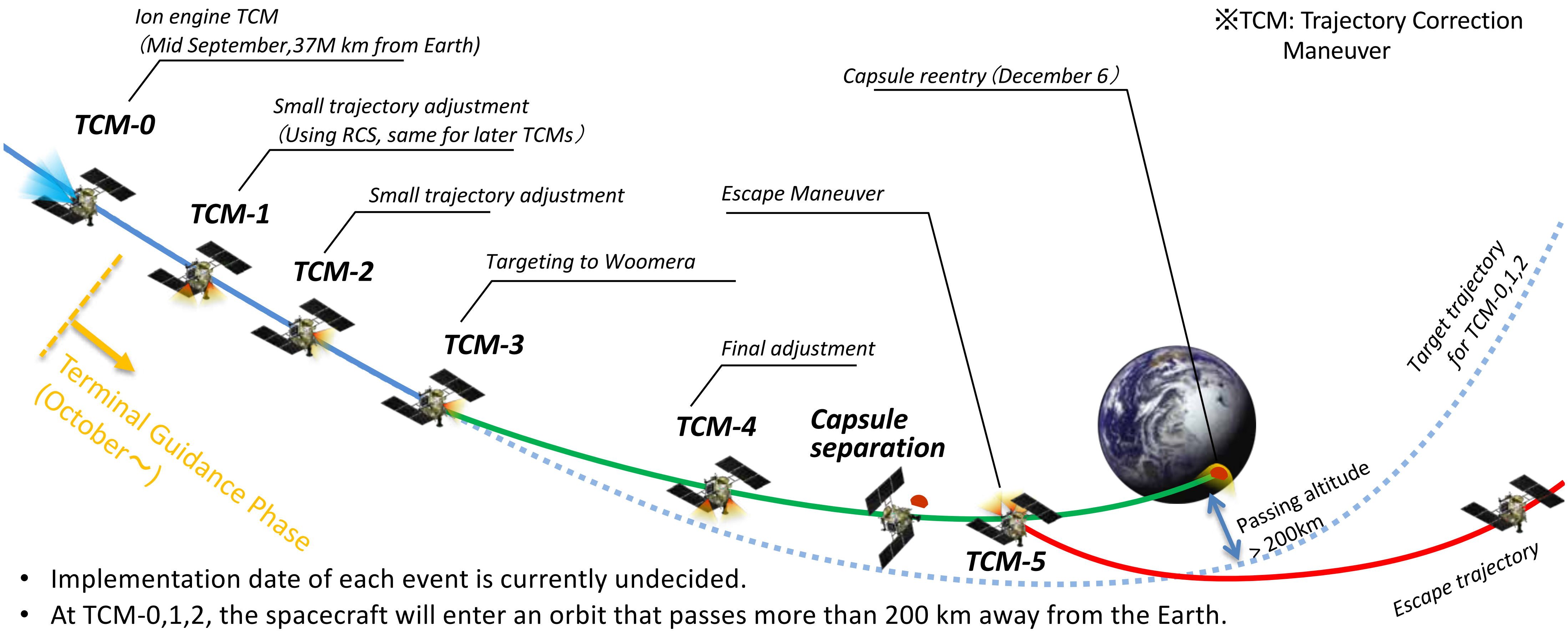
Return cruise operation plan

Return phase orbit map



(image credit：JAXA)

Earth return final guidance phase



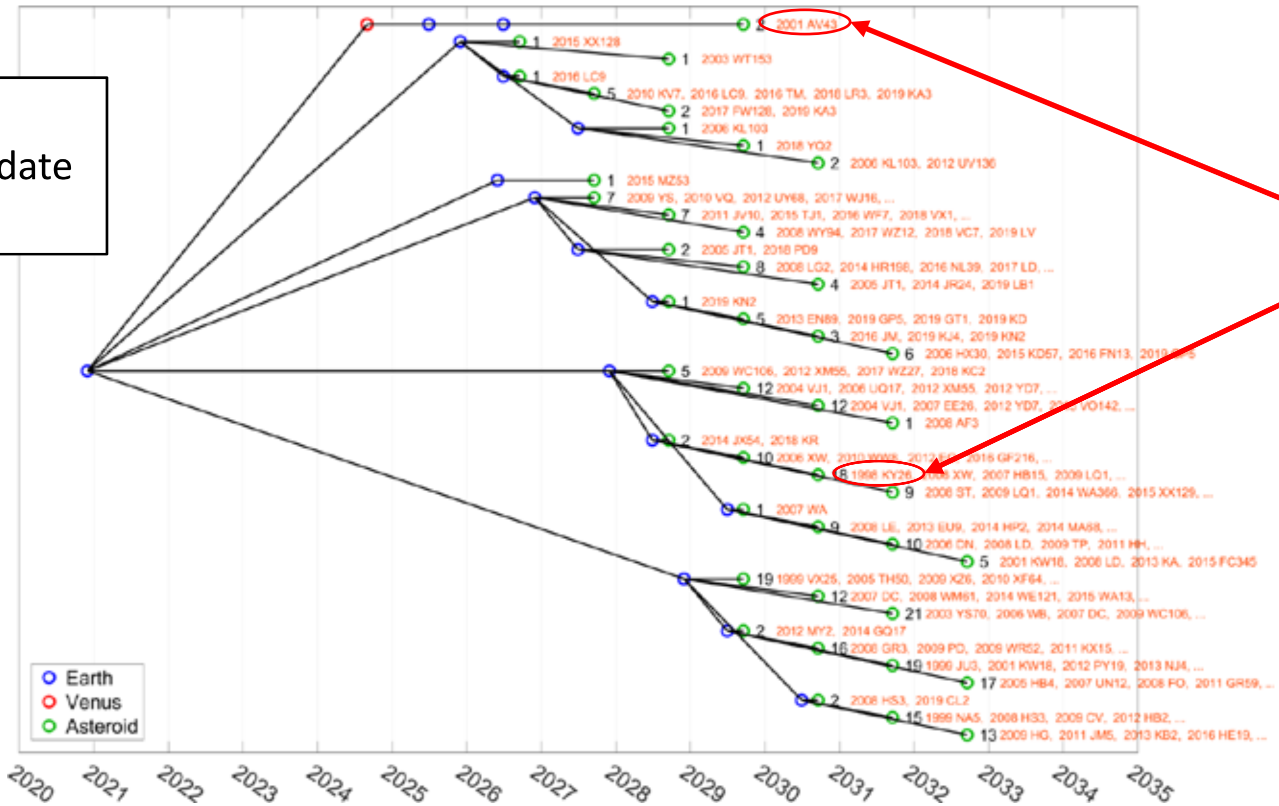
- Implementation date of each event is currently undecided.
- At TCM-0,1,2, the spacecraft will enter an orbit that passes more than 200 km away from the Earth.
- After capsule separation, the spacecraft will divert from the reentry trajectory by TCM-5.

(Image credit：JAXA)

Search for candidate objects

The search for celestial bodies that can be reached by around 2030, based on the remaining spacecraft fuel, operating conditions, and a scientific study of celestial bodies, resulted in two small body candidates for rendezvous.

Orbit transition diagram of candidate celestial bodies

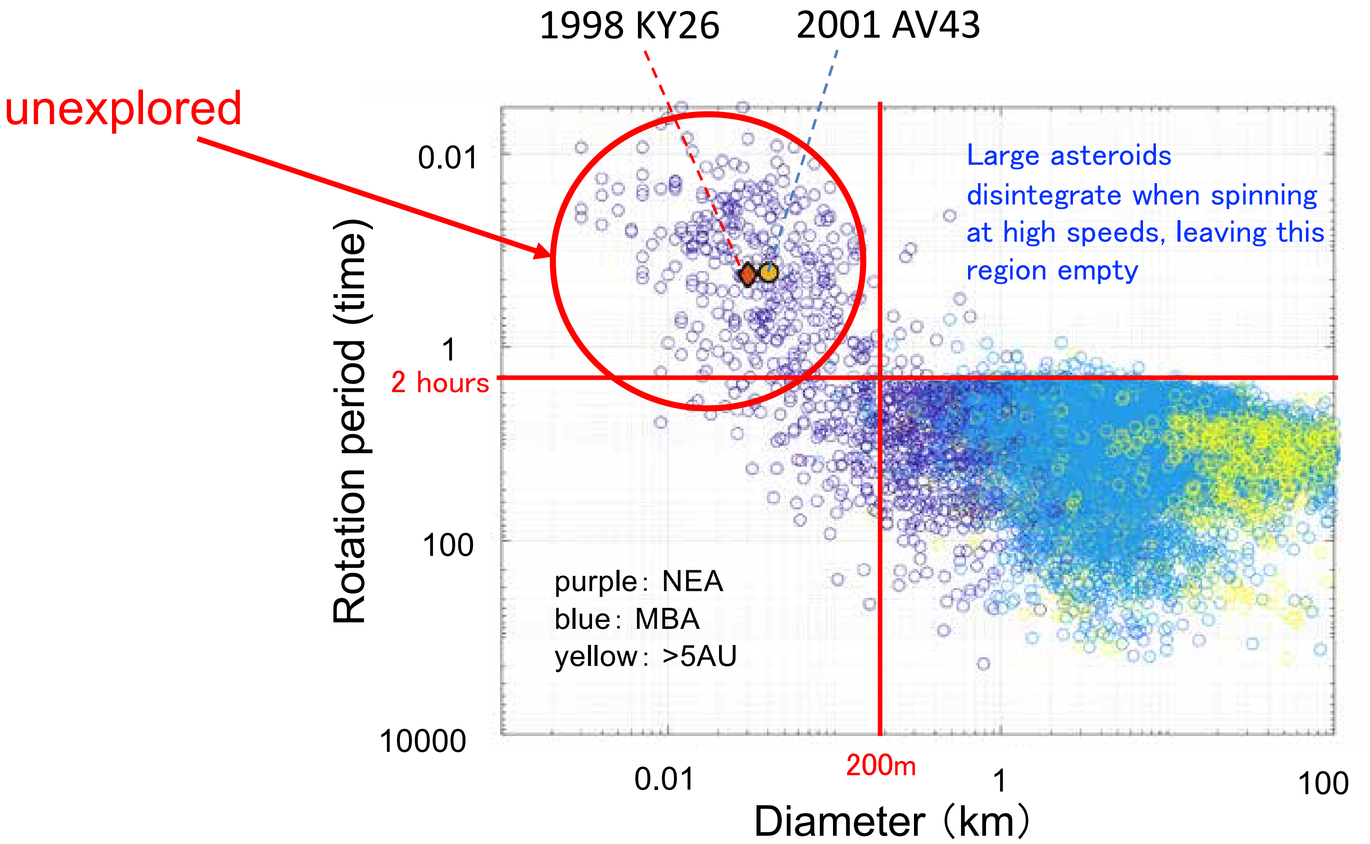


Candidate celestial bodies

2001AV43
1998 KY26

（image credit：JAXA）

Relationship between asteroid diameter and rotation period



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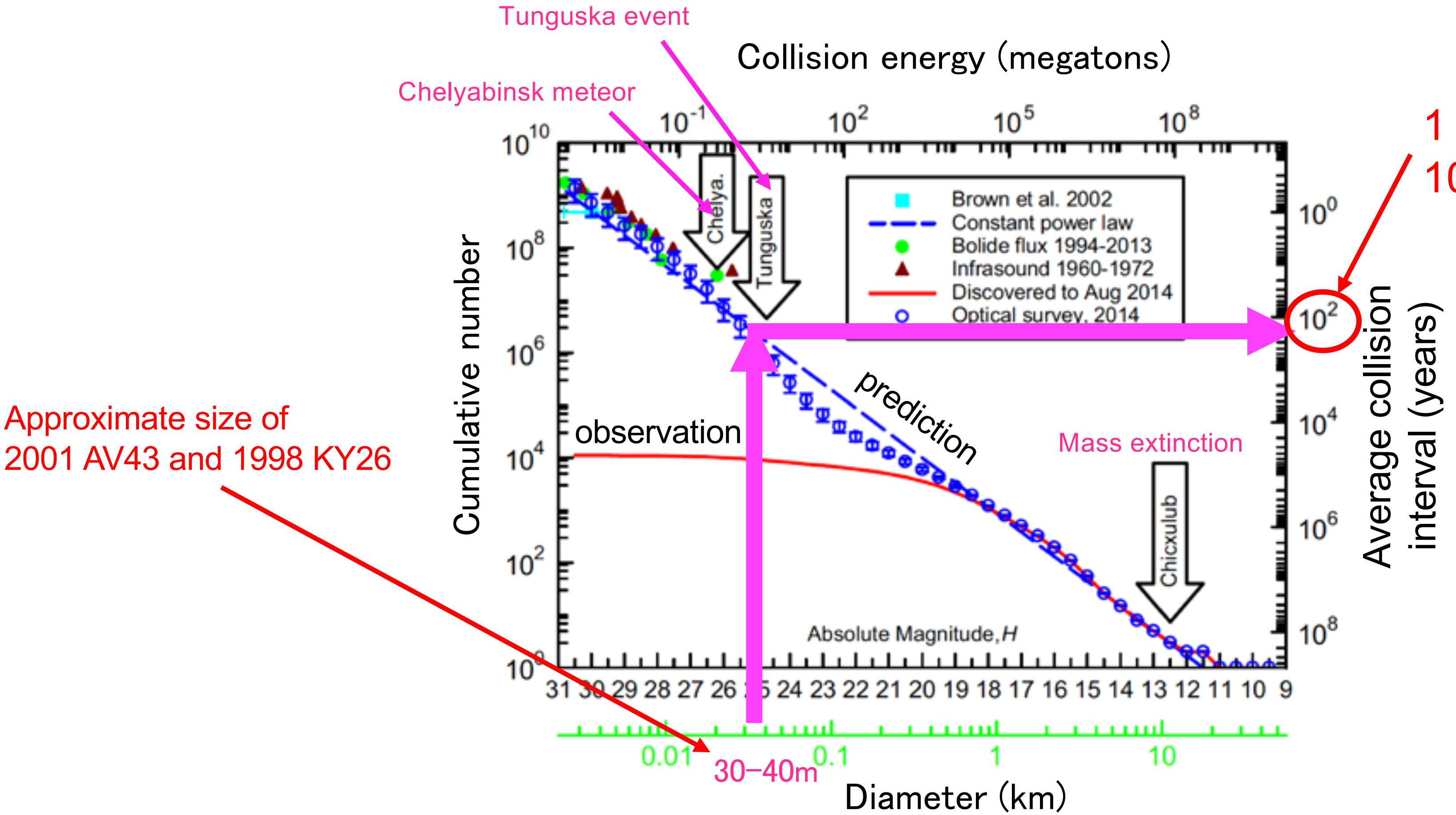
Prediction of asteroid collision frequency



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