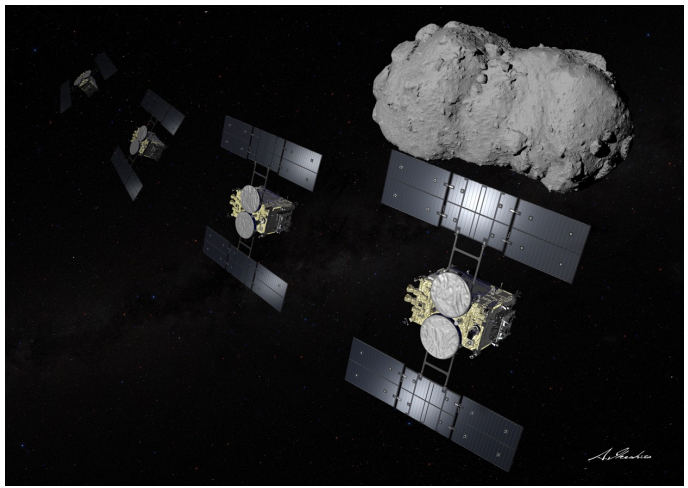
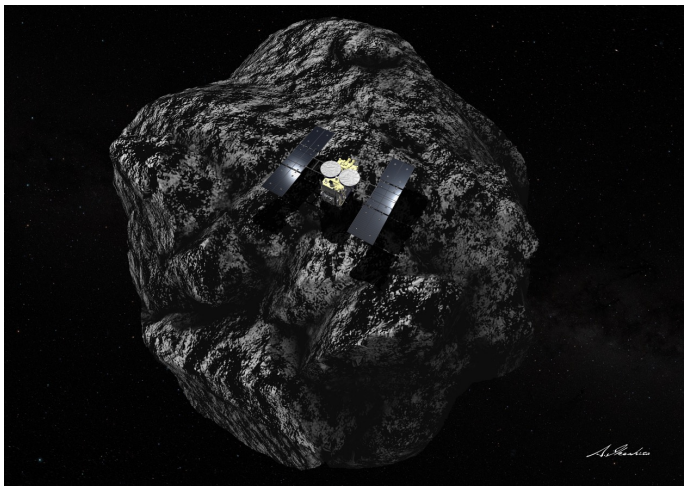
8th IAA Planetary Defense Conference : PDC2023

Hayabusa2 Extended Mission : Hayabusa2#

2001 CC21



1998 KY26



3 April 2023 @ Vienna, Austria

Makoto Yoshikawa[1], Yuya Mimasu[1], Satoshi Tanaka[1], Masatoshi Hirabayashi[2], Takanao Saiki[1], Satoru Nakazawa[1], and Yuichi Tsuda[1]

([1]JAXA, [2]Auburn University)

Overview

- Hayabusa2 mission (3 Dec. 2014 – 6 Dec. 2020) was successfully finished.
- We have extended the mission as Hayabusa2#.

  # (SHARP) : Small Hazardous Asteroid Reconnaissance Probe
- The target asteroids are (98943) 2001 CC21 (flyby in 2026) and 1998 KY26 (rendezvous in 2031).
- Up to now, the spacecraft has been operating smoothly.

The purpose of Hayabusa2#

- Long-term operation of spacecraft in space (more than 11 years longer than the plan)
- Fast flyby operation
- Exploration of a very small (size ~30m) asteroid

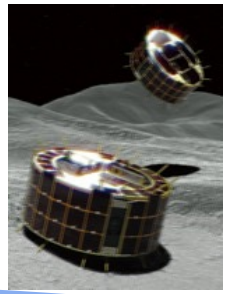
Hayabusa2 : Mission scenario

Launch
Dec 3, 2014

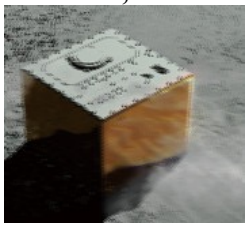
Earth swing-by
Dec 3, 2015

Ryugu arrival
June 27, 2018

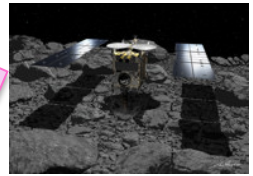
MINERVA-II-1 separation
Sep 21, 2018



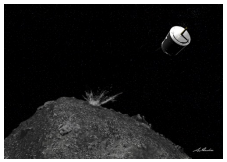
MASCOT separation
Oct 3, 2018



Target marker separation
Oct 25, 2018

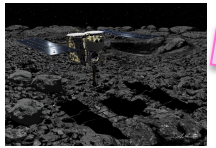


First touchdown
Feb 22, 2019



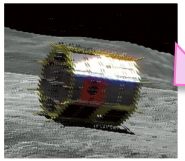
Impactor (SCI)
5 April, 2019

Target marker separation
May 30, 2019



Second touchdown
July 11, 2019

Target marker separation
Sept. 17, 2019



MINERVA-II2 separation
Oct. 3, 2019

Artificial satellites around Ryugu

Ryugu departure
Nov 13, 2019

Earth return
Dec. 6, 2020

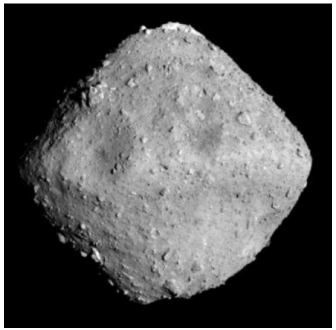
Sample analysis & Extended mission

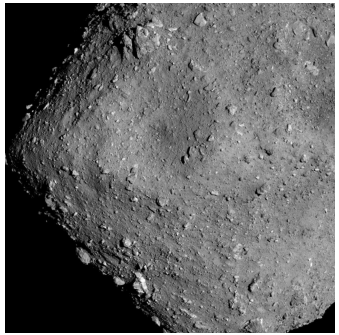
Successfully finished!

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

Asteroid Ryugu

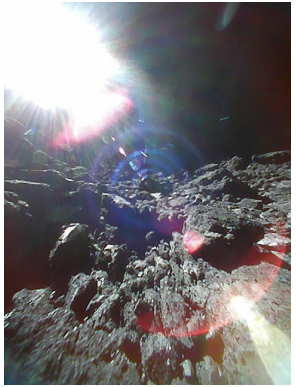
Global image





©JAXA, U. Tokyo & collaborators

Surface

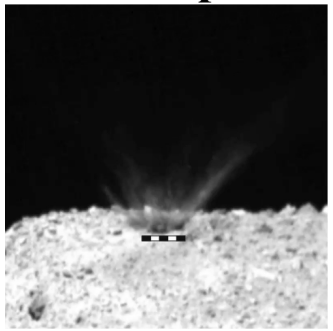


MINERVA-II-1

MASCOT

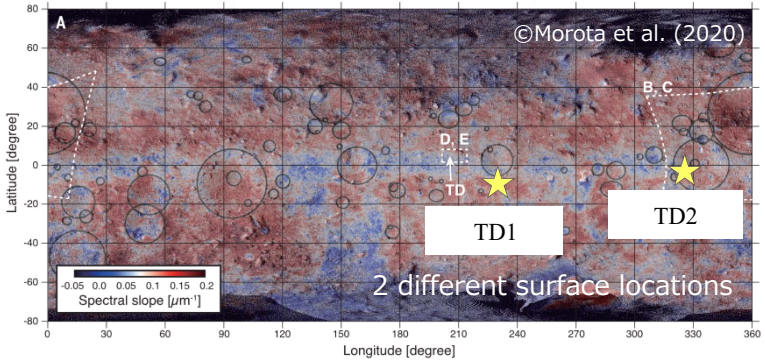
©JAXA, DLR, CNES

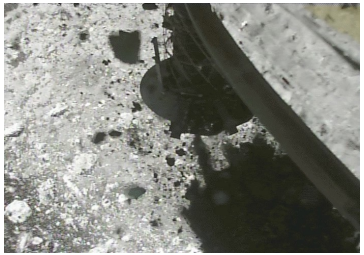
Impact experiment



©Arakawa et al. (2020)

Touchdown



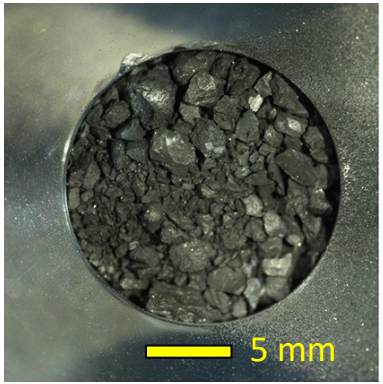


1st touchdown

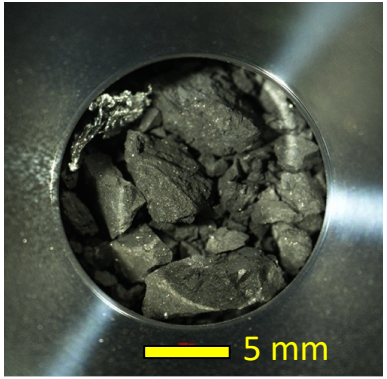
2nd touchdown

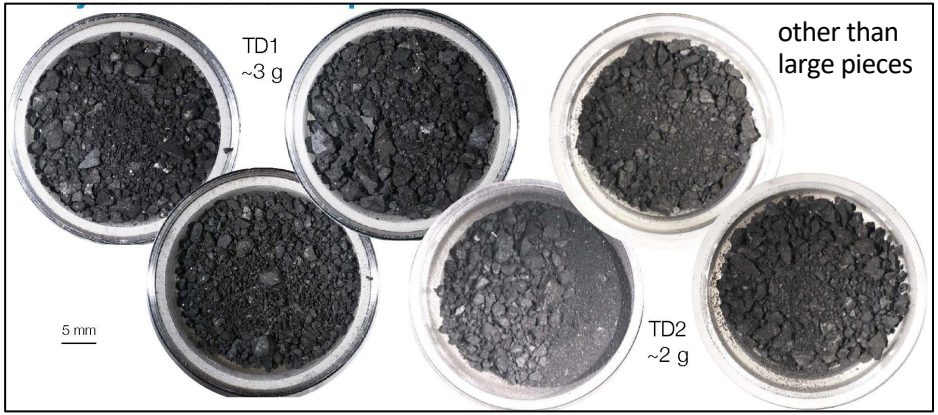
Samples of Ryugu

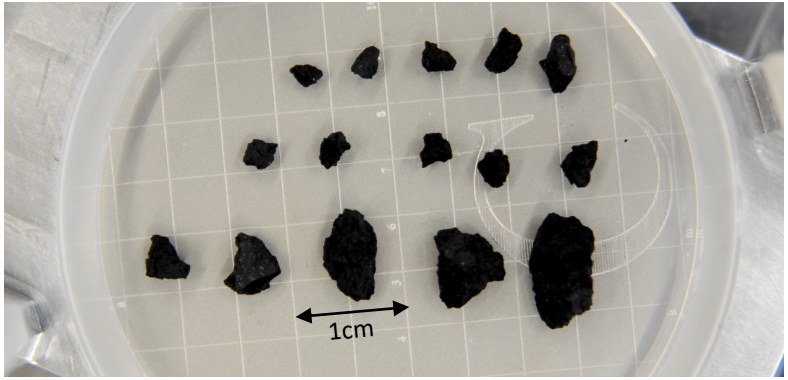
Ryugu samples from TD1



Ryugu samples from TD2

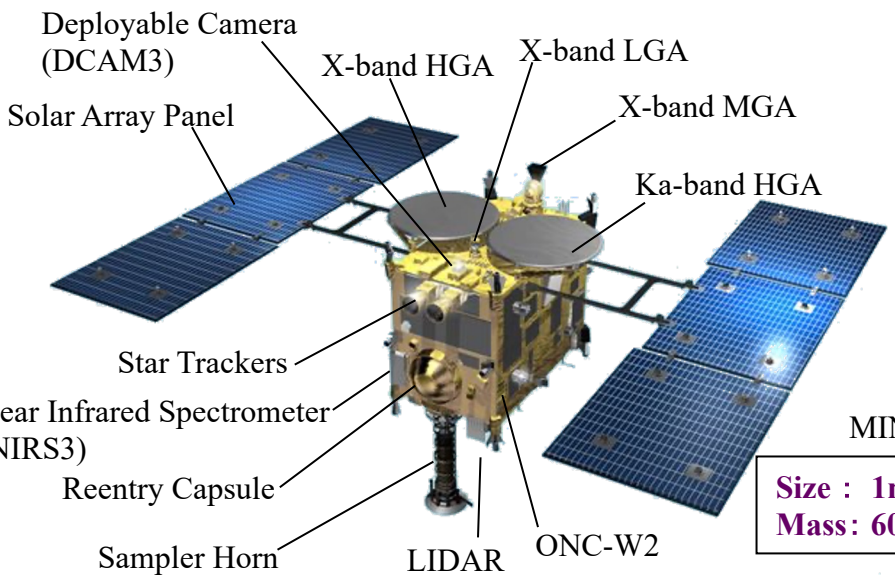


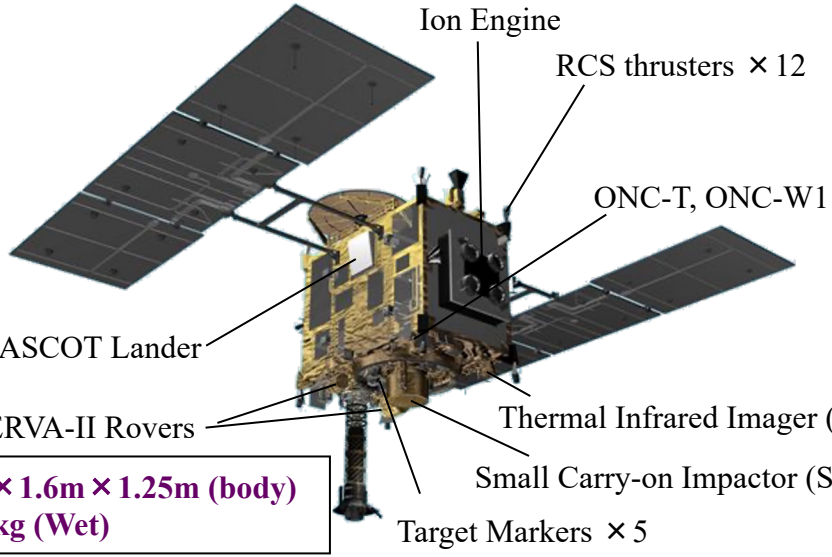




Large pieces

Hayabusa2 Spacecraft

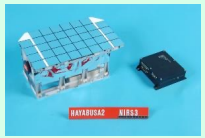




Size : 1m × 1.6m × 1.25m (body)
Mass : 609kg (Wet)


ONC


LIDAR


NIRS3

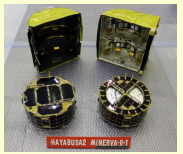

TIR

Science Instruments

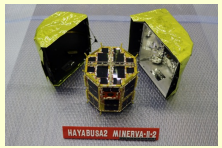
MASCOT

by DLR and CNES

MINERVA-II-1



MINERVA-II-2



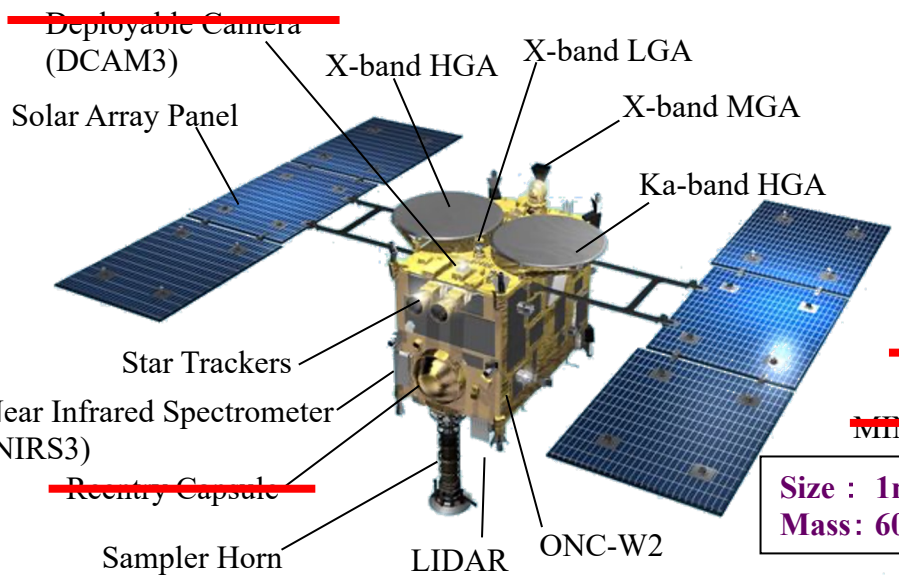
II-1 : by JAXA MINERVA-II Team
II-2 : by Tohoku Univ. & MINERVA-II consortium

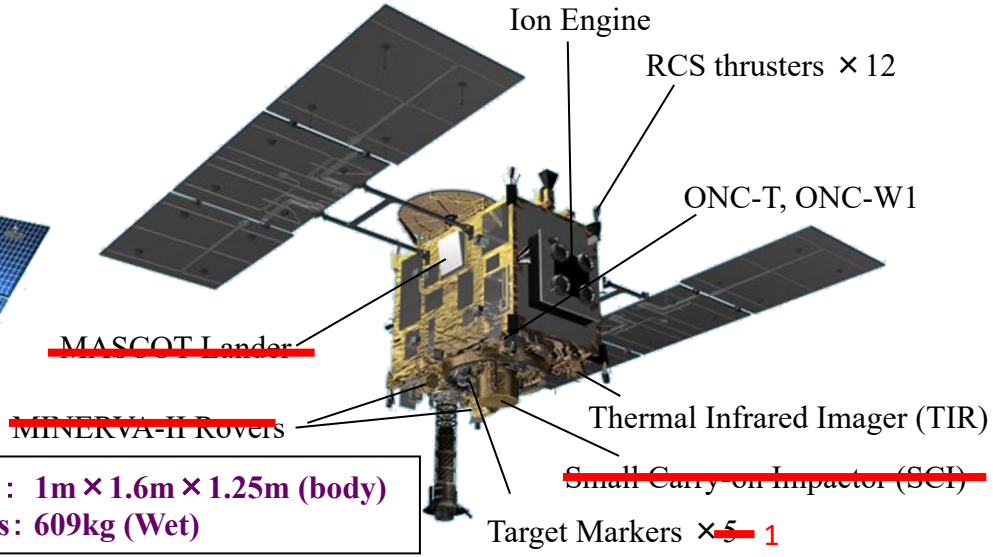
Small Lander and Rovers

(image credit : JAXA)

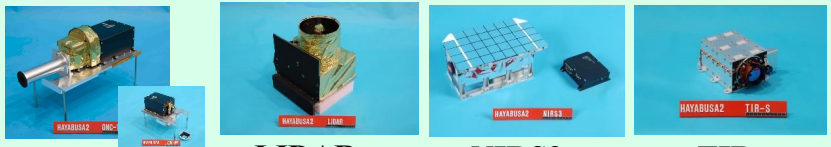
Hayabusa2 Spacecraft

~~Not present in the extended mission~~





Size : 1m × 1.6m × 1.25m (body)
Mass : 609kg (Wet)



Science Instruments

~~**MASCOT**~~ ~~**MINERVA-II-1**~~ ~~**MINERVA-II-2**~~

~~by DLR and CNES~~

~~II-1 : by JAXA MINERVA-II Team~~
~~II-2 : by Tohoku Univ. & MINERVA-II consortium~~

Small Lander and Rovers

(image credit : JAXA)

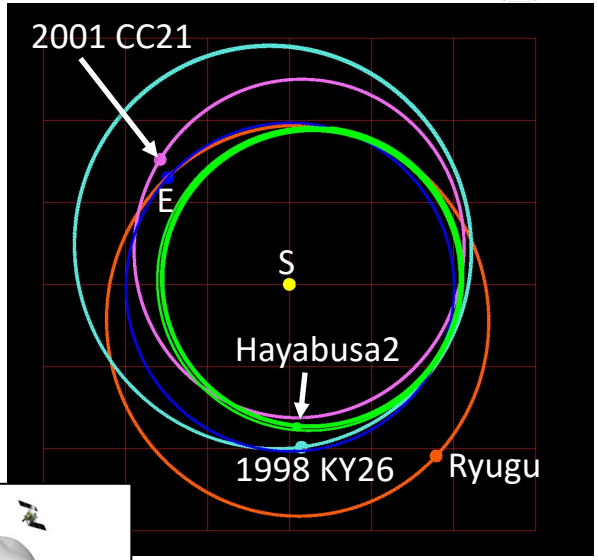
Hayabusa2 Extended mission

Hayabusa2#

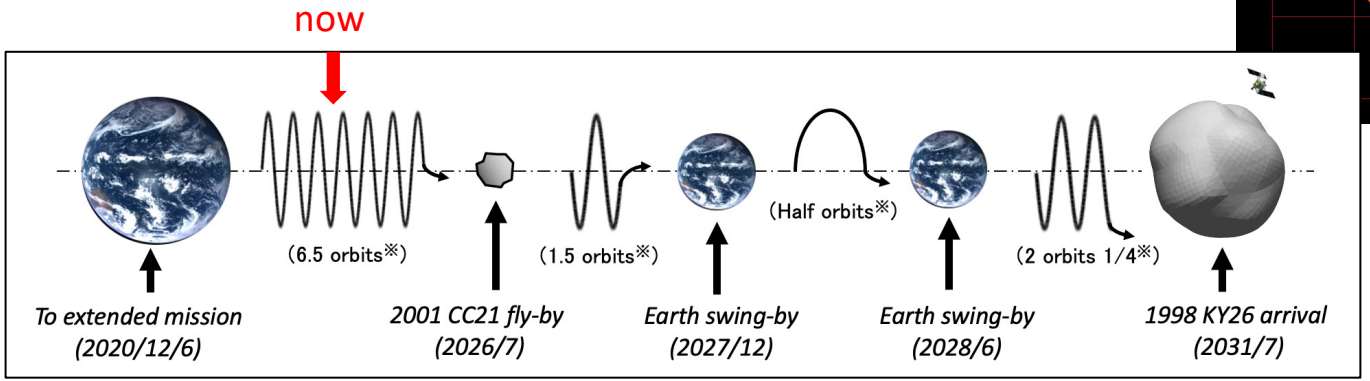
 # (SHARP) : Small Hazardous Asteroid Reconnaissance Probe

- After returning to the Earth in December 2020, we continue to operate Hayabusa2.
- After the main mission, the spacecraft dose not have major problems. 50% of xenon (the fuel for ion engines) remained.

- The next target is the flyby of 2001 CC21 in July 2026.
- The final target is the rendezvous of 1998 KY26 in July 2031.



Object positions on 8 Feb. 2023



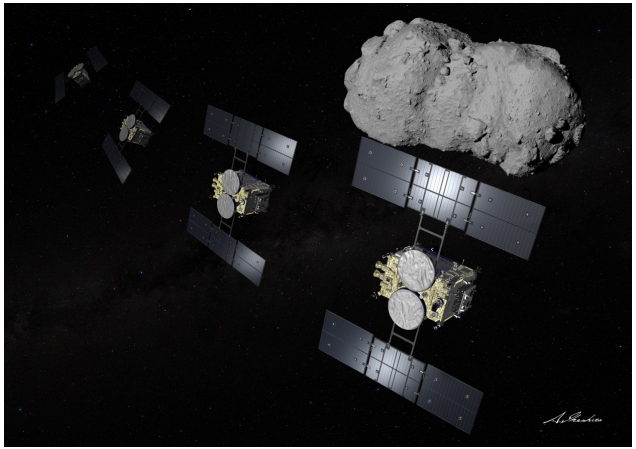
※ indicates the number of orbits around the Sun.

（Image credit：JAXA）

The target asteroids of Hayabusa2#

Poster by M. Hirabayashi

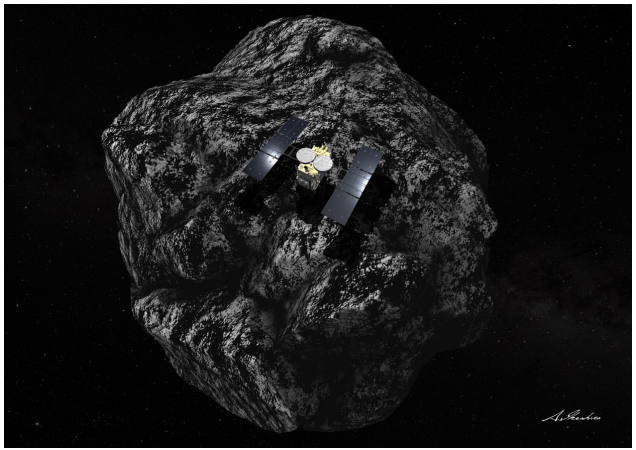
2001 CC21



Artist's illustration (by A. Ikeshita)

Shape	elongated?
diameter	700 m (albedo 0.15 assumed)
Spin period	5.017 hours
Spectral type	L type
Semimajor axis	1.03 au
Orbital period	1.05yr(383 day)

1998 KY26



Artist's illustration (by A. Ikeshita)

Shape	Spherical (from radar observation)
Av. diameter	About 30 m
Spin period	10.7 min (0.178 hr)
Tumbling motion	No short-term variability detected
Spectral type	Possible carbonaceous asteroid
Semimajor axis	1.23 au
Orbital period	1.37yr(500 day)

Shape model:

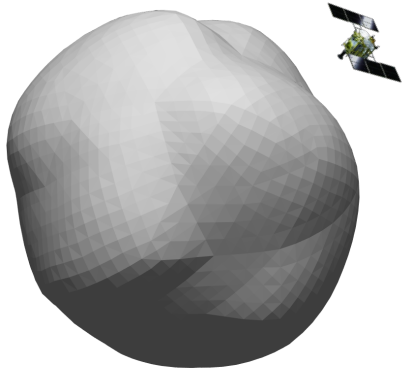
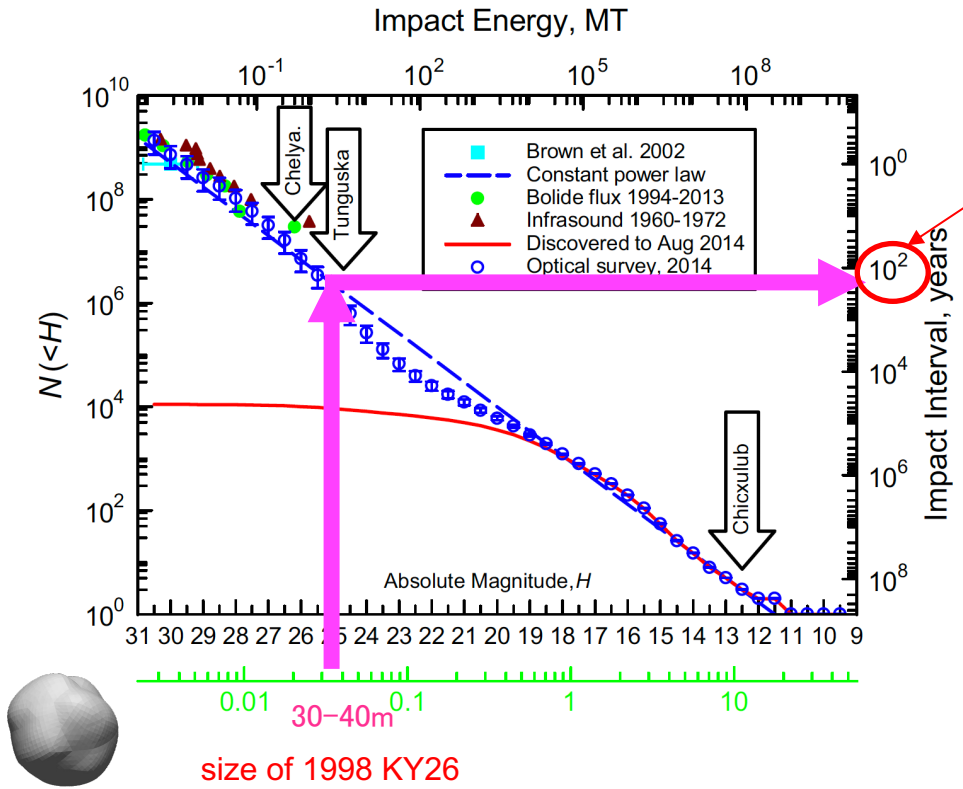


Image credit:
Auburn University, JAXA

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.

Prediction of asteroid collision frequency



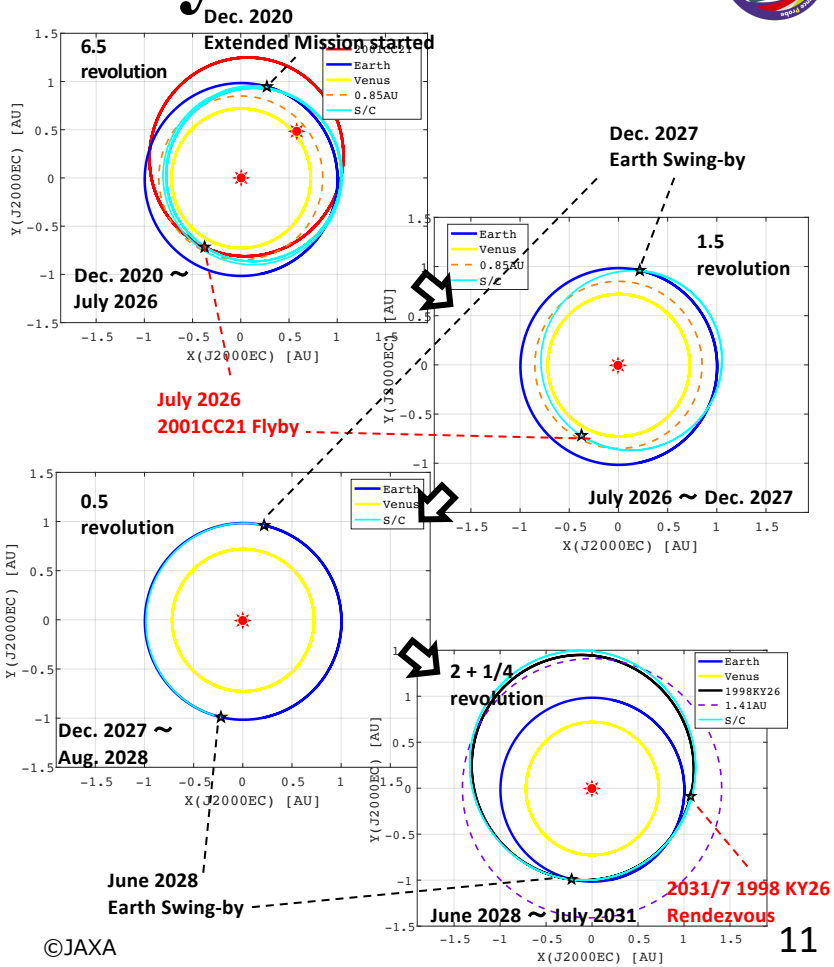
A disaster once every 100 to 200 years!

1998 KY26 is exactly the type of asteroid that should be realistically consider the Earth collision.

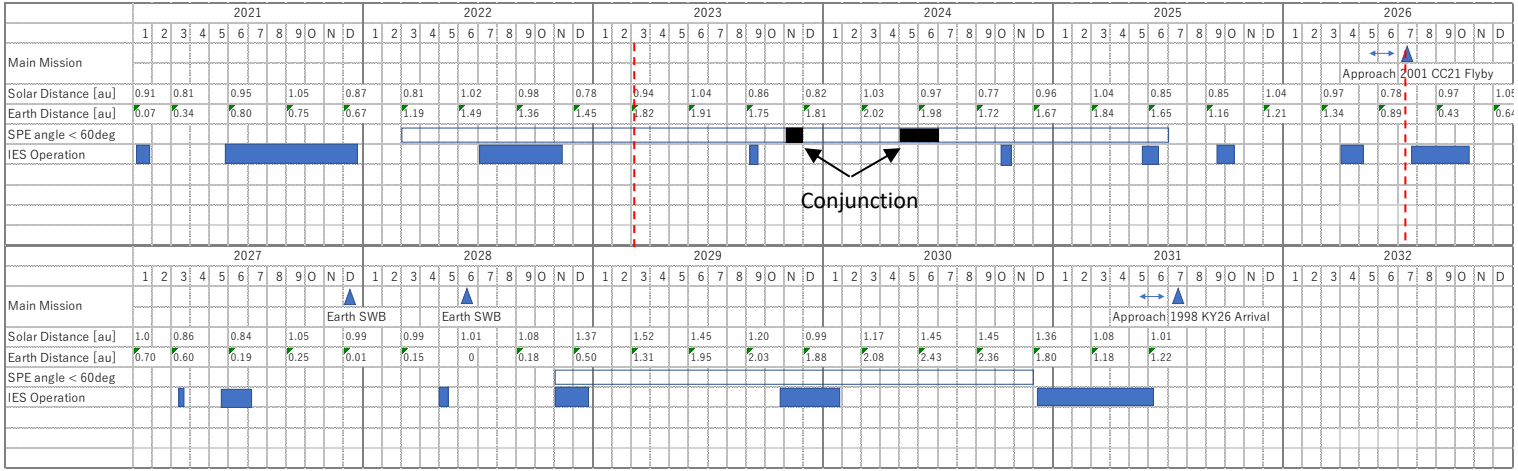
(Modified from Harris and D'Abramo, Icarus 257 (2015) 302–312)

Mission Sequence of Hayabusa2#

Timing	Event	Engineering Achievement	Science Achievement
2021/1 ～ 2026/7	Deep Space Cruise	Acquisition of long-term operation technique of spacecraft under the resource-saving scheme in deep space	・Zodiacal Light Observation ・Exoplanet Observation
2026/7	Flyby 2001 CC21	・Super proximity flyby to asteroid ・Precise targeting technique for the asteroid flyby contributes to Planetary Defense study	Flyby Observation of L-type Asteroid
2027/12	Earth Swing-by	・Completion of 1st leg of long-term deep space operation ・3rd Earth swing-by	Calibration of on-board science equipment by Moon observation
2028/6	Earth Swing-by	・Completion of 2nd leg of long-term deep space operation ・4th Earth swing-by	Calibration of on-board science equipment by Moon observation
2031/7	Rendezvous 1998 KY26	・Completion of 3rd leg of long-term deep space operation ・Multi-rendezvous to asteroid ・Acquisition of exploration technique to the fast rotator, which also contributes to Planetary Defense study	・Clarification of formation and evolution of Fast Rotator ・Acquisition of the scientific knowledge which contributes to Planetary Defense study



IES Operation Plan in Extended Mission



Orbit Plan Concept

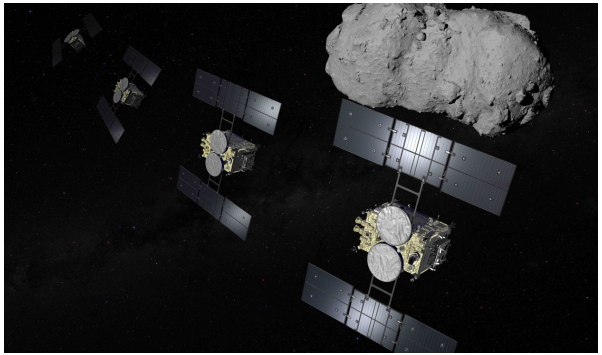
- One-unit IES thrusting operation is assumed to use.
- Stop IES during perihelion region (solar distance < 0.8au)
- Put a priority to minimize the delta-V before the asteroid flyby in order to surely arrive at 2001 CC21
- To minimize the delta-V between asteroid flyby and 1st Earth swing-by as second priority

※IES : Ion Engine System

Required delta-V to 1998 KY26

Phase	Delta-V
Earth Return ~ Now	600 m/s
Now ~ CC21	115 m/s
CC21 ~ Earth SWB1	192 m/s
Earth SWB1 ~ Earth SWB2	30 m/s
Earth SWB2 ~ KY26	426 m/s

Operations for the flyby of 2001 CC21

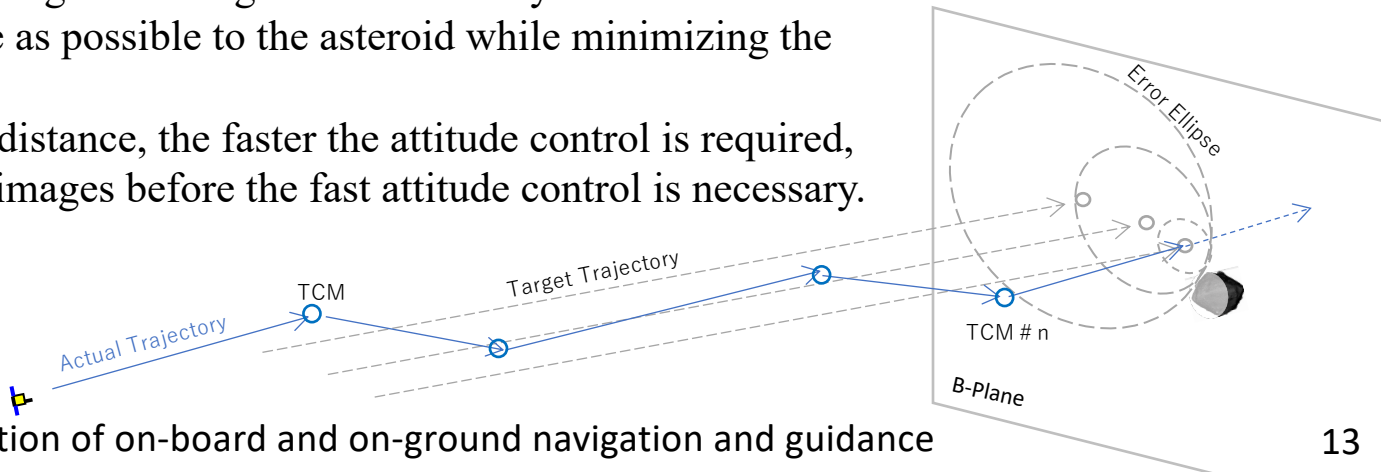


Artist's illustration (by A. Ikeshita)

Flyby data

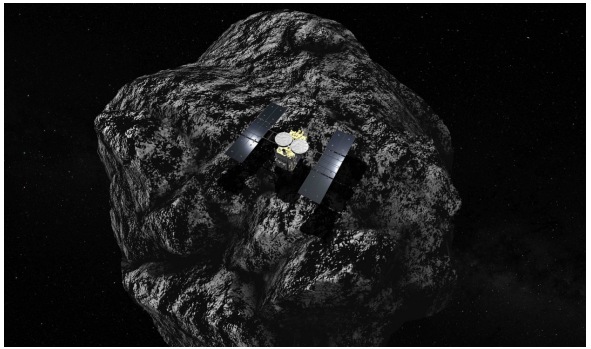
- flyby date : July 2026
- Relative velocity at flyby : about 5km/s
- Flyby distance : less than 100 km (considering the capability of the telescopic optical navigation camera, ONC-T)

- Hayabusa2 was not intended for flyby exploration, so flyby operations are challenge to the limits of navigation and guidance accuracy for us.
- We try to approach as close as possible to the asteroid while minimizing the risk of collision.
- Since the shorter the flyby distance, the faster the attitude control is required, we are considering to take images before the fast attitude control is necessary.



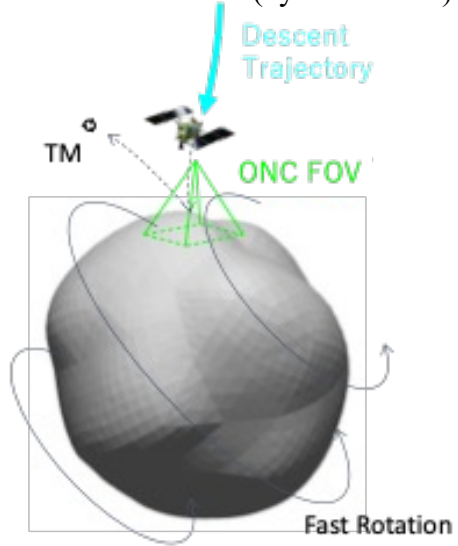
Combination of on-board and on-ground navigation and guidance

Rendezvous with 1998 KY26



Artist's illustration (by A. Ikeshita)

- Hayabusa2 will arrive at 1998 KY26 in July 2031.
- We will observe this asteroid by using the remote sensing instruments onboard, such as Optical Navigation Camera (ONC), Near Infrared Spectrometer (NIRS3), Thermal Infrared Imager (TIR), and Laser Altimeter (LIDAR).
- Hayabusa2 has one target maker (an artificial landmark) and one projectile, so we are considering how to use these things.



Touchdown?

- Since 1998 KY26 is rotating rapidly, the centrifugal force is larger than the gravity attraction at almost all the surface except for the polar regions.
- If we try to touchdown on the surface of this asteroid, we cannot use our method for the touchdown to Ryugu (the method using the target marker).
- One of the possibilities to execute touchdown is to cnage GNC (Ground Navigation Control) software to use the natural feature tracking without relying on the target marker.

Summary

- Hayabusa2 mission (3 Dec. 2014 – 6 Dec. 2020) was successfully finished.
- We have extended the mission as Hayabusa2#.

  # (SHARP) : Small Hazardous Asteroid Reconnaissance Probe
- The target asteroids are (98943) 2001 CC21 (flyby in 2026) and 1998 KY26 (rendezvous in 2031).
- Up to now, the spacecraft has been operating smoothly.

The purpose of Hayabusa2#

- Long-term operation of spacecraft in space (more than 11 years longer than the plan)
- Fast flyby operation ← **basic technology for impactor**
- Exploration of a very small (size ~30m) asteroid ← **basic information for very small NEOs**