Operation status for the asteroid explorer, Hayabusa2, in the vicinity of Ryugu

September 5, 2018

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2 :

- Current status
- Astrodynamics
- MINERVA-Ⅱ

Contents

0. Hayabusa2 & mission flow outline
1. Project status & overall schedule
2. Box-B operation
3. Small Monitoring Camera (CAM-H)
4. Astrodynamics
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7. Future plans

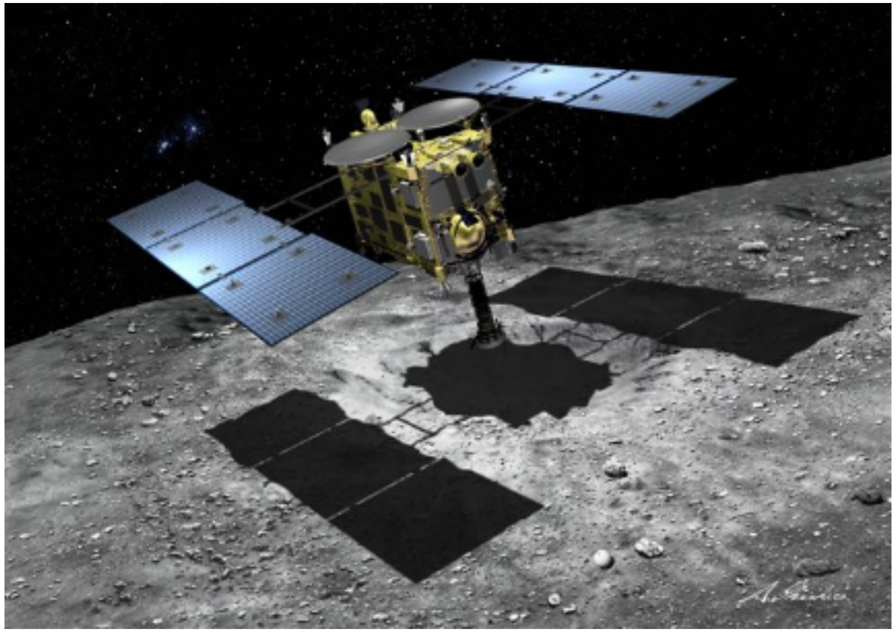
Overview of Hayabusa2

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

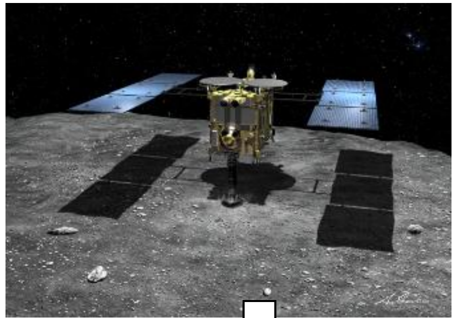
Primary instruments
Sampling mechanism, re-entry capsule, optical cameras, laser range-finder, scientific observation equipment (near-infrared, thermal infrared), impactor, miniature rovers.

Mission flow

Launch
3 Dec 2014

Earth swing-by
3 Dec 2015

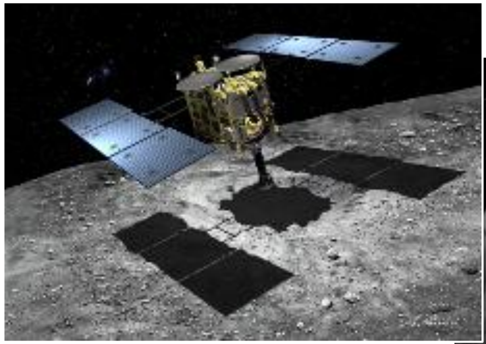
Arrival at asteroid
June 27, 2018



Examine the asteroid by remote sensing observations. Next, release a small lander and rover and also obtain samples from the surface.

Use an impactor to create an artificial crater on the asteroid's surface

Depart asteroid
Nov–Dec 2019



After confirming safety, touchdown within the crater and obtain subsurface samples

Earth return
late 2020

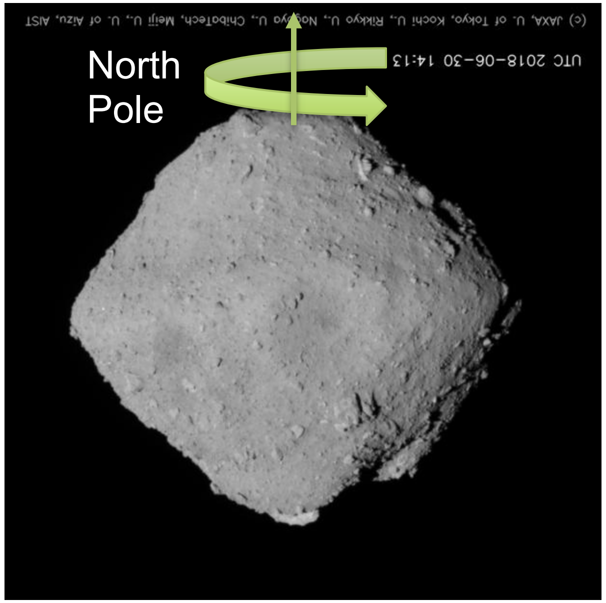
Sample analysis

(Illustrations: Akihiro Ikeshita)

Points to note

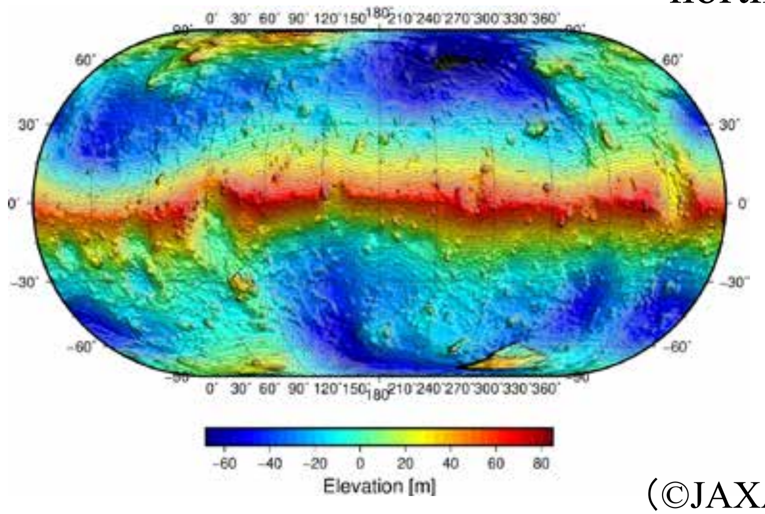
<u>Pay attention to the orientation of the asteroid !</u>

Ryugu images show the northern direction of Ryugu pointing upwards.



（©JAXA、U. of Aizu et al.）

north pole
↑



（©JAXA）

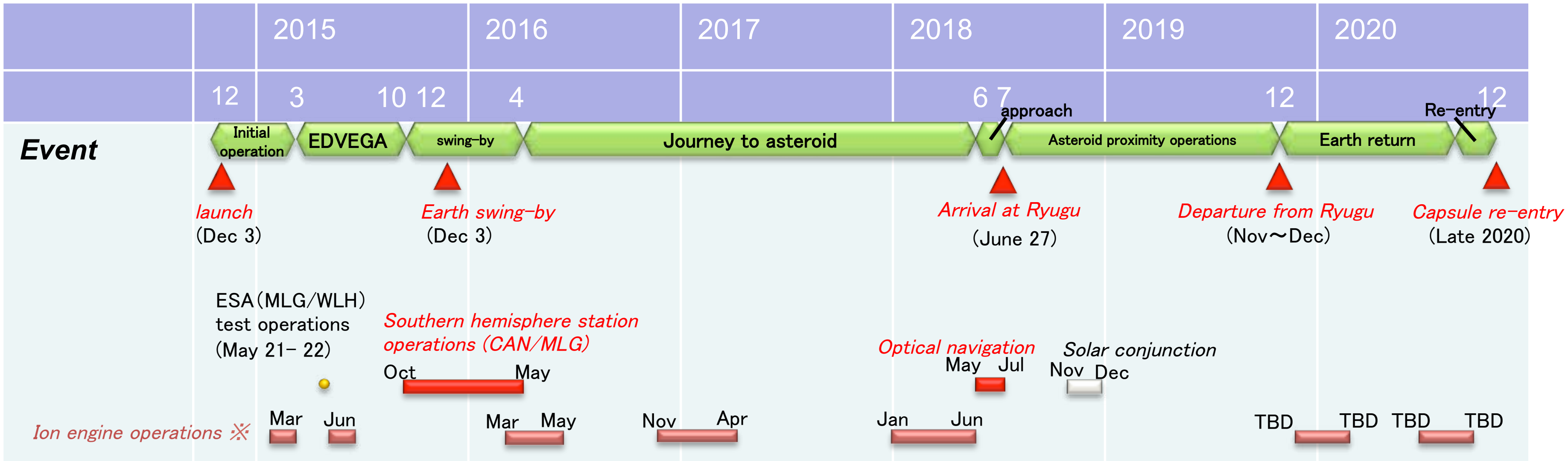
Example of a Ryugu “map”

1. Current project status & schedule overview

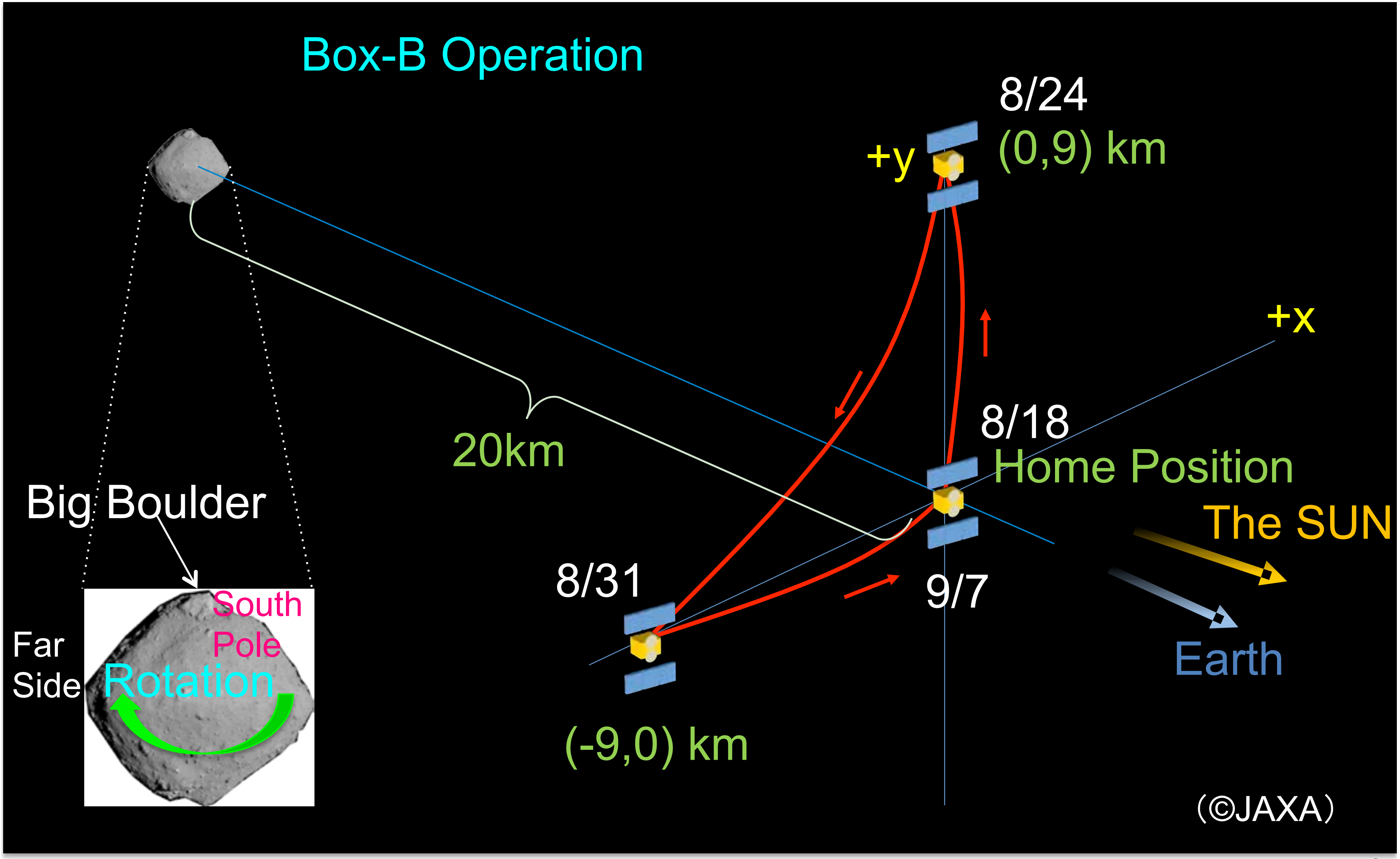
Current status：

- Box-B operations began on August 18. On August 24, the spacecraft reached 9km in the +y direction, followed by 9km in the –x direction on August 31. Purpose of the operation was to image Ryugu around the south pole and evening side.
- Preparation for the approach operations to be carried out in September and October.
- Rehearsal 1 for the touchdown operation is scheduled from September, 11-12.

Schedule overview:



2. Box-B Operation



2. Box-B Operation

Ryugu imaged during Box-B operations

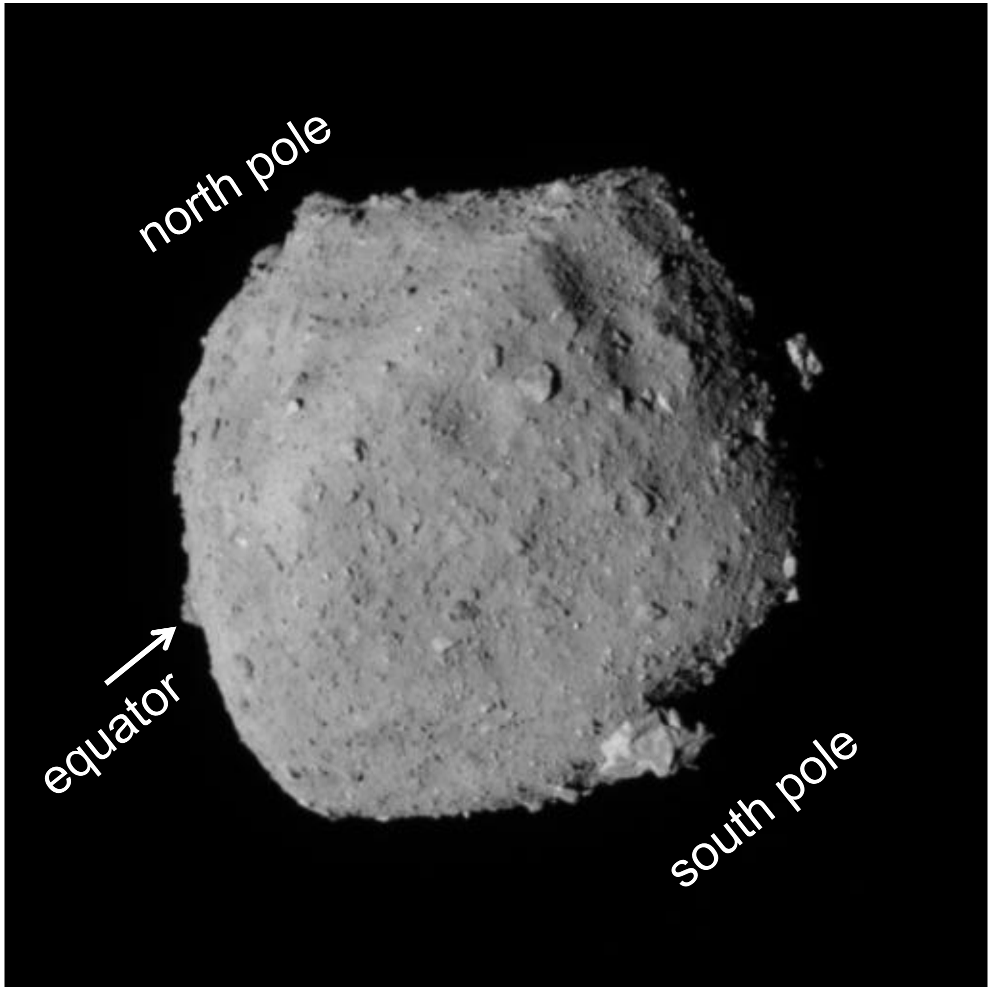
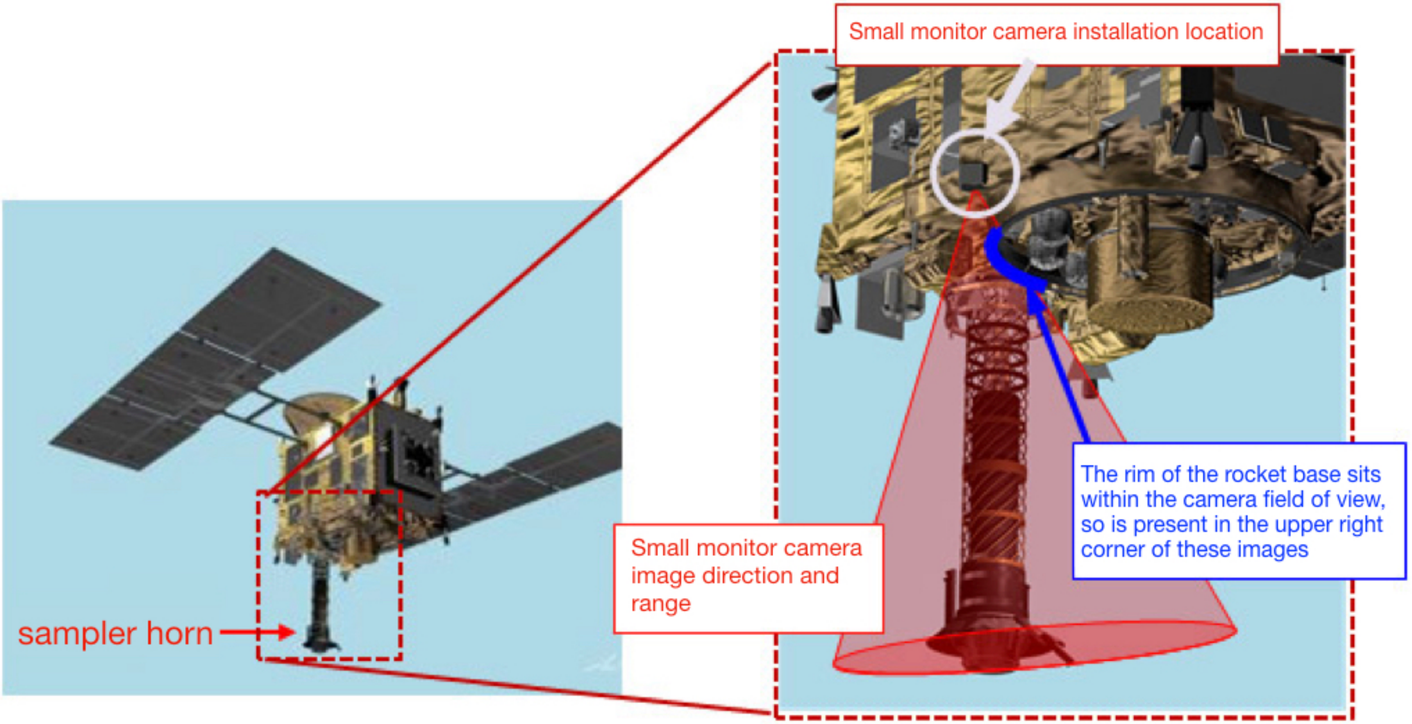


Image captured with the Optical Navigation Camera – Telescopic (ONC-T) on August 24 at around 17:00 JST. Image taken from +y = about 9km. The distance to Ryugu is about 22 km.

Image credit: JAXA, U. of Tokyo, Kochi U, Rikkyo U, Nagoya U, Chiba Institute of Technology, Meiji U, U of Aizu, AIST.

3. Small Monitor Camera（CAM−H）

- Camera built & mounted from donation funds.
- View down sampler horn.



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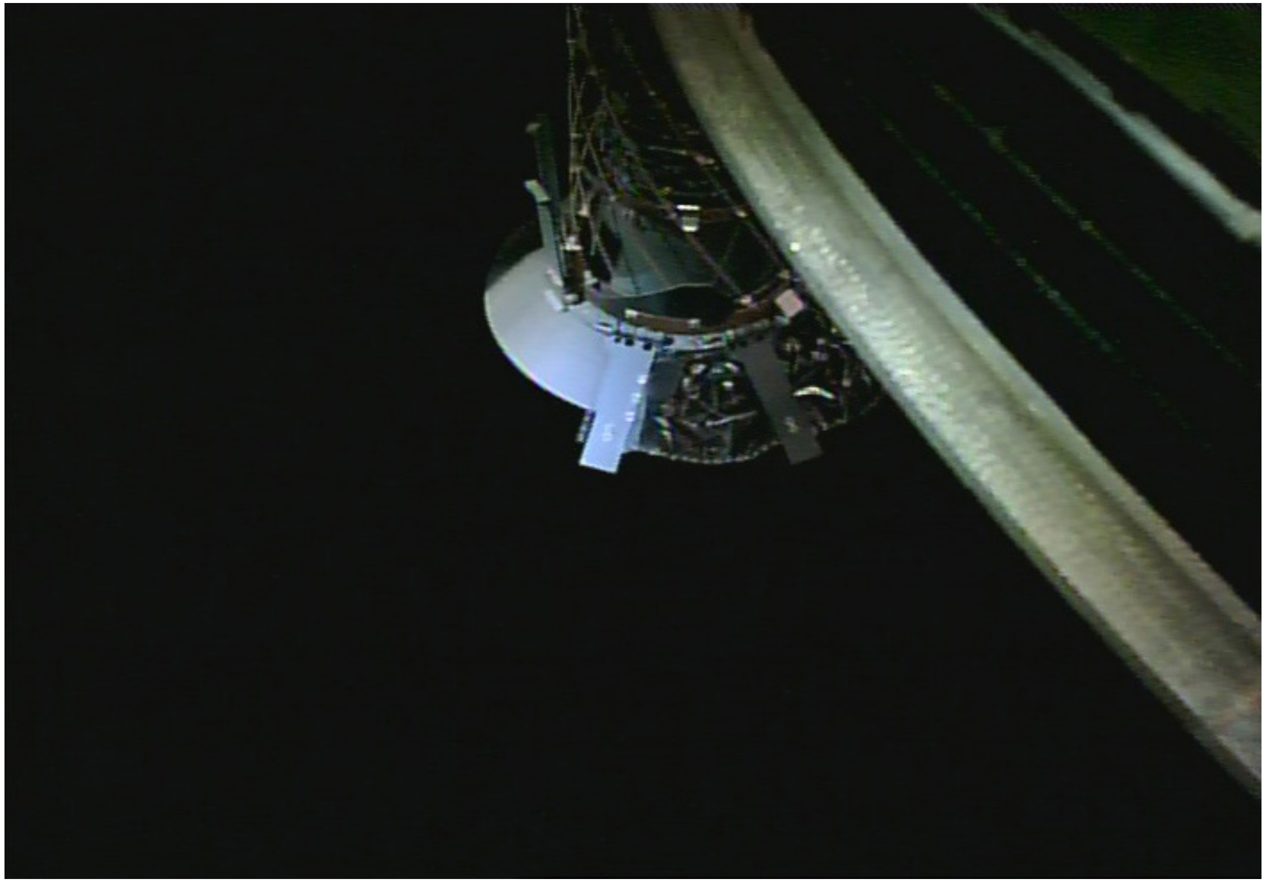
3. Small Monitor Camera（CAM–H）

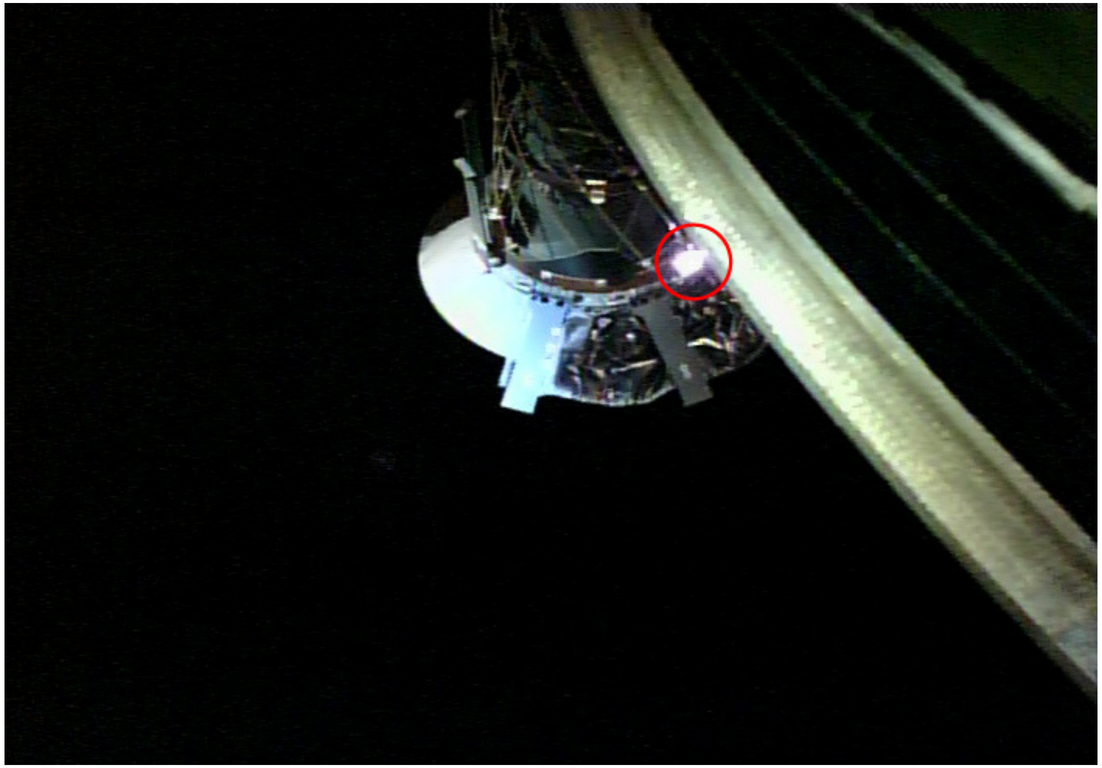
Current appearance of sampler horn



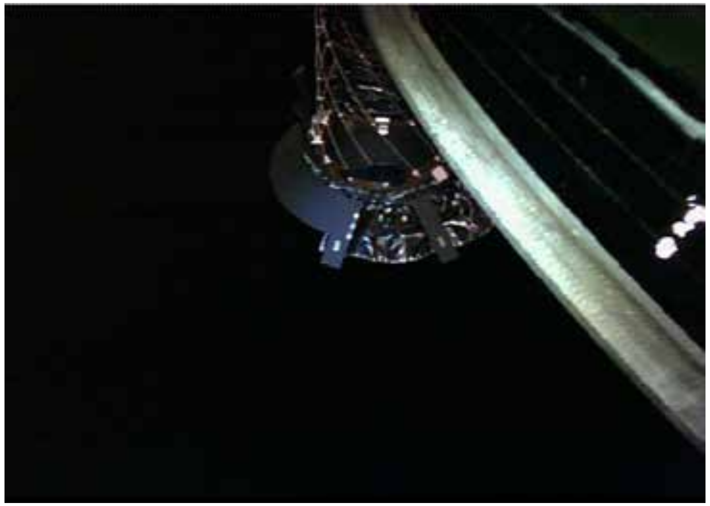
Sampler horn imaged by the Small Monitor Camera (CAM-H) on August 14, 2018

3. Small Monitor Camera（CAM–H）

Reference



Sampler horn test photograph captured by the Small Monitor Camera (CAM-H) on April 16, 2018. The shiny surface in the red circle is the target plate of the sampler horn irradiated with the LRF-S2 laser.



Sampler horn test photograph by the Small Monitor Camera (CAM-H) on December 5, 2014.

4. Astrodynamics

- What is astrodynamics?
  - General flight dynamics handled in space engineering.
  - Orbital and attitude motion, navigation, guidance, control etc.
- Hayabusa2 astrodynamics team activities
  - Orbit estimation of the Hayabusa2 probe and asteroid Ryugu.
  - Creation and evaluation of the gravitational field model of asteroid Ryugu.
  - Evaluation of orbital motion in the vicinity of the asteroid.
  - Estimation of asteroid parameters used for exploratory operations and influence the actual operation system.
- What we learned from previous observations:
  - Gravity of the asteroid (mass)
  - Dynamical environment near the asteroid
  - Asteroid's orbit

Topics for today (gravity of the asteroid; dynamical environment near the asteroid)

4. Astrodynamics

Analysis method

- By simultaneously using radio observation data (range, range-rate etc) of the spacecraft acquired by the ground stations, relative observational data of the asteroid acquired by the onboard instruments (laser altimeter & camera images), the precise orbit of the probe and the gravitational acceleration from asteroid Ryugu were estimated.
- The gravity estimate for asteroid Ryugu was carried out using data acquired during the Gravity Measurement Descent Operation (performed 8/6- 7). Combined with the volume information calculated from the shape model, it is possible to estimate the bulk density of the asteroid.
- The dynamic environment near asteroid Ryugu could then be evaluated, using the estimated gravity information.

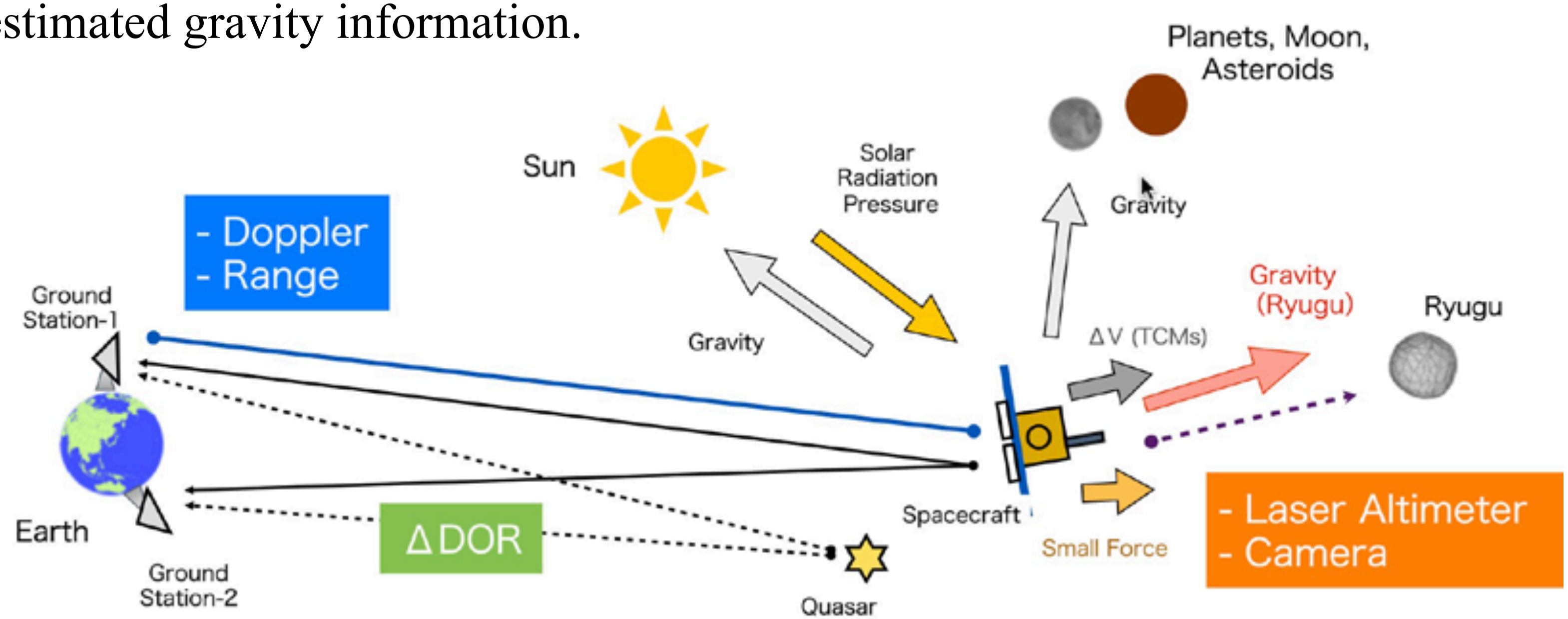
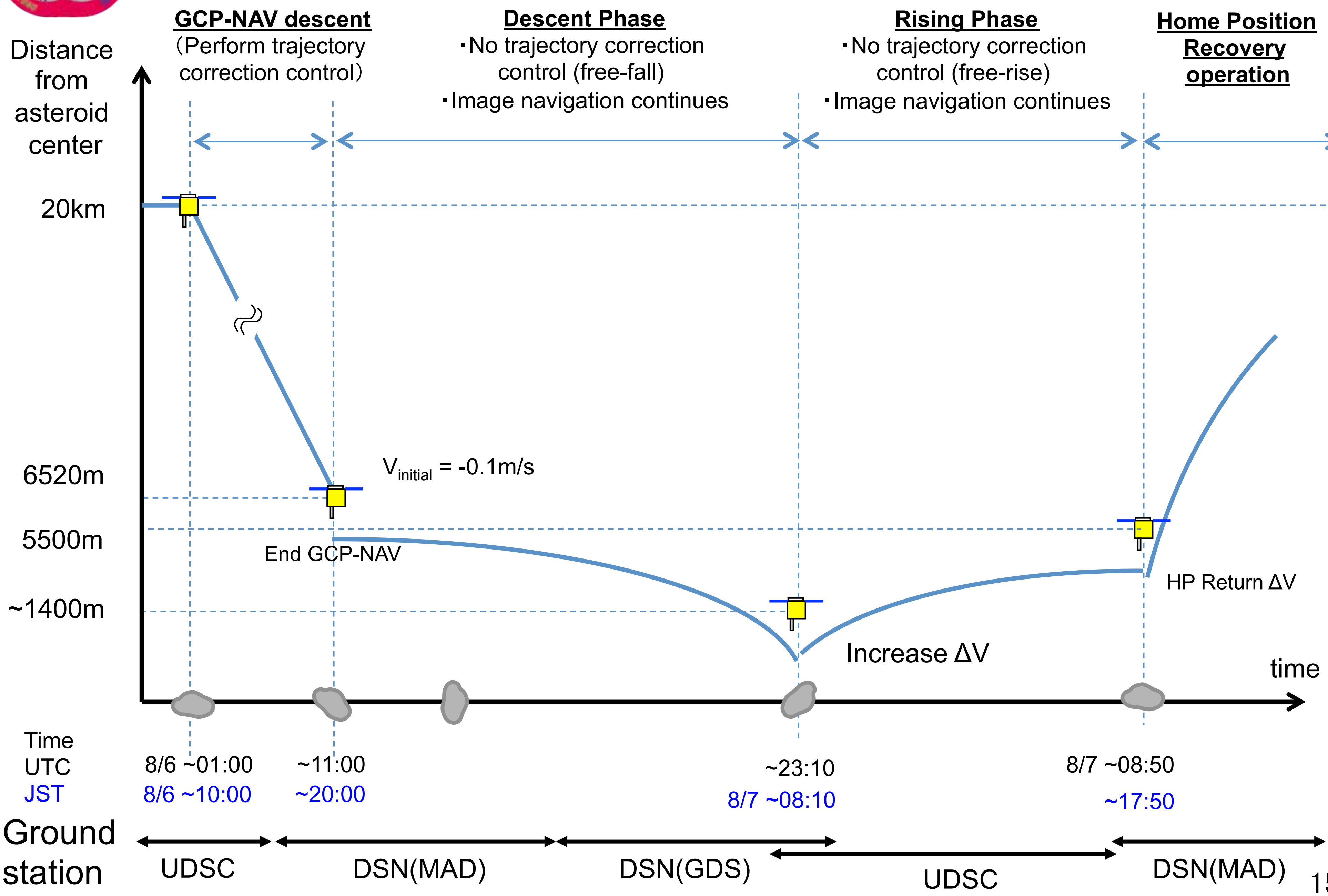


Image of precise orbit determination

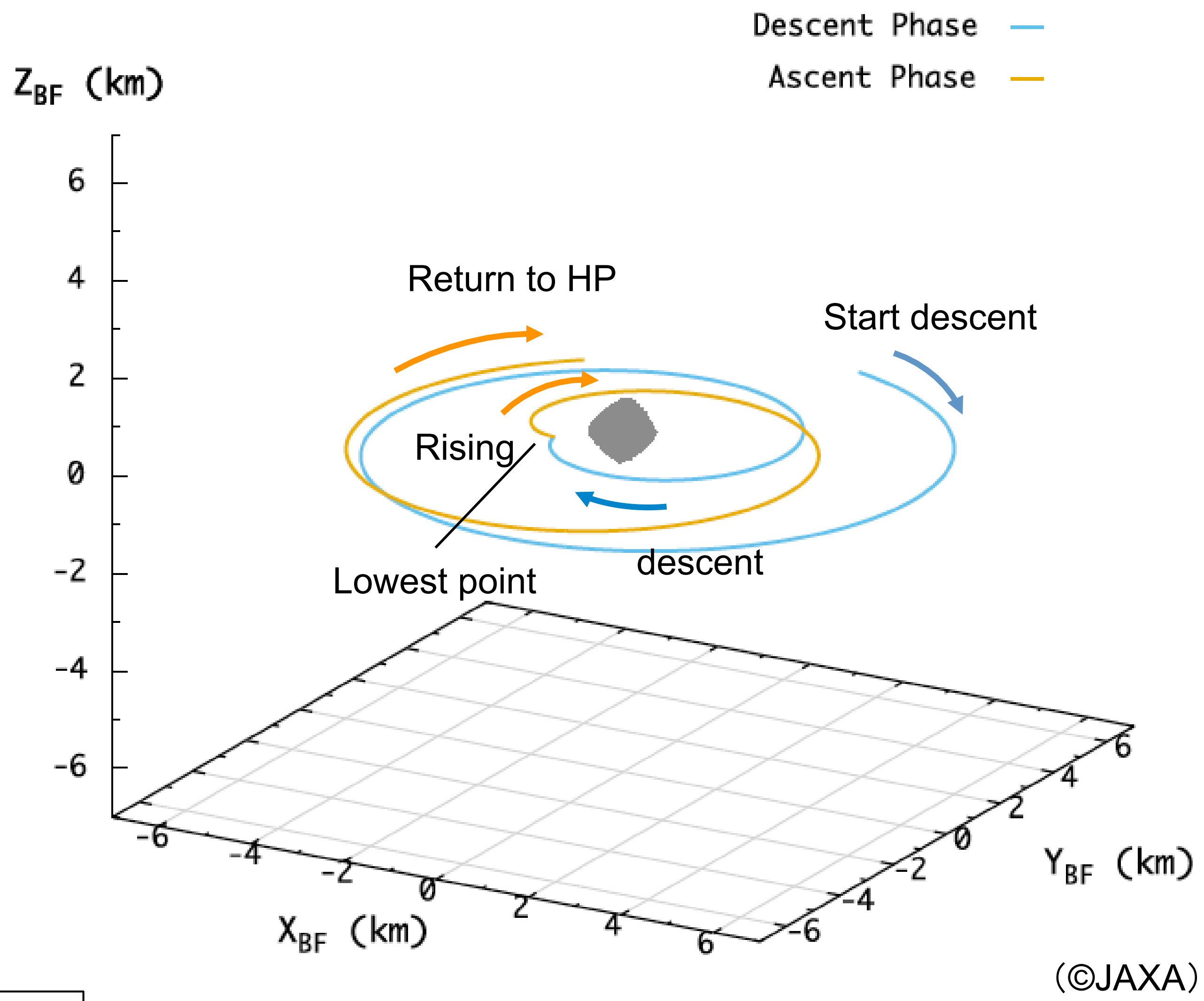
4. Astrodynamics



4. Astrodynamics

- Descent phase began from ~6,500m altitude, continuing with free-fall motion for about 12 hours.
- Performed trajectory control ΔV at the lowest point (altitude ~850m) and changed to rising phase.
- Relative to the orientation of the rotation of the asteroid, in the asteroid fixed coordinate system, the orbit approached and ascended at the equatorial plane (XY plane) of the asteroid.
- GM (G: gravitational constant, M: mass) obtained during the Gravity Measurement Descent Operation is:

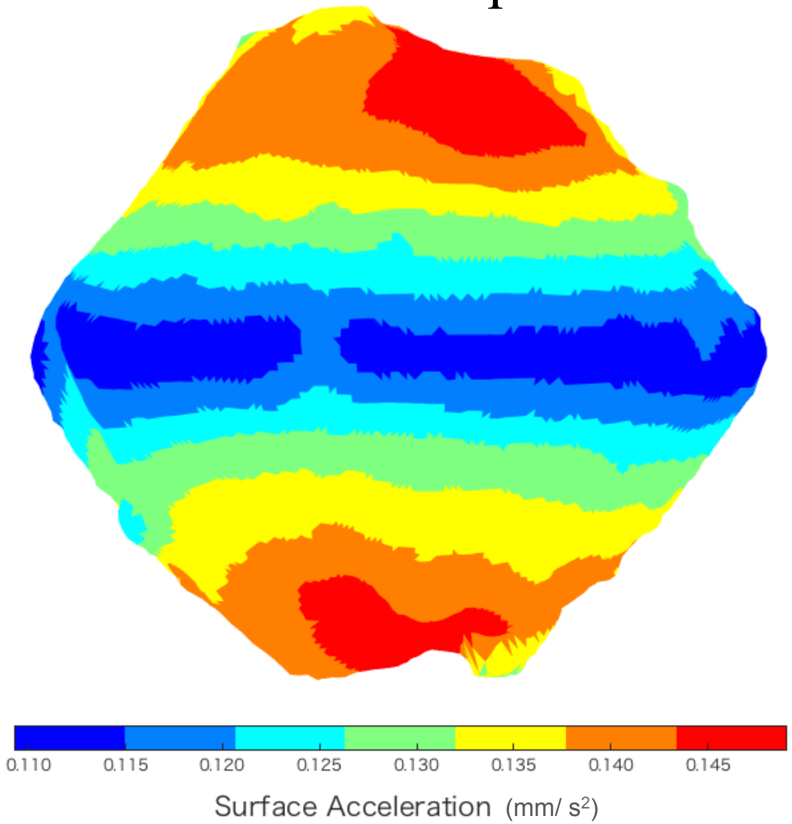
GM=~30 (m^3/s^2) → Mass：~450 million tons



Orbit trajectory in the roid fixed coordinate system

4. Astrodynamics

- Evaluation of the acceleration environment on the asteroid surface from the estimated gravitational information.
- The acceleration information in the vicinity of the asteroid will be used for future touchdown operations etc.

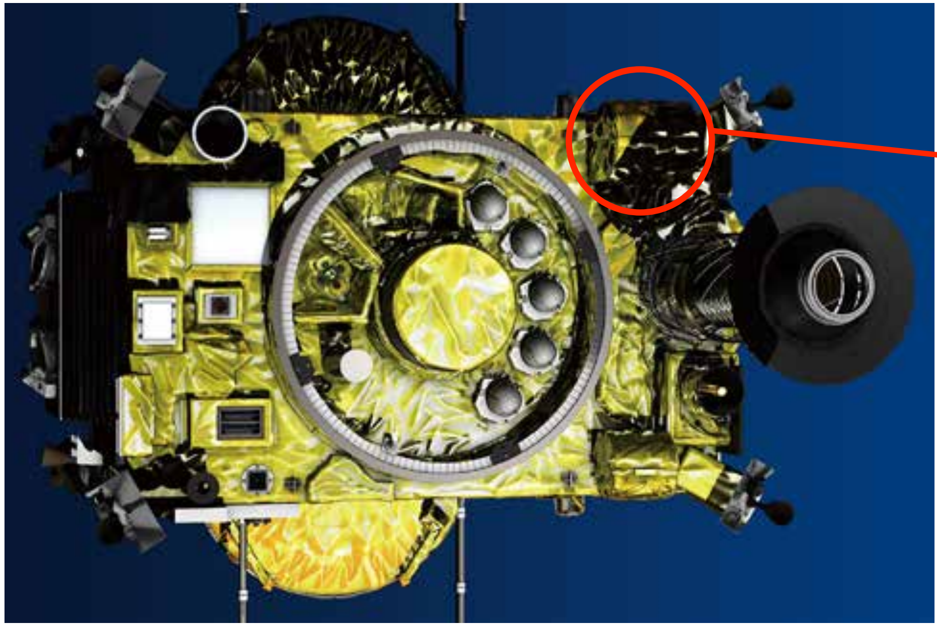


Acceleration on the surface of Ryugu (©JAXA)

- ✓ The surface acceleration variation is of the order of 0.11～0.15 [mm/ s^2]
- ✓ The acceleration near the poles is large, and small in the vicinity of the equator.
- ✓ Gravity at the equator is
  - Approx. 1/80,000 the Earth.
  - Several times Itokawa.

5. Asteroid Exploration Rover MINERVA-Ⅱ1

MINERVA-II is the successor of MINERVA installed in Hayabusa spacecraft.



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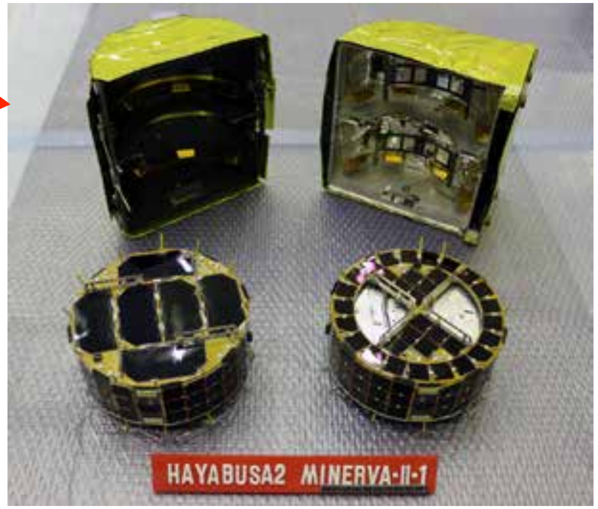
MINERVA-II1(Rover-1A, Rover-1B)



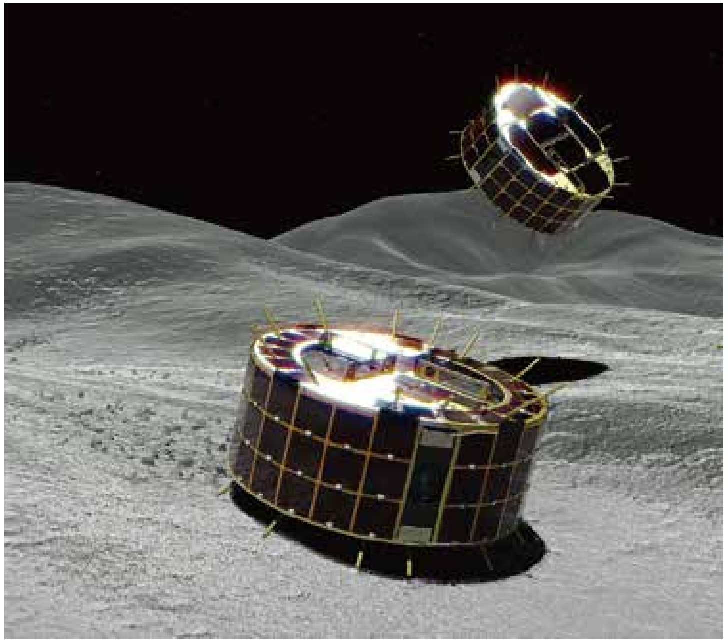
Produced at JAXA

＜ Cooperation makers, universities, groups, etc.＞
Aichi University of Technology, University of Aizu, Addnics corp., Antenna Giken Co., Ltd., ELNA , CesiaTechno, The University of Tokyo, Tokyo Denki University、Digital Spice Corp., Nittoh Inc., Maxon Japan, DLR, ZARM

- Weight (including deployment)
  MIMERVA-II1 :2.5kg
- MINERVA-II1
  Twin rovers

5. Asteroid Exploration Rover MINERVA-Ⅱ1

MIcro Nano Experimetal Robot Vehicle for Asteroid the Second Generation



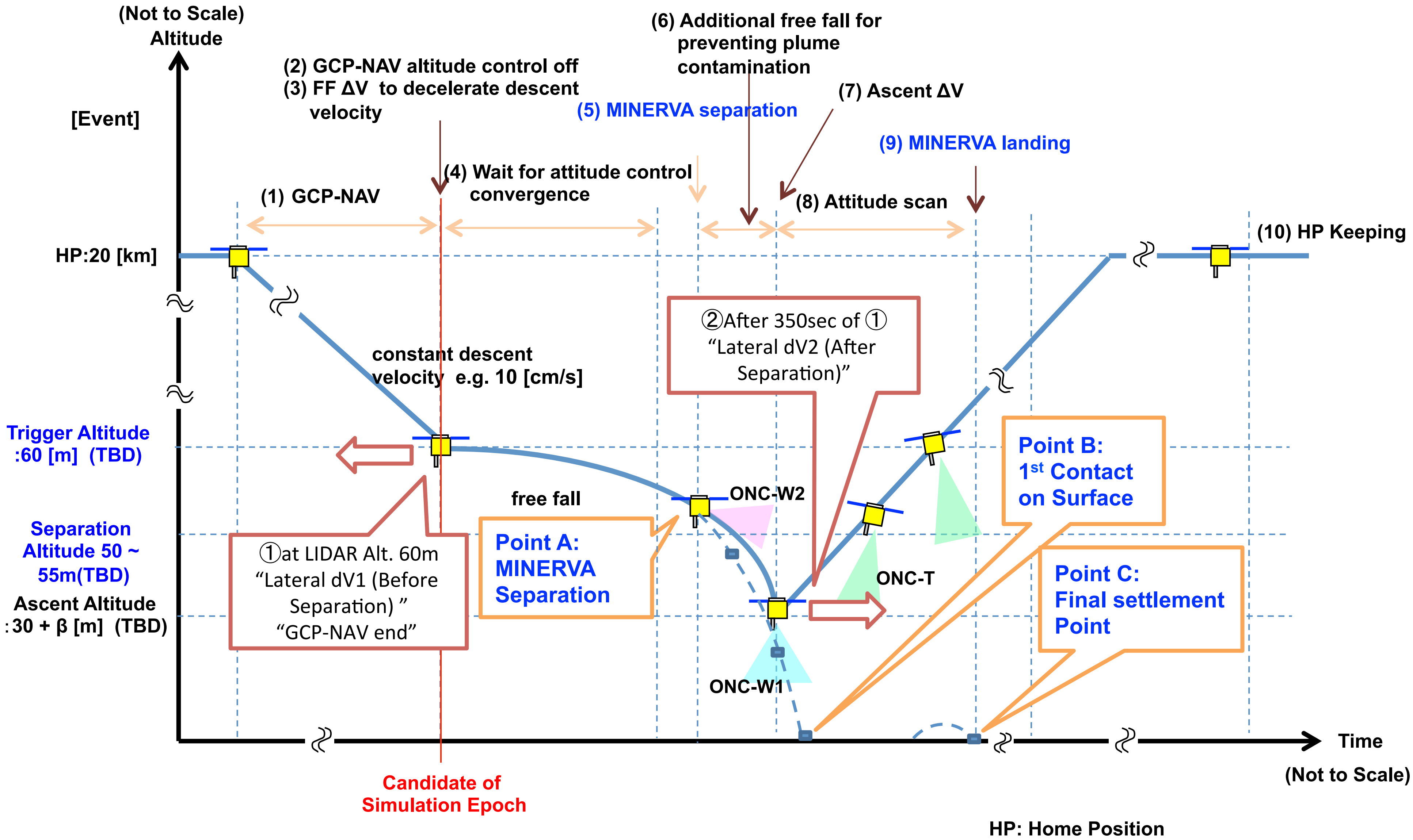
(©JAXA)

- New hopping mobility
- Adaptation with AI
- Small, light-weight,
- Low power consumption
- Autonomous behavior
- Scientific observation （stereo sensing, thermometer)

5. Asteroid Exploration Rover MINERVA-Ⅱ1

body size	Cylinder (hexadecagonal pole) Diameter: f180[mm] Height: 70[mm]
weight	1A:1151[g], 1B:1129[g]
actuators	DC motor
sensors	4 cameras(1A), 3 cameras(1B) photodiodes, accelermeter thermometers, gyro
com.	32k[bps](max)

5. Operation Sequence



6. Operation Schedule

Operation Schedule

Touchdown 1 rehearsal 1: September 11 ~ 12
(Arrival at lowest altitude : September 12)

MINERVA-II-1 operation: September 20 ~ 21
(MINERVA-II-1 separation : September 21)

MASCOT operation: October 2 ~ 4
(MASCOT separation : October 3)

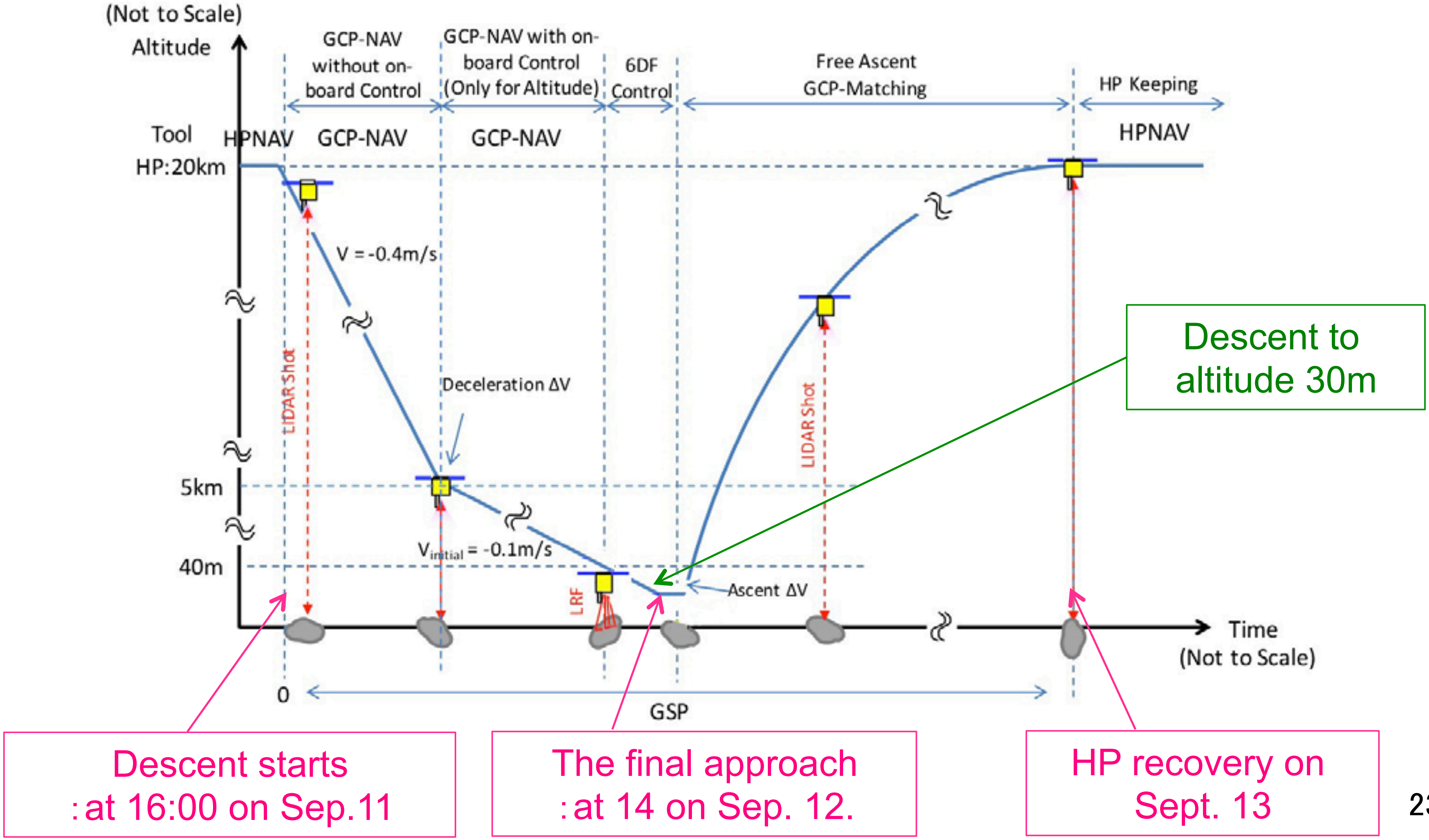
Touchdown 1 rehearsal 2: mid-October

Touchdown 1: late-October

Note: date of operations may be changed.

6. Rehearsal 1 for Touchdown 1

Outline: Touchdown rehearsal for information collection and abortion strategy development.



7. Future Plans

■Schedule for press briefings

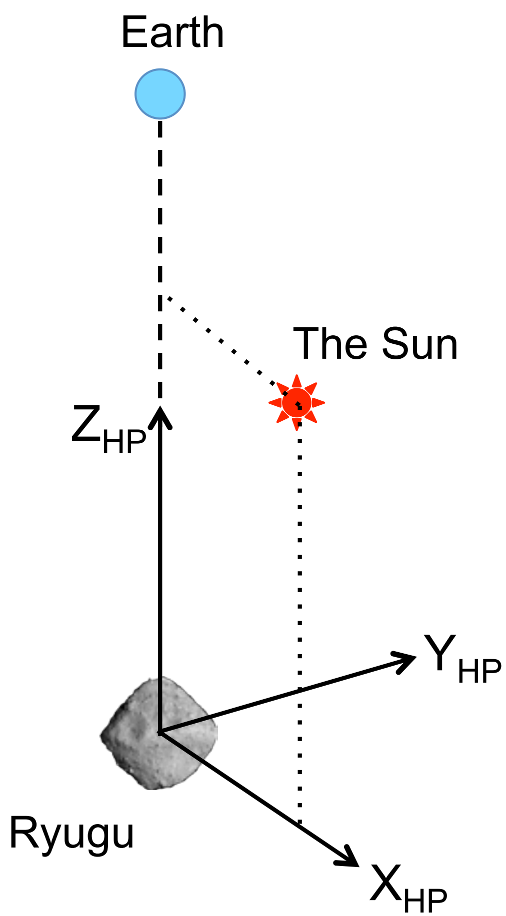
- Sept. 27（Thursday）15:30～16:30
- Oct. 11（Thursday）15:30～16:30 (TBD)

■Press Center (Sagamihara)

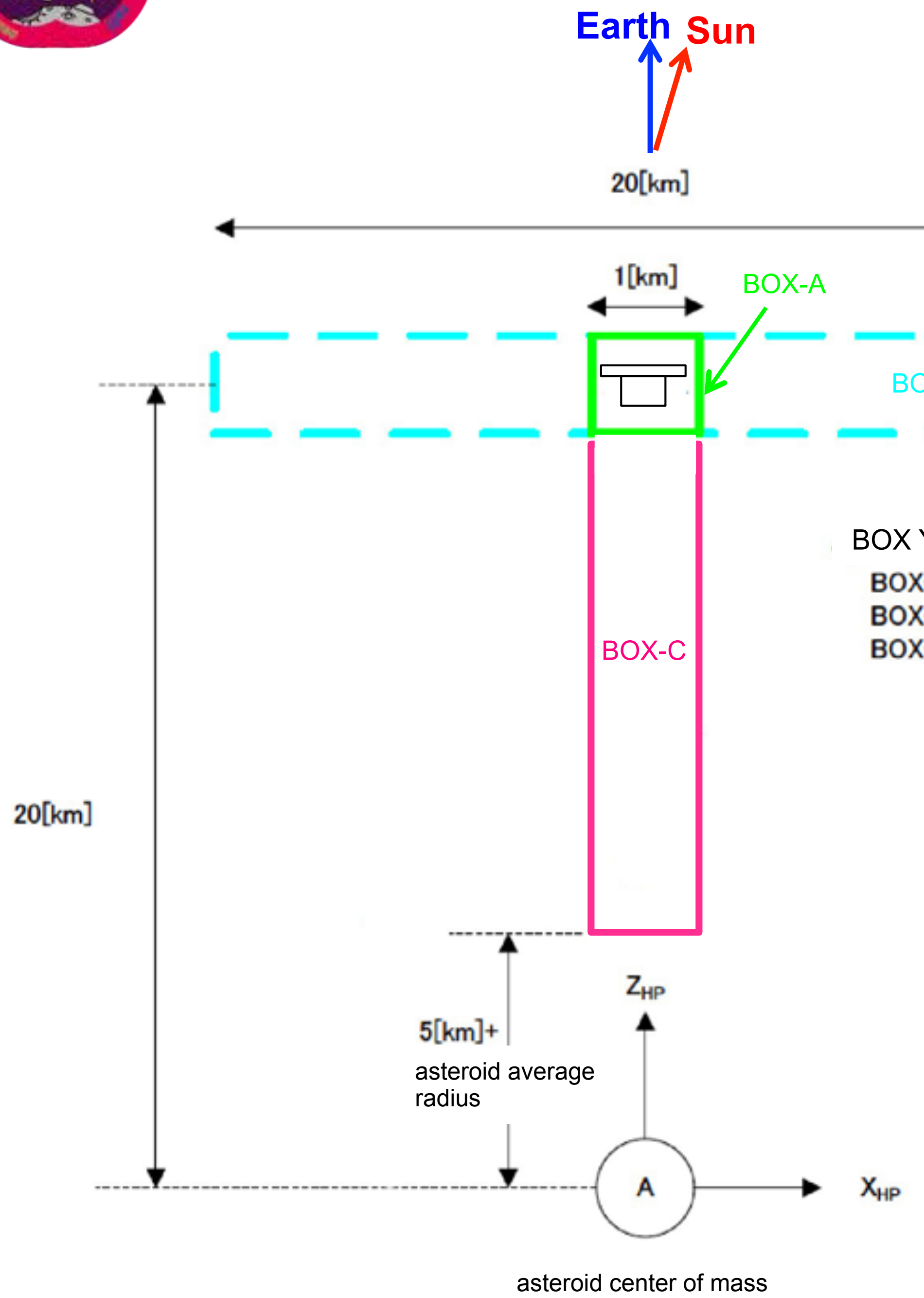
- Sept. 21 (Friday) : MINERVA-II Operation
- Oct. 3 (Wednesday) : MASCOT Operation

Reference

Home Position Coordinate System



BOX definition



Home position coordinate system (X_{HP}, Y_{HP}, Z_{HP})

(Reference material)

BOX Y_{HP}-direction size

BOX-A : 1[km](±500[m])
BOX-B : 20[km](±10[km])
BOX-C : 1[km](±500[m])

BOX-A operation : operations while hovering at 20km altitude. Regular operation standard.

BOX-B operation : Tour observation. Hovering area extended horizontally to enable observations to either side of the asteroid.

BOX-C operation : Hovering area extended vertically to enable observations at low altitude.

Selection of landing site candidates for MINERVA-Ⅱ

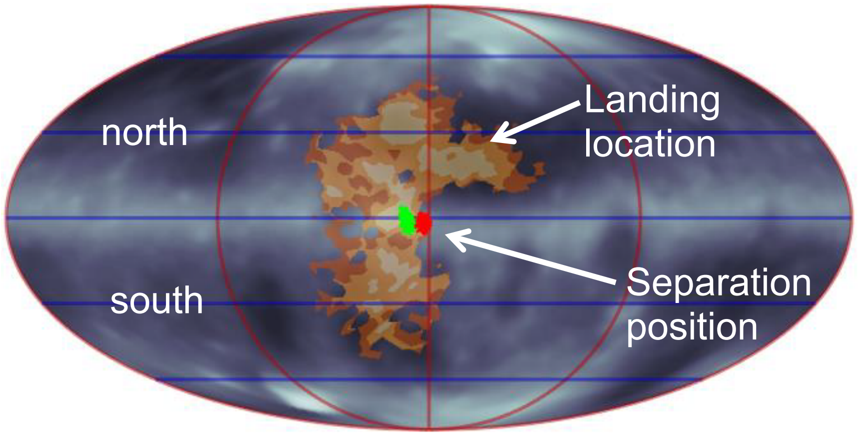
Conditions for MINERVA-II landing site selection：

- □ Landing site does not overlap with spacecraft touchdown candidates.
- □ Landing site does not overlap with MASCOT landing site candidates.
- □ The altitude of the spacecraft after separation must not be lower than 30m.
- □ Ensure communication with ground station.
- ■ Ensure communication with Hayabusa2 spacecraft.
- ■ Not high temperature region, and fewer parts in shadow

・Due to the equatorial ridge, separation near the equator results in widely spaced landing points to the north and south.

・Separating in the southern hemisphere may result in a spacecraft altitude below 30m.

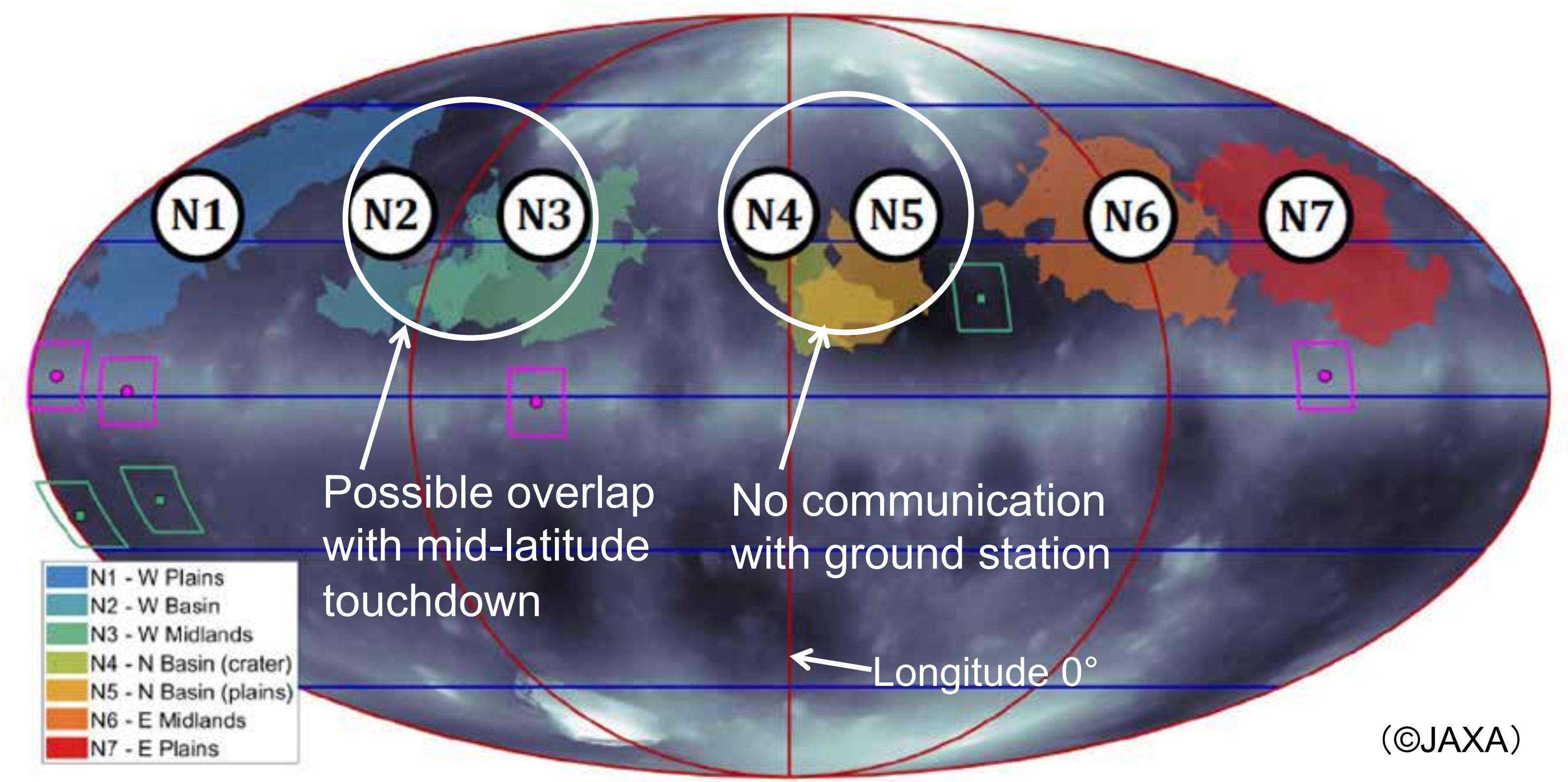
・Separate in northern hemisphere, more than 100m north of the equator.



When separating near the equator, the landing position spread north and south.

Selection of landing site candidates for MINERVA-Ⅱ

Landing site candidates for MINERVA-II: northern hemisphere



・Touchdown・confirm no overlap with MASCOT's landing site.
・Also consider observability etc. using the ONC-T camera.

Candidate locations：N6 > N1 > N7

Strategy toward the successful touchdown