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

July 19, 2018

JAXA Hayabusa2 Project

Today's Topics

Regarding Hayabusa2:

- Current status of the mission
- Science (remote sensing, sample, TIR)
- Mission schedule

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1. Current status and overall schedule of the project.
2. Anticipated scientific achievements
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5. Mission schedule
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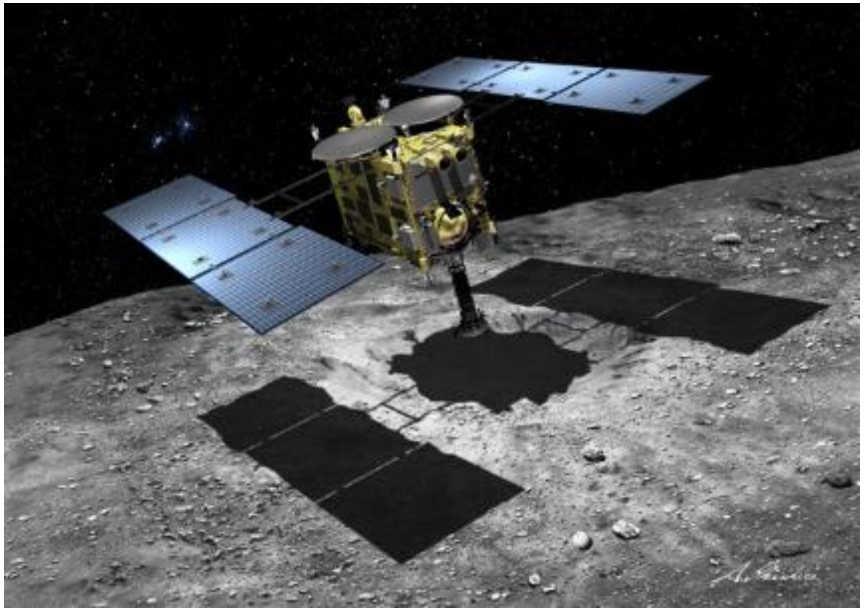
Overview of Hayabusa2

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	2018
Earth return	2020
Stay at asteroid	Approx. 18 months
Target body	Near-Earth asteroid Ryugu

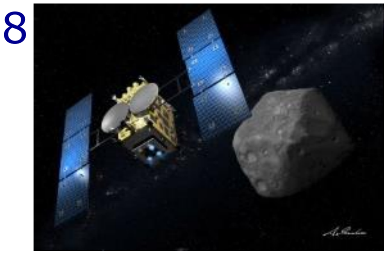
Primary instruments
Sampling mechanism, re-entry capsule, optical cameras, laser range-finder, scientific observation equipment (near-infrared, thermal infrared), impactor, miniature rovers.

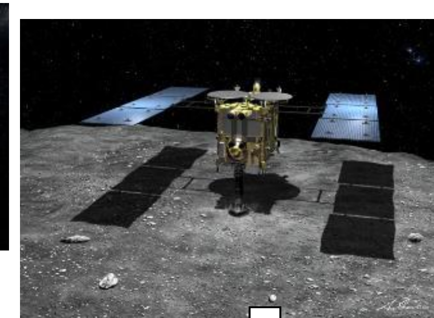
Mission flow

Launch
3 Dec 2014

Earth swing-by
3 Dec 2015

Arrival at asteroid
June 27, 2018

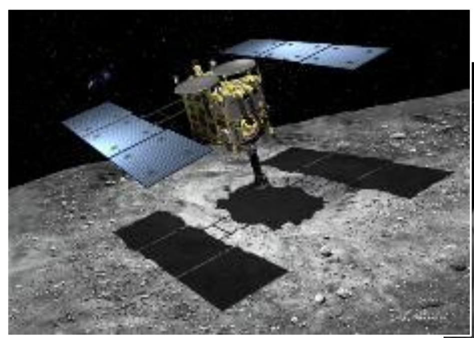




Examine the asteroid by remote sensing observations. Next, release a small lander and rover and also obtain samples from the surface.

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

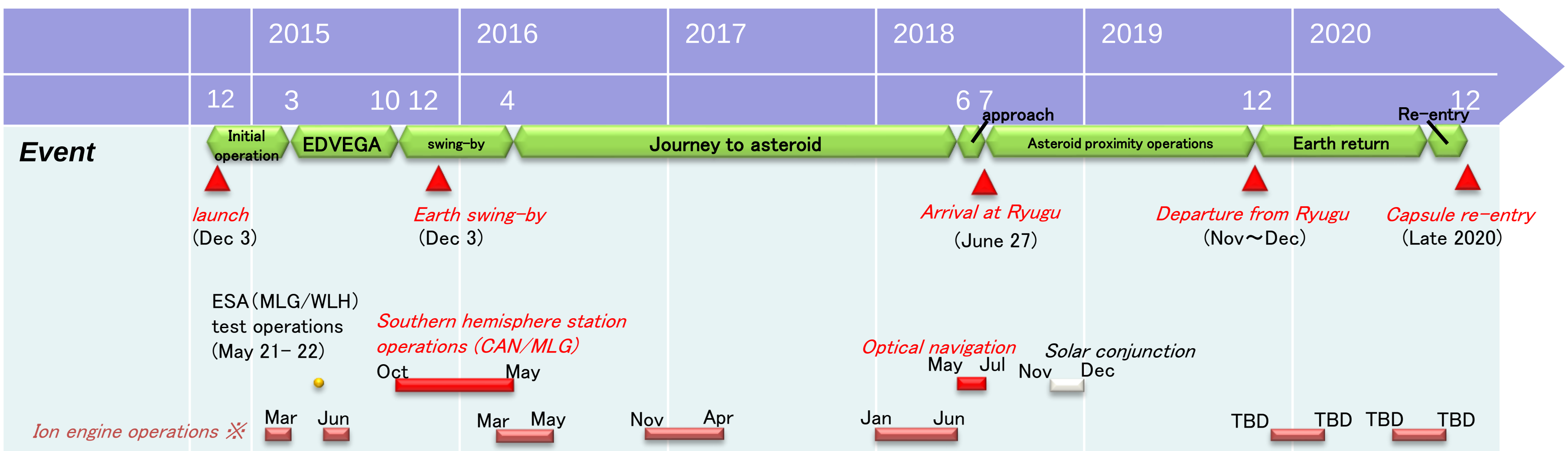
(Illustrations: Akihiro Ikeshita)

1. Current status and project schedule

Current status：

– Since arrival at Ryugu (June 27, 2018), the spacecraft has maintained the Home Position (BOX-A) at an altitude of 20 km.
– Remote analysis has continued using the onboard observational instruments (ONC, LIDAR, NIRS3, TIR).
– This week (July 16-) focused on preparation for the transition from BOX-A to low altitude (BOX-C), with the descent taking place today.

Schedule overview：

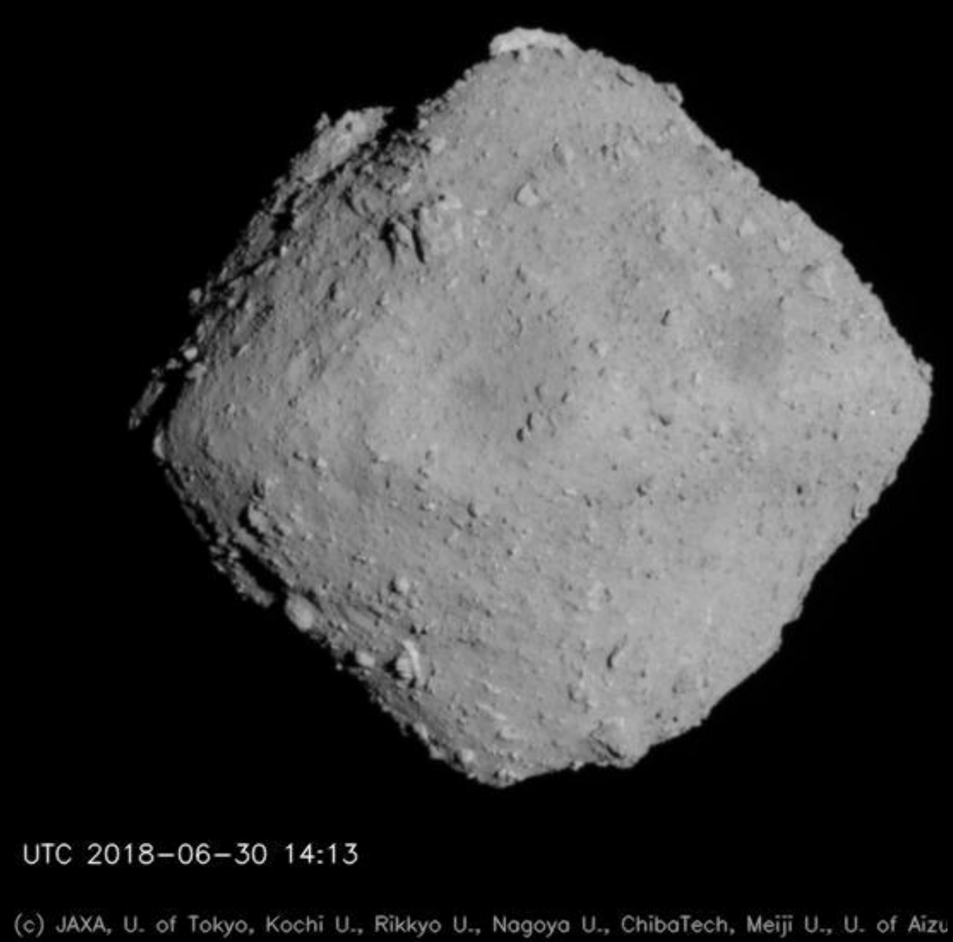


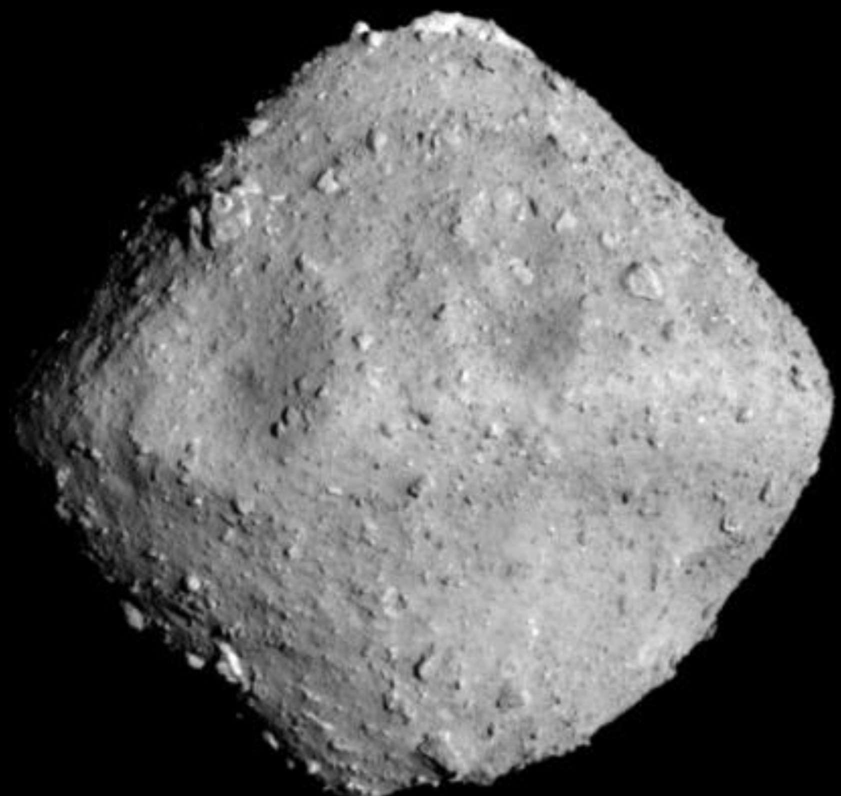
2. Anticipated Scientific Achievements

June 27, 2018　Arrival at Ryugu

2.1 Appearance of Ryugu

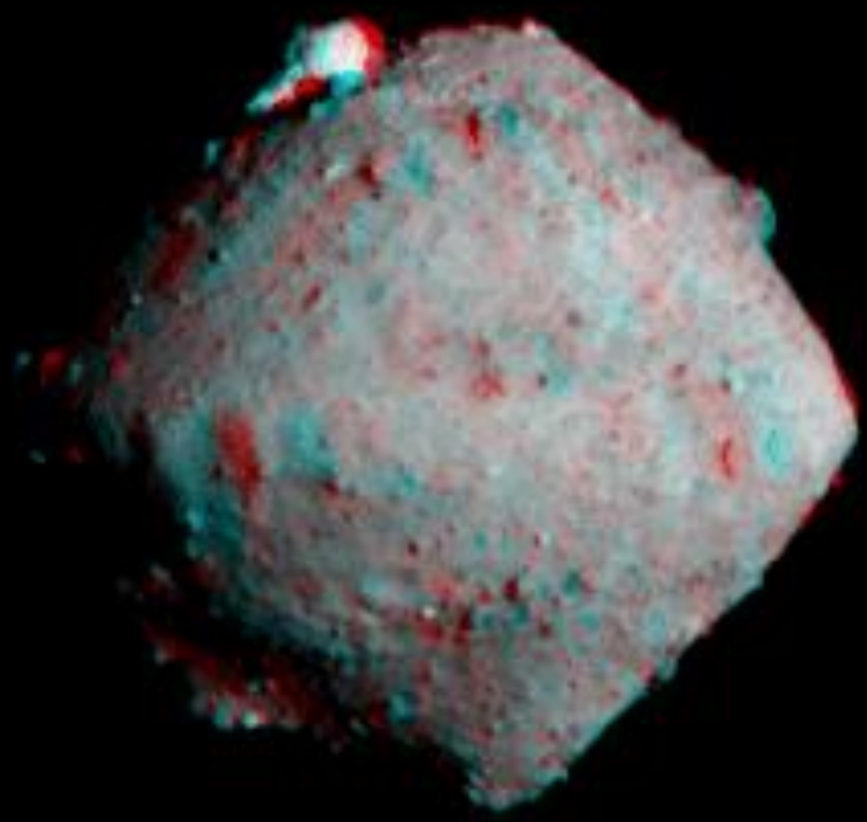
- The surface is very dark. The axis of rotation is nearly perpendicular to orbital plane.
- Features include craters, numerous boulders (including rocks up to 130m in size) and a grooved terrain.





UTC 2018-06-26 03:50

2.1 Appearance of Ryugu

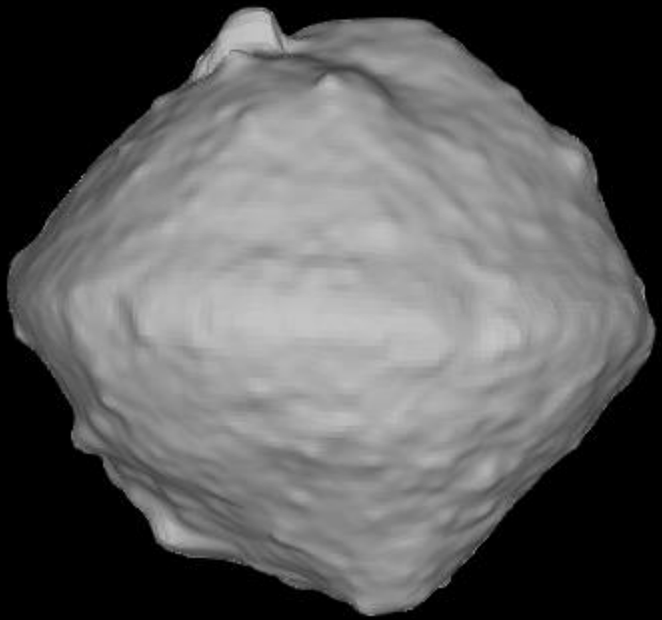


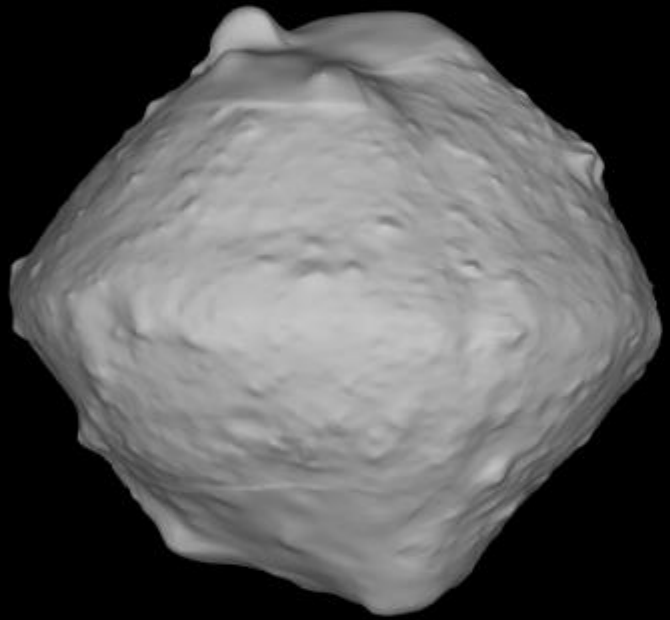
(animation）

Image credit：JAXA, University of Aizu, University of Tokyo, Koichi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, AIST

2.2 Shape Model of Ryugu

The shape model was constructed using two different methods, but they are in good agreement.





(animation)

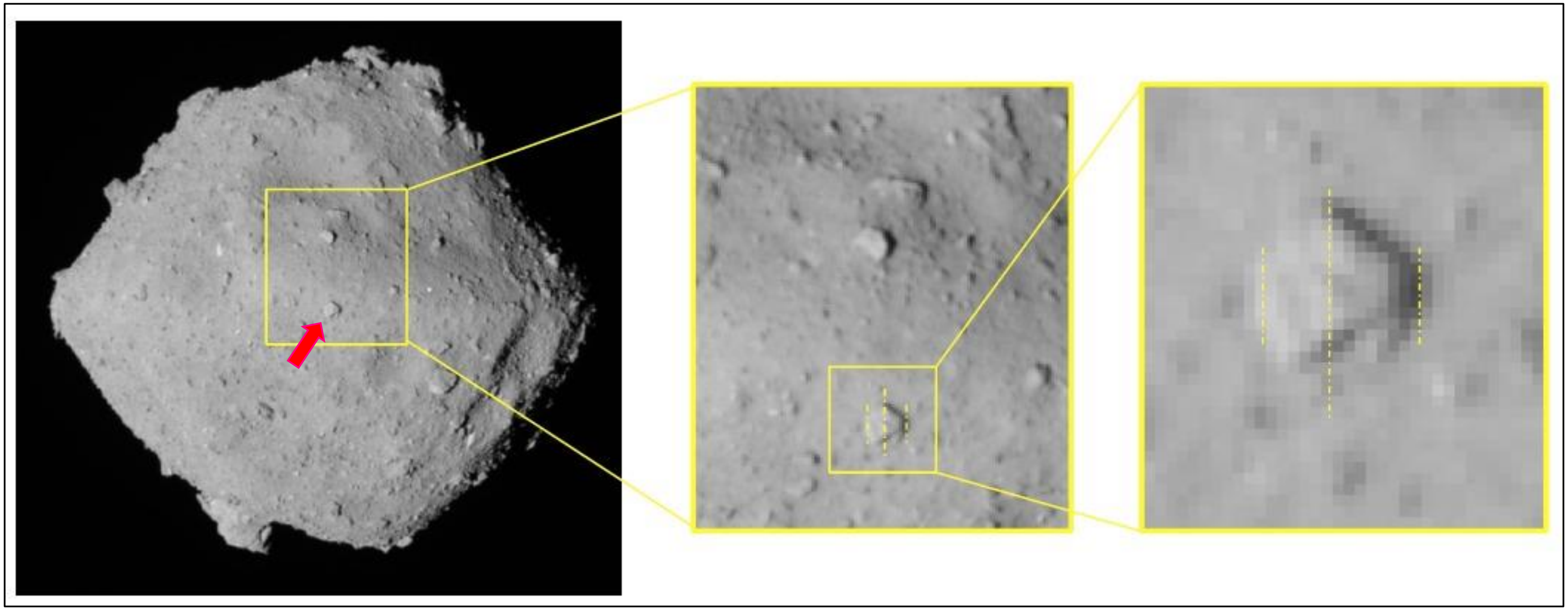
Shape model by the University of Aizu (SfM)

Shape model by Kobe University (SPC)

image credit：University of Aizu, Kobe University (shape models), Auburn University (movie), JAXA

2.3 Ryugu at zero degrees longitude

Selecting the position for zero degrees longitude



Credit ：JAXA, University of Tokyo, Koichi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST.

Selection：

・Early on, Project Members identified a prominent feature: 2 rocks that were vertically aligned.

・In the image, the lower rock is near the equator and creates a suitable landmark.

Note：The photograph here shows the asteroid's North Pole at the top (the opposite to the published images)

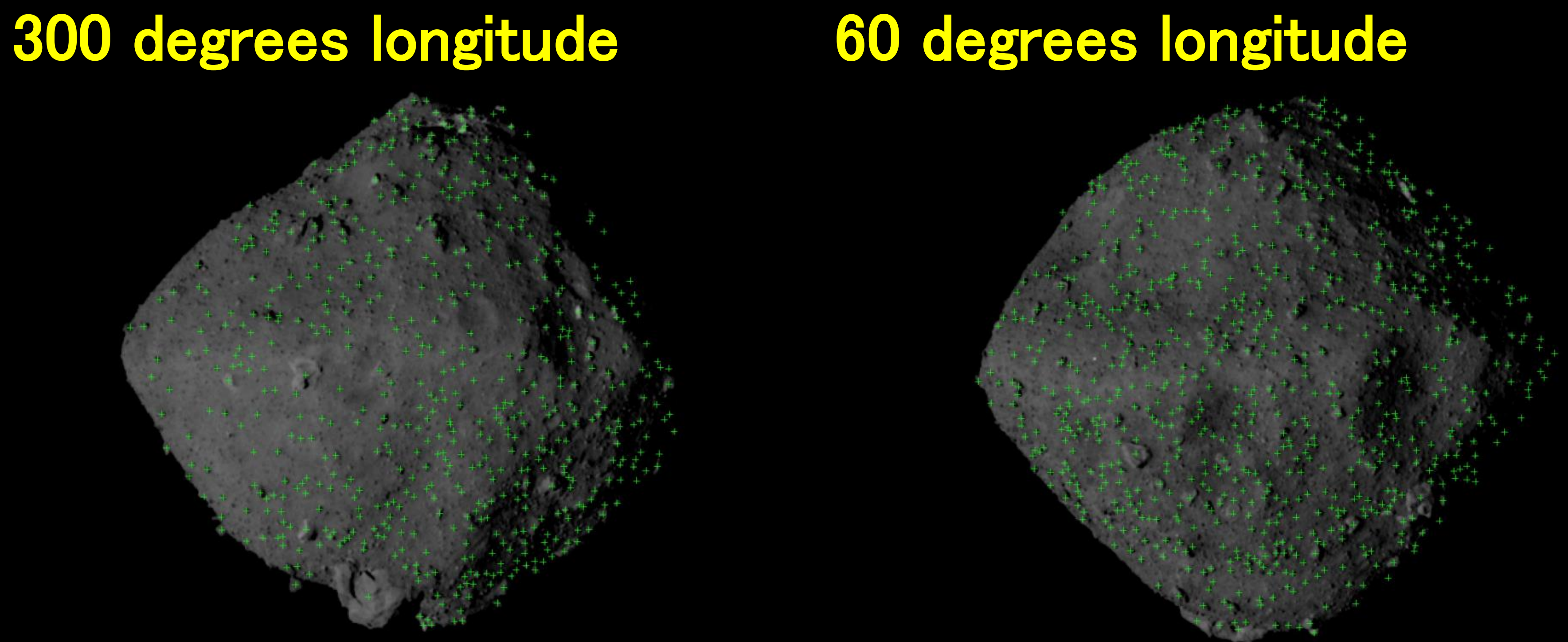
Reasons for selection：
・Good visibility
・The center is easily seen
・Notable topology
・Close to the equator

2.4 Mt Fuji and Ryugu at 20 km

(animation)

Created by Yasuhiro Yokota（JAXA）:（using http://www.city.fuji.shizuoka.jp/page/gazou/fmervo000001dsro.html ）

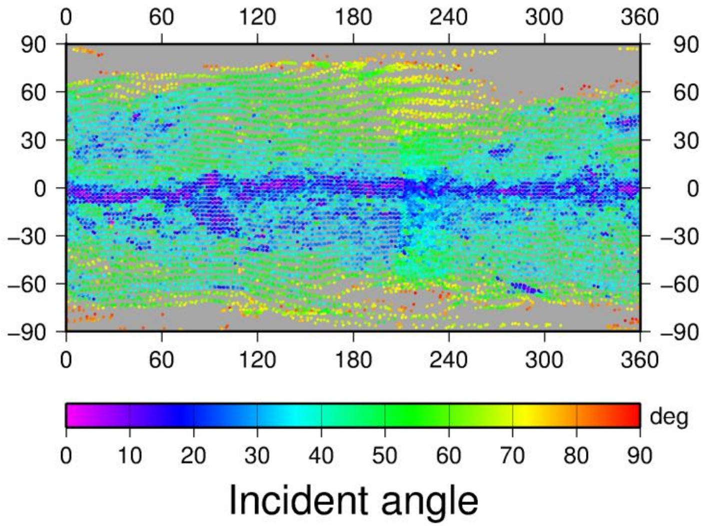
2.5 Boulder distribution on the surface of Ryugu



credit: Kindai University/JAXA/U. Tokyo/Koichi U./Rikkyo U./Nagoya U./Chiba Inst. Tech/Meiji U/U. Aizu/AIST

- There are many boulders on the small celestial body: possibly the asteroid consists of fragments of the parent asteroid.
- The number density (number per unit area) varies greatly over the surface.
- The distribution of boulders is key to deciding the best location for the touchdown points where the surface samples will be collected.
- The distribution is also useful for understanding and confirming surface material migration.

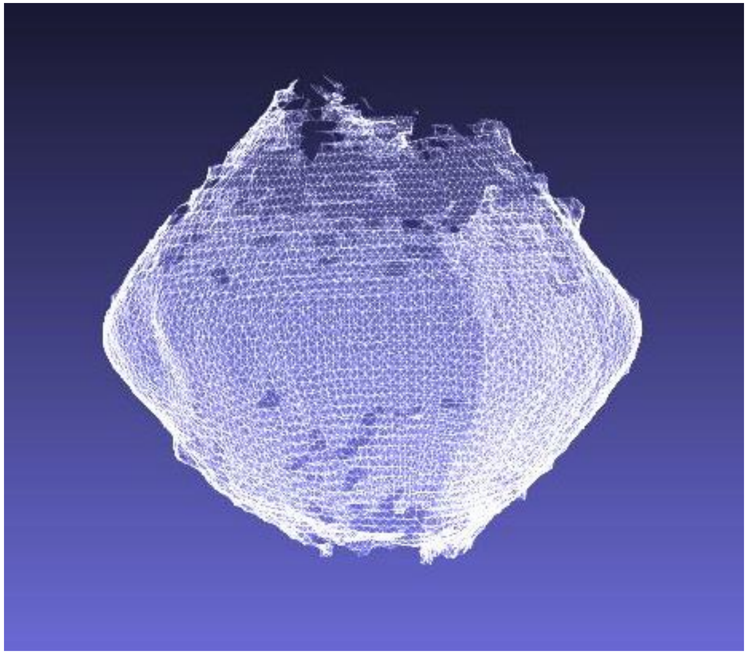
2.6 LIDAR Shape Measurement



Global topographical data for Ryugu was acquired from a LIDAR scan on July 11.

(Top) Map showing the distribution of the measured points. Color indicates the angle between the laser irradiation and the asteroid surface (irradiation from directly overhead is zero degrees). Surface data (to calculate the angle) was acquired from the shape model.

(Right) Shape of Ryugu measured by the laser altimeter. It almost coincides with the shape model.



Credit: NAOJ/JAXA/Chiba Institute of Technology/U. of Aizu/Nihon U./Osaka U.

2.7 Anticipated scientific achievements

- **Visible (ONC) ･Near infra-red（NIRS3）reflection spectrum: dark and flat.**
  - Characteristics of Ryugu's reflection spectrum differ from any meteorite.
  - On the other hand, it resembles that of comets and asteroids.
  - Very dark surface: possibility of high abundance of carbonaceous material.
  - While nearly homogenous, there are also regional characteristics, so we await future precise analysis.

- **Reconstruction of the parent body of Ryugu**
  - The big boulders suggest that Ryugu formed by the accumulation of debris from the destruction of the parent asteroid.
  - Narrow down the Landing Site Selection (LSS) based on observational results:
    - First of all, the safety and scientific value is evaluated.
    - Details of the potential sample material and understanding of the geological context.
  - Verification upon sample return, comparison with OSIRIS-Rexe exploration results.

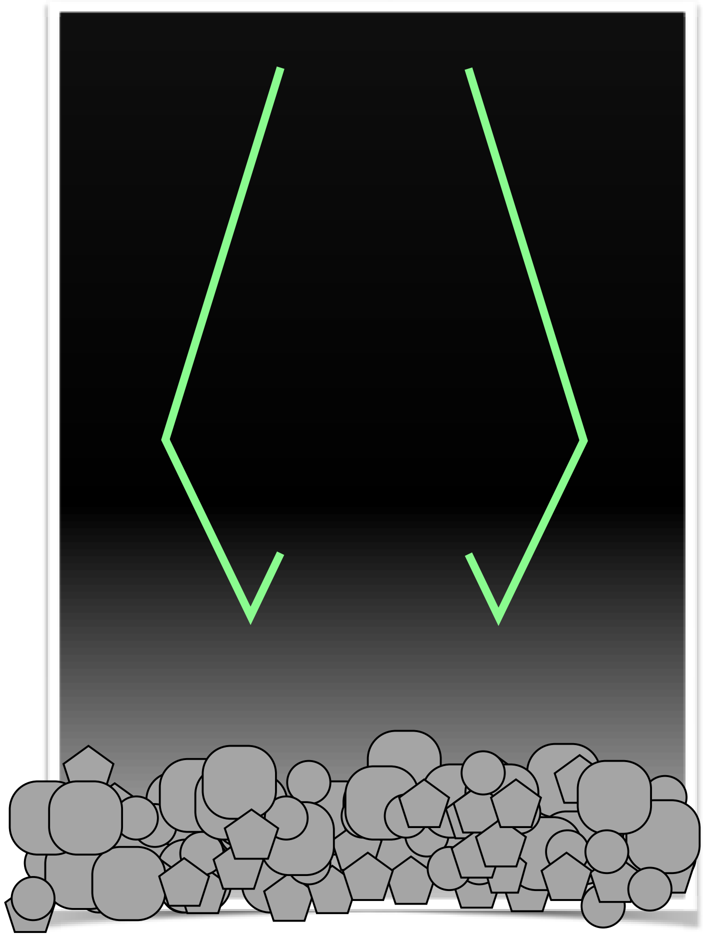
3. Expectation for sample analysis

Hayabusa2 sample:

Scientific analysis requires a minimum sample of 100 mg collected from multiple locations (3 areas) on the surface of the celestial body, analyzed promptly with state-of-the-art technology in 2020 without terrestrial contamination.

1. Surface particles are collected by firing bullets (make from 5 g of tantalum) inside the sample horn.

3. Expectation for sample analysis



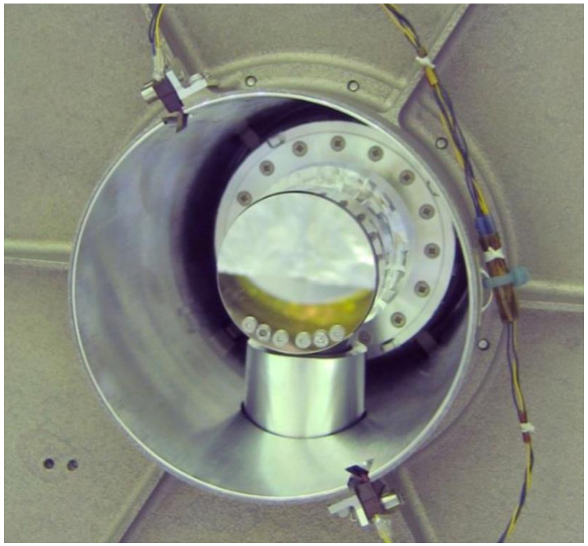
(アニメーション)

Hayabusa2 sample：

Scientific analysis requires a minimum sample of 100 mg collected from multiple locations (3 areas) on the surface of the celestial body, analyzed promptly with state-of-the-art technology in 2020 without terrestrial contamination.

2. Surface particles are collected by using the inverted tip of the sampler horn.

3. Expectation for sample analysis



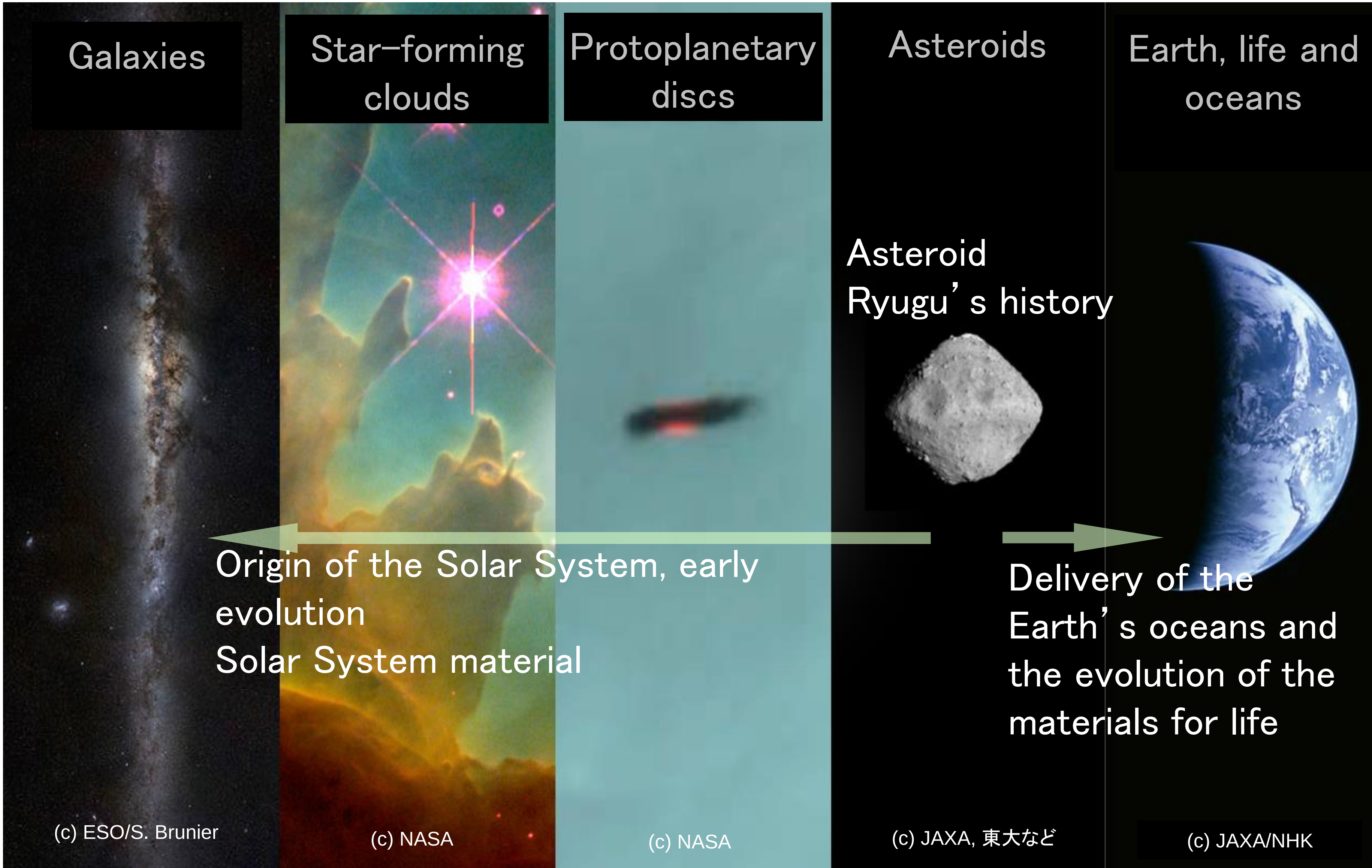
Sample catcher：

Stores collected particles. Samples collected from the three surface locations are separately stored in the three-sectioned structure.

Sample container:

Seal the sample container, store and return to Earth. Any gas component generated from the sample can also be analyzed.

3. Expectation for sample analysis



3. Expectation for sample analysis

Initial analysis of the Ryugu sample (2021–)
・Scientific desciprtion of the Ryugu sample
・Scientific understanding of the observations of the material.
・Information leading to greater understanding of the origin of the Solar System, the oceans on the Earth and the evolution of the materials for life.

6 teams:
1. Chemical analysis team
2. Petrology and mineralogy team for the coarse sample
3. Petrology and mineralogy team for the fine grain sample
4. Volatile materials analysis team
5. Condensed organic matter analysis team
6. Organic molecule analysis team

・Present scientific signifcance of the Ryugu sample.

4. Initial observational results with the mid-infrared camera

Outline of the TIR observation

Light curve released

★Observation & Operation of the TIR

06/06　TIR observation check
06/07　Ryugu light curve observation (1)@2000km, diameter ～0.5 pixels.
06/18　Ryugu light curve observation (2)@200km, diameter ～5 pixels.
06/09−22　Ryugu・1 shot imaging (almost daily)

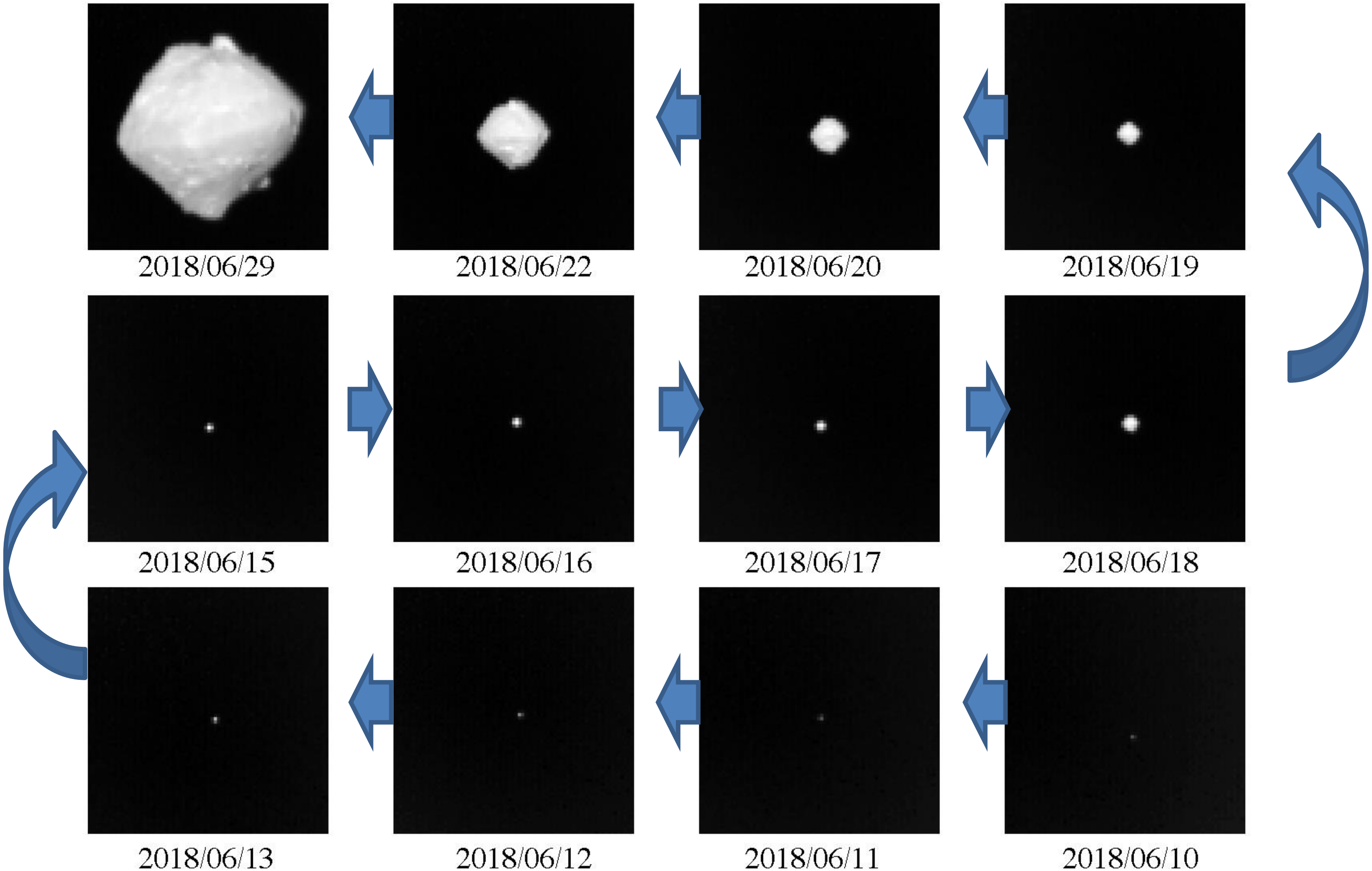
Ryugu is getting bigger (now) !!

06/27　＜Arrival at Ryugu＞
06/29　Dark observation (orientated towards deep space)
06/30　Global observation of Ryugu (1)@20km, diameter～50 pixels.
07/02　Observation to survey image distortion
07/03　TIR observation program update

Thermography published (now) !!

4. Initial observational results with the mid-infrared camera

Ryugu growing steadily larger

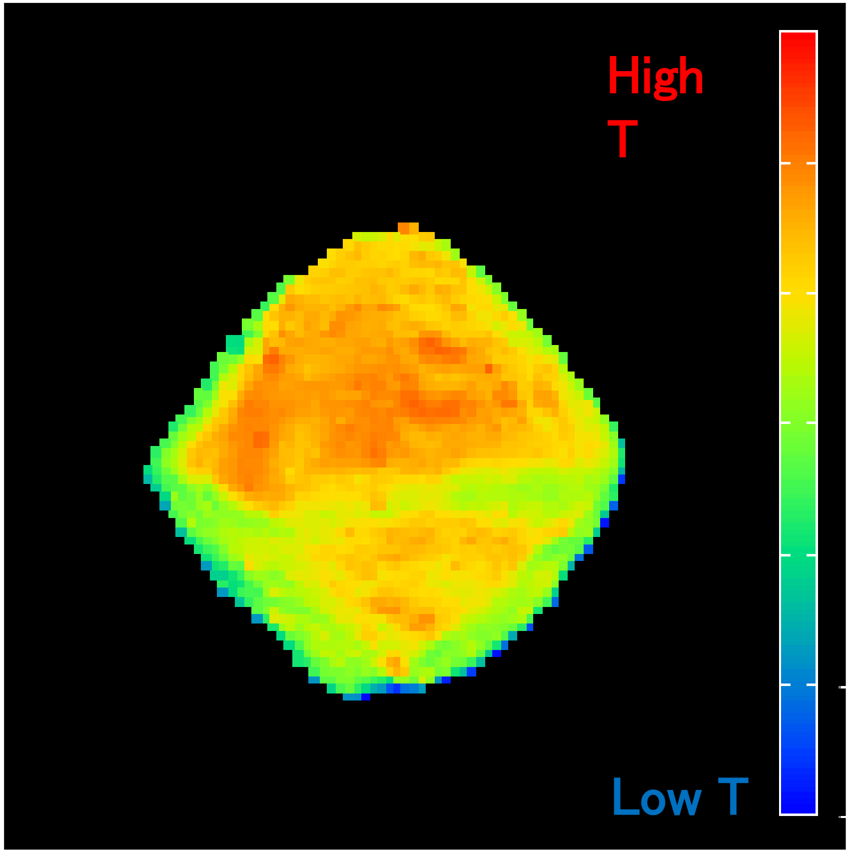


Provided by：JAXA, U. of Aizu, Rikkyo U, Chiba Institute of Technology, Ashikaga U., Hokkaido University of Education, Hokkaido Kitami Hokuto High School, AIST, National Institute for Environmental Studies, U. of Tokyo, DLR, Max Planck Institute, Stirling U.

4. Initial observational results with the mid-infrared camera

TIR Thermography（1 rotation）

Image date & time：June 30, 2018, 07:02 – 14:45（UTC）, every 8 minute, 1 rotation
Image capture location ：20 km altitude above Ryugu（home position）, ~20m／pixel
Solar distance：0.987AU（1AU：annual average distance between the Earth and Sun：~1.496 billion km）



(animation）

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4. Initial observational results with the mid-infrared camera

TIR Thermography（feature）

Image date & time：June 30, 2018, 07:02 – 14:45（UTC）, every 8 minute, 1 rotation
Image capture location ：20 km altitude above Ryugu（home position）, ~20m／pixel
Solar distance：0.987AU（1AU：annual average distance between the Earth and Sun：~1.496 billion km）

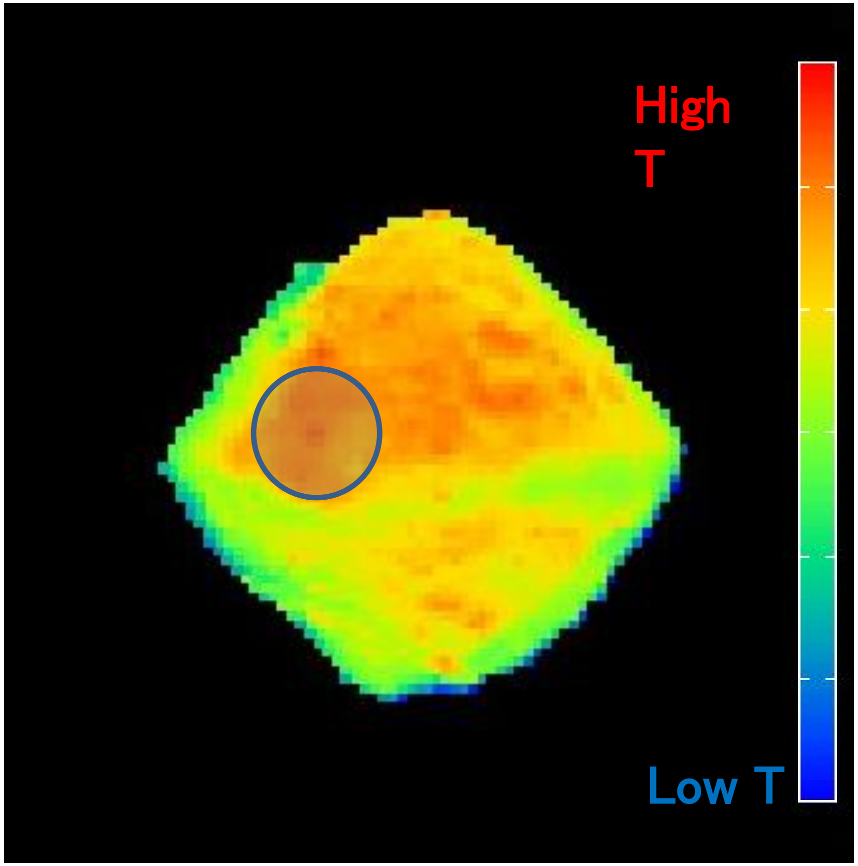
★Main features

・Capture of the characteristic terrain（overall shape, huge crater・boulder）

・North−South temperature difference（seasonal change due to inclination of rotation axis: summer/winter ）

・Morning ～noon～evening temperature cycle captures

・Absolute temperature (in progress)



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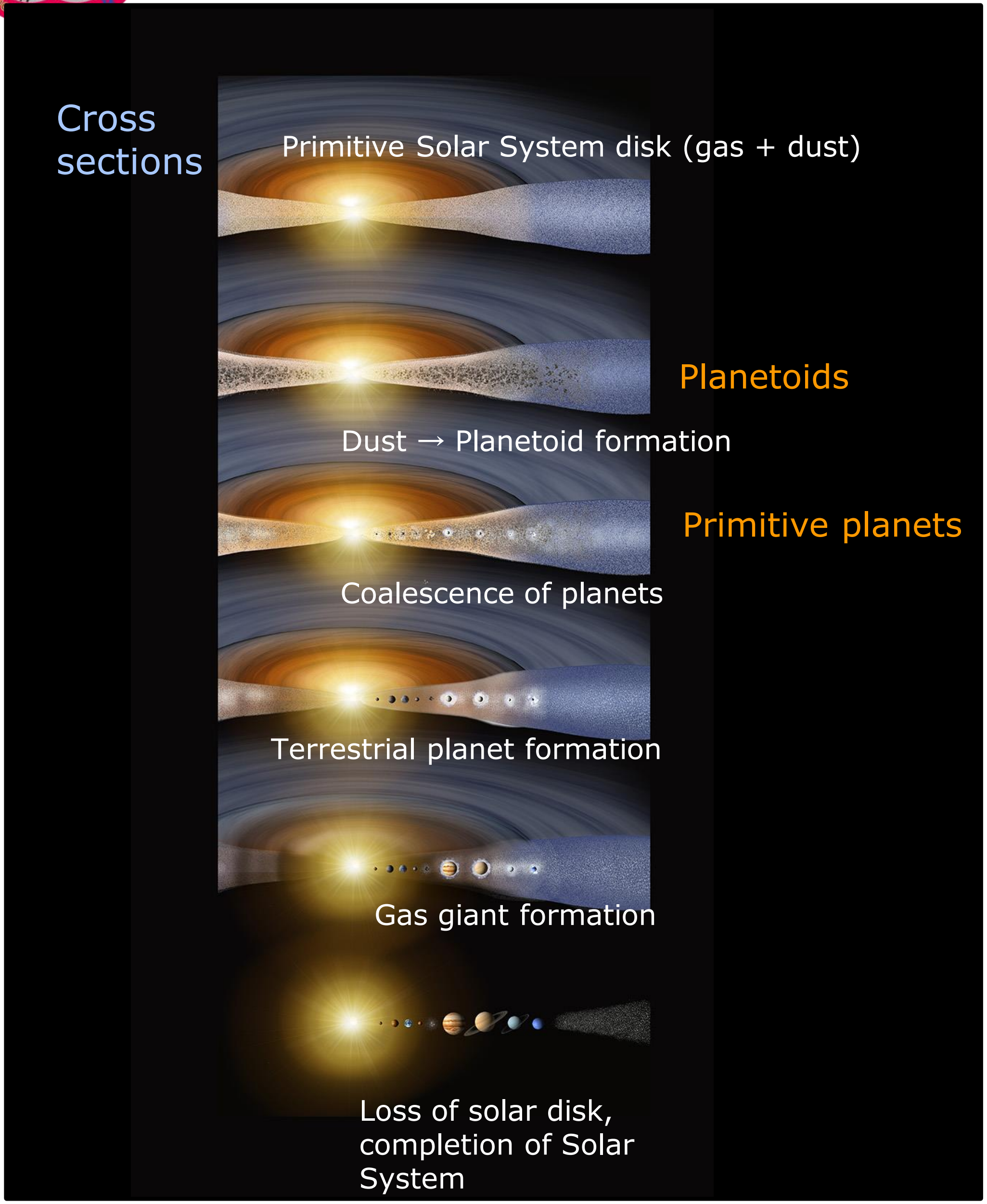
Science: Elucidating the birth and evolution of the Solar System



Topics

① Investigating the materials that formed the planets

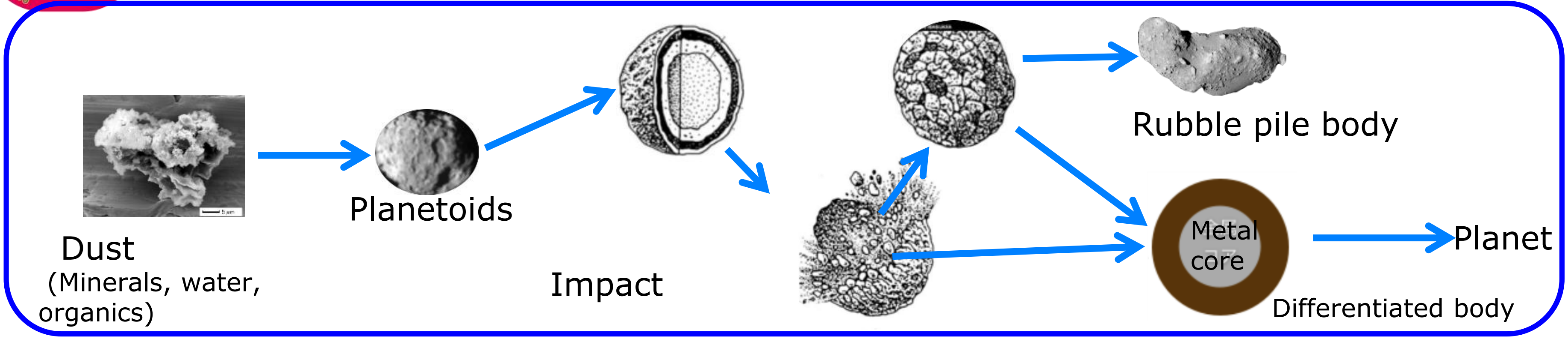
What materials existed in the primitive Solar System disk, and how did they change up to the formation of planets?

② Investigating the formation processes of the planets

How do celestial bodies grow from planetoids to planets?

Ref: from fact sheet

② Investigating planetary formation



- Elucidate the structure of planetoids that eventually became planets.
- Elucidate what processes occurred during the collisions, coalescence, and accumulation of celestial bodies.

↓

Elucidate formation processes from planetoid to planet

Keywords:

- Rubble pile body: A celestial body formed from accumulated rubble
- Impacts and coalescence: When celestial bodies collide, the resulting fragments can combine to form a new body
- Accumulation: Accumulation of fragments resulting from a collision via the force of gravity

4. Initial observational results with the mid-infrared camera

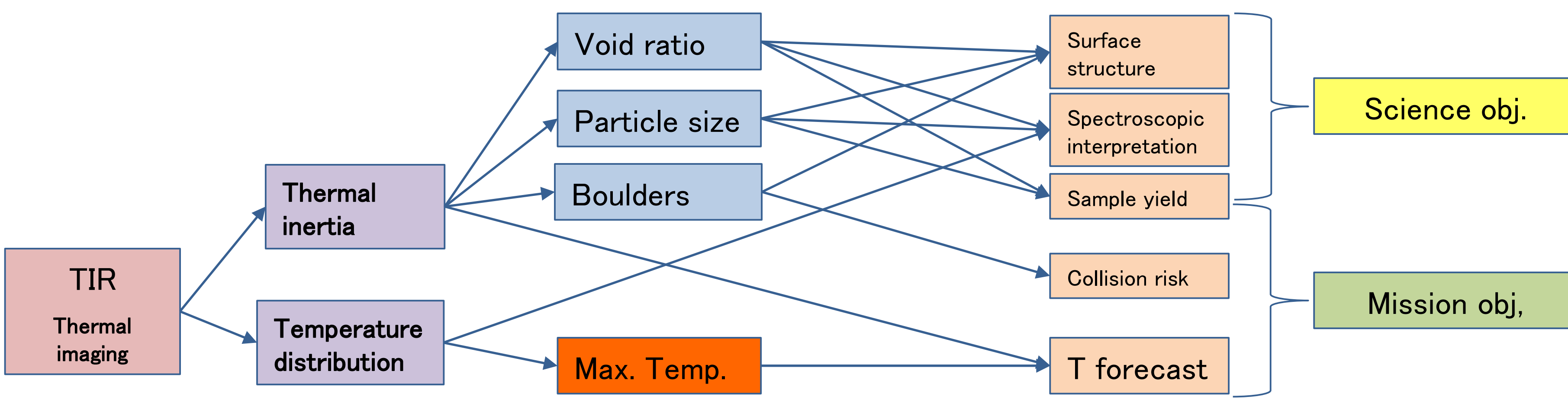
Contribution of the TIR to the Landing Site Selection (LSS)

★Science objectives：scientific features of asteroid Ryugu

- ◆ Estimation of geological features at the asteroid surface layer（rocky, gravel, sand etc）
- ◆ Interpretation of spectroscopic data（eliminate influence from particle size voids and head radiation）
- ◆ Sample selection and yield（select region where a sample with varying particle sizes can be collected）

★Mission objectives：perform safe & reliable operation of the spacecraft

- ◆ Increase in sample yield（select region with particle sizes suitable for collection by sampler）
- ◆ Temperature forecast（exclude areas that are too hot for the spacecraft）
- ◆ Avoid obstacles（select from regions with less dangerous rock masses for the spacecraft）



4. Initial observational results with the mid-infrared camera

TIR Observation：summary

- Successful global thermal imaging of the asteroid (excluding part of the polar regions) by TIR!

  This is a first for two-dimensional imaging of a small body at 10μm

- Detection of characteristic terrain and seasonal changes on asteroid Ryugu by thermal imaging!

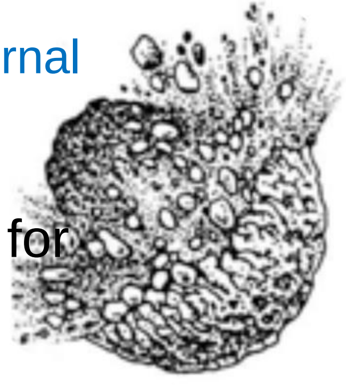
  Overall shape, huge crater and boulders, north and south temperature difference.

- Measurement of thermophysical characteristics of the “boulder” originating from within the parent body! ⇒ Future detailed investigation

  Elucidate the formation of asteroid Ryugu and the process of internal evolution!

- Acquire information on both science and mission necessary for selecting landing sites!

  Particle size distribution, temperature environment, collision avoidance etc.



5. Mission Schedule

Current operation plan

- Normal observation is from the Home Position with an altitude of about 20 km　＝　BOX-A

- Lower altitude operations:
    - BOX-C operation：Jul. 17-2, lowest altitude approximately 6km（7/20～22）
    - Medium & high altitude operation：Aug. 1-2, lowest altitude approximately 5km（8/1）
    - Gravity measurement and descent operation: Aug. 6-7, lowest altitude approximately 1km（8/7）

- Tour observation
    - BOX-B operation：late Aug.

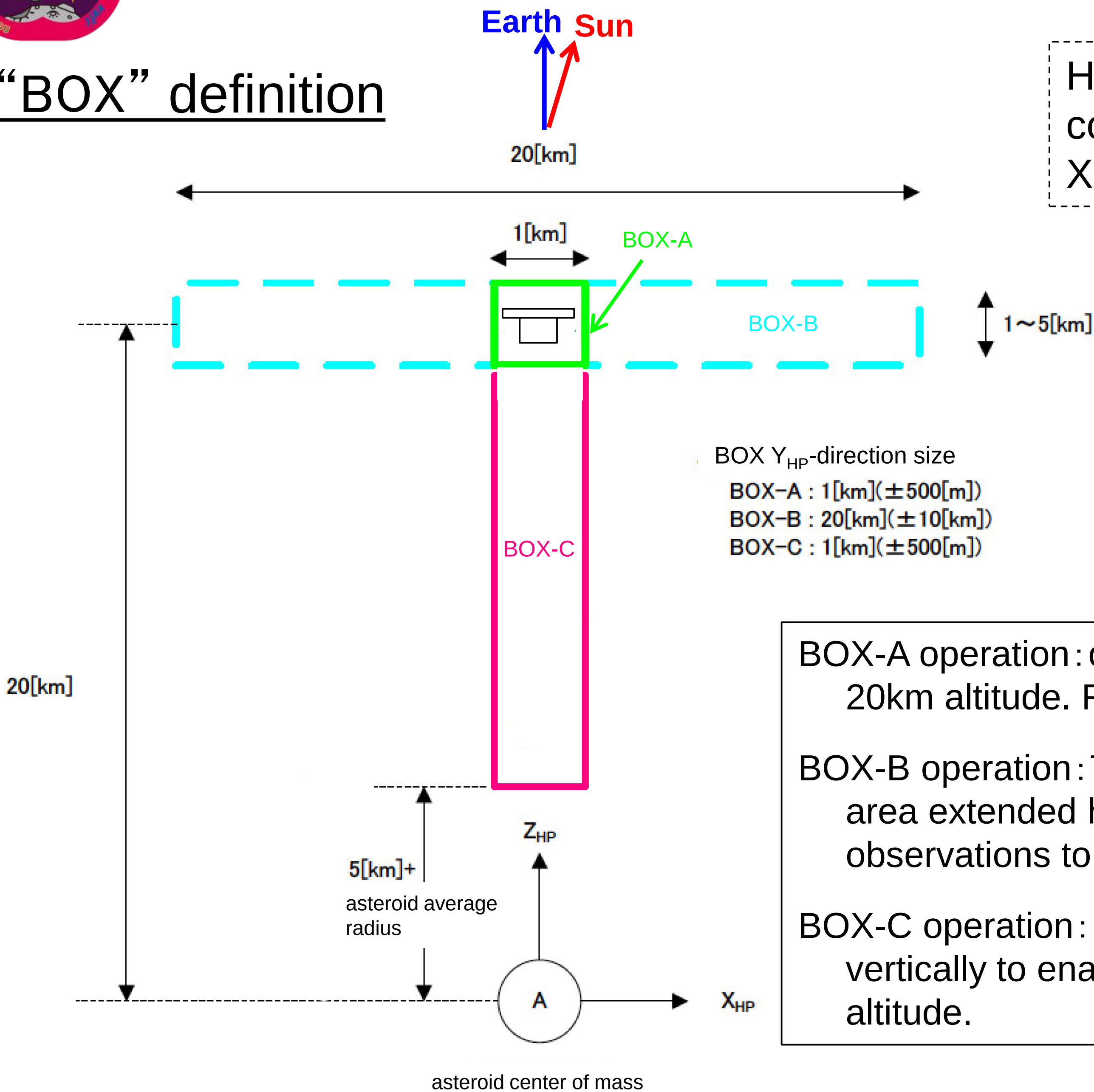
※ “BOX” is explained on the following slide

5. Mission Schedule

"BOX" definition

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

(Reference material)



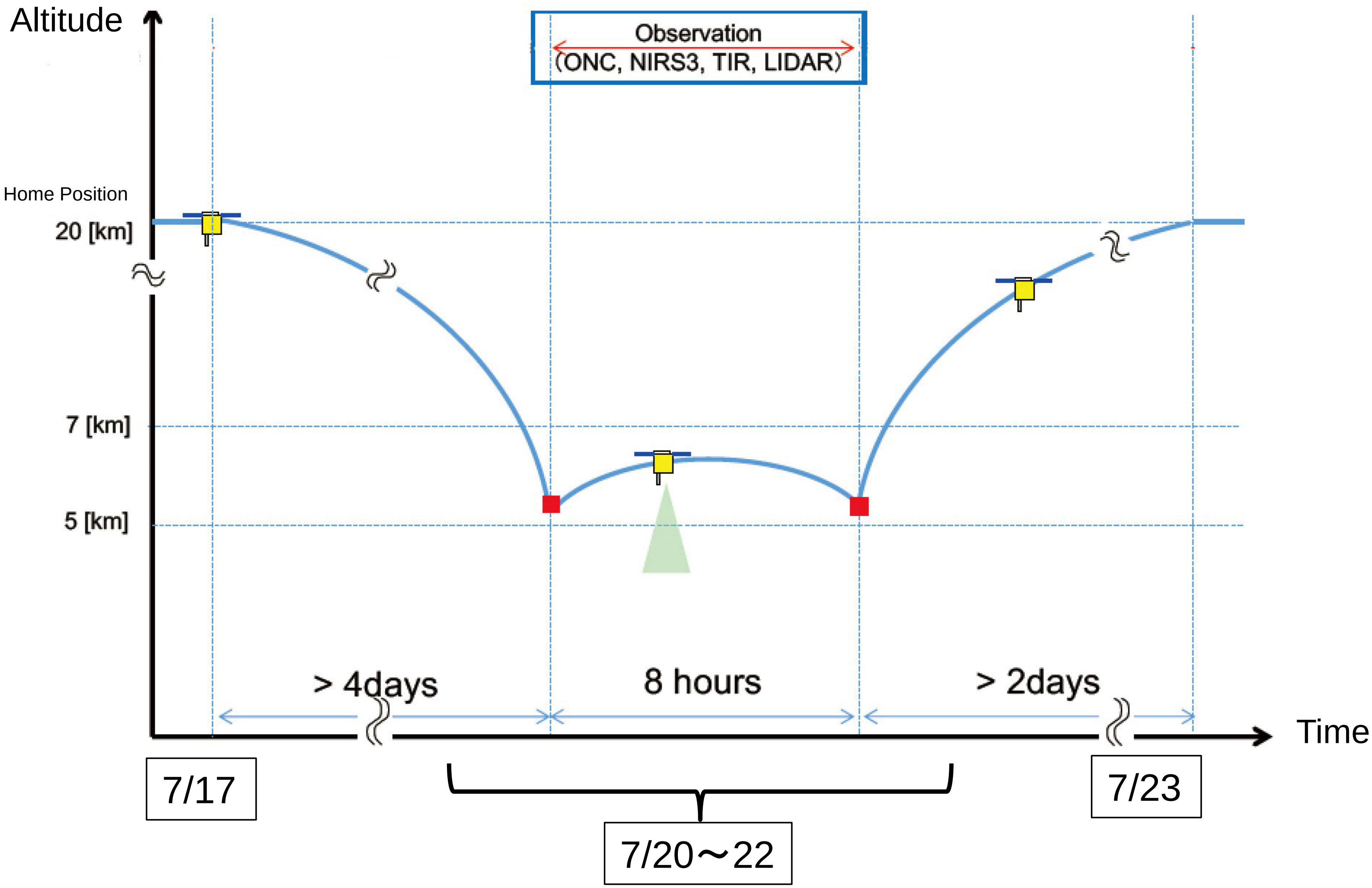
BOX-A operation: operations while hovering at 20km altitude. Regular operation standard.

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.

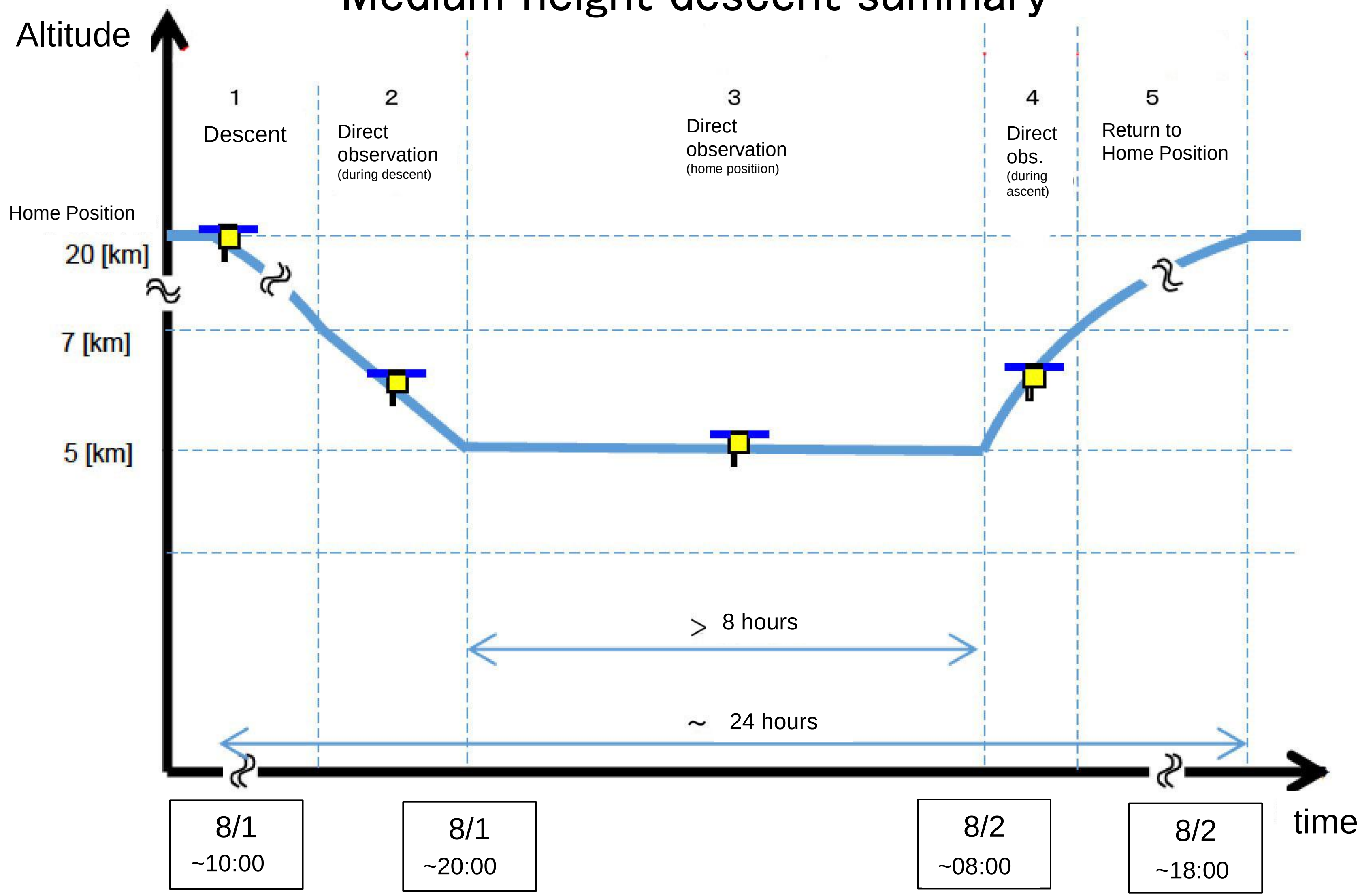
5. Mission Schedule

BOX-C operation summary



5. Mission Schedule

Medium height descent summary



※ Time in JST. This may change depending on adjustments in the operation plan and situation

5. Mission Schedule

Medium height descent summary

No	Phase	Overview	Altitude
1	Descent from Home Position	Descent from Home Position. Use the same descent technique (GCP-NAV) as touchdown. NIRS3 is ON.	20～7 km
2	Direct Observations (Descending)	ONC-T、TIR observations start. Directly image surface below.	7～5 km
3	Direct Observations (Hovering)	While maintaining 5km altitude, directly image surface below.	5 km
4	Direct Observations (Ascending)	After accelerating to ascend, directly image the surface below until an altitude of 7km.	5～7 km
5	Return to Home Position	While ascending, begin the data downlink	7～20 km

※For GCP-NAV see next slide.

5. Mission Schedule

Comparison between medium height descent operation and BOX−C operation

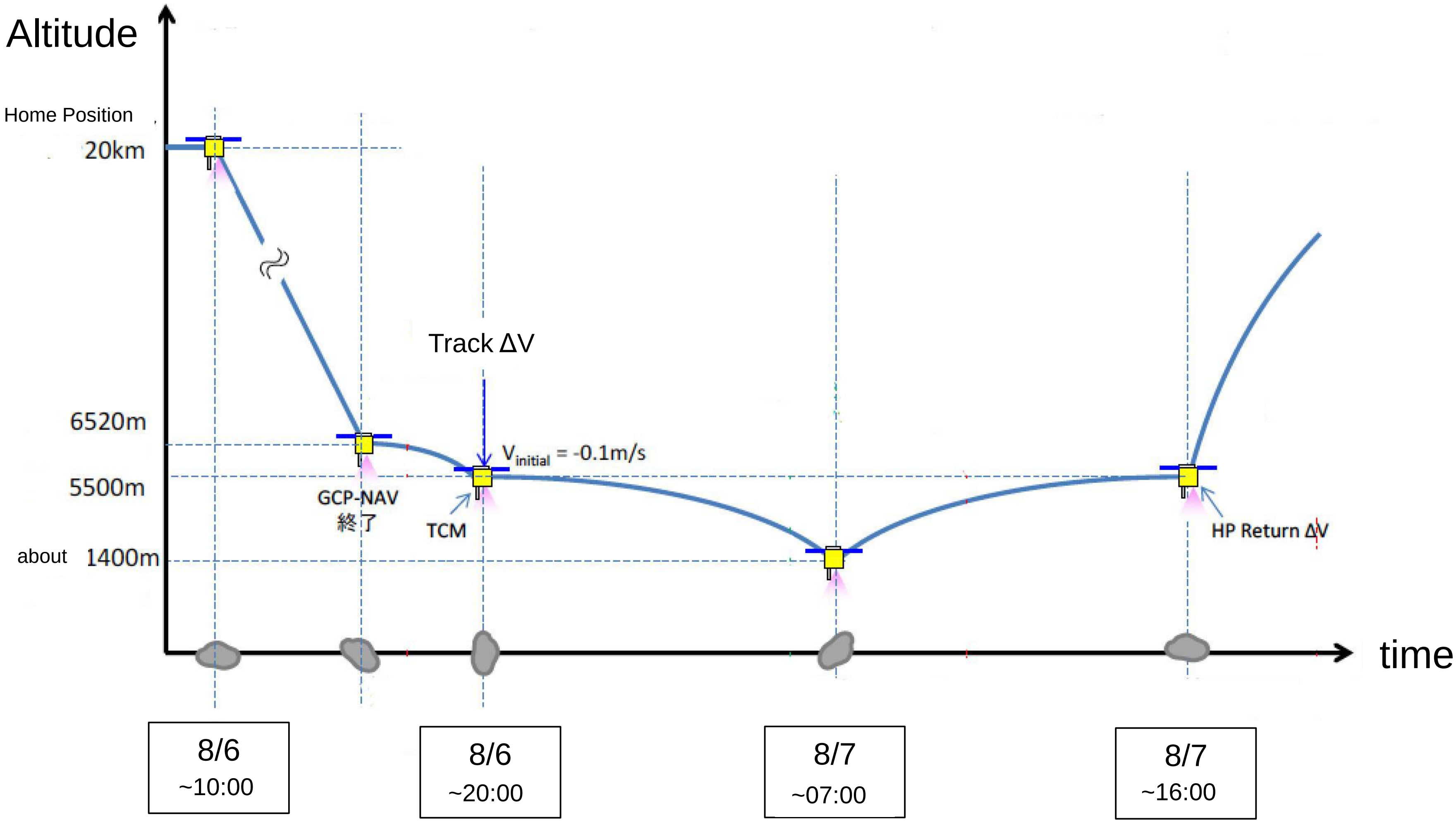
Phase	Medium height descent	BOX-C operation
Descent time	Half-day	Descent over several days
Position control during descent	GCP-NAV	HPNAV
Position control during observations	GCP-NAV Hovering using HPNAV	Free motion depending on advanced ΔV
Observation time	8 hours	About 10 hour
Observation angle	+Z towards Earth	Scan operation implemented
Operation concept	Reduce altitude and observe at a target point and angle. (Precisely guide down to a target point in the same manner as landing)	Reduce altitude while hovering. (Approximately reduce the altitude by extending the same hovering technology)

Note：GCP-NAV (Ground Control Point Navigation)
→ A method of finding the position & speed of the spacecraft by observing features on the asteroid surface.

HPNAV (Home Position Navigation)
→ A method of finding the position & speed of the spacecraft from the direction to the image center and attitude data of the spacecraft

5. Mission Schedule

Gravity measurement descent operation overview



※ Time in JST. This may change depending on adjustments in the operation plan and situation

5. Mission schedule

Year	Month, day	Event	Status
2018	January 10	Third stage of ion engine operation begins	Complete
	June 3	Ion engine operation ends	Complete
	June 3	Start of asteroid approach (distance: 3100km)	Complete
	June 27	Arrival at asteroid Ryugu (altitude 20km)	Complete
	End of July	Medium altitude observations #1 (alt. 5km)	Planning
	August	Decent to measure gravity (alt.1km)	Planning
	Late August	Determination of landing site	Planning
	Sept – Oct	Period for touchdown operation #1	Planning
	Sept – Oct	Period for rover deployment #1	Planning
	Nov – Dec	Solar conjunction (communication unavailable)	Planning
2019	January	Medium altitude observations #2 (alt. 5km)	Planning
	February	Period for touchdown operation #2	Planning
	Mar – Apr	Crater generation operation	Planning
	Apr – May	Period for touchdown operation #3	Planning
	July	Period for rover deployment #2	Planning
	Aug – Nov	Remain near asteroid	Planning
	Nov – Dec	Departure from asteroid	Planning

This schedule may be changed for multiple factors after arrival at Ryugu. Please note therefore, that the situation is not fixed, except where marked ‘Complete’.

6. Future Plans

■Media coverage and information release:

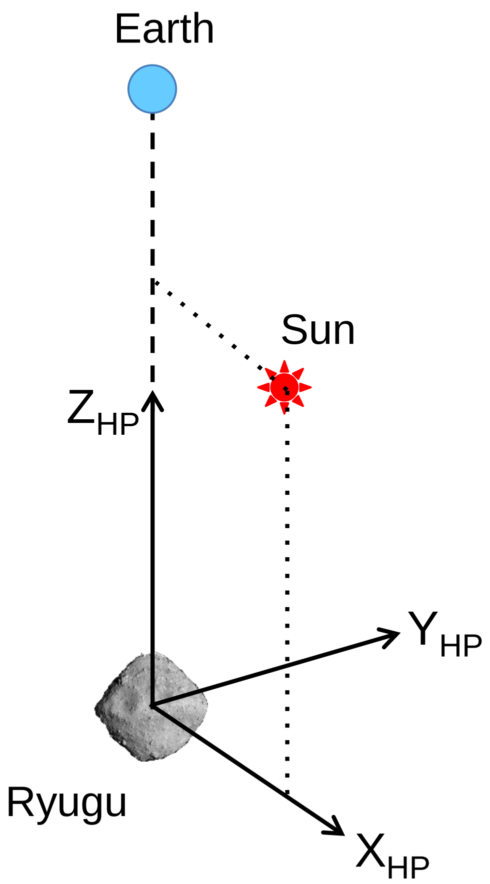
- Schedule for press briefing in August： August 2, August 23

■Outreach events

- JAXA Sagamihara open campus:
  - July 27–28, there is a Hayabusa2 corner
- Children's event (in Japanese)
  - Why Hayabusa2? Any questions classroom
  - Sept 2（Sunday）2 – 4 pm
  - Sagamihara City Museum
  - Online broadcast planned

Reference material

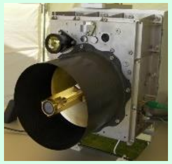
Home Position Coordinate System

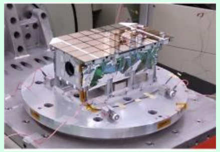


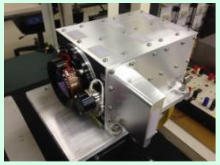
Primary spacecraft components

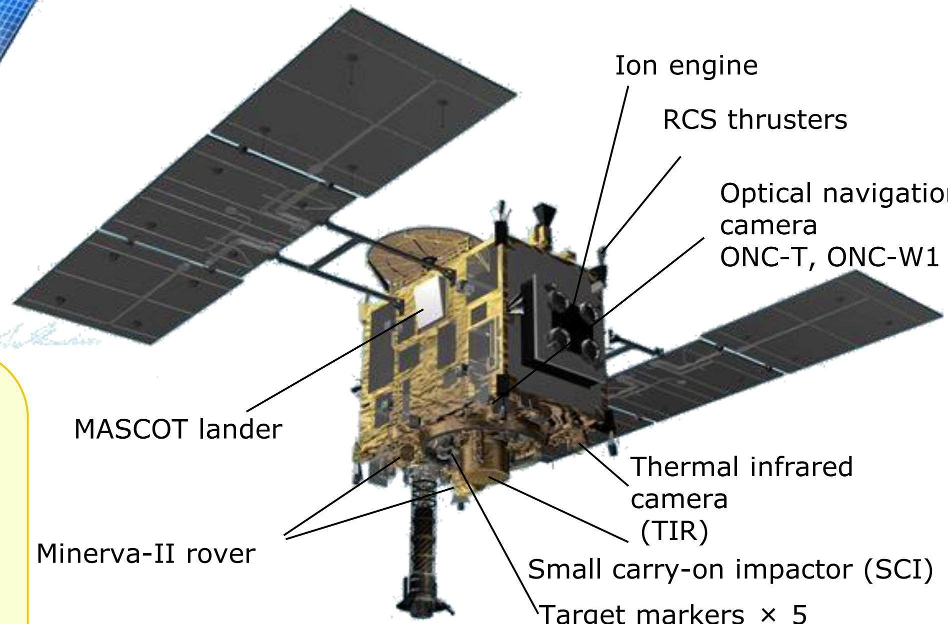
Scientific observation equipment


Optical navigation camera ONC-T


Laser altimeter LIDAR


Near-infrared spectrometer NIRS3


Thermal infrared camera TIR



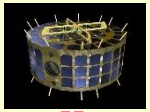
Small lander & rover

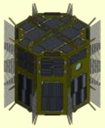
MASCOT

Created by DLR and CNES

Minerva 2


II-1A


II-1B


II-2

II-1: By the JAXA Minerva-II team

II-2: By Tohoku Univ. & the Minerva-II Consortium

Size: 1 ×1. 6×1. 25 m (main body)
Solar paddle deployed width 6 m
Mass : 609 kg (incl. fuel)

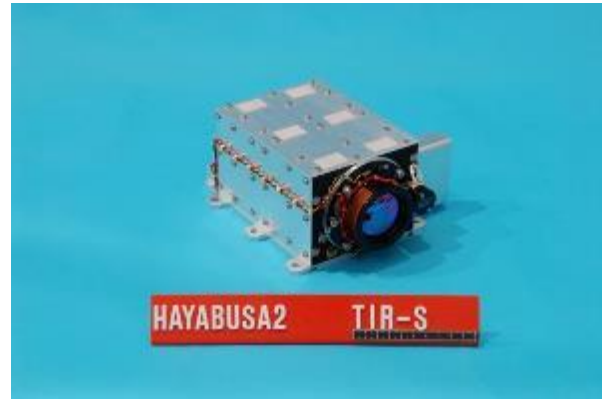
Remote sensing equipment

Optical Navigation Camera (ONC)

ONC-T (telephoto)   ONC-W1,W2 (wide-angle)

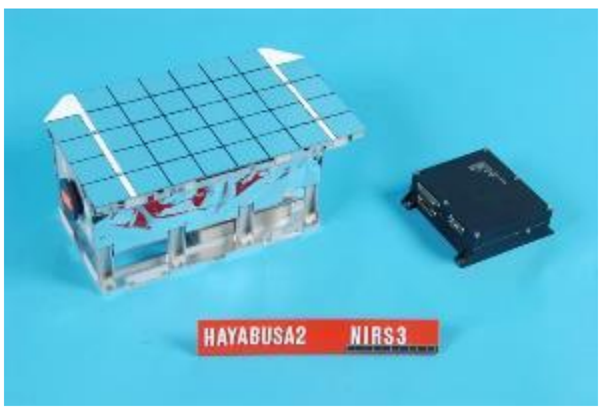
Imaging for scientific observation and navigation

Thermal Infrared Camera (TIR)



8–12 µm imaging: Measures asteroid surface temperature

Near-infrared Spectrometer (NIRS3)



Infrared spectra including the 3-µm band: investigates mineral distributions on the asteroid surface

Laser Altimeter (LIDAR)

Measures distance between the asteroid and the spacecraft in a range of 30 m–25 km

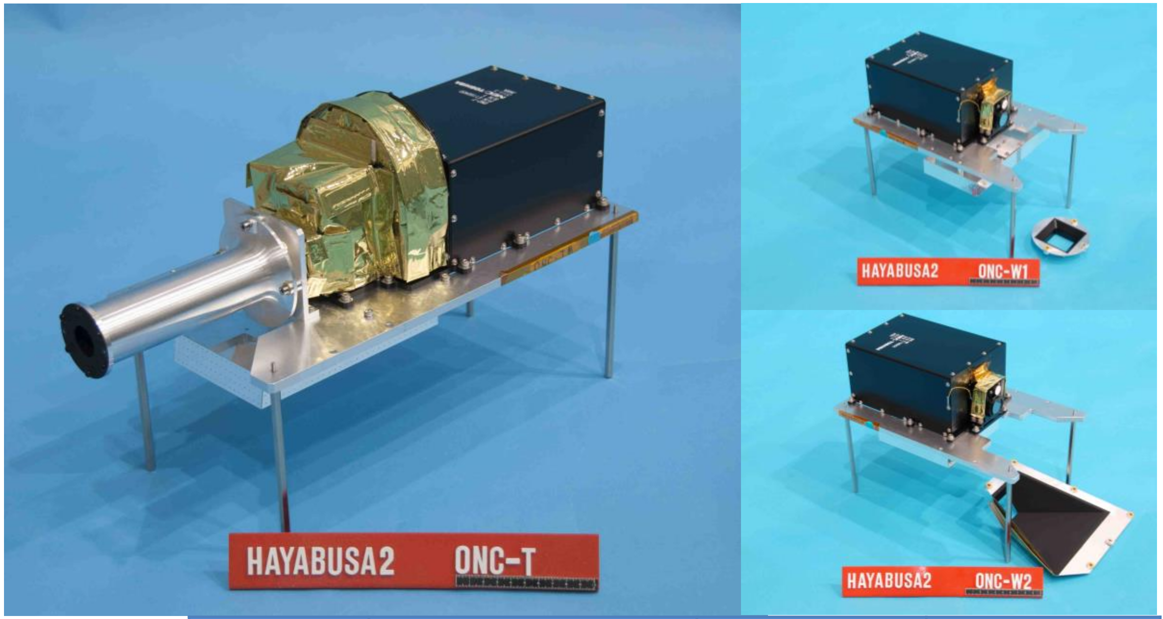
Optical navigation camera (ONC)

ONC: Optical Navigation Camera

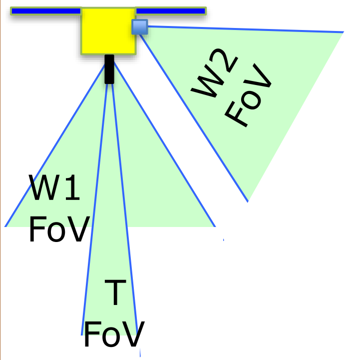
Objective: Images fixed stars and the target asteroid for spacecraft guidance and scientific measurements

Scientific measurements:

- Form and motion of the asteroid:
  Diameter, volume, direction of inertial principal axis, nutation
- Global observations of surface topography
  Craters, structural topography, rubble, regolith distribution
- Global observations of spectroscopic properties of surface materials
  Hydrous mineral distribution, distribution of organic matter, degree of space weathering
- High-resolution imaging near the sampling point
  Size, form, degree of bonding, and heterogeneity of surface particles; observation of sampler projectiles and surface markings



- Elucidation of features of target asteroid
  - Distribution of hydrous minerals and organic matter, space weathering, boulders
- Sampling site selection
  - Basic information on where to collect asteroid samples
- Ascertaining sample state
  - High-resolution imaging of sampling sites

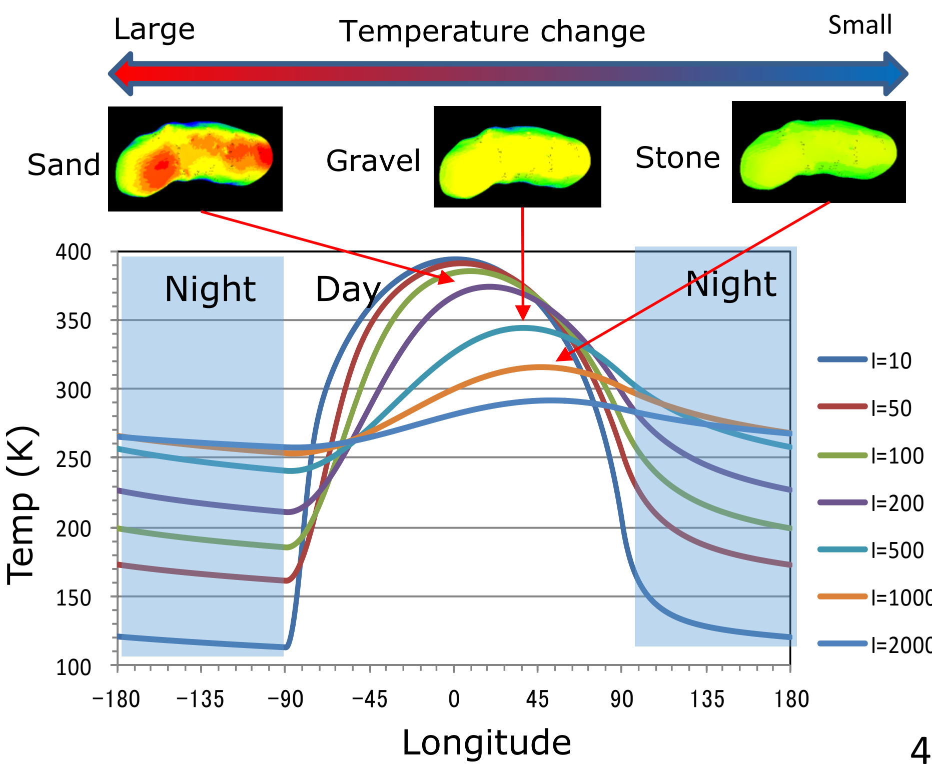


	ONC-T	ONC-W1	ONC-W2
Detector	2D Si-CCD (1024 × 1024 px)		
Viewing direction	Downward (telephoto)	Downward (wide-angle)	Sideward (wide-angle)
Viewing angle	6.35° × 6.35°	65.24° × 65.24°	
Focal length	100 m–∞	1 m–∞	
Spatial resolution	1 m/px @ 10-km alt. 1 cm/px @100-m alt.	10 m/px @10-km alt. 1 mm/px @1-m alt.	
Observation wavelength	390, 480, 550, 700, 860, 950, 589.5 nm, and wide	485–655 nm	

Thermal infrared camera (TIR)

TIR=Thermal Infrared Imager

The surface temperature of the asteroid changes over the day, rising in sunlight and decreasing at night.
Diurnal change in surface temperature is large in fine soils like sand and highly porous rock, and small in dense rock.
We will examine the physical state of the asteroid's surface by 2D imaging (thermography) of thermal radiation from the asteroid.



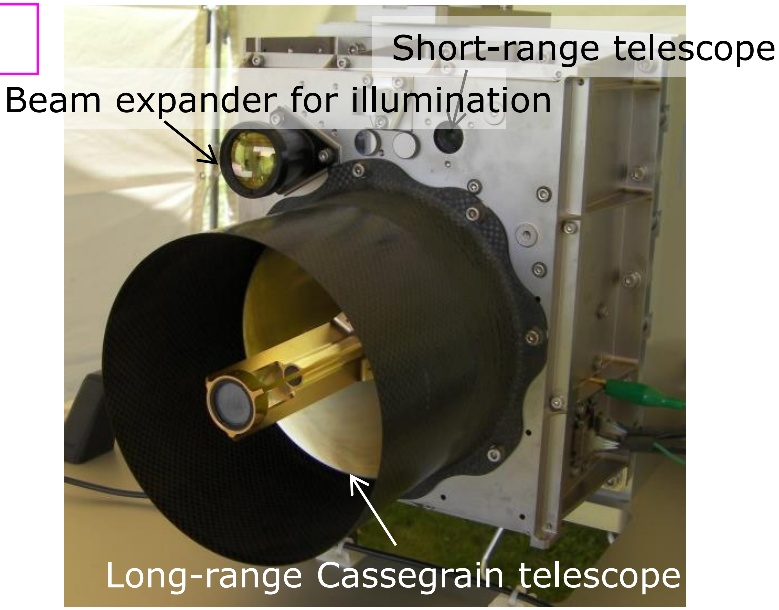
- Detector : 2D uncooled bolometer
- Observation wavelength : 8–12 μm
- Observed temperatures : −40 to 150 °C
- Relative accuracy : 0.3 °C
- Dimensions : 328 × 248 (effective)
- Viewing angle : 16° × 12°
- Resolution : 20 m (20-km alt.)
  5 cm (50-m alt.)

Laser altimeter (LIDAR)

LIDAR: Light Detection And Ranging

- Pulse-type laser altimeter
- A pulse YAG laser with a 1.064-μm wavelength is emitted toward the target object, and the altitude is measured by measuring the return time of the laser beam.
- The LIDAR aboard Hayabusa 2 could perform measurements from 30 m–25 km.

- LIDAR is a navigation sensor used for approach and landing at a target, and a scientific observation device used to measure shape, gravity, and surface characteristics, and for dust observations.
- It also has a transponder function that can perform space laser ranging (SLR) experiments with ground LIDAR stations.



Laser altimeter engineering model

<u>Scientific objectives</u>

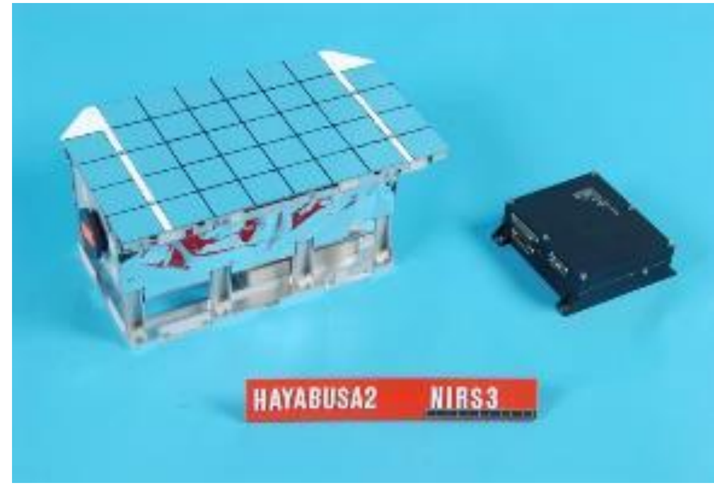
- Terrain and gravity field observations of the target asteroid
- Observations of albedo distribution at various surface points
- Observations of dust floating around the asteroid

- Asteroid form, mass, porosity, and deviation
- Asteroid surface roughness
- Dust floating phenomena

Near-infrared spectrometer (NIRS3)

NIRS3: Near-infrared Spectrometer
('3' from 3 μm)

Infrared absorption of hydroxyl groups and water molecules is observed in 3-μm band reflection spectra in the near-infrared region. NIRS3 investigates distributions of hydrous minerals on the asteroid surface by measuring reflection spectra in the 3-μm band.



- Observation wavelength range: 1.8–3.2 μm
- Wavelength resolution: 20 nm
- Full field of view: 0.1 deg
- Spatial resolution: 35 m (20-km alt.)
  2 m (1-km alt.)
- Detector temperature: −85 to −70 °C
- S/N ratio: 50+ (wavelength 2.6 μm)