# Asteroid explorer, Hayabusa2, reporter briefing

April 11, 2019

JAXA Hayabusa2 Project

# Topics

Regarding Hayabusa2,

- Small Carry-on Impactor (SCI) operation results
- Crater Search Operation (Post-SCI)

# Contents

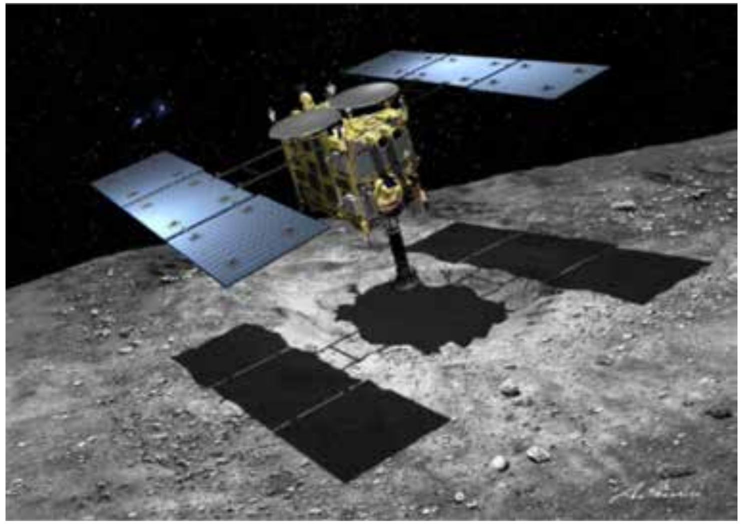
# Overview of Hayabusa2

**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

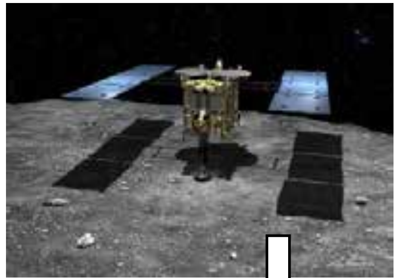
Launch → Arrival at asteroid

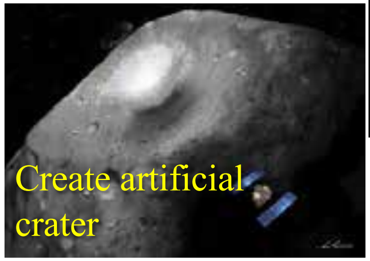
3 Dec 2014

Earth swing-by
3 Dec 2015

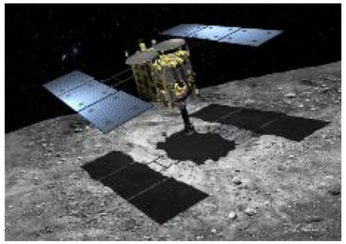
June 27, 2018

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



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

Earth return ← Depart asteroid

late 2020

Nov–Dec 2019

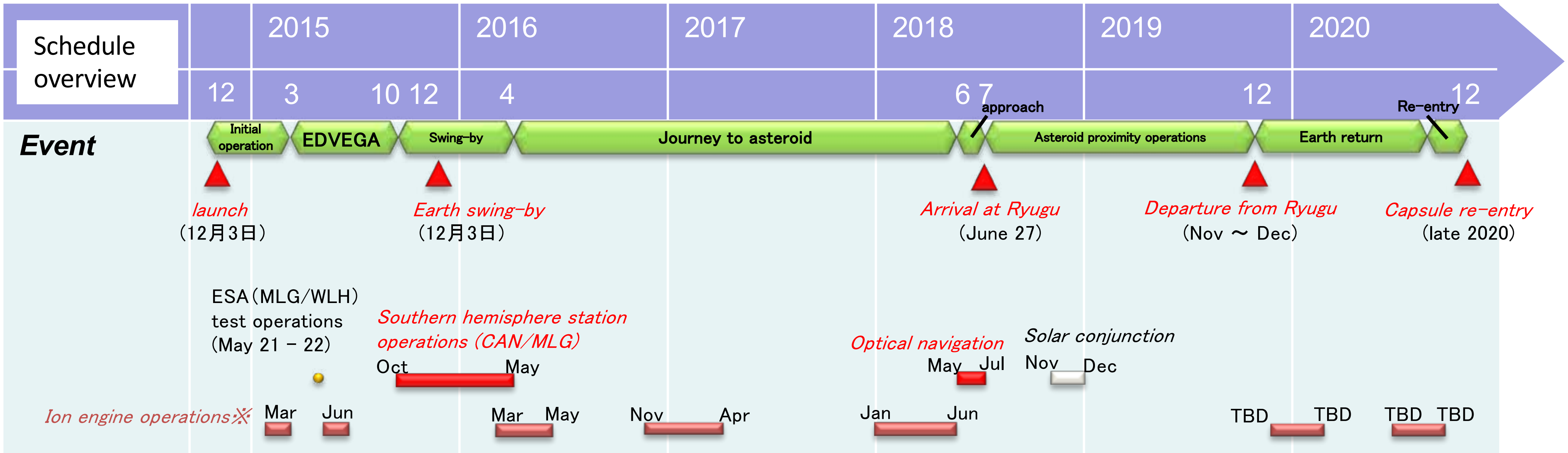
Sample analysis

(Illustrations: Akihiro Ikeshita)

# 1. Current project status & schedule overview

Current status:

- On April 5 at 11:56 JST (on-board time) the Small Carry-on Impactor (SCI) separated from the spacecraft. The separation of the SCI and ejector from the surface of Ryugu were confirmed via images, and the impact experiment is considered a success.
- As of April 11, Hayabusa2 is on its way back to the home position.



# 2. Small Carry-on Impactor Operation Results

■Results from the impact experiment operation

- The separation of the Small Carry-on Impactor (SCI) began on April 3, and the SCI separated from the spacecraft on April 5 at 10:56 JST (on-board time). The SCI operation has continued since then, and it is expected that the spacecraft will return to the home position around April 18.
- The separation of the SCI was also confirmed by the Optical Navigation Camera – Wide angle (ONC-W1) and the Thermal Infrared Camera (TIR), in addition to other telemetry.
- The collision of the SCI liner (copper plate) with Ryugu was confirmed with images captured by the deployable camera (DCAM3).
- Based on the above, the goal of colliding an impactor with Ryugu has been achieved (one of the minimum successes of engineering goal is completed)
- In the future, we will search for the crater that may have been formed.

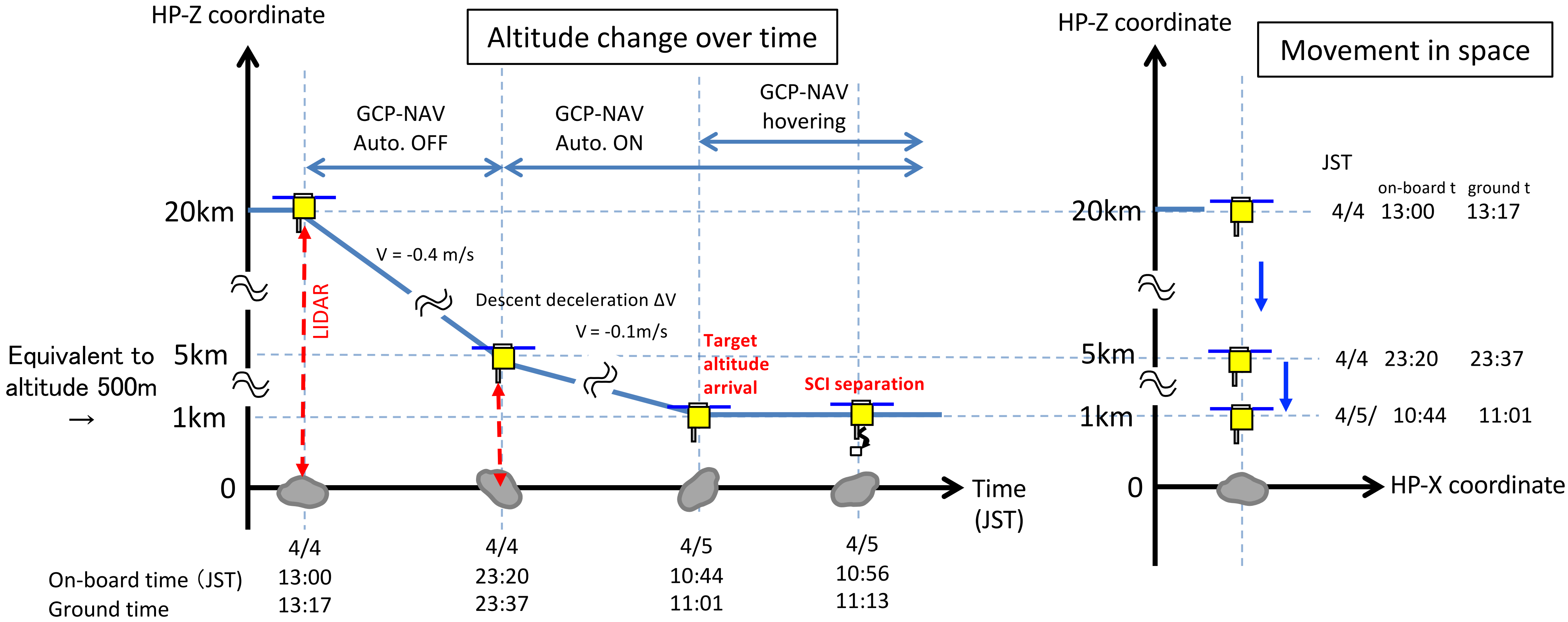
# 2. Small Carry-on Impactor Operation Results

| item | Ground time : JST<br>() on-board time | Judgement |
|---|---|---|
| Gate 1 | 4/4 12:12<br>4/4 13:17 (13:00) | Begin judgement to start descent (@20km)<br>Decent began |
| Gate 2 | 4/4 23:37（23:20）<br>4/4 23:55 | Decent decelerationΔV（40cm/s→10cm/s）<br>Confirm descent continuation（@5km) |
| Gate 3 | 4/5 09:57 | Final separation judgement（GO judgement） |
| SCI separation | 4/5 11:13 (10:56) | Confirm SCI separation |
| DCAM3 separation | 4/5 11:32 (11:14) | Confirm DCAM3 separation |
| DCAM3 communication | 4/5 11:50 | DCAM3 communication check |
| SCI operation | 4/5 11:53（11:36）<br>4/5 11:56 | SCI explosion time<br>Confirm state of spacecraft after SCI explosion |
| Gate ５ | 4/5 13:45 | Judgement that SCI separation and evacuation sequence were performed safely. |
| Gate 6 | 4/5 15:12 | Judgement to return to home position (GO judgement) |

# 2. Small Carry-on Impactor Operation Results

Actual operation

From home position to separation of the SCI

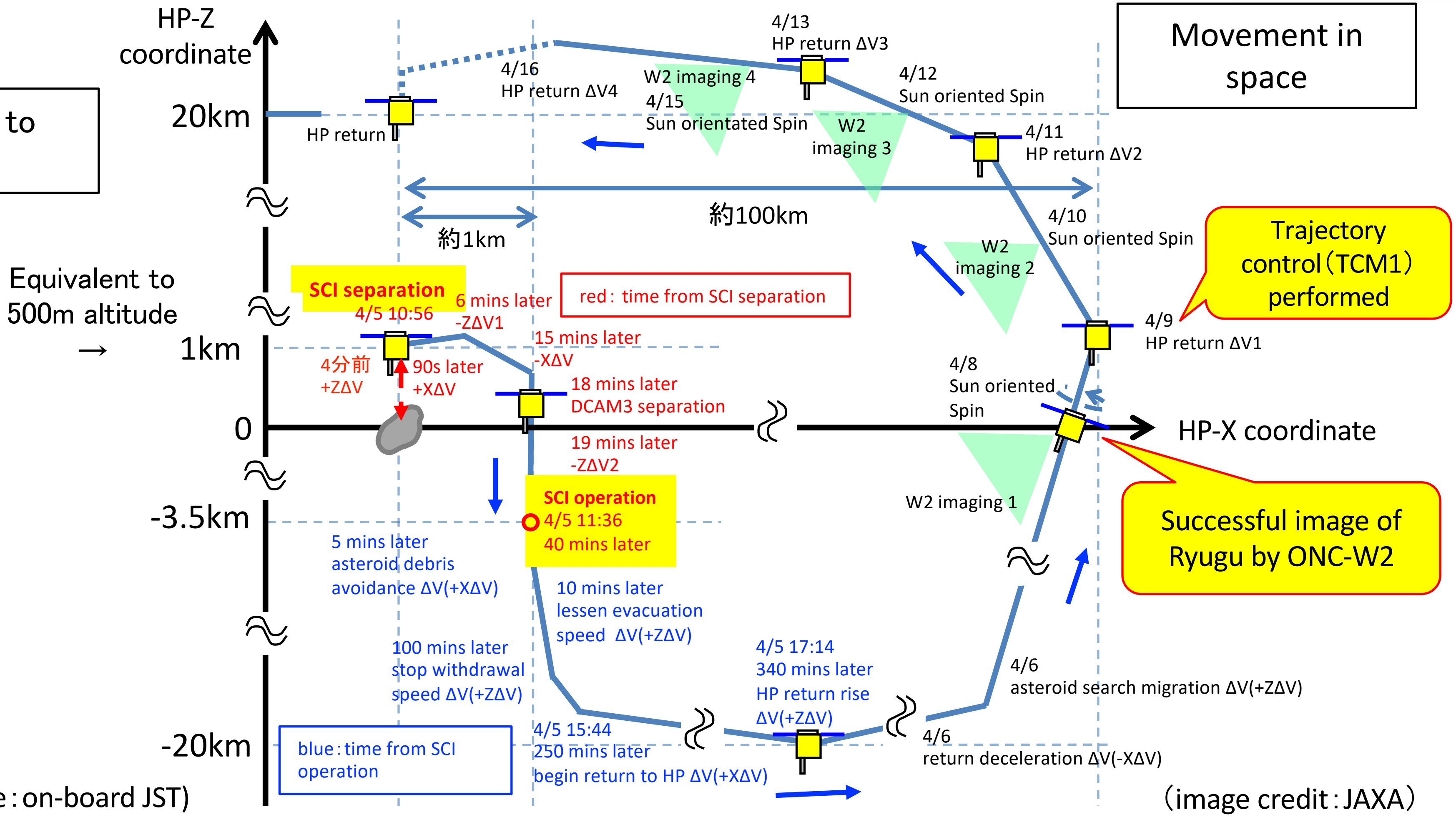



（image credit：JAXA）

# 2. Small Carry-on Impactor Operation Results

Actual operation

From SCI separation to home position




（time：on-board JST）

（image credit：JAXA）

# 2. Small Carry-on Impactor Operation Results

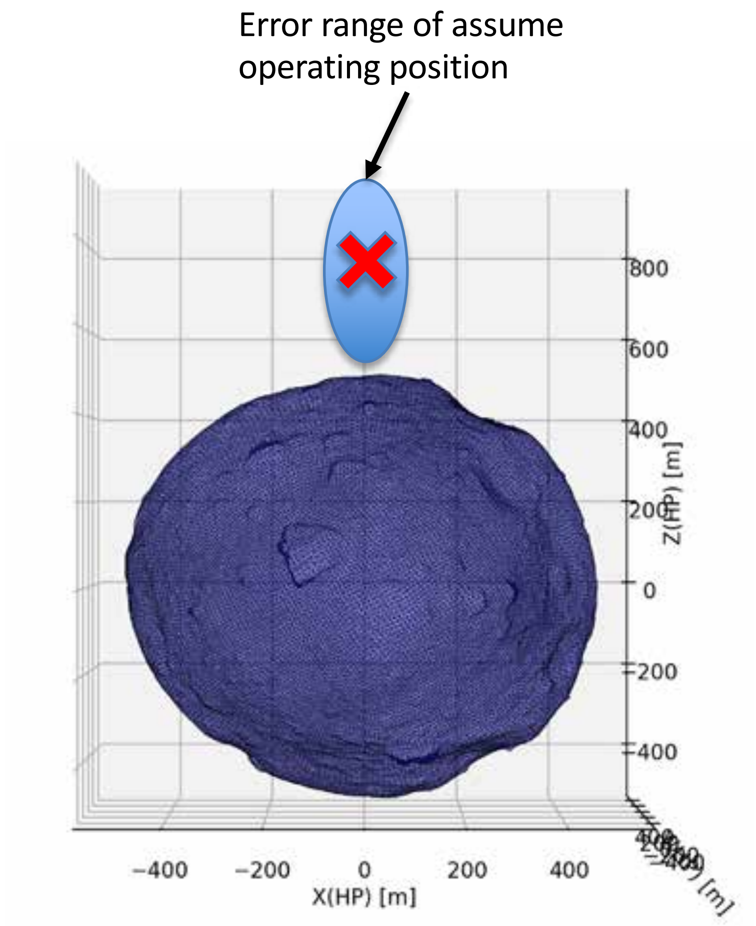
■Operating position for the SCI

- Control of the spacecraft position at the time of separation is estimated to within a 10m error.
- The estimated separation speed from the image showing the separation of the SCI is about 20cm/s, almost as expected.
- The lateral velocity at the time of the SCI separation was also small.

<u>Although the details are currently being analysed, the height of the SCI detonation is estimated to be about 300m.</u>

■Evacuation of the spacecraft

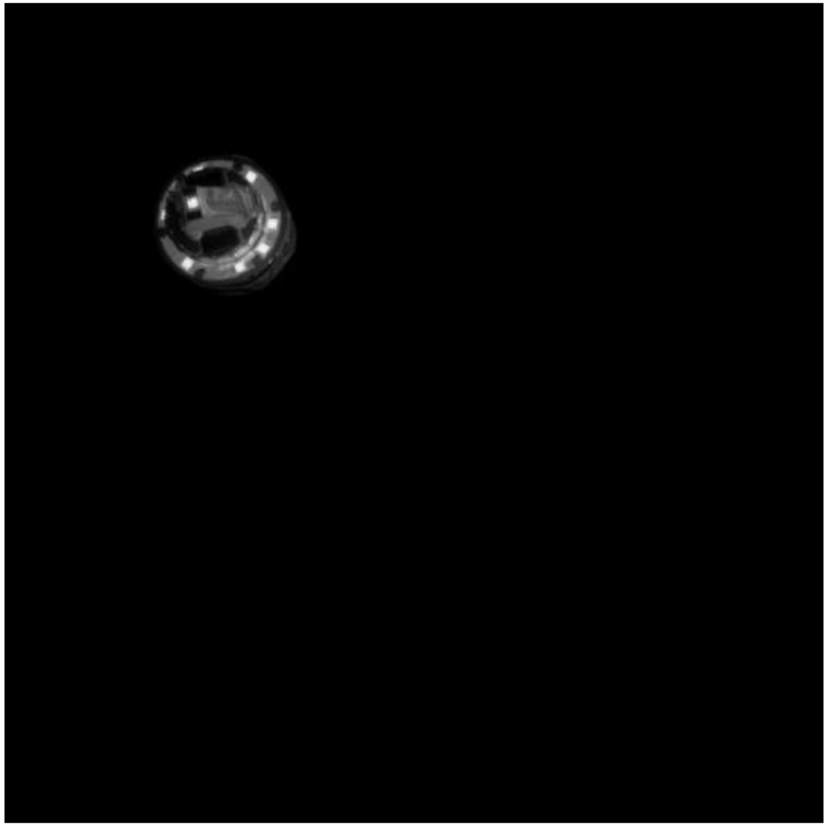
- The RCS thruster injection at the time of evacuation was performed correctly, and the spacecraft was able to evacuate to a safe area.
- <u>At the current time, the spacecraft status is normal.</u>




（image credit：JAXA）

# 2. Small Carry-on Impactor Operation Results

SCI captured with the ONC-W1



The top of the image is towards the north pole of Ryugu.

SCI captured with the ONC-W1 a few seconds after separation.

Separation time: April 5, 2019, 10:56 JST (on-board time)

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

# 2. Small Carry-on Impactor Operation Results

First release

## SCI captured by the TIR


(Animation)

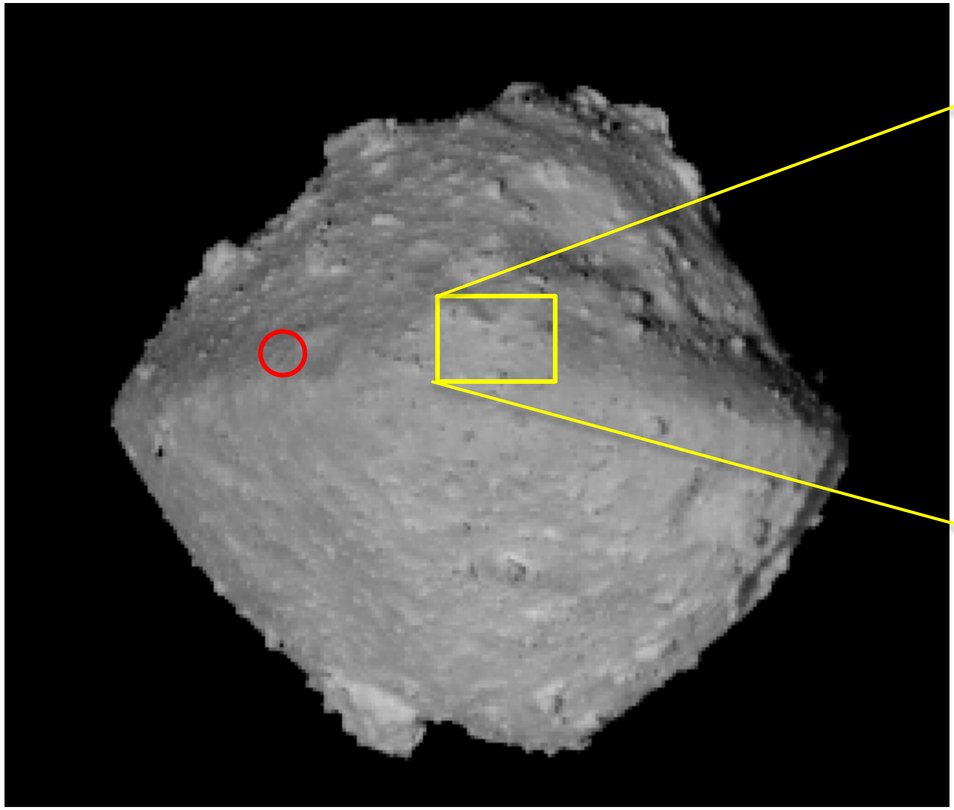
- ・Imaging interval　: 2s
- ・Image integration : 0.25s
- ・Number of images : 30s
- ・Imaging duration　: 60s
- ・Image height : about 500m

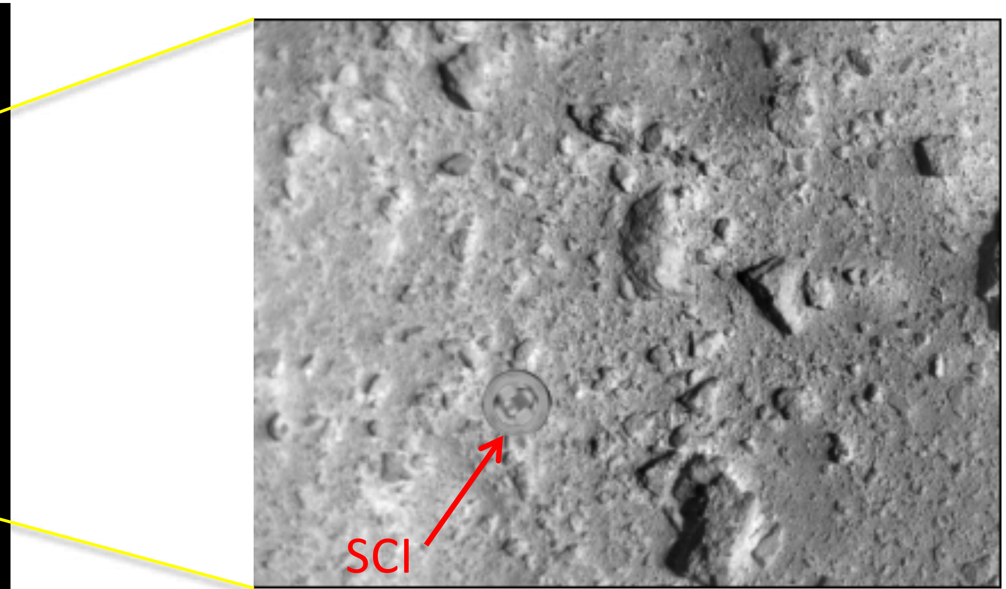
The top of the image is towards the north pole of Ryugu. The spacecraft is imaging while rising.

(Image credits : JAXA, Ashikaga University, Rikkyo University, Chiba Institute of Technology, University of Aizu, Hokkaido University of Education, Hokkaido Kitami Hokuto High School, AIST, National Institute for Environmental Studies, University of Tokyo, German Aerospace Center (DLR), Max Planck Society for the Advancement of Science, Stirling University.)

# 2. Small Carry-on Impactor Operation Results

Location of SCI images（approximately 40 minutes before detonation & collision）





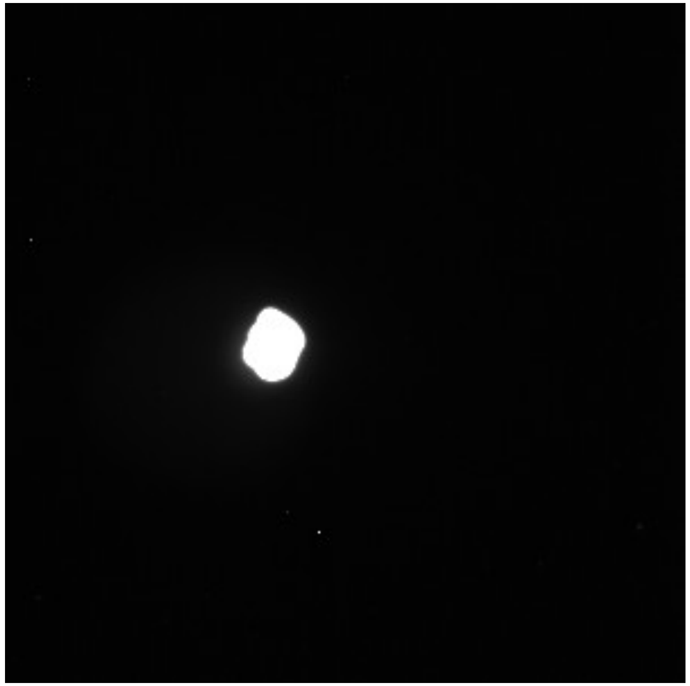

The red circle is near target center (around S01). Since the SCI separated about 40 minutes before detonation and collision, the separation position is approximately 30° to the east. Top is the north pole.

(Image credits：JAXA, Ashikaga University, Rikkyo University, Chiba Institute of Technology, University of Aizu, Hokkaido University of Education, Hokkaido Kitami Hokuto High School, AIST, National Institute for Environmental Studies, University of Tokyo, German Aerospace Center (DLR), Max Planck Society for the Advancement of Science, Stirling University.)

# 2. Small Carry-on Impactor Operation Results

■ Plan to return to the HP

- 4/8 image of Ryugu with the ONC-W2
- 4/9 image of Ryugu even captured by the Star Tracker (STT)



Ryugu images by the STT on April 9 at 12:42 JST (on-board time). Top is the north pole of Ryugu. （Image credit：JAXA）

- 4/9 the spacecraft was 100km away from the asteroid, as planned. dV was implemented for return to HP.
- Currently, the return to the HP is planned around 4/18.

# 3. Imaging with the deployable camera (DCAM3)

## Images from the analog camera

First release

Image about 2 seconds after the SCI detonation.
(Image released at the 4/5 press conference)

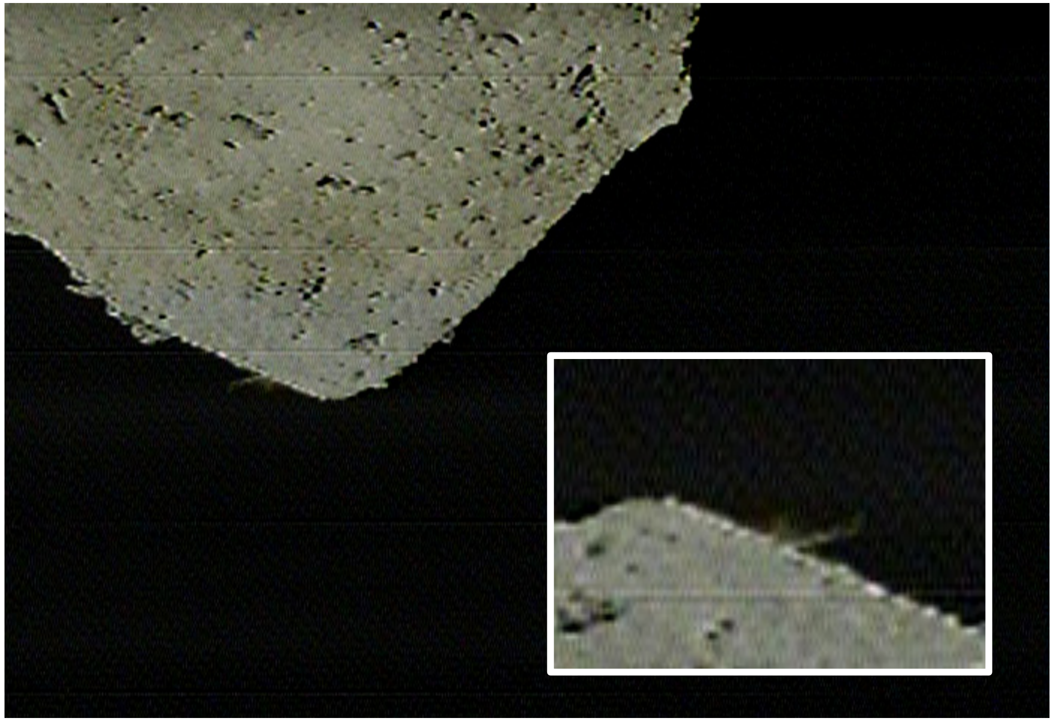
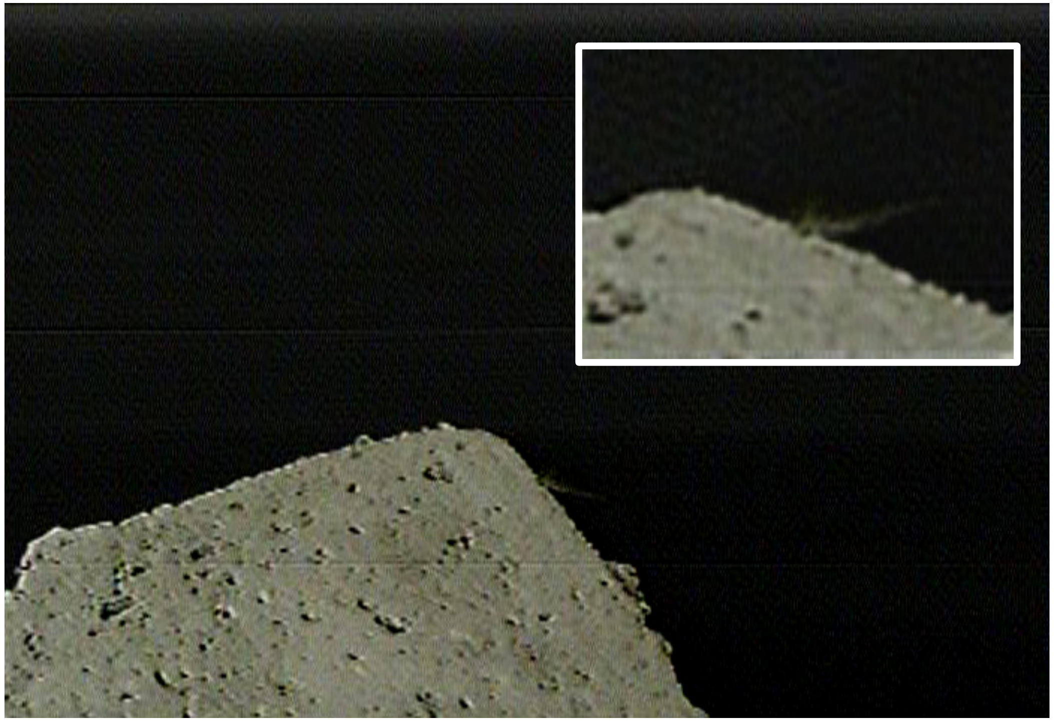


Image about 25 seconds after the SCI detonation



(Image credit: JAXA, Kobe University, Chiba Institute of Technology, University of Occupational and Environmental Health, Kochi University, Aichi Toho University, University of Aizu, Tokyo University of Science.)

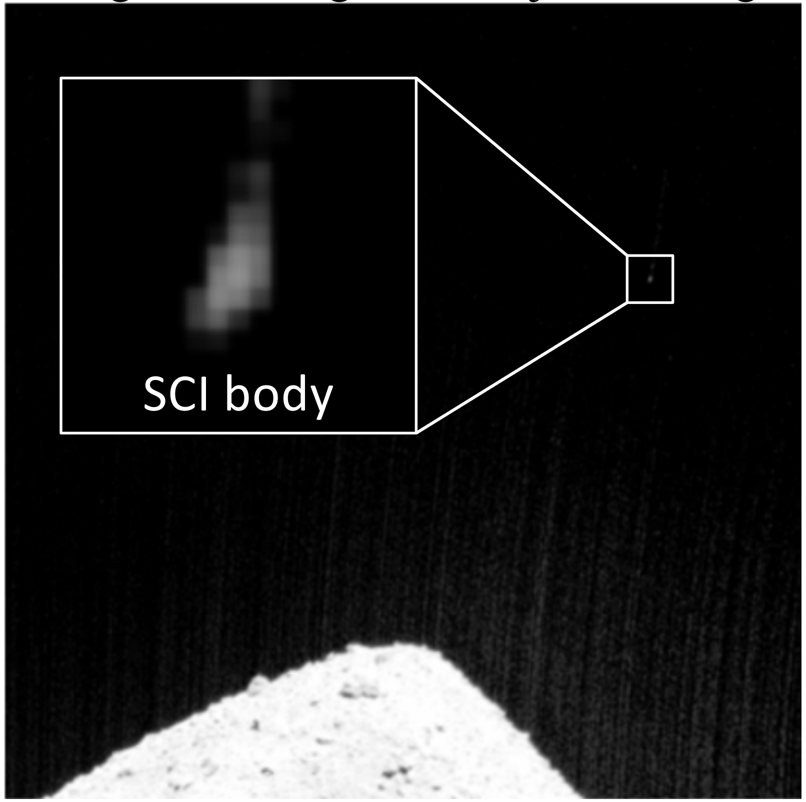
# 3. Imaging with the deployable camera (DCAM3)

First release

## Images from the digital camera

About 185 seconds before SCI detonation


Enlarged and brightness adjusted image




（Image credit：JAXA、Kobe University, Chiba Institute of Technology, Kochi University University of Occupational and Environmental Health ）

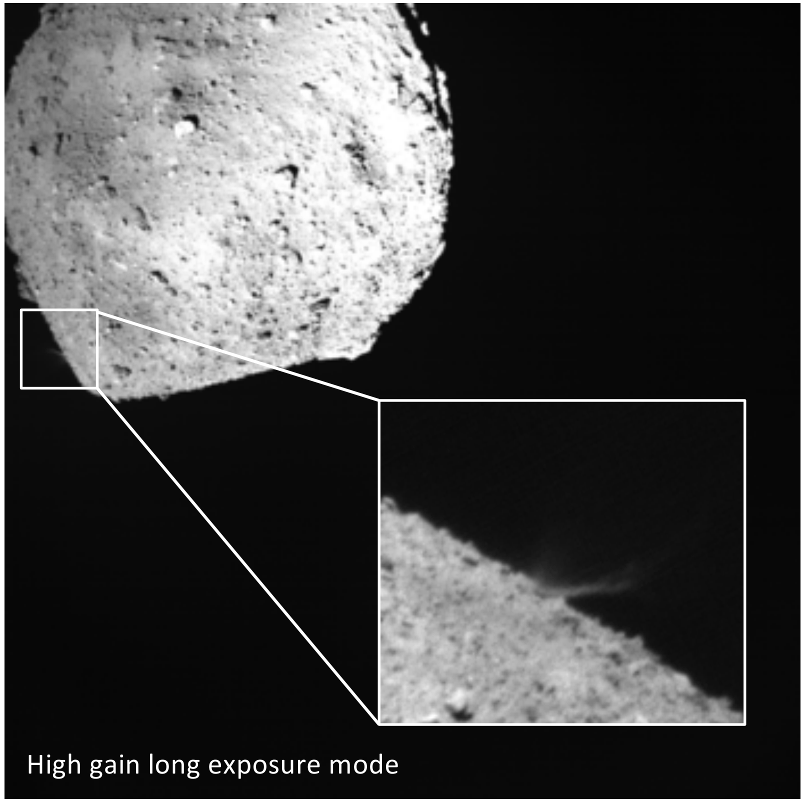
# 3. Imaging with the deployable camera (DCAM3)

## Images from the digital camera

First release

About 14 seconds before SCI operation


About 3 seconds after SCI operation

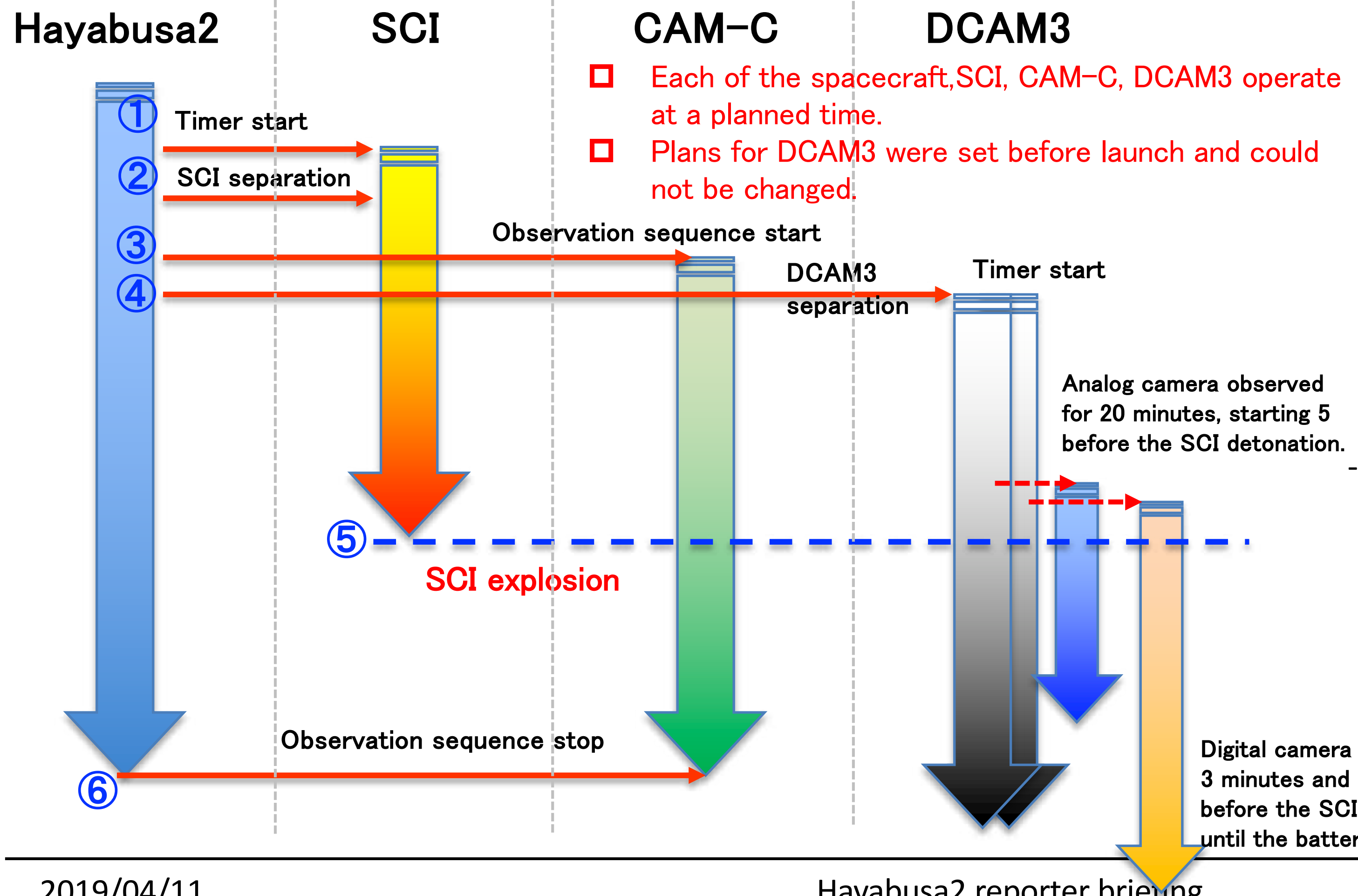


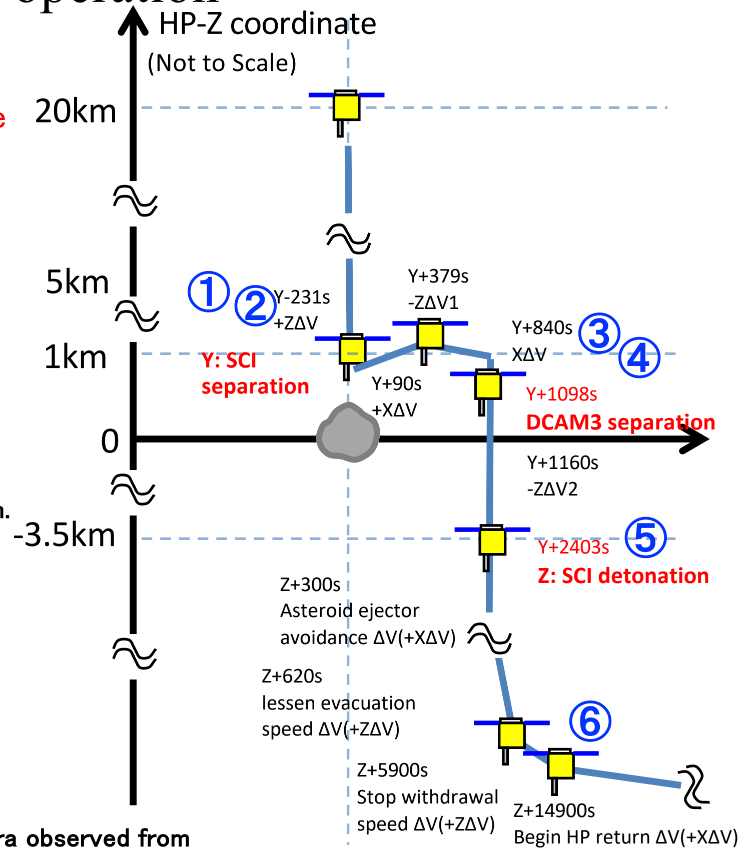

（Image credit：JAXA、Kobe University, Chiba Institute of Technology, Kochi University University of Occupational and Environmental Health ）

# 3. Imaging with the deployable camera (DCAM3)

Overview of the deployable camera DCAM3 operation

- Each of the spacecraft,SCI, CAM-C, DCAM3 operate at a planned time.
- Plans for DCAM3 were set before launch and could not be changed.

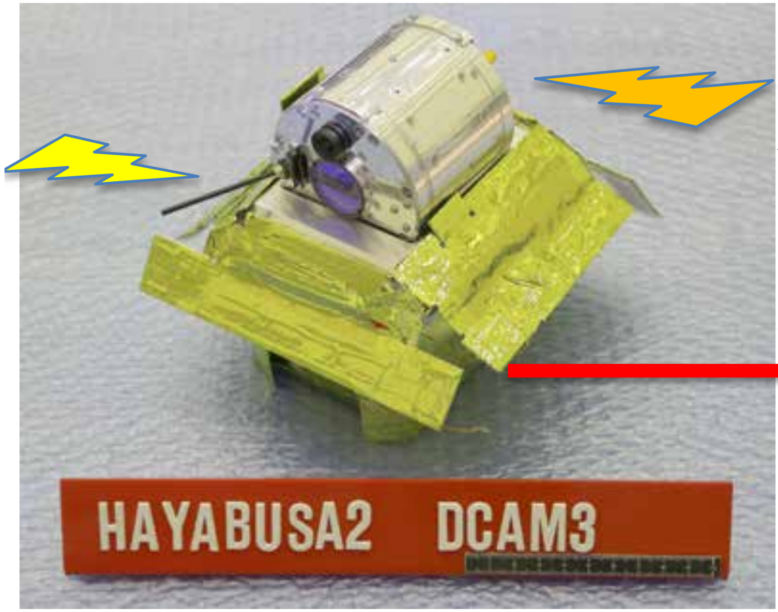



(image credit：JAXA)

# 3. Imaging with the deployable camera (DCAM3)

DCAM3 System configuration




Analog antenna
＋receiver（both systems）
（mounted on the +Z surface）



Digital receiving antenna
（mounted on +Z surface）

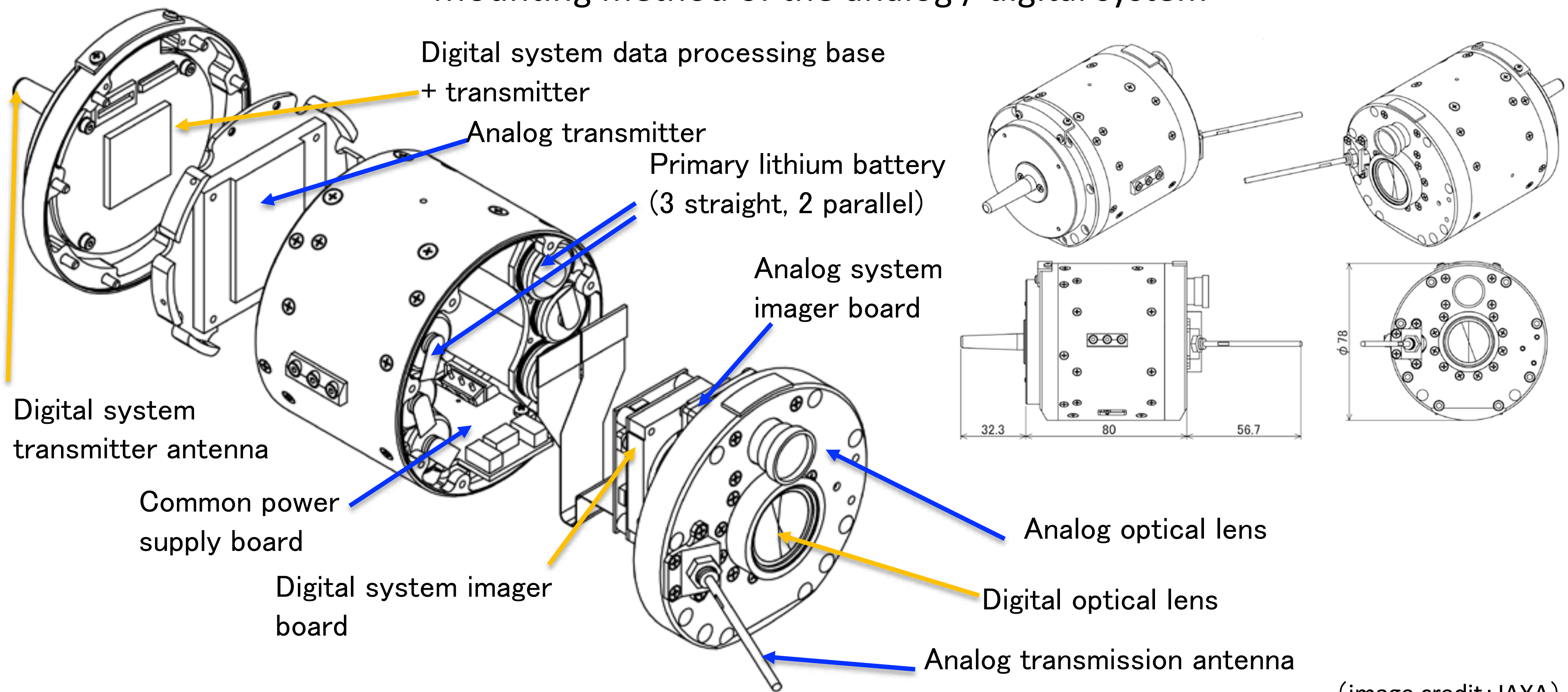
Camera controller CAM−C
−Analog data processing unit
− Digital data processing unit
（mounted inside spacecraft）


CAM−H（mounted on −Y surface）


（image credit：JAXA）

# 3. Imaging with the deployable camera (DCAM3)

Mounting method of the analog / digital system




(image credit：JAXA)

# 3. Imaging with the deployable camera (DCAM3)

- 18 minutes after separation, DCAM3 operated for over 5 hours.

- Everything worked according to the scheduled sequence (details currently being analysed).

- As planned, the analog system observed for 20 minutes and the images sent via radio to the spacecraft. 500 images are thought to have been acquired and these are being analysed (not all images contain Ryugu).

- The digital system imaged and observed for 3 hours or more and the images were confirmed to have been received by the spacecraft.

## Results of the deployable camera operation

| Date & time (onboard) | | time since SCI detonation | Event | |
|---|---|---|---|---|
| UT | JST | | Onboard | Ground |
| 2019/04/05 02:14 | 2019/04/05 11:14 | - 0:22 | CAM-C observation program began | |
| **2019/04/05 02:14** | **2019/04/05 11:14** | **- 0:21** | **DCAM3 separation** | |
| 2019/04/05 02:31 | 2019/04/05 11:31 | - 0:04 | | Ground confirmation of DCAM3 separation<br>・Separation switch status->SEP<br>・Confirm speed change of 0.6~0.7mm/s via Doppler |
| 2019/04/05 02:31 | 2019/04/05 11:31 | - 0:05 | Analog system observation begins | |
| 2019/04/05 02:32 | 2019/04/05 11:32 | - 0:03 | Digital system observation begins | |
| 2019/04/05 02:36 | 2019/04/05 11:36 | 0:00 | SCI detonation | |
| 2019/04/05 02:51 | 2019/04/05 11:51 | + 0:14 | Analog system observation stops | |
| 2019/04/05 02:53 | 2019/04/05 11:53 | + 0:17 | | Confirm that DCAM3 is unaffected by SCI detonation and continues normal operation |
| 2019/04/05 03:04 | 2019/04/05 12:04 | + 0:28 | Digital communication rate<br>4Mbps->1Mbps | |
| 2019/04/05 03:59 | 2019/04/05 12:59 | + 1:23 | CAM-C observation program completes. Digital system continues observation. | |
| **2019/04/05 07:04** | **2019/04/05 16:04** | **+ 4:28** | | **Digital system stop observation command** |
| 2019/04/05 07:22 | 2019/04/05 16:22 | + 4:46 | Digital system observation stops | |
| 2019/04/05 07:39 | 2019/04/05 16:39 | + 5:03 | | Confirm stop of the digtal system observation from the ground. Image information stored on CAM-C was then downloaded from the spacecraft and from this, we selected images for downloading. |

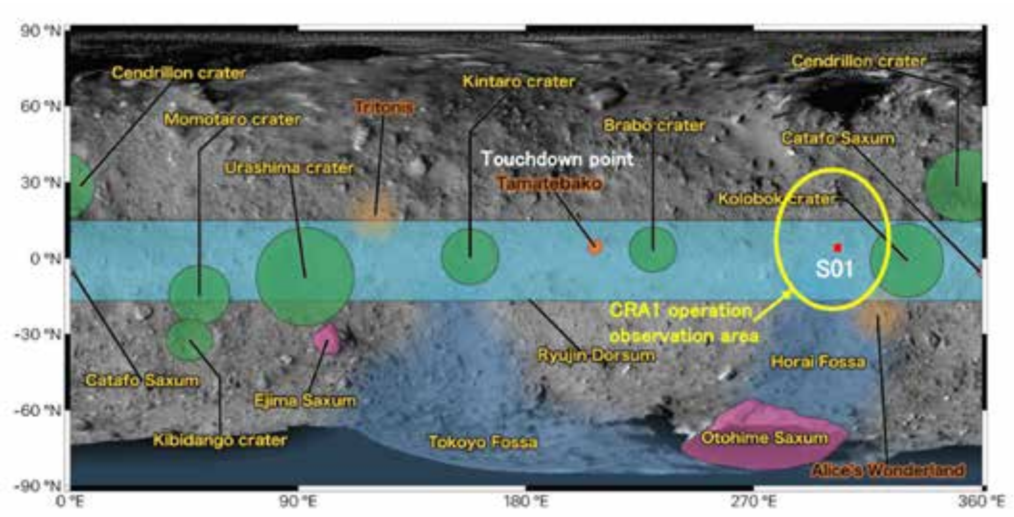
# 4. Crater Search Operation (Post-SCI)

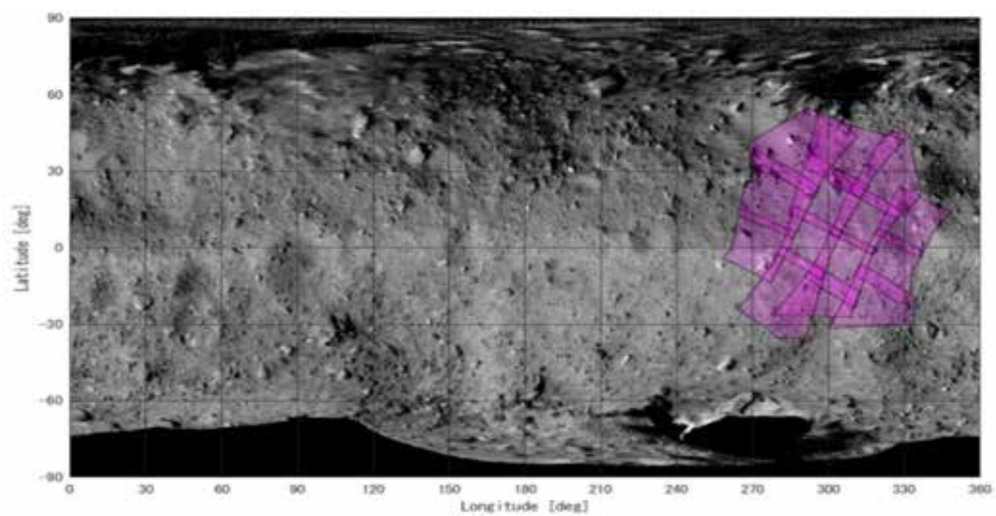
■Crater Search Operation (Post-SCI) (CRA2)

- Obtain detailed data on the area where the Small Carry-on Impactor (SCI) appears to have collided.
- Operation schedule：April 23～25
- Lowest altitude will be approximately 1.7km

# 4. Crater Search Operation (Post-SCI)

## CRA2 location



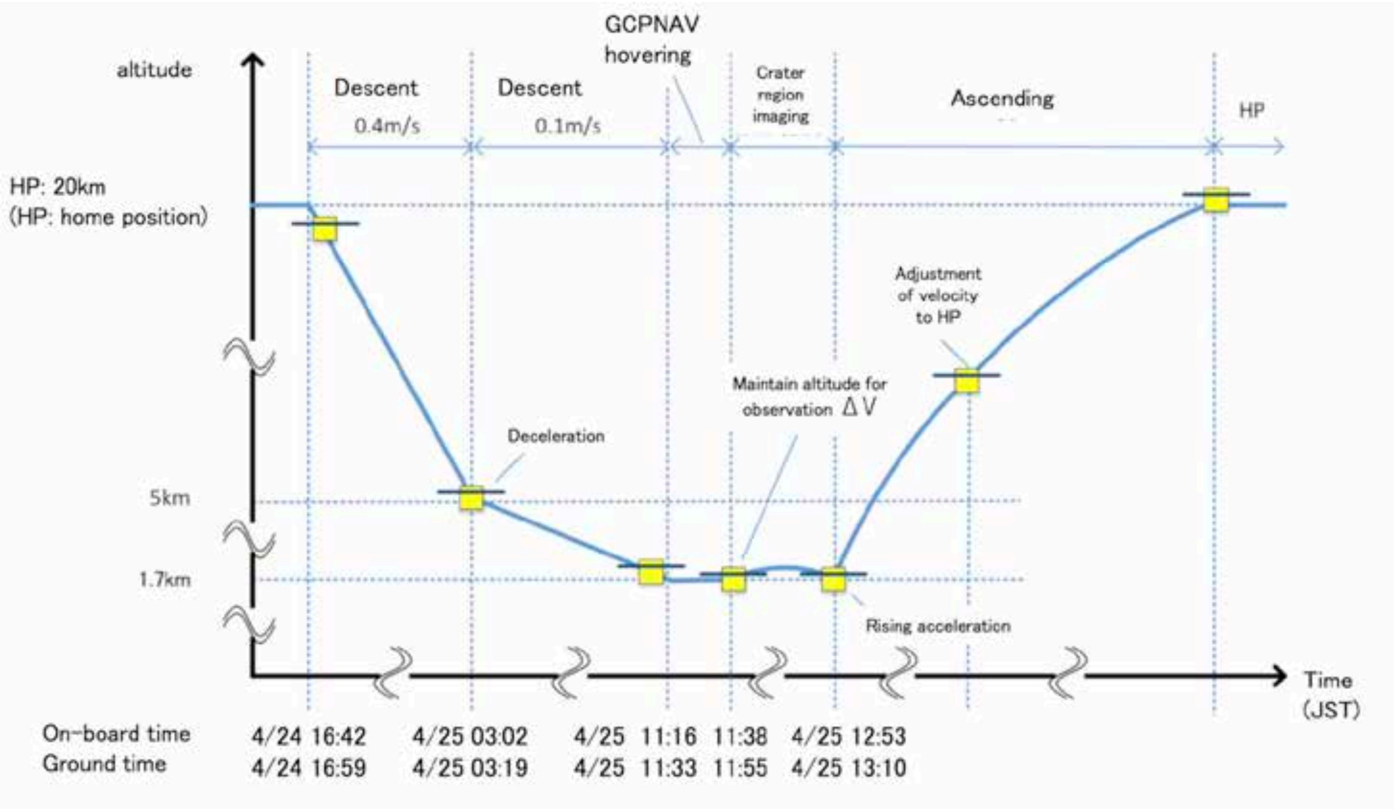




Note）The observation area for CRA2 is the same as the area observed in advance of the SCI operation by CRA1.

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

# 4. Crater Search Operation (Post-SCI)

## Plan for the Crater Search Operation (Post-SCI) (CRA2)




The observation will be conducted while maintaining an altitude of about 1.7km.

(Image credit：JAXA)

# 5. Other topics

Operation control room live broadcast (youtube)

- Implemented as PR for real-time transmission of Hayabusa2 and space exploration.
- Play count（As of 2019/4/10 at 15 JST）
  - Japanese edition : 109,233
  - Simultaneous English interpretation : 143,281


- During the broadcast, we also provided real-time subtitles (summary captions) for the deaf and hearing impaired.

※ Due to the broadcasting system, these subtitles were not displayed on the press center display screen.

【what are summary captions？】These are used to support deaf viewers by conveying the contents of a story in a written summary. This time, we created live subtitles with assistance from the written interpreter group, “Momiji”, in Sagamihara City.

（Image credit：JAXA）

# 5. Other topics

## EGU（European Geosciences Union）

- European Geosciences Union General Assembly 2019 is currently being held in Vienna, Austria (April 7 – 12).
- On April 9, there was a session on Hayabusa2 and OSIRIS-REx, followed by a lively discussion.
- There were 8 announcements related to Hayabusa2.

# 6. Future plans

■Operation plan

- April 23～25： Crater Search Operation (Post-SCI)（CRA2）

■Press and media briefings

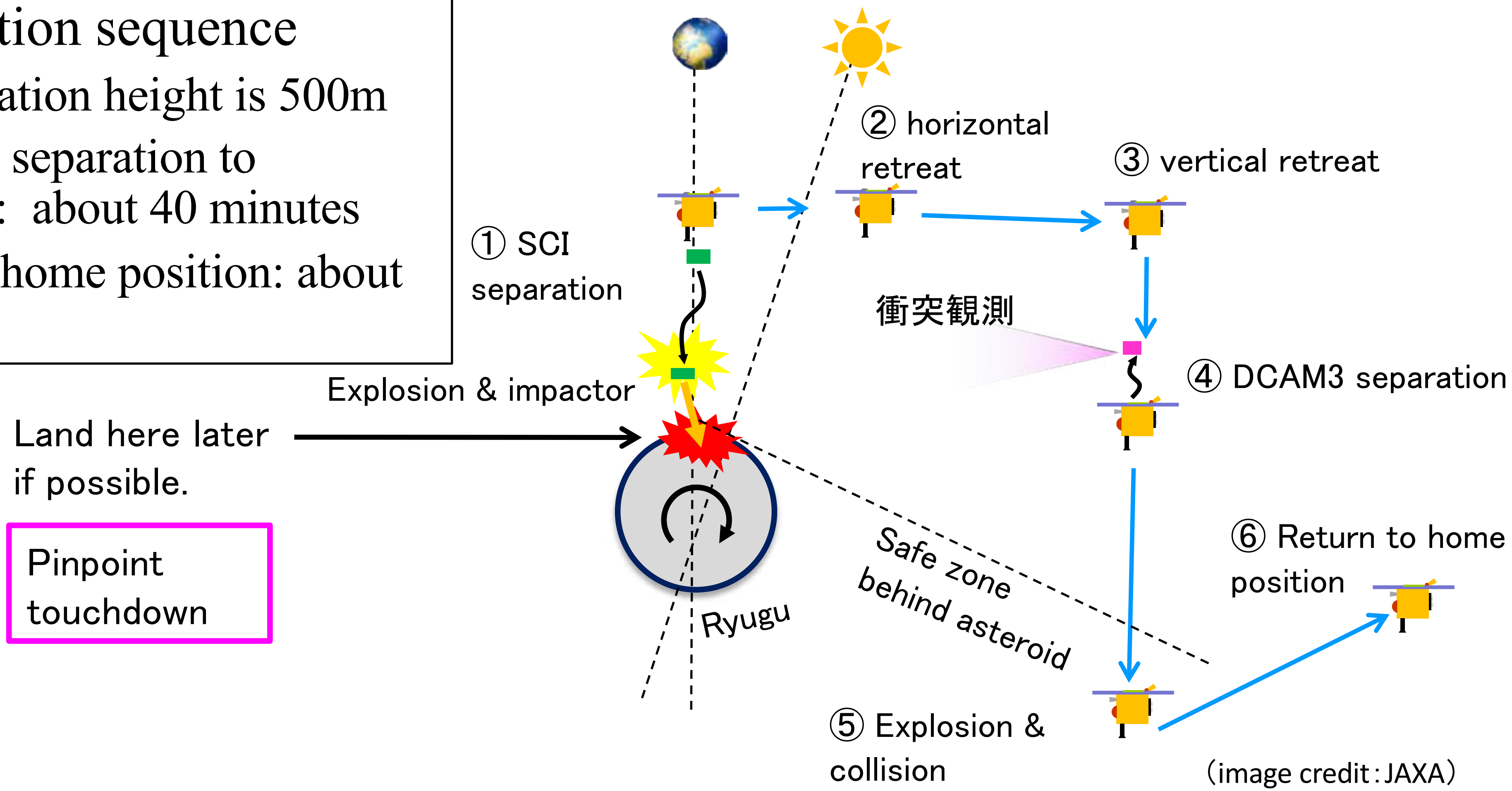
- April 18 10:30～12:00 ： Opportunities for interviews with the visiting OSIRIS-REx project members in Japan @ JAXA Sagamihara Campus.

# Reference material

# Small Carry-on Impactor operation

## SCI operation sequence

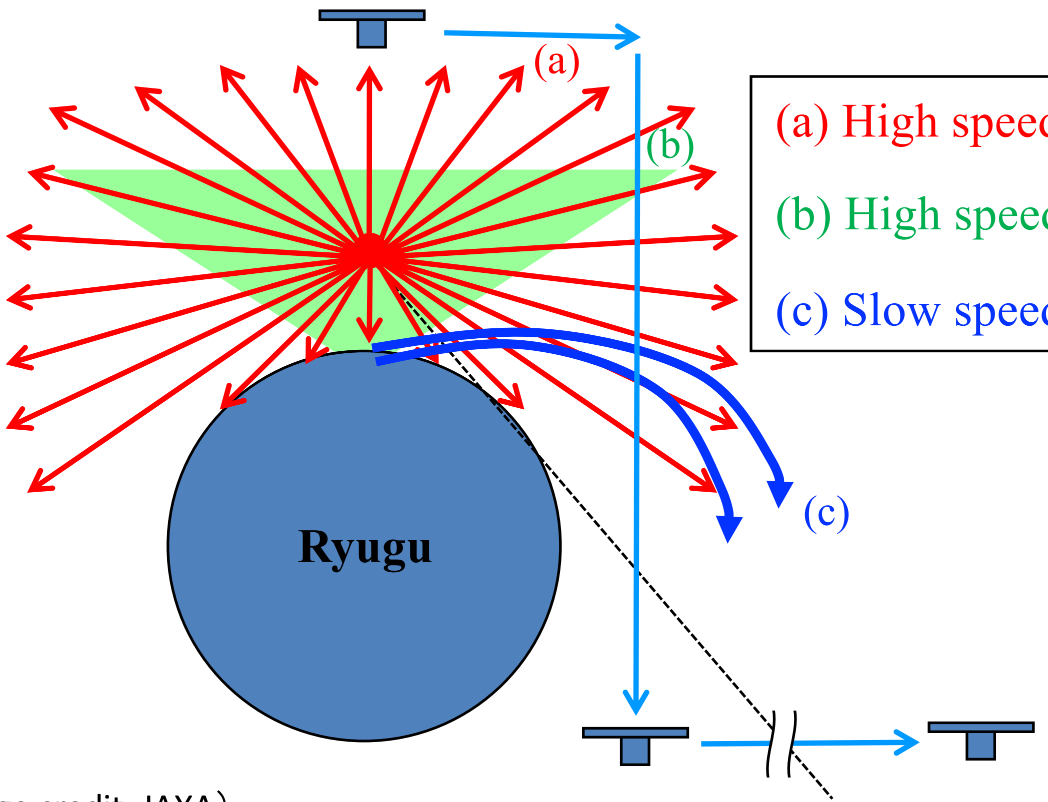
- SCI separation height is 500m
- From SCI separation to explosion:  about 40 minutes
- Return to home position: about 2 weeks




(image credit：JAXA)

# Small Carry-on Impactor operation

## How to avoid debris and ejector



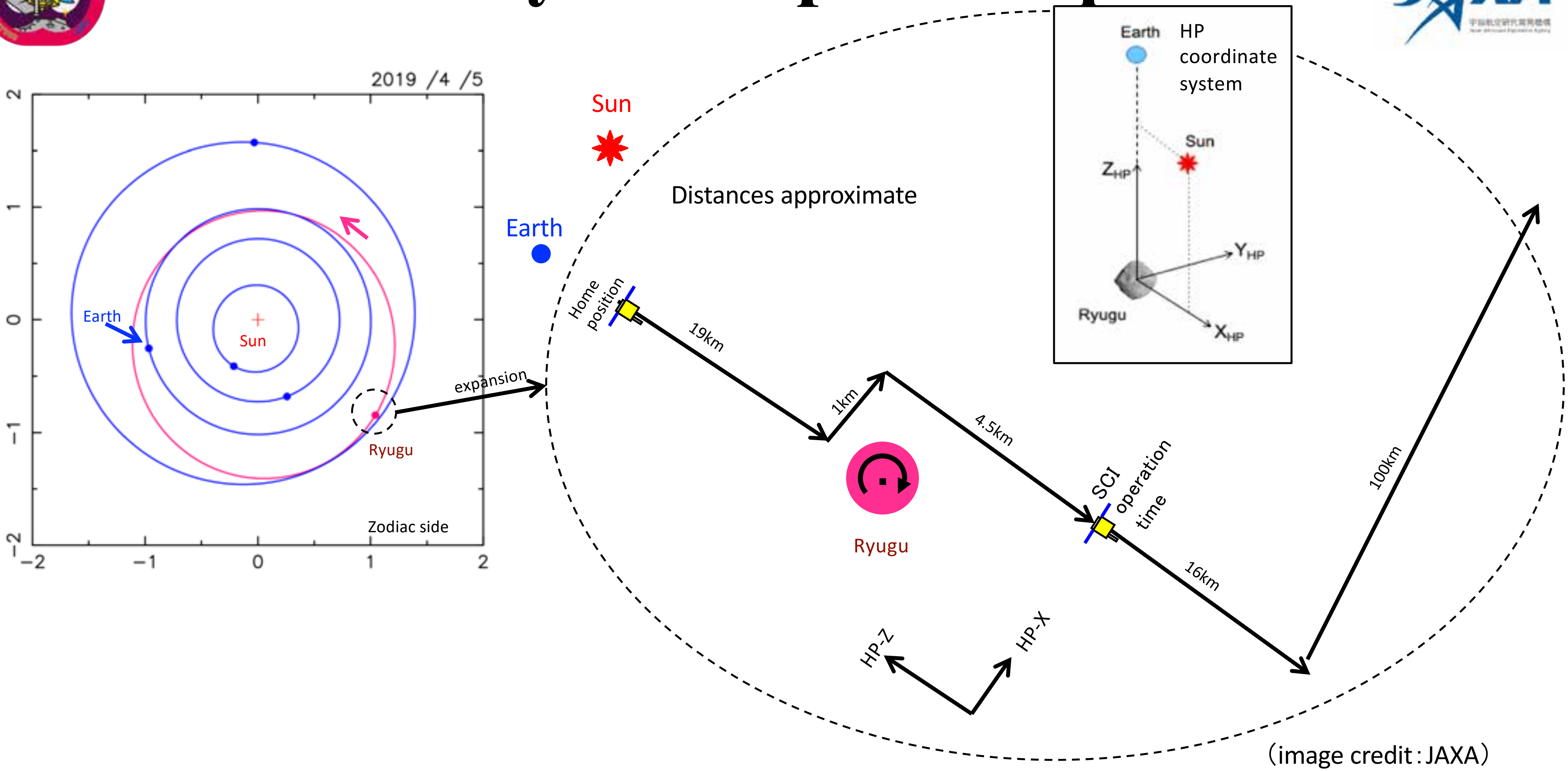

① Avoid debris
Debris that scatters during the detonation of the small carry-on impactor is avoided in the shadow of the asteroid.

② High-speed ejector avoidance
Collision with high speed ejector at the time of impact. Avoid in the shadow of the asteroid as with ①.

③ Slow ejector avoidance
Low speed ejector sent into an orbit trajectory is avoided by increasing the distance from the asteroid. The impact from collision is small as the speed of the slow ejector thrown to ultra-high altitudes is low and collision probability is small.

(image credit：JAXA)

# Small Carry-on Impactor operation




（image credit：JAXA）

# Small Carry-on Impactor

## Selection of impact target point and reason for choice

Constraint

Target point at a subearth latitude (~6°N) during the SCI collision (predicted collision area has a radius of about 200m = latitude / longitude ±30° in 3σ).

Selection criteria for target points

1st priority: Area where a generated crater can be found.

2nd priority: Area which is suitable for landing.

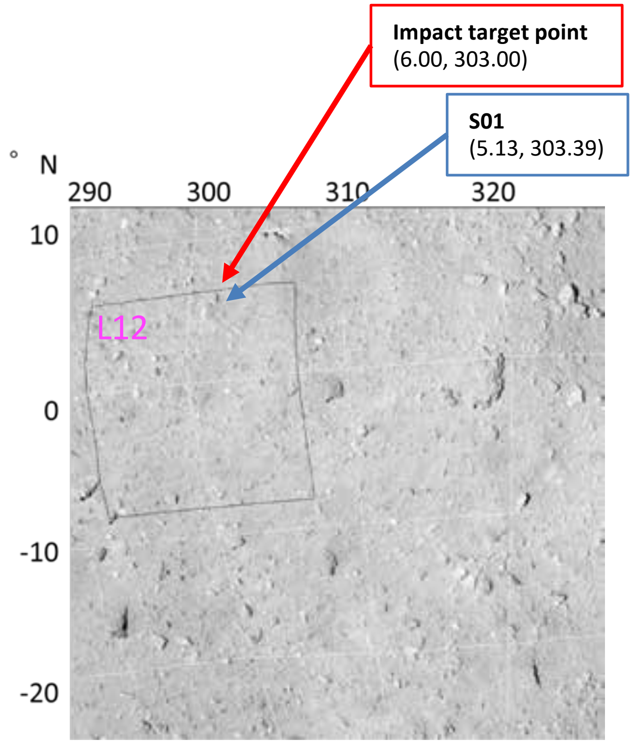
→ Flat areas with a layer of sand are desirable.

Collision target point latitude and longitude (6.00°, 303.00°)

Flat areas are scattered around the vicinity of the flat region L12 (where the next touchdown candidate, S01, is located).

Possibility to collect a sample from areas other than TD1 (Horai Fossa and the eastern hemisphere).

This is a geological area very similar to TD1 and the depth distribution of matter and structure can be discussed by comparing with the TD1 sample with an excavated sample.

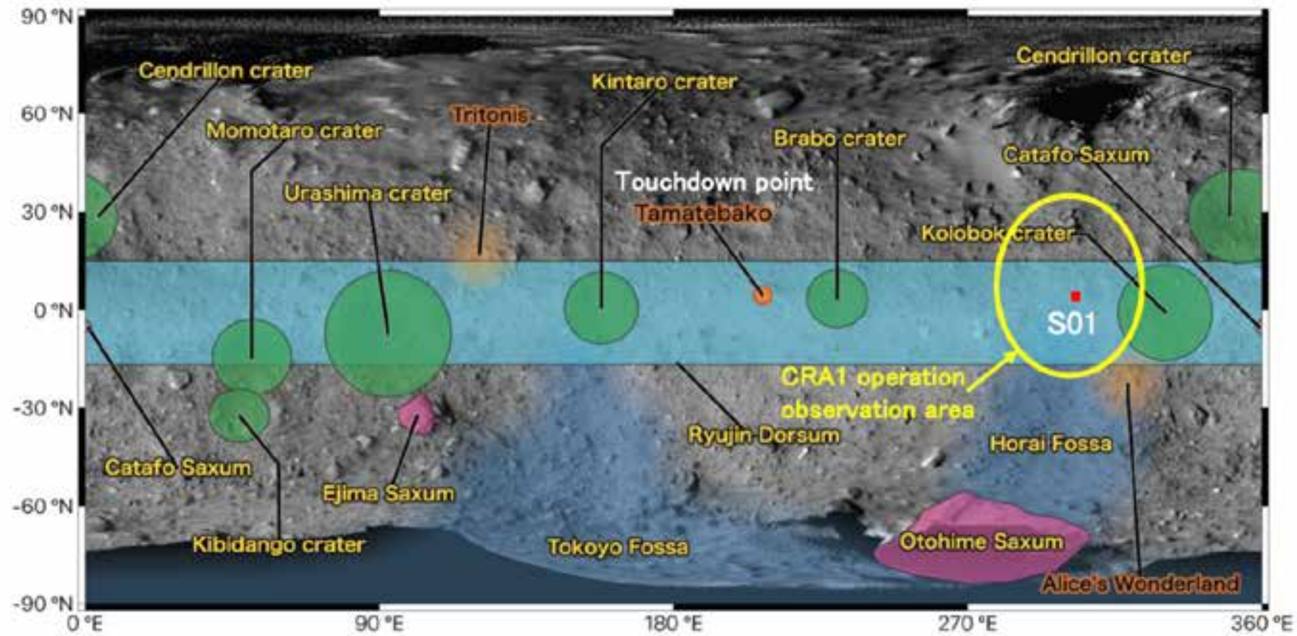


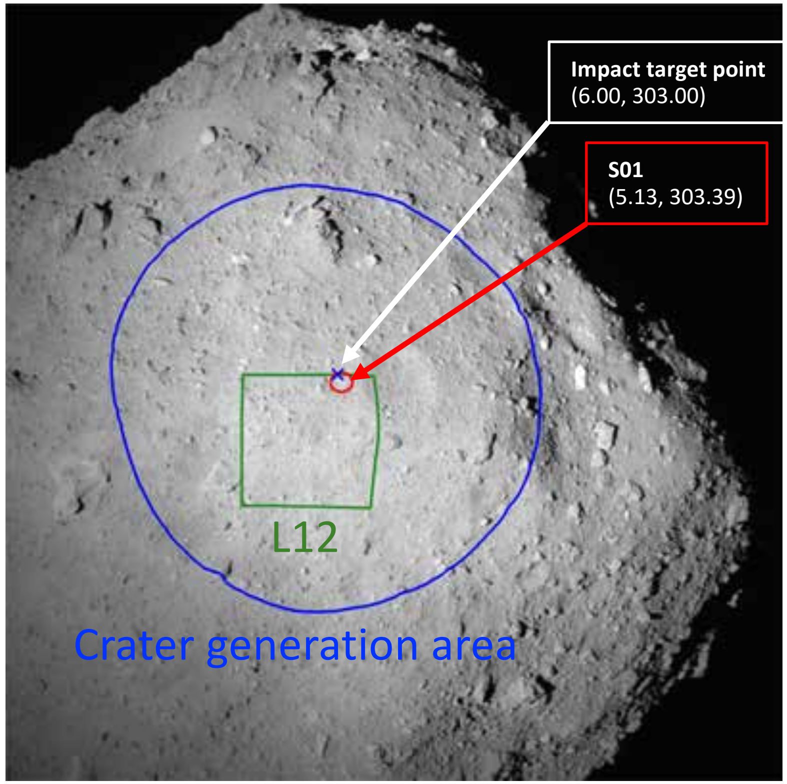

Captured by the ONC-T, hovering for MASCOT deployment (approximately 3km altitude)

(Image credit: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute, Meiji University, University of Aizu, AIST.)

# Small Carry-on Impactor

## S01・CRA1・crater generation area



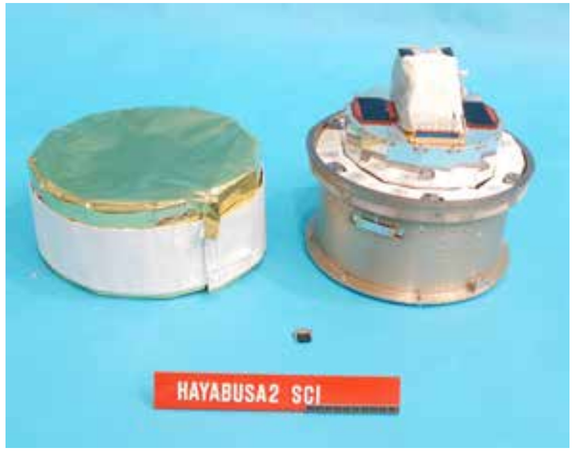

Note: The observation area for the CRA1 operation is the same as that of the crater generation area with the SCI.

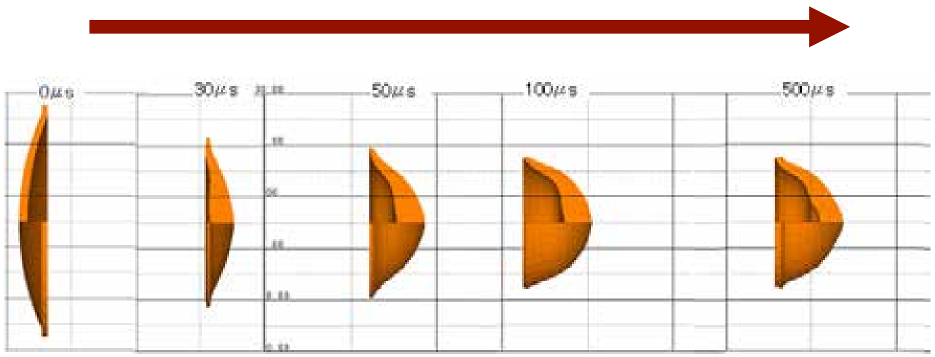
（Image credit：JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute, Meiji University, University of Aizu, AIST.）

# Small Carry-on Impactor

SCI：Small Carry-on Impactor

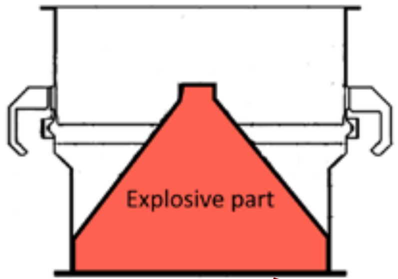
- Shape: conical (diameter 300mm、weight 14kg, explosive: ~9.5kg)
- Liner (impactor part): Pure copper（2kg), thickness ~5mm
- Explosive: HMX based PBX (Plastic bonded explosive)
- Explosive accelerates liner to 2 km/s in about 1/1000 seconds.




Copper plate (liner) that deforms as it flies

Cross section




Explosive part

Copper plate

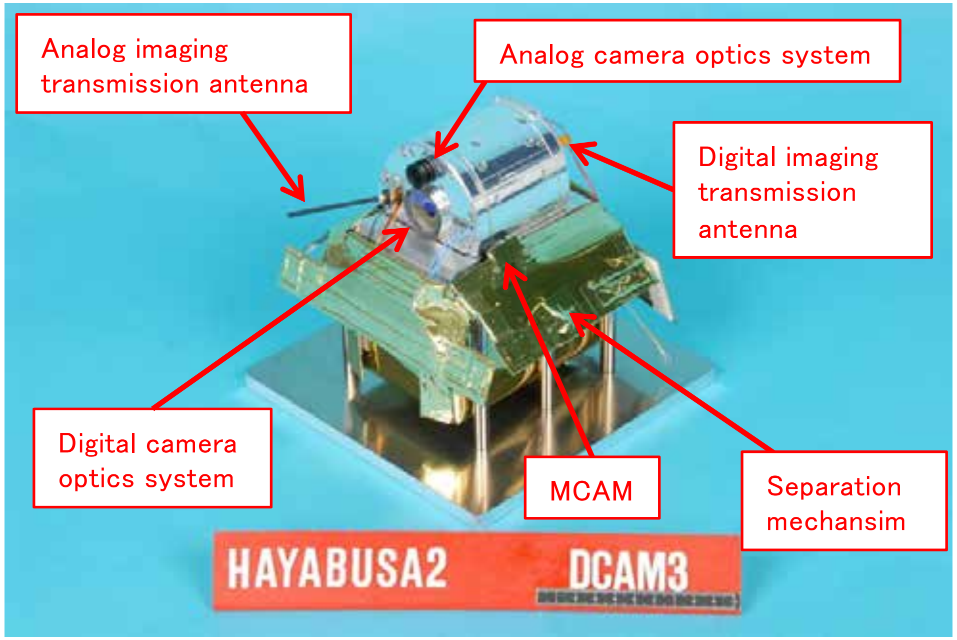
（Image credit：JAXA）

# Deployable camera

Outline of the deployable camera (DCAM3)

- Deployable camera has a cylindrical Φ80 mm × 78 mm shape, excluding the lens and protruding antenna.
- There are two built-in cameras; one analog camera that can transmit images in low resolution but in real time, and one digital camera for digital communication of high resolution images.
- There is also an analog and digital transmitting antenna for sending images.
- The battery enables imaging and wireless data transmission for up to 3 hours (depending on conditions).
- Images can be transmitted to the mothership wirelessly even at distances of 10km or more.
- A small monitor camera (MCAM) is mounted on the separation mechanism to try and capture images of how DCAM3 separates and leaves.

DCAM3 = Deployable Camera 3
Successor to DCAM1 and 2, mounted on the solar sail, IKAROS.

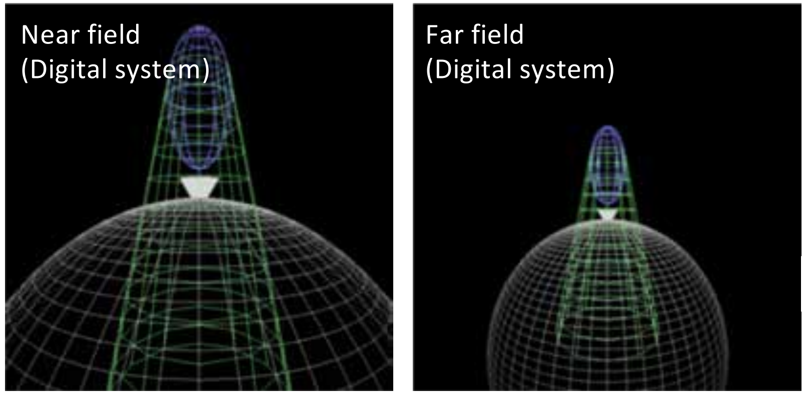



(Image credit：JAXA)

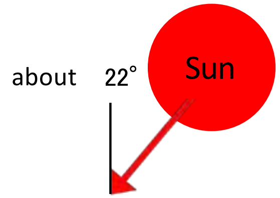
# Deployable camera

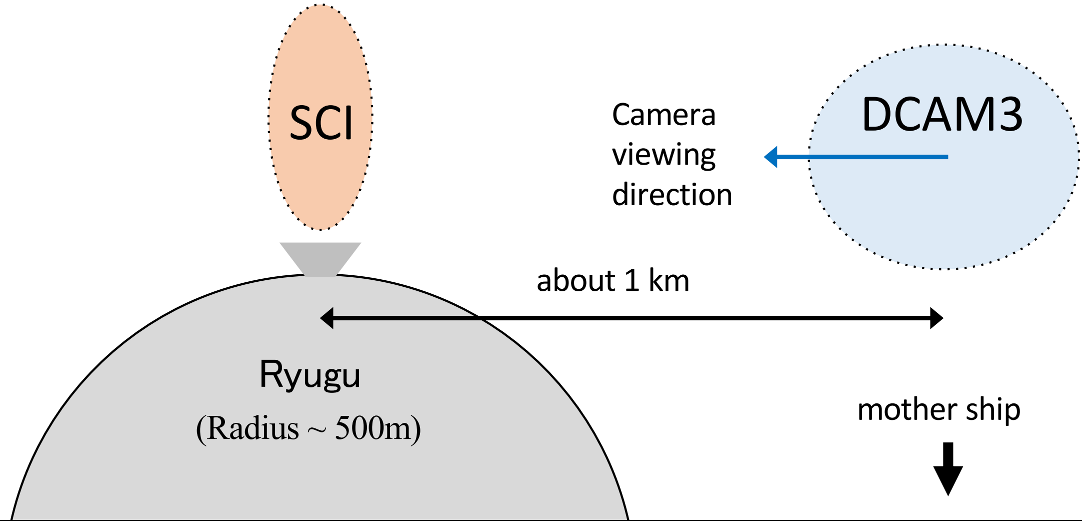
Outline of observations from deployable camera (DCAM3)

- Observe the impact from about 1km distance:
  - Ryugu
  - Scattered material generated during the collision
  - High speed debris (digital only)
  - Low speed dust (digital only)
  - SCI main body before explosion (digital only)
- Analog system: color, viewing angle 71ºx53º, 720x526 pixels, resolution about 10m. Digital system: Monochrome, viewing angle 74ºx74º, 2000x2000 pixel, resolution about 1m.
- Analog system can send data to the mother ship in real time. Digital system is delayed before sending.



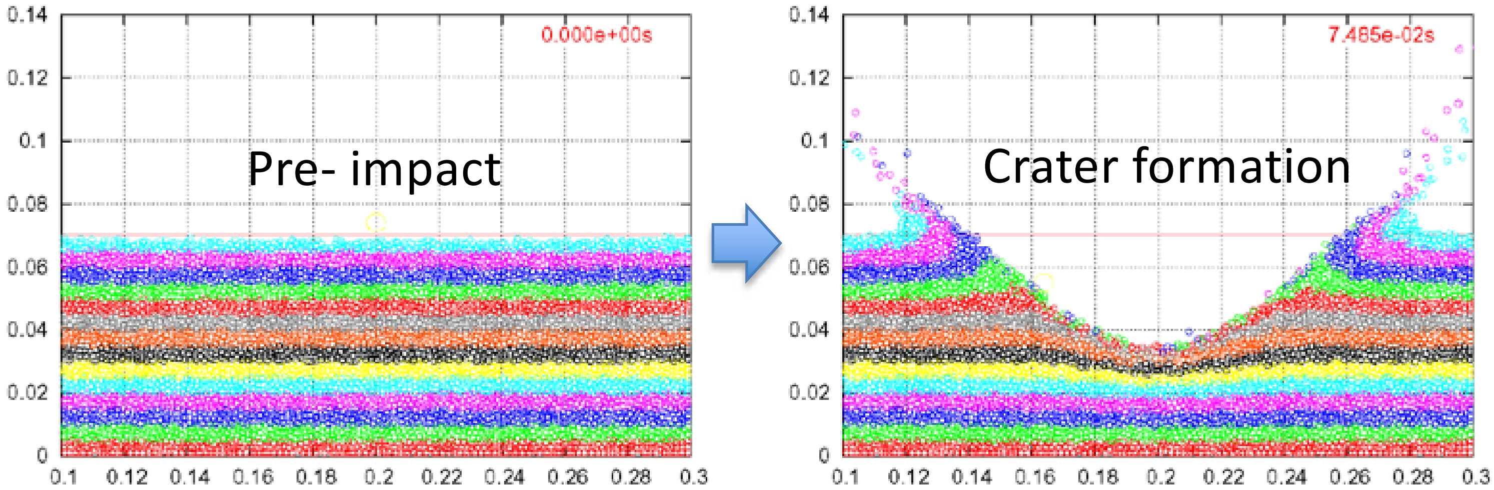
(Ogawa et al., Space Sci. Rev. 208, 125-142, 2017)

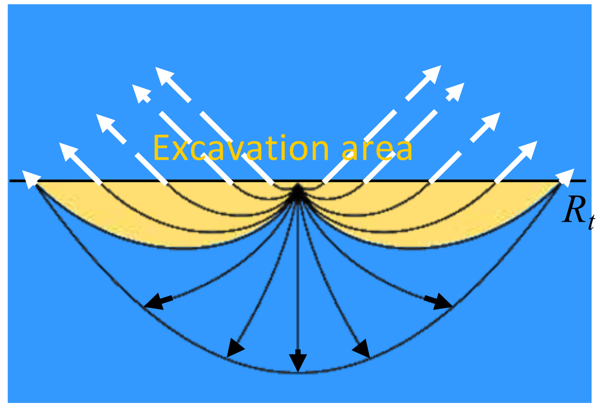


# Crater excavation depth

- Depth of the excavation area is about 1/10 of the crater diameter.



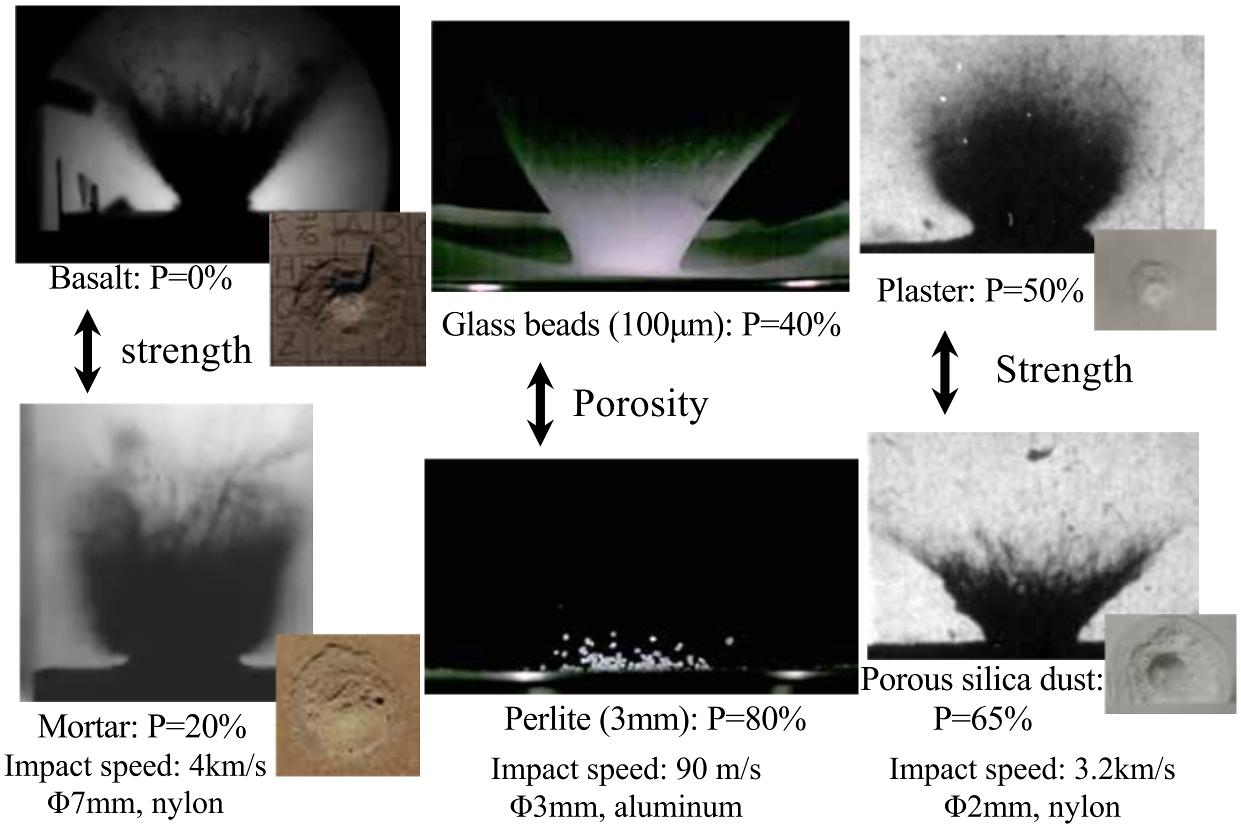




Excavation model

An example of numerical simulations of crater formation impacts on a granular layer (sand). Color corresponds to the depth prior to collision. (Provided by Koji Wada)

(Image credit: Chiba Institute of Technology)

# Ejector seen during collision experiments




P: Porosity

φ : Projectile diameter

Courtesy of Kobe University
Arakawa Laboratory

# Impactor Experiment Science

To understand the repeated collisional growth and destruction of celestial body evolution

- What kind of collision crater can / cannot form on the surface of Ryugu?
  - Observation of the crater formation process and measurements of the formed crater size and shape.
    - Construction of a collision physics model (scaling law) based on the collision experiment in real asteroid material and environment.
    - Construction of scaling rules for Ryugu's collisional history and surface age estimation (crater chronology)

**Scaling law:** a universal equation connecting collision conditions and the properties of the formed crater.

- What's going on below Ryugu's surface?
  - Exposure and collection of subsurface material via crater formation → Assessment of the impact of space weathering and surface flow.
  - In-situ observation of ejector → Estimate subsurface conditions (porosity, particle size, distribution etc.)

Principal role of DCAM3

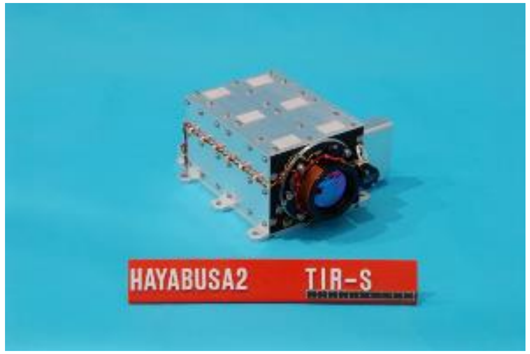
- Does Ryugu's surface move easily?
  - Measurement of terrain changes from the impact → Understand the effect of impact vibrations, the presence of few small craters.
- In case we hit a boulder…
  - Crater on boulder measurement or measurement of fragments from boulder destruction → Estimated strength of asteroid material

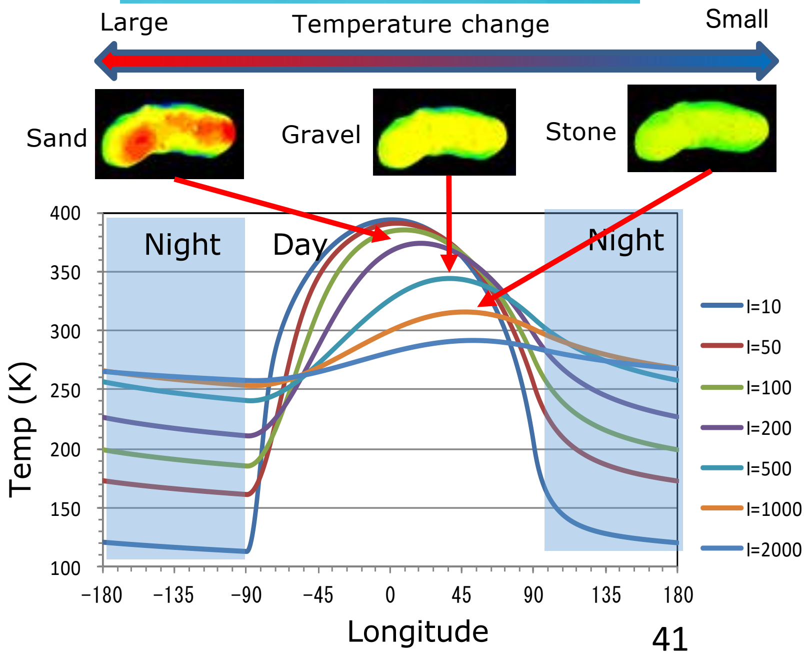
# Thermal infrared camera (TIR)

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.
The physical state of the asteroid's surface is investigated 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.)



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