Asteroid explorer, Hayabusa2, reporter briefing

March 18, 2019

JAXA Hayabusa2 Project

Topics

Regarding Hayabusa2:

- Descent operations
- Small Carry-on Impactor(SCI) operation
- Deployable camera(DCAM3)
- Impactor experiment science

Contents

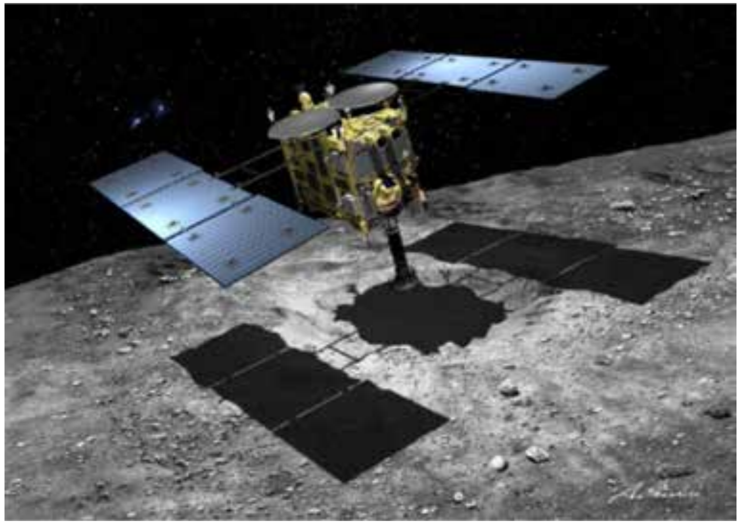
Overview of Hayabusa2

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

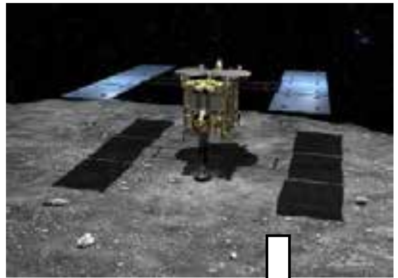
Launch → Arrival at asteroid

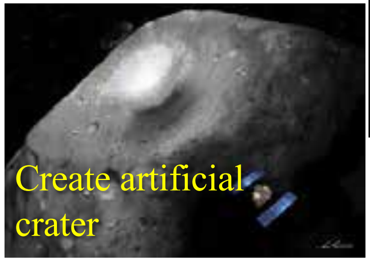
3 Dec 2014

Earth swing-by
3 Dec 2015

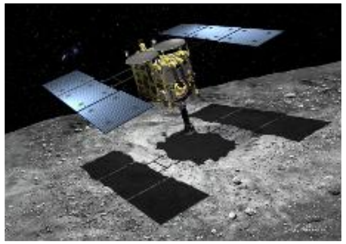
June 27, 2018

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

Nov–Dec 2019

late 2020

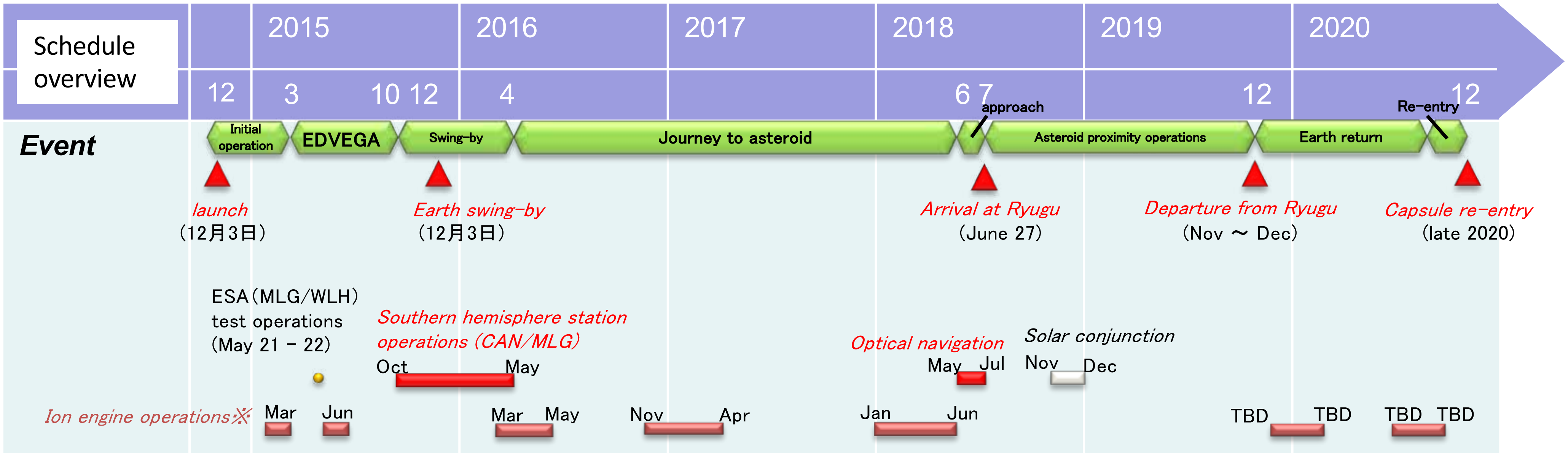
Sample analysis

(Illustrations: Akihiro Ikeshita)

1. Current project status & schedule overview

Current status :

- Descent observation operation (DO-S01) was performed between March 6 – 8, and observations of the S01 area (touchdown candidate site) were made from an altitude of 22m.
- In preparation for the Small Carry-on Impactor operation, "Crater Search Operation (Pre-SCI)" (CRA1) will be performed from March 20 to 22.



2. Descent operation

■Descent observation operation(DO-S01)

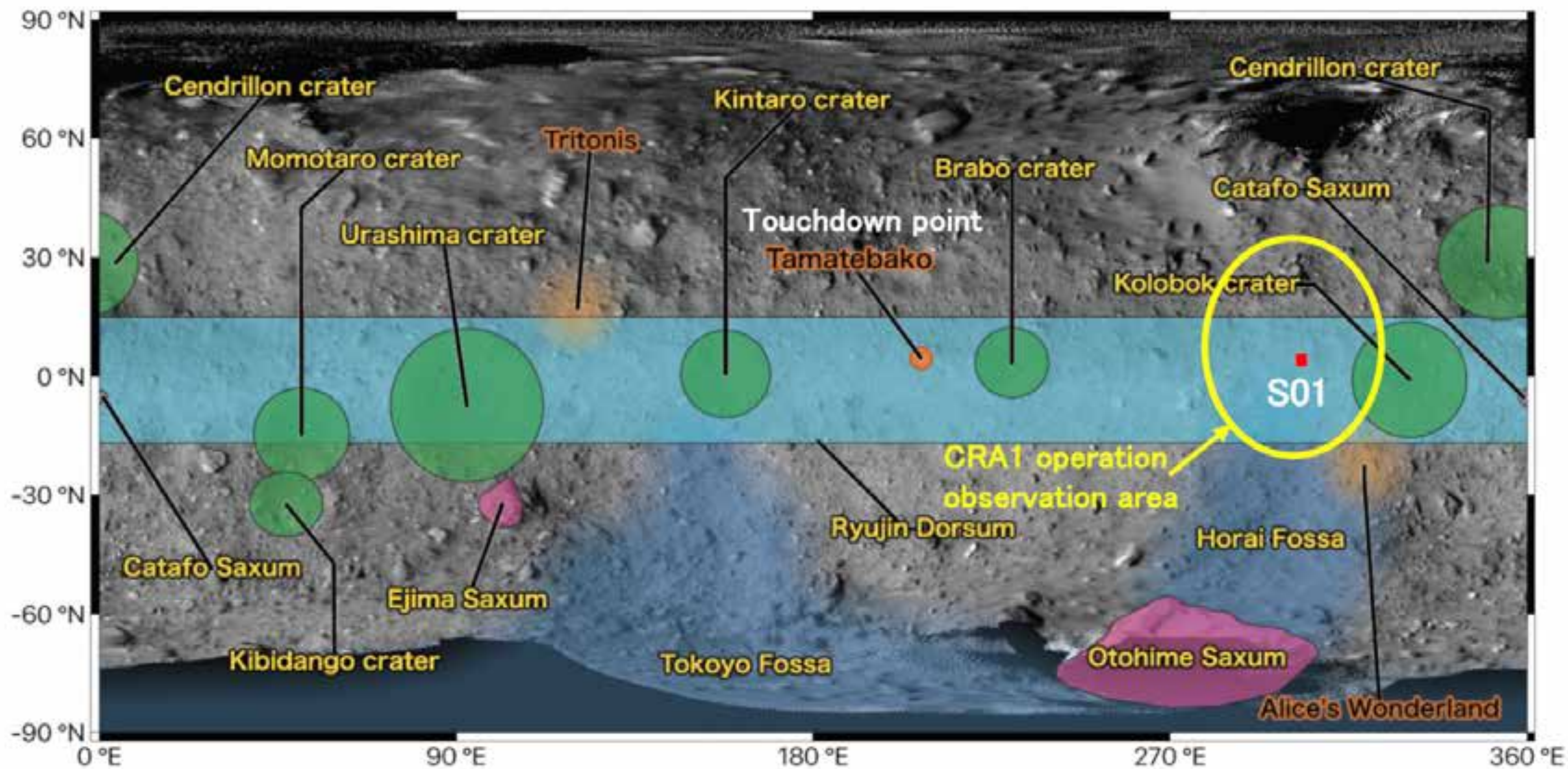
- Investigate the S01 area at low altitudes
- Operation schedule：March 6～8(performed)
- Descent down to 22m

■Crater search operation(Pre-SCI)(CRA1)

- Get detailed data on the area to generate a crater with the Small Carry-on Impactor(SCI)prior to that experiment
- Operation schedule: March 20～22
- Lowest altitude approximately 1.7km

2. Descent operation

Location of S01 and CRA1

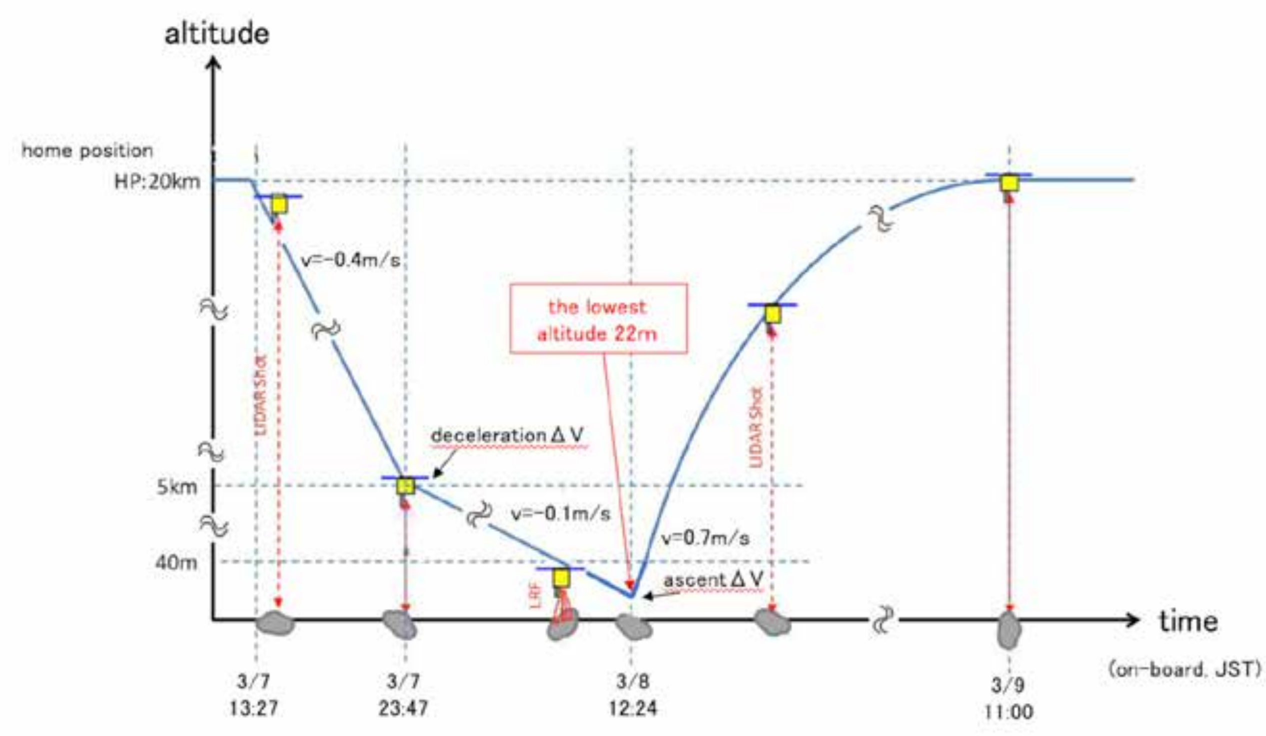


Note: The observation area of CRA1 is the same as the crater generation area using the Small Carry-on Impactor.

(Image credit：JAXA)

2. Descent operation

Results of the Descent Observation Operation (DO-S01)



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(Image credit：JAXA)

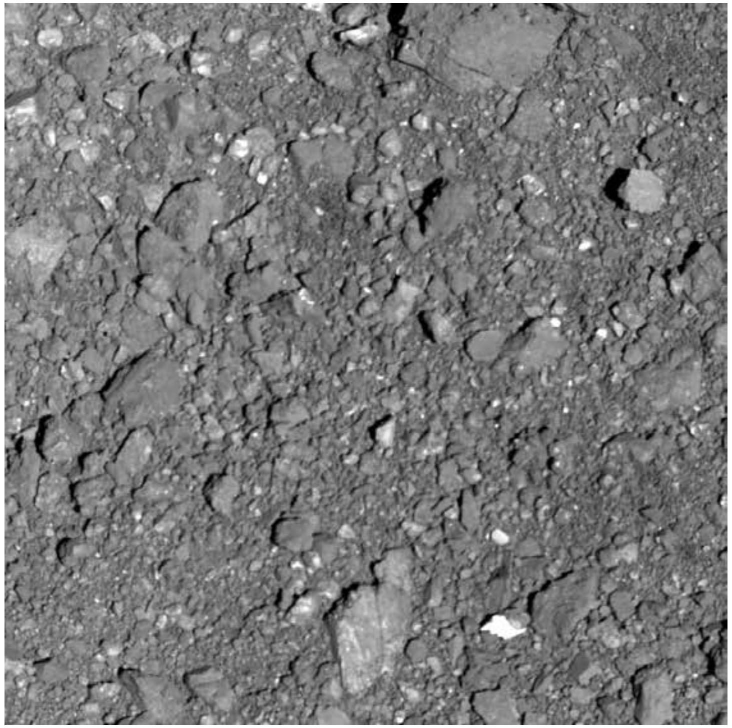
Results：

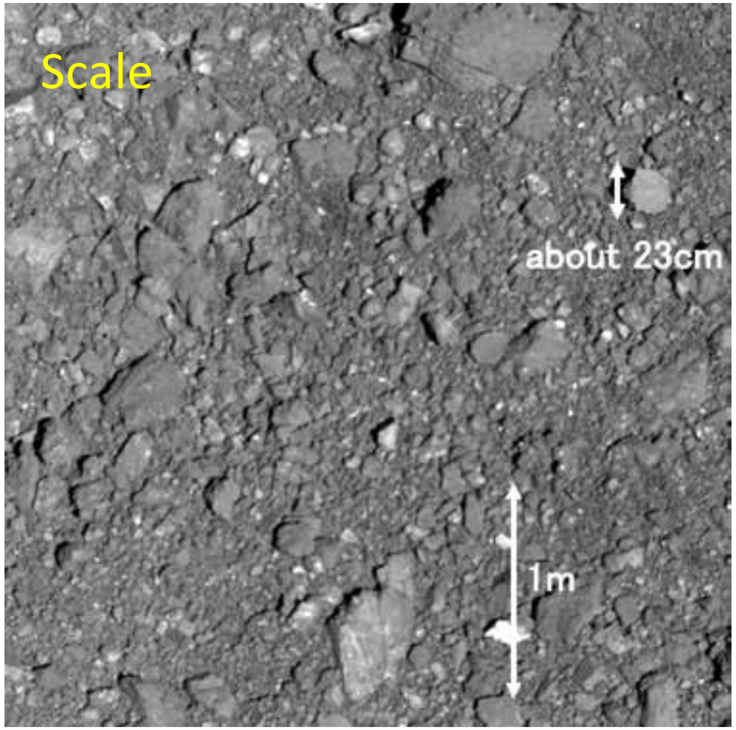
- Detailed data of S01 was successfully obtained and is currently being analyzed.
- The ONC-W1 received roughly half the light intensity and the image was stained. Although no major abnormalities on the other instruments were seen, they are currently being checked.
- We confirmed all instruments can be used without any issues for operations other than touchdown, including the ONC-W1.

2. Descent operation

First release

Images taken of the S01 area



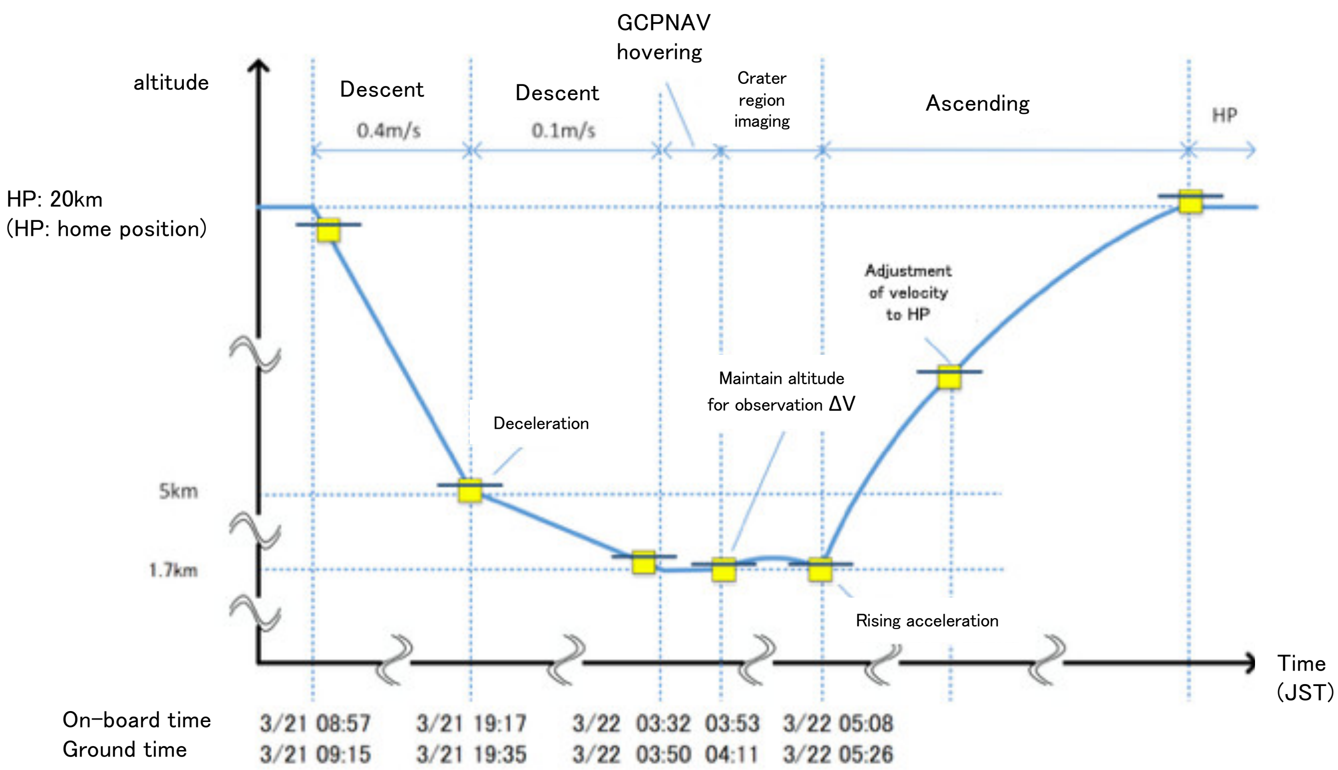


Images from the DO-S01 operation
・Camera : ONC-T
・Image time(JST) :
March 8, 2019 12:24
・Image altitude : 35m

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

2. Descent operation

Plan for the Crater Search Operation (pre-SCI)(CRA1)



(Image credit：JAXA)

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

3. Small Carry-on Impactor operation

Outline and purpose of operation

- The impact device generates an artificial crater on the surface of Ryugu.
- Collect information about the interior of the asteroid by examining the crater formation and generated crater.
- At a later date, touchdown at or around the generated crater and try to collect subsurface material. However, if the condition of the surface of Ryugu is dangerous for touchdown, the touchdown will not be attempted.

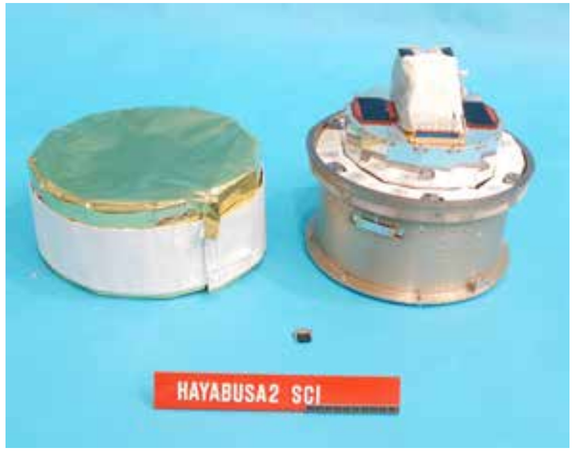
Operation schedule

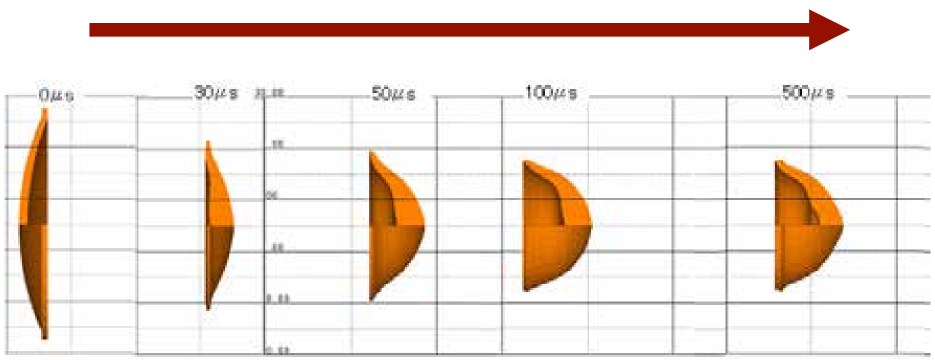
- SCI operation：April 4～6
- Crater generation date & time： April 5 at 11:36（onboard time, JST）.

3. Small Carry-on Impactor operation

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.

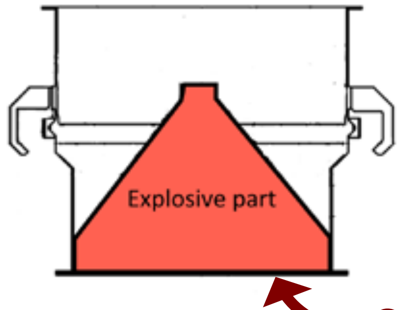




Copper plate (liner) that deforms as it flies

(Image credit：JAXA)

Cross section



Explosive part

Copper plate

3. Small Carry-on Impactor operation

Test of the Small Carry-on Impactor experiment (SCI) (October 17～27, 2011)

① Experiment location (moment of ignition)
The projectile is launched towards the lower left from an enclosed ignition point (center right) surrounded by a 3m high concrete wall.

② Projectile shape
Observed flight speed is 2km/s. The outer diameter is about 135mm and weight 2kg. The shape is like a helmet.

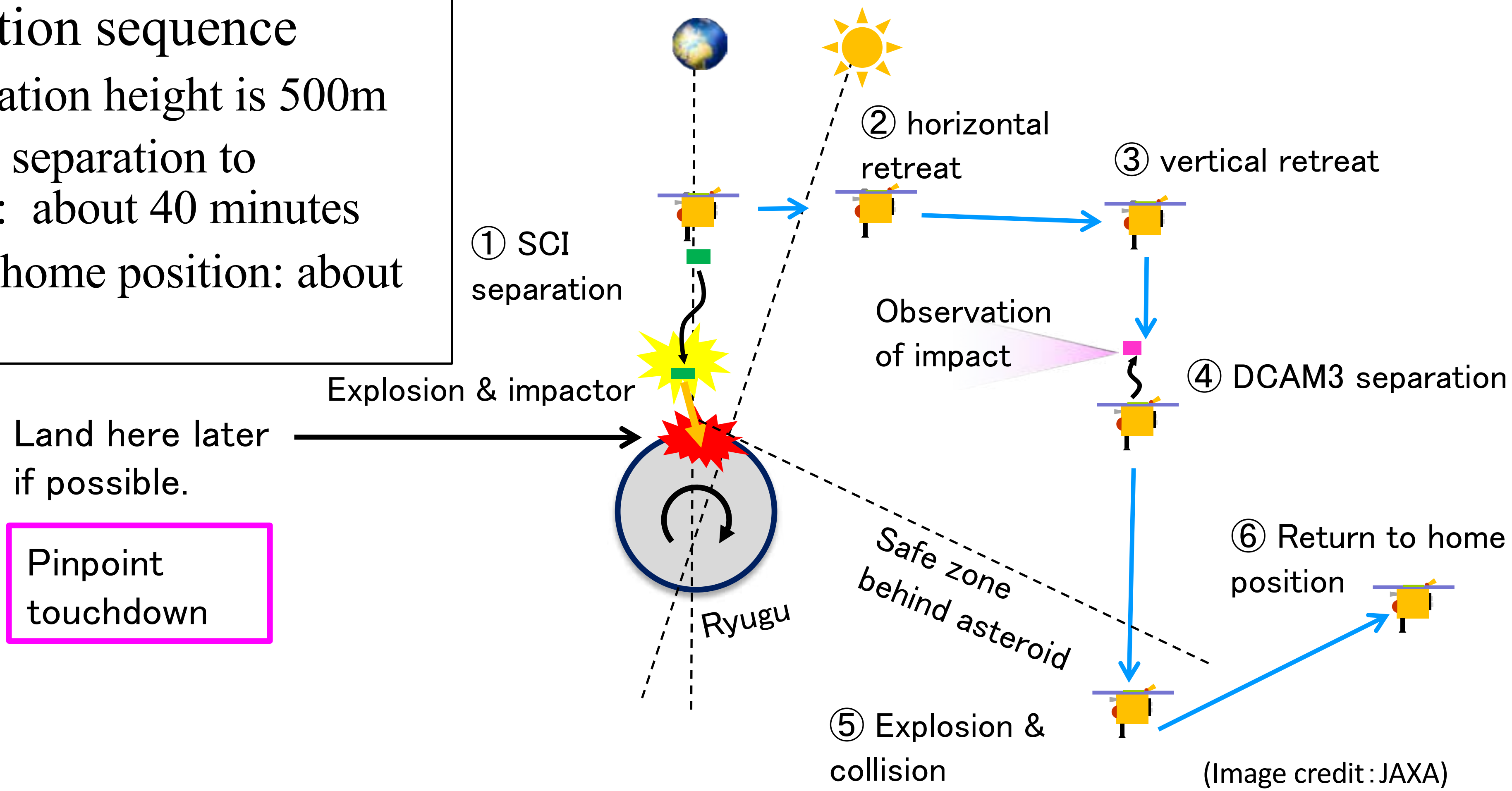
③ Target pierced
The projectile pierced the target. The mark of a single passage is pierced in the target (4m x 4m) at 100m from the launch point.

④ Moment of impact
The moment when the projectile collided with the earth and sand target at 100m from the launch point.

(Image credit : JAXA)

3. Small Carry-on Impactor operation

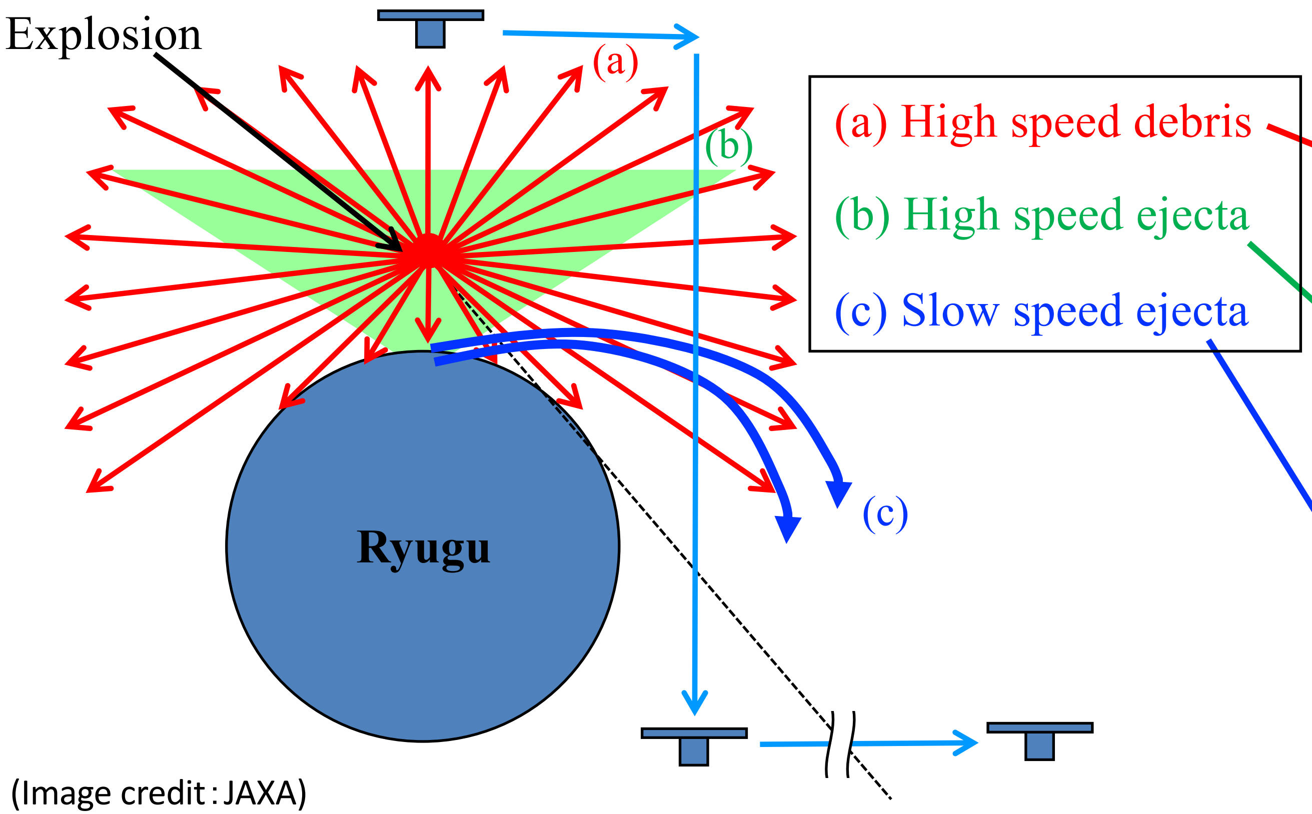
SCI operation sequence
- SCI separation height is 500m
- From SCI separation to explosion: about 40 minutes
- Return to home position: about 2 weeks



(Image credit：JAXA)

3. Small Carry-on Impactor operation

How to avoid debris and ejecta



(Image credit : JAXA)

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 ejecta avoidance
Collision with high speed ejecta at the time of impact is avoided in the shadow of the asteroid as with ①.

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

3. Small Carry-on Impactor operation

Selection of impact target point and reason for choice

Constraint

Target point at a subearth latitude (~6°N) during the SCI impact (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

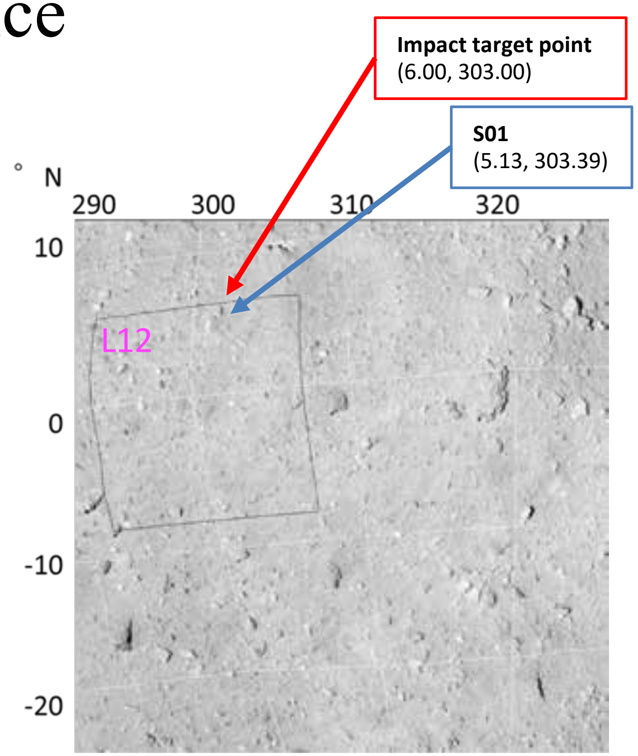
→Flat areas with sand layer are desirable.

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).

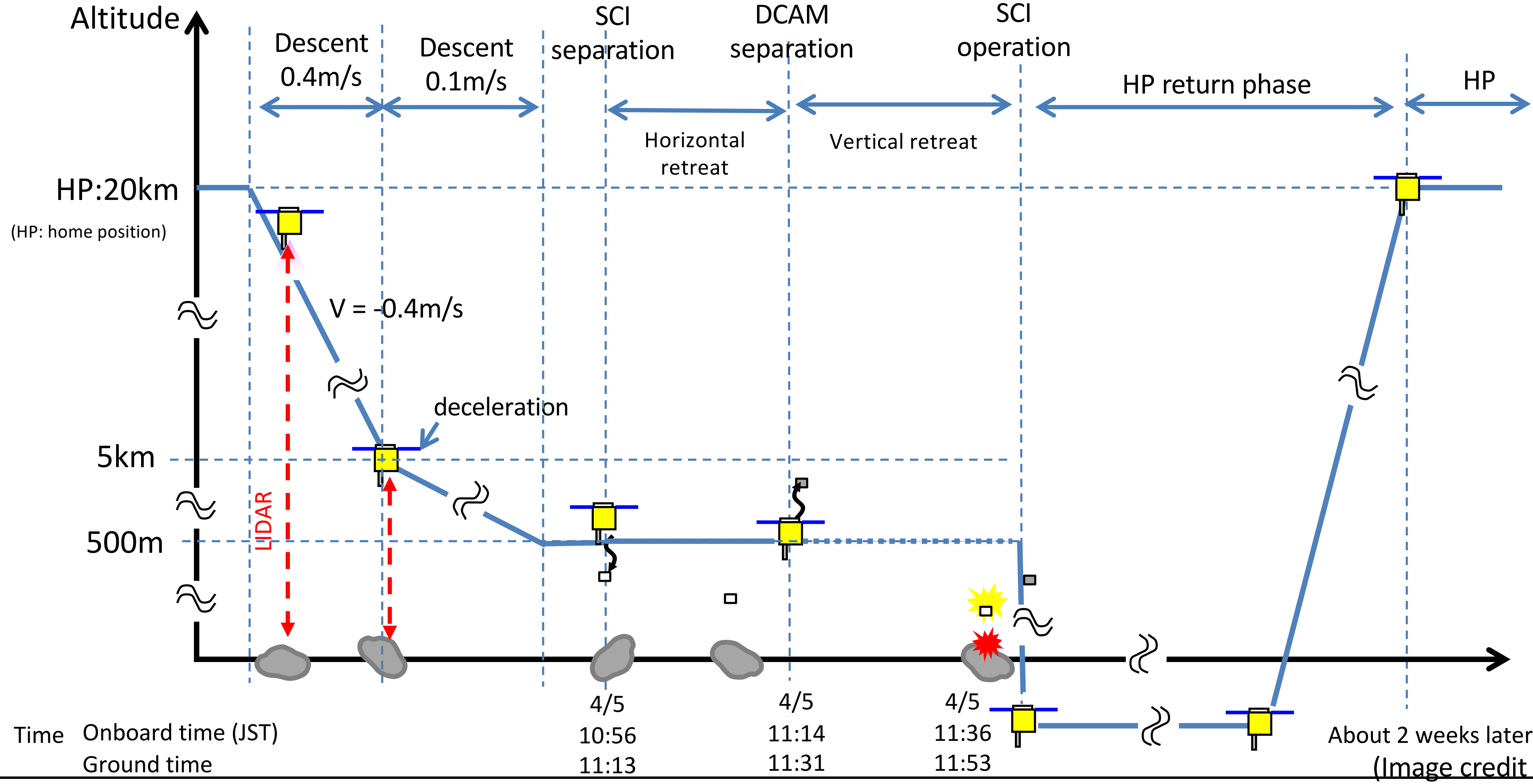
This is a geological area very similar to TD1 and the depth distribution of material and structure can be discussed by comparing with the TD1 sample with excavated sample.



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

(Image credit：JAXA, University of Tokyo, et. al.)

3. Small Carry-on Impactor operation



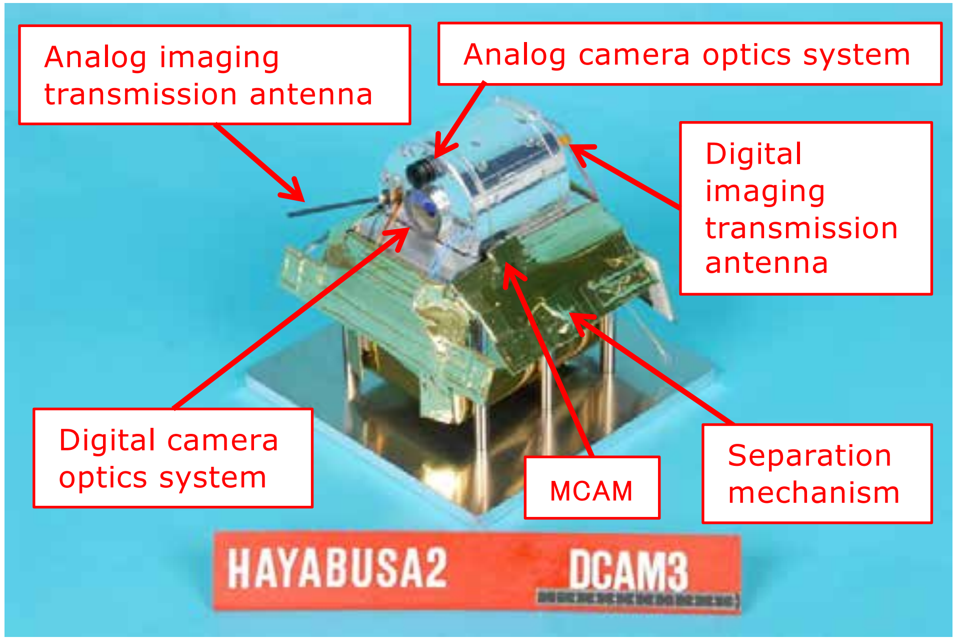
(Image credit：JAXA)

4. Deployable camera

Outline of the deployable camera (DCAM3)

- Deployable camera has a cylindrical Φ80 mm × 78 mm shape, excluding the protruding lens and 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 a 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 DCAM 1 and 2, mounted on the solar sail IKAROS

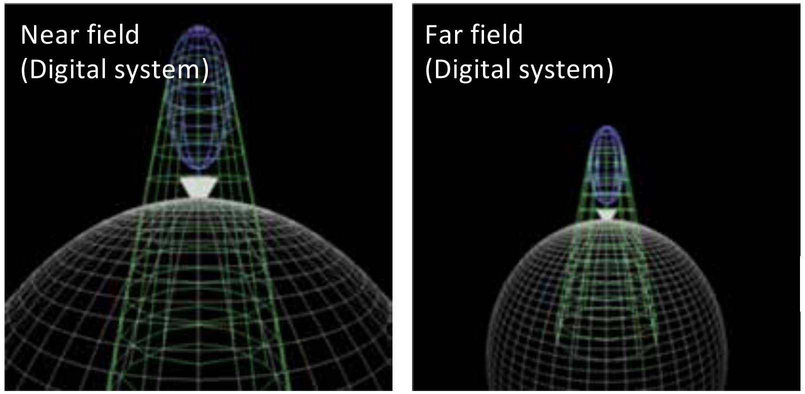


(Image credit : JAXA)

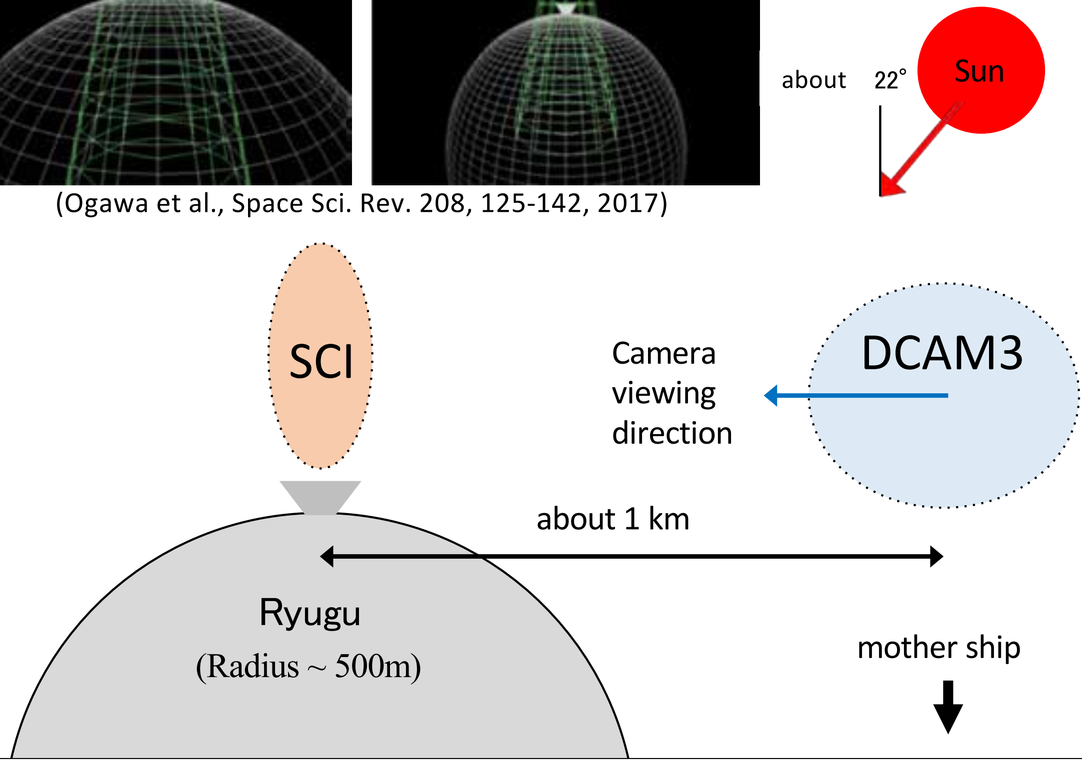
4. Deployable camera

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 71°x53°, 720x526 pixels, resolution about 10m.
  Digital system: Monochrome, viewing angle 74°x74°, 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)



(Image credit : Kobe Univ.)

5. Impactor Experiment Science

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

- What kind of impact 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 impact physics model (scaling laws) based on the impact experiment in real asteroid material and environment.
    - Construction of scaling rules for Ryugu's collisional history on the surface and surface age estimation (crater chronology)

Scaling law: a universal equation connecting impact 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 ejecta motion → Estimate subsurface conditions (porosity, particle size distribution etc.)

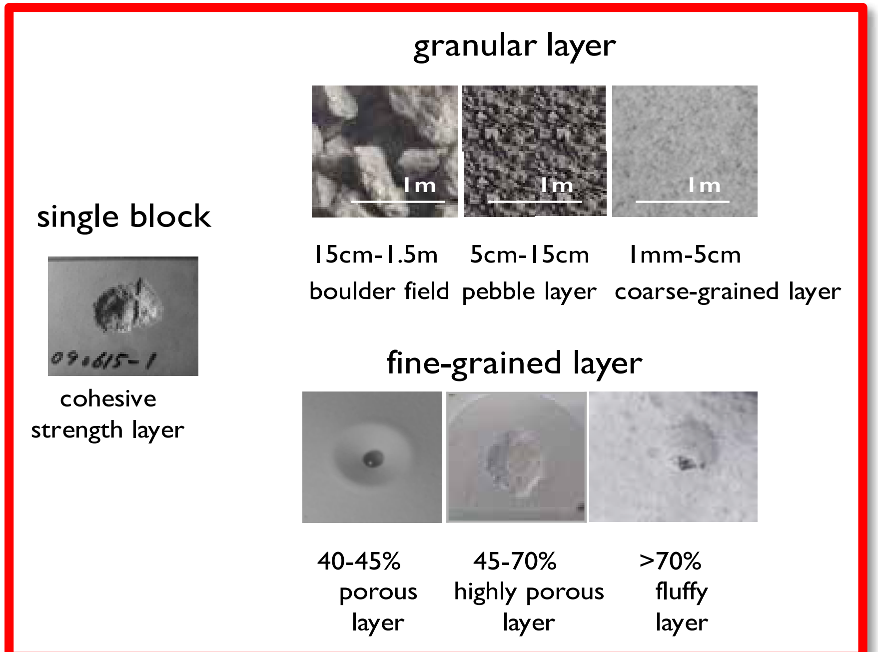
principal role of DCAM3

- Does Ryugu's surface move easily?
  - Measurement of terrain changes caused by 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 → Estimate strength of asteroid material

5. Impactor Experiment Science

Expected crater size

Classification	Subdivision	Crater diameter	Ejector deposited layer diameter ※	Applied scaling law ※※
Monolithic: >1.5m	Strength layer Porosity <40%	70 cm – 10 m	-	Strength regime
Granular layer: Particle size 1mm-1.5m	Boulder field Particle size: 15cm-1.5m	< 15 cm – 1 m	-	Strength regime
	Pebble layer Particle size: 5-15cm	2 – 10 m	4 m – > 20m	Gravity regime
	Coarse-grained layer Particle size: 1mm- 5cm	2 - > 10 m	4 m - > 20 m	Gravity regime
Fine-grained layer: Particle size <1mm	Porosity 40-45%	1 – 10 m	2 m - > 20 m	Gravity＋strength regime
	Porosity 45-75%	30 cm – 1m	60 cm - 2 m ?	Gravity＋strength regime
	Porosity >75%	< 40 cm	-	Gravity + strength regime



Arakawa, M., Wada, K., Saiki, T. et al. Space Sci Rev (2017) 208: 187.
https://doi.org/10.1007/s11214-016-0290-z

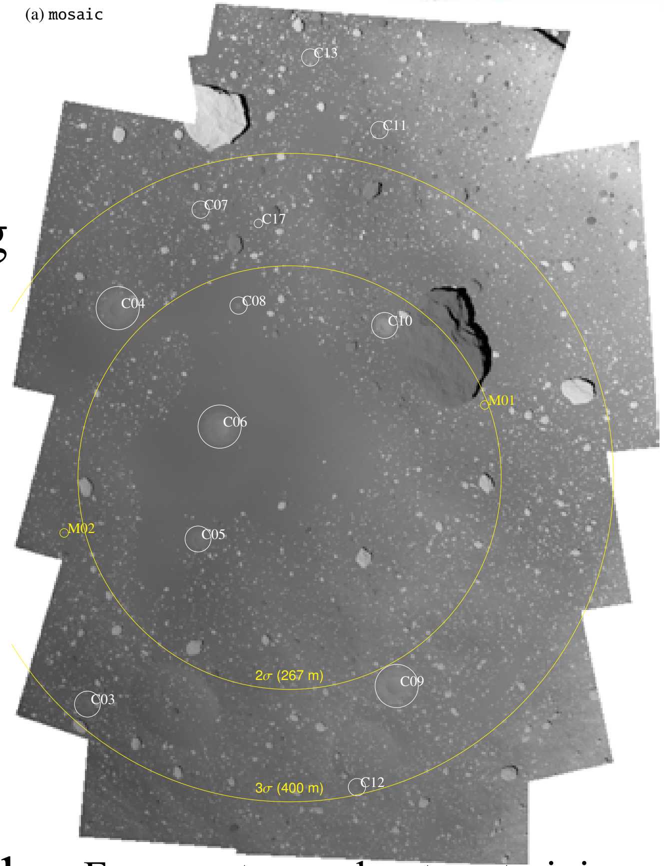
※ Distinct ejecta layer deposited around crater.

※※ The scaling law applied changes depending on whether the target’s strength or gravity dominates during crater formation.

5. Impactor Experiment Science

Crater search：basically, search by eye

- DCAM3 imaging → estimate impact position
- Comparison with pre/post low altitude ONC & TIR imaging (CRA1,2) → impact position, crater identification.
  - Low altitude image scan of predicted impact area two weeks prior and three weeks after impact.
    - ONC-T resolution：∼17cm/pix@ altitude 1.7km
    - TIR resolution：∼1.7m/pix@ altitude 1.7km
- Images of SCI separation with ONC-W1 etc. → SCI separation confirmation, explosion location estimation.
- In addition, dust observations after SCI impact with TIR and LIDAR → Collision confirmation



From crater exploratory training (ONC-T image mosaic)
(Image credit：JAXA)

6. Other topics

■Overseas presentations

・At the 50th Lunar & Planetary Science Conference (LPSC) –a research meeting in the USA– there will be a special session of Hayabusa2 and a briefing session for local media.

・Date・Place：March18～22、The Woodland, Texas, US.

・Special session for Hayabusa2: 13 oral (3/19), 28 posters (3/20)

・There are also several presentations related to Hayabusa2 in other sessions.

・Local media briefing session is scheduled to be held on March 19, 11:45 ～ 12:30 (local time). The content will cover an explanation of touchdown and science results.

7. Future plans

■Operation plans

- March 20～22：Crater Search Operation (Pre-SCI)（CRA1）
- April 4～6：Small Carry-on Impactor operation（SCI）

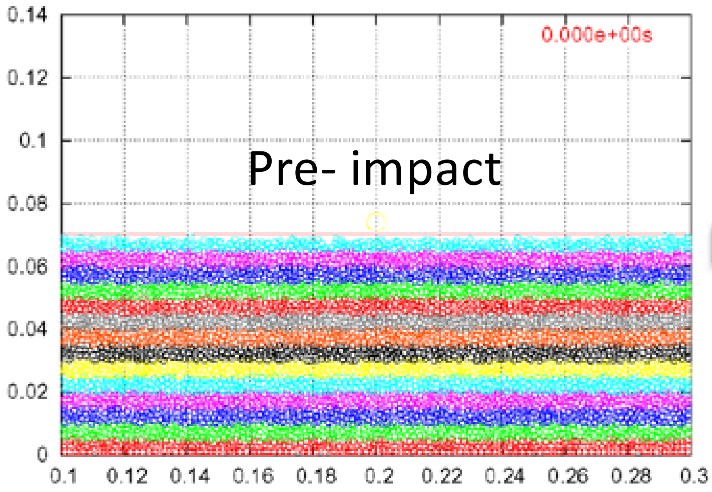
■Press and media briefings

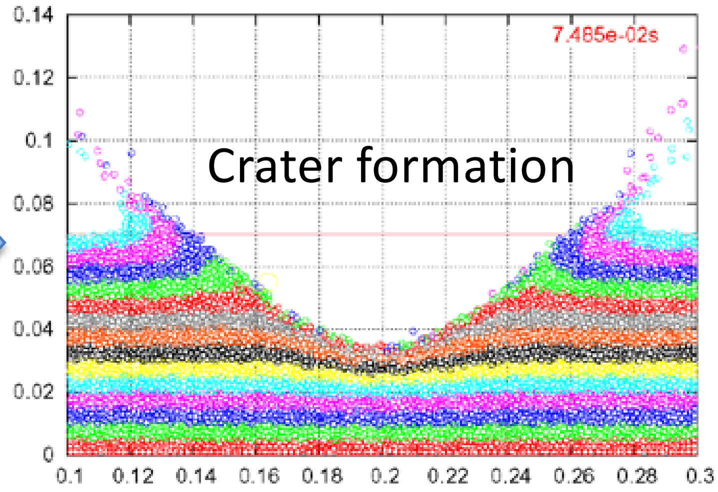
- April 2 14:00～　Regular press briefing session @JAXA Tokyo office
- April 5　8:30～　Press center opens @JAXA Sagamihara Campus

Reference

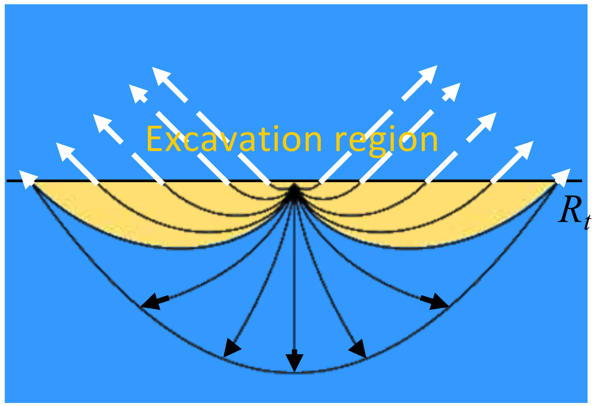
Crater excavation depth

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





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)



Excavation model

(Image credit：Chiba Institute of Technology)

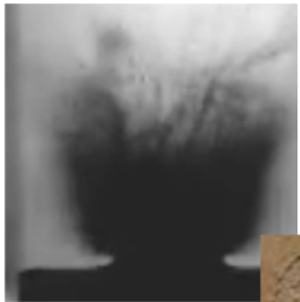
Ejector seen during collision experiments

Large blocks | Granular (sand) layer | Powder layer

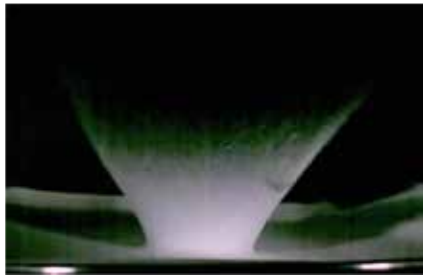


Basalt: P=0%

↕ strength

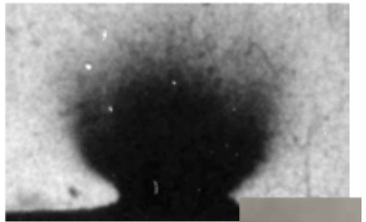
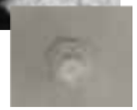


Mortar: P=20%
Impact speed: 4km/s
Φ7mm, nylon

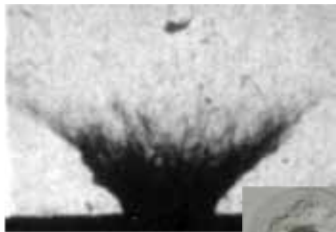

Glass beads (100μm): P=40%

↕ Porosity


Perlite (3mm): P=80%
Impact speed: 90 m/s
Φ3mm, aluminum



Plaster: P=50%

↕ Strength



Porous silica dust: P=65%
Impact speed: 3.2km/s
Φ2mm, nylon

P: Porosity
φ : Projectile diameter

Courtesy of Kobe University Arakawa Laboratory

Ejector (curtain) size and evolution forecast

Impact on sand (gravity regime)

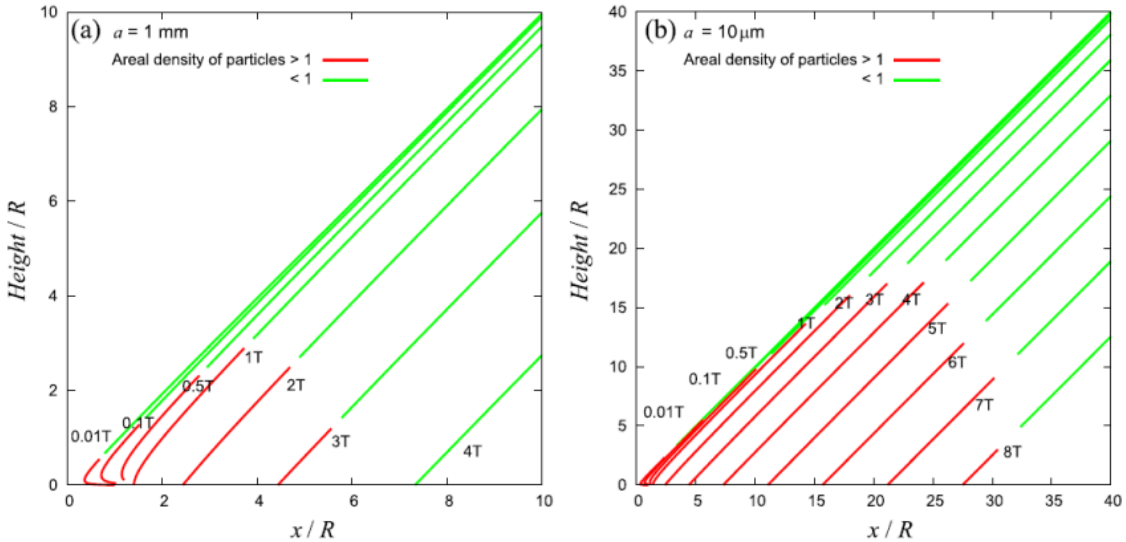


Fig. 6 The cross section of the ejecta curtain proceeding with time, assuming a typical sand target ($C_2 = 0.64$ and $\mu = 0.41$), and the radius of constituent ejecta particles is (**a**) 1 mm and (**b**) 10 μm. The horizontal axis shows the distance x from the impact point and the vertical axis shows the height from the target surface, both being normalized by the final crater radius R. The time labeled for each curtain is normalized by the crater growth time $T = 0.92(R/g)^{1/2}$ for a typical sand target, where g is the surface gravity (Holsapple and Housen 2007). With g and R being 2.6×10^{-4} m/s^2 and 5 m, respectively, T is calculated to be 128 sec. The red lines show a dense part of curtains with an areal density of particles >1, while the green lines show a sparse part

Impact on bedrock (strength regime)

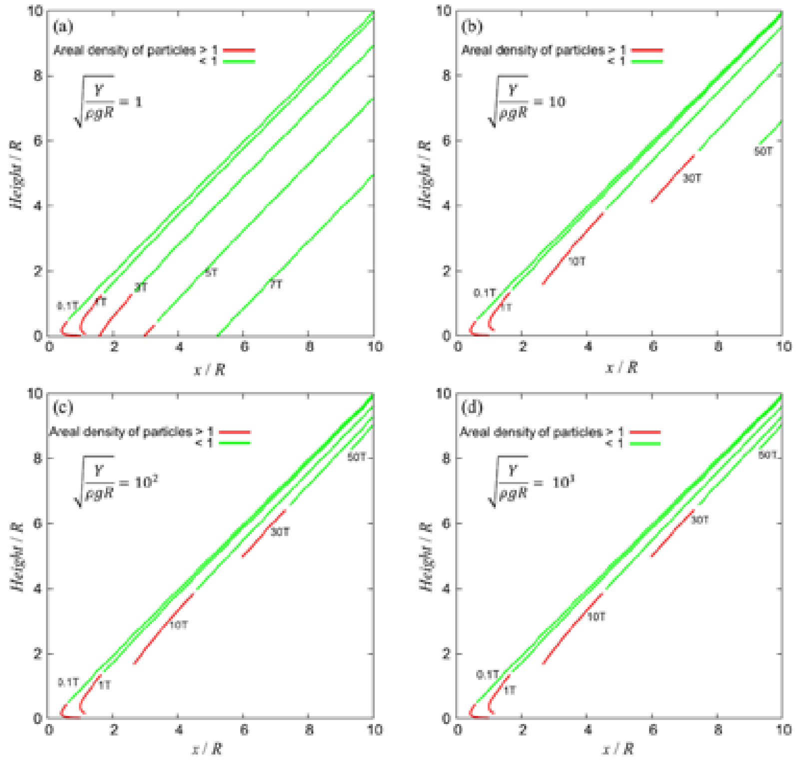
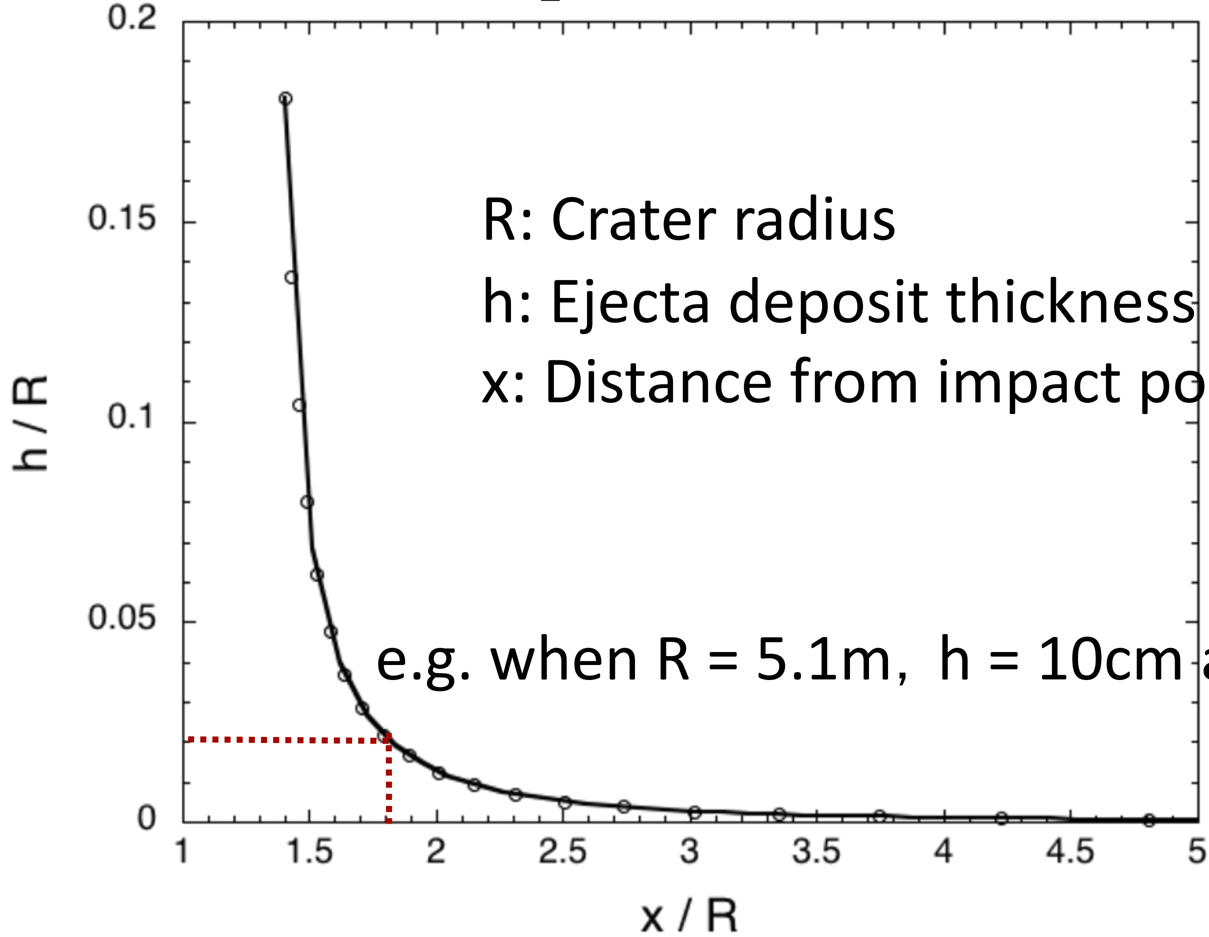


Fig. 11 Same as Fig. 6, but assuming the strength regime scaling law with parameters of $C_3 = 0.53$ and $\mu = 0.55$ (Housen and Holsapple 2011). The ejecta curtains proceed differently, depending on the target strength Y with $(Y/\rho g R)^{1/2}$ = (**a**) 1, (**b**) 10, (**c**) 100, and (**d**) 1000. The crater growth time T is given by $T = 0.44R/(Y/\rho)^{1/2}$ for a typical rock target (Holsapple and Housen 2007). Here we assume $R = 1$m, then (**a**) $T = 27.3$ sec, (**b**) 2.73 sec, (**c**) 0.273 sec, and (**d**) 0.0273 sec. When giving the areal density of curtains, we assume the radius of the constituent ejecta particles to be 1 mm

Arakawa, M., Wada, K., Saiki, T. et al. Space Sci Rev (2017) 208: 187.
https://doi.org/10.1007/s11214-016-0290-z

Ejector deposit layer thickness distribution (for impact on sand)



R: Crater radius

h: Ejecta deposit thickness

x: Distance from impact point（crater center）

e.g. when R = 5.1m, h = 10cm at x = 9m

(Image credit：Kobe University)

Ryugu subsurface structure (metamorphic grade) prediction

If the surface is static…

Metamorphic cause	Layer thickness (depth)
Space weathering by solar wind	Several microns
Thermal alteration by solar heating	10 cm
Space weathering by galactic cosmic rays	~ 1 m
No metamorphosis (fresh)	> 1 m

If the surface flows (mixing), doesn't the degree of metamorphism depend on this depth?