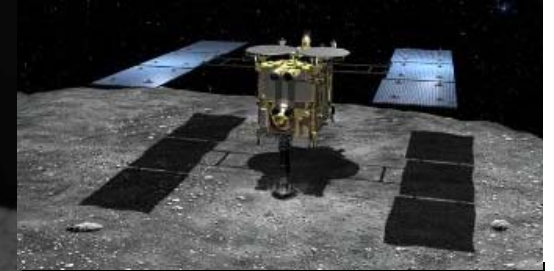


Hayabusa2 Mission Status

Yuichi Tsuda
Project Manager, Hayabusa2
Institute of Space and Astronautical Science
Japan Aerospace Exploration Agency

Small Bodies Assessment Group 22nd Meeting, Jan.16, 2020





Hayabusa2 Mission Scenario



Launch
Dec.3, 2014



Earth Gravity Assist
Dec.3, 2015



Ryugu Arrival
Jun.27, 2018



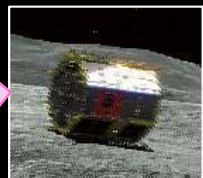
MINERVA-II-1 Deployment
Sep.21, 2018



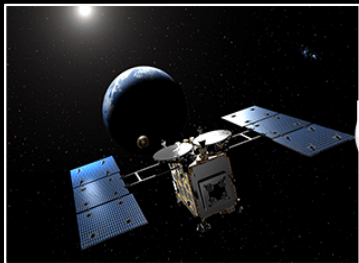
MASCOT Deployment
Oct.3, 2018



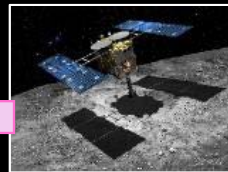
Ryugu Departure
Nov.13.2019



Earth Return
Nov.-Dec. 2020



Target Markers Orbiting Touchdown
Sep.16, 2019

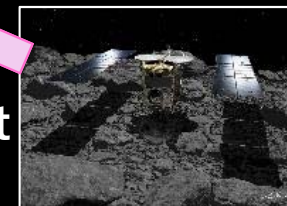


Second Touchdown
Jul.11, 2019

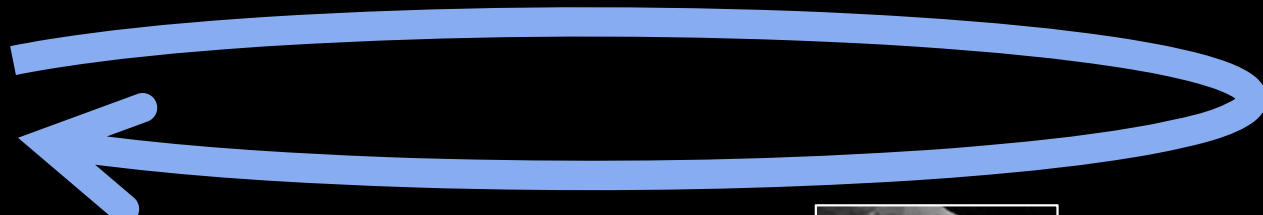
Kinetic Impact
Apr.5, 2019



First Touchdown
Feb.22, 2019



MINERVA-II-2 Orbiting
Oct.2, 2019



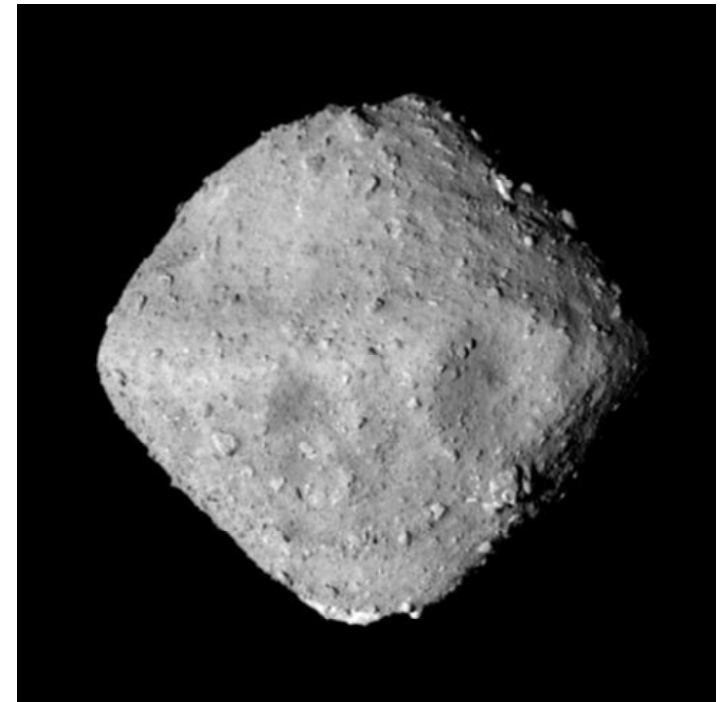
We are here!



Scientific Parameters of Ryugu



- **Top shape** with a very circular equatorial bulge
- Spectrum type: **Cb**
- **Radius: mean ~ 450 m**
(equatorial ~ 500 m, polar ~ 440 m)
- Mass: ~ 450 million ton ($GM \sim 30 \text{ m}^3\text{s}^{-2}$)[※]
- Rotation axis: $(\lambda, \beta) = (180^\circ, -87^\circ)$
- **Obliquity: $\sim 8^\circ$**
- Rotation period: $P = 7.63$ hours
- **Reflectance factor (v-band) : 0.02**
- Crater number density: as much as those on Itokawa and Eros
- **Many boulders**: the largest near the south pole is ~ 130 m across
- Optical spectra: flat spectra, bluer in equatorial bulge and poles
- **Hydraulic Minerals**: NIR spectra identifies uniform flat (slightly redder) spectra with water absorption
- brightness temperature: strong roughness effect (flat diurnal Temperature variation), higher thermal inertia in the equatorial bulge



(©JAXA, University of Tokyo & collaborators)

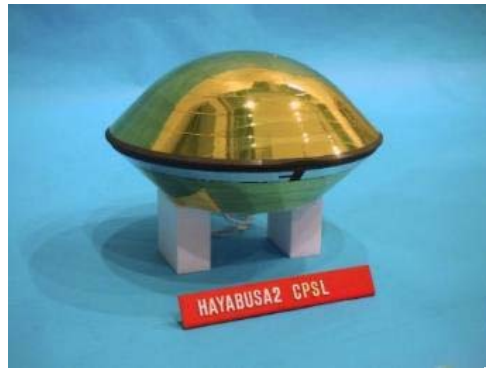
([※]The gravity at the equator is eighty-thousandth of the Earth and a few times of Itokawa)



Hayabusa2 and its 12 Deployables



Reentry Capsule



Deployable Camera (DCAM3)

Deployed on Apr 5, 2019

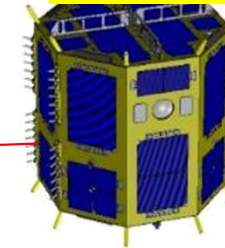


MASCOT Lander

Landed on Oct 3, 2018



Inserted to orbit on Oct 2, 2019



MINERVA-II2 Rover

Landed on Sep 21, 2018



Landed on Feb 22, 2019
and Jul 11, 2019

Impacted on Apr 5, 2019



Small Carry-on Impactor (SCI)

1 Landed on Oct 25, 2018

1 Landed on May 29, 2019

2 Inserted to orbit on Sep 16, 2019



Target Markers

MINERVA-II-1A
and
MINERVA-II-1B
Rovers



Asteroid Prox Phase Accomplishments



Year	Month/Date	CriticalOps	Event	Status
2018	Jun. 3		Approach Guidance Start (Dist.=3100km)	Complete
	Jun. 27		Asteroid Arrival (Alt.=20km)	Complete
	Jul. 17-24		Box-C Descent Observation (Alt.=6.5km)	Complete
	Jul. 31-Aug.2	★	Mid. Altitude Descent (Alt.=5km)	Complete
	Aug. 5-7	★	Gravity Measurement Descent (Alt.=1km)	Complete
	Aug. 18-Sep. 7		Box-B Obs. (Alt.=20km, Dawn-Dusk Obs.)	Complete
	Sep. 11-12	★	Touch Down Rehearsal TD1-R1 (Alt.=600m)	Aborted
	Sep 20-21	★	MINERVA-II-1 Deployment (Alt.=55m) to Site N6 "Tritonis"	Success
	Oct. 2-5	★	MASCOT Deployment (Alt.=51m) to Site MA-9 "Alice's Wonderland"	Success
	Oct. 14-15	★	Touch Down Rehearsal TD1-R1A (Alt.=22m)	Complete
	Oct. 23-25	★	TD Rehearsal/TM Release TD1-R3 (Alt.=12m)	Complete
	Nov. 23-Dec. 29		Conjunction Orbit Operation (Max Alt.=110km)	Complete
2019	Feb. 20-22	★	Touch Down Operation 1 (TD1-L08E1) to Site L08E1 "Tamatebako"	Success
	Mar. 6-8	★	TD2 Candidate Site Descent Observation DO-S01 (Alt.=22m)	Complete
	Mar. 20-22	★	Pre-Impact Scan Observation CRA1, (Alt=1.6km)	Complete
	Apr. 3-6	★	Kinetic Impact Operation (SCI) to Site S01 "Omusubi-Kororin" (Alt.=500m)	Success
	Apr. 23-25	★	Post-Impact Scan Observation CRA2, (Alt=1.6km)	Complete
	May 14-16	★	TM Release PPTD-TM1 (Alt.=50m)	Aborted
	May 28-30	★	TM Release Retrieval PPTD-TM1A (Alt.=9m)	Complete
	Jun. 11-13	★	Crater/TD2 Site Descent Observation (Alt.=9m)	Complete
	Jul. 8-11	★	Touch Down Operation 2 (PPTD) to Site C01-Cb "Uchideno-Kozuchi"	Success
	Sep 12-22	☆	TM Orbiting Operation (Alt=1.0km)	Success
	Sep 28-Oct 8	☆	MINERVA-II-2 Deployment (Alt=1.0km)	Success
	Nov. 13		Leaving Home Position (Asteroid Departure)	Complete
	Dec. 2		Return Ion Engine Cruise Start	Complete



Critical Operations: Plan vs Actual



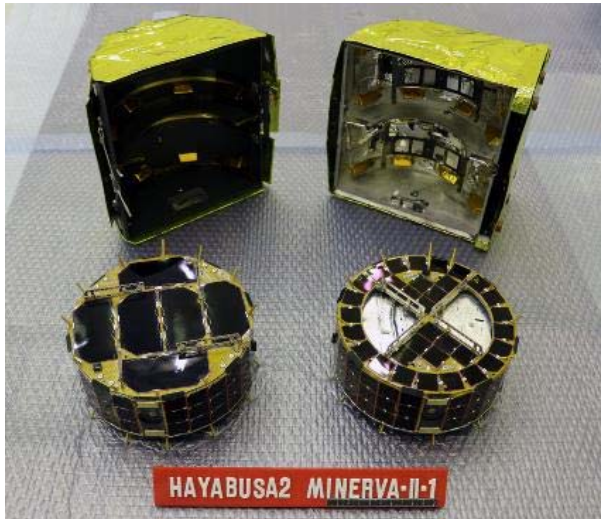
	Plan	Actual
Low-Altitude Descent	: 17	18
Touchdown/Sampling	: 1-3	2
Landed Rover	: 4	4
Artificial Crater	: 1	1
Used Target Marker	: 5	4
Orbiting Object	: 0	3



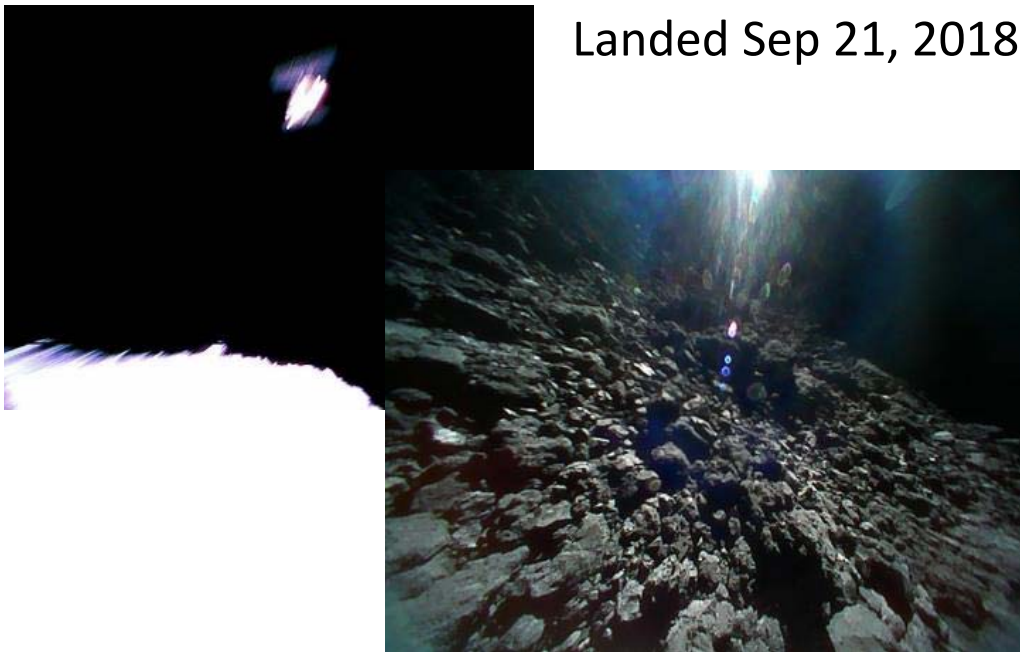
Rover/Lander Operations



MINERVA-II-1-a & -b



Landed Sep 21, 2018



MASCOT

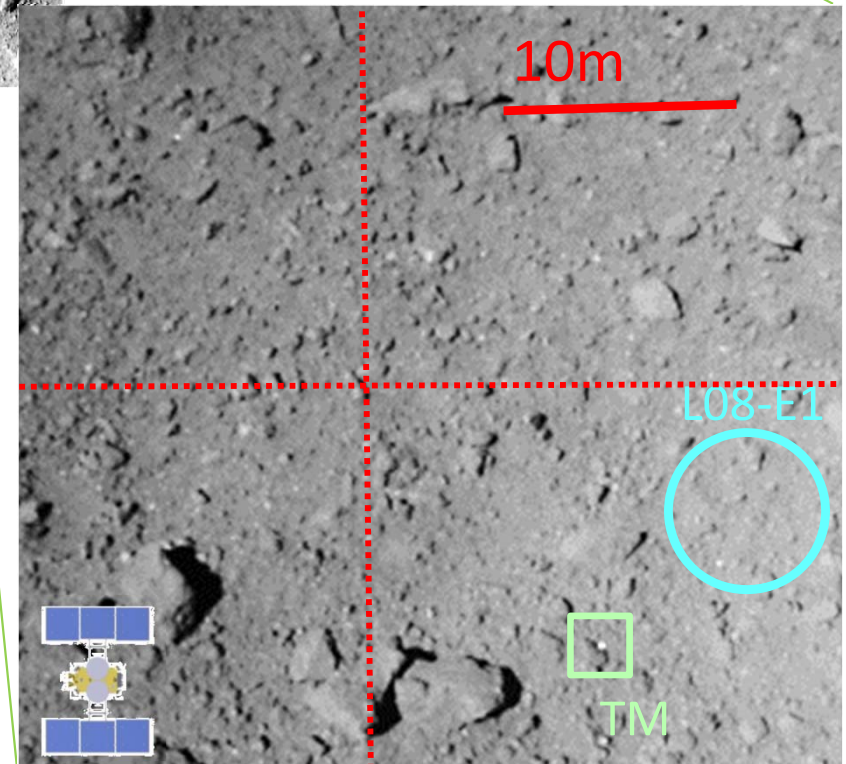
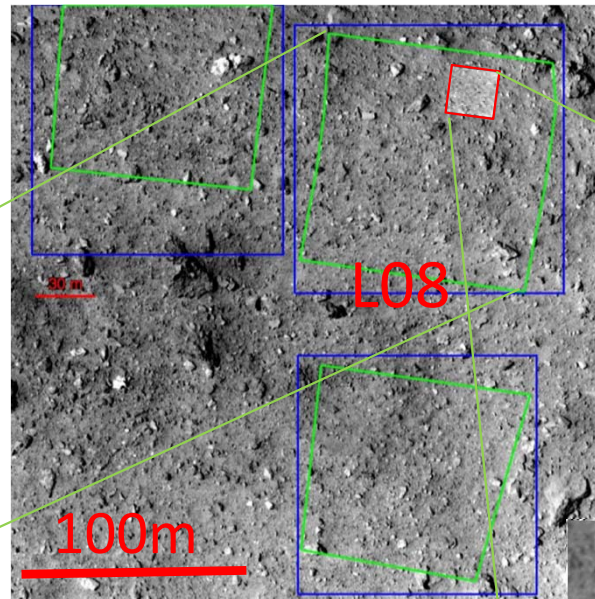
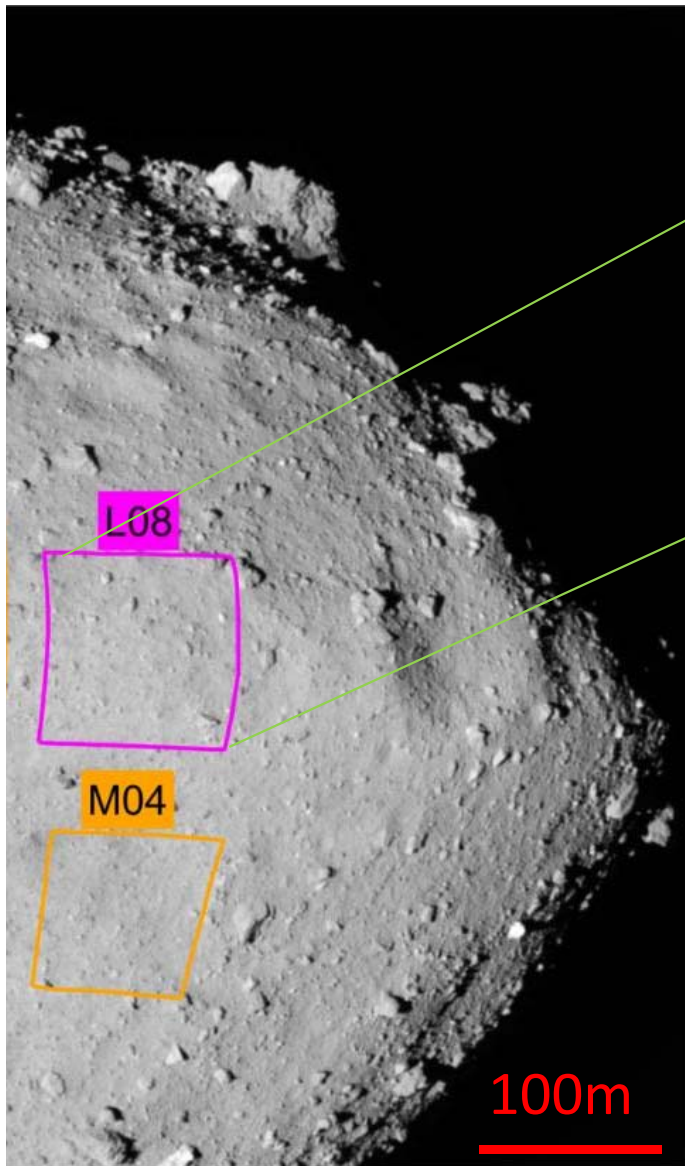


Landed Oct 3, 2018





TD1 Landing Site Narrowing-down Process

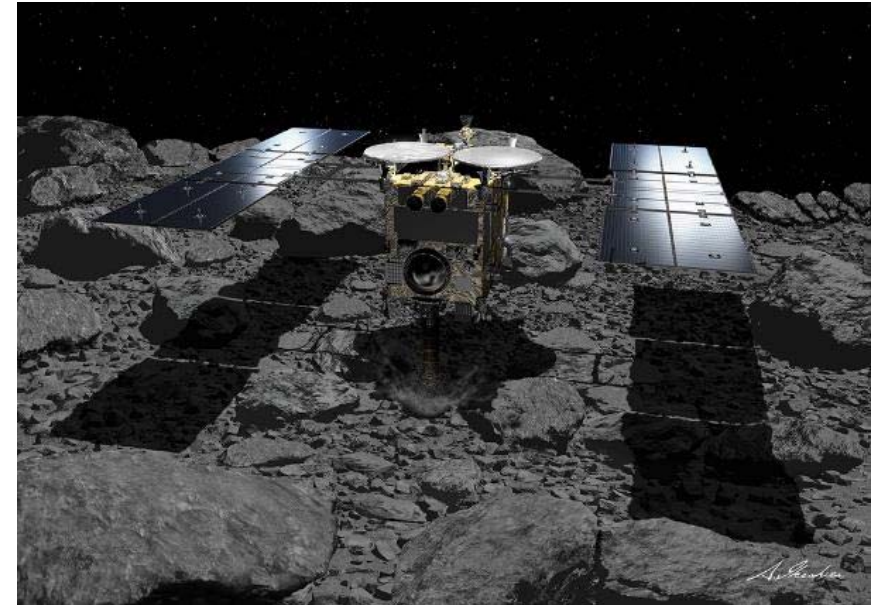
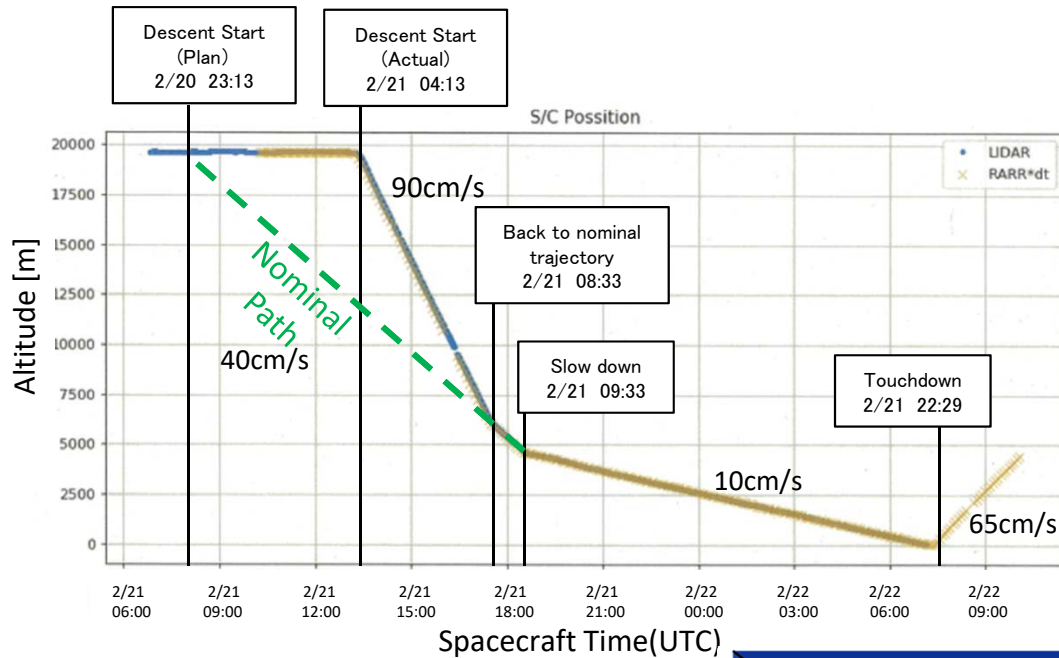


- 20m-spun L08 is selected for the primary landing zone.
- L08-B1 was selected for TM drop target, and was settled 15.4m off to the south-east.
- 6m-spun L08-E1 was selected for the TD1 landing target, which is located 4m north-east of TM.

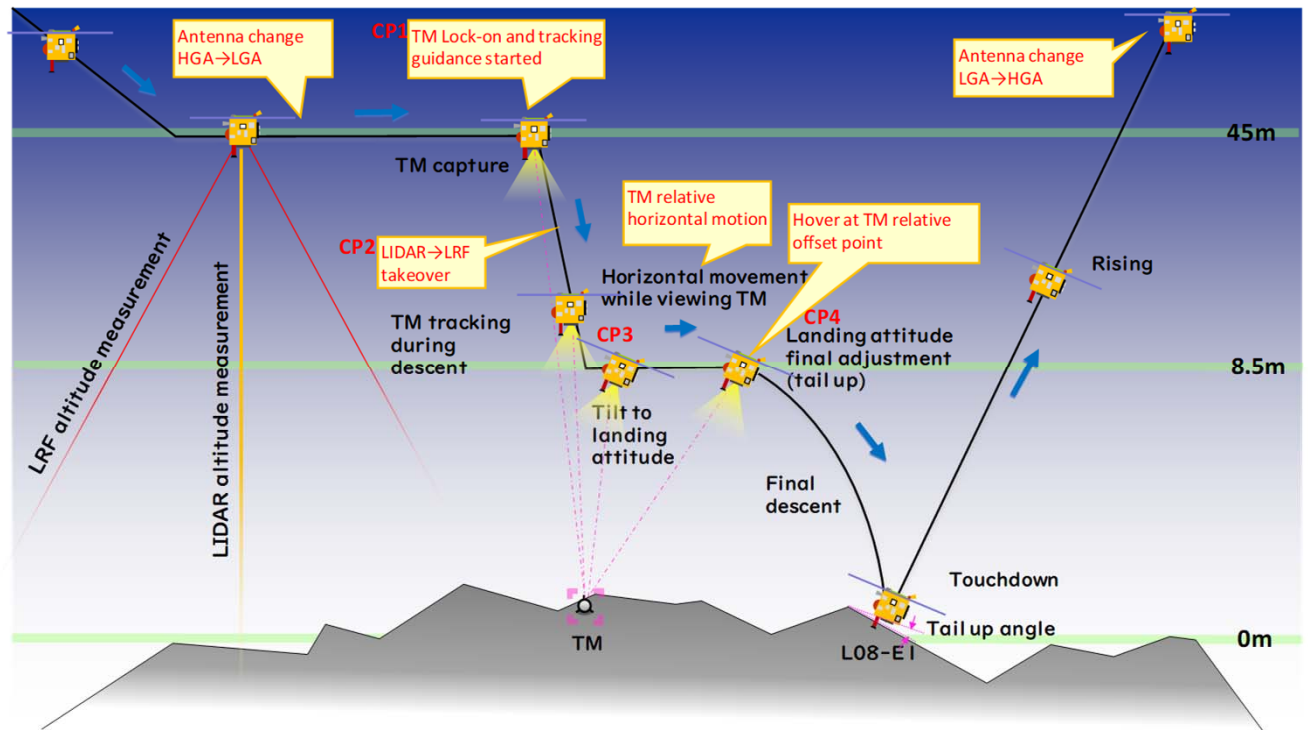
(Image Credit : JAXA/UTokyo/Kochi U/Rikkyo U/Nagoya U/Chiba Inst Tech/Meiji U/U Aizu/AIST)



Touchdown #1 Summary

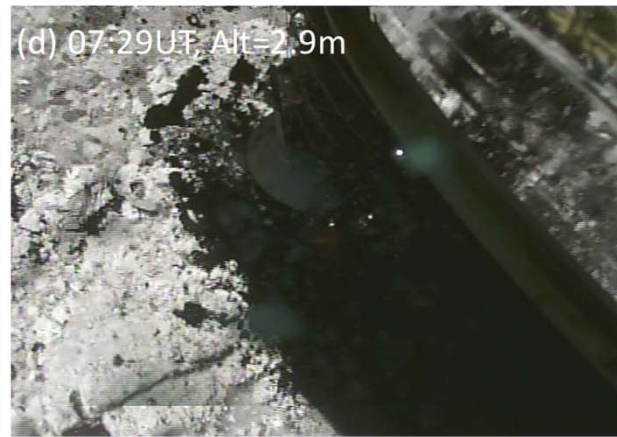
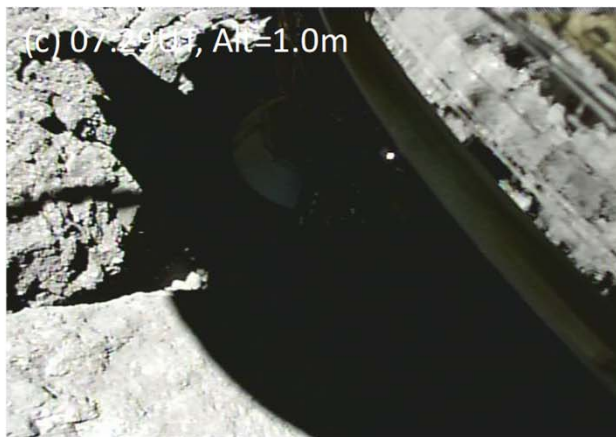


- Date: Feb.20-22, 2019.
- Landing Target L08-E1 "Tamatebako" (treasure box).
- Descent start delayed by 5hrs due to a spacecraft mis-configuration.
- Full autonomous operation <45m.

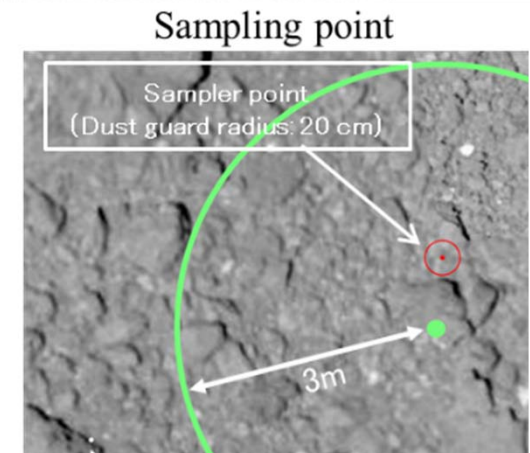
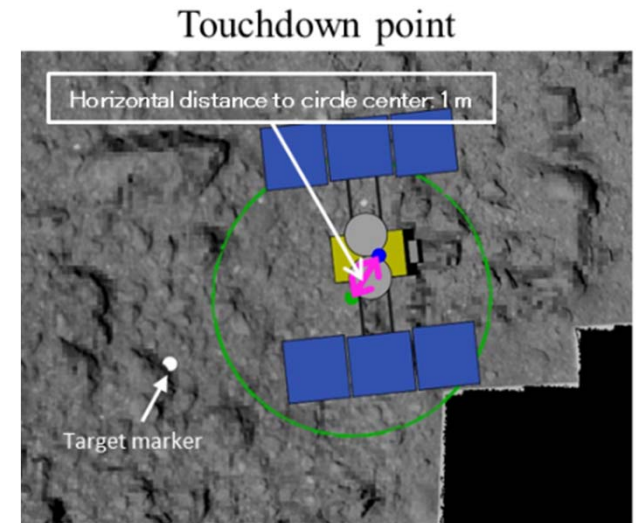




Touchdown #1 Result

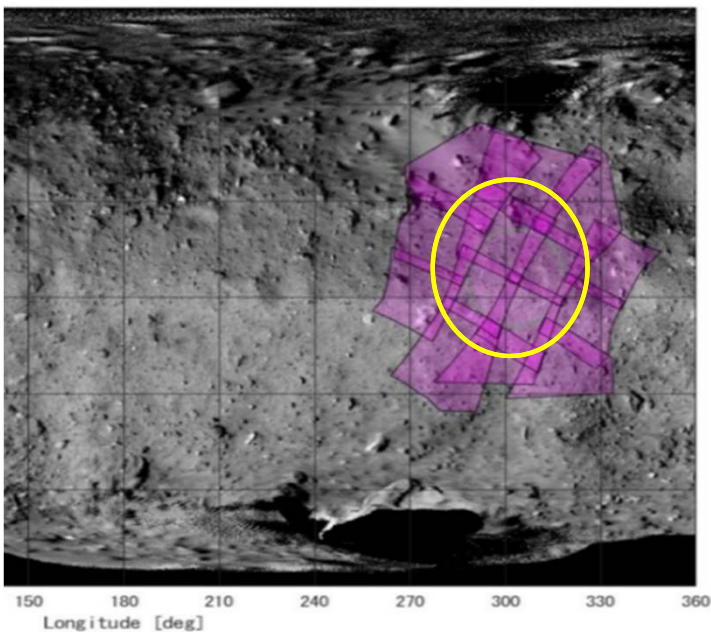
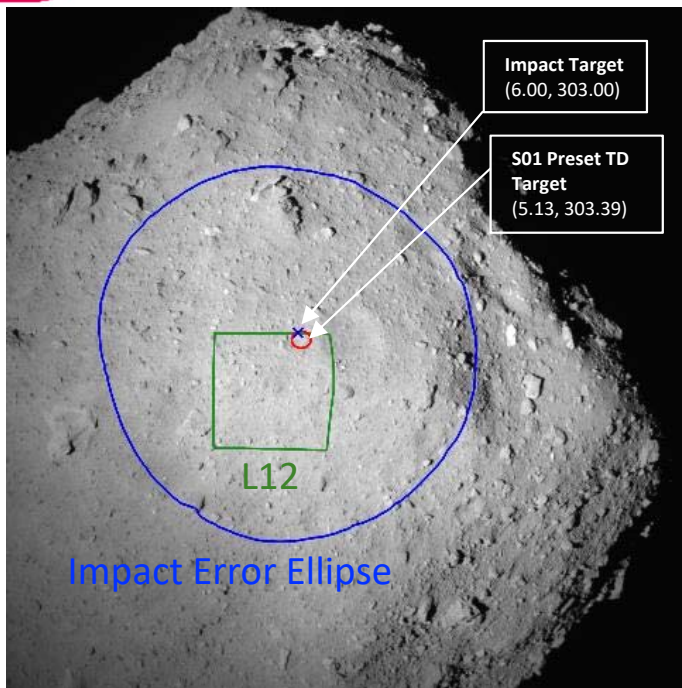


- All sequences went normally.
- 1m accuracy landing achieved.
- Many fragments observed!
- Considerable degradation on optical instruments (ONC and LRF).





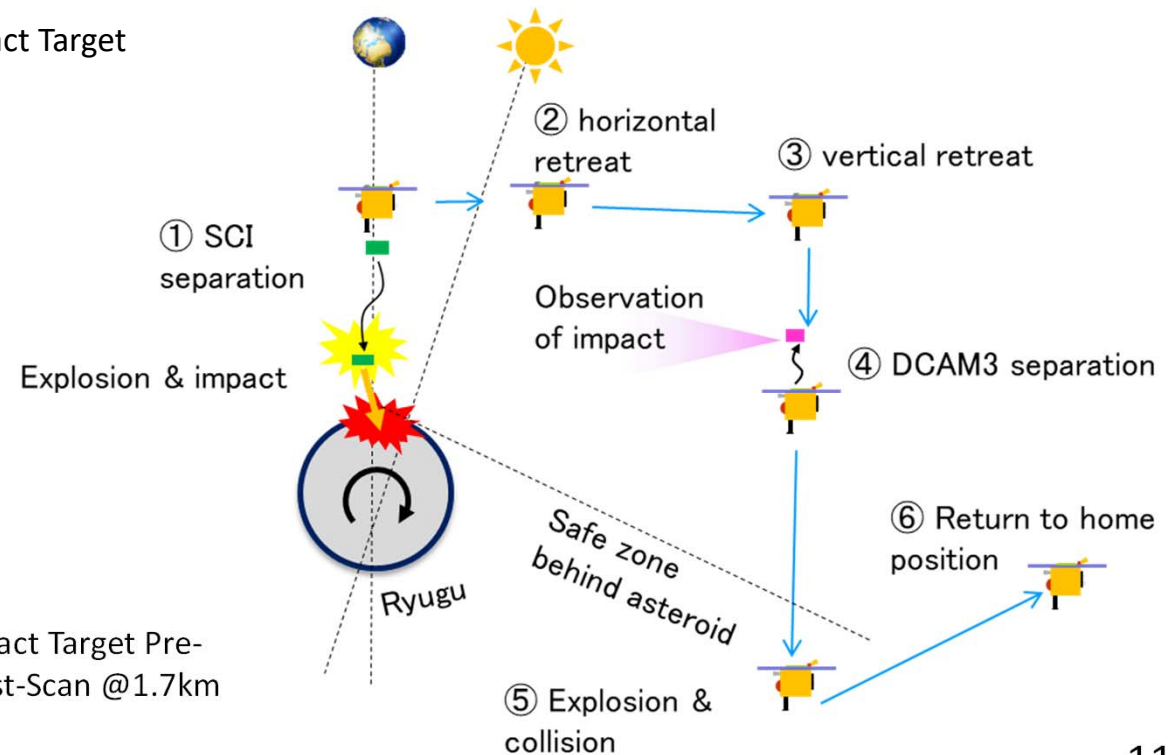
SCI Kinetic Impact Operation Summary



- Impact Target :
S01 "Omusubi-Kororin" (Rolling rice ball)
- Date (2019):
Pre-Impact Scan Observation(CRA1) Mar. 20-22
Impact Operation(SCI) Apr. 3-6
Post-Impact Scan Observation(CRA2) Apr. 23-25
- Impactor deployed at Apr.5 01:56UT
- DCAM3 deployed at Apr.5 02:14UT

Impact Target

Impact Target Pre-
/Post-Scan @1.7km





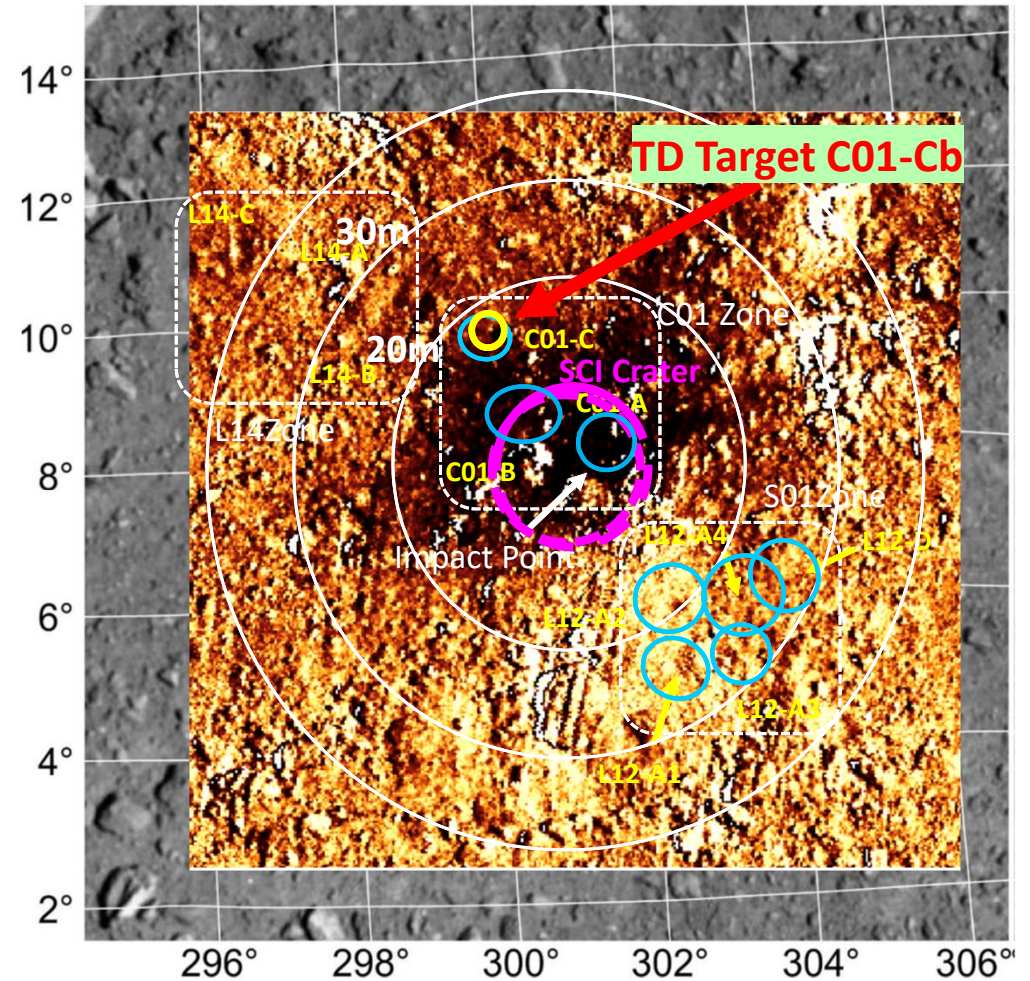
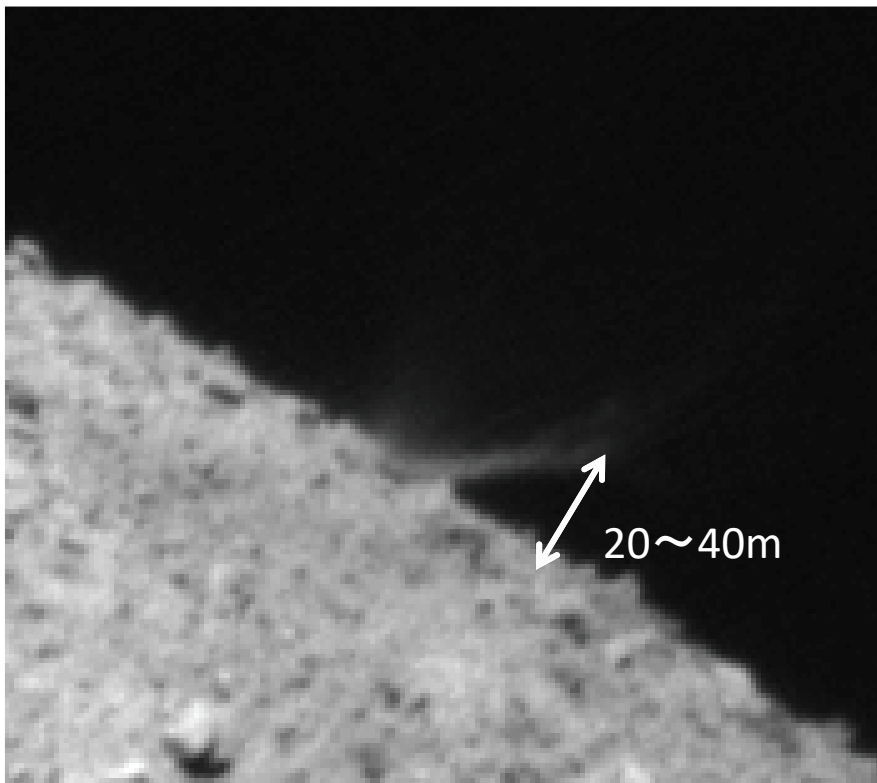
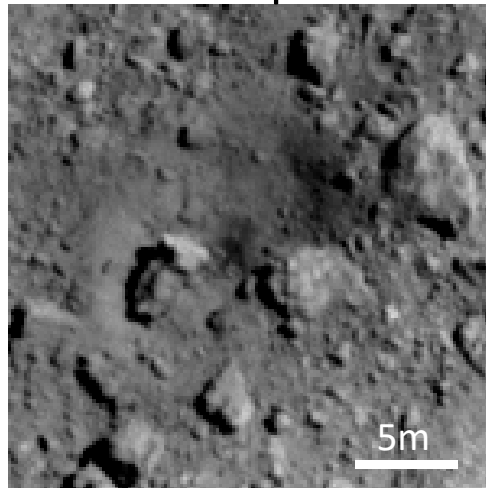
Kinetic Impact Operation Result



Before Impact



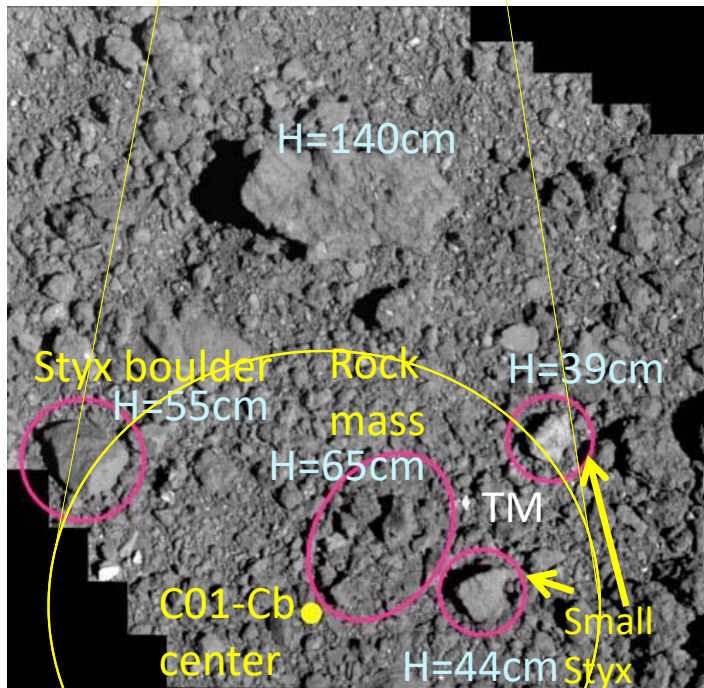
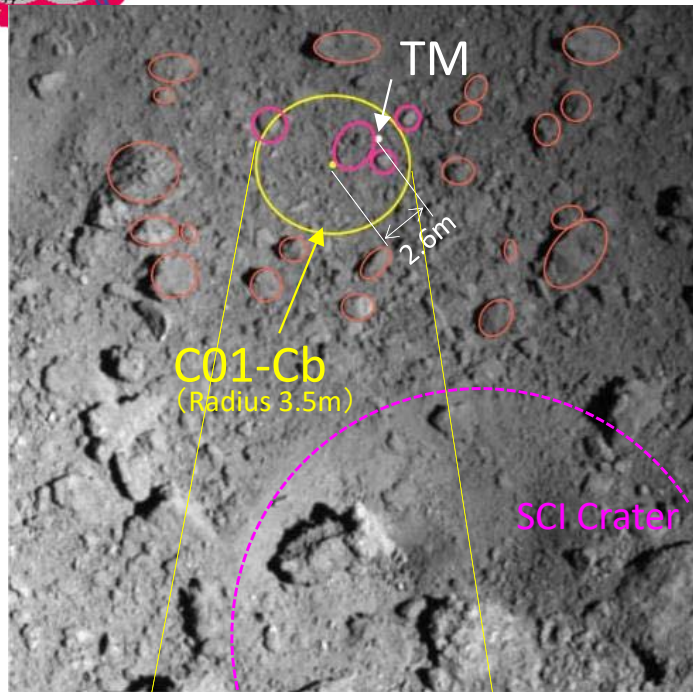
After Impact



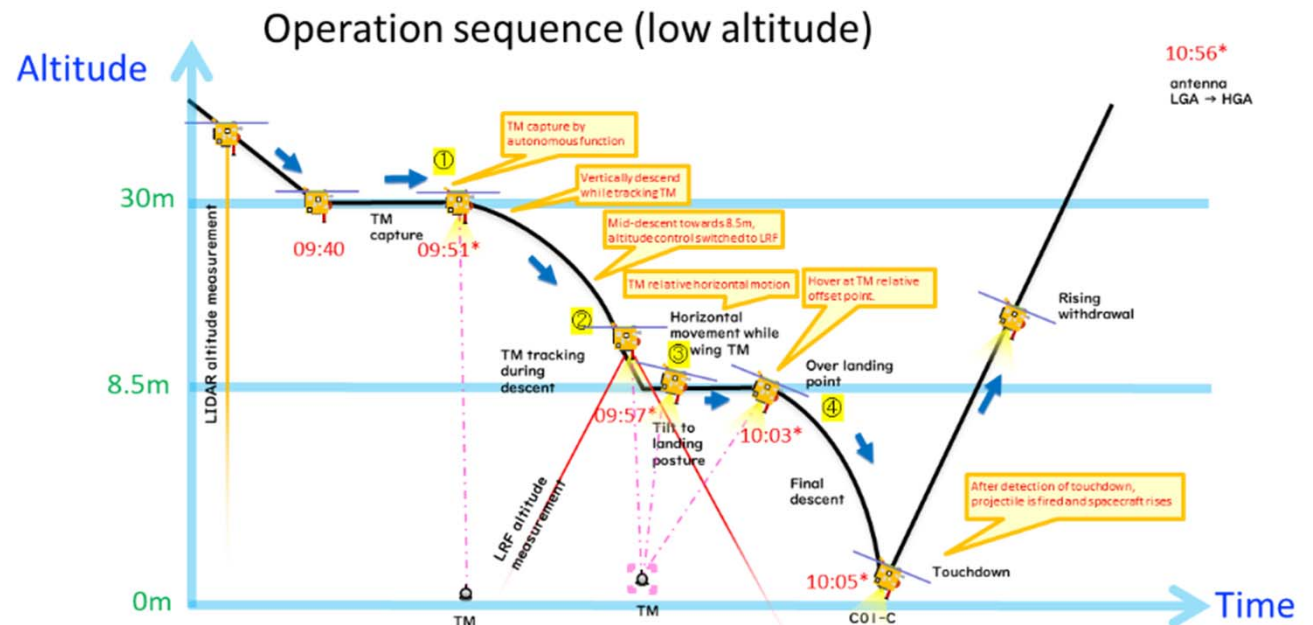
- Impact accuracy was 30m.
- A 10m-diameter artificial crater was generated.
- 11 TD candidates were found nearby the crater
- Crater ejecta accumulation is estimated to be thicker in North region than South.
- C01-Cb was selected as the TD2 target.



Touchdown #2 (PPTD) Operation Summary

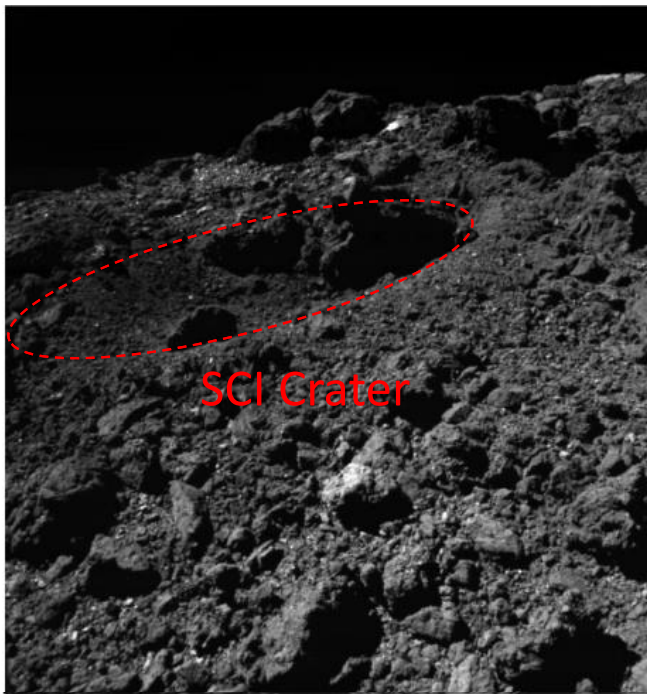


- Landing Target C01-Cb “Uchideno-Kozuchi” (Treasure Hummer)
- TM was placed perfectly within C01-Cb on May 30, 2019.
- PPTD was conducted on Jul.8-11, 2019.
- The sequence was modified to adopt degraded optical sensors. The spacecraft full-autonomous sequence was lowered to <30m. (c.f. TD#1 <45m)
- Acceptable landing accuracy was <3.5m. (c.f. TD#1 <3m)

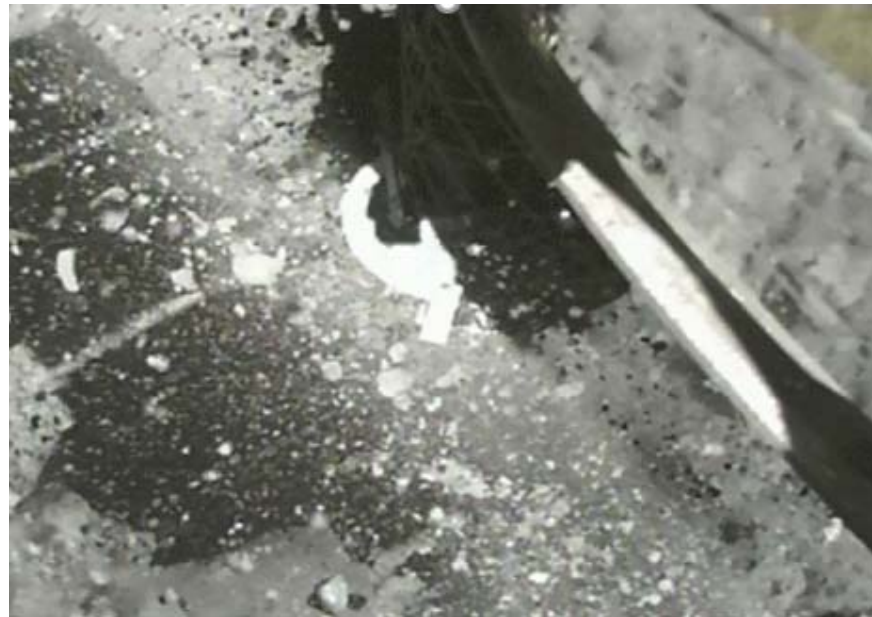




Touchdown #2 (PPTD) Operation Result



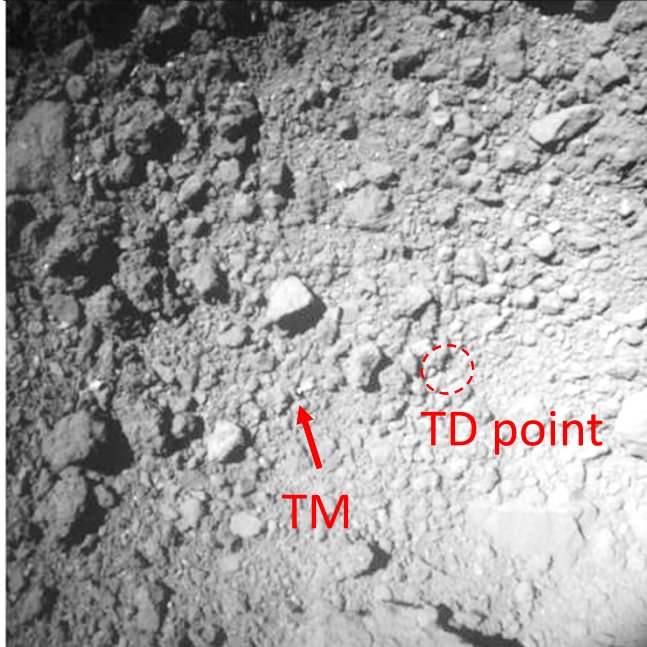
SCI Crater



- All the sequence went normally.
- Landing accuracy was 60cm!
- Many fragments observed again.

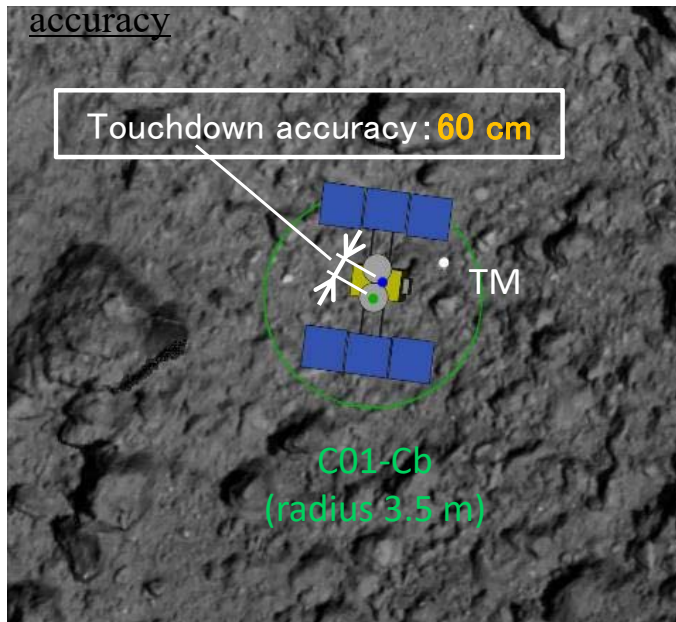
2nd touchdown

Sampler horn ground point



TM

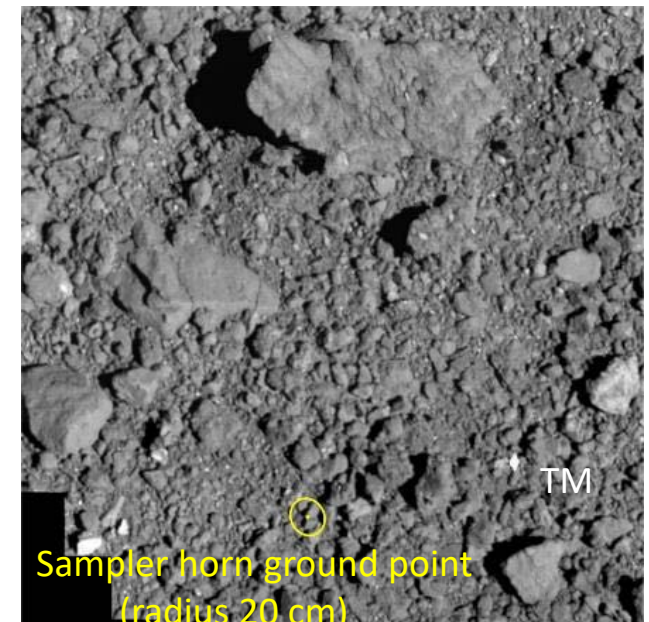
TD point



Touchdown accuracy: 60 cm

C01-Cb
(radius 3.5 m)

TM



Sampler horn ground point
(radius 20 cm)

TM

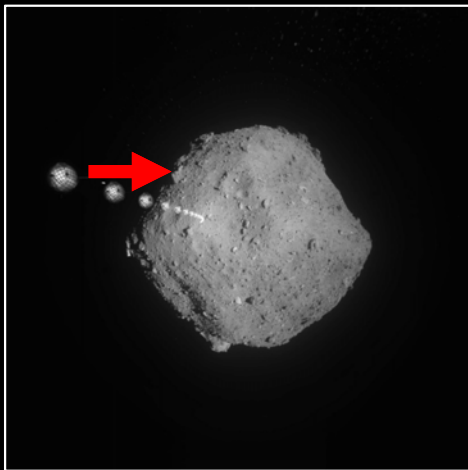


Target Markers/Rover Orbiting around Ryugu

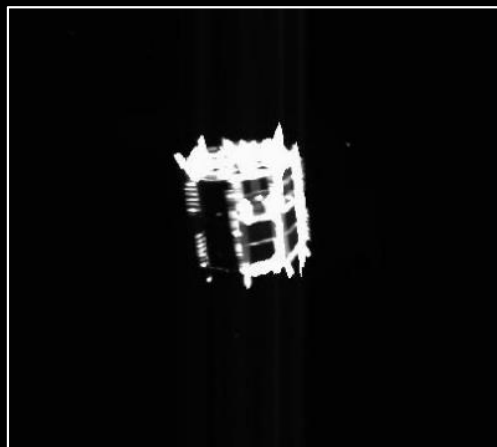
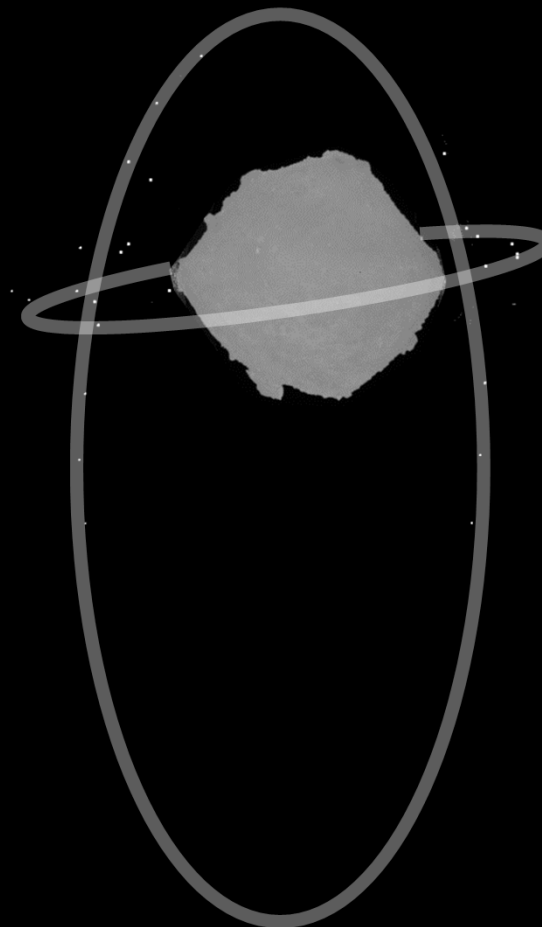
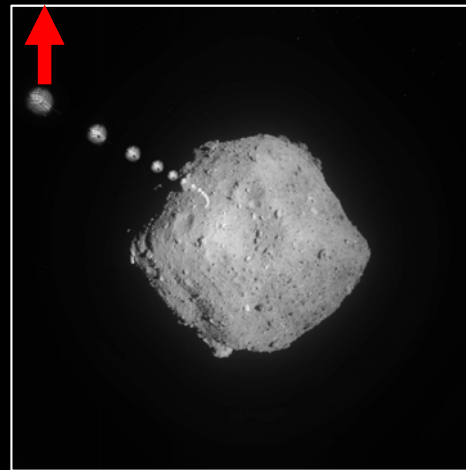


- Objective: **Gravity science**
- Two TMs were inserted to $r=1.5\text{km}$ equatorial and polar orbits on Sep 16, 2019.
- MINERVA-II-2 rover was inserted to $r=1.5\text{km}$ equatorial orbit on Oct 2, 2019.
- Three objects were successfully tracked by ONC-T for several days!

TM-E separation (ONC-W1)
(2019/9/16 16:17UTC)



TM-C separation (ONC-W1)
(2019/9/16 16:24UTC)



MINERVA-II-2 separation (ONC-W2)
(2019/10/2 15:57UTC)



Conclusion: Achievements of Hayabusa2



◆ Seven engineering “World’s Firsts”

1. Mobile activity of rovers on small body
2. Multiple rovers deployment on small body
3. 60cm-accuracy landing and sampling
4. Artificial crater forming and observation of impact process
5. Multiple landing on extraterrestrial planet
6. Subsurface material sampling
7. Smallest-object constellation around extraterrestrial planet

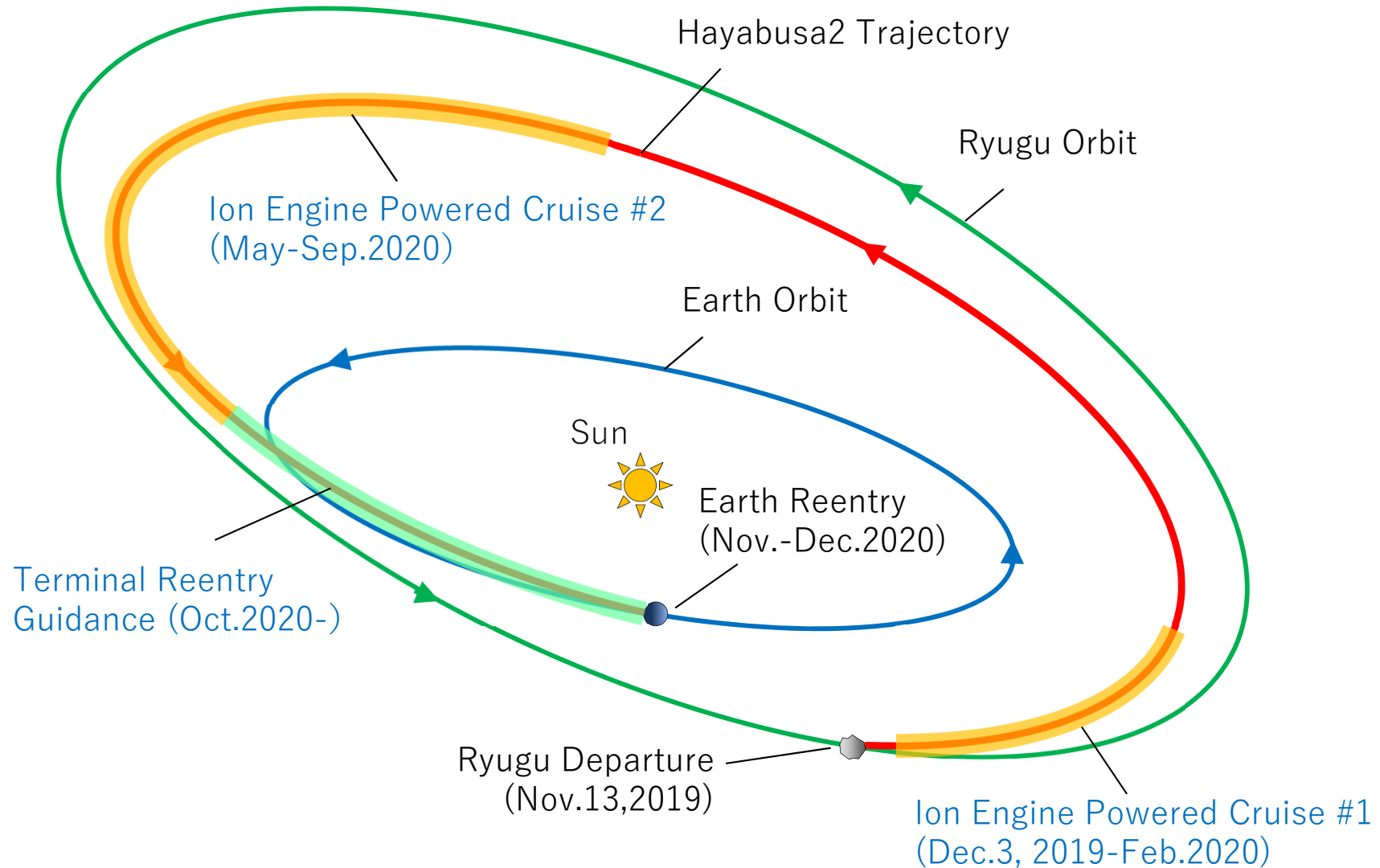
◆ Initial scientific outcomes

Four papers published in *Science* and many in other journals





Hayabusa2 Return Phase Trajectory



*Hayabusa2 will return to Earth in
November-December 2020.*



A. Saito