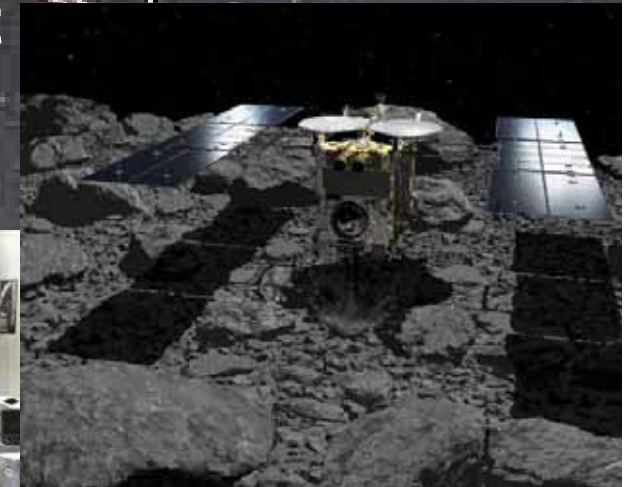
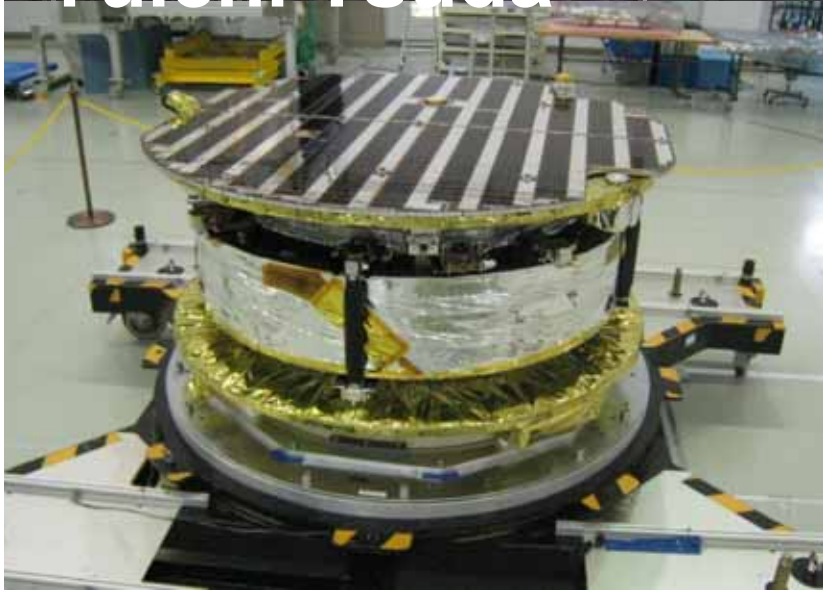


**CanSat took me to Earth orbits, Asteroids, and Beyond! -An experience of 1st-generation CanSat student**

**Institute of Space and Astronautical Science, JAXA  
Yuichi Tsuda**



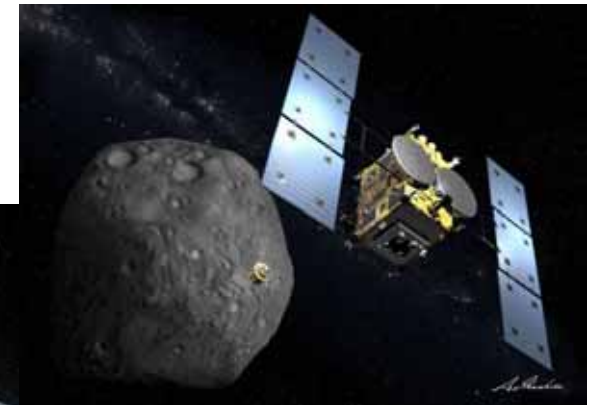
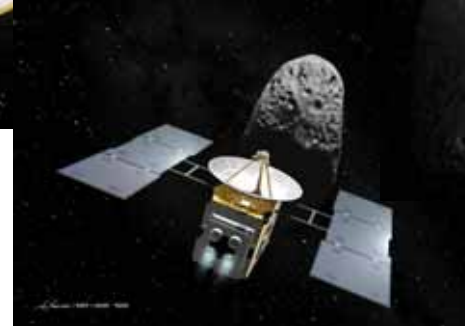
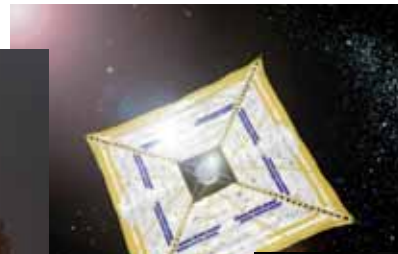
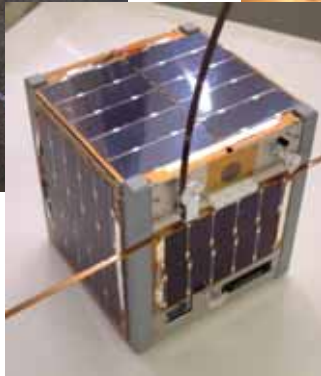
# Yuichi Tsuda

Professor, Institute of Space and Astronautical Science  
Japan Aerospace Exploration Agency

My field: Innovative spacecraft system, Solar system exploration, Astrodynamics

## My history

- CanSat (1st generation!)
- CubeSat (1st generation!) *Student project manager, U of Tokyo "XI-IV"*
- IKAROS (World first deep space solar sail) *Deputy project manager*
- Hayabusa2 (Asteroid sample return mission) *Project Manager*



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## **The beginning (1999~2003)**

Journey begins suddenly...

---

In 1998 when I was a student in Prof. Nakasuka's lab,

Professor: There is a workshop in Hawaii.  
Do you want to go?

Me: Wow, Hawaii!? I will go.  
By the way what's that workshop for?

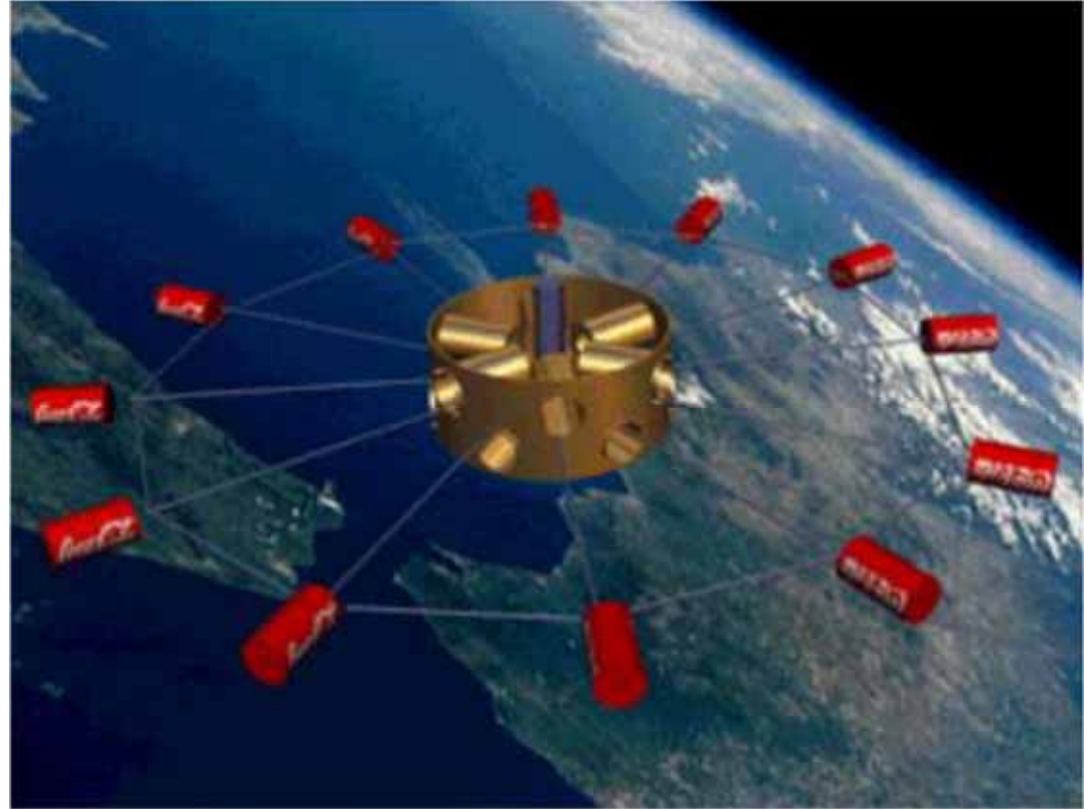
The workshop was "University Space Systems Symposium"  
where the CanSat was born.

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## Birth of “CanSat” Concept

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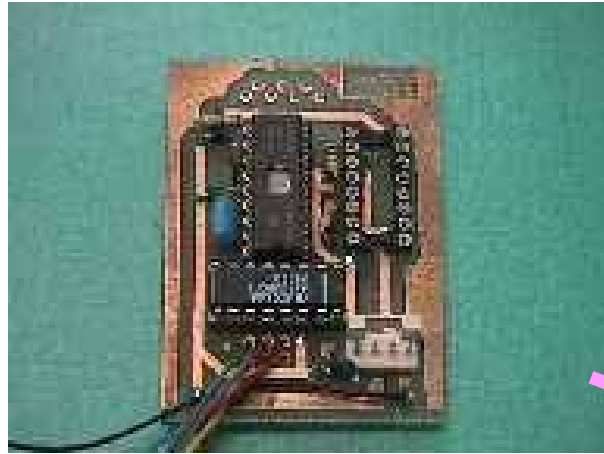
Initial Concept: launch all the CanSats and operate them in next USSS (one year later)

“Let’s make a satellite out of this Coke-can !!”  
*Prof. Bob Twiggs, Stanford University*

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# First work

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Main Board

Parachute

Battery

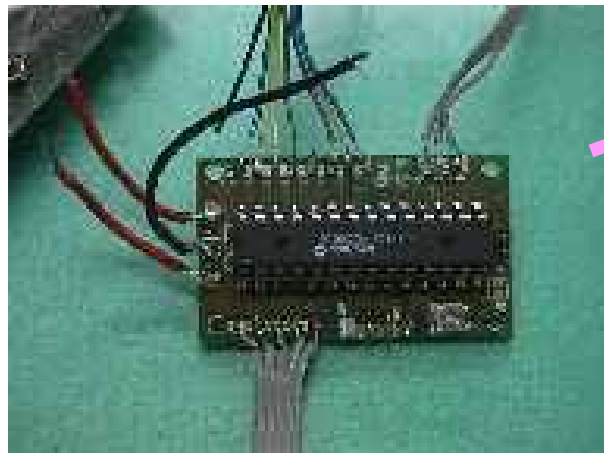


350ml Juice Can

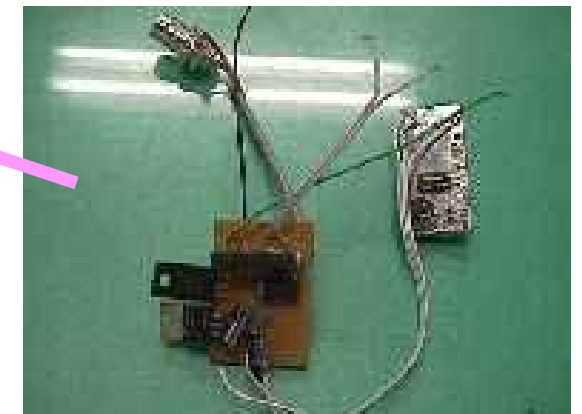
Antenna



Sensors Board



Com encoder (TNC)



Transmitter



# 1st Generation “CanSats”

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Pre-final model

Flight model of CanSat #003

Three 1st generation CanSats developed by U of Tokyo.



# Launched in Black Rock Desert, 1999

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Test as you fly.  
Fly as you test.



Prepare backup.

---

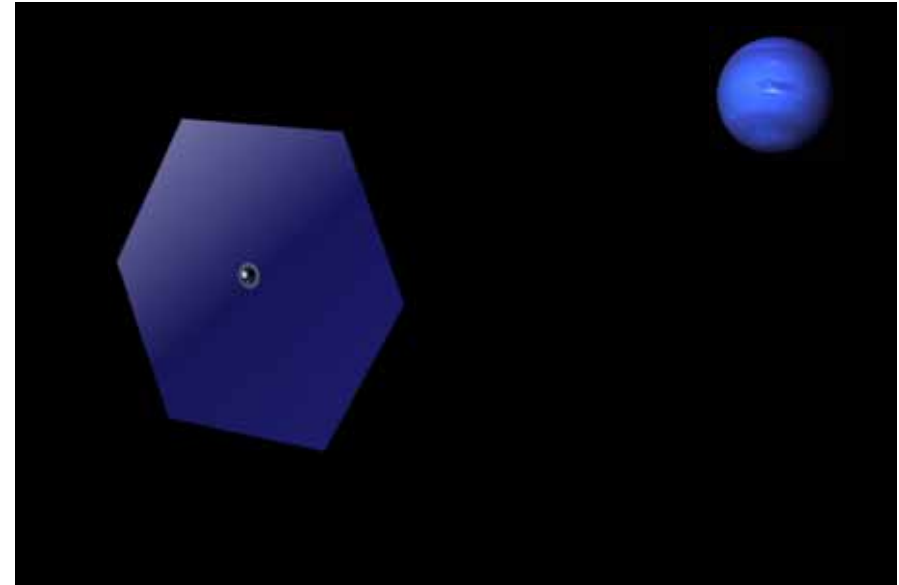


# Want to make a Real Satellite ! ~ CanSat to CubeSat

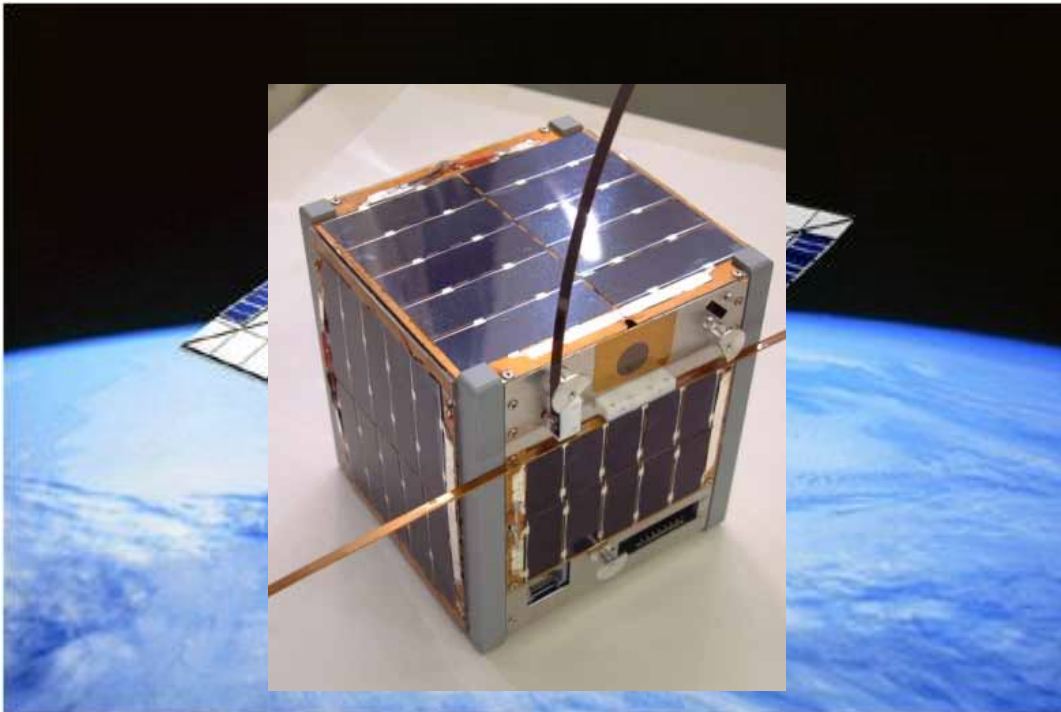
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Proposal from Prof. Twiggs again .  
Let's make a 10cm-cubic satellites!

Thin space membrane + CubeSat = ?



Ref. Tsuda, Nakasuka, Aoki, Nagashima,  
Space Transportation Symposium, 1999

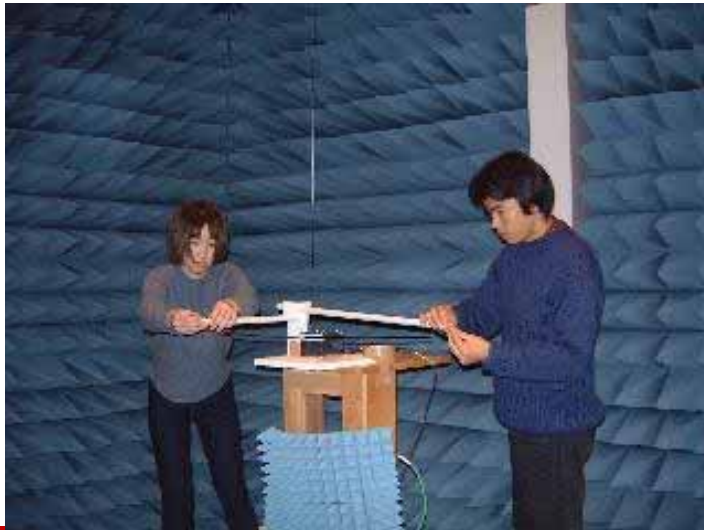
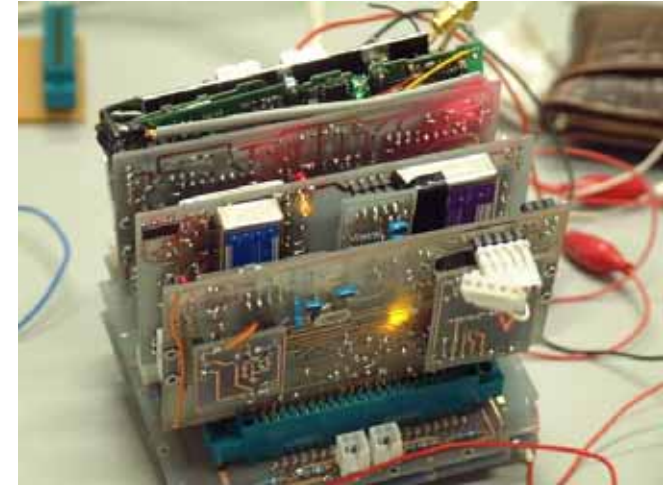


- 1998 Pluto explorer concept with 200m-diameter thin flexible solar cells. How to fold it? "*Tsuda-folding*"
- 1999 We proposed "CubeSat + Space Membrane" concept, but finally resulted in...

# Textbook does not teach us.

---

The unexplored world should be pioneered by ourselves!

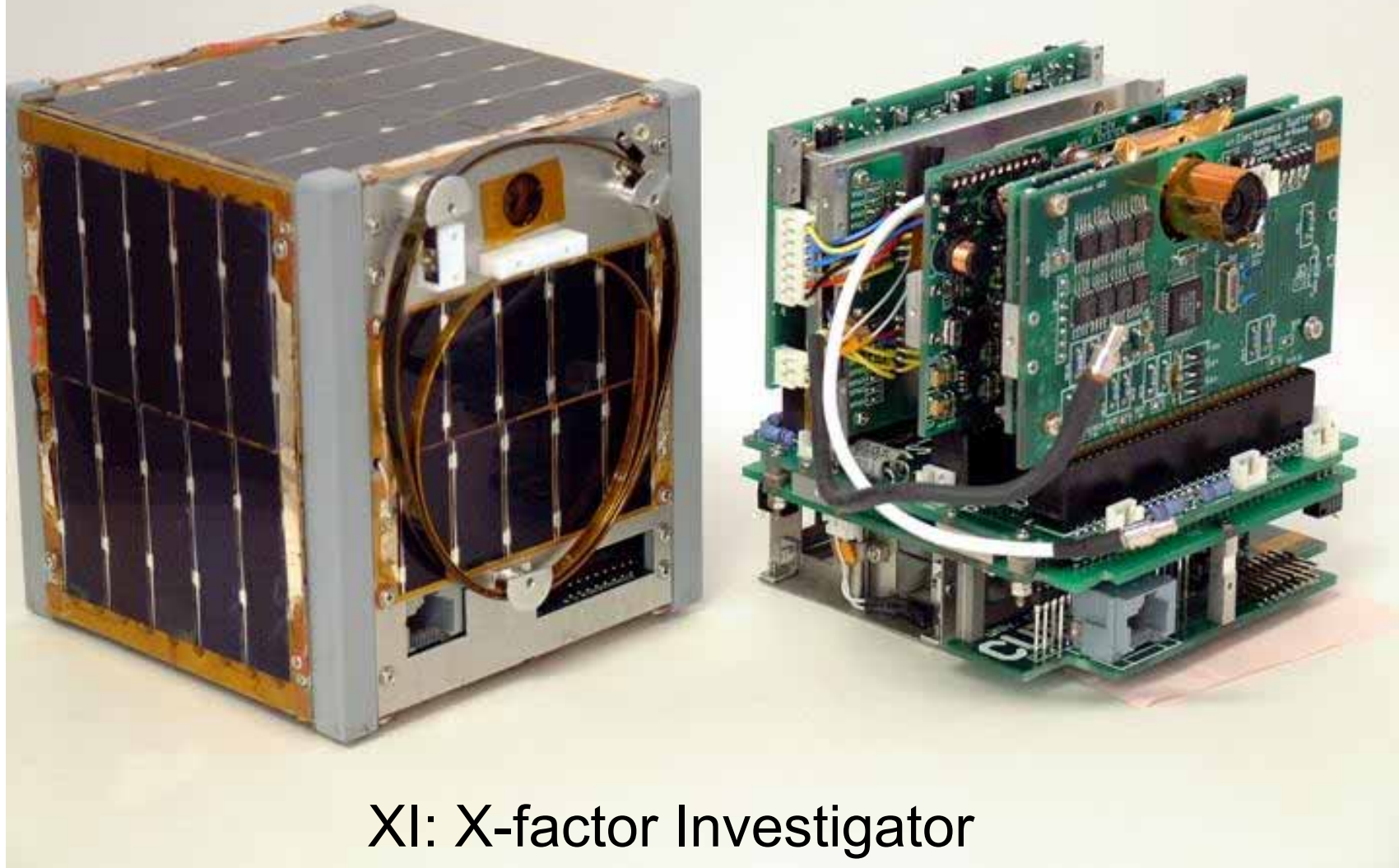




# World First CubeSat "XI-IV"

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*University of Tokyo's CubeSat Project "XI"*



XI: X-factor Investigator



---

2003/06/30 18:15:26 (local time)  
**XI-IV was Launched!!!**



CubeSat XI-IV Photo Gallery July – November 2003, University of Tokyo ISSL



7.30 South Atlantic



9.14 Azores Islands



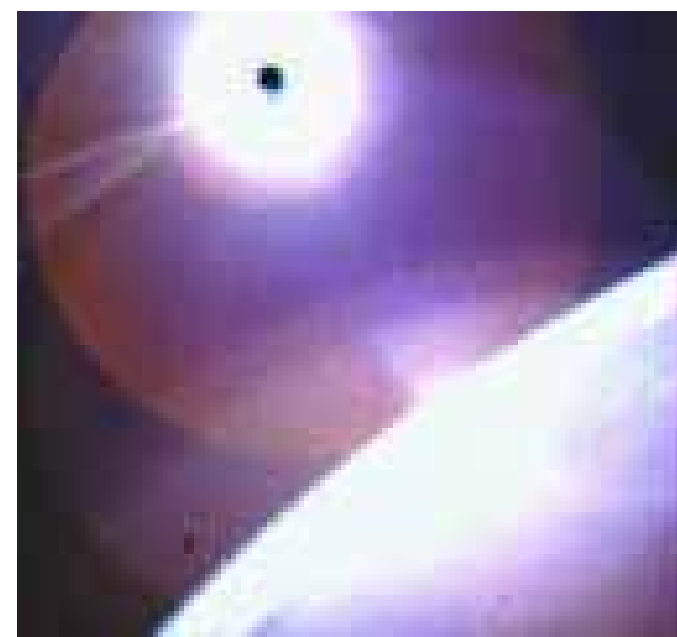
9.17 East Timor



10.5 Bangladesh



10.5 Tibet



11.03 Egypt

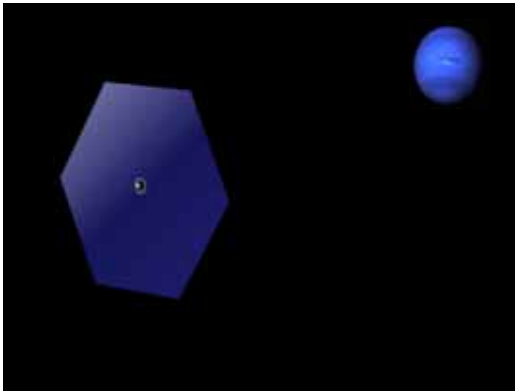
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## **From CubeSats to Deep Space Exploration (2003 ~ )**



# “Continuity” in my first 10 years of carrier

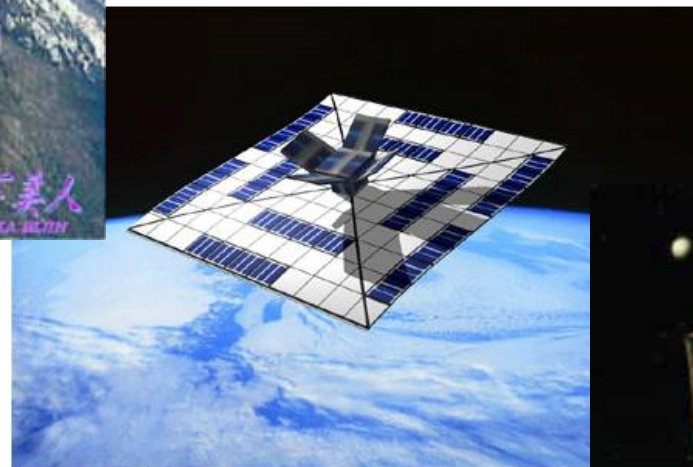
(C)JAXA



1998  
Pluto explorer using space  
membrane technology  
(Concept study)

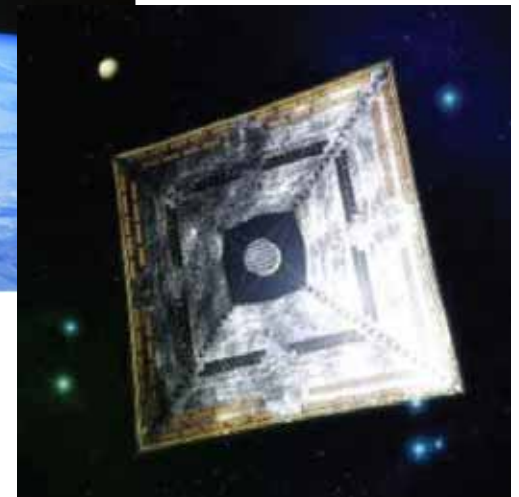


1999  
CanSat membrane deployment experiment  
(Concept study + Development)  
→ *CanSat w/o membrane*



2000  
CubeSat membrane deployment experiment  
(Concept study + Development)  
→ *CubeSat w/o membrane*

2007  
IKAROS Solar Power Sail Demonstrator  
→ *Real Space mission!*

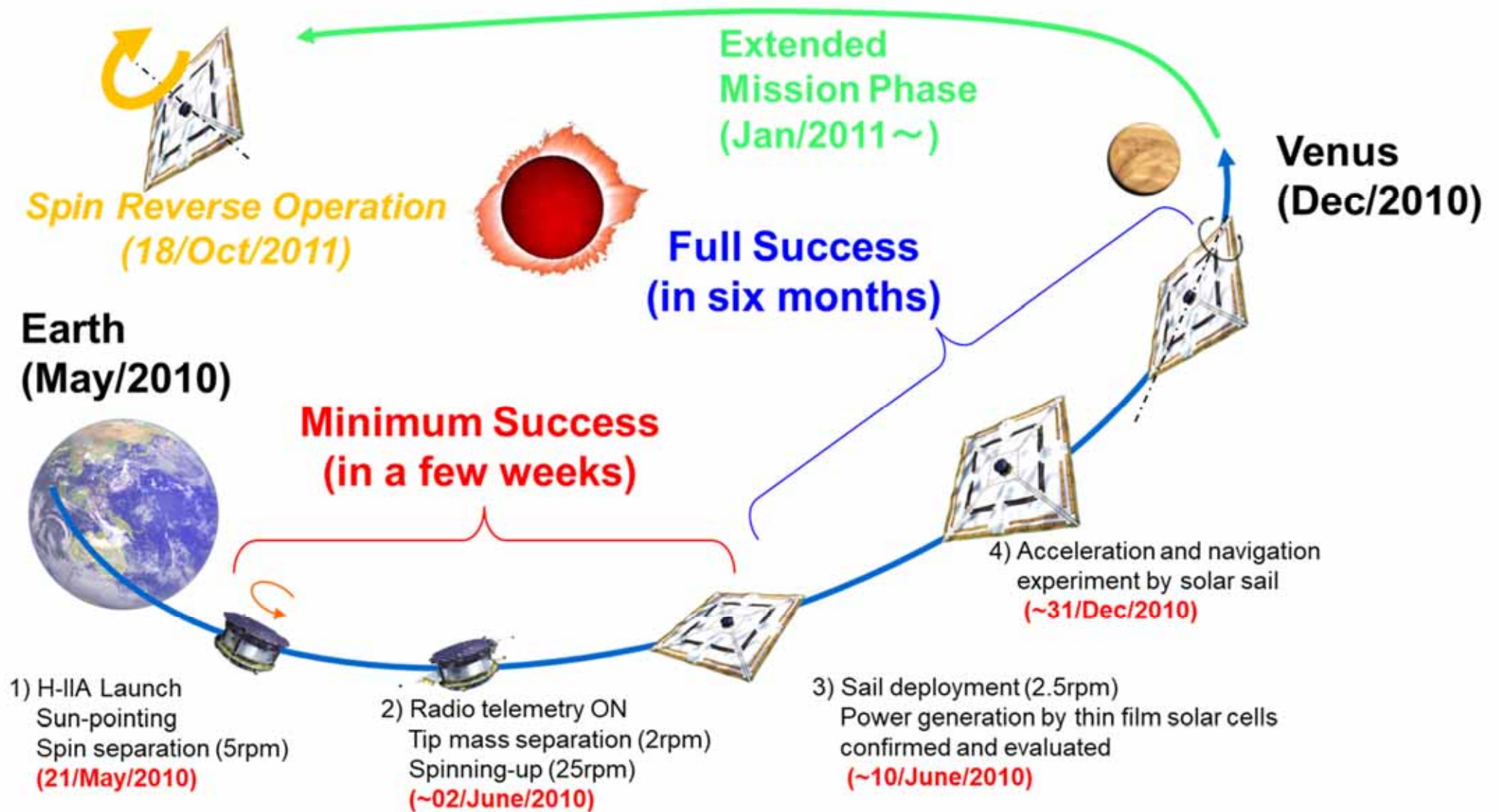


# IKAROS (Interplanetary Kite-craft Accelerated by Radiation Of the Sun)

---



# Mission Sequence of IKAROS





# Selfie in Space!

Self-photo to confirm the sail deployment in interplanetary field by interplanetary CanSat.



Jun 14, 2010.

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## **Toward Hayabusa2**

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# Hayabusa2 Mission



Sample return mission to a C-type asteroid "Ryugu"

Launch  
Dec.3, 2014



Earth Gravity Assist  
Dec.3, 2015



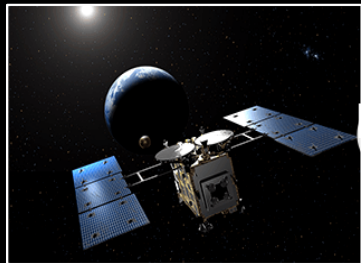
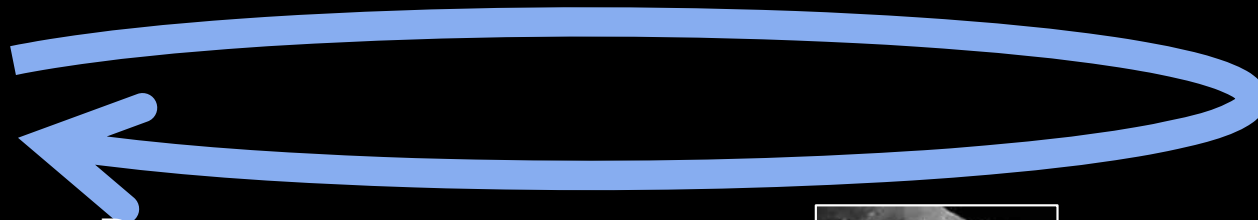
Ryugu Arrival  
Jun.27, 2018



MINERVA-II-1 Deployment  
Sep.21, 2018



MASCOT Deployment  
Oct.3, 2018



Earth Return  
Dec.6, 2020

Ryugu Departure  
Nov.13.2019



Target Markers Orbiting  
Sep.16, 2019

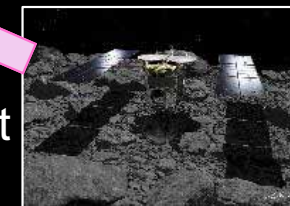


Second  
Touchdown  
Jul.11, 2019

Kinetic Impact  
Apr.5, 2019



First Touchdown  
Feb.22, 2019



MINERVA-II-2 Orbiting  
Oct.2, 2019



# Hayabusa2's mission history



Launch

Earth Swinby

Ion Engine Cruise

Ryugu Arrival

Minerva-II1 landing

—Success

Mascot landing

—Success

Touch down #1

—Success

Kinetic Impact

—Success

Touch down #2

—Success

Minerva-II2 orbiting/landing

—Success

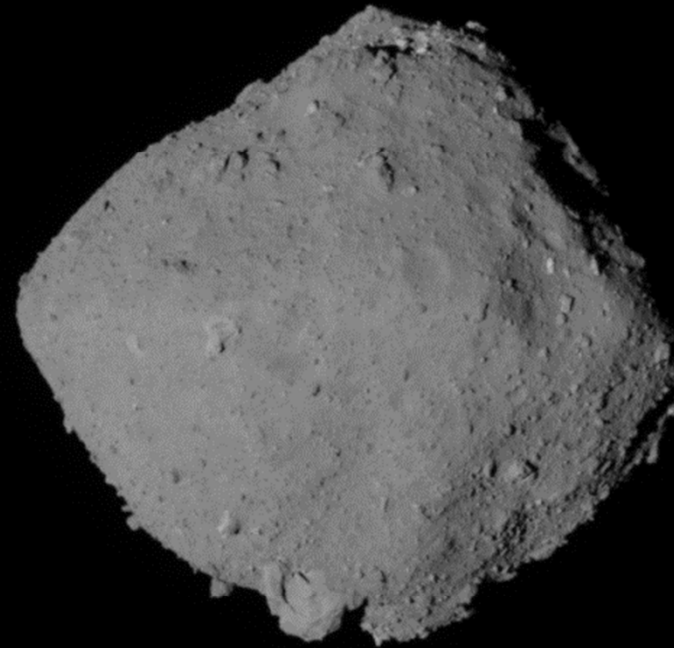
Earth Return

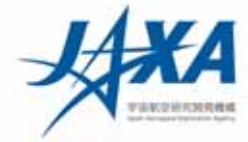
Got Ryugu sample!

—to Extended Mission

# Asteroid “Ryugu”

- **Top shape** with a very circular equatorial bulge
- Spectrum type: Cb (Carbon-rich)
- Diameter: ~ 900 m
- Mass: ~ 450 million ton
- Obliquity: ~ 8 °
- Rotation period :  $P = 7.63$  hours
- Reflectance factor (v-band) : 0.02
- Terrain: **Very bumpy**

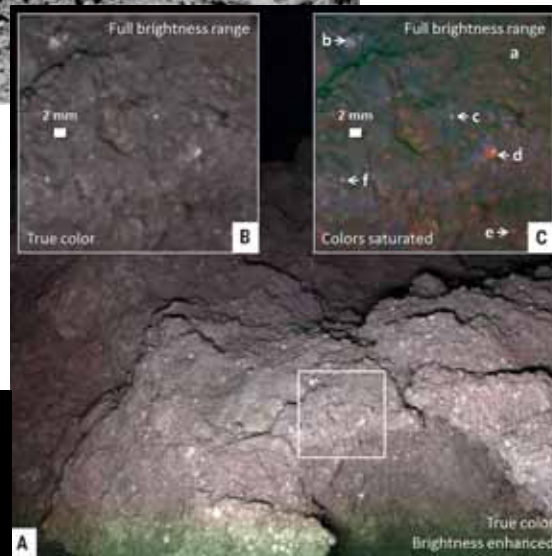
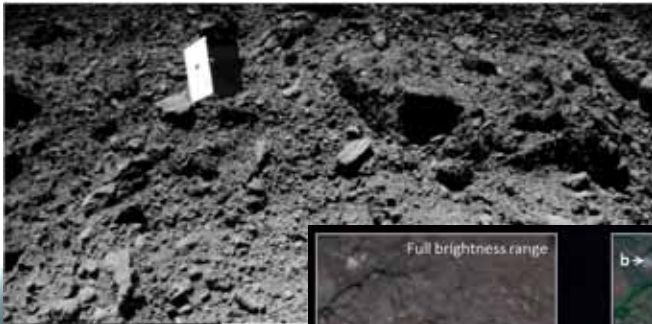




# Accomplishments of Hayabusa2 (1/2)

- 1. Mobile activity of exploration robots on small body
- 2. Multiple robots delivery to small body surface

MASCOT taken by ONC-W2



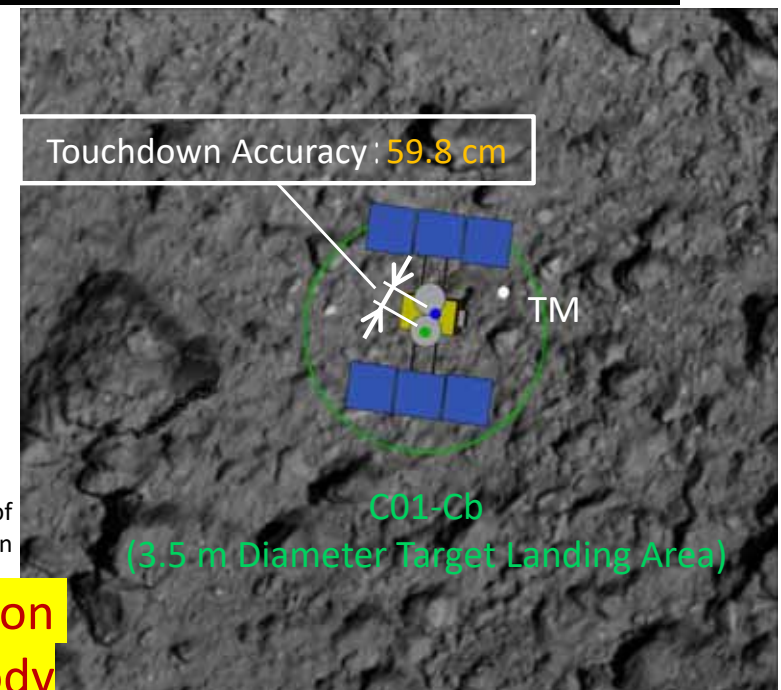
MASCOT images



MINERVA-II-1A image



MINERVA-II-1A image



Landing accuracy of the 2nd touchdown

- 3. 60cm-accuracy landing and sampling on extra-terrestrial celestial body

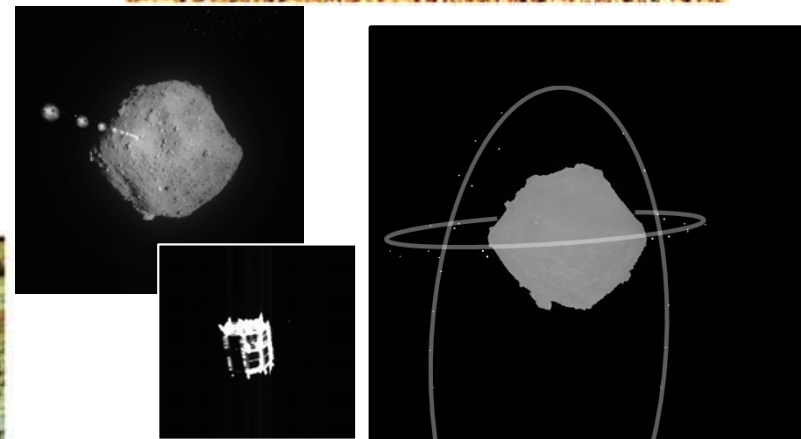
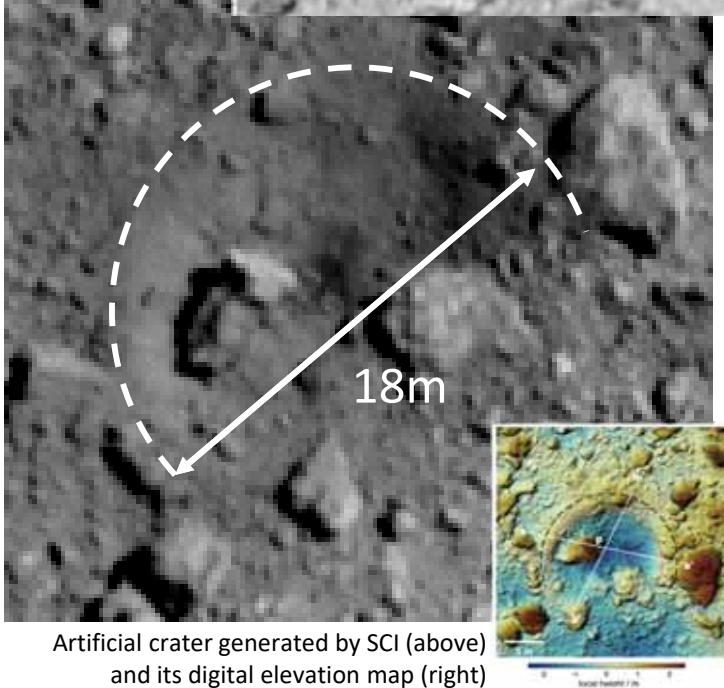
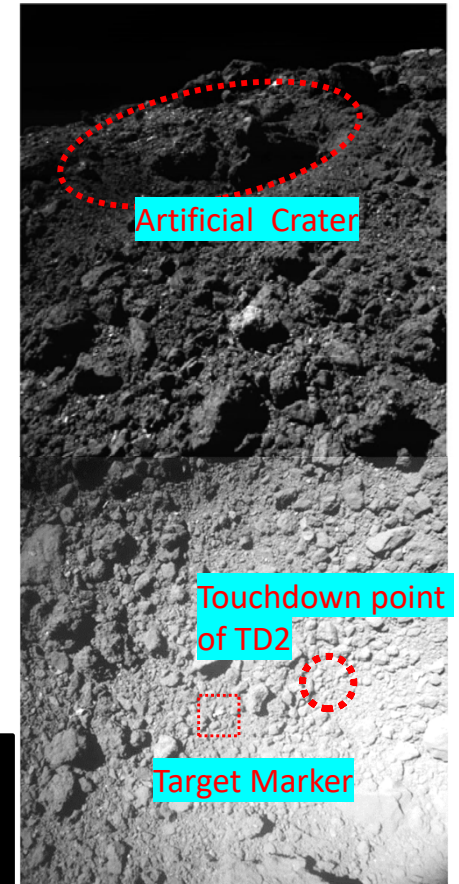
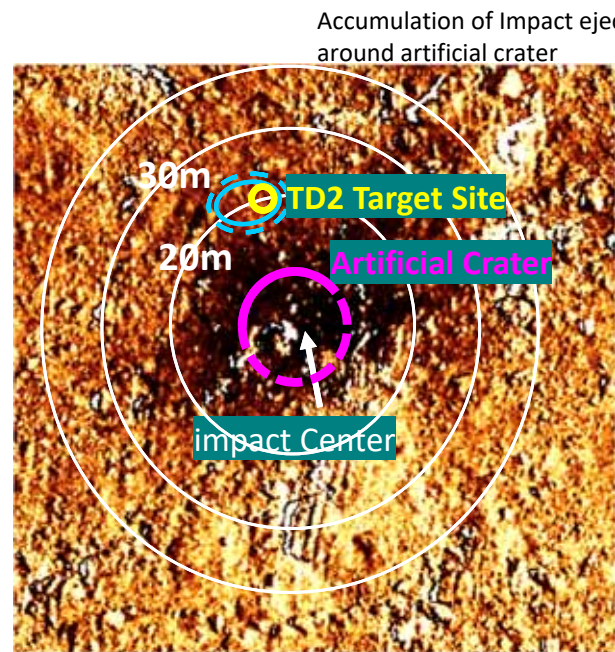
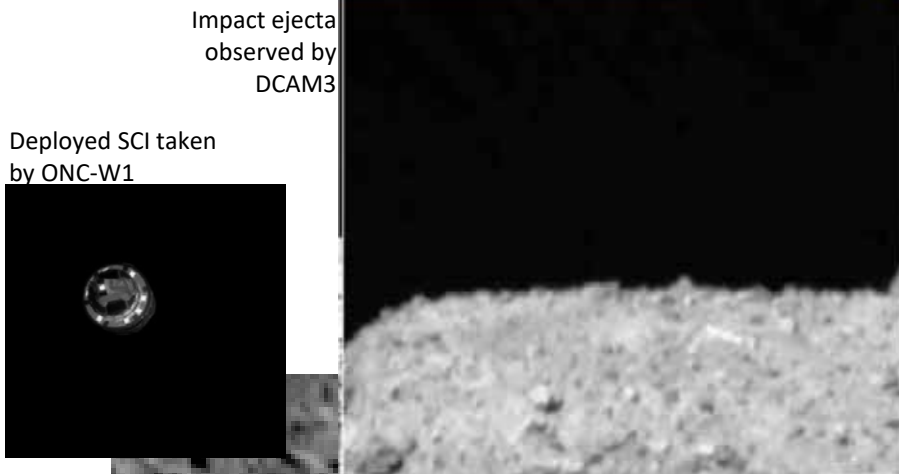




# Accomplishments of Hayabusa2 (2/2)

4. Artificial crater forming and detailed observation of impact process

5. Multiple landings on extra-terrestrial celestial body  
6. Subsurface material Collection

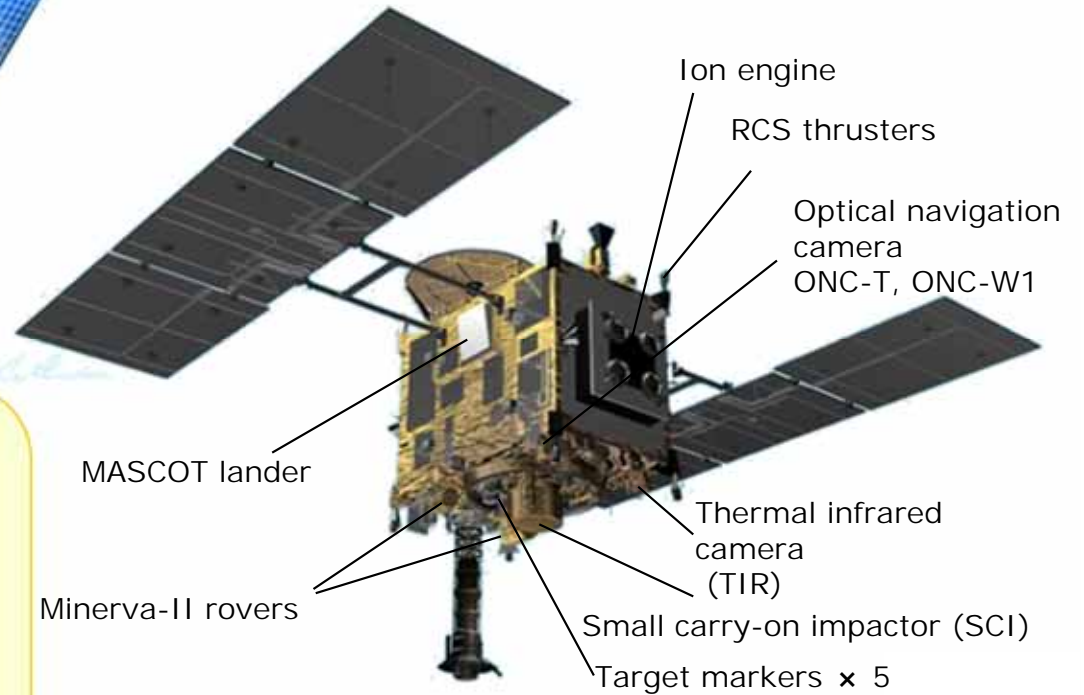
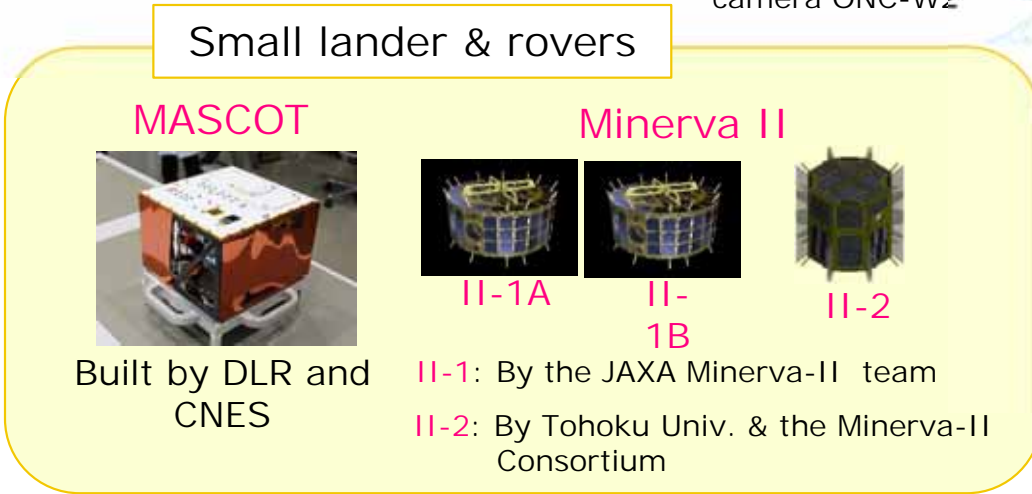
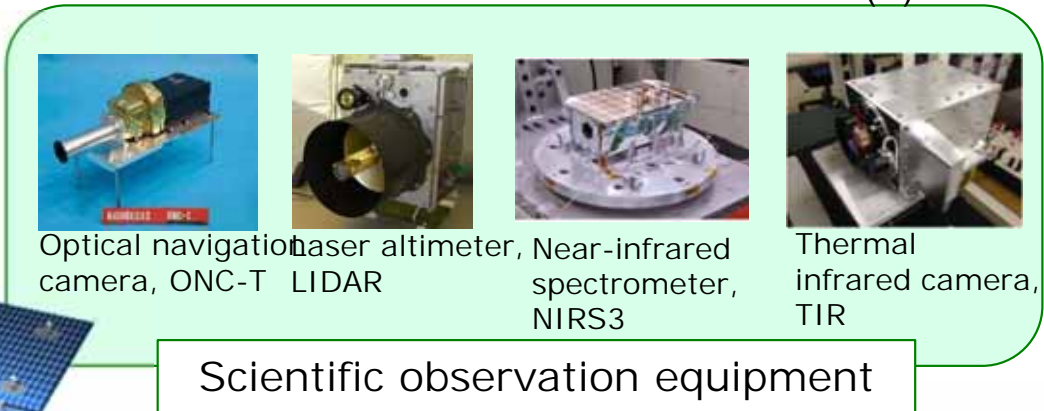
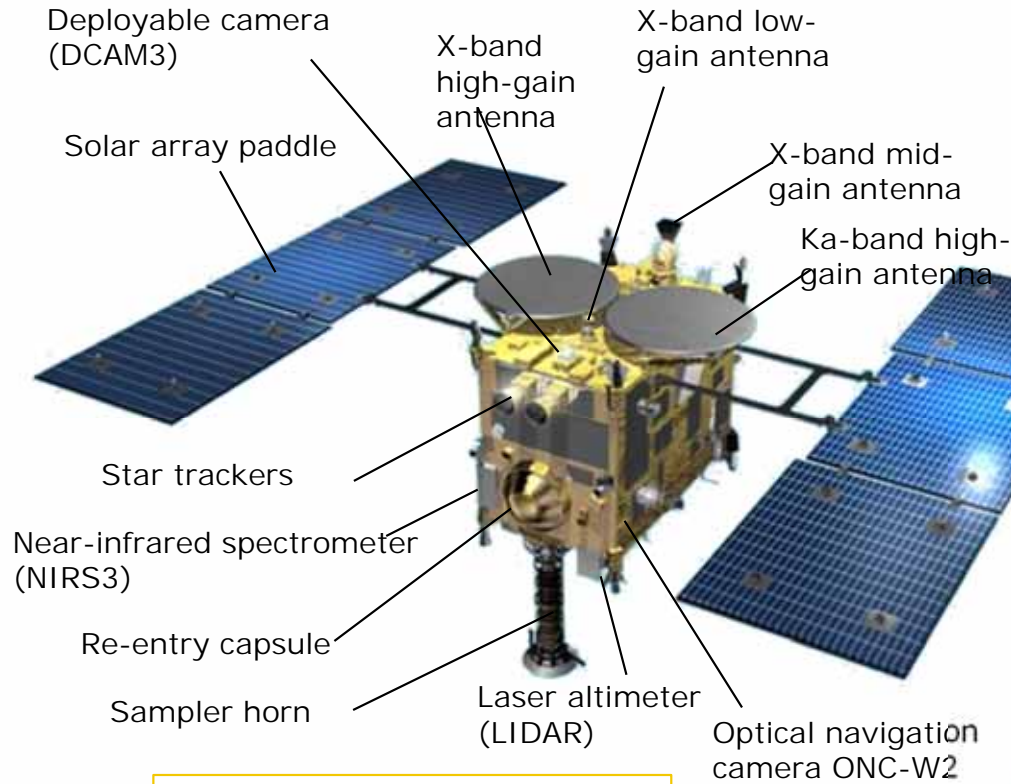


7. Smallest-object constellation around extra-terrestrial celestial body





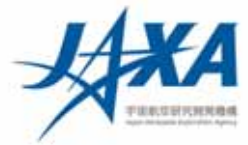
# Hayabusa2 spacecraft



Size: 1 × 1.6 × 1.25 m (main body)  
 Solar paddle deployed width 6 m  
 Mass : 609 kg (incl. fuel)

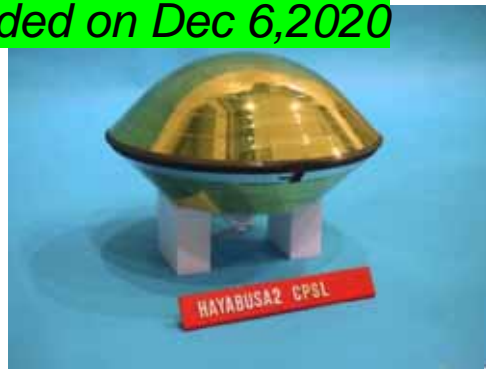


# Hayabusa2 and its 12 Deployables



Reentry Capsule

Landed on Dec 6, 2020



Deployable Camera (DCAM3)

Deployed on Apr 5, 2019



MASCOT Lander

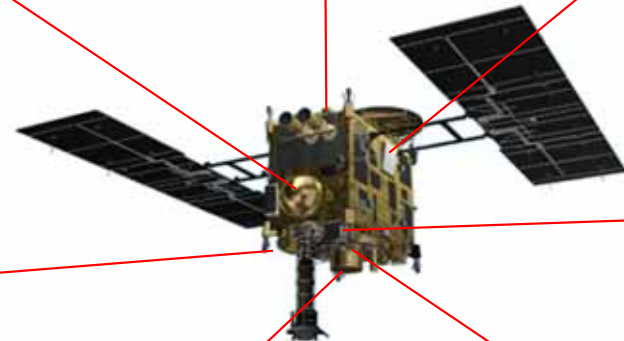
Landed on Oct 3, 2018



Landed on Sep 21, 2018



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



Inserted to orbit on Oct 2, 2019



MINERVA-II2 Rover

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



# Hayabusa2's biggest highlight: Touch down/Sample Collection

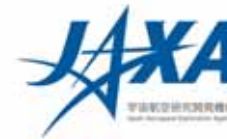


(©JAXA)

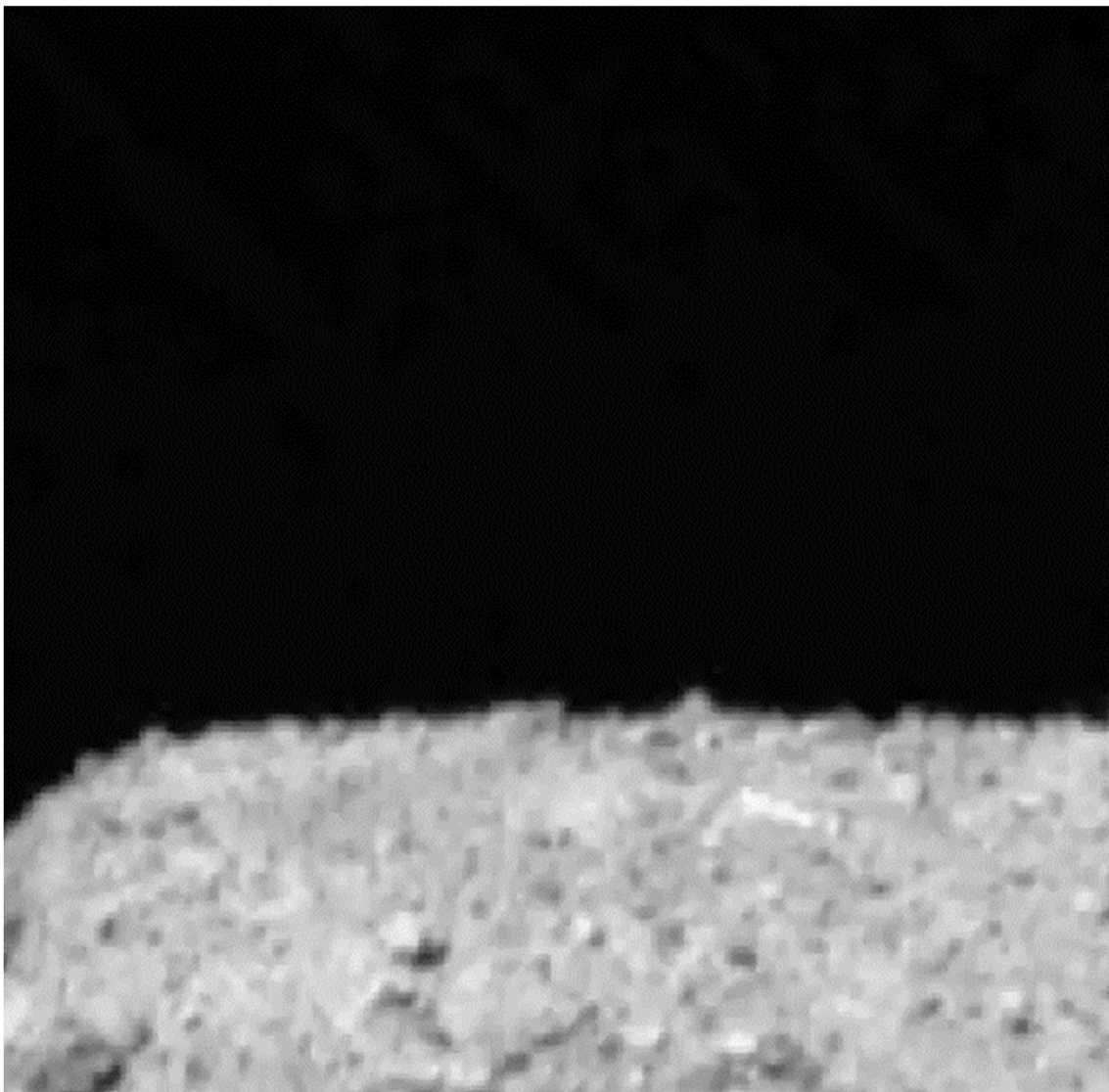




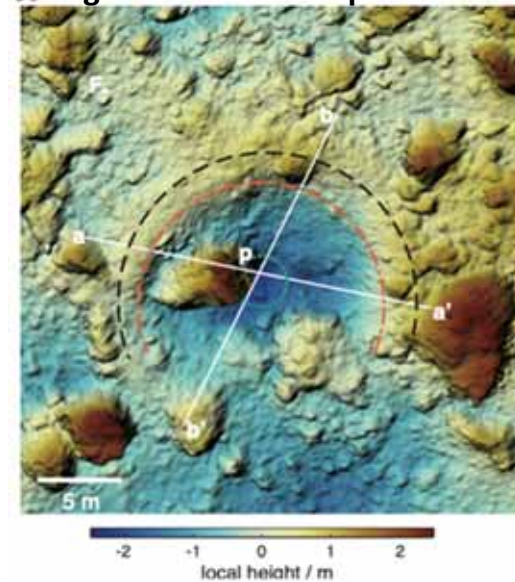
# Success in making Artificial Crater



Cratering Process photographed by DCAM3



Digital Elevation Map of Crater

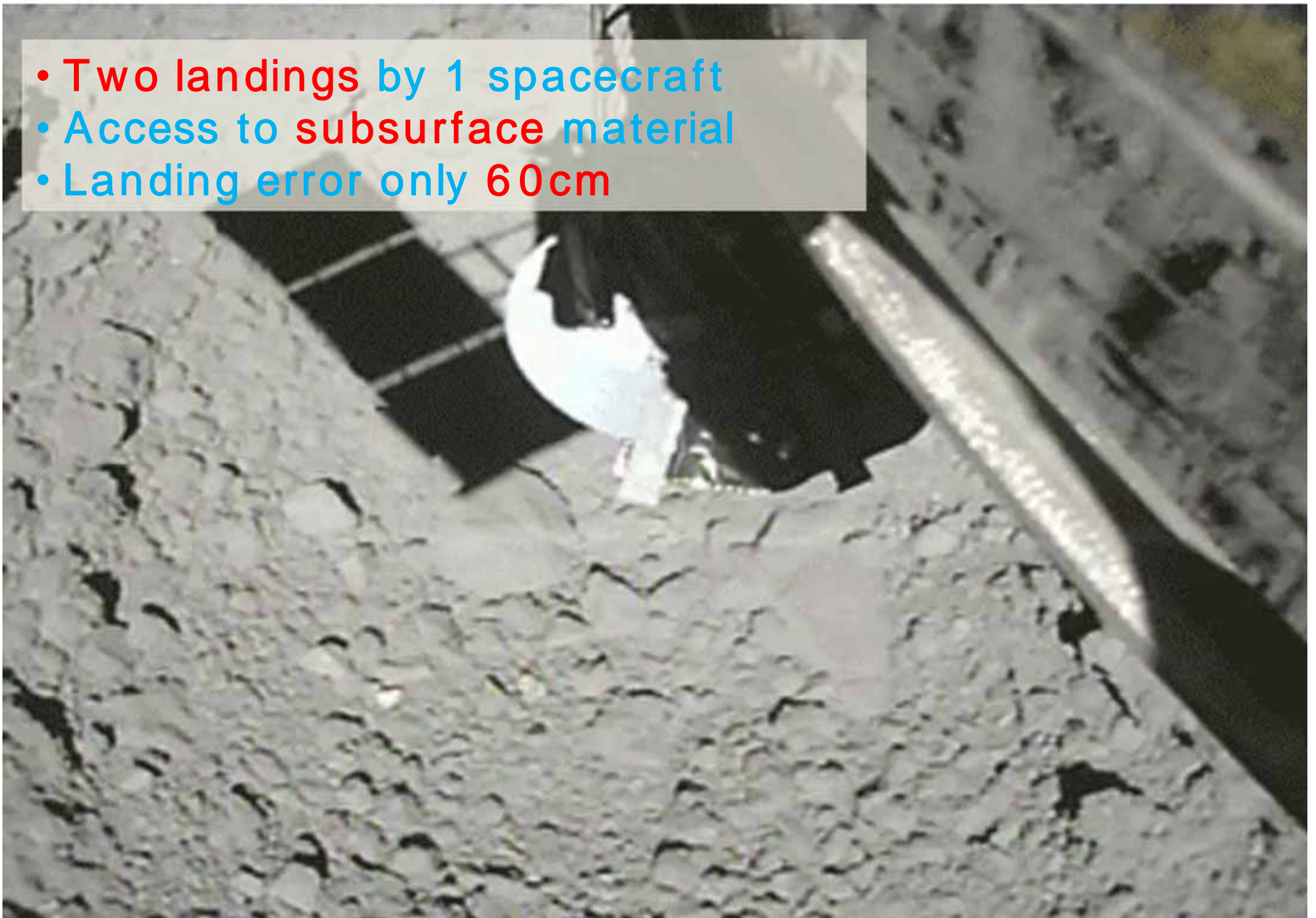


Terrain change before/after impact



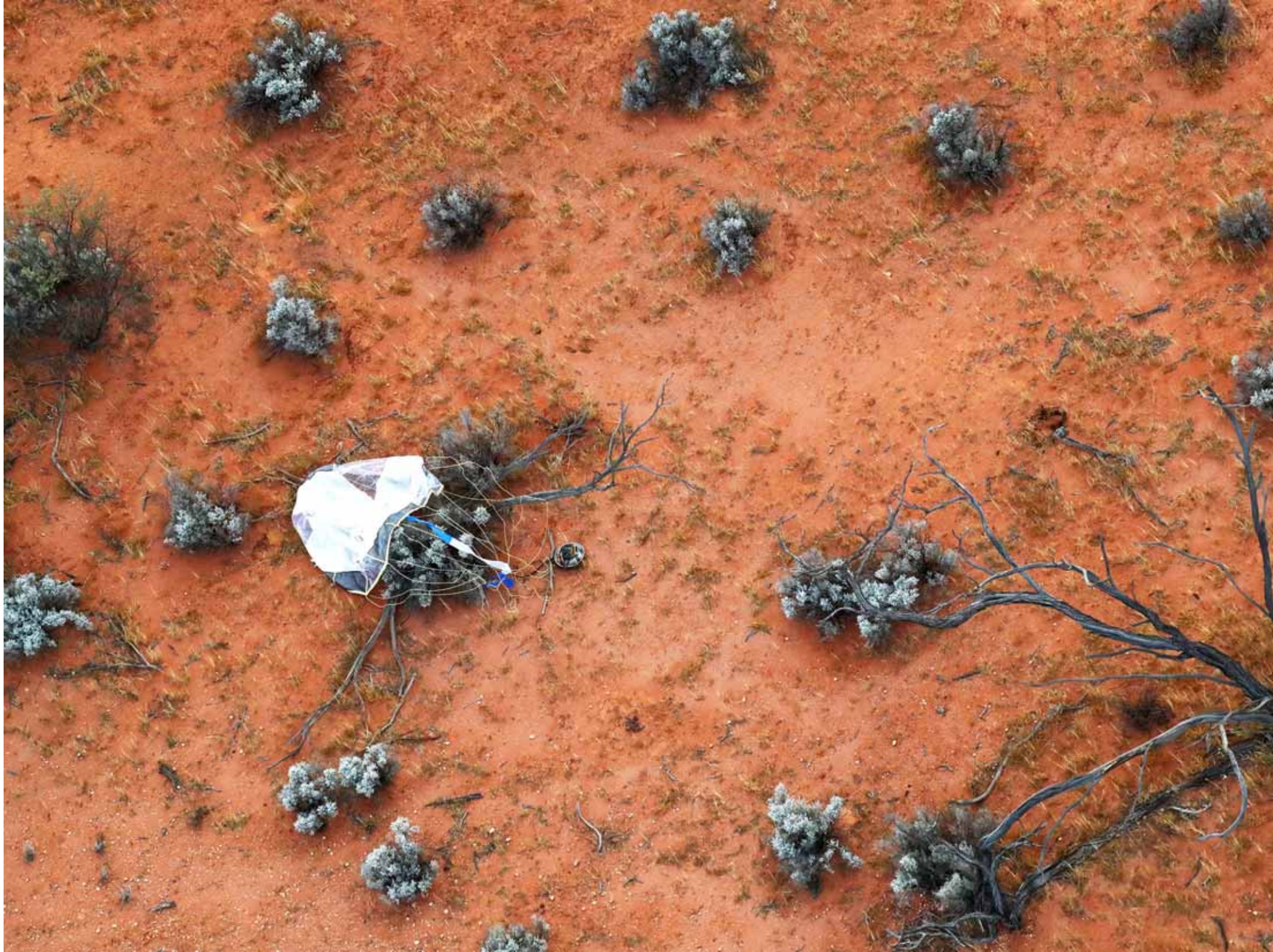
(c)Arakawa et al.,2020

- Two landings by 1 spacecraft
- Access to subsurface material
- Landing error only 60cm



Succeeded in the 2nd touchdown on Ryugu at 01:06UTC, July 11, 2019.







Ryugu samples found in the sample container!

Sample yield : 5.4g (requirement: 0.1g)



# Hayabusa2 Extended Mission

Hayabusa2 (Small Hazardous Asteroid Reconnaissance Probe)

2026 Asteroid “2001 CC21” Flyby

2031 Asteroid “1998 KY26” Rendezvous

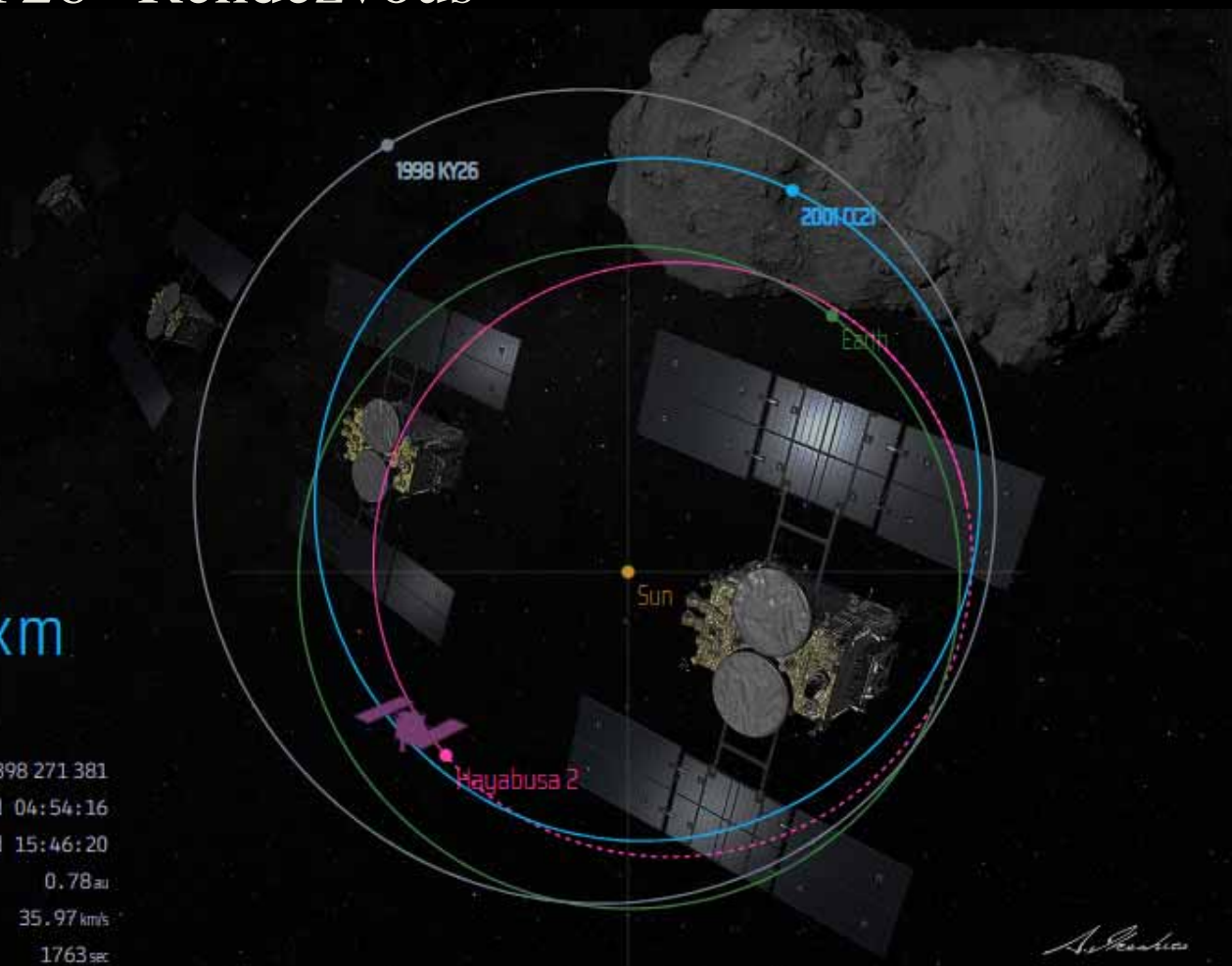
Hayabusa2#

From Earth

264 468 321km

Asteroid Explorer "Hayabusa2"

Total distance travelled:	2 898 271 381
Time since launch:	L+3268d 04:54:16
Time since start of Extended Mission:	R+1073d 15:46:20
Distance between Sun and spacecraft:	0.78 au
Velocity relative to the Sun:	35.97 km/s
Radio wave round trip time:	1763 sec



*N. Kuroki*



CanSat/CubeSat experience brought me to push the boundary of the space exploration.



Thank you for your attention.

(C)JAXA

Feb 22, 2019 at Sagamiara Space Operation Center (at the success of the 1st touchdown)