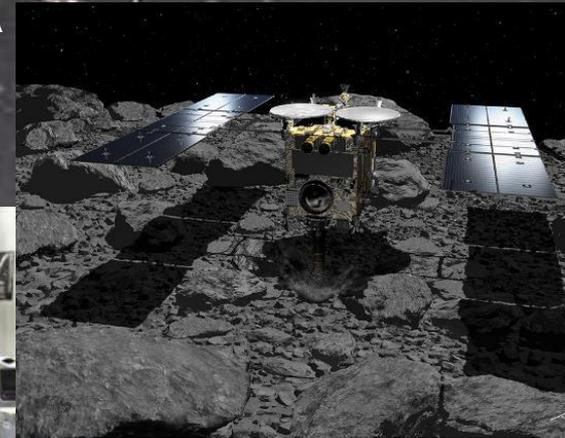
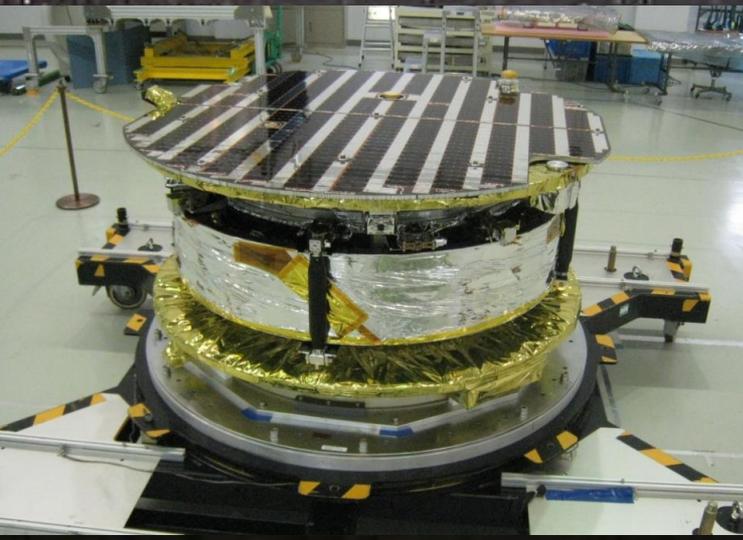


Road to Hayabusa2 from CanSat and CubeSat

Institute of Space and Astronautical Science, JAXA
(CanSat & CubeSat 1st Generation)

Yuichi Tsuda



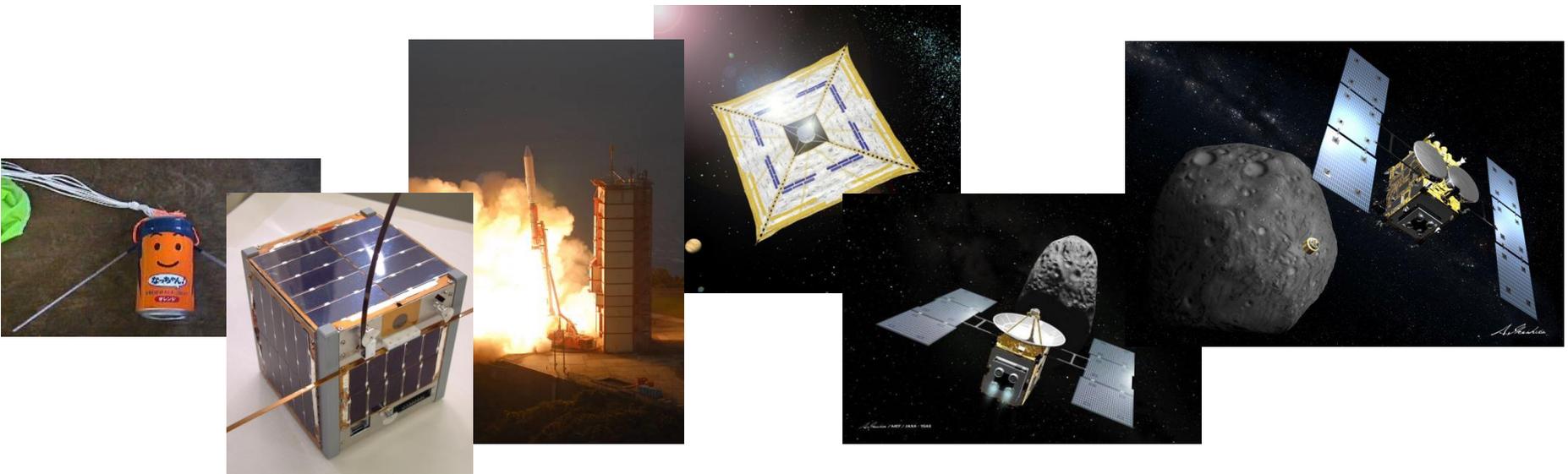
Yuichi Tsuda

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*



The beginning (1999~2003)

Journey begins suddenly...

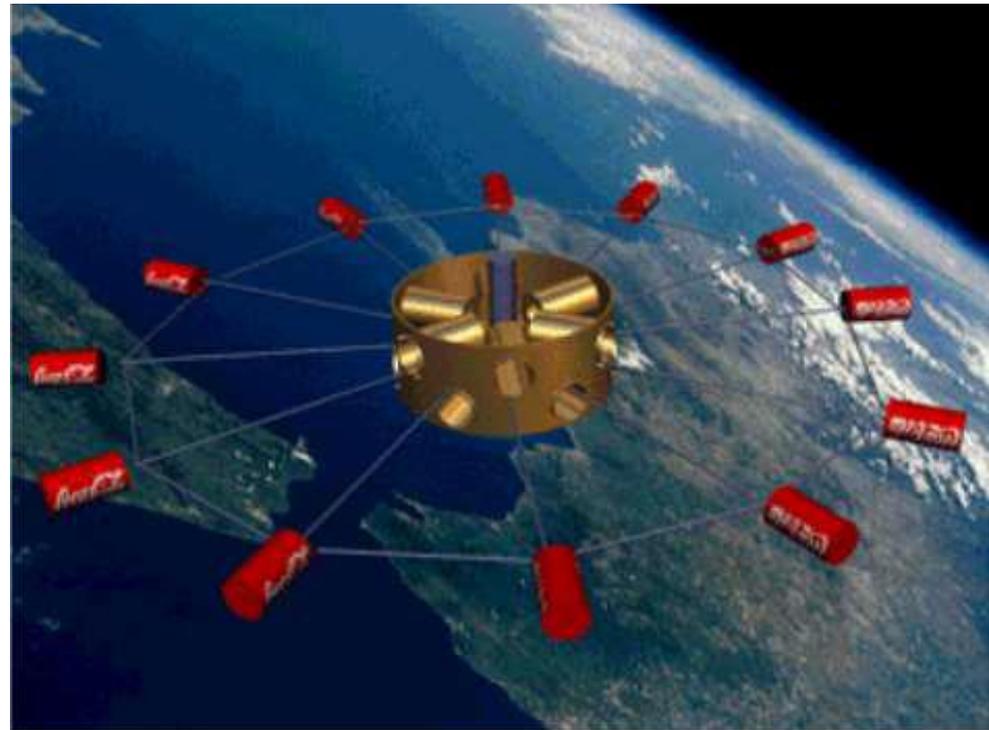
In 1998 when I was a student in Prof. Nakasuka's lab,

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

Me: Wow, Hawaii!? I will go.
By the way what will we do there?

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

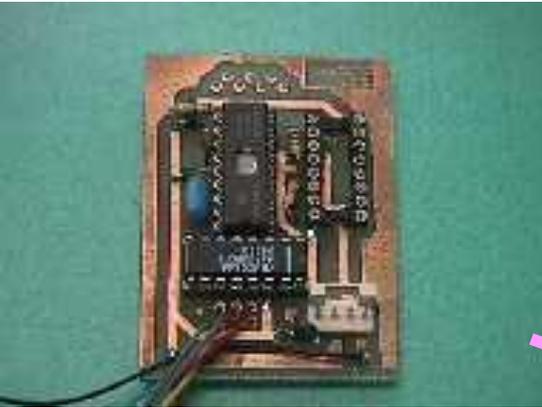
Birth of “CanSat” Concept



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

First work



Main Board

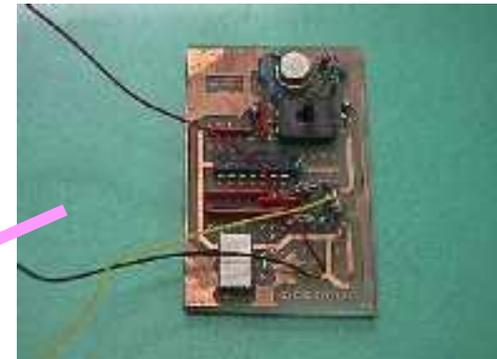
Parachute

Battery

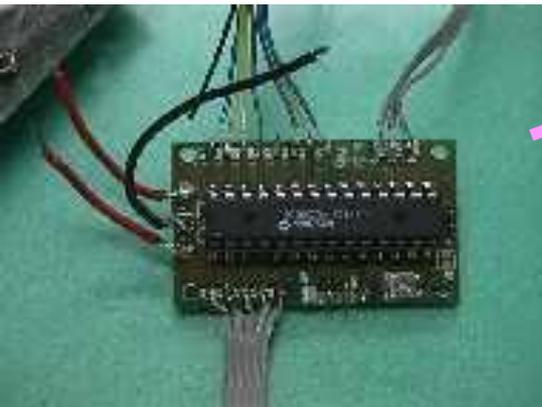


350ml Juice Can

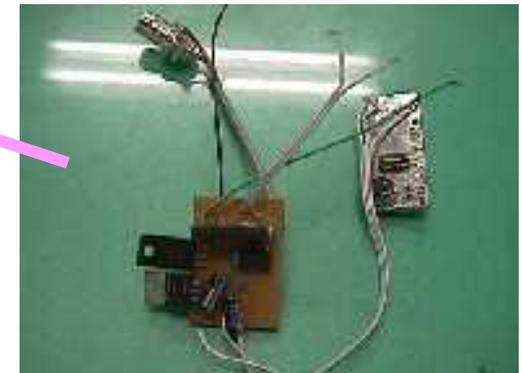
Antenna



Sensors Board



Com encoder (TNC)



Transmitter

1st Generation “CanSats”



Pre-final model



Flight model of CanSat #003

Three 1st generation CanSats developed by U of Tokyo.

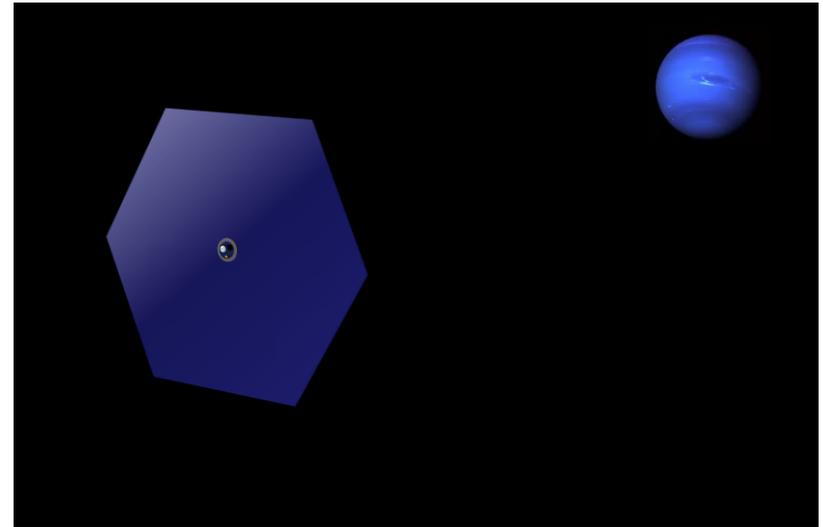
Launched in Black Rock Desert, 1999



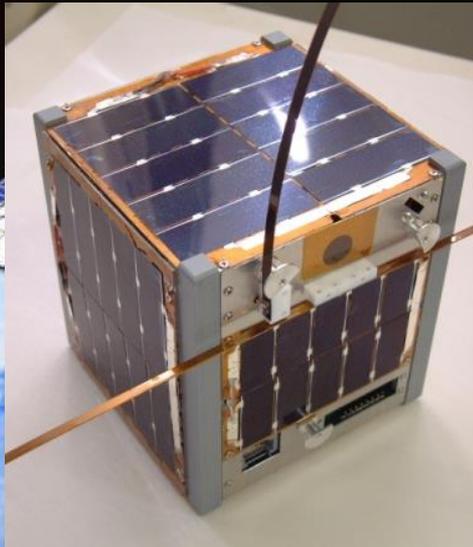
Want to make a Real Satellite ! ~CanSat to CubeSat

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

Thin space membrane + CubeSat = ?



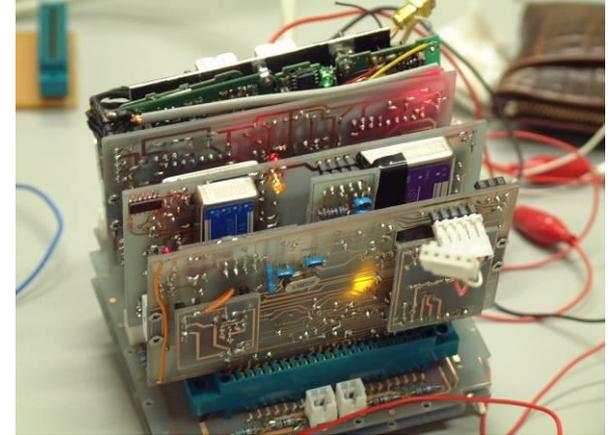
Ref. Tsuda, Nakasuka, Aoki, Nagashima,
Space Transportation Symposium, 1999



- 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...

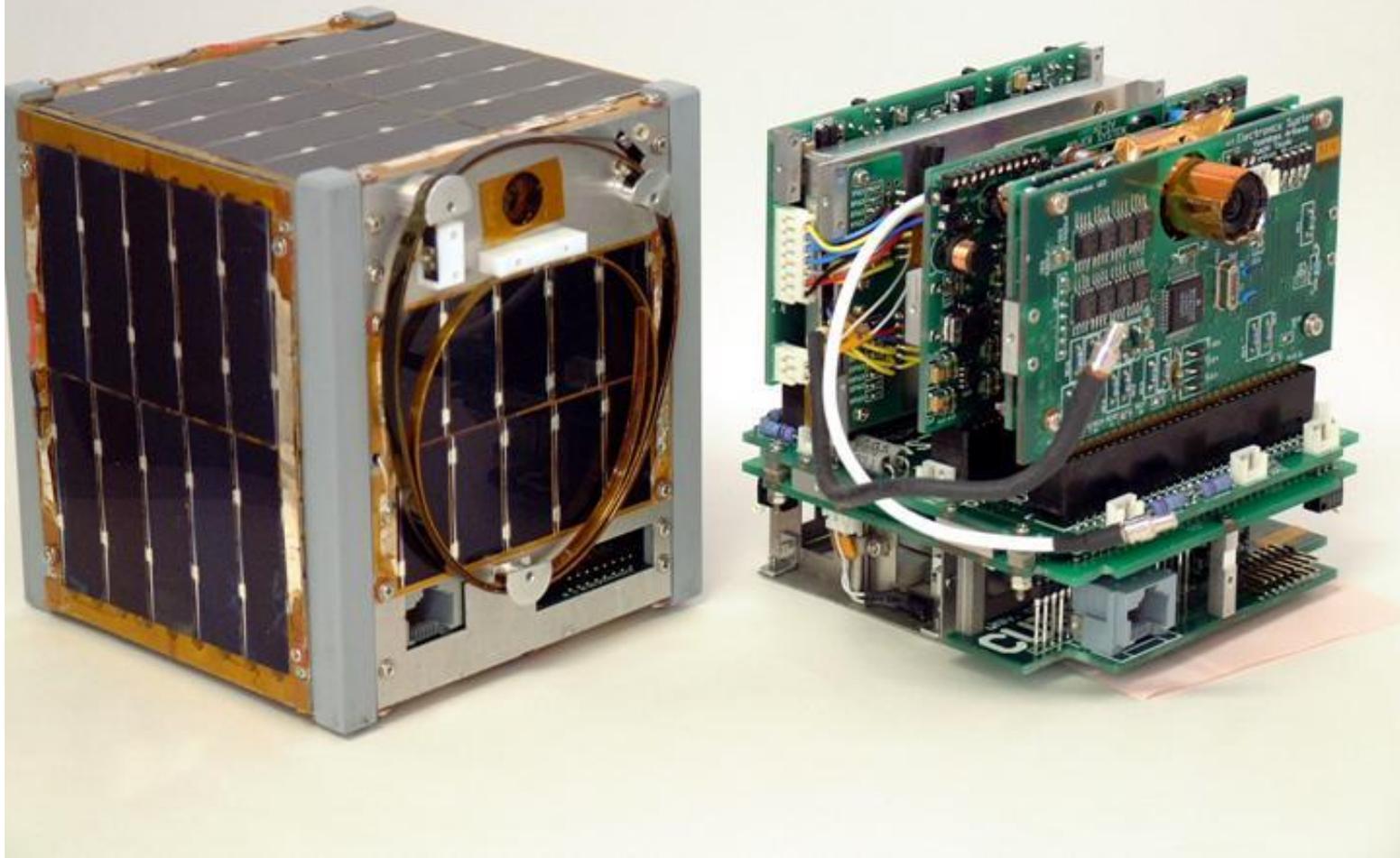
Textbook does not teach us.

The unexplored world should be pioneered by ourselves!



World First CubeSat “XI-IV”

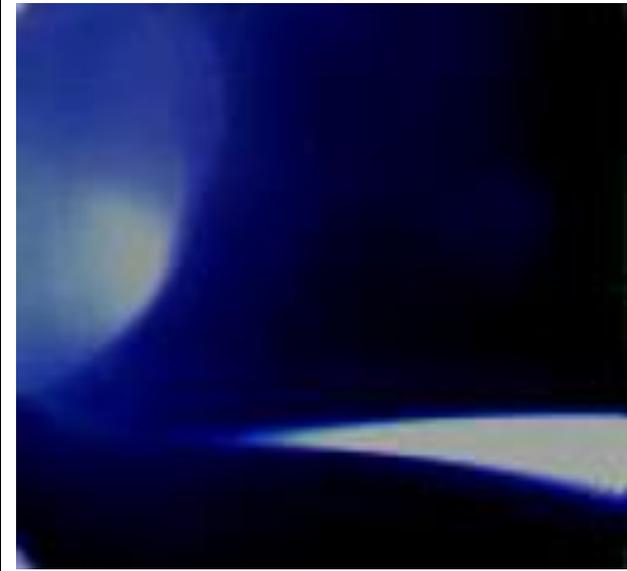
University of Tokyo's CubeSat Project “XI”



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



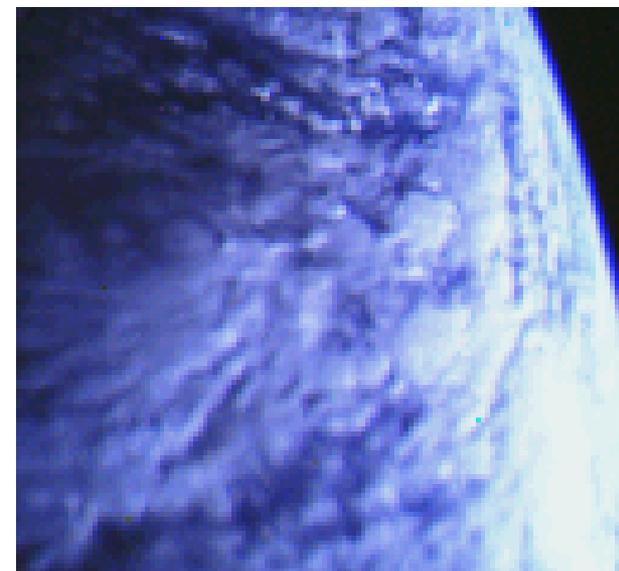
CubeSat XI-IV Photo Gallery July – November 2003, University of Tokyo ISSL



7.30 South Atlantic



9.14 Azores Islands



9.17 East Timor



10.5 Bangladesh



10.5 Tibet

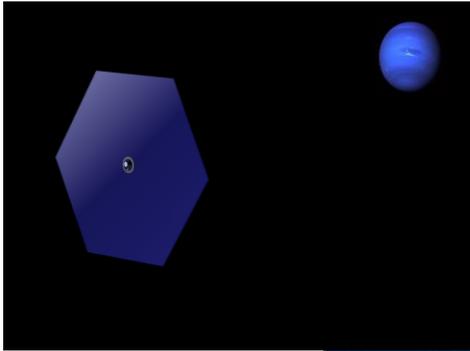


11.03 Egypt

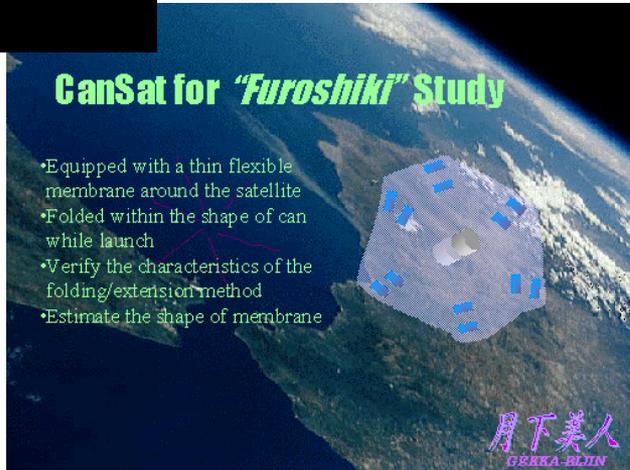
From CubeSats to Deep Space Exploration (2003~)

“Continuity” in my first 10 years of carrier

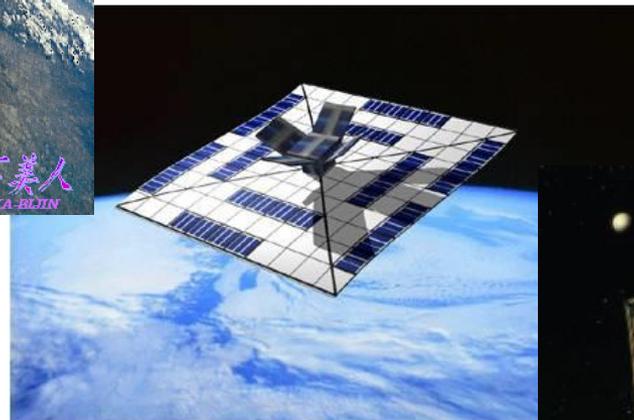
(C)JAXA



1998
Pluto explorer using space
membrane technology
(Concept study)

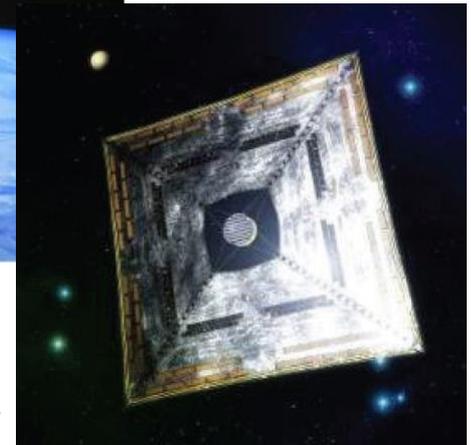


1999
CanSat membrane deployment experiment
(Concept study + Development)
→ *CanSat w/o membrane*



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

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

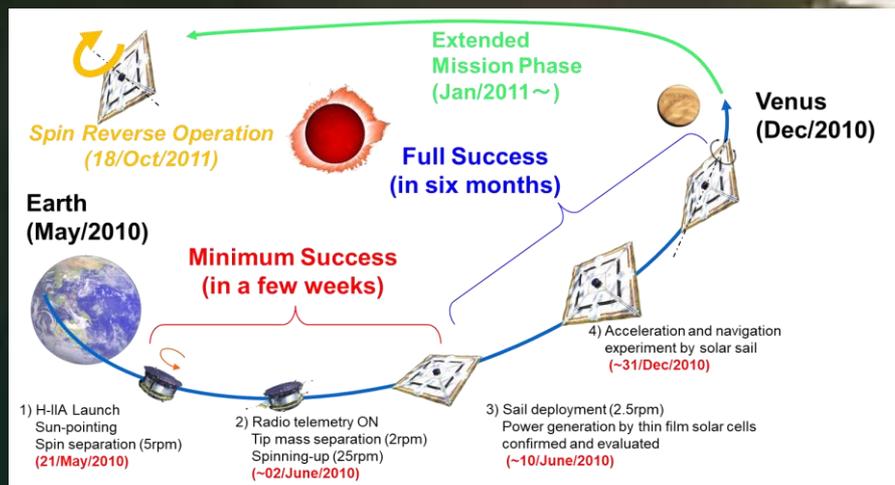
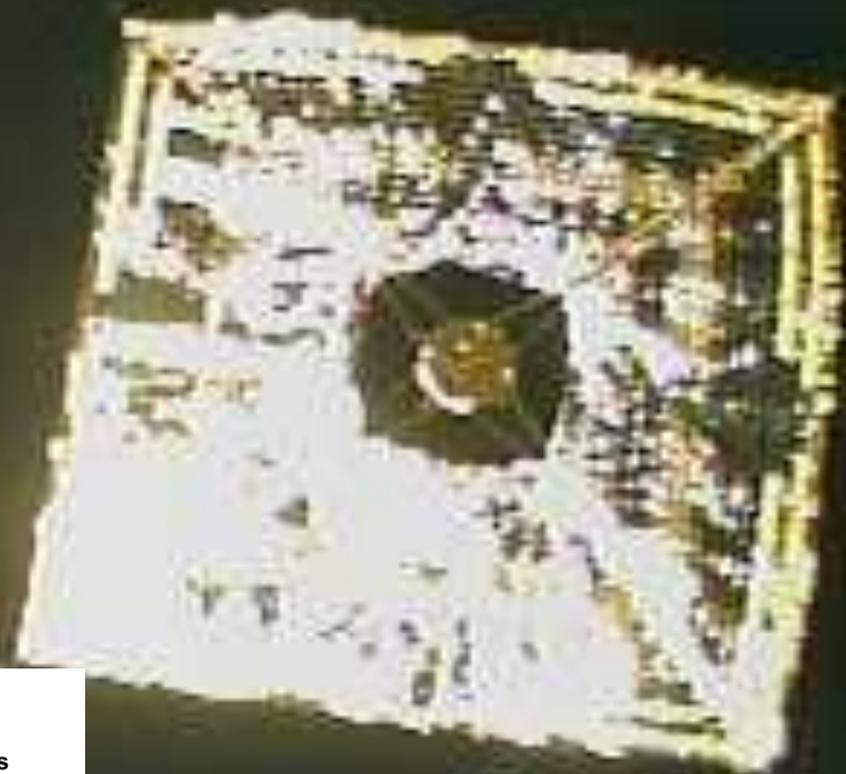


IKAROS (Interplanetary Kite-craft Accelerated by Radiation Of the Sun)

(C)JAXA



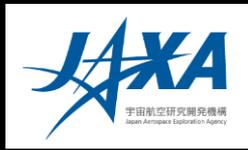
Solar Power Sail Tech-Demo Mission "IKAROS"



Toward Hayabusa2



Hayabusa2 Mission



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

Launch
Dec.3, 2014



Earth Gravity Assist
Dec.3, 2015



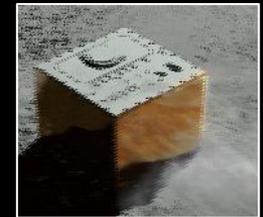
Ryugu Arrival
Jun.27, 2018



MINERVA-II-1 Deployment
Sep.21, 2018



MASCOT Deployment
Oct.3, 2018



Only 400 million km to Earth return!

Ryugu Departure
Nov.13, 2019

Earth Return
Dec.6, 2020

Target Markers Orbiting
Sep.16, 2019

MINERVA-II-2 Orbiting
Oct.2, 2019

Second

Touchdown
Jul.11, 2019

Kinetic Impact
Apr.5, 2019

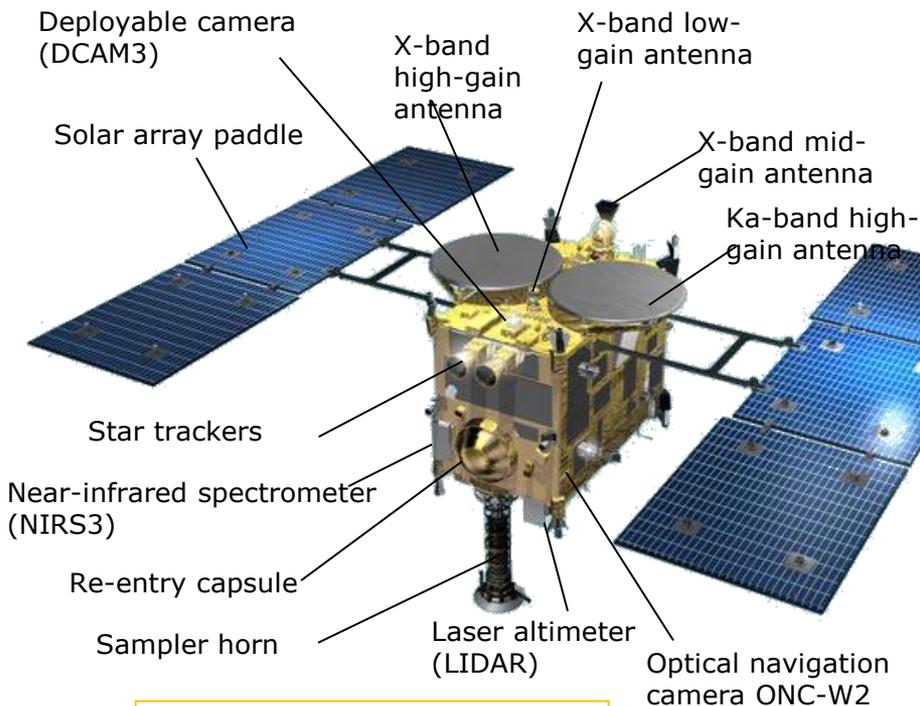
First Touchdown
Feb.22, 2019



Hayabusa2 spacecraft



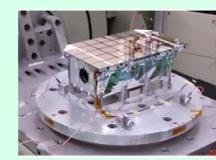
(C)JAXA



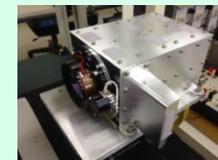
Optical navigation camera, ONC-T



Laser altimeter, LIDAR



Near-infrared spectrometer, NIRS3



Thermal infrared camera, TIR

Scientific observation equipment

Small lander & rovers

MASCOT



Built by DLR and CNES

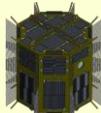
Minerva II



II-1A



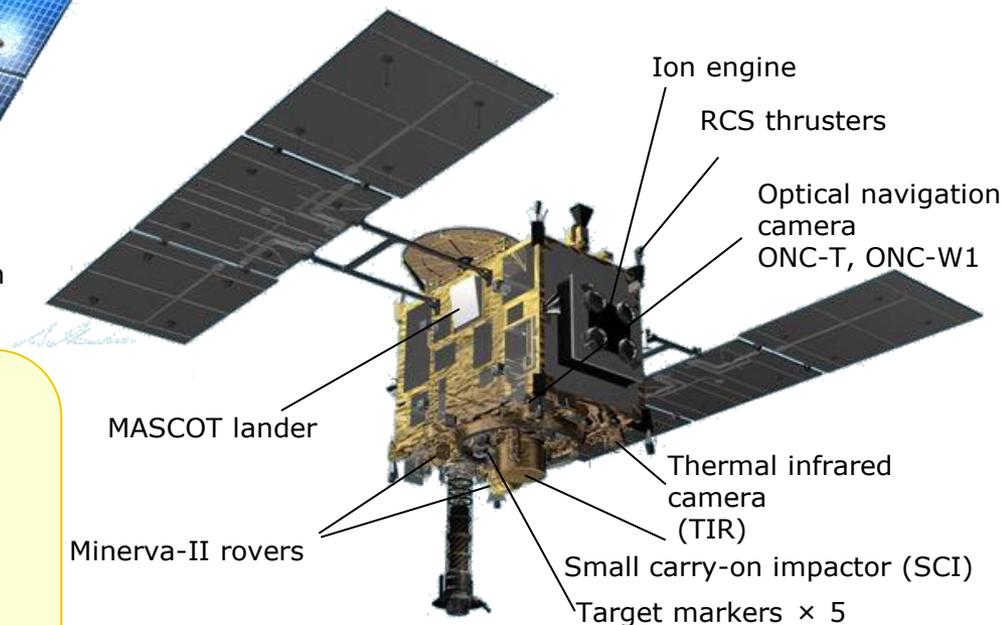
II-1B



II-2

II-1: By the JAXA Minerva-II team

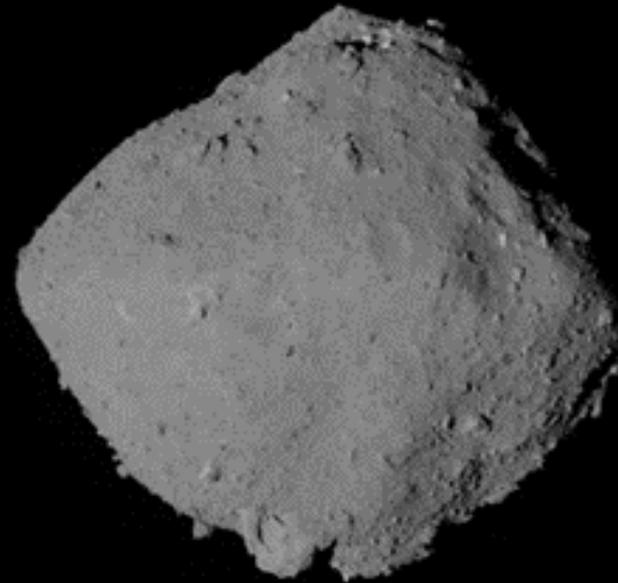
II-2: By Tohoku Univ. & the Minerva-II Consortium



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

C-type Asteroid “Ryugu”

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



Surface Exploration with 4 Robots



MINERVA-II-1-A & B
by JAXA
(Nickname : Hibou, Owl)

(Image credit: JAXA)



MASCOT
by DLR/CNES

(Image credit: MASCOT/DLR/JAXA)

Sep, 21, 2018



(Image credit: 東北大, JAXA)

MINERVA-II-2
by U of Tohoku and
University consortium
(nickname: Ulula)

Oct. 5, 2018

Oct. 2, 2019

Touch down sequence





Touchdown #1 Result



(C) JAXA

- All sequences went normally.
- 1m accuracy landing achieved.
- Many fragments observed!

(a) 07:26UT, Alt=8.5m

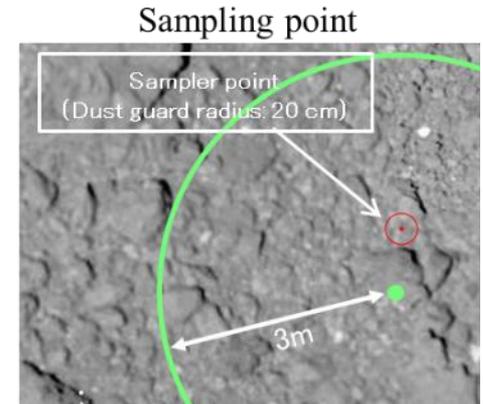
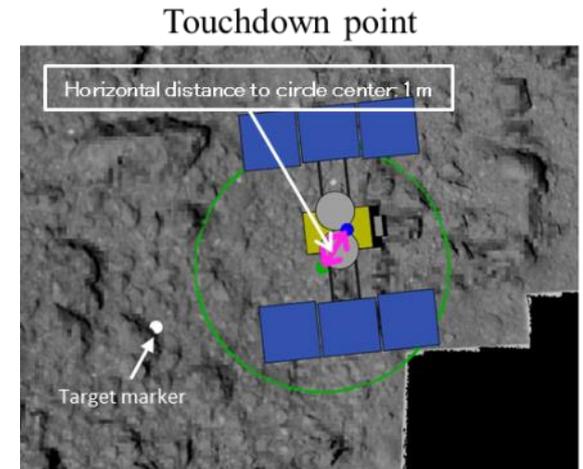
(b) 07:28UT, Alt=4.1m

(c) 07:29UT, Alt=1.0m

(d) 07:29UT, Alt=2.9m

(e) 07:29UT, Alt=8.0m

(f) 07:28UT, Alt=49.6m



Kinetic Impact (Artificial Crater Forming) April 25, 2019

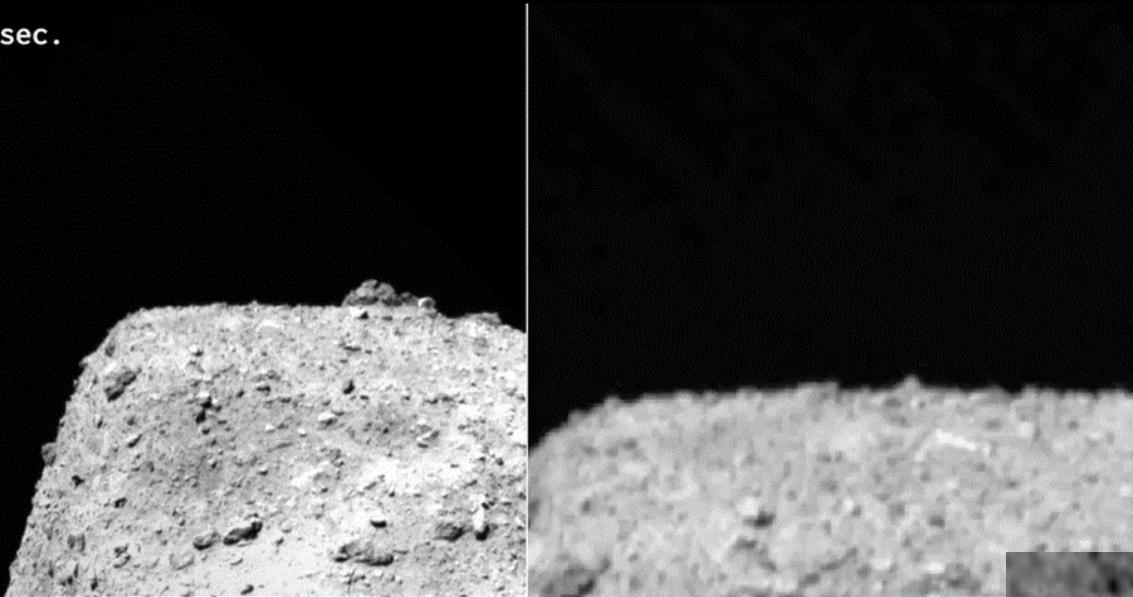
Impact Event Observation by DCAM3 (←*CanSat again!*)

Kinetic Impact Result

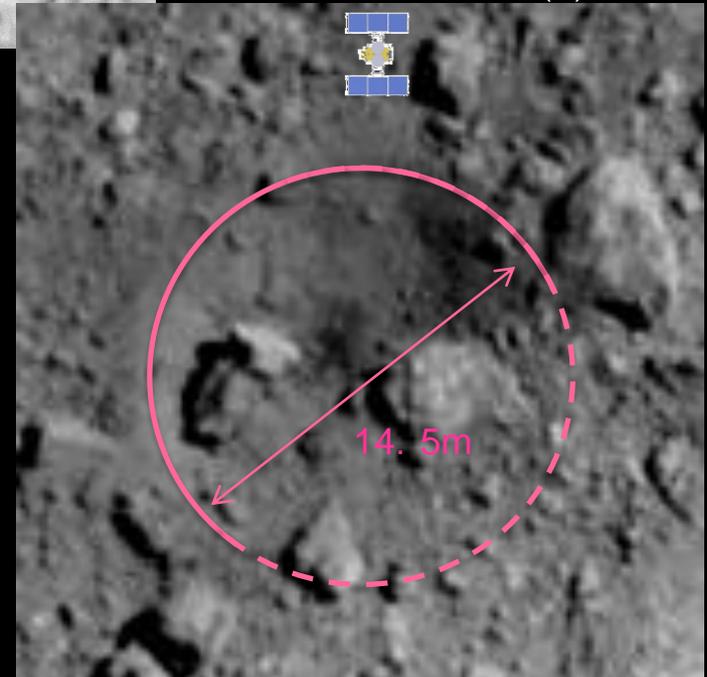
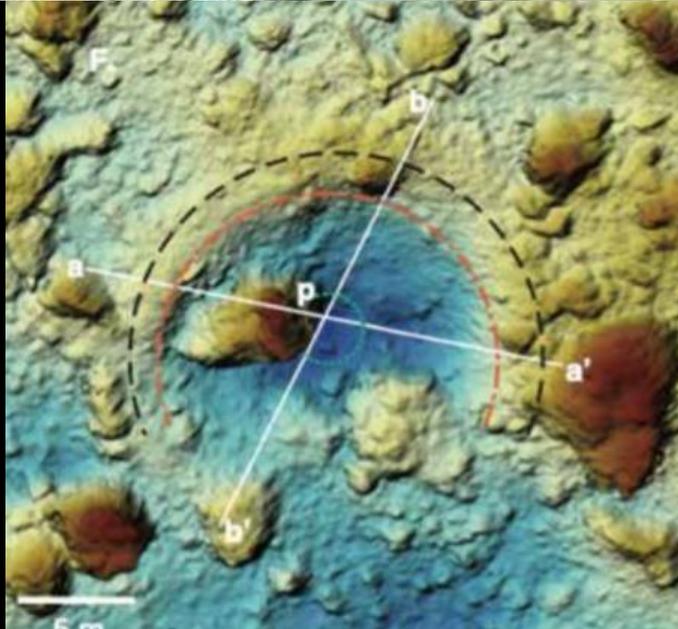
April, 5, 2019

-185 sec.

(C) JAXA

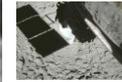
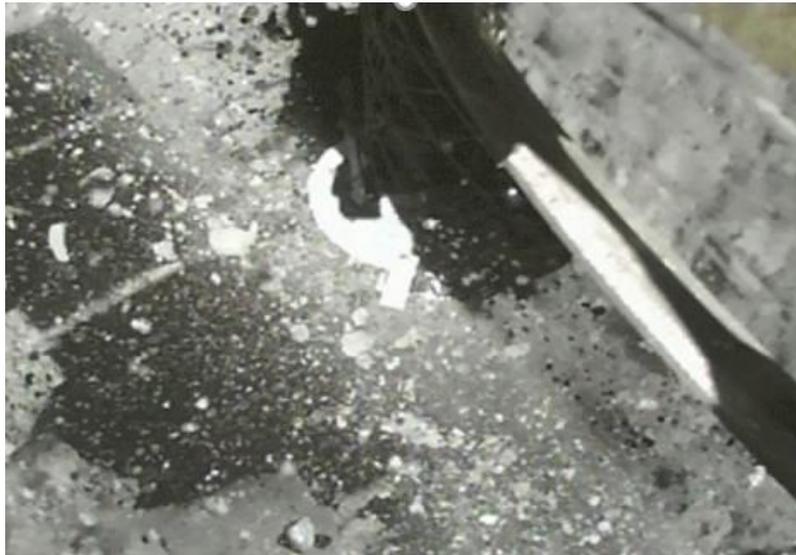
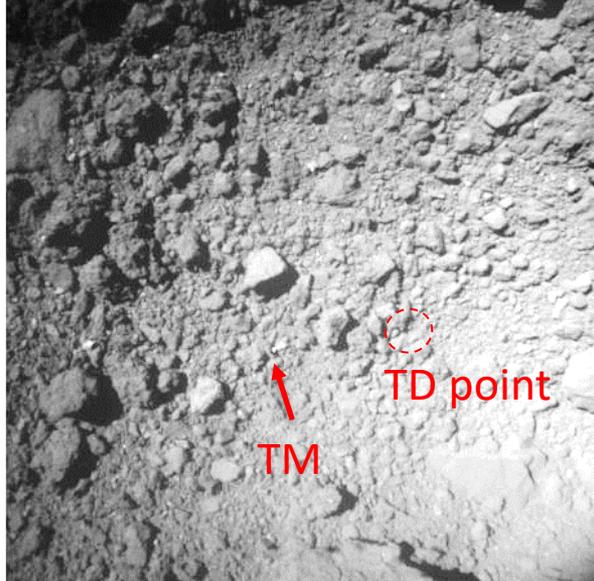
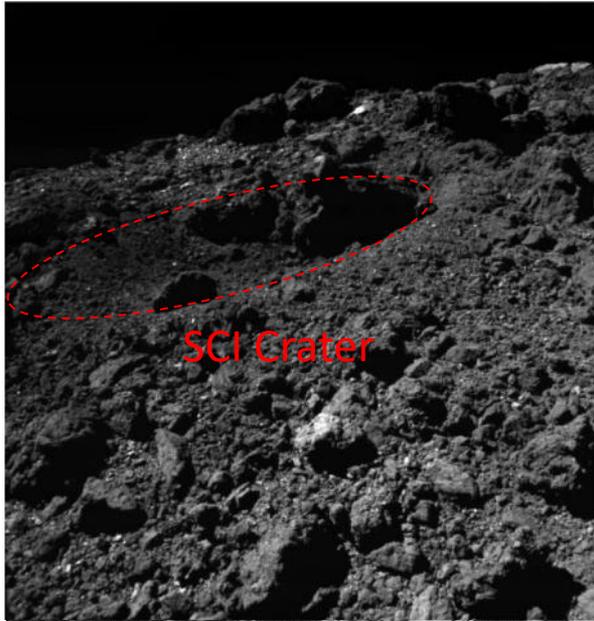


(C) JAXA





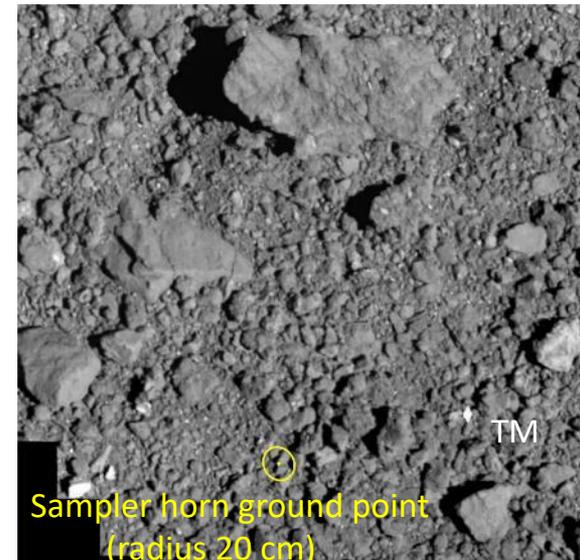
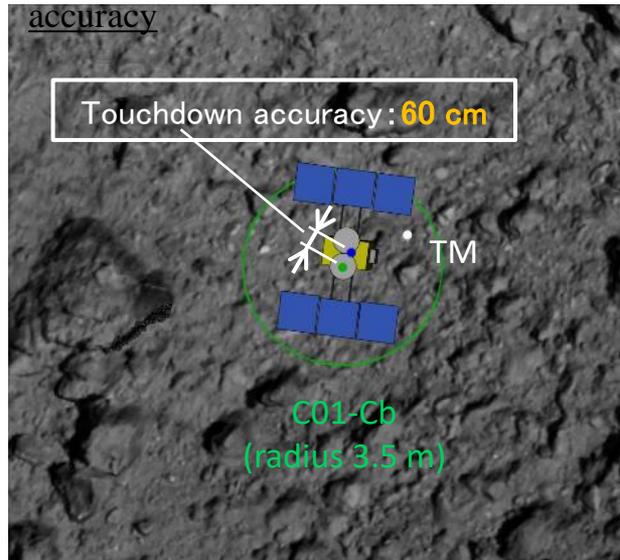
Touchdown #2 (PPTD) Operation Result



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

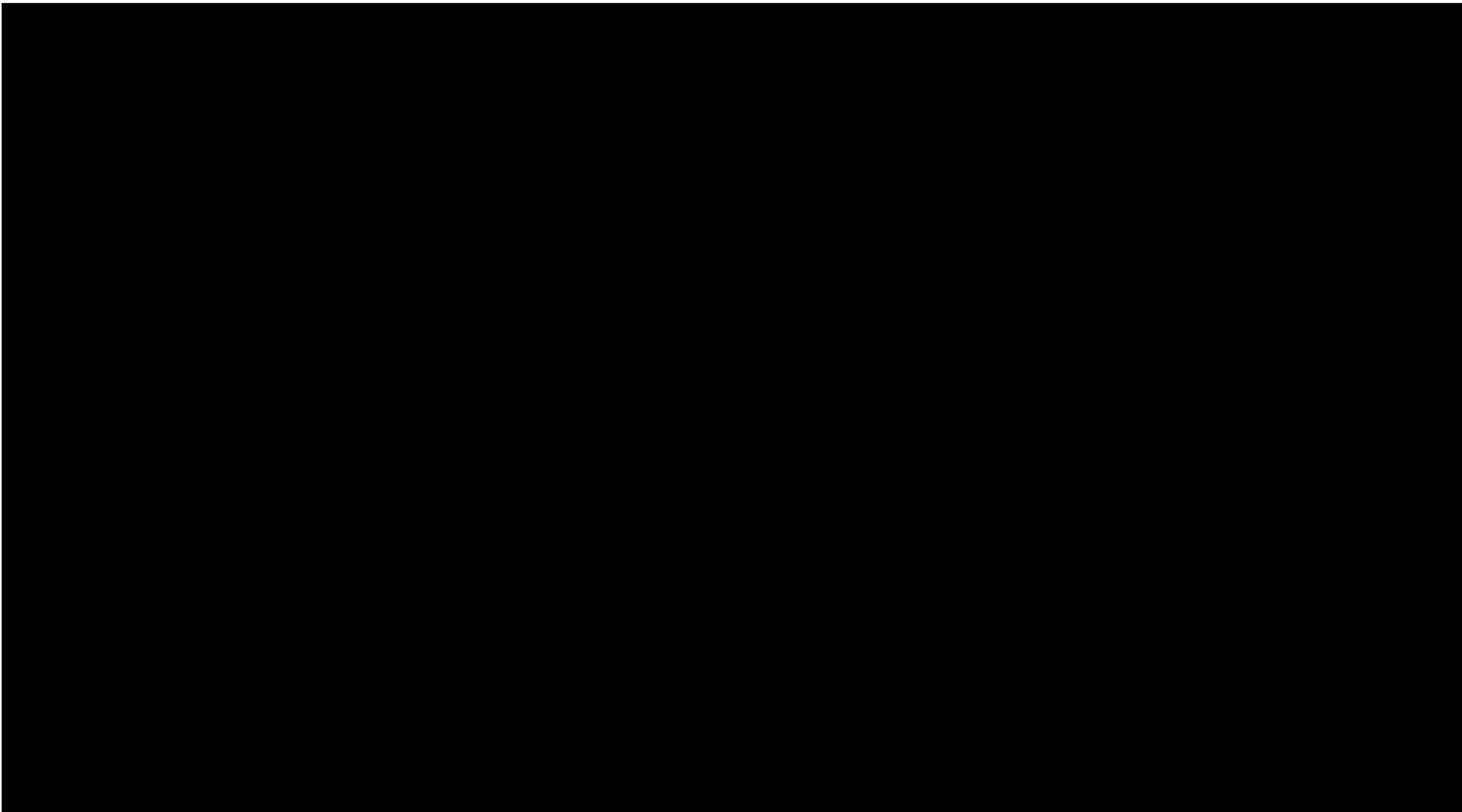
2nd touchdown accuracy

Sampler horn ground point





Reentry capsule recovery operation @ Woomera



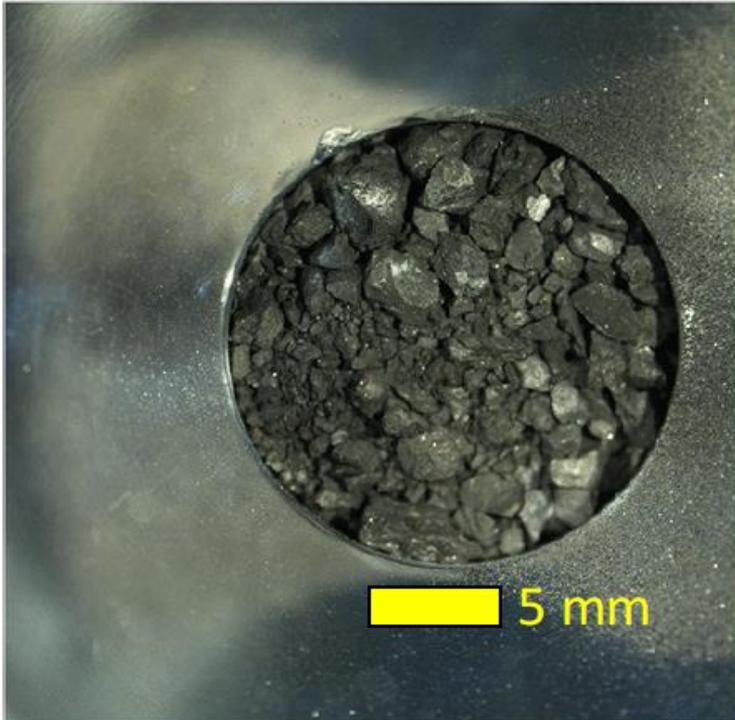
(C)JAXA



We've got plenty of Ryugu sample!

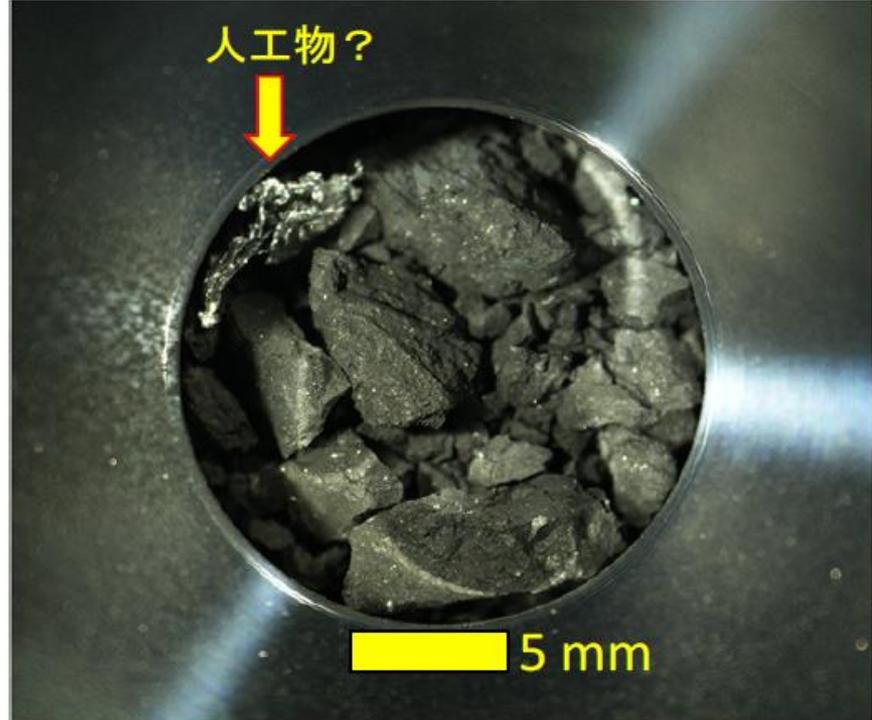
Total yield: 5.4g (> design criterion: 0.1g)

(C)JAXA



Chamber A

Sample of the 1st Touchdown



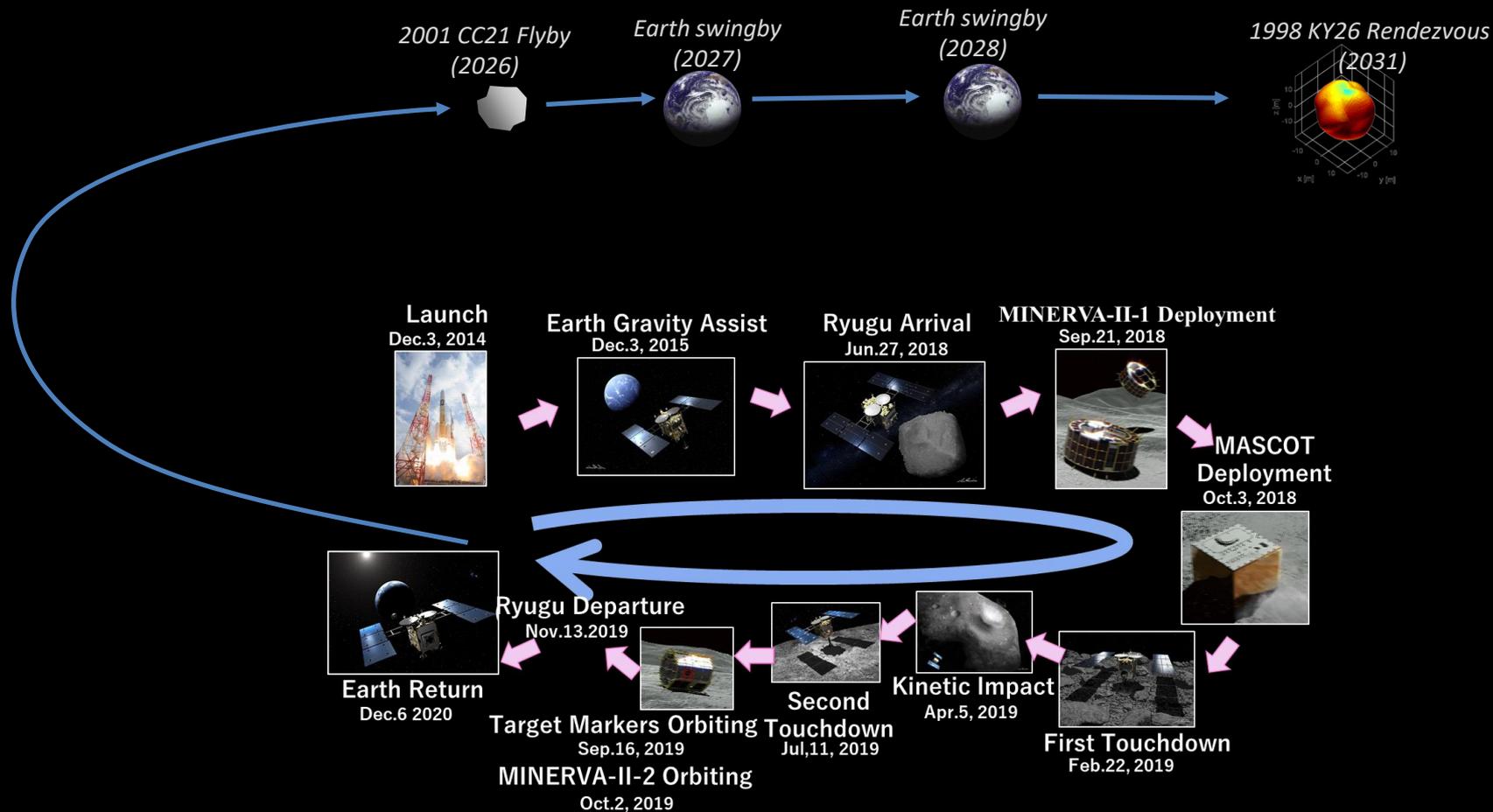
Chamber C

Sample of the 2nd Touchdown

※Chamber B was open between Touchdown #1 and #2, and many small Ryugu particles were found.



Hayabusa2 Extended Mission Plans



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



Thank you for your attention.

(C)JAXA

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