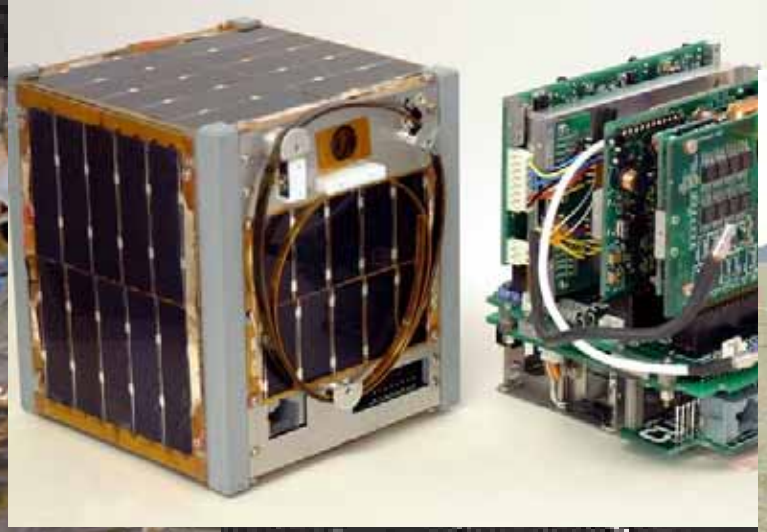
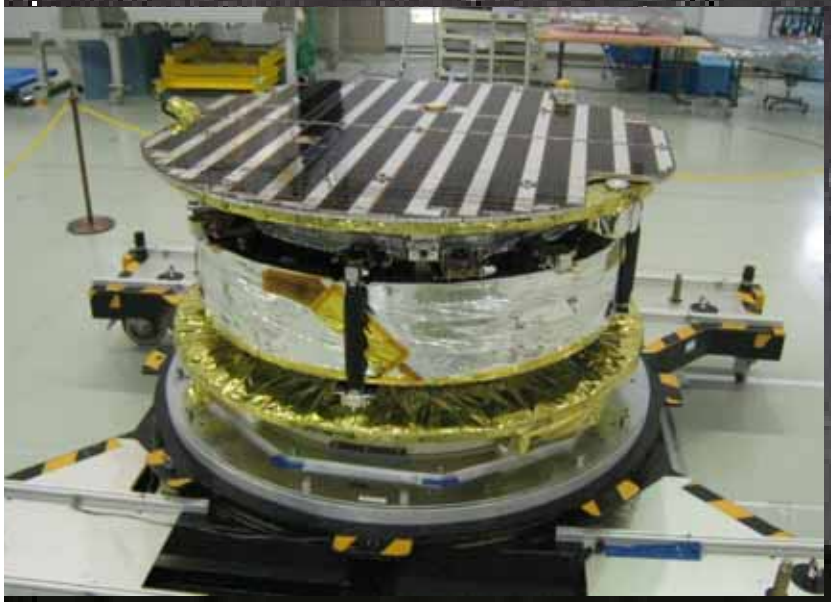
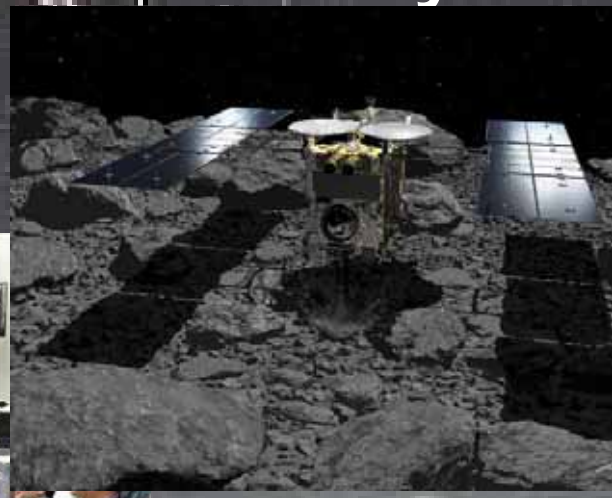


Deep Space Explorer's 20-year Journey

CanSat & CubeSat 1st Generation

Yuichi Tsuda





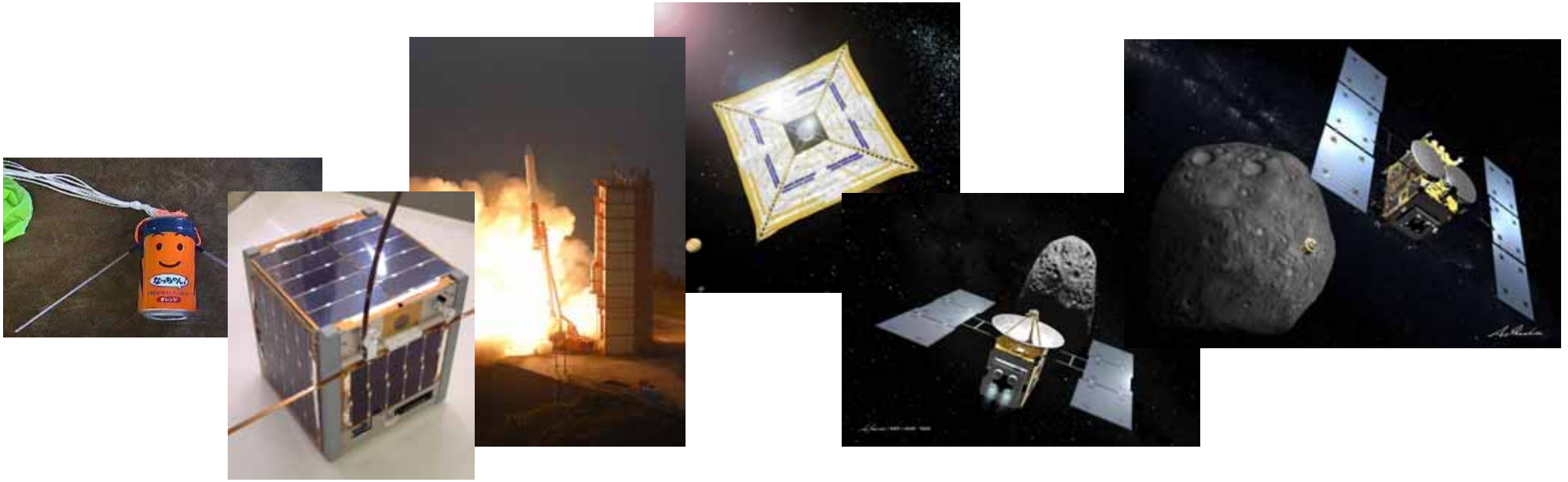
Yuichi Tsuda

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）

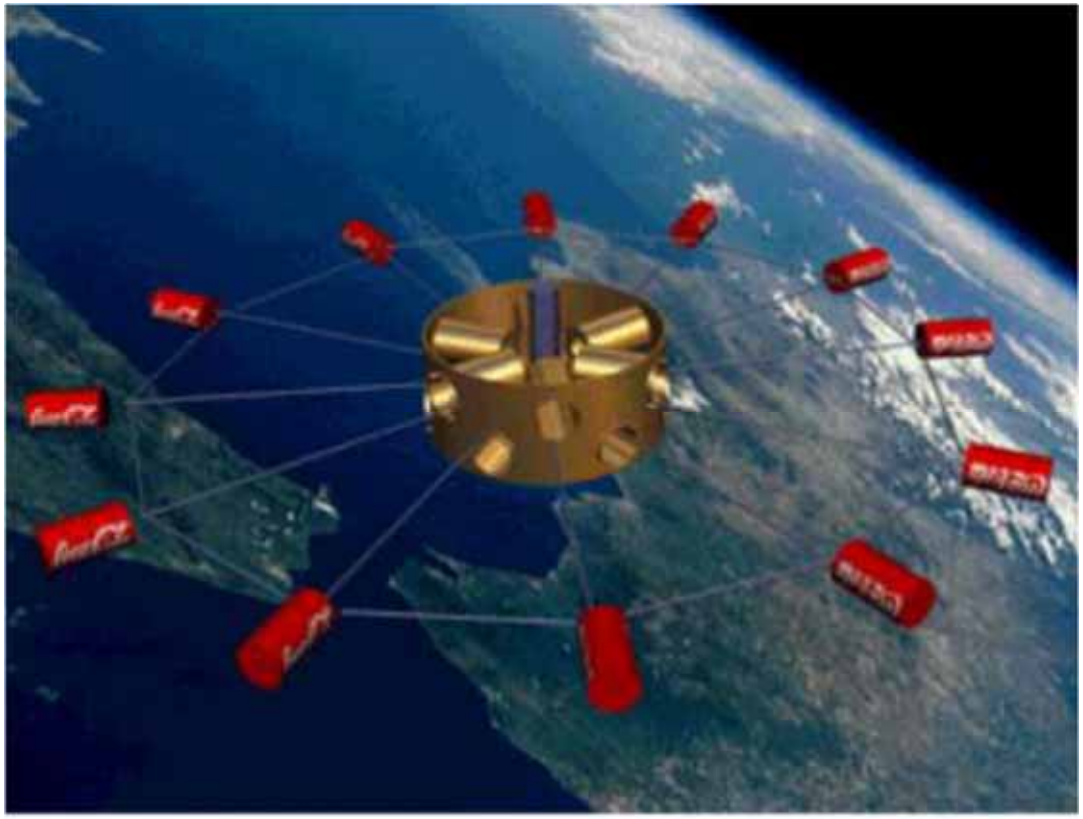
In 1998 when I was a student in Prof. Nakasuka's lab,

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

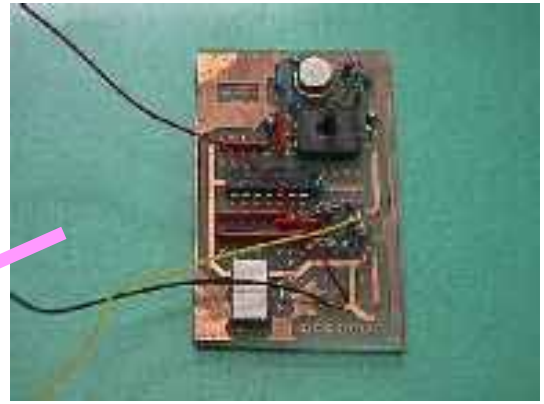
First work

Main Board

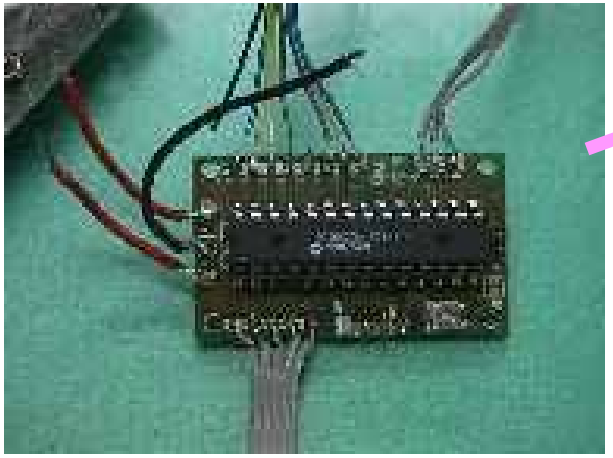
Parachute

Battery

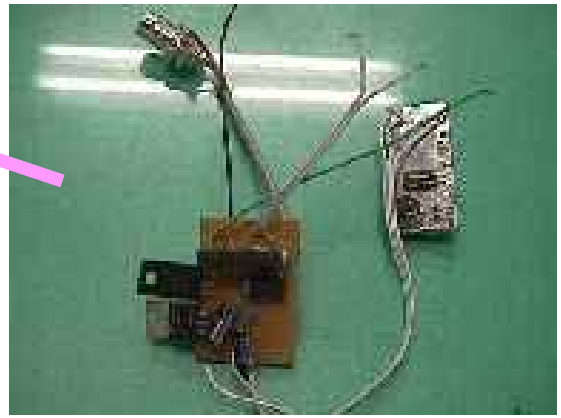
350ml Juice Can



Sensors Board



Com encoder (TNC)



Transmitter

Antenna

1st Generation “CanSats”

Pre-final model

Flight model of CanSat #003

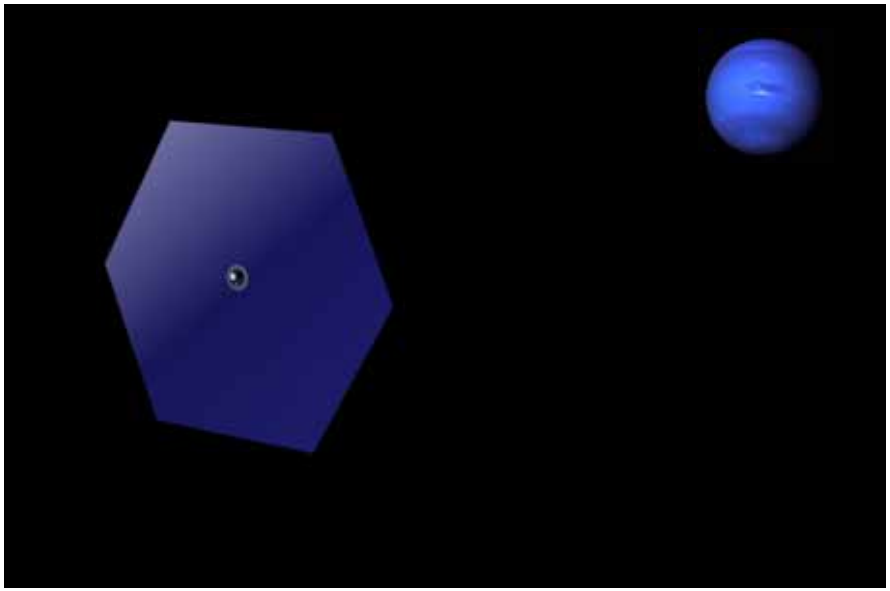
Three 1st generation CanSats developed by U of Tokyo.

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 = ?



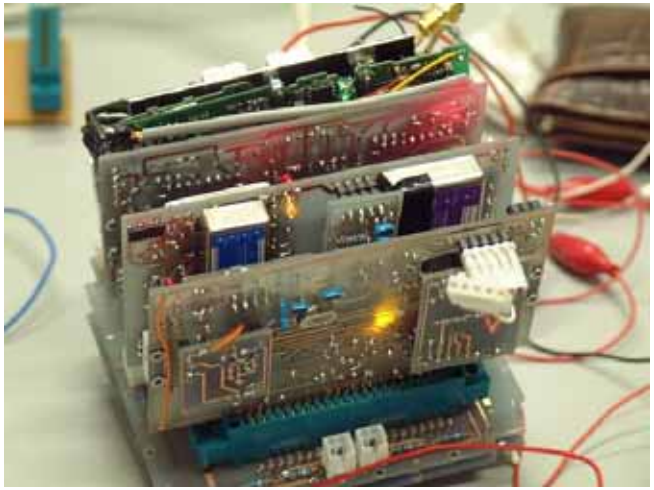
Ref. Tsuda, Nakasuka, Aoki, Nagashima,
Space Transportation Symposium, 1999

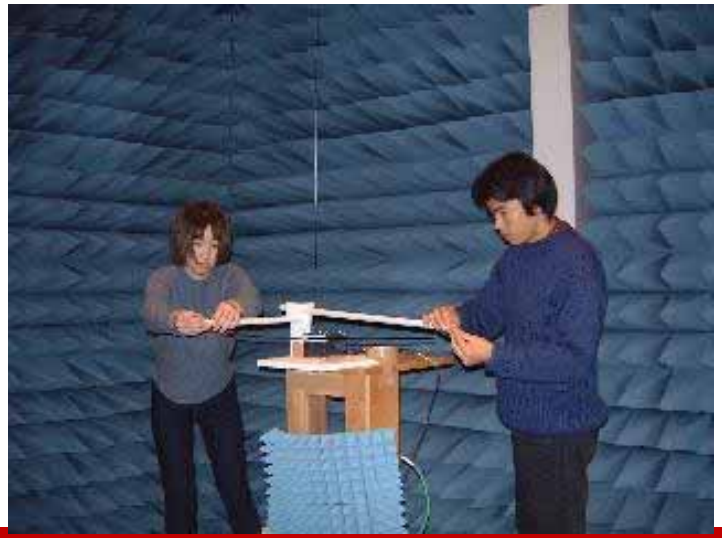
1998 Pluto explorer concept with 200m-diameter thin flexible solar cells. How to fold it? "*Tsuda-folding*"

1999 We proposed "CubeSat + Space Membrane" concept, but finally resulted in...

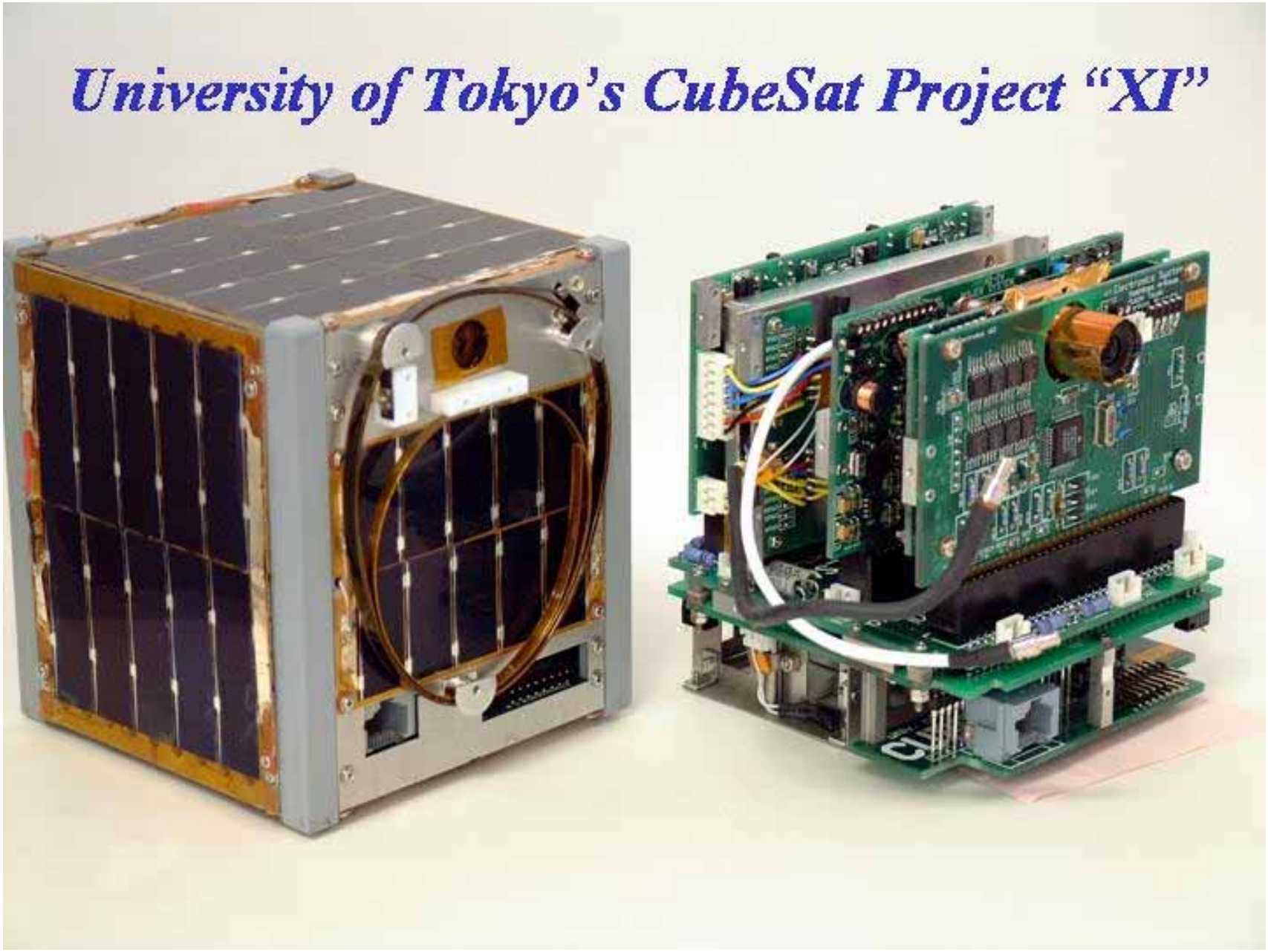
Textbook does not teach us.

The unexplored world should be pioneered by ourselves!





World First CubeSat “XI-IV”

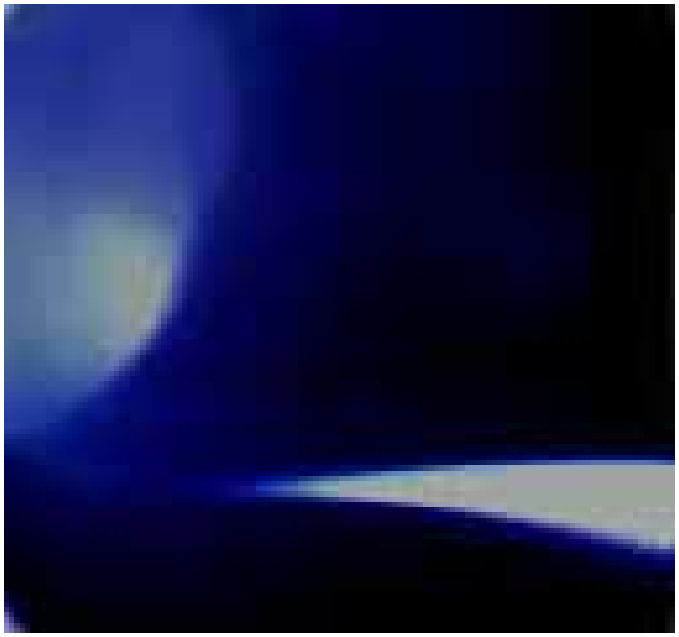


2003/06/30 18:15:26 (local time)

XI-IV was Launched!!!

CubeSat XI-IV Photo Gallery

July – November 2003, University of Tokyo ISSL



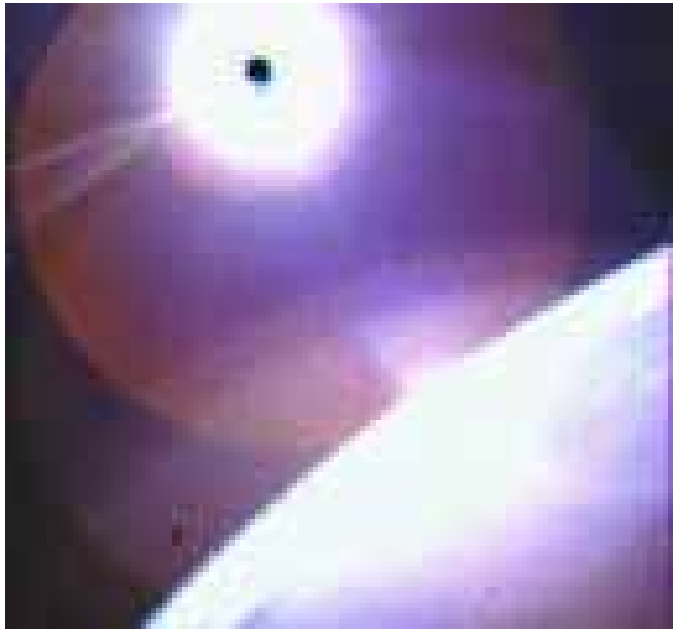
7.30 South Atlantic

9.14 Azores Islands

9.17 East Timor

10.5 Bangladesh

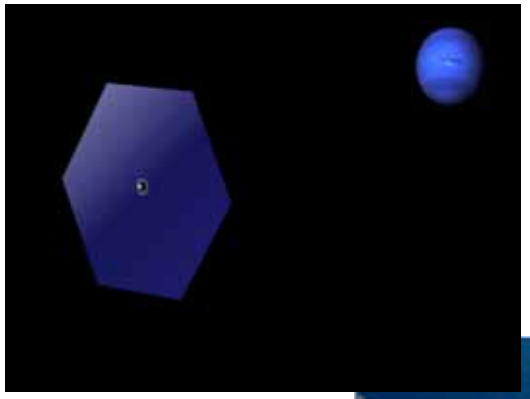
10.5 Tibet



11.03 Egypt

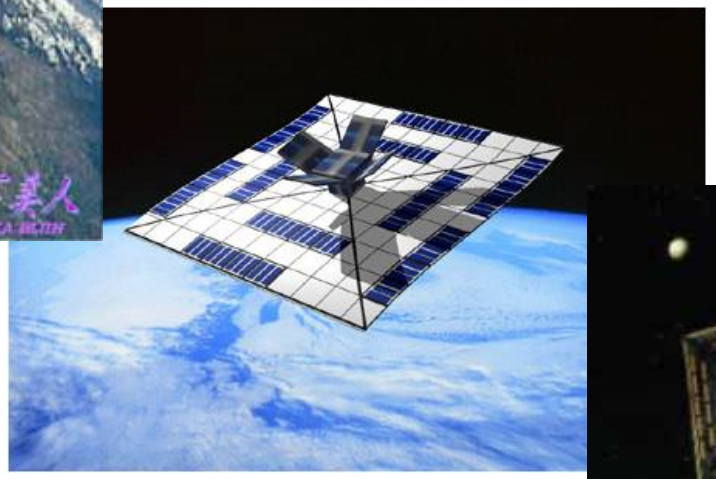
From CubeSats to Deep Space Exploration (2003～)

“Continuity” in my first 10 years of carrier

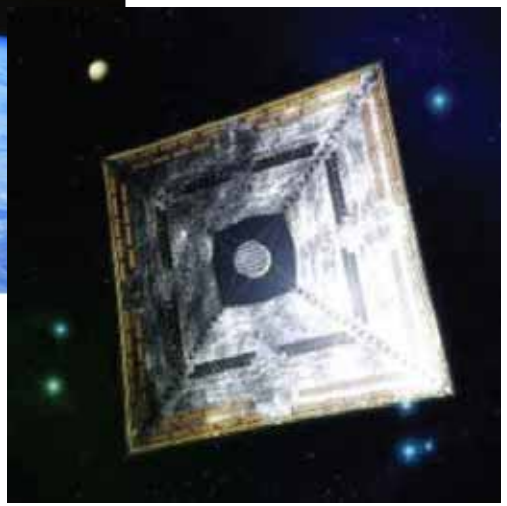


1998
Pluto explorer using space membrane technology
(Concept study)

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



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



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

Tiny (and maybe stupid) Membrane Deployment Experiment

Deployment experiment for CanSat (1999)

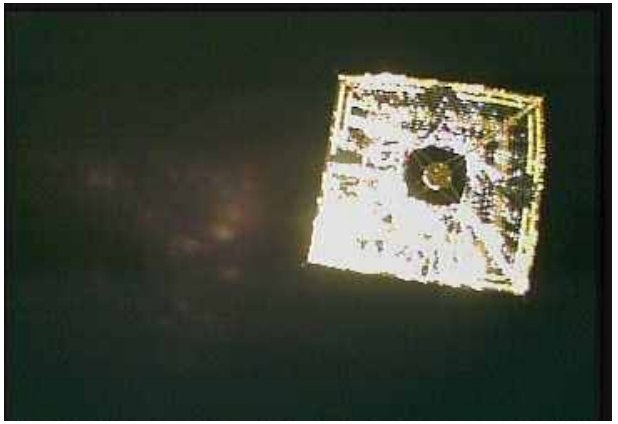
Deployment experiment for CubeSat (2000)

..But I didn't stop sticking to Membrane

2002
Vacuum Chamber Drop Test(D=2m)

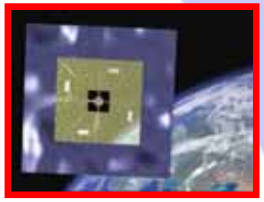
2003
Balloon Drop Test (D=4m)

2003-2004
Spin Table Test (D=2.5m)



2010
Deep Space Spacecraft IKAROS (D=20m)

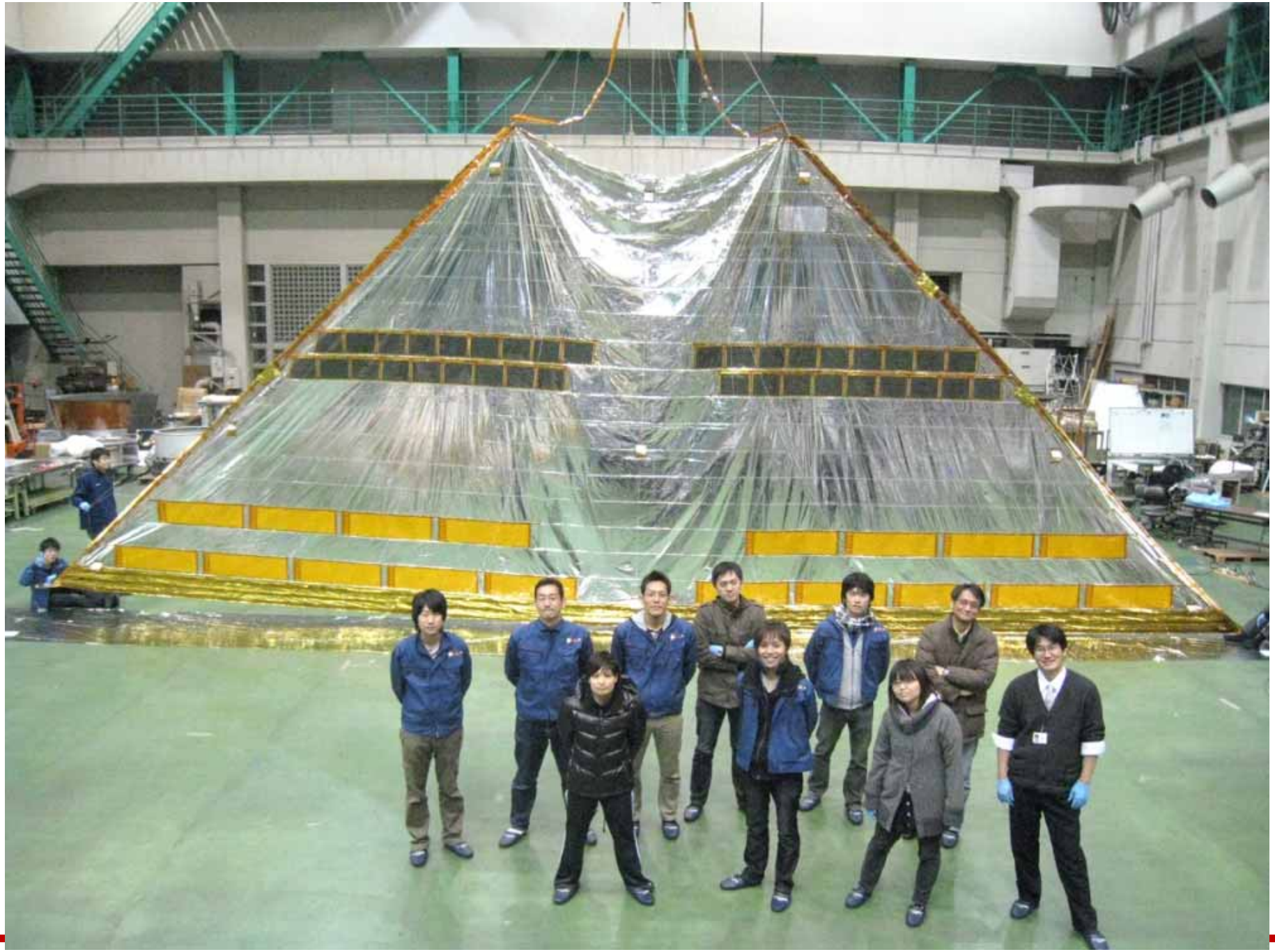
2004
Sounding Rocket Zero-gravity flight (D=10m)



2006
Small Sat Demonstration SSSAT (D=2.7m)

2006
Balloon Test (D=20m)

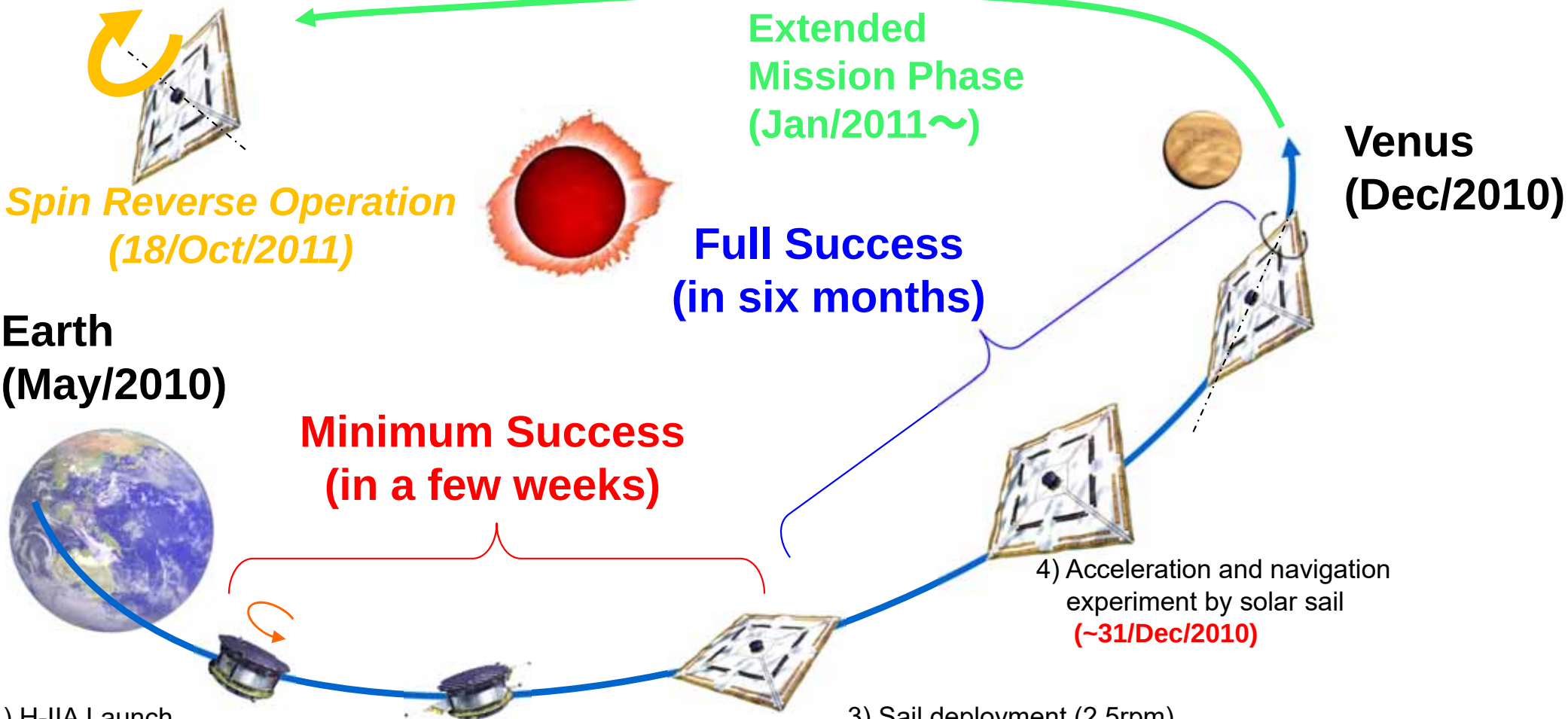
IKAROS sail was completed!



1, 2, 3, Fold!

IKAROS is ready to launch!

Mission Sequence of IKAROS



Japan's "Deep Space Month" !

June 13, 2010, JAXA Sagamihara Space Operation Center

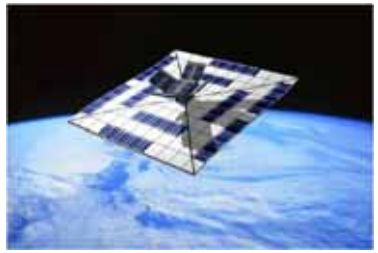
Three mission teams at once. ("Hayabusa", "IKAROS" and Venus Explorer "Akatsuki")

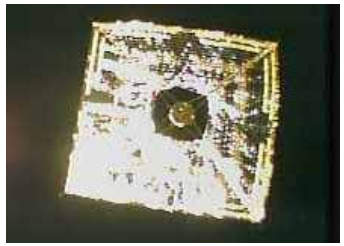
Succeeded in Solar Sail Deployment!

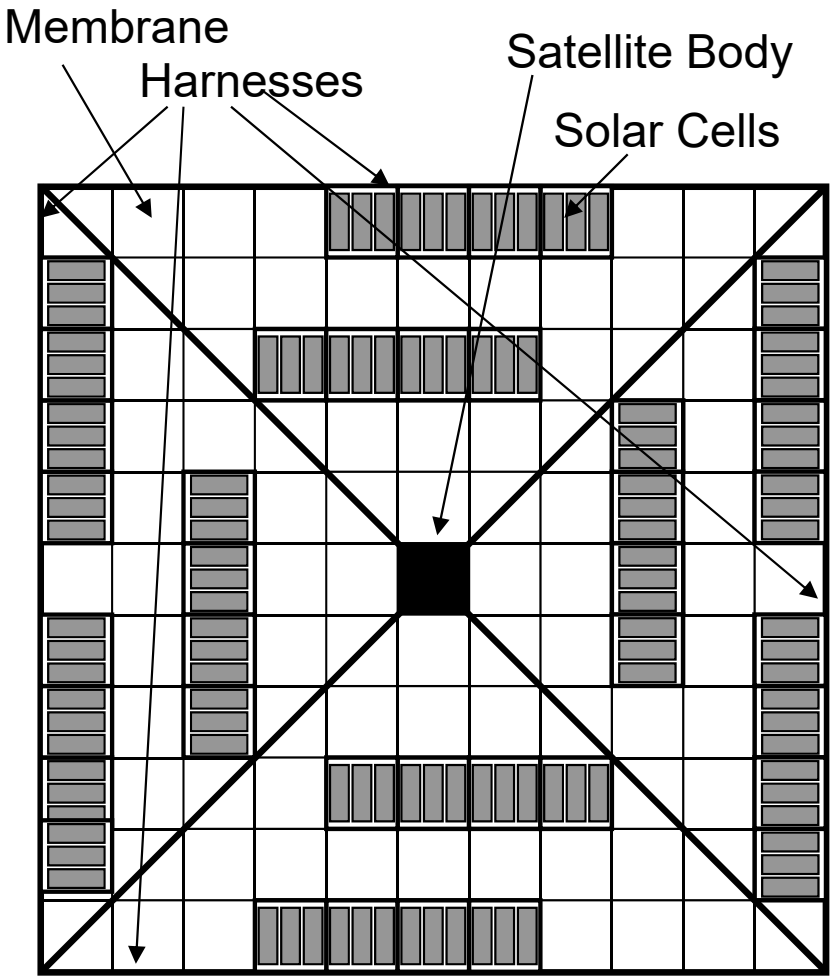
June 14, 2010, Images taken by DCAM ← *Another CanSat!*

DCAM

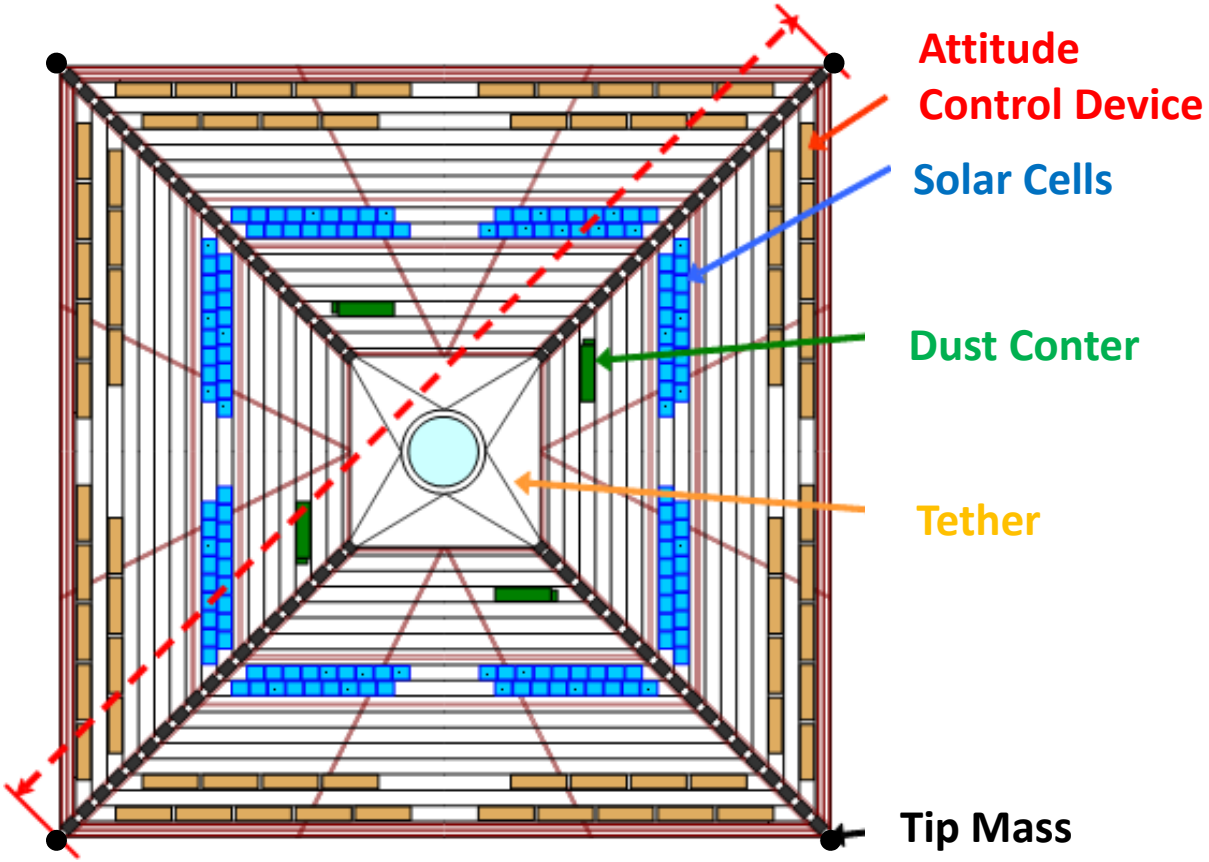
10-year journey was not in vain.







88cm×88cm



14m×14m

My experience as Mission Designer

Impact of CubeSat & IKAROS

CubeSat

Impact：

- **Started from a small laboratory**
- **“Nano satellite” concept was born through CubeSat.**
- **Nowadays many colleges, high schools, industries and governments all over the world involved in the CubeSats**

IKAROS

Impact

- **Realization of the 100-year dream of mankind: “solar sail technology”.**
- **Very competitive research area, won by 15 million-dollar tiny mission.**
- **Solar sail textbooks always refer to IKAROS!**

CubeSat has opened up the nano/pico-satellite world.
IKAROS has opened up the new world of space exploration.
CanSat has opened up the new educational world!

Success tips: *Small satellite style*

- **Team with good visibility, quick decision**
  - Keep the team compact
  - Keep the team flat
- **Use and pull out your ability right**
  - Create the team directly connected to things/products.
  - Clearly identify when you should/should not challenge.
- **Quick & multiple-cycle PDCA with solid engineering management**
  - To fail is the best way to learn. Many PDCA cycles provide you many “fail” opportunity - for success in the end!
  - “Test as you fly, fly as you test” is even critical for smaller, lower-cost, more challenging missions.

“Guiding Principles for UNISEC-Global”

http://www.unisec-global.org/guidingprinciples.html

Guiding Principles for UNISEC-Global

January 26, 2018

<Technology and Procedure>

1. Be honest regarding project feasibility – openly recognize the technology and schedule risks that may impact success.
2. Build a system that can work as designed in an environment where subsequent fixing is impossible.
3. Only when you did your best to succeed, you could learn something even if you failed.
4. Remember that there are rules that you must follow - from the Outer Space Treaty to through internal rules in your project.

<Management>

5. Refer to the achievements of others in the past and build your own achievement on that background.
6. Setup appropriate and realistic targets considering your capability and capacity
7. Recognize the pressure in other team members working to demanding deadlines on challenging projects; support and help reduce their stress wherever possible.
8. Evaluate your results realistically and reflect them to your subsequent activities.

<Fundamental spirit>

9. Use imaginative and innovative ways of achieving the maximum result using available personnel, technical and financial capabilities even if they are limited.
10. Identify and work with your rivals and compete to stimulate innovation & mutual growth. Recognize other people's successes and use these to stimulate yourself further.
11. Respect a spirit of mutual assistance. Seek ways to contribute to others, not only seeking help for yourself.
12. Be careful not to be misled by the "bewitching nature and allure of space" or by flattering words. Be modest, constructively critical and sincere.

My Comrades since CanSat and CubeSat

■Hayabusa mission (asteroid sample return tech-demo spacecraft)

- Many students/staffs were CanSat/CubeSat-experienced persons.
- Contributed to touchdown operation, and saving the missing spacecraft.

■IKAROS mission (deep space solar sail demonstrator)

- Key development members were all from CanSat/CubeSat.
- Collaborating with many UNISEC-member universities.
- Contributed to perfect success in sail deployment and interplanetary cruise.

■Hayabusa2 Mission (asteroid sample return spacecraft)

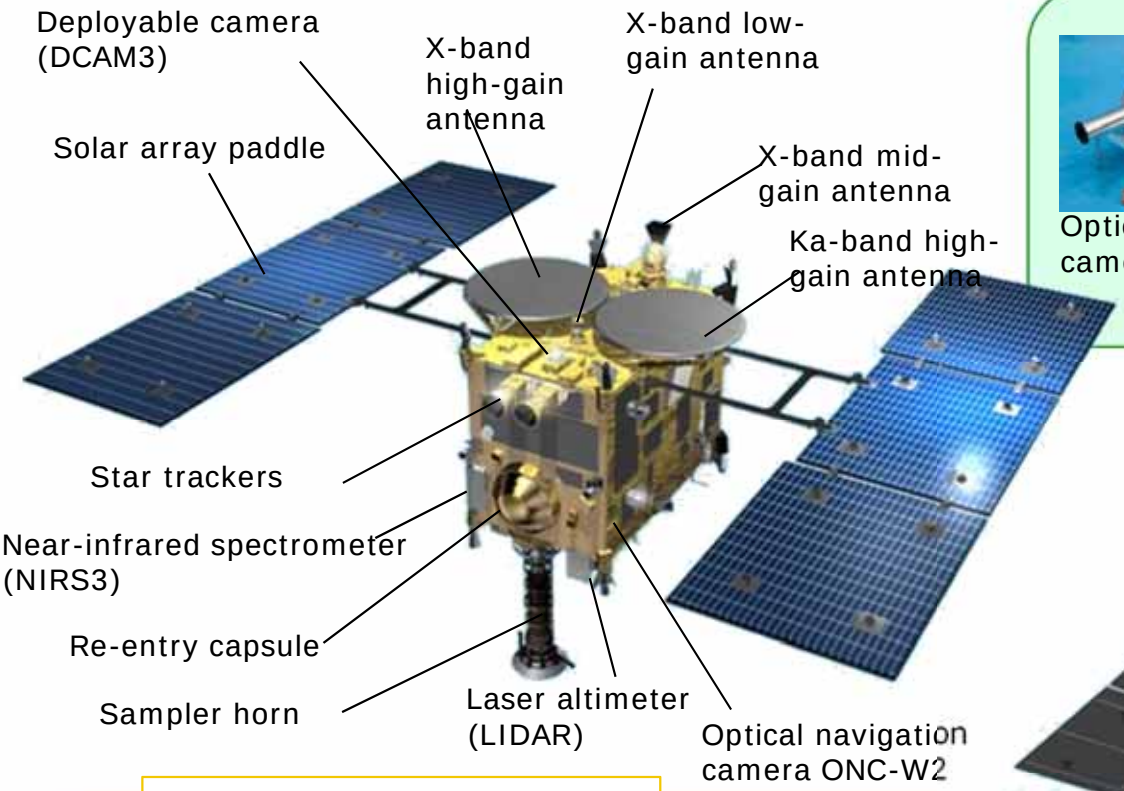
- Many managers in the development sub-teams were from CanSat/CubeSat, including project manager (me).
- CanSat/CubeSat members guided the project to the extraordinary success in unexplored asteroid “Ryugu”.
- Compilation of our “*Small satellite style*” management.

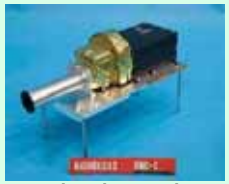
My comrades, my style as an engineer, my journey as a deep space explorer were originated from CanSat and CubeSat.

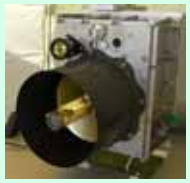

Mission structure
Thermal, Attitude Control
Mission Electronics
Project manager
Deputy Manager

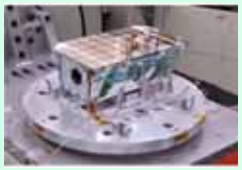
Toward Hayabusa2

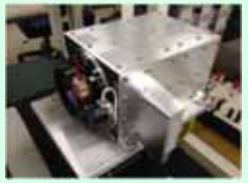
Hayabusa2 spacecraft



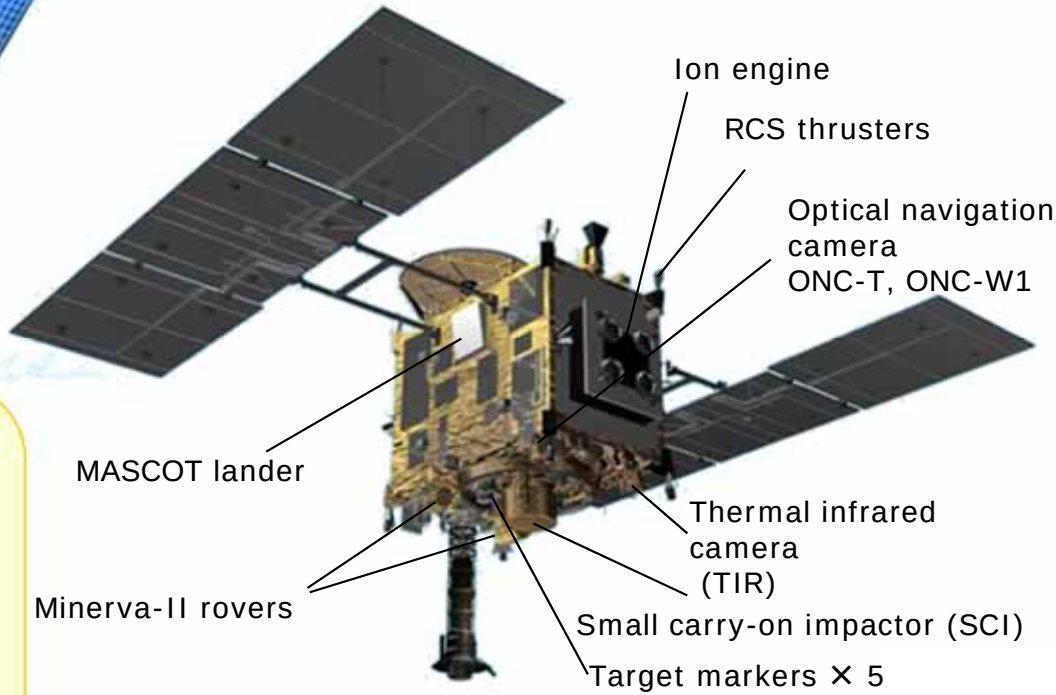

Optical navigation camera, ONC-T


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)

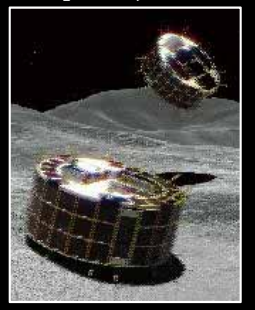
Hayabusa2 Mission History

Launch
Dec.3, 2014

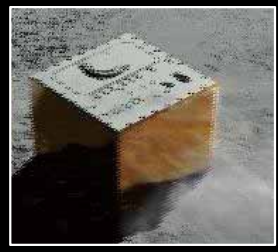
Earth Gravity Assist
Dec.3, 2015

Ryugu Arrival
Jun.27, 2018

MINERVA-II-1 Deployment
Sep.21, 2018



MASCOT Deployment
Oct.3, 2018



Only 400 million km to Earth return!

First Touchdown
Feb.22, 2019

Kinetic Impact
Apr.5, 2019

Second Touchdown
Jul,11, 2019

Target Markers Orbiting
Sep.16, 2019

Ryugu Departure
Nov.13.2019

MINERVA-II-2 Orbiting
Oct.2, 2019

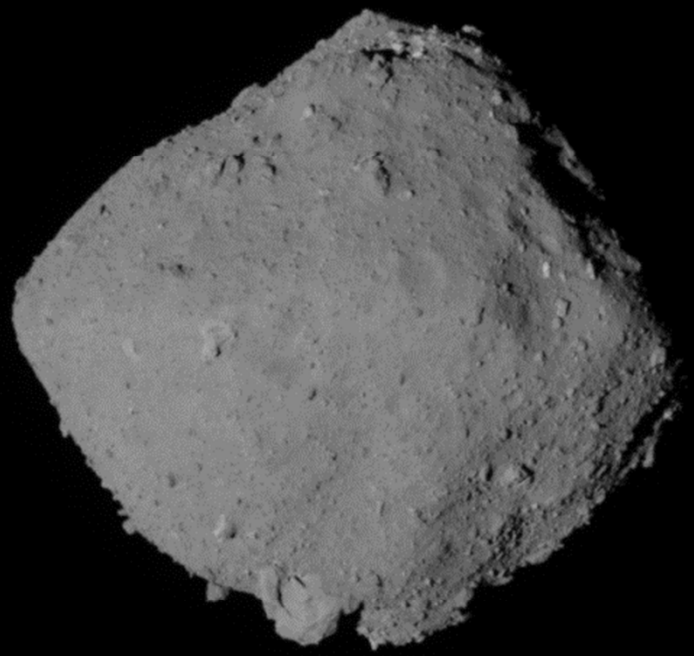
Earth Return
Nov.-Dec. 2020

We are here!

MD [D V|p srvlxp #534<#

C-type Asteroid “Ryugu”

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



HAYABUSA2 ONC-T TIME: UT 2018/07/10 06:05:08

Surface Exploration with 4 Robots

(Image credit：JAXA)

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


(Image credit：MASCOT/DLR/JAXA)

MASCOT
by DLR/CNES

Sep, 21, 2018

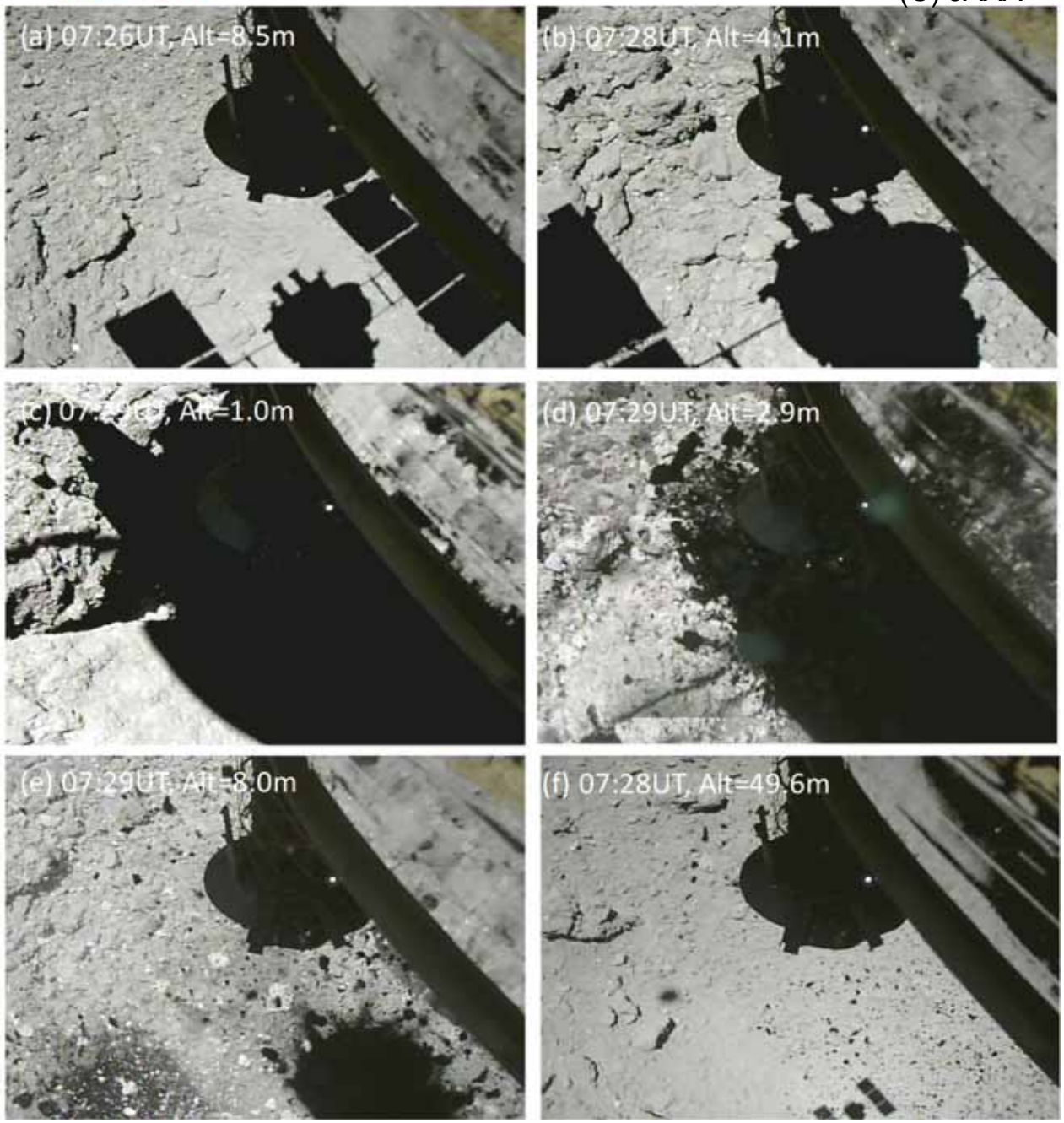
Oct. 5, 2018

(Image credit：**東北大**, JAXA)

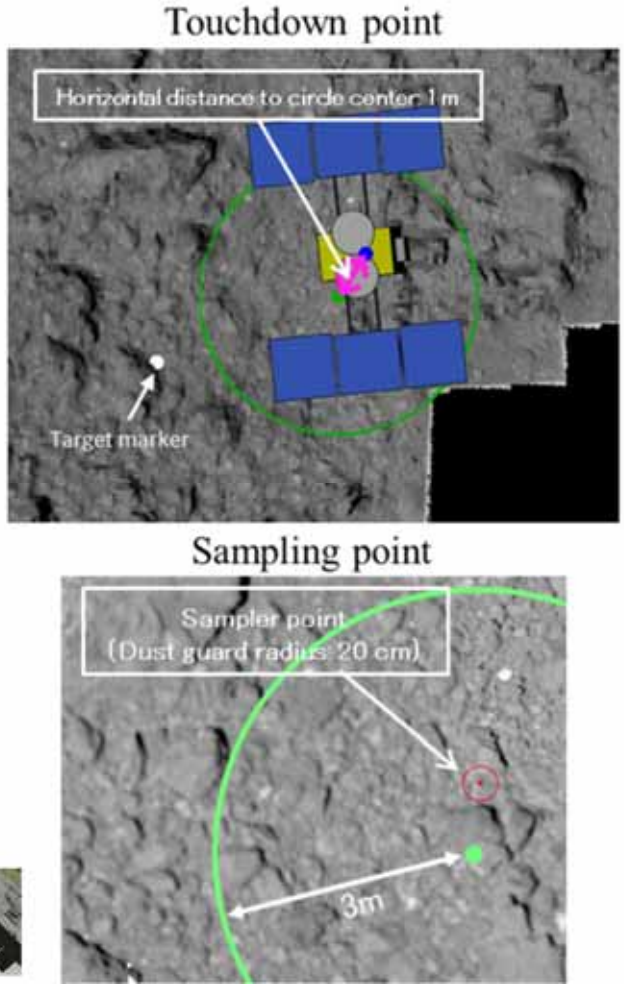
MINERVA-II-2
by U of Tohoku and
University consortium
（nickname: Ulula)

Oct. 2, 2019

Touchdown #1 Result

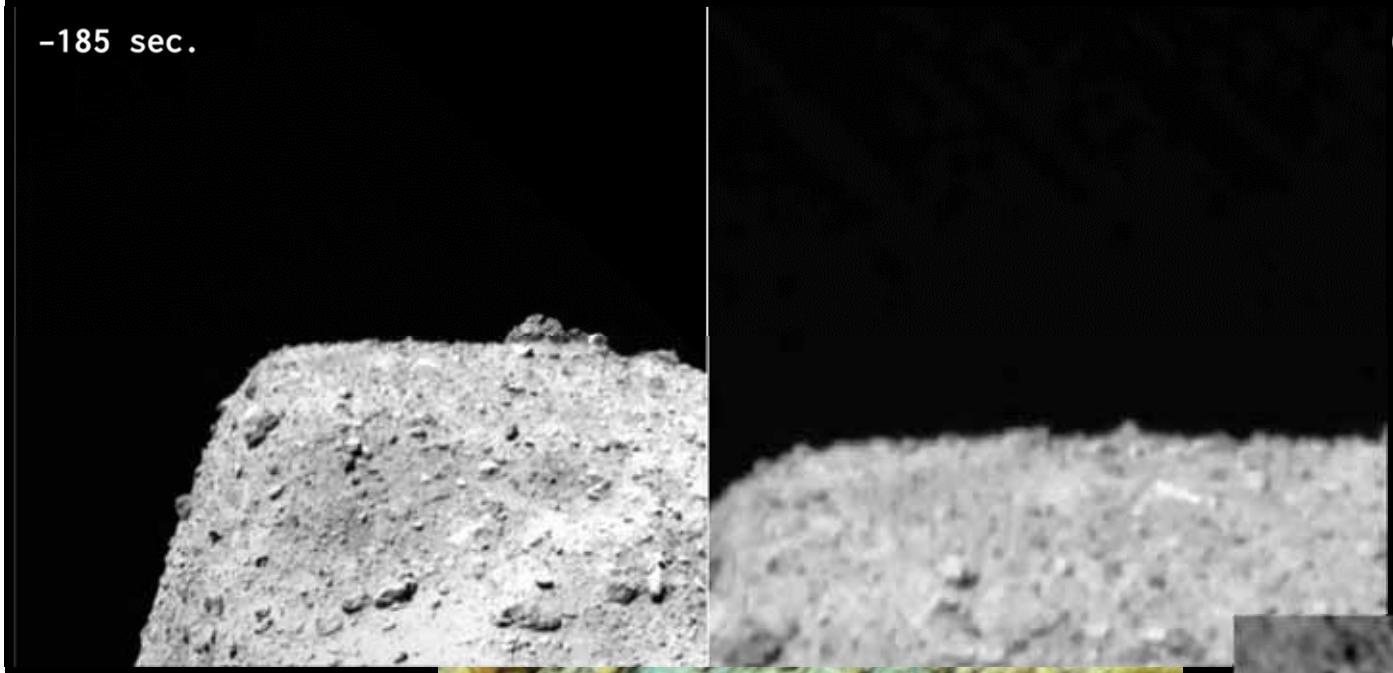


- All sequences went normally.
- 1m accuracy landing achieved.
- Many fragments observed!

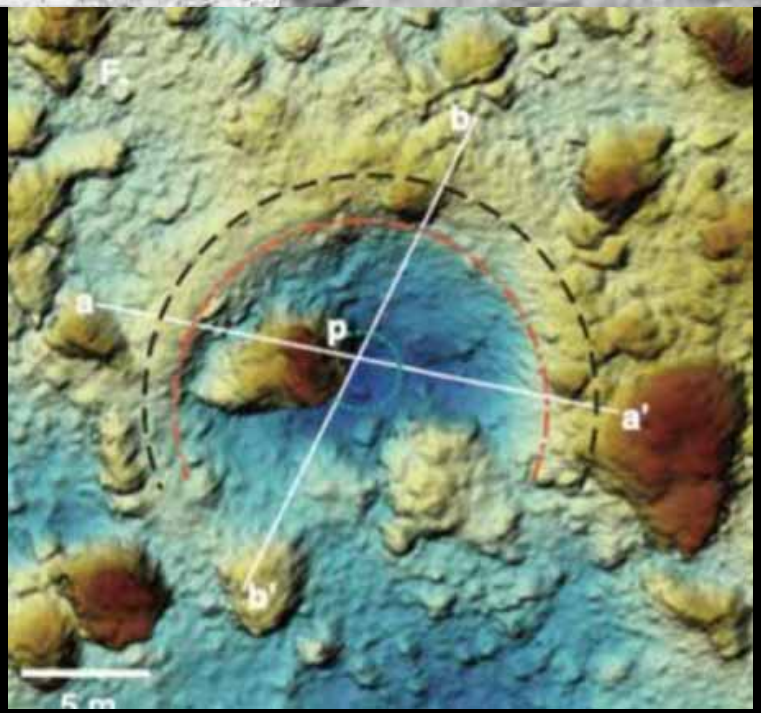


Kinetic Impact Result

April, 5, 2019

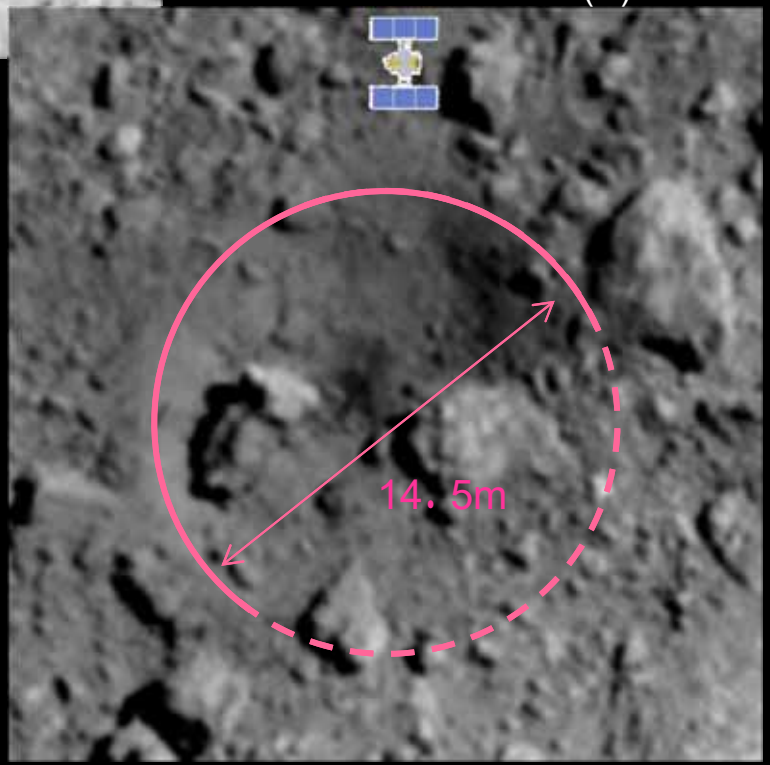


(C) JAXA

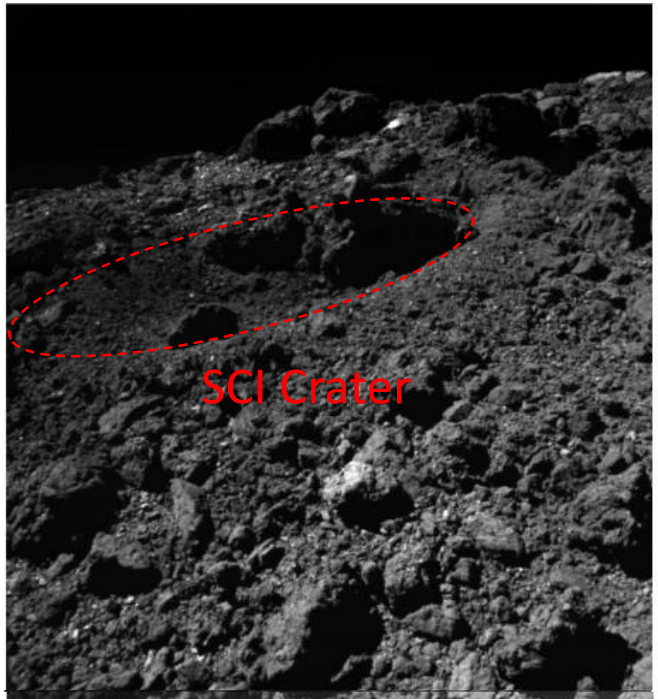


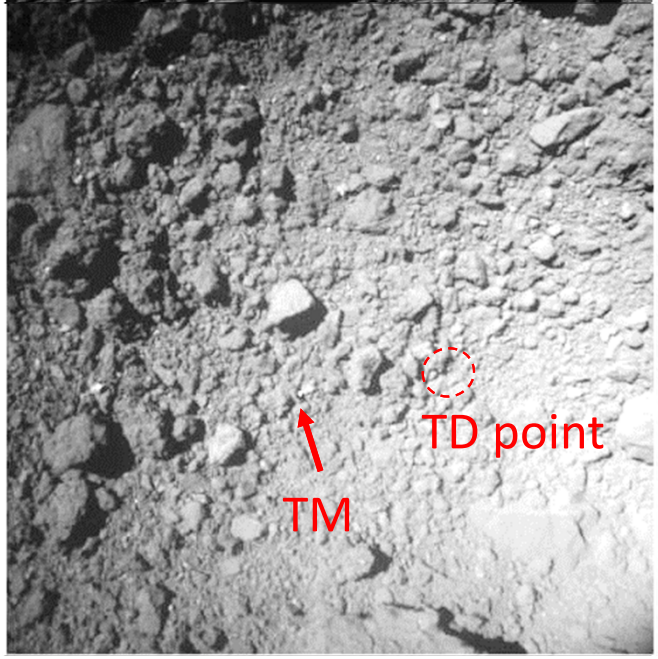
Arakawa et al., 2020

(C) JAXA



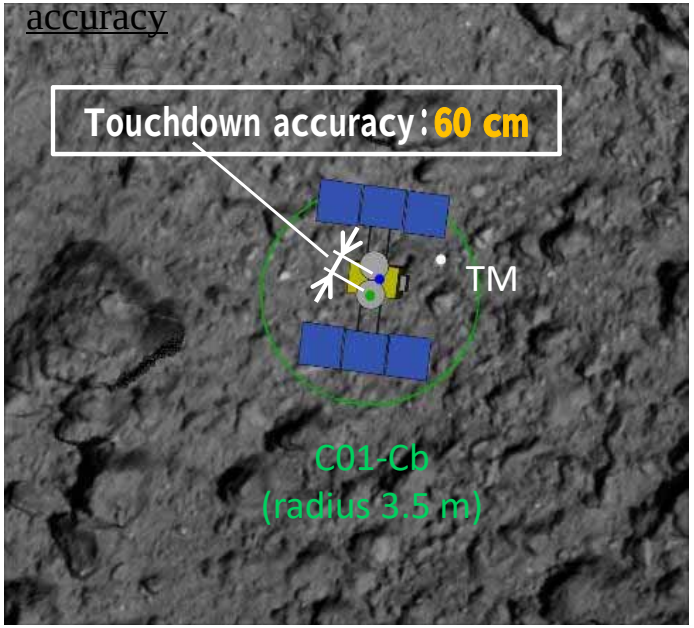
Touchdown #2 (PPTD) Operation Result



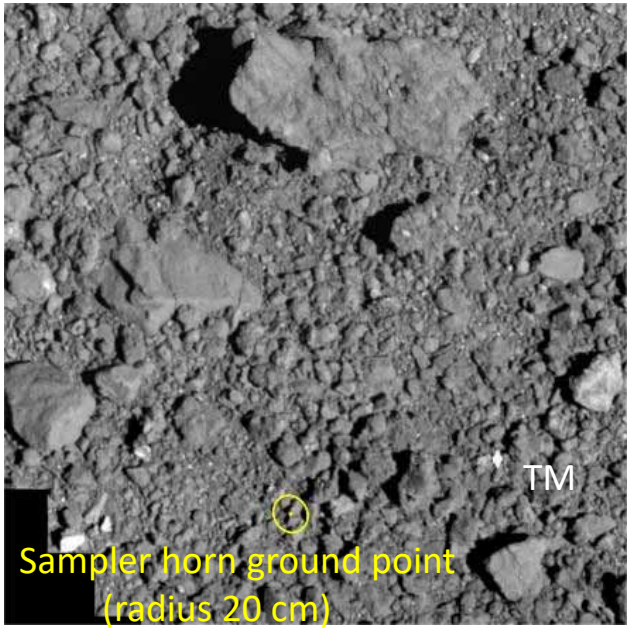


- All the sequence went normally.
- Landing accuracy was 60cm!
- Many fragments observed again.

2nd touchdown accuracy



Sampler horn ground point




◆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


May CanSat/CubeSat push the boundary of the space exploration further!
Thank you for your attention.