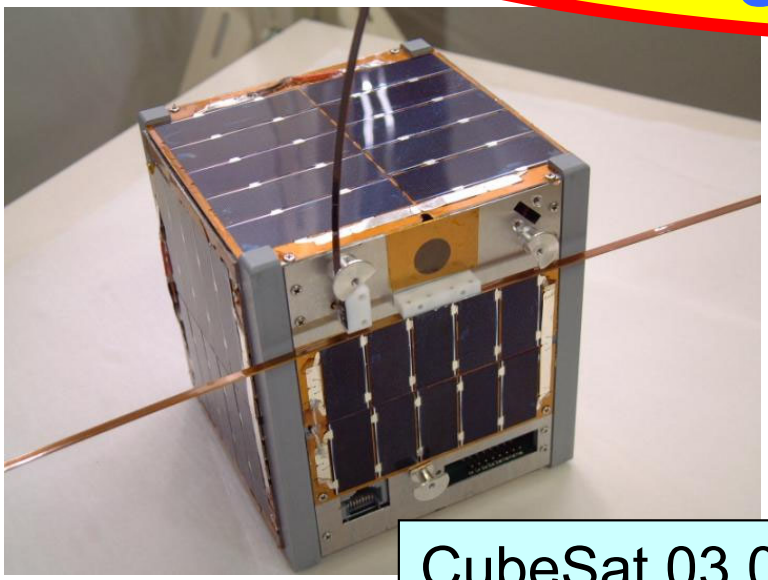
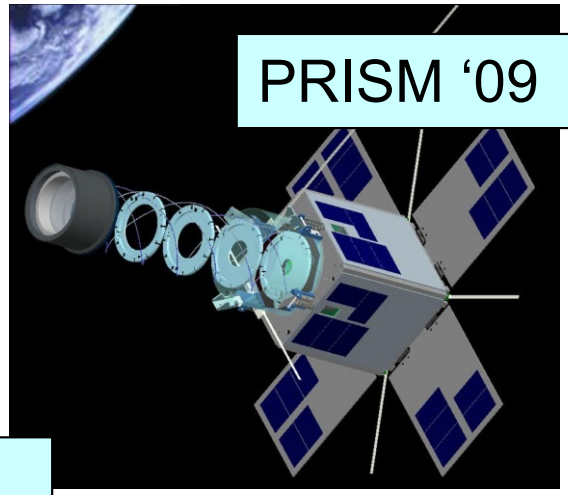
UNISEC History and Future

- Plenary Talk at 10th UNISEC-GLOBAL Meeting -

Shinichi Nakasuka
University of Tokyo





Contents

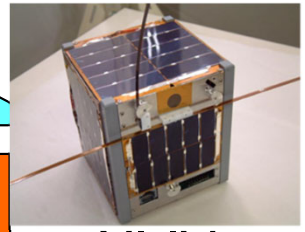
- History of Japanese University Practical Satellite Projects
  - Before Dawn of Japanese University Satellites
  - CanSat (1998～)
  - CubeSat（1999～）
  - Education Based on Satellites/CanSats
- History of UNISEC (2002～)
- Contributions to Space Industry
- 12 guiding principles of UNISEC

Before Dawn of Japanese University Satellites (～1998)

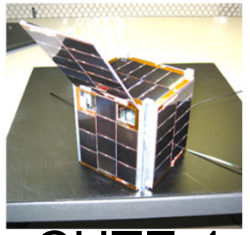
Initial Phase of Japanese History of University Micro/Nano Satellite Activities

Follow-on projects by many universities

1st launch of CubeSat (2003.6)



XI-IV
(Univ. Tokyo)



CUTE-1
(Titech)

2003 NPO Status

2002 UNISEC

2001 Pre-UNISEC

2000

1999

CubeSat(2000-): Real Pico-satellite to be launched to orbit

CanSat (1999-) : Sub-orbital(4km) experiment of quasi-real satellites. Real operation

1998

USSS (University Space Systems Symposium: 1998-)
Discussion on real space projects by Japan-US students

1993

Satellite Design Contest (1993-) : 1st step paper work training

Satellite Design Contest (1993～)

- Contest on mission ideas and satellite design for 50kg (or less) class satellites
  - "Mission Category" and "Design Category"
- Paper work: no real satellites were developed
- Evaluation was made by experts, not real world

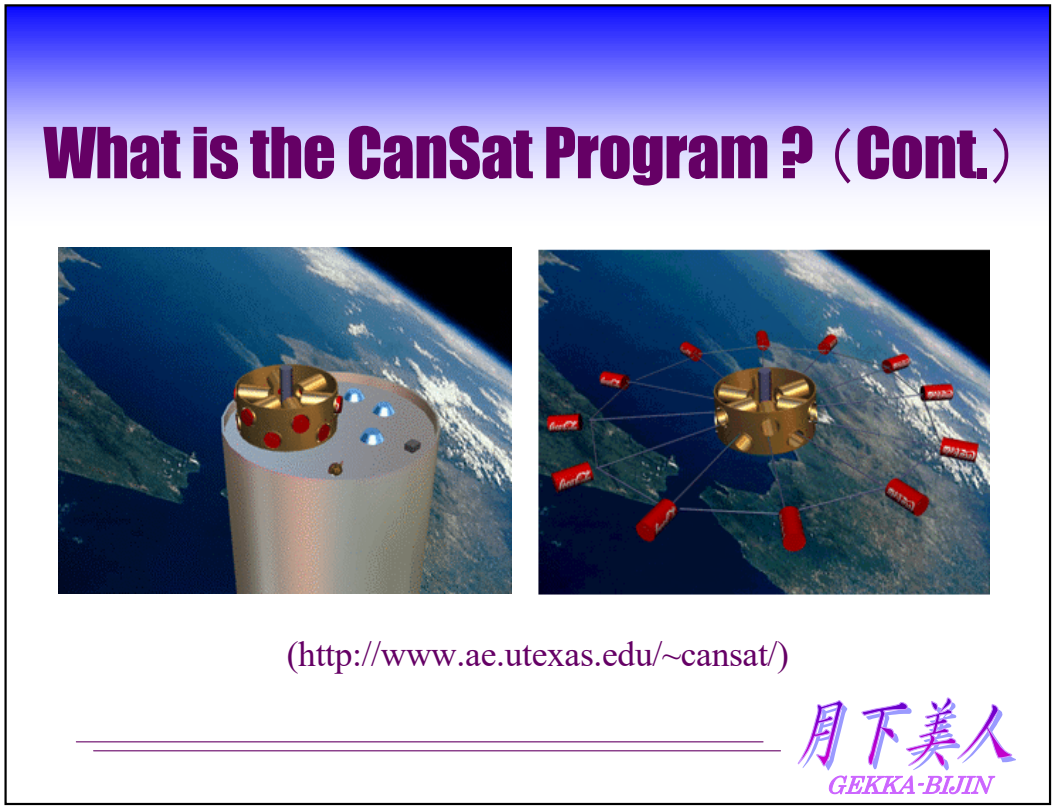
- However, students and professors worked very hard to create mission ideas and to design satellites.
- They could learn a lot knowledge and know-how towards actual satellite development
- Strong motivation came from "sense of rivalry" between universities
  - Tokyo Inst. of Tech.: 7 wins Tohoku Univ.: 6 Tokyo Univ.: 5

CanSat and CubeSat concepts were proposed in USSS

1998	Oahu	CanSat proposed
1999	Kauai	CubeSat proposed
2000	Big Island, Hiro	
2001	Big Island, Kona	
2002	Oahu	
2003	Oahu	
2004	Oahu	
2005	Oahu	

CanSat (1998～)

Birth of CanSat at 1st USSS 1998

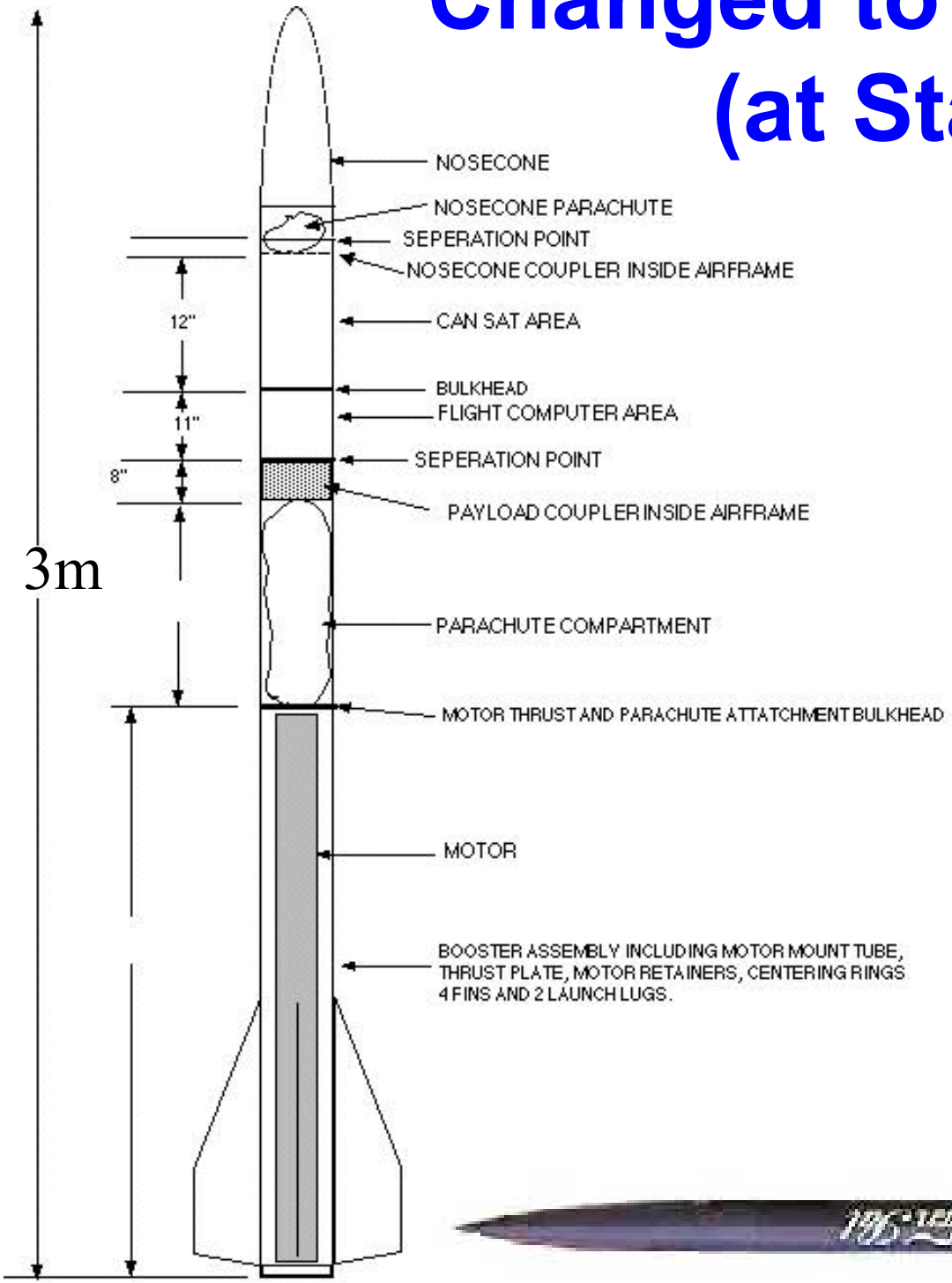


Initial Concept: launch all the CanSats and operate them in next USSS (one year later)

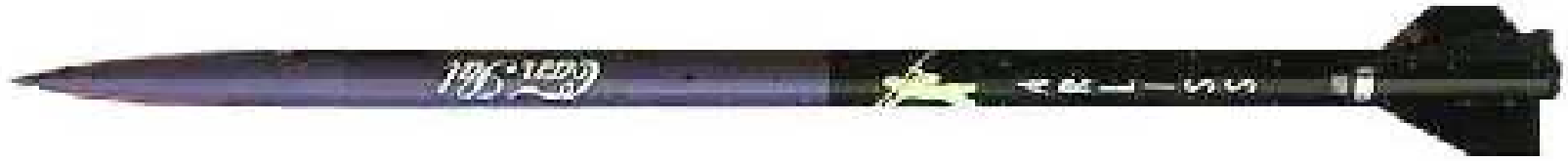
"Let's make a satellite out of this Coke-can !!"

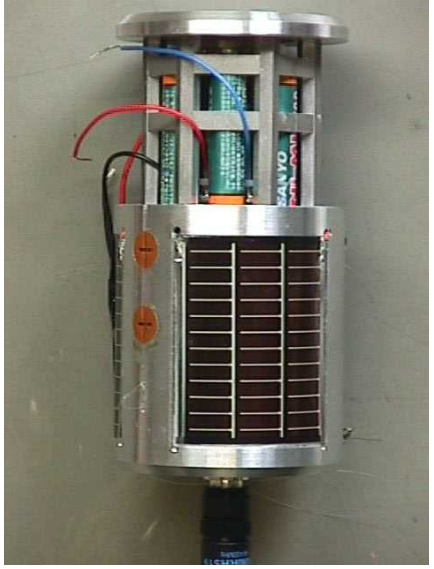
Prof. Bob Twiggs, Stanford University

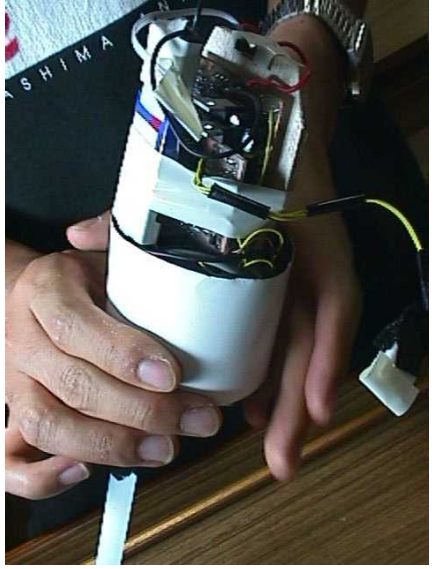
Changed to Suborbital Launch (at Stanford, April 1999)



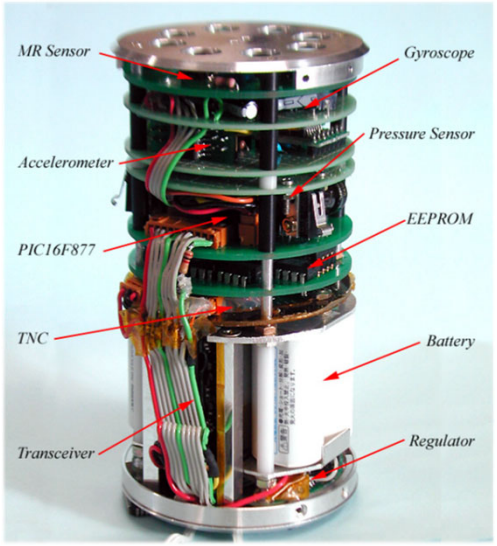
- AEROPAC Amateur Rocket group
- Lift 1.8 kg to 12000ft
- Three 350ml sized cans or one “Large sized can (open class)”
- One flight cost: $400
- at Black Rock Playa (Nevada, USA)







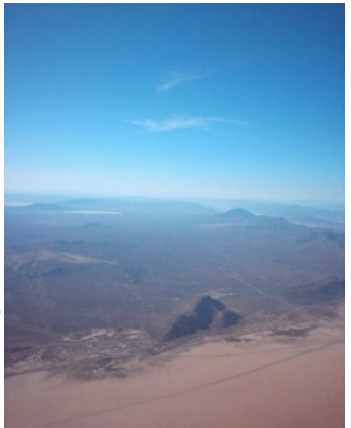
Initial Training for satellite development CanSats 1999 - now



ARLISS (A Rocket Launch for International Student Satellites)

- Annual suborbital launch experiment in USA -

- ARLISS 1999 : Sept. 11 (Japan:2, USA:2)
  - Univ.of Tokyo, Titech, Arizona State, etc.
- ARLISS 2000: July 28-29 (Japan:4, USA:3)
- ARLISS 2001: August 24-25 (Japan:5, USA:2)
- ARLISS 2002: August 2-3 (Japan:6, USA:3)
- ARLISS 2003: Sept.26-27 (Japan:6, USA:3)
- ARLISS 2004: Sept.24-25 (Japan:6, USA:3)
- ARLISS 2005: Sept.21-23 (Japan:7, USA:3)
- ARLISS 2006 Sept.20-22 (Japan:8 USA:3 Europe:1)
- ARLISS 2007 Sept.12-15 (Japan:10 USA:3 Korea:1)
- ARLISS 2008 Sept.15-20: 10th Memorial ARLISS !

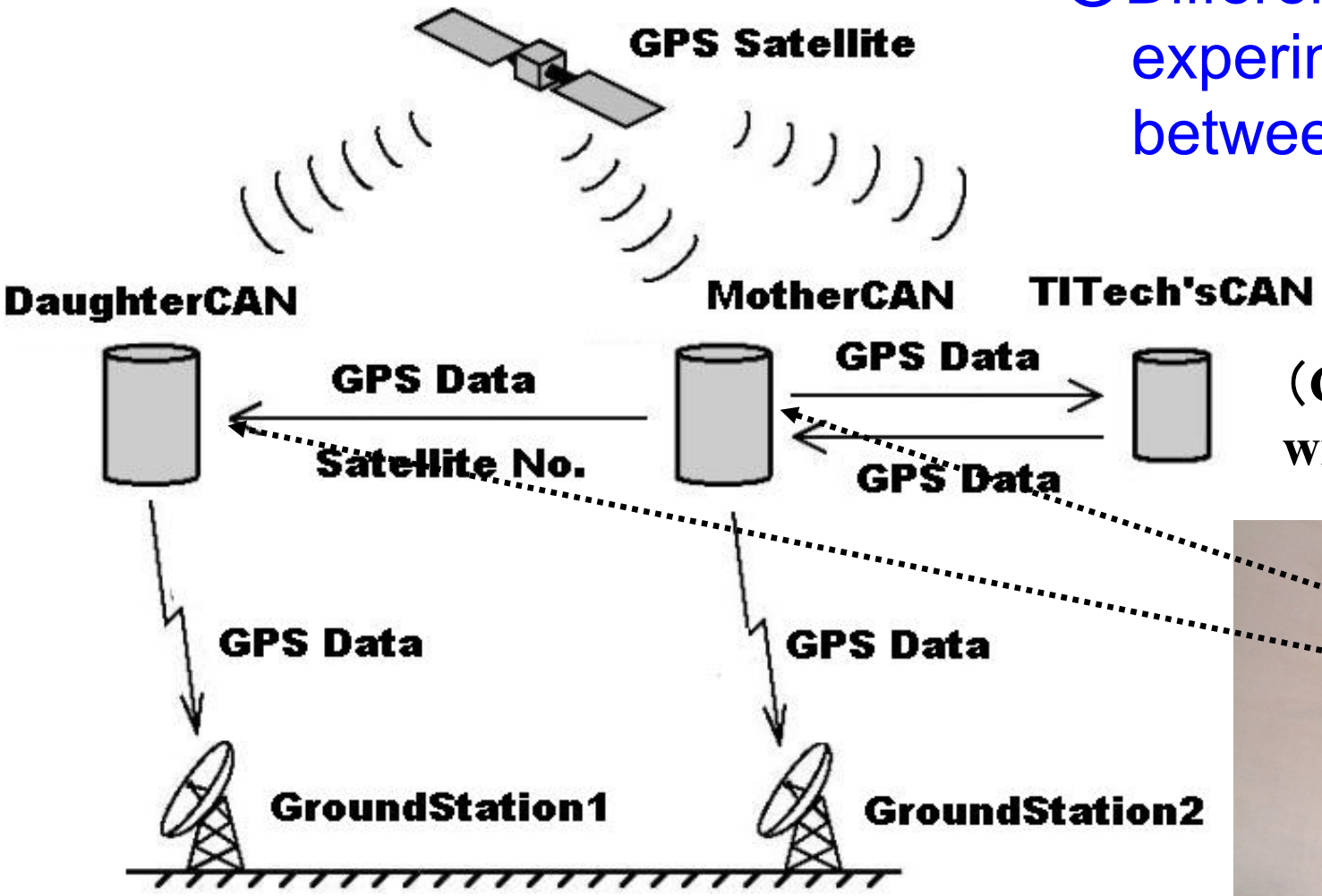


- ARLISS 2016 18th （Japan:12, USA:2, Korea, Egypt)
- ARLISS 2017 19th Sept.13-17 (Japan:13 USA:2 Kore
- ARLISS 2018 20th Memorial !! --- ARLISS 2024 24th

Example) DGPS Experiment (2000)

Pre-experiment for future Formation Flying in Space

- GPS measurement and downlink
- Differential GPS experiment by crosslink between three CanSats



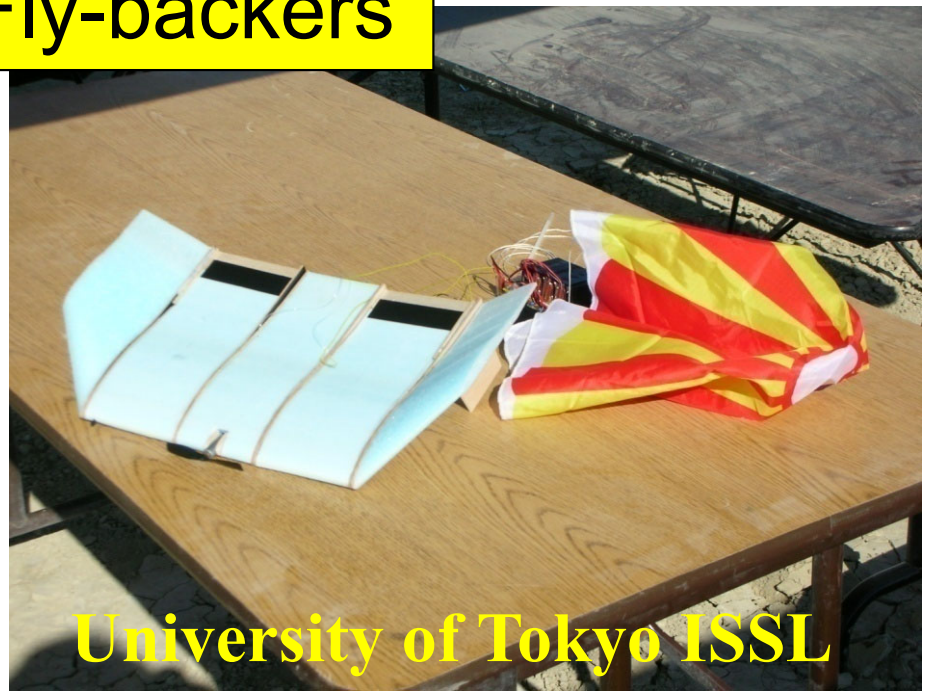
（Collaboration with Titech）

Opening Ceremony and Briefing (September 10, 2018)

More than 100 students participated in 20th anniversary

One Example: CanSat Comeback Competition

Fly-backers


University of Tokyo ISSL

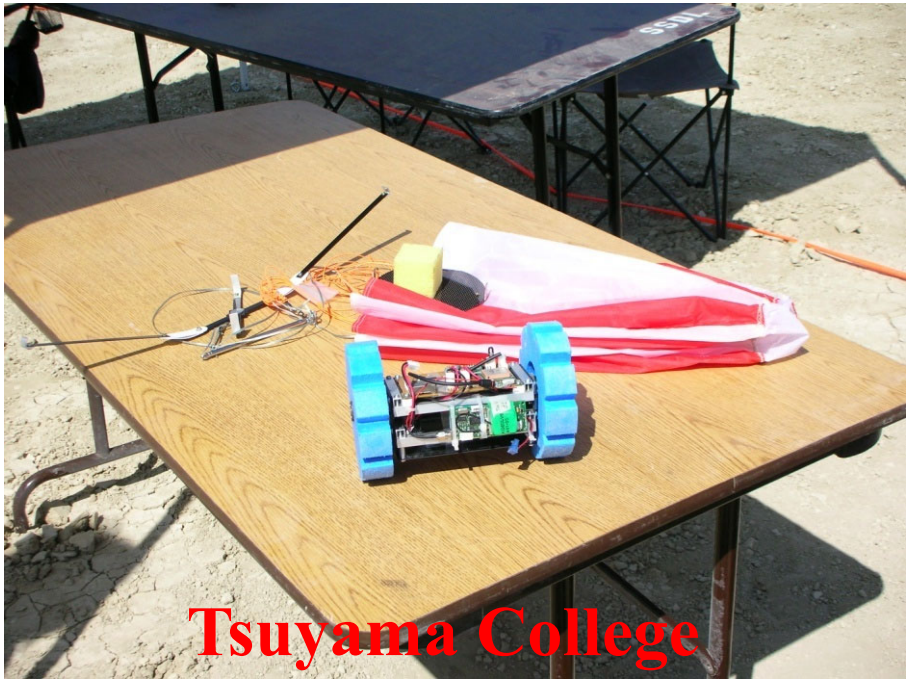

Titech Matunaga Lab B


Kyushu Tech. Cho Lab A

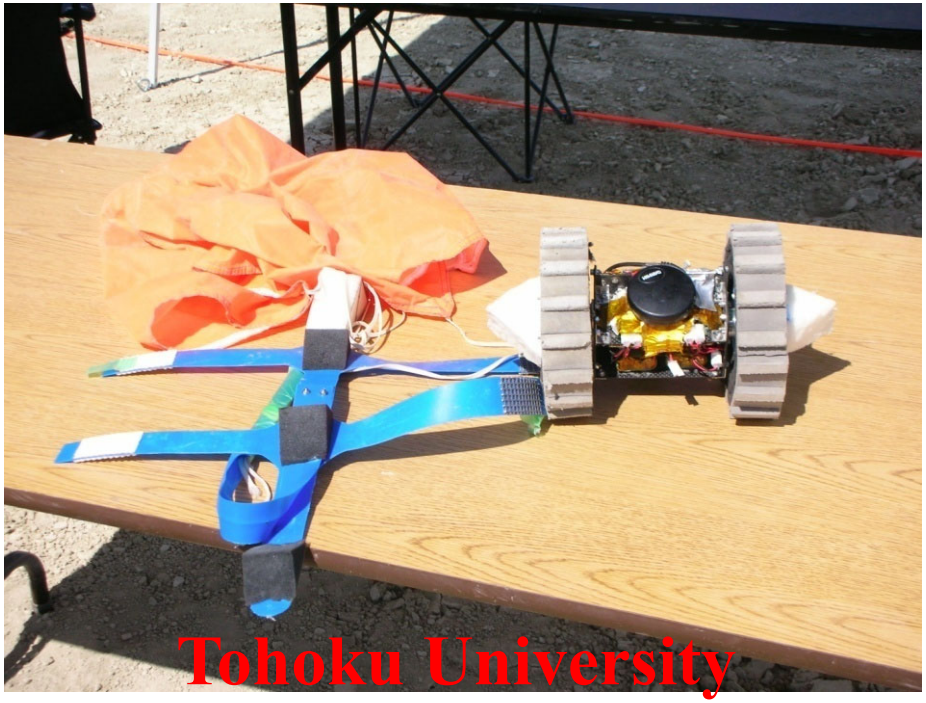

Kyushu Tech. Cho Lab B

Rovers

University of Tokyo B3

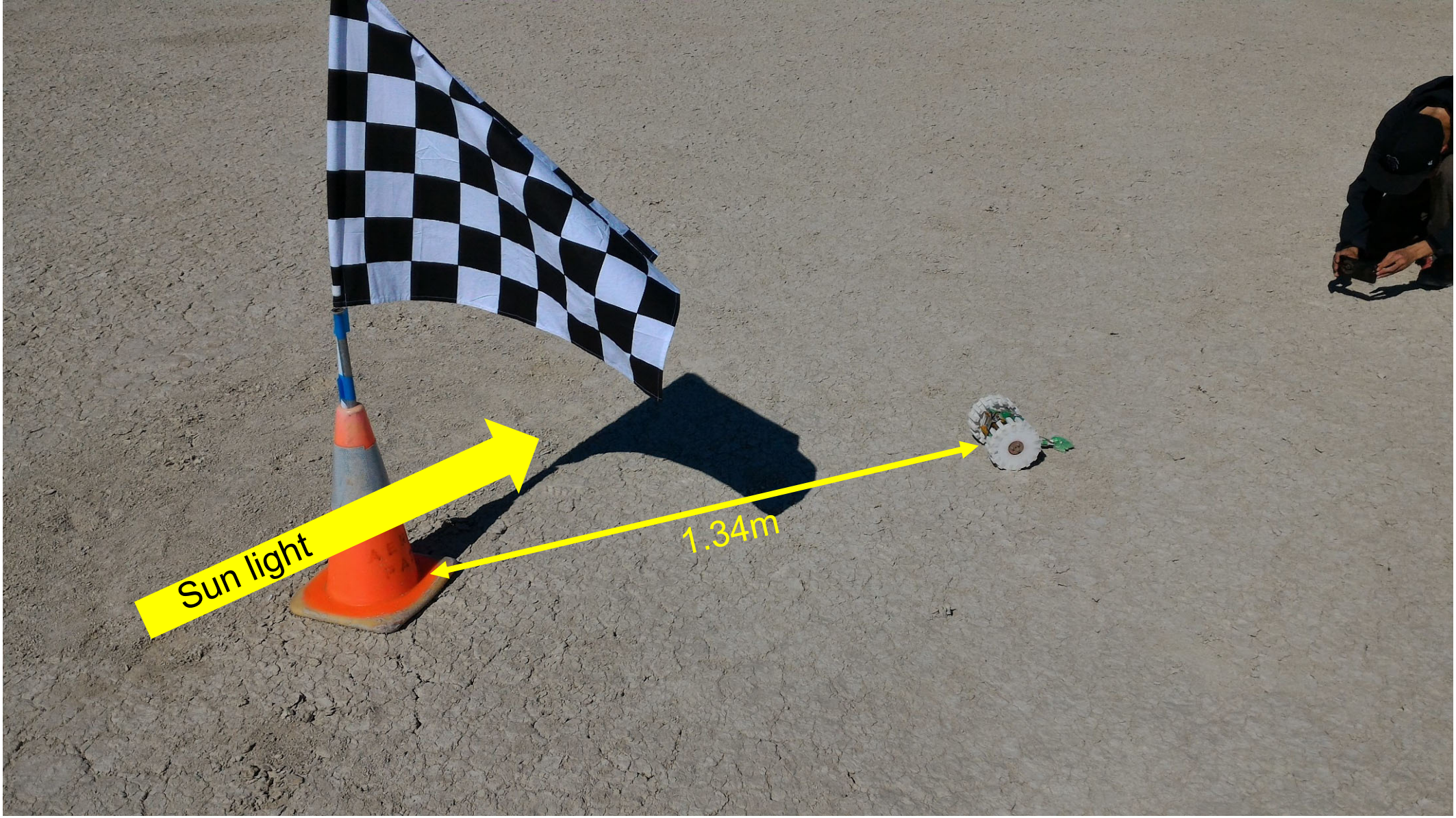


Tsuyama College



Tohoku University

Univ. for Electro Comm.



2017, our team reached 1.34m to the target by GPS navigation, and changed to “camera navigation” to reach the target. But…

Because of coming sun-light, its camera could not recognize the target and gave up after some waiting time.

They still had one more chance on two days after…

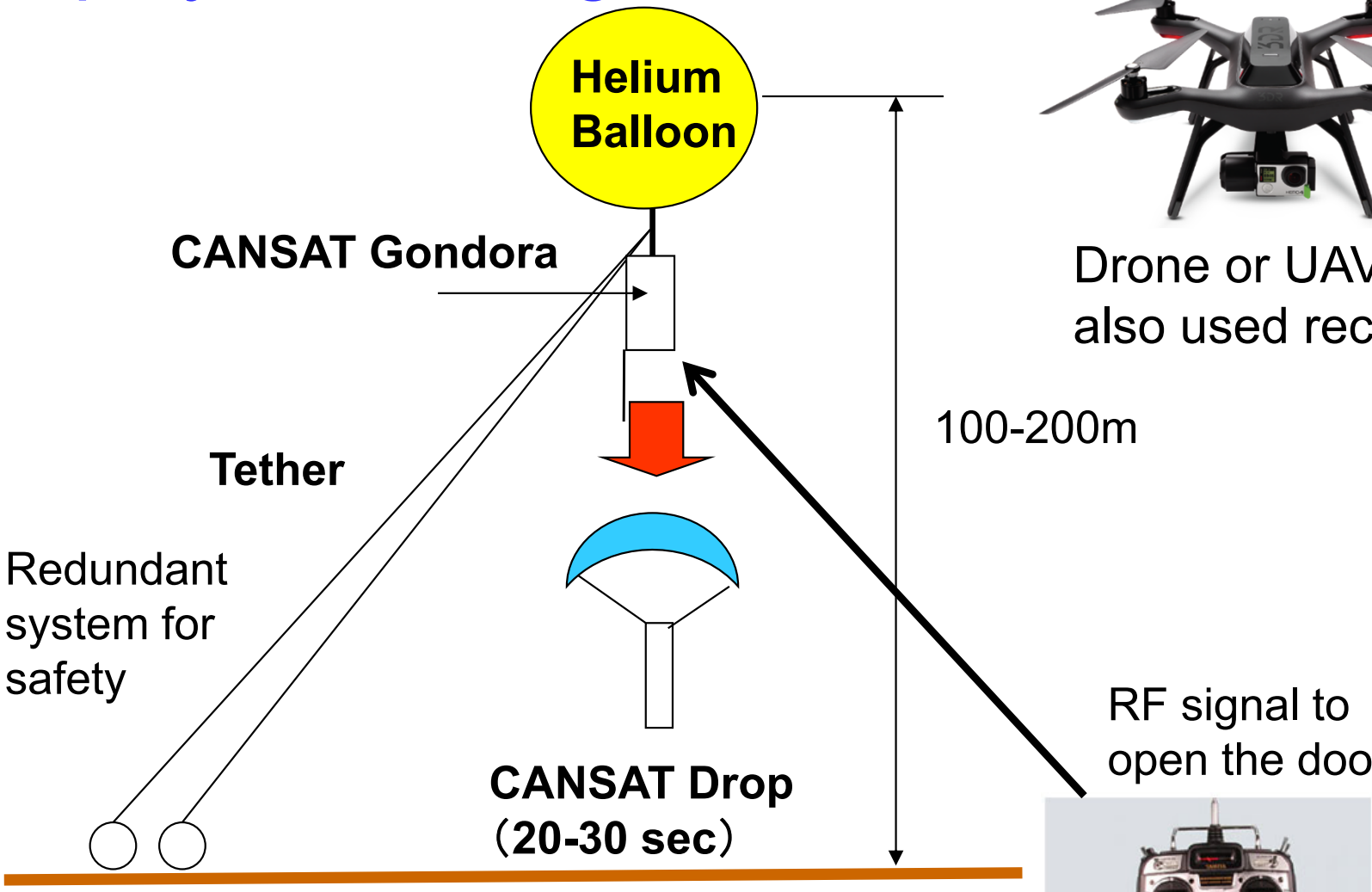
- They modified the strategy and changed the software.
- They did on-site tests many times to check the new software.

- And realize “0 m” to the target in their second run !!

This is really a “problem solving” !!

Strong motivation “We want to win the competition!”

CanSat in Japan
Deployment using Helium Balloon or Drone



Drone or UAV are also used recently

Radio controller (“propo”)

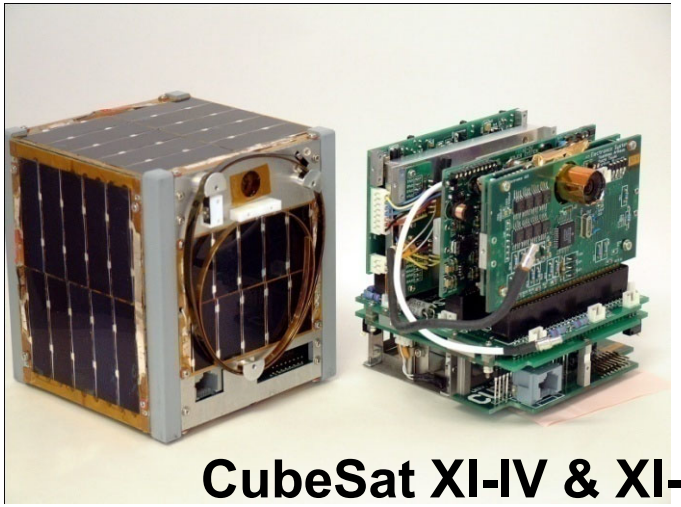
CubeSat (1999～)

Emerge of Nano/pico-Satellites in Japan

World First CubeSats launch by Univ.Tokyo and Titech (2003.6.30)

- University level budget (30K$)
- Development within 2 years
- Surviving in space for 21+ years
- Ground operations, frequency acquisitions, launch opportunity search processed by ourselves
- We start with the situation;

- No components on Website
- Limited budget
- Almost no knowledge about real satellite development



CubeSat XI-IV & XI-V

Russian Launch

Search for Launch Opportunity
- Sending Many Letters -

Launch

Date : 2003 6/30
23:15:26 (JST)
Place: Plesetsk
Orbit: 830km SSO

Launch Vehicle Provider

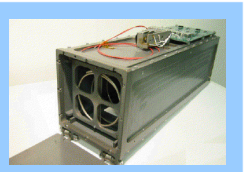
Eurockot

other satellites

60kg

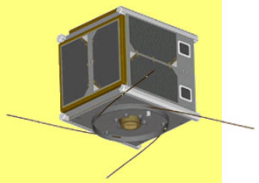
Separation System Developer

CalPoly



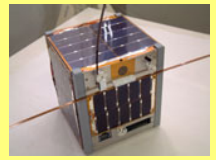
CubeSat Developer

Standford Univ.
U of Toronto
Aalborg Univ
Denmark T.



CubeSat & Separation System Developer

U of Tokyo

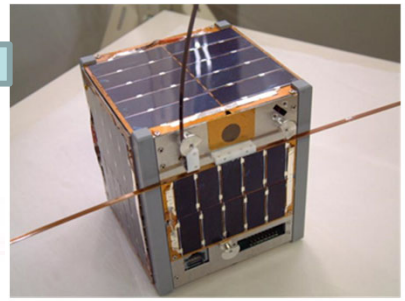


Tokyo Inst. Tech.

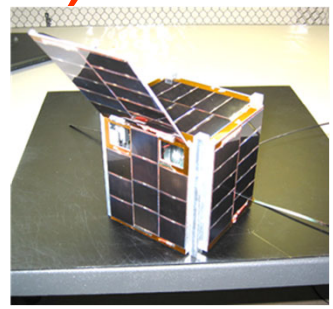
Upper stage "BREEZE-KM" released 8 satellites

Launch of the World First CubeSat (XI-IV, CUTE-1) by “ROCKOT”

2003/06/30 18:15:26 (Russia, Plesetsk)



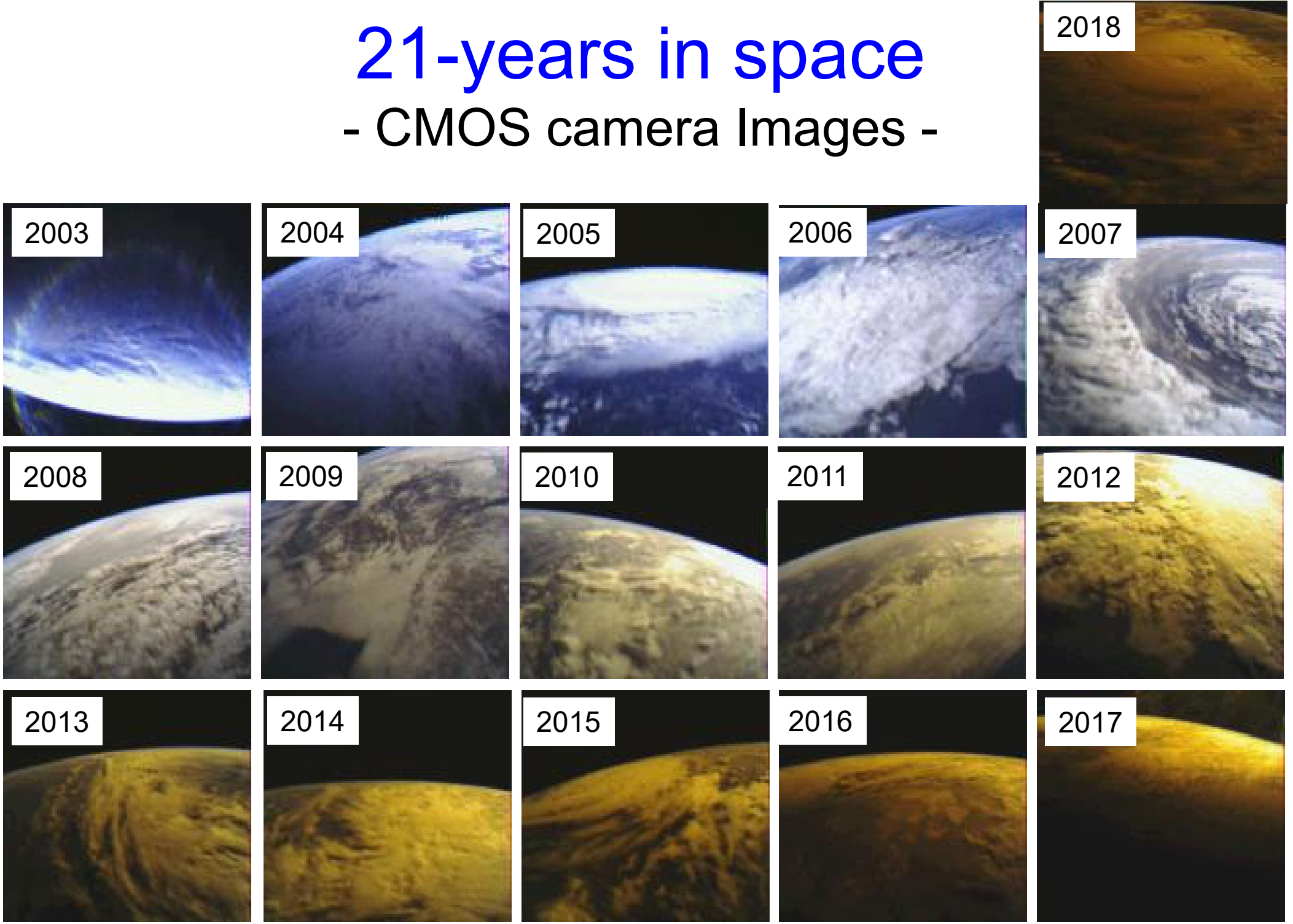
XI-IV



CUTE-1

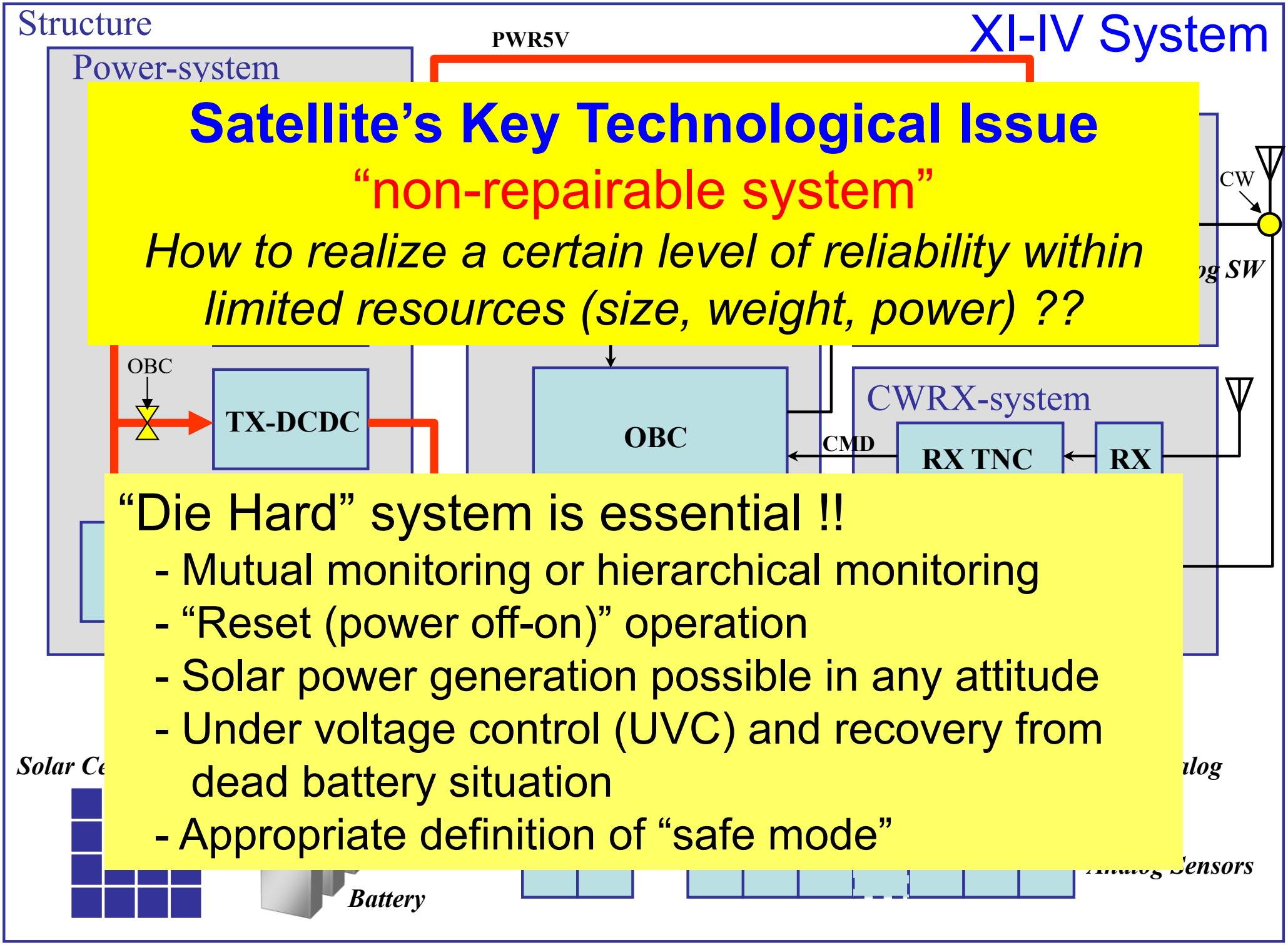
21-years in space

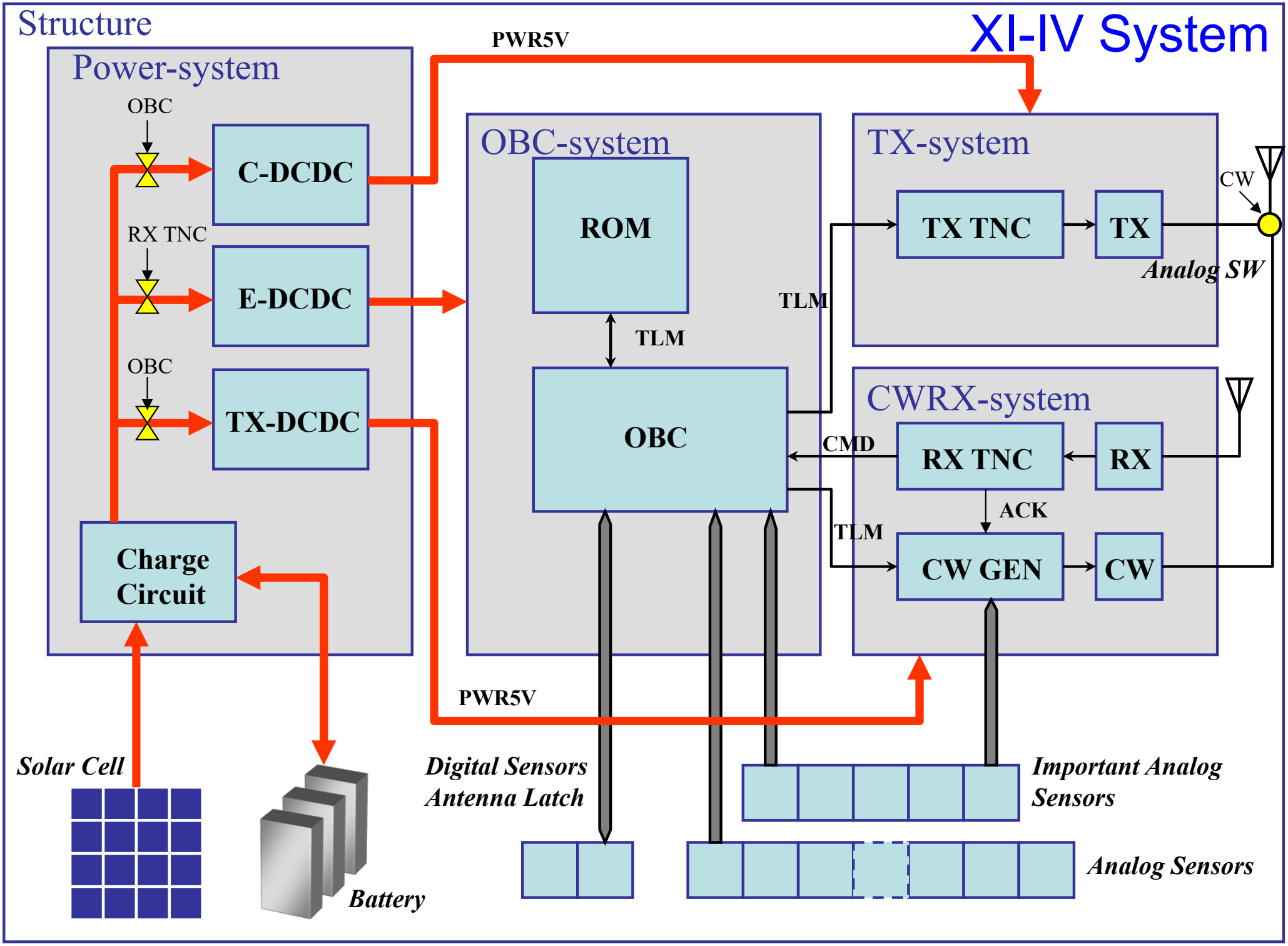
- CMOS camera Images -



Key strategy to be world first CubeSat

- No components on web-site for CubeSat
  - Everything should be internally-made
- No ground test facilities in our university
- We only have little money ($30,000)
- Key strategies employed in our first CubeSat
  - Find out and pursue what we can do within our limited resources, not aiming at supreme level
  - Find outside supporters (technical, part donation)
  - Make it as simple as possible (start from very very simple CubeSat)
  - Implement survivability as much as possible


Structure
XI-IV System
Power-system
PWR5V
Satellite's Key Technological Issue
"non-repairable system"
How to realize a certain level of reliability within limited resources (size, weight, power) ??
CW
OBC
TX-DCDC
OBC
CWRX-system
CMD
RX TNC
RX
"Die Hard" system is essential !!
- Mutual monitoring or hierarchical monitoring
- "Reset (power off-on)" operation
- Solar power generation possible in any attitude
- Under voltage control (UVC) and recovery from dead battery situation
- Appropriate definition of "safe mode"
Battery


Structure
XI-IV System
Power-system
OBC
C-DCDC
RX TNC
E-DCDC
OBC
TX-DCDC
Charge Circuit
PWR5V
OBC-system
ROM
TLM
OBC
TX-system
TX TNC
TX
CW
Analog SW
TLM
CWRX-system
CMD
RX TNC
RX
ACK
TLM
CW GEN
CW
PWR5V
Solar Cell
Battery
Digital Sensors
Antenna Latch
Important Analog Sensors
Analog Sensors

Nakasuka, Funase Lab.

Intelligent Space Systems Laboratory
The University of Tokyo

15	1
Satellites Launched	Satellites will be launched soon
19	125
Years of In-orbit Satellite Operations	Students Graduated

@2020

Capacity Building Support

Education Experiment

XI-IV (2003)
In operation (17 years)

XI-V (2005)
In operation (15 years)

PRISM (2009)
In operation (11 years)

MicroDragon (2019)
In operation
Collaborator: VNSC

HODOYOSHI 1, 3, 4 (2014)
In operation (6 years) Collaborator: Axelspace, NESTRA

Earth Observation

Strix-α (2020)
In operation
Collaborator: Synspective

PROCYON (2014)
End of operation (3 years)
Collaborator: JAXA

Space Science

Nano-JASMINE
Awaiting launch
Collaborator: NAOJ

Number of satellite developed by laboratory
- 3rd most in the world

4 Start-ups from laboratory
Many Prizes from the world
- Frank J Malina Medal
- APRSAF Excellence Award
- Small sat of the year finalist

Technology Demonstration

TRICOM-1R (2018)
End of operation (0.5 years)
Collaborator: JAXA

RWASAT-1 (2019)
In operation (1 years)
Collaborator: Rwanda

AQT-D (2019)
In operation (1 years)
Collaborator: UT-SPL

Entertainment

G-Satellite (2020)
In operation
Collaborator: TOCOG, JAXA

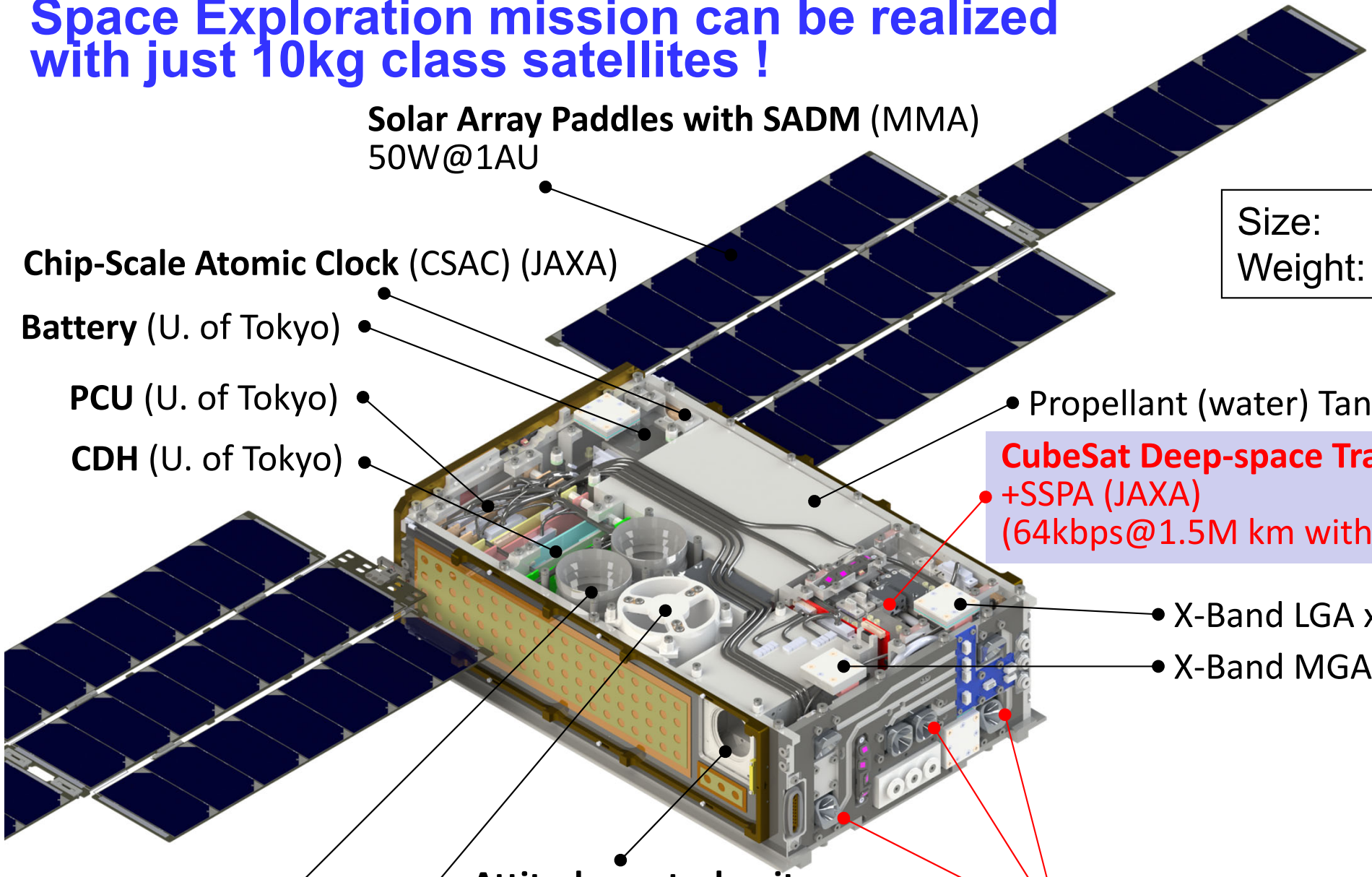
Space Exploration

EQUULEUS (2022)
will be launched in 2021
Collaborator: JAXA

Next-Generation 6U CubeSat (2023)
under development

Versatile 6U

Space Exploration mission can be realized with just 10kg class satellites !



Solar Array Paddles with SADM (MMA)
50W@1AU

Chip-Scale Atomic Clock (CSAC) (JAXA)

Battery (U. of Tokyo)

PCU (U. of Tokyo)

CDH (U. of Tokyo)

Size: 6U
Weight: 11kg

Propellant (water) Tank

CubeSat Deep-space Transponder
+SSPA (JAXA)
(64kbps@1.5M km with MGA)

X-Band LGA x5(JAXA)

X-Band MGA (JAXA)

Attitude control unit
(IMU, STT, SS, RW) (BCT)
(<0.02deg pointing accuracy)

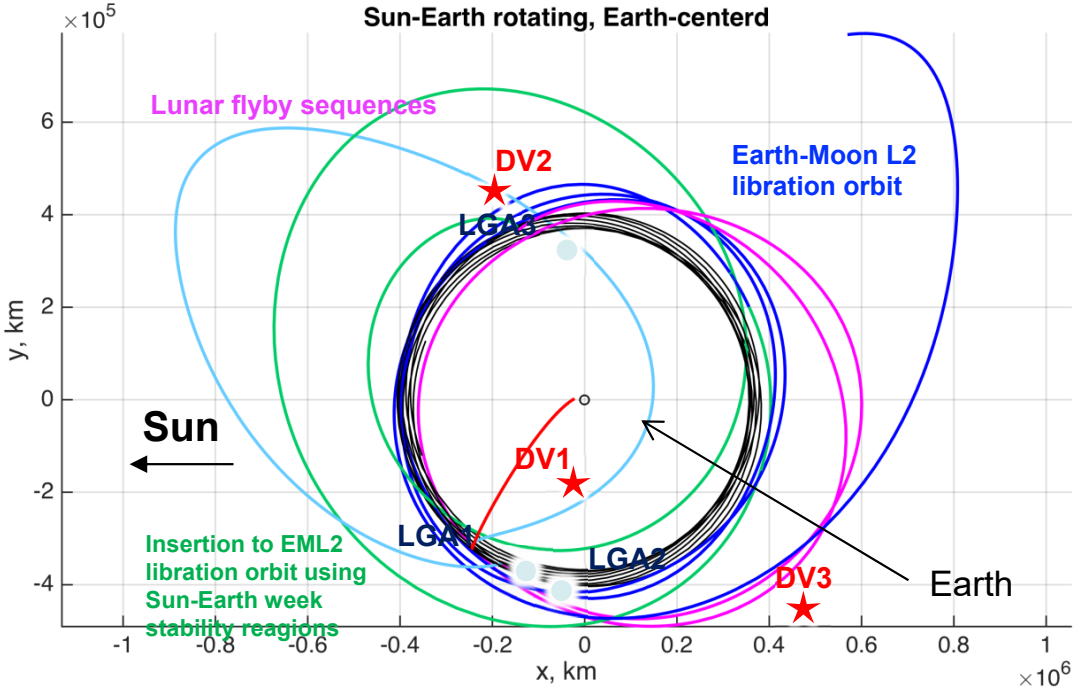
Water resistojet thrusters
(DVx2, RCSx4) (U. of Tokyo)
(Isp >70s, Delta-V >70m/s)

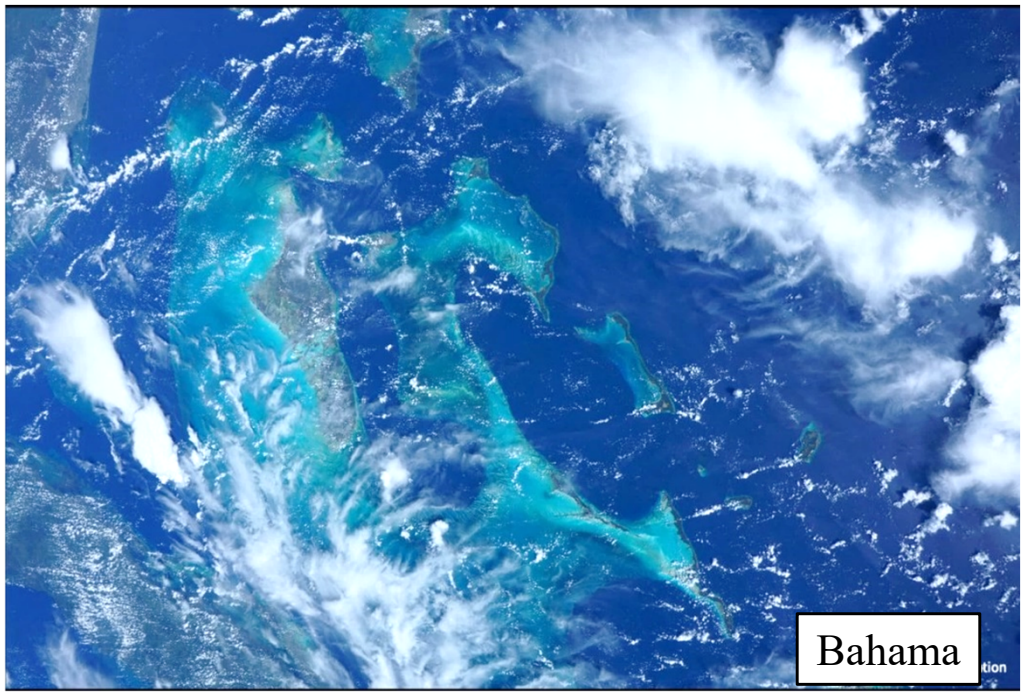
PHOENIX (plasmasphere obs.) (U. of Tokyo)

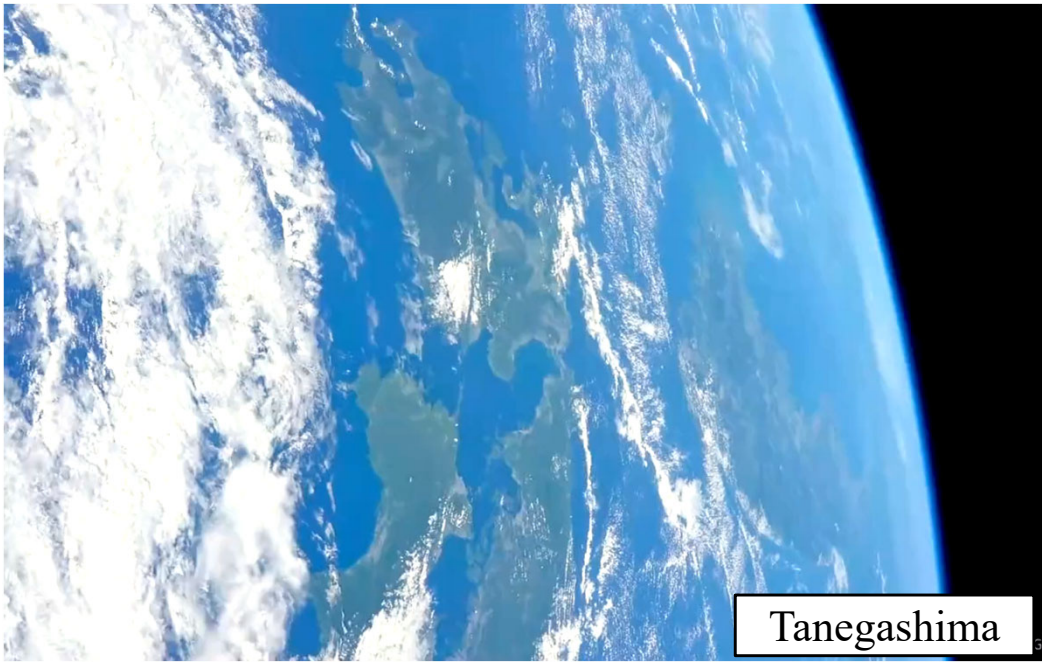
DELPHINUS (lunar impact flashes obs.) (Nihon Univ.)

2022.11.22 Moon as seen from 5550km alt

Launched on Nov 16, 2022, flying towards EML2







SONY Sphere-1 EYE (Entertainment Mission)

History of UNISEC (2002～)

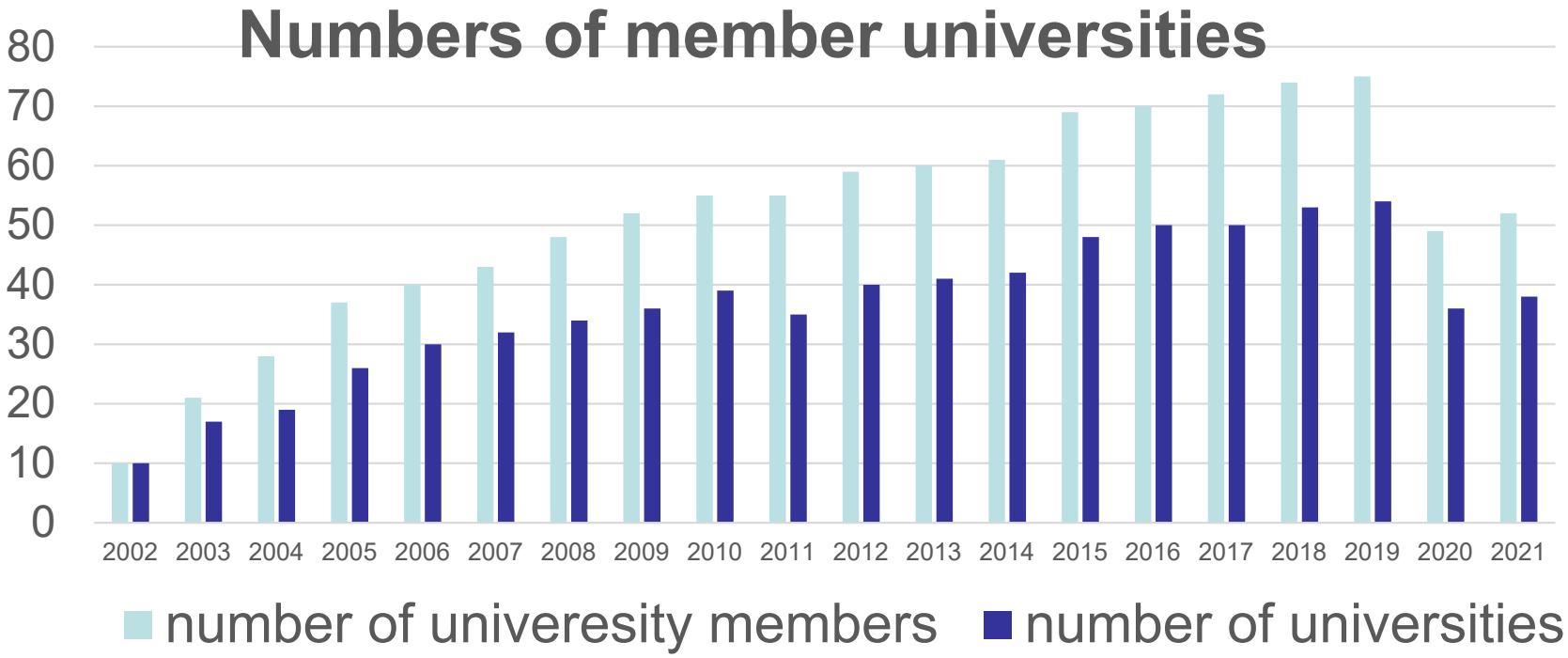
Overall Missions and Activities of **UNISEC**

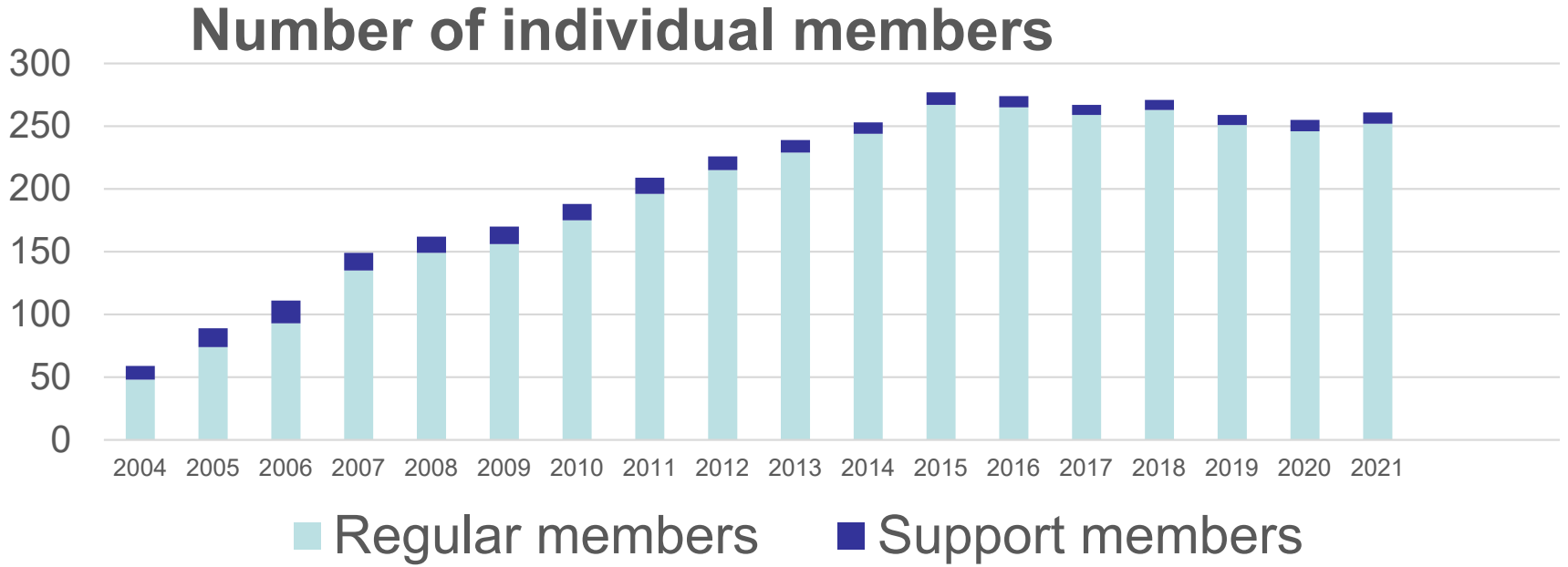
(UNIversity Space Engineering Consortium)

- UNISEC Missions: **http://www.unisec.jp**
  - Education and human resource training for space development and utilizations
  - Innovative space technology “seeds” development
- Activities to be Supported:
  - Joint experiment, joint development, joint education, etc.
    - ARLISS and other CanSat events, joint rocket launch experiments
  - Seminars to students on technical, safety and legal issues
  - Workshop, symposium, technology exchange, etc.
  - Consultation on legal matters (frequency, export law, etc.)
  - “UNISEC Lecture Series”
  - Internationalization: “UNISEC-GLOBAL,” KiboCube
  - Finding “rivals” within the community !

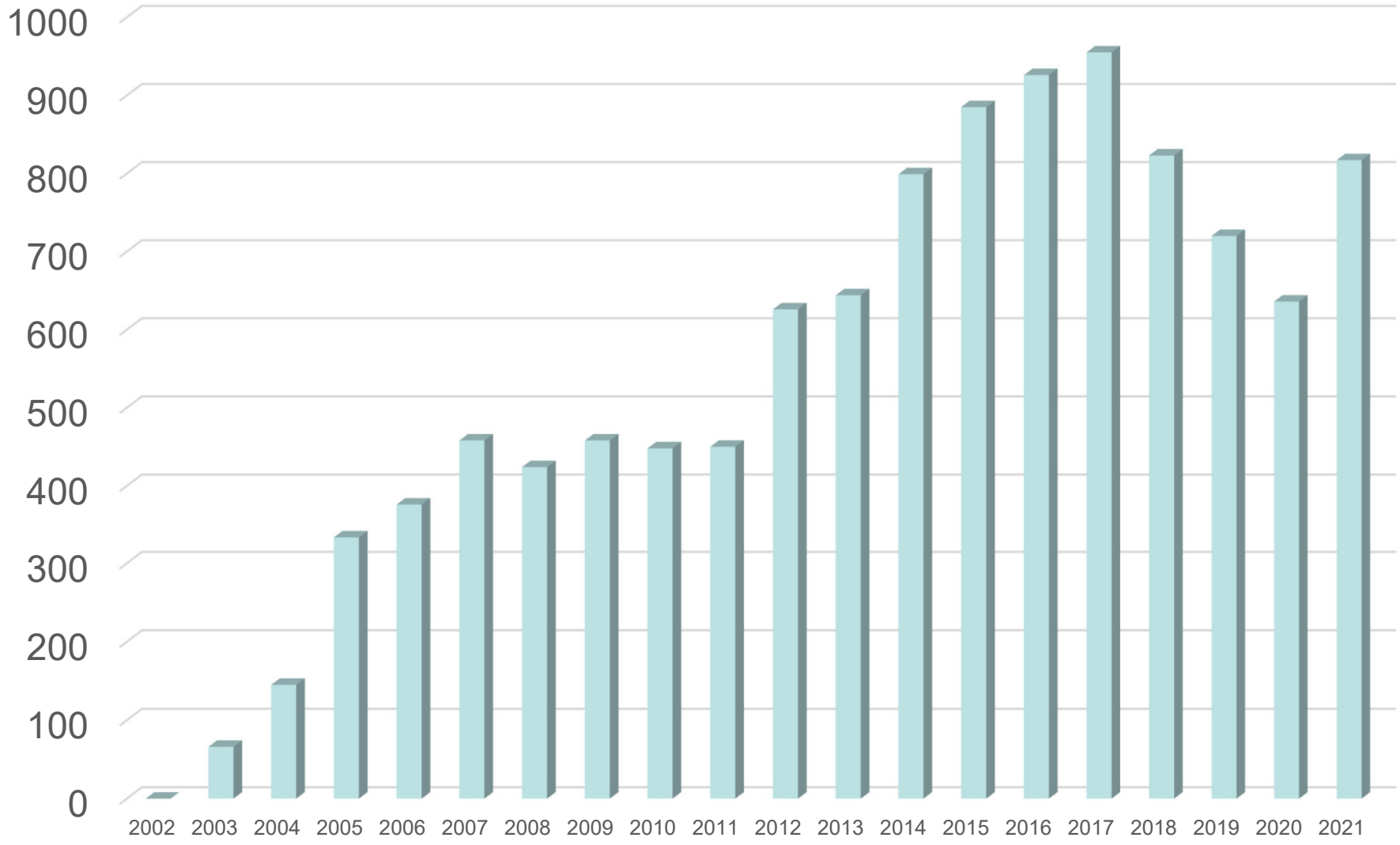
UNISEC
University Space Engineering Consortium

Growth of UNISEC





Number of student members



60+ University satellites Launched within UNISEC (2003-2020)

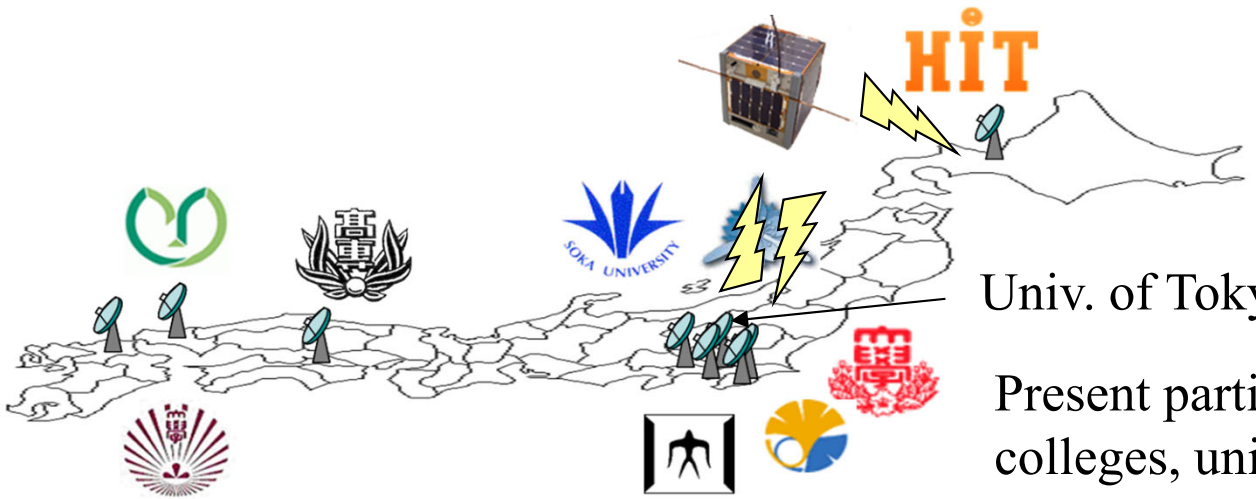
Many universities trained by CanSat started real satellite projects including 1kg to 50kg class satellites.

UNISEC Gradually Enlarged Activities

1. Joint purchase of parts for student projects (2008-)
2. Organizing study research groups such as ground operation, satellite design, attitude control WG, etc. (2004-)
3. UNISEC Ground Station Network (2004-)
4. Consultation on frequency permission, export license procedure, buying foreign components, etc. (2015-)
5. Joint satellite project “UNITEC-1” (2008-10)
6. Satellite technology conference “Nano-satellite Symposium” and “Takumi Conference” (2011-)
7. Giving lectures to students whose universities do not provide lectures on space technologies (“UNISEC Lecture Series”) (2012-)
8. Exchanging experiences of failures in satellite projects “Lessons Learned Sharing Workshop” (2020-)

UNISEC Ground Station Network

- Many ground stations (amateur) are connected via internet and used for other university satellite operations.
  - Extended visible windows of satellite.
  - Backups of failed ground stations and rapid satellite operation



Actually used for operating many university satellites !

- Worldwide network was tried as an experiment
  - Germany (Wurzburg), Sweden(Kiruna), Korea (Seoul)
  - USA (Calpoly, Hawaii, Stanford, Santa Clara, etc)

Competition using Satellite Project "UNITEC-1" (2008-2010)

- 22 university joint satellite project
  - Launched to deep space trajectory as piggyback of Akatsuki (Venus orbiter)
  - All the function is done automatically
  - "Downlink only" communication system
- Competition of OBC survival over long period in deep space environment
  - 10 universities' OBCs were tested in ground tests and 6 OBCs were selected
  - MOBC asks each OBC to do a predefined task and obtains reply from them to check
  - The results are downlinked via low speed C-band communication

35x35x35cm, 21kg
power: 23W
C-band downlink only
No attitude control

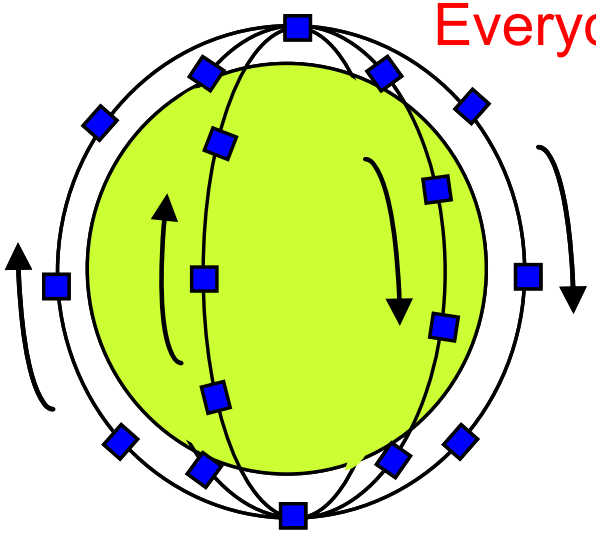
Launch on May 21, 2010

Contribution to Space Industry

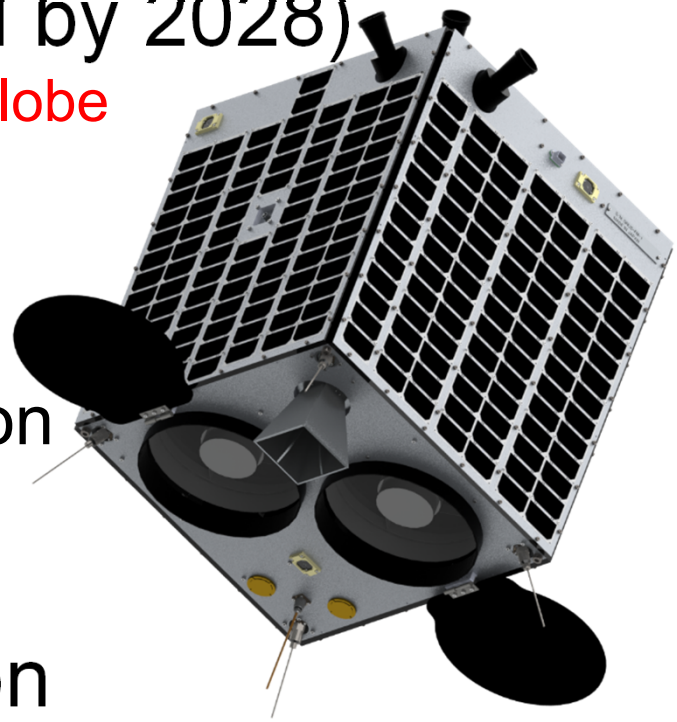
Optical Start-up Company “Axelspace”

- GRUS（10-20 sats to be developed by 2028）

Everyday coverage of the whole globe



2.5m resolution images

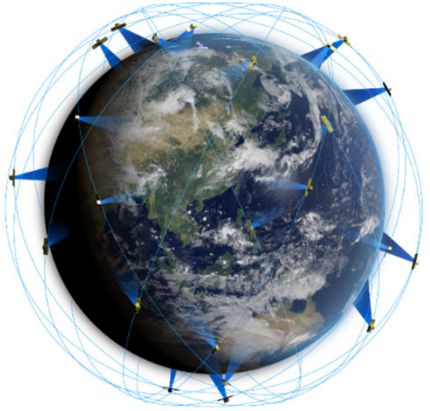


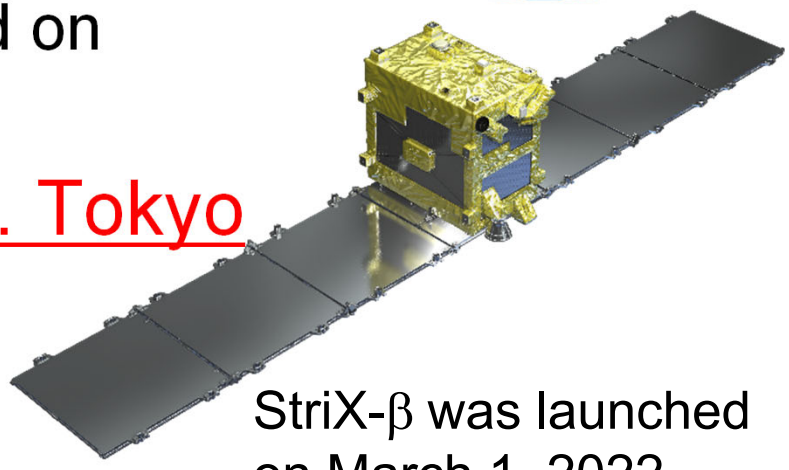
“AXELGLOBE” constellation

Additional 4 Satellites
Launched on March 22, 2021

SAR Start-up Company “Synspective”

- 20-30 satellites to be launched by 2028
- The first satellite “StriX-α” was launched on December 15, 2020
  - Demonstration: 3m ground resolution
  - 140kg, 0.7m cubic size, designed based on Hodoyoshi technologies
- Satellite bus was developed by Univ. Tokyo





StriX-β was launched on March 1, 2022
StriX-1 (operational) was launched on September 16, 2022

First Light of StriX-α
2021/2/8 Noon (JST)
South Florida, USA

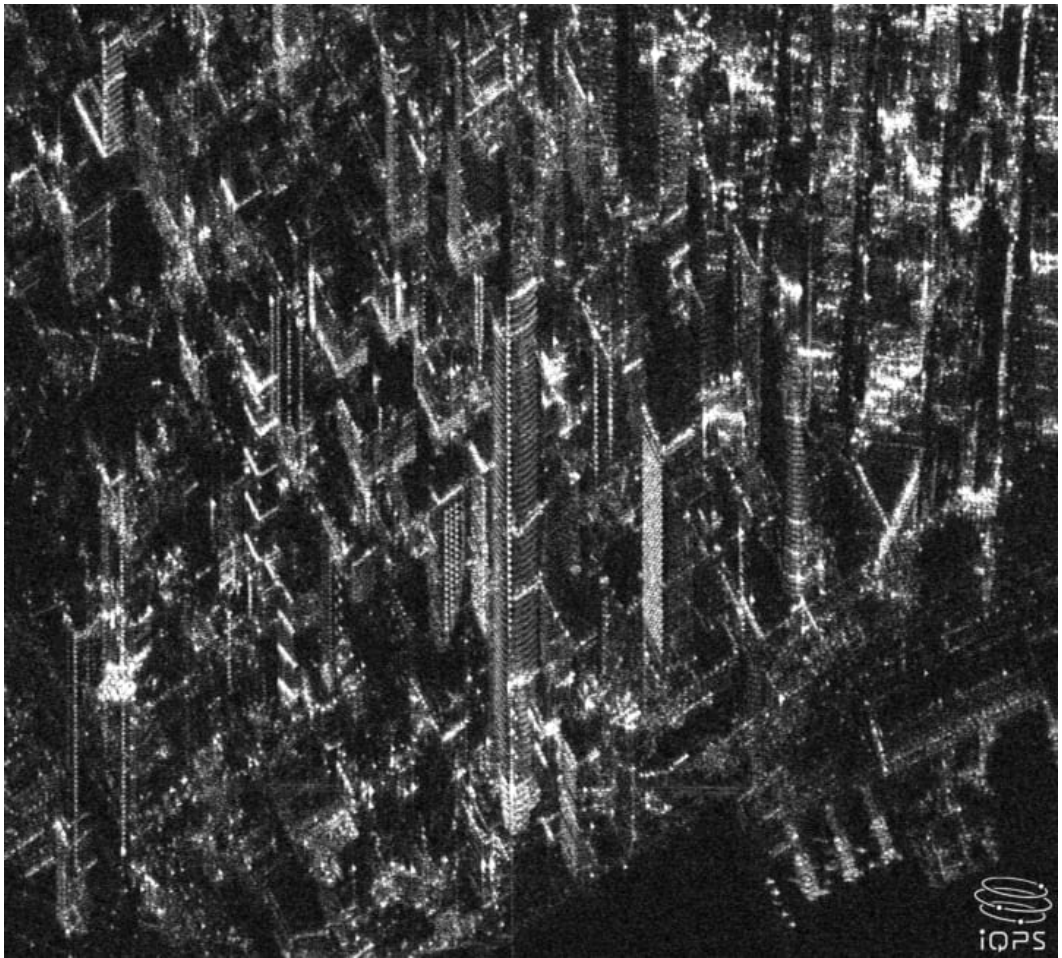
iQPS Inc.

X-band SAR Satellite “Izanagi” and “Izanami”
Izanami launched by FALCON 9 in Jan 2021.

Start-up company from Kyushu University

Targeting to obtain 70cm resolution.

San Francesco GSD 1.8m



Start-up for High-end 6U CubeSats

- Versatile satellites to be used for Earth observation, space science/exploration, capacity building for foreign countries
- Collaboration with start-up company "ArkEdge Space"
- Constellations for various applications are under study.
  - Obtaining several funds from government and is now developing more than 10 satellites

H-IIB launch September 25, 2019

Arkedge Space

MOU to develop 3U CubeSat to be deployed from ISS

Rwanda's first satellite "RWASAT-1" (launched in 2019)

News from Africa (09/05/2018)

Smart Africa, Rwanda Sign Deal With Tokyo University For Satellite Technology

Taarifa
We Give You The Facts, You Connect The Dots

UNISEC Guiding Principles (1)

< 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.

1. Be honest regarding project feasibility – openly recognize the technology and schedule risks that may impact success

- Development process in most cases requires more time than expected ---- Schedule risk
- Usually design cannot work in the initial trial, and even if engineering model (EM) works, flight model (FM) with the same design sometimes does not work
  ---- Technology risk
- At the last moment of the FM integration, a certain engineer working on attitude control gets ill and no one can take over his task ---- Human resource risk

- Identify possible risks beforehand and take appropriate pre-cares such as having large schedule margin/backups.

UNISEC Guiding Principles (2)

< Management >

5.Refer to the achievements of others in the past and build your own achievement on that background.

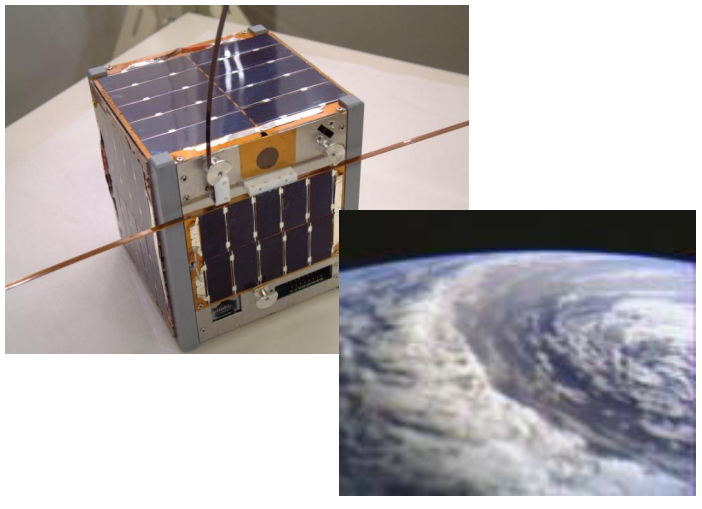
6.Setup appropriate and realistic targets considering your capability and capacity

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.

6. Setup appropriate and realistic targets considering your capability and capacity

- One of the most important considerations in early phase of satellite development is;
  - To know the level of your skills and your resources
  - And to decide the target mission suitable for you
- Past experiences in Japan
  - Some universities tried to develop a satellite which had very high level and difficult missions in the first project, but they could not achieve it and the satellite did not work in space
  - University of Tokyo's XI-IV did not aim at high level of mission, but XI-IV could survive over 21 years and extra-success level was achieved
  - Higher level missions can be done in your 2nd or later projects



UNISEC Guiding Principles (3)

< 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.

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.

Future…… ?

- **Collaborative project "UNISEC-Initiative"**
  - Joint satellite constellation missions (shown later)
  - Ground station network-type not so expensive and easy to participate project
  - Project focusing on more space utilization
- **International university community's contribution to sustainability of human being on the Earth**
  - Let's consider what we can do to contribute
- **More education on "space utilization"**
  - Earth observation, etc. to persuade governments
- **Consultation on how to get funding from each country's government**
  - Future space development plan should be taught