Emerge of Micro/nano/pico-satellites (< 100kg)

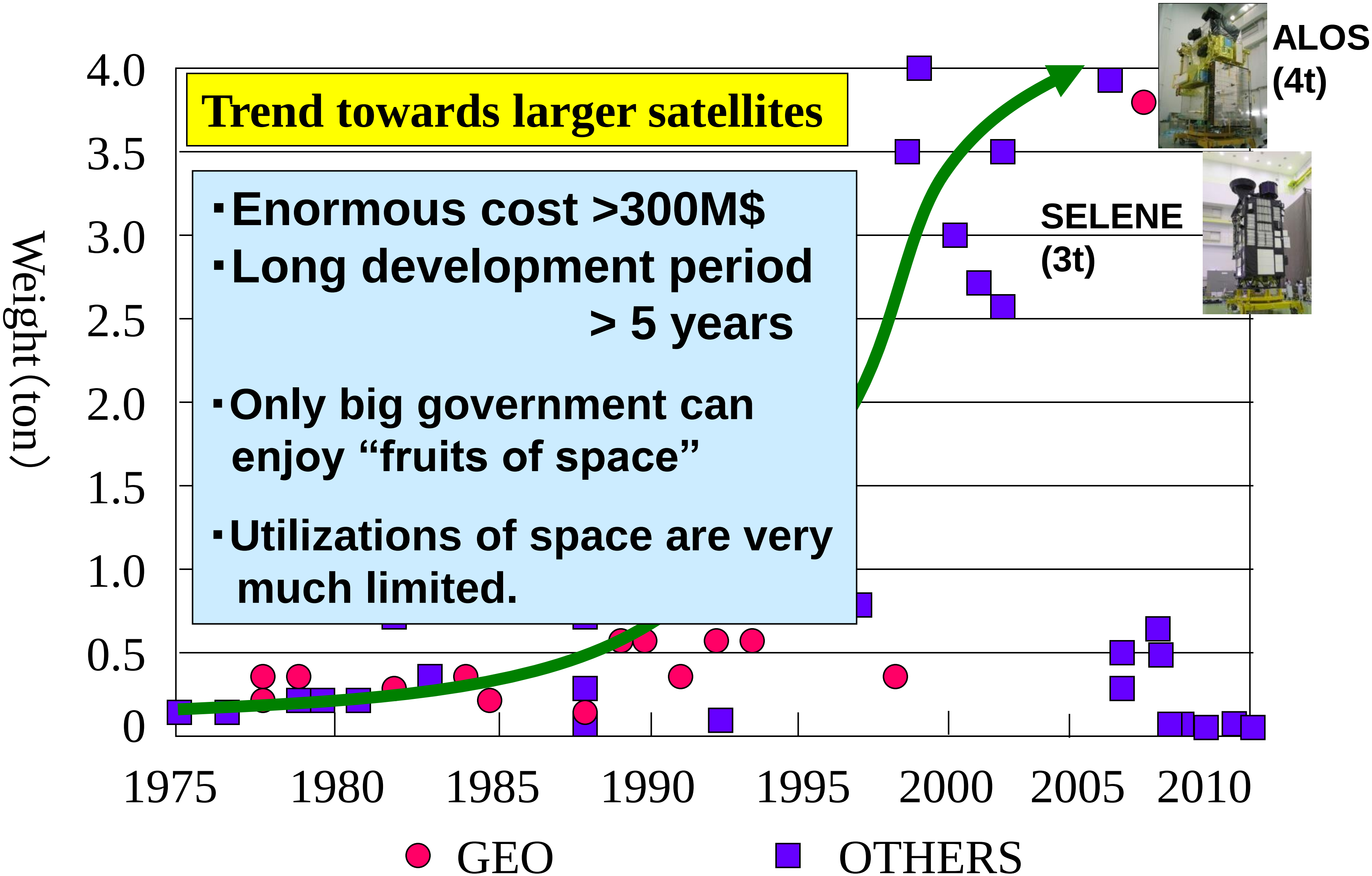
Part 2

Shinichi Nakasuka
University of Tokyo

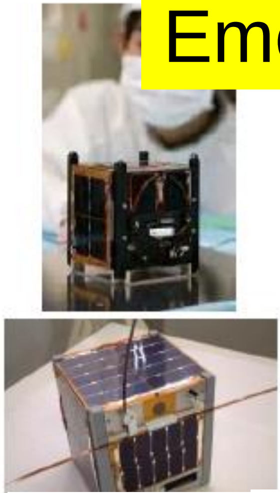
Satellites become too big and expensive !!

Trend towards larger satellites

- **Enormous cost >300M$**
- **Long development period > 5 years**
- **Only big government can enjoy "fruits of space"**
- **Utilizations of space are very much limited.**



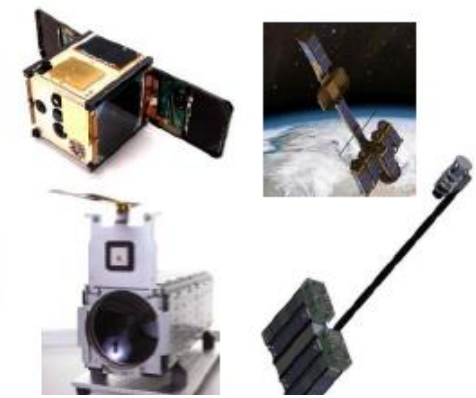
Emerge of Micro/nano/pico-satellites (<100kg)



Education

OPUSAT（1U：1kg）

XI-Ⅳ（1U：1kg）



Remote sensing Telescope

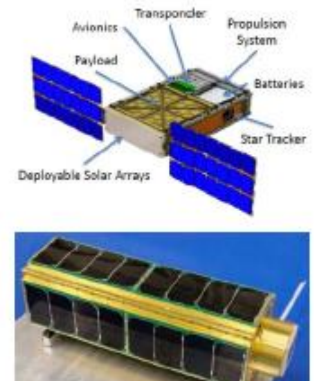
AeroCube(1.5U：2kg)　　AAReST

Dove,Flock（3U：4kg）

Weather

MiRaTA（3U）

MicroMAS（3U）



Bio-engineering

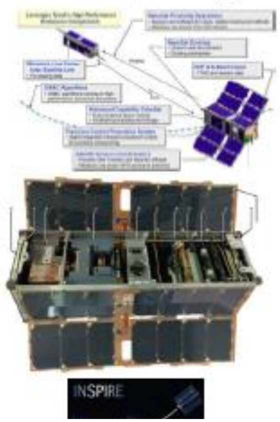
BioSentinel計画案（6U）

SPORESAT（3U：5.5kg）

Re-entry

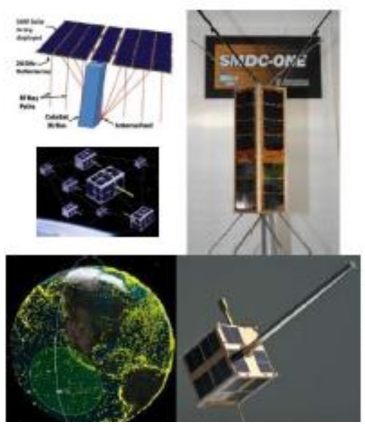
再突入回収（3U）

Sunjammer



Rendezvous/ docking

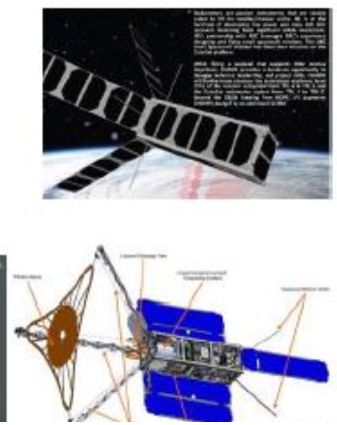
INSPIRE（3U）



Communication

高速通信・ISARA（3U）

低速通信・AISSAT-1（6kg）



Space Science

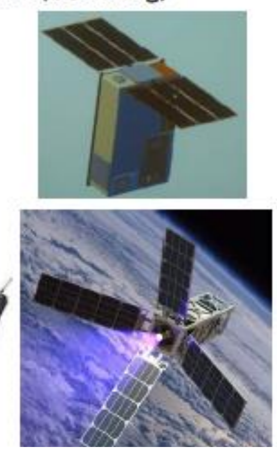
RACE（3U）

FS-7（3U）

Atmosphere

（可視・近赤外）

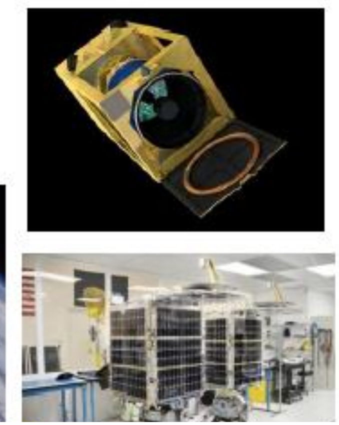
NEMO-AM（15kg）



Exploration

LWaDi（6U）

CAT（3U）



High Resolution.

SCOUT（50kg）

Skysat（120kg）

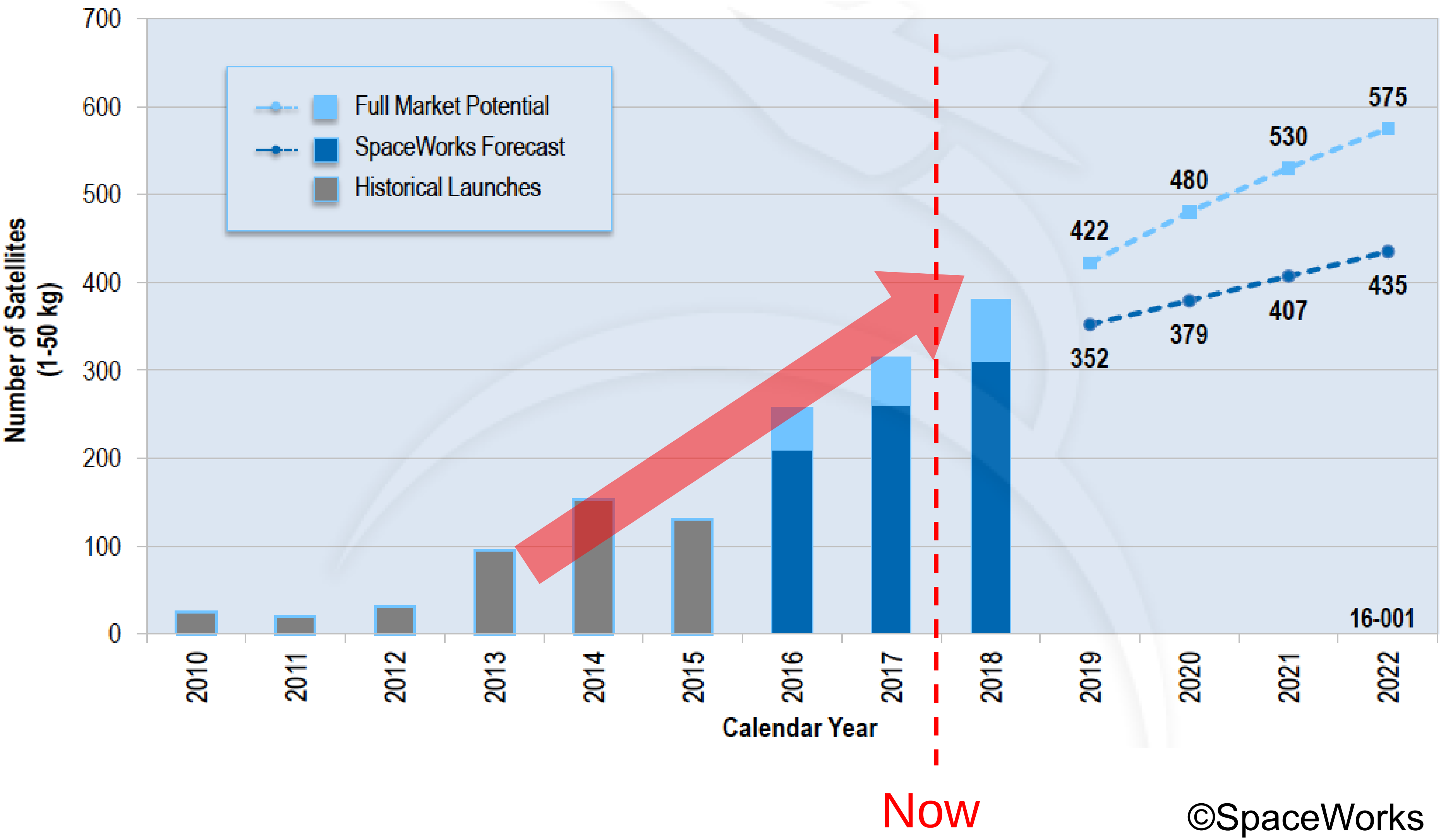
Active players: University and venture companies

Can also be developed by emerging countries, local governments, etc.

“Game Change” by Lean Satellites

- Very low cost (>200M$ → <5M$)
  - Leads to new missions, business, space sciences…
  - Introduce new users (companies, new countries..)
  - Can be used as educational tools
  - Can be very challenging (failures can be allowed)
- Short life cycle (>5 years → <1-2 years)
  - One life cycle possible during univ.’s student years
  - More iterations possible (from “project” to “program”)
  - Early return of investment (good for business)
- Simple and transparent satellite system
  - Easy to design, operate and do trouble shooting
  - Development members can see the total system

Growing trend of < 50kg satellites

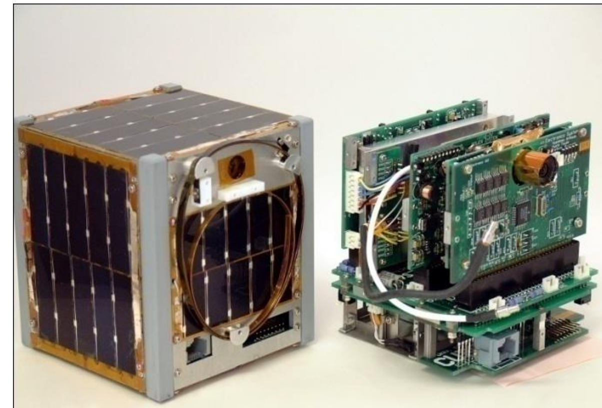


©SpaceWorks

Emerge of Nano/pico-Satellites in Japan

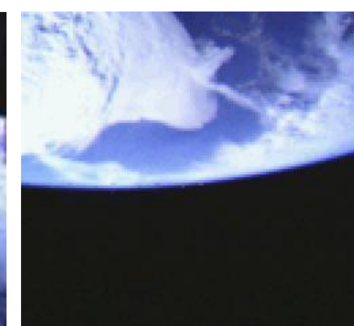
World First CubeSats launch by Univ.Tokyo and Titech (2003.6.30)

- University level budget (30K$)
- Development within 2 years
- Surviving in space for 15 years
- Ground operations, frequency acquisitions, launch opportunity search processed by ourselves



CubeSat XI-IV & XI-V

Russian Launch



1～50kg (Micro/Nano-sat):
Starting from education but higher level satellites appear

University of Tokyo's (UT's) History
- 10 satellites developed (9 launched) -

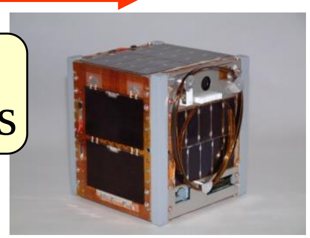
2003 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18

[1] Education, Camera test

CubeSat XI-IV
(ROCKOT) 2003/6

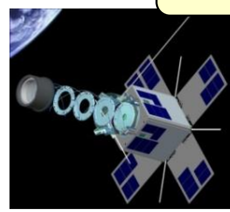
World First CubeSat !

[2] Education, CIGS solar cells



CubeSat XI-V
(COSMOS) 2005/10

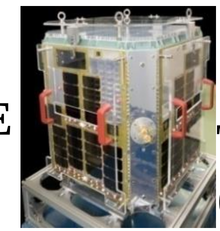
[3] 30m GSD Remote sensing



PRISM
(H-IIA) 2009/1

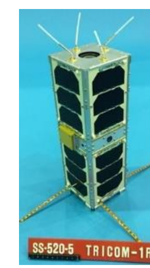
[9] Astrometry (top-science)

NANO-JASMINE
(TBD)



[8] Comm.

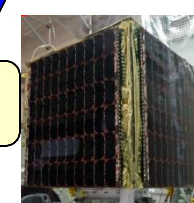
TRICOM-1R
(2018/2)



[4][5][6] Remote sensing, S&F

HODOYOSHI-1,3,4
(DNEPR) 2014/6,11

[7] Deep space exploration



PROCYON
(H-IIA) 2014/12

[1]-[8]:Launched [9]: Waiting for launch

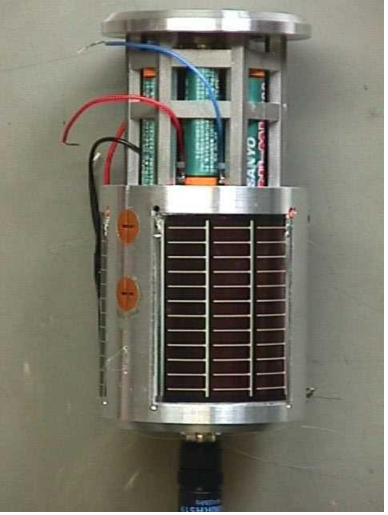
MDG (remote sensing, 50kg) launched,
EQUULEUS (14kg, deep space)
are being developed.

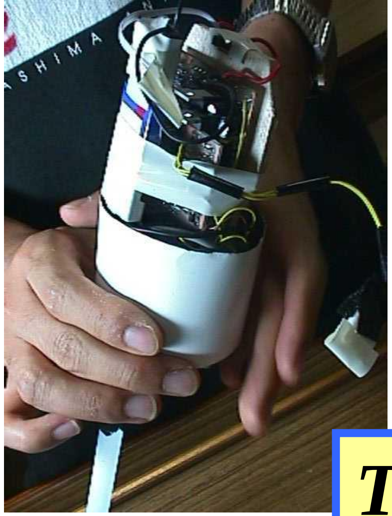
→ development ▼ launch

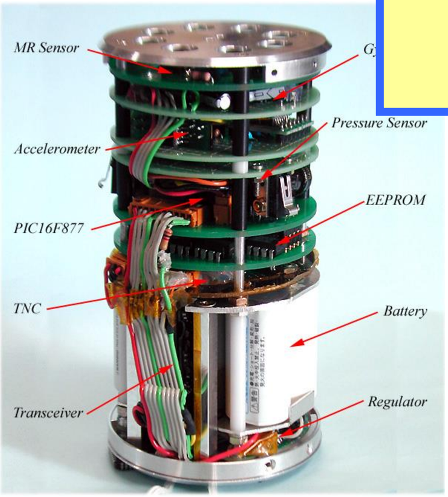
University of Tokyo’s History on Micro/nano/pico-satellites (2000 – 2009)

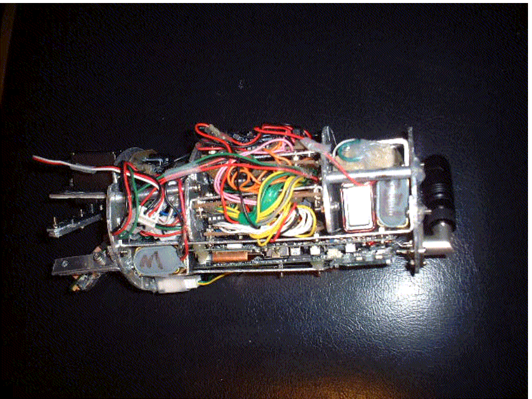
- Starting from Education and Experiments -

Training step: CanSat 1999-now









ARLISS (A Rocket Launch for International Student Satellites)
- Annual suborbital launch experiment -

- 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 !!

Opening Ceremony and Briefing (September 10, 2018)

Come-Back Competition

Simple criteria, Competition makes motivation

Participating Universities 2002

Univ. of Tokyo

Kyushu Univ.

Nihon Univ.

45m to the target (World Record of Flyback Type)

Tohoku Univ.

te
of Technology

Stanford Univ.

ROVER

Comeback Competition

2017 Champion

University of Tokyo's rover achieved

0m

to the target

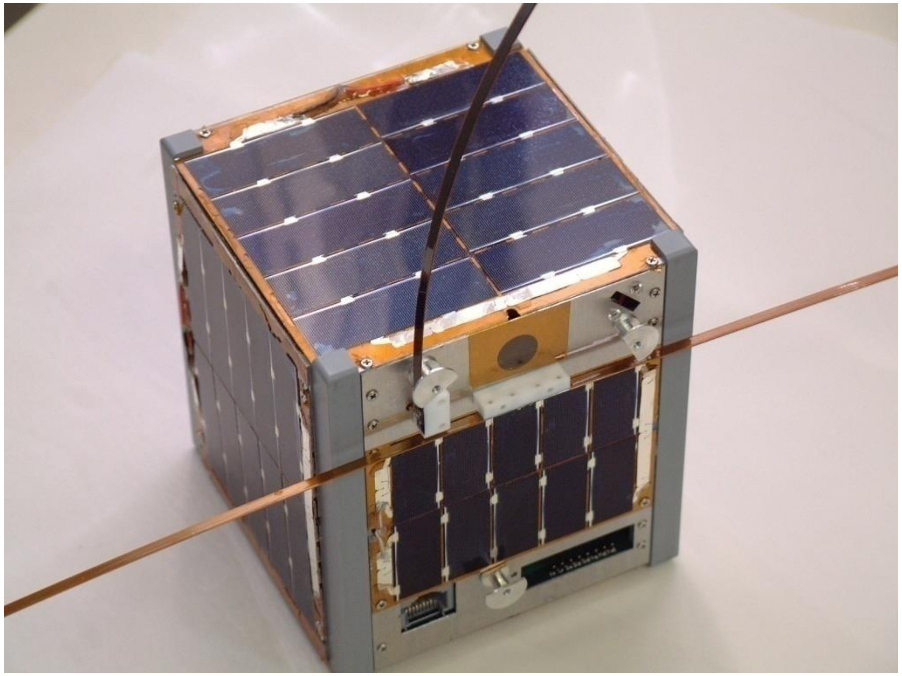
20th Anniversary Gifts to AEROPAC (Sept 14, 2018)

CubeSat "XI-IV (Sai Four)"

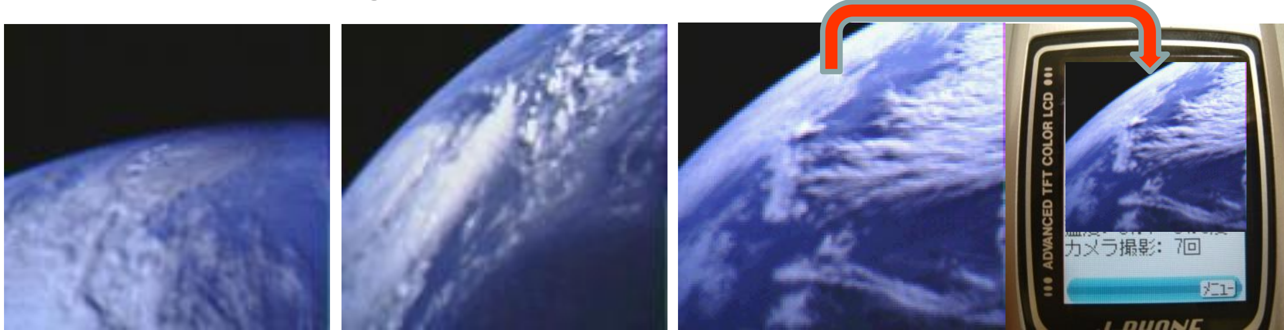
Intelligent Space Systems Laboratory
University of Tokyo
ISSL

Mission: Pico-bus technology demonstration in space, Camera experiment
Developer: University of Tokyo
Launch: ROCKOT (June 30, 2003) in Multiple Payload Piggyback Launch

Size	10x10x10[cm] CubeSat
Weight	1 [kg]
Attitude control	Passive stabilization with permanent magnet and damper
OBC	PIC16F877 x 3
Communication	VHF/UHF (max 1200bps) amateur frequency band
Power	Si solar cells for 1.1 W
Camera	640 x 480 CMOS
Expected life time	??



Captured Earth Images are Distribution to Mobile Phones



Basic Specifications of XI-IV

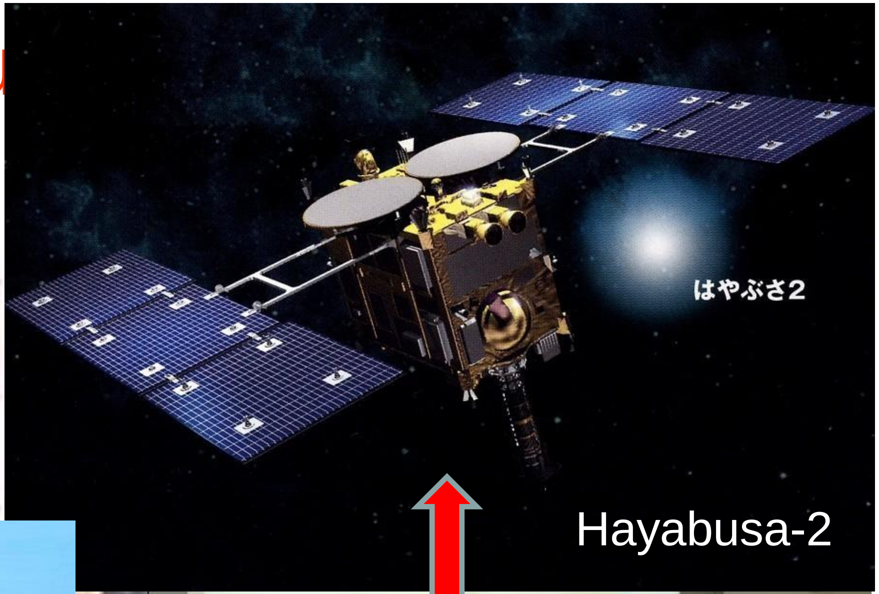
● Structure		10cm cubic, 1kg, Aluminum A7075 body
● C&DH		
	OBC	PIC16F877 4MHz（Program memory 8k, RAM 368)
	Data Storage	EEPROM 32k + 224k
● Communication System		
	Downlink	430MHz band, FSK, 1200bps, 800mW
	Uplink	144MHz band, FSK, 1200bps
	Beacon	430MHz band, CW, 80mW
● Power System		
	Battery	Lithium-ion battery, 8 cells, 6.2AH
	Solar Cells	Monocrystal silicon, 60 cells, 1.1W(ave)
	Consumption	0.6W(ave), 5.4W(max)
● Attitude Control		<u>Passive stabilization using permanent magnet and damper</u>
● Sensors		Voltage, Current, Temperature, CMOS camera

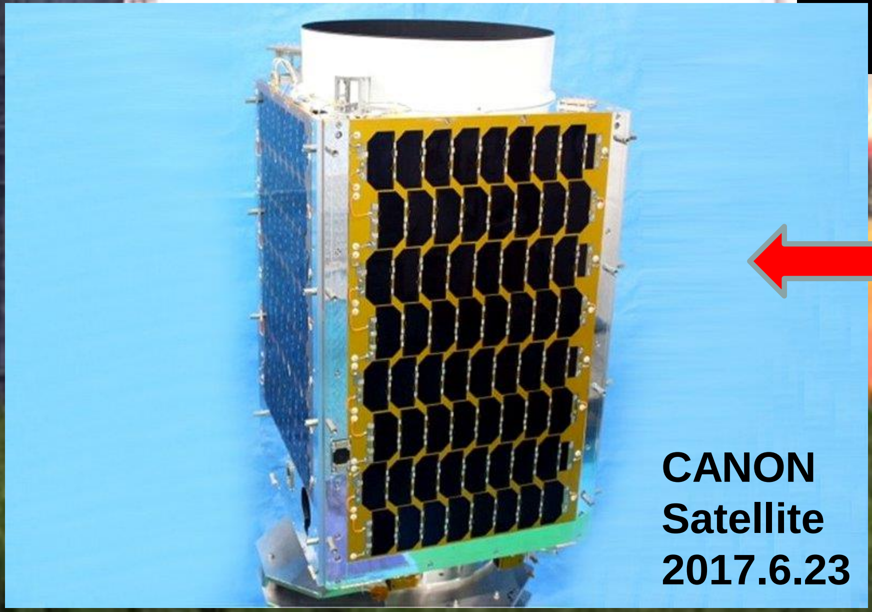
Mission: Education, Pico-bus demonstration in space

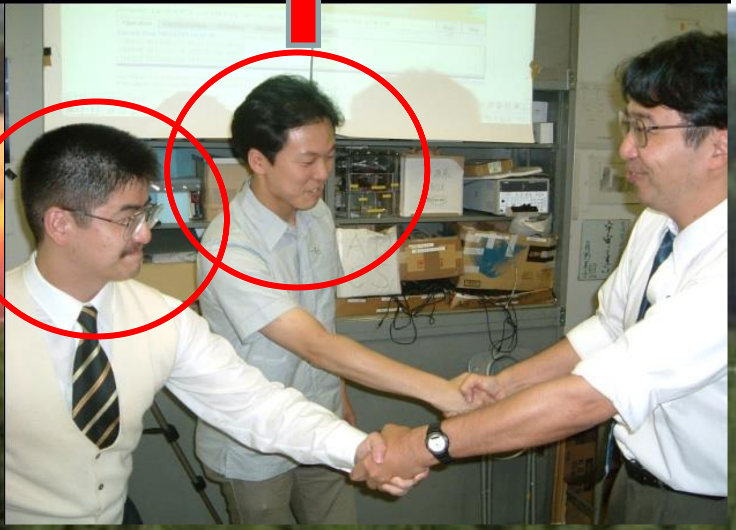
Launch of the World First CubeSat (XI-IV, CUTE-1) by “ROCKOT”

2003/06/30 18:15:26 (Ru

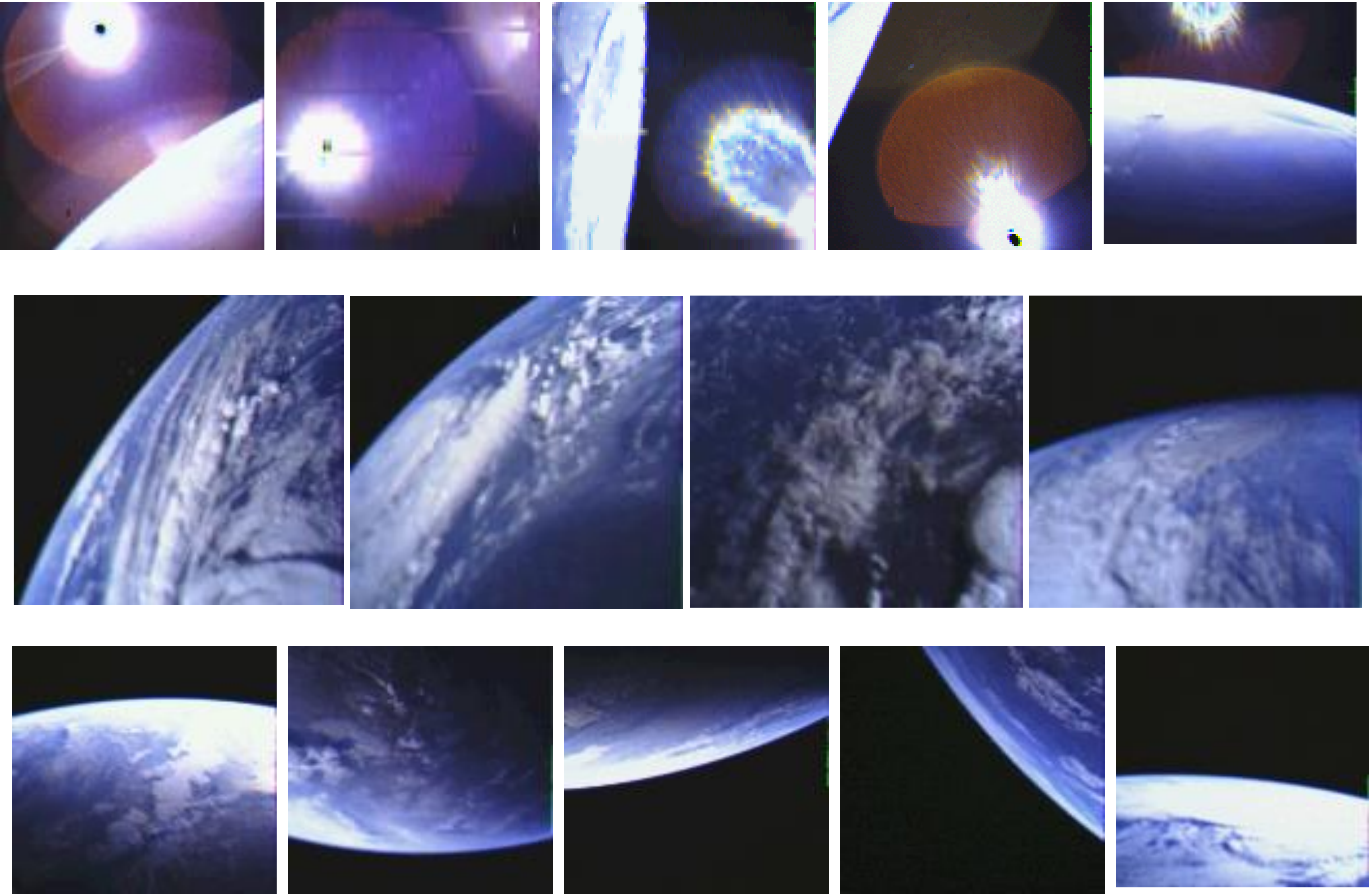
Contribution to human resource training was more than expected !







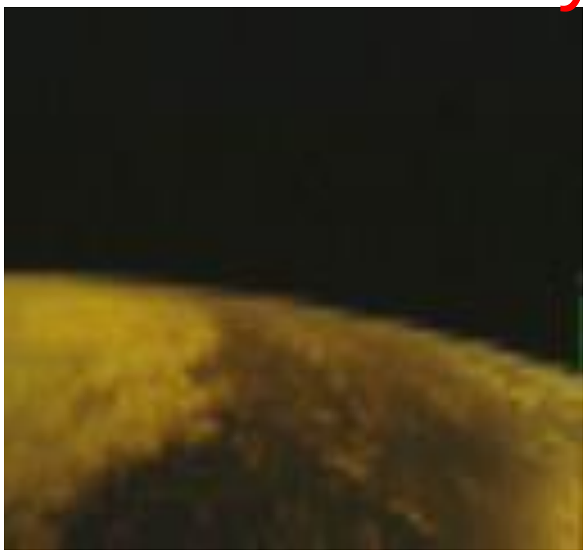
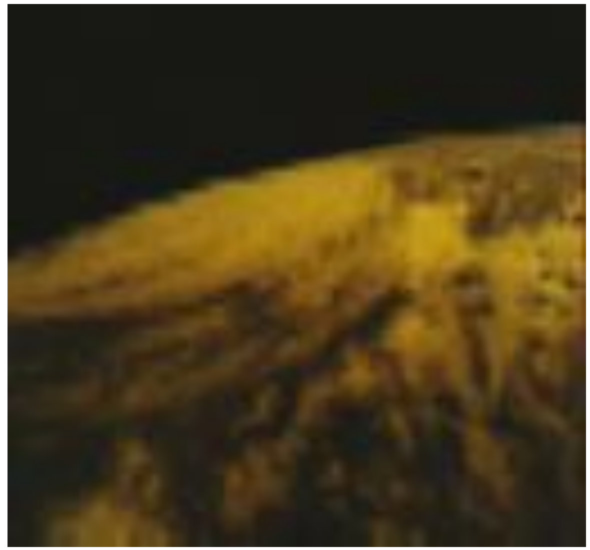
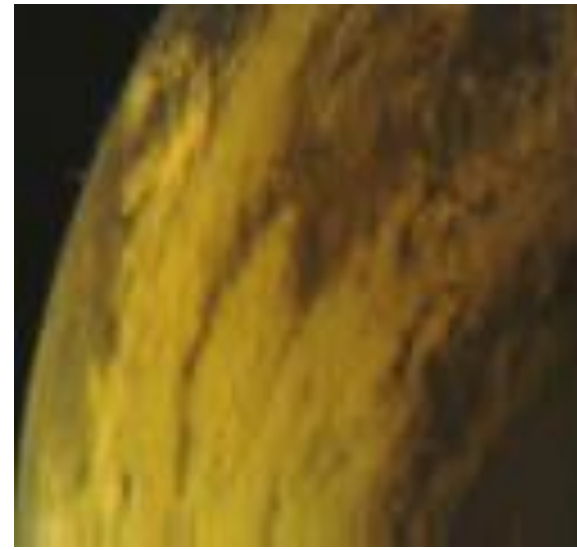
700+ pictures downlinked for 15 years

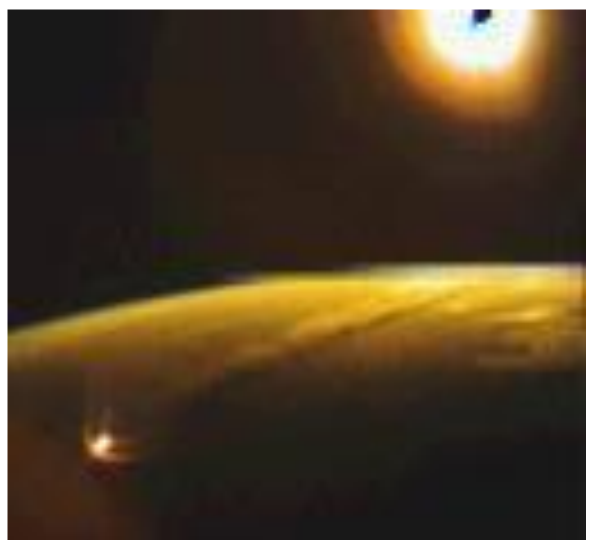


XI-IV is still perfectly working after 15 years in orbit

Sepia color !
Get older ?

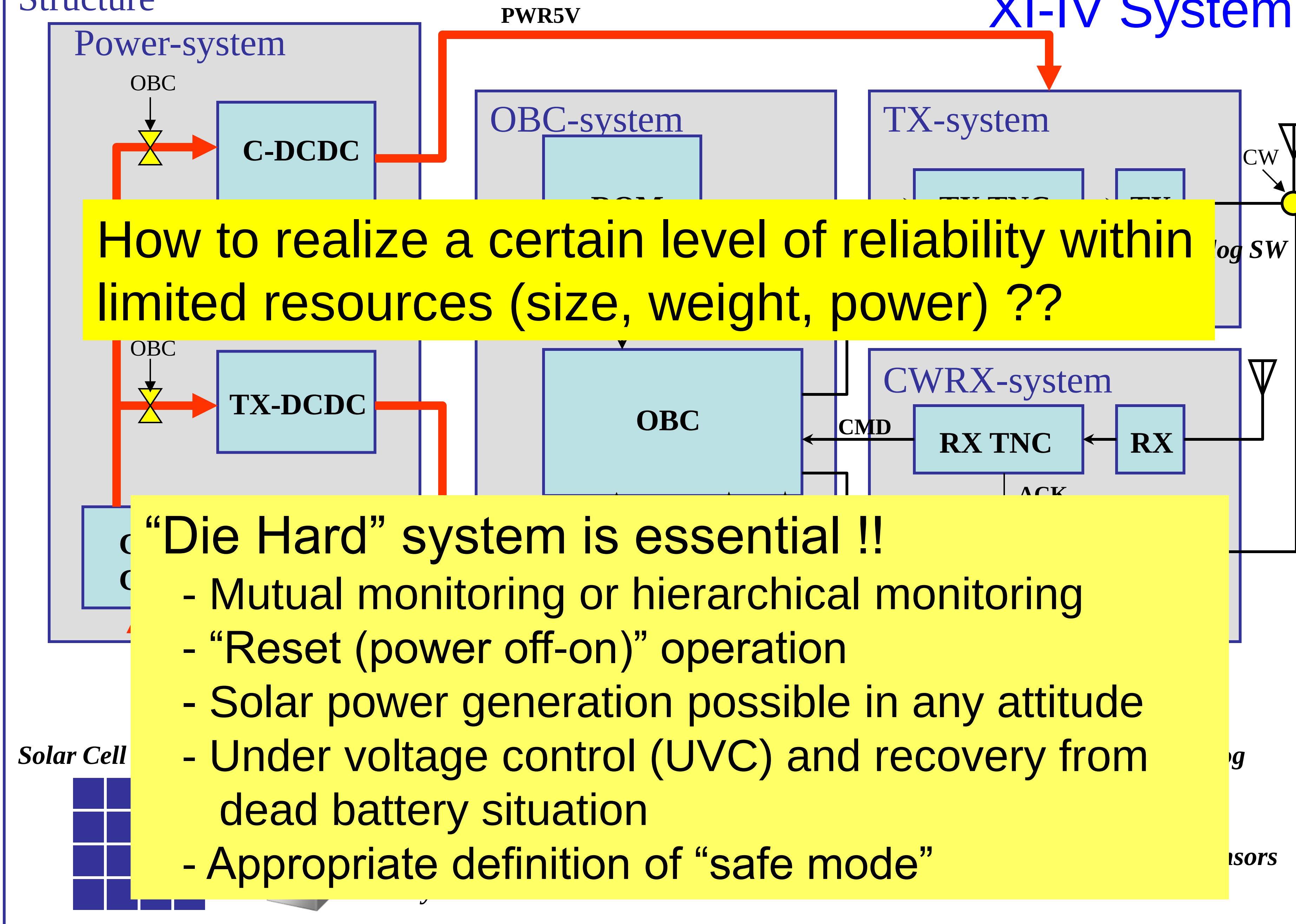
Recently Downlinked Photos


Structure

XI-IV System



How to realize a certain level of reliability within limited resources (size, weight, power) ??

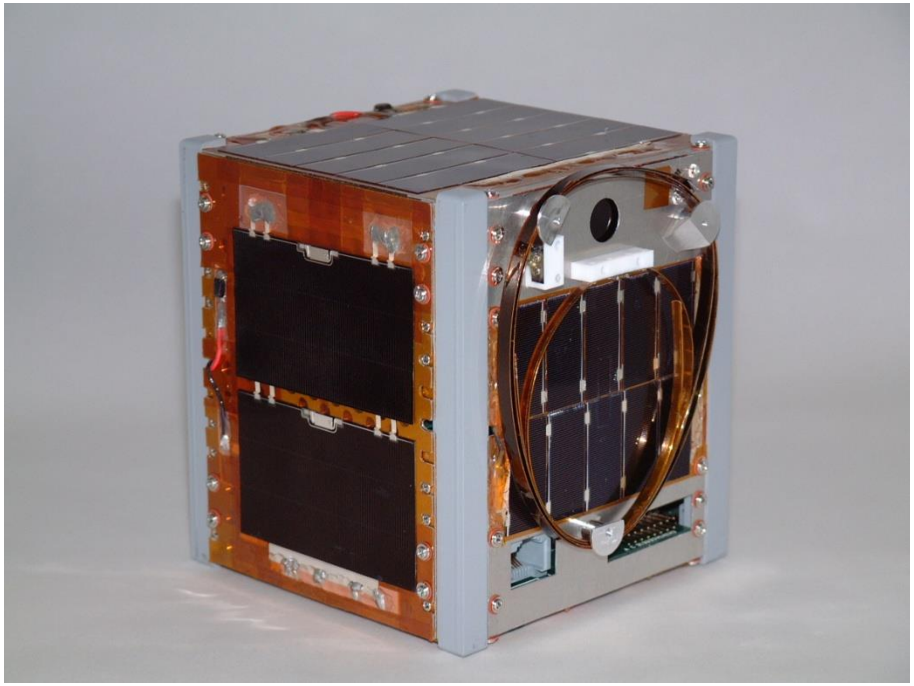
"Die Hard" system is essential !!

- 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"

CubeSat "XI-V (Sai Five)"

Mission: CIGS solar cell demonstration, Advanced camera experiment
Developer: University of Tokyo
Launch: COSMOS (October 27, 2005) deployed from "SSETI-EXPRESS"

Size	10x10x10[cm] CubeSat
Weight	1 [kg]
Attitude control	Passive stabilization with permanent magnet and damper
OBC	PIC16F877 x 3
Communication	VHF/UHF (max 1200bps) amateur frequency band
Power	Si, GaAs, CIGS cells
Camera	640 x 480 CMOS
Mission life	> 5 years



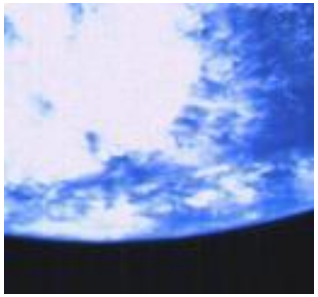
SSETI-EXPRESS

T-POD deployment System

Deployed from SSETI-EXPRESS in space

JAXA/NEDO CIGS Solar Cells

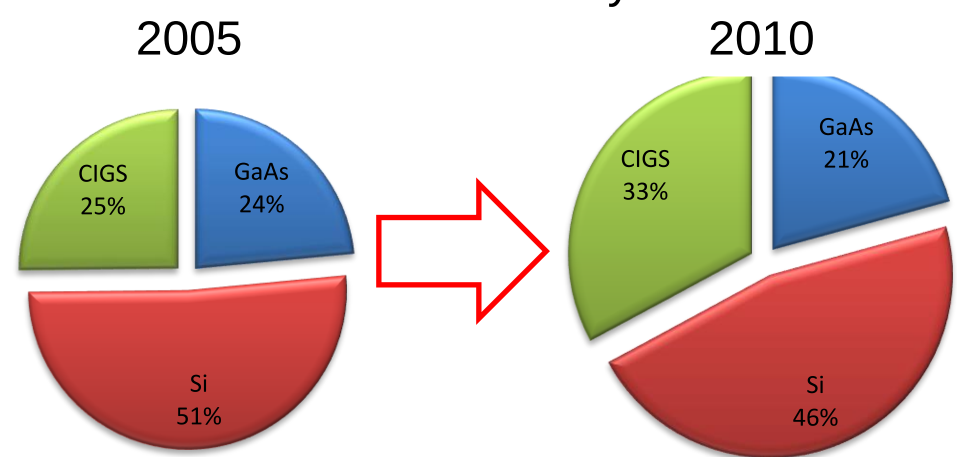
Captured Earth Images



CIGS Solar Cell Test in Space

- **Three type solar cells on XI-V**
  - **±Y,-Z →GaAs 16%**
  - **+X,+Z →Si 12%**
  - **-X →CIGS 10%**

Ratio of Power Generation by Three Cells



CIGS Solar cell portion increased
Because of its radiation tolerance

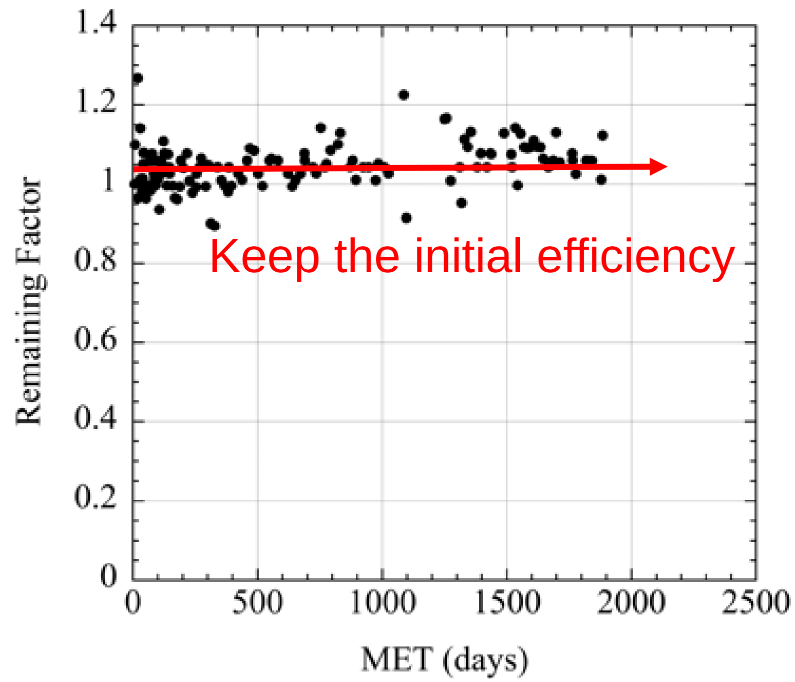


Fig. Flight data of current in CIGS solar cell module on Cubesat XI-V

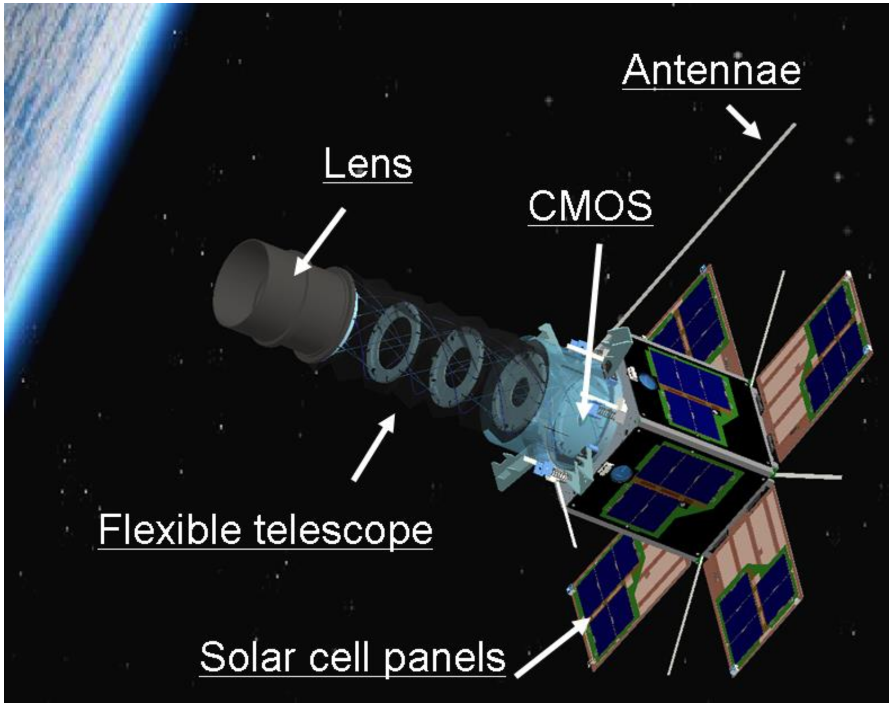
Kawakita,et.al., Space Experiments of Cu(In, Ga)Se_2 thin-film solar cells by Japanese small satellites

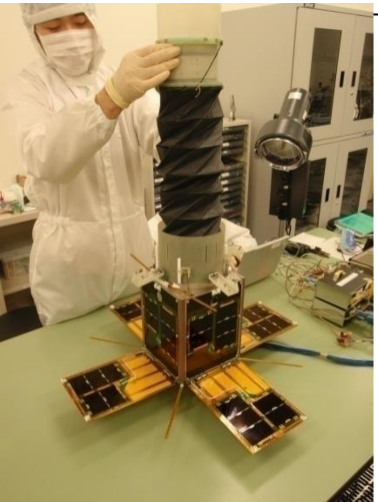
Micro/nano/pico satellite for “Quick test bench of new technoloies”

PRISM "Hitomi"

Mission: Earth Remote Sensing (20 m GSD, RGB) with Deployable Boom
Developer: University of Tokyo
Launch: H-IIA (Jan 23, 2009) Piggyback with GOSAT (CO_2 monitoring sat)

Size	20x20x40[cm] in rocket 20x20x80[cm] in space
Weight	8.5 [kg]
Attitude control	3-axis stabilization with Sun, Magnet sensor, MEMS gyro magnetic torquers
OBC	SH2, H8 x 2, PIC x 2
Communication	VHF/UHF (max 9600bps)
Mission life	> 2.5 years





Captured images

Mexico Seashore

US Desert

Kita-Kyushu (Japan)

Wide Angle Camera

2009.4.17
Mexico

Educational Significances of CanSat/Micro/Nano/Pico-Satellite Projects

- ***Practical Training of Whole Cycle of Space Project***
  - Mission conceptualization, satellite design, fabrication, ground test, modification, launch and operation
  - Know <u>what is important</u> and what is not.
- ***Importance for Engineering Education***
  - Synthesis (not Analysis) of an really working system
  - <u>Feedbacks from the real world</u> to evaluate design, test, etc.
  - Learning from failures (while project cost is small)
- ***Education of Project Management***
  - Four Managements: "*Time, human resource, cost and risk*"
  - Team work, conflict resolution, discussion, documentation
  - International cooperation, negotiation, mutual understanding
- ***Also contributions to other technology areas !***