Day #2 01.21 21:00~23:00 (JST)

KiboCUBE Academy

Lecture 2-2

How to Make Your Satellite Survive in Space

University of Tokyo

Shinichi Nakasuka

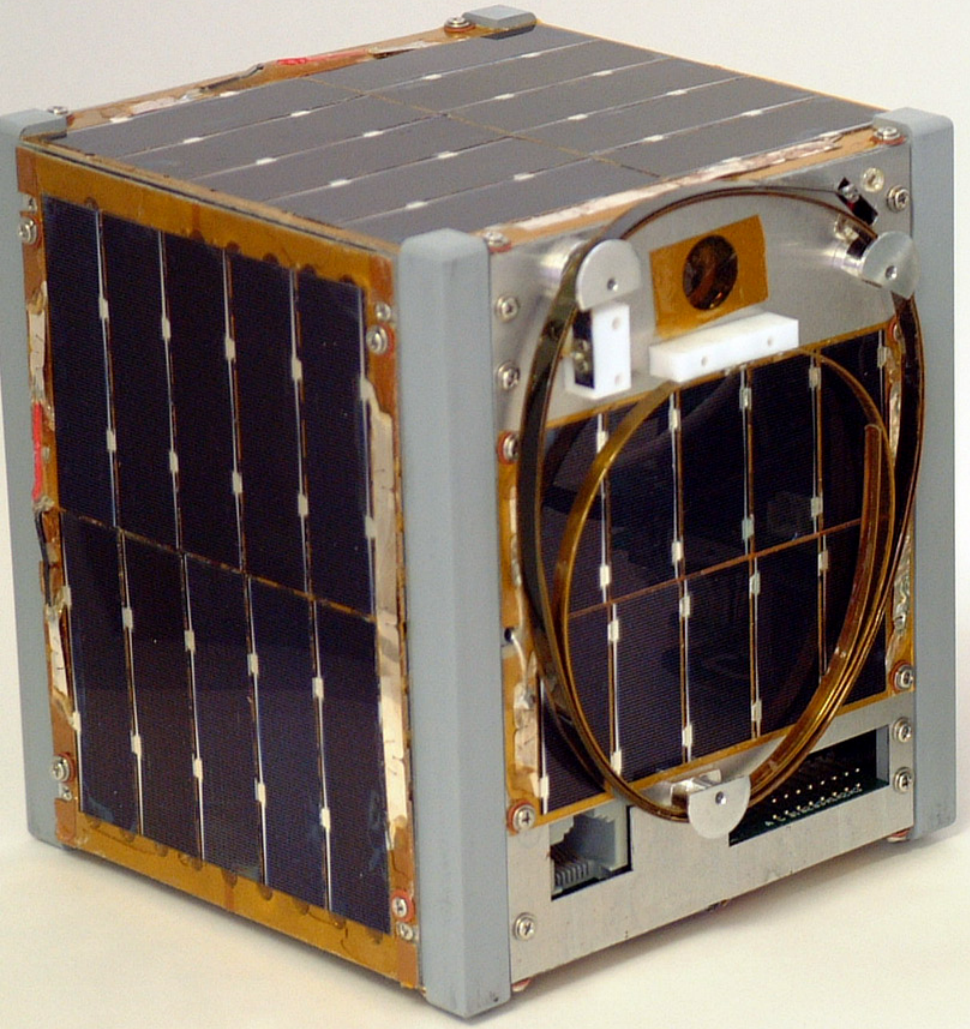
This lecture is NOT specifically about KiboCUBE and covers GENERAL engineering topics of space development and utilization for CubeSats.
The specific information and requirements for applying to KiboCUBE can be found at:
https://www.unoosa.org/oosa/en/ourwork/psa/hsti/kibocube.html

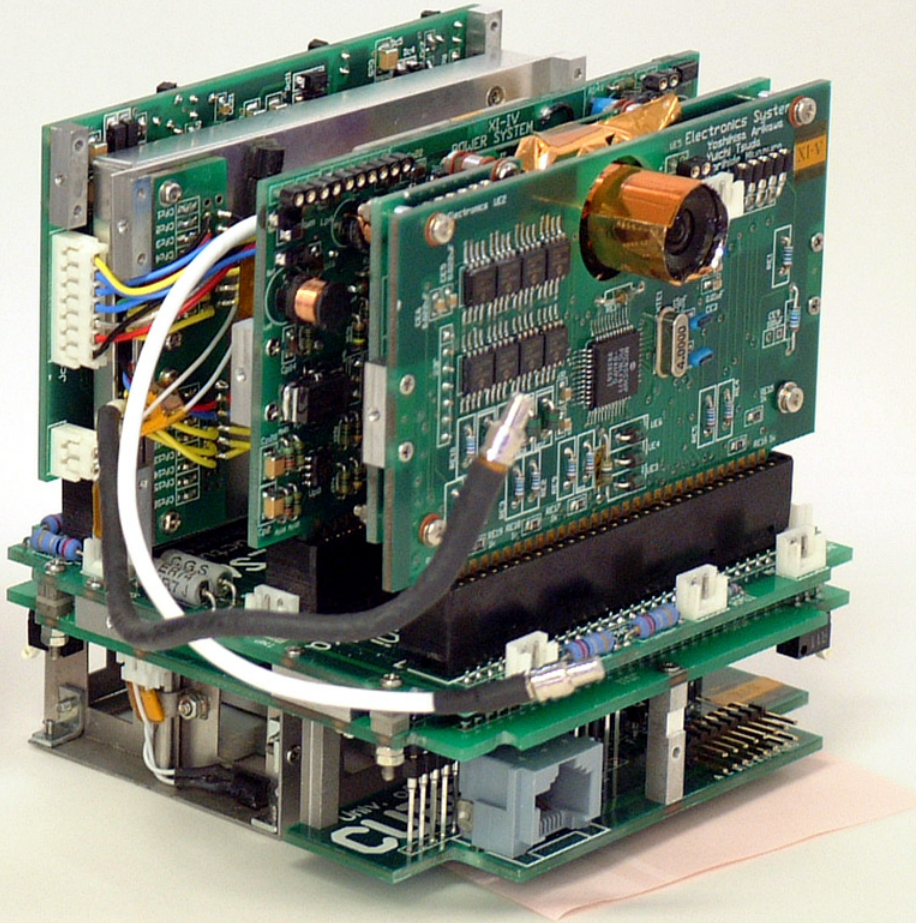
JAXA

UNISEC University Space Engineering Consortium JAPAN

United Nations Office for Outer Space Affairs ★ Japan Aerospace Exploration Agency
Kibo CUBE

University of Tokyo's CubeSat Project "XI"



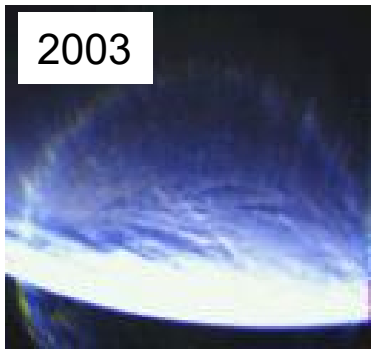


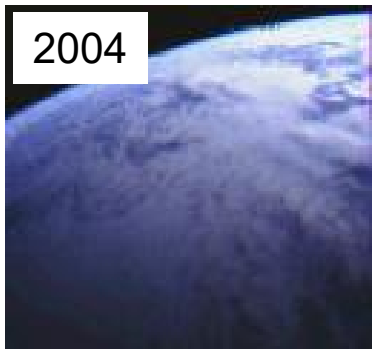
CubeSat "XI-IV" (Launched in Jun.2003)

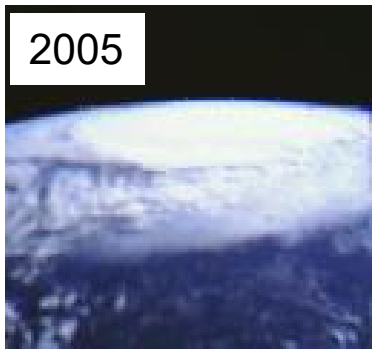
"XI-V" (Launched in Oct.2005)

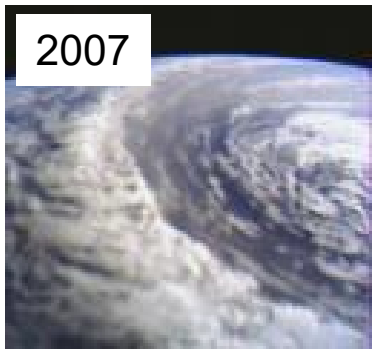
Survived for 17 years in orbit !

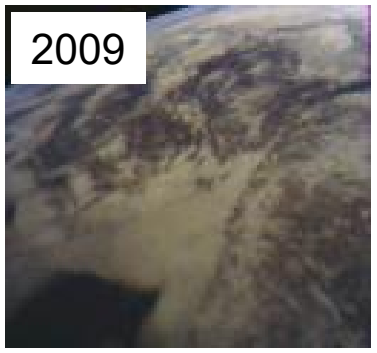
- Image by CMOS Camera onboard XI-IV -

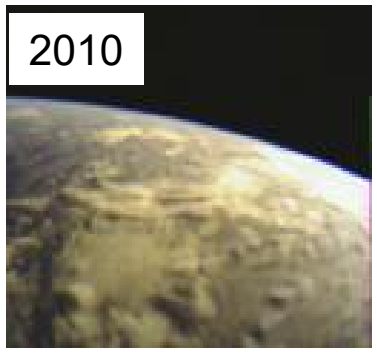


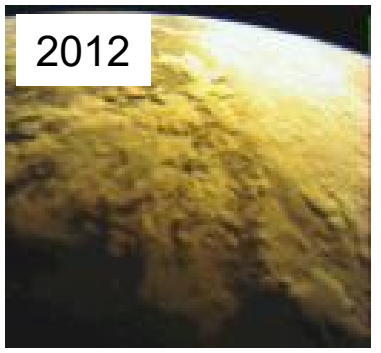


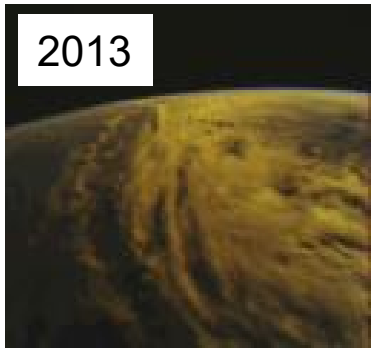


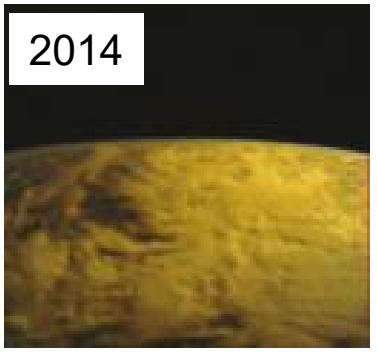


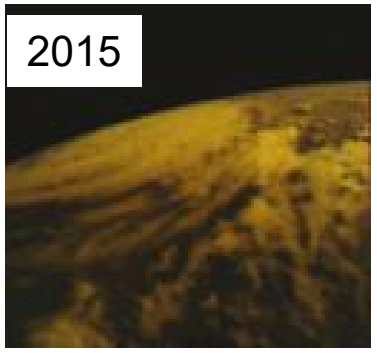


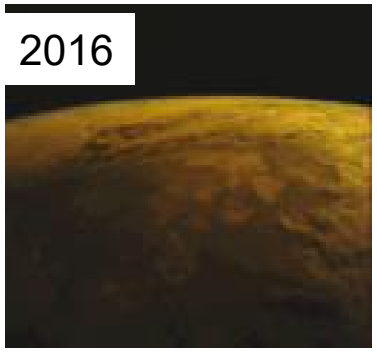


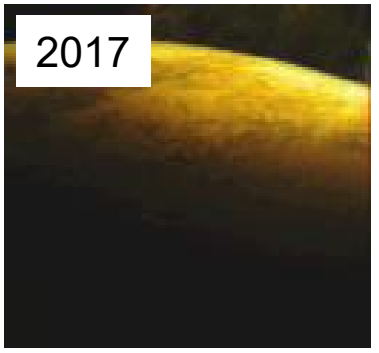






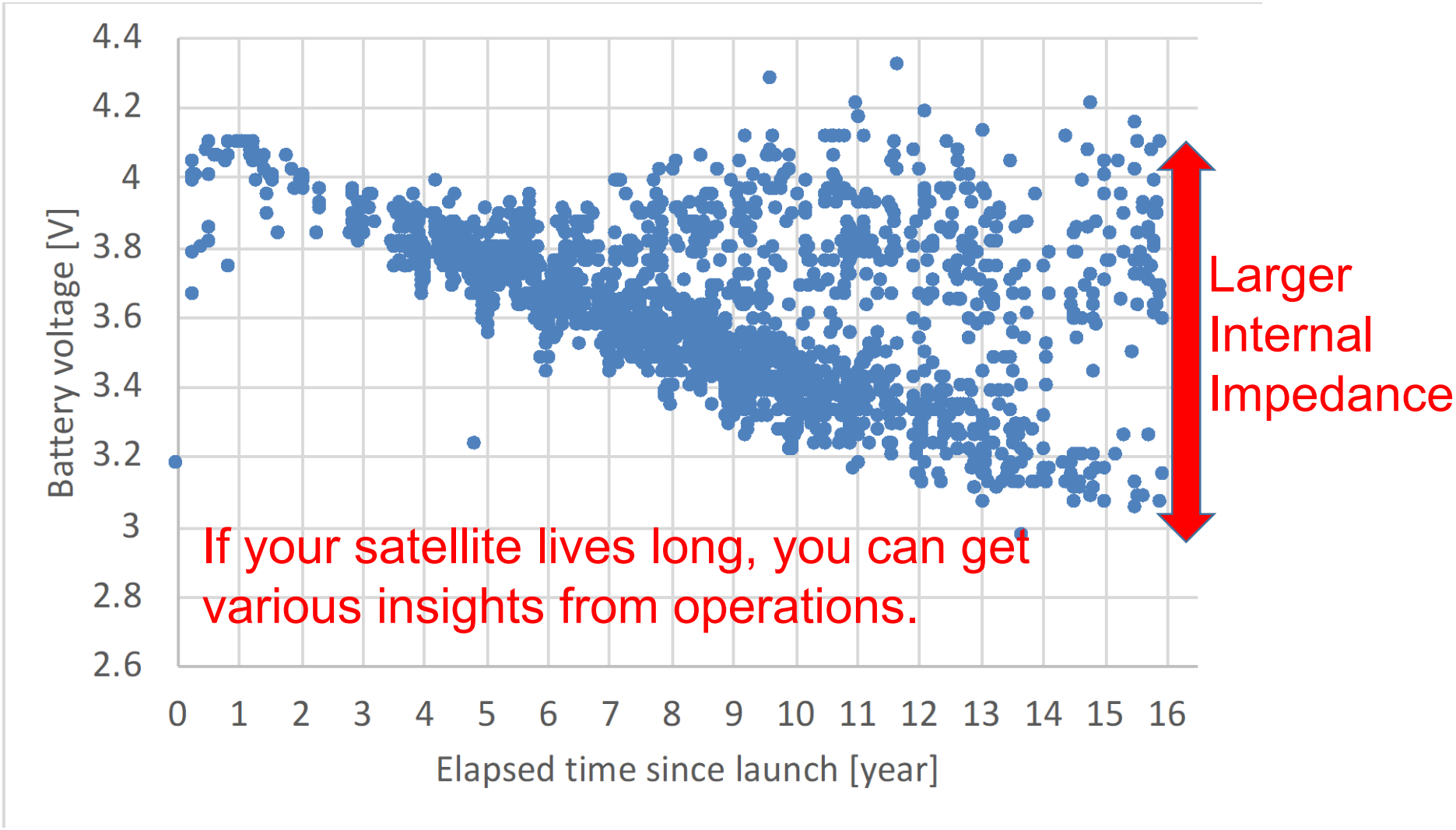






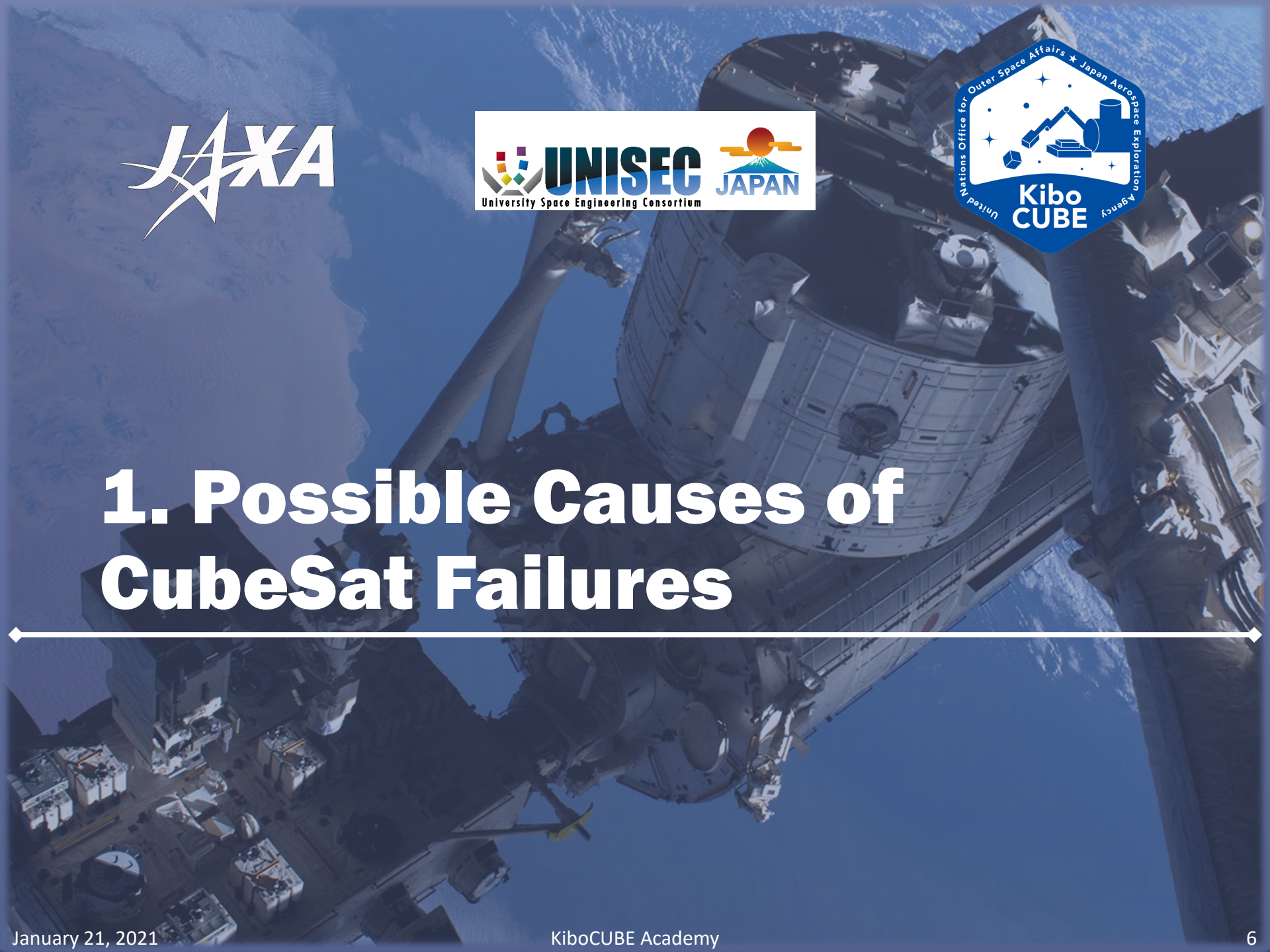
17-year trend in space

- Li-ion battery voltage history -



Contents

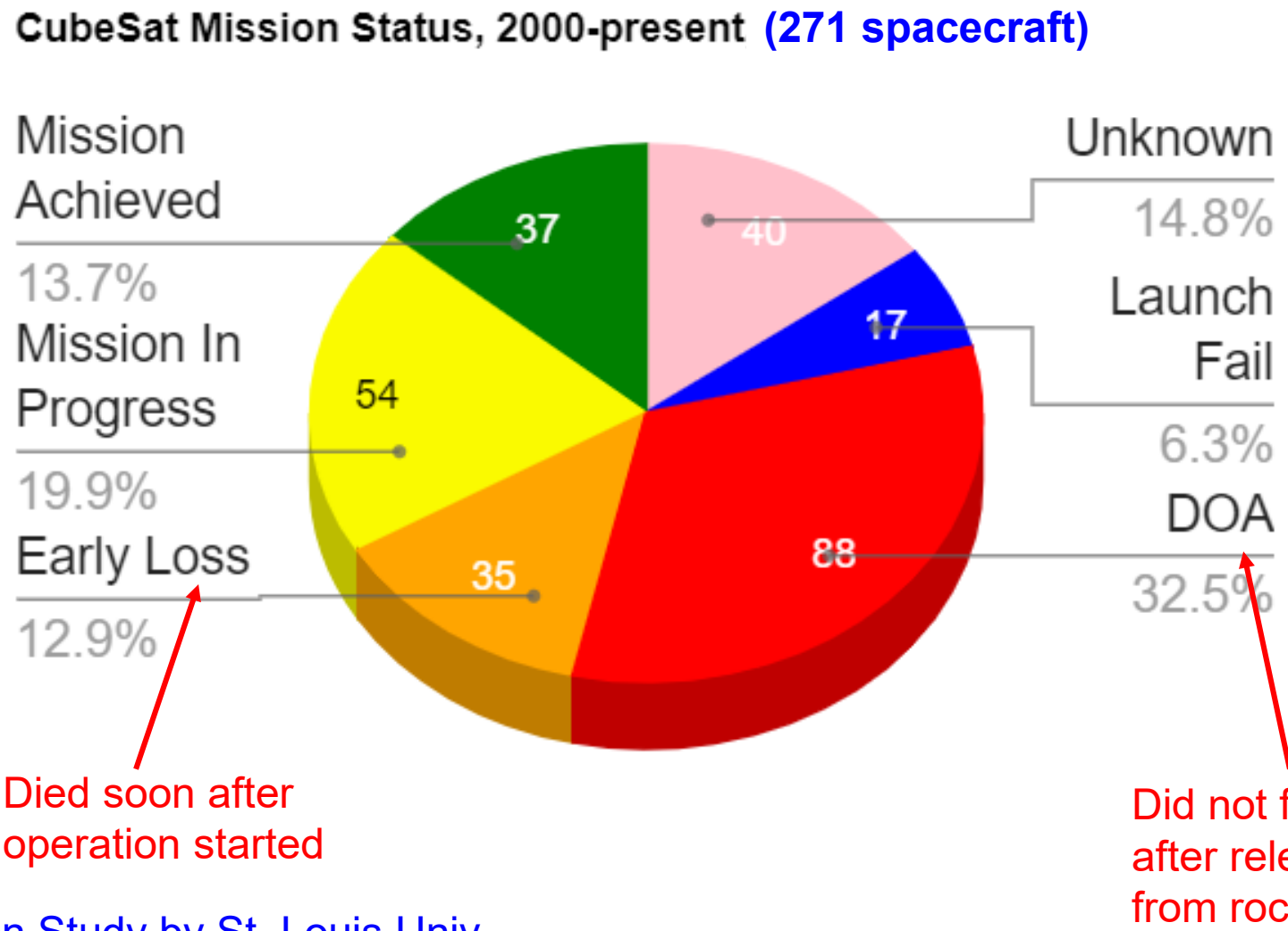
1. Possible causes of CubeSat failures
2. Why space systems are difficult ?
3. Make your satellite “Die Hard” !
4. Start with very simple satellite
5. Study and training before CubeSat
6. Define the target outcome of the project
7. Summary



1. Possible Causes of CubeSat Failures

Past Failures of CubeSat

Failure rate is about 50%



Based on Study by St. Louis Univ.
https://sites.google.com/a/slu.edu/swartwout/home/cubesat-database

Frequent Causes of Failure and Countermeasures

What should you take special care of ?

- Radiation causes electronics failures
  - ✓Use space-proven parts or conduct radiation tests
- Electric power subsystem fails to provide power, or battery voltage cannot be recovered
  - ✓Design satellite behaviors under low battery voltage
  - ✓Make solar power generation possible in any situation
- Communication subsystem fails to communicate with ground station because of insufficient RF power or EMI (Electro Magnetic Interference), etc.
  - ✓Calculate link equation correctly and add enough link margin
  - ✓Conduct ground tests using EM or FM in realistic situation
  - ✓Find and consult communication technology experts

2. Why Space Systems are Difficult ?

Why space system is difficult?

- Harsh Space Environments -

■ Vacuum	Vaporization, cold welding, friction, electric discharge, change of material, heat spot….
■ Radiation	Electronics parts malfunction and breakdown, degradation of solar cells and materials…..
■ Thermal	Large temperature differences/cycles, heat shock, heat spot…..
■ Launch	Vibration, shock, acceleration, sound vibration…..
■ Distance	Long range communication over 500-2000km…..

Others: Atomic Oxygen, Plasma, Debris/Meteoroids, Ultraviolet rays

“Non-maintainable System”

How to prepare countermeasures ?

- A satellite cannot be touched until the end of its life once it is launched.:

  called “non-maintainable system”

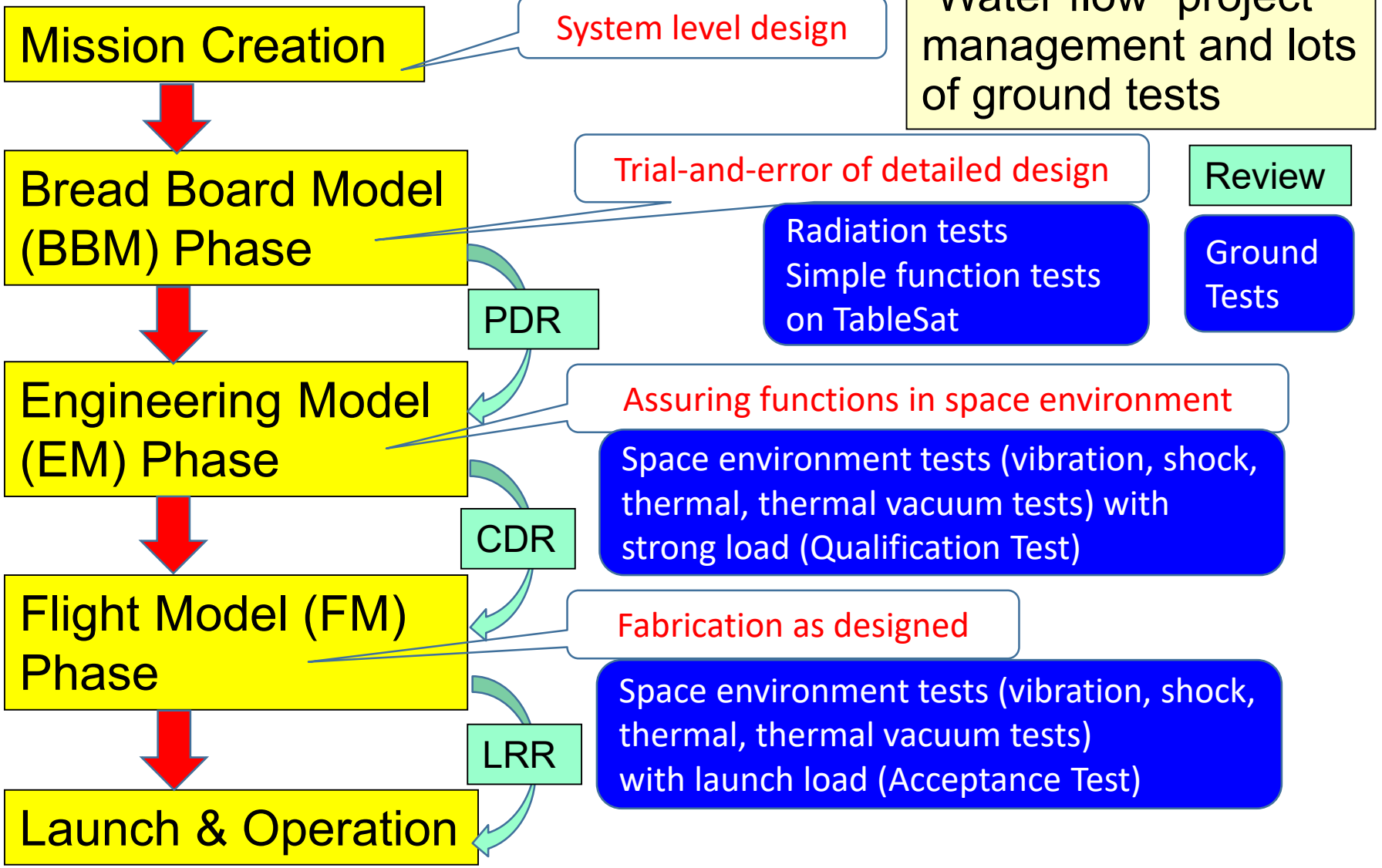
- Sometimes a satellite should survive in space for more than 10 years without any human interactions. Therefore……

- Imagine all the possible events and anomalies which may happen to your satellite and prepare countermeasures for them

- Conduct ground tests in various settings to ensure proper functioning of your satellite in space environment in various operation modes

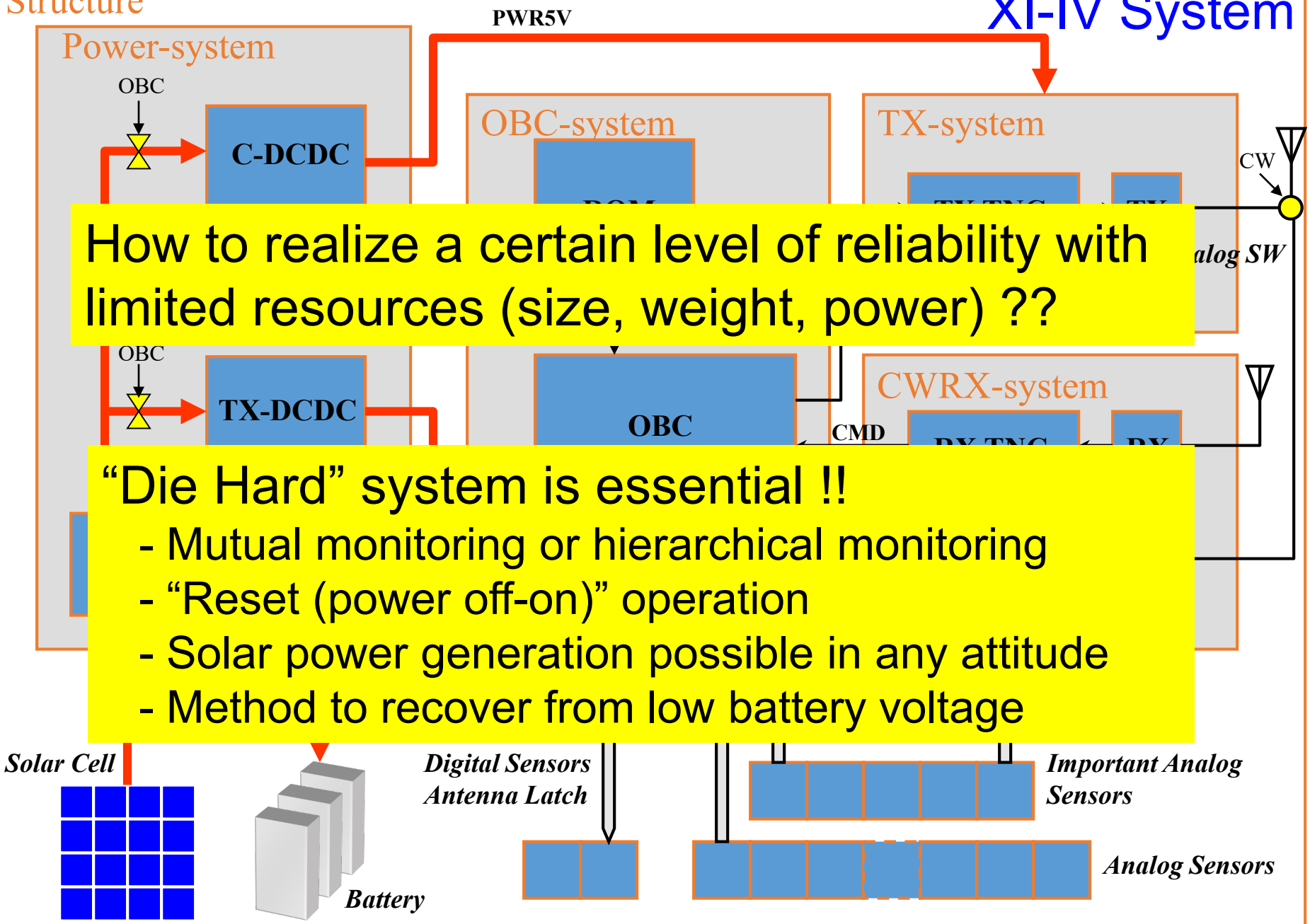
3. Make Your Satellite “Die Hard” !

Water Flow Type Project Management



“Table-sat” assures proper functionalities and connections between components

XI-IV System

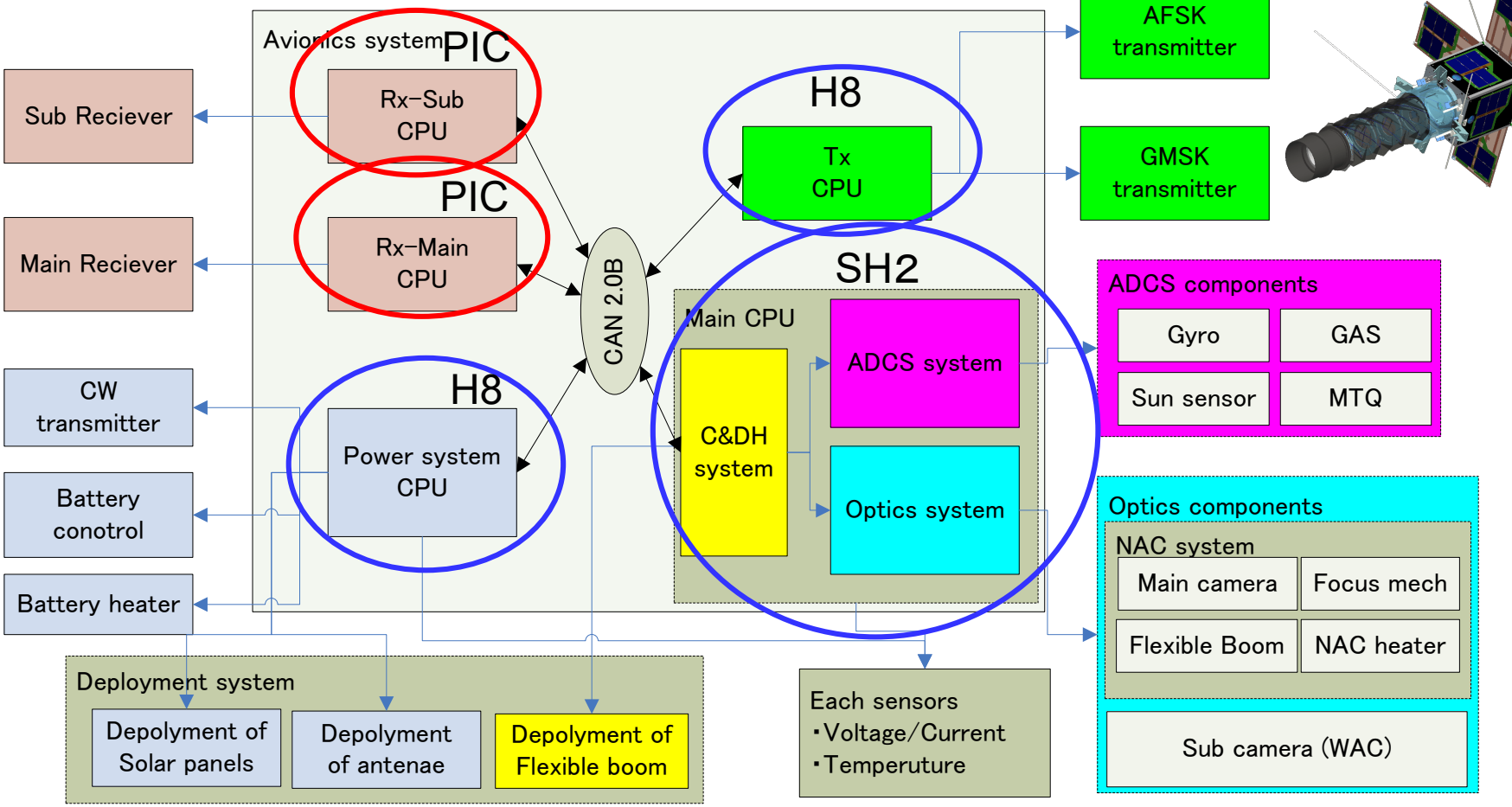


How to realize a certain level of reliability with limited resources (size, weight, power) ??

"Die Hard" system is essential !!

- Mutual monitoring or hierarchical monitoring
- "Reset (power off-on)" operation
- Solar power generation possible in any attitude
- Method to recover from low battery voltage

PRISM System Diagram

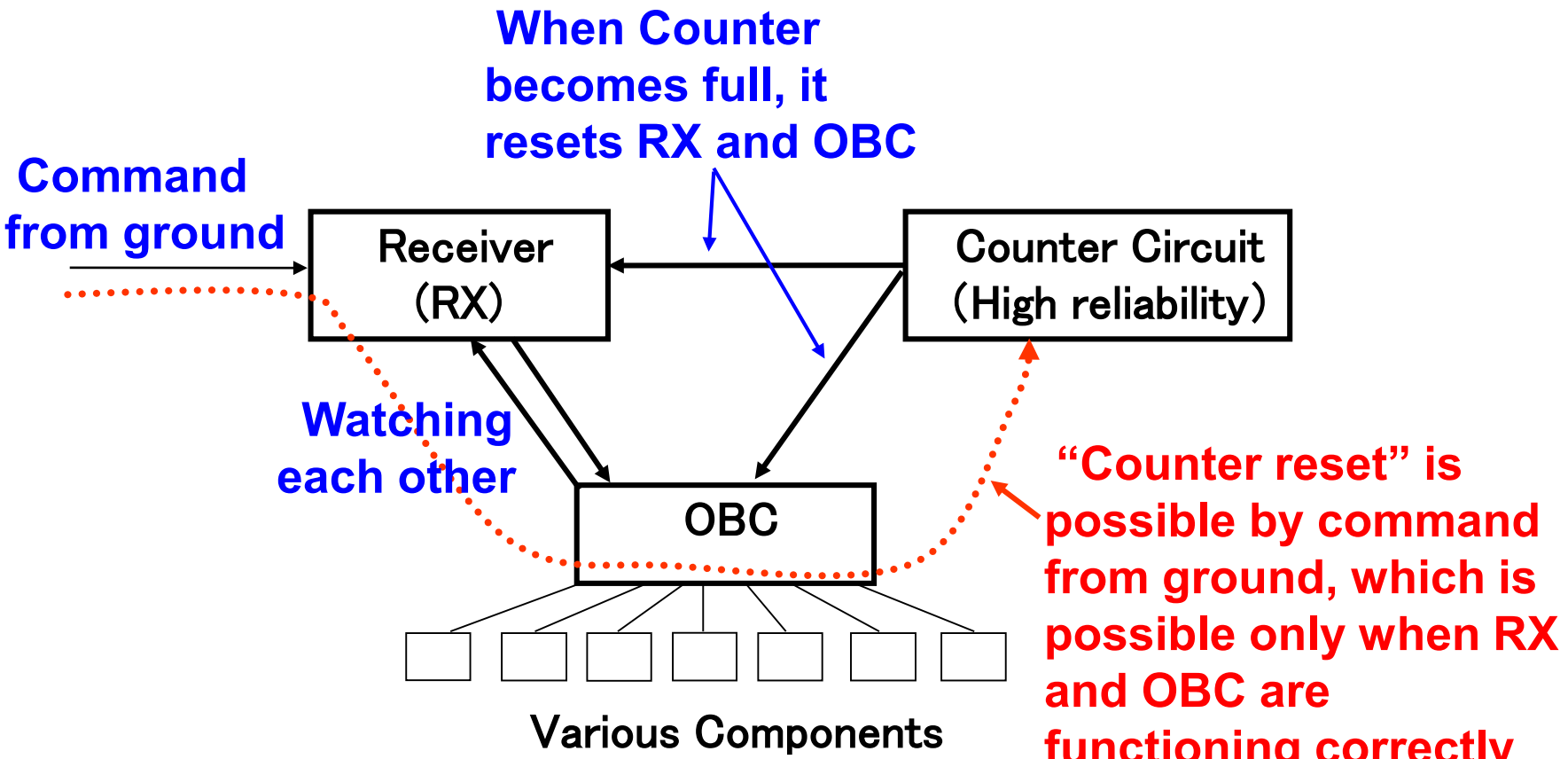


Combination of "High performance but may-be-weak" processor and "Low performance but very robust and space-proven" processor

Example of Useful “Reset” Mechanism

Usage of Counter Circuit

One thoughtful idea to use “counter circuit” for reset mechanism



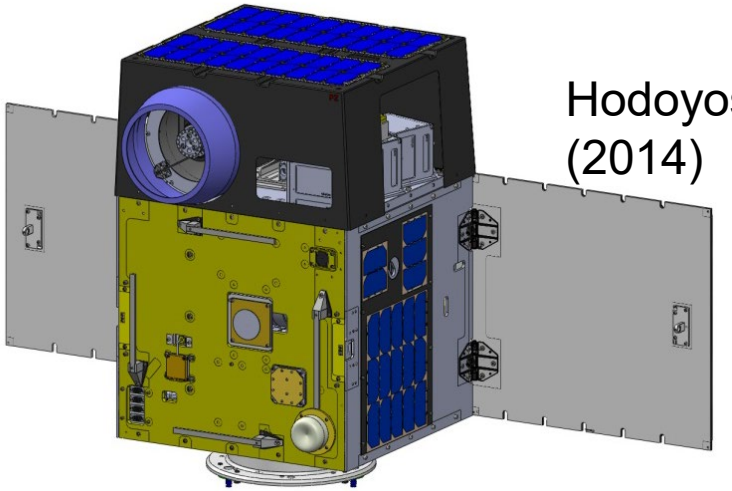
Use Reliable Communication System

You should somehow communicate with satellite.

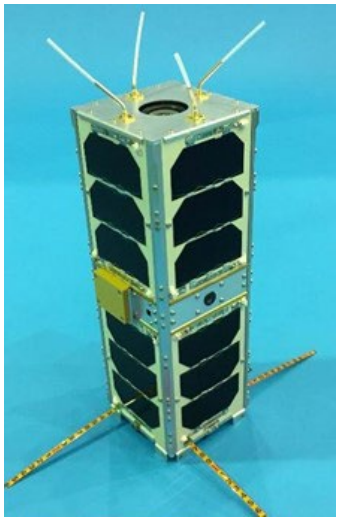
- "Center line" is very important !
  - Assure functioning of Ground station ⇒ Receiver ⇒ OBC route
  - Should use reliable CPU inside receiver
  - It is recommended that command from ground can reset components without using OBC
- Design effective antennae
  - Antenna should be stowed during launch and take proper shape after deployment
- Even if any components fail, some information should be downlinked to ground
  - CW beacon can be used as a backup for telemetry downlink
- Functional redundancy
  - If you use S-band for house keeping and X-band for mission data, but in case of S-band failure, X-band can also be used for house keeping telemetry downlink

Solar power generation in any attitude

Solar paddle type vs. Body mount type



Hodoyoshi-4
(2014)

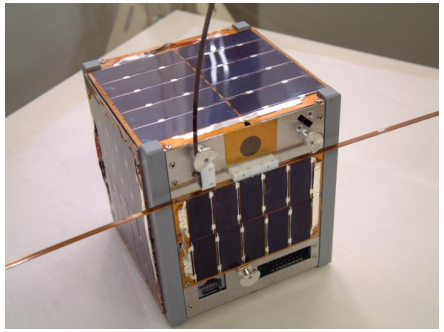


TRICOM-1R
(2018)

- ● Very large power generation
- ✓ Power generation is possible only when attitude control works

- ✓ Limited power generation
- ● Power generation is possible regardless of attitude

For 1U CubeSat, body mounted cells on all the 6 surfaces are recommended.



4. Start with Very Simple Satellite

“Simple” is Best

- In your 1st project, start with a simple and easy-to-realize type of mission, and if you still have additional time/budget, then try to consider additional mission
  - start from “KISS” = Keep It “Stupidly Simple”
- “Functioning CubeSat in space” in itself is an important mission.
  - Pursue survivability as much as possible
- Find out and pursue what you can do with your limited resources, not aiming at too high level
- Try to find external supporters
  - Technical consultation, testing facility, donation, etc.
  - Promotion of your activities to general public is important

5. Study and Training before CubeSat

Study and Training before CubeSat

What should you learn before developing CubeSat?

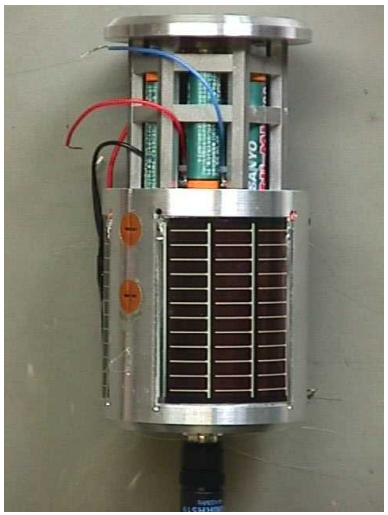
- Basic knowledge on mathematics, physics, rigid body dynamics, electronics, radio frequency…..
- Printed circuit board (PCB) design to realize certain functions
- Orbital mechanics, attitude dynamics/control and thermal/structure dynamics for space systems
- Practical training using “real” projects

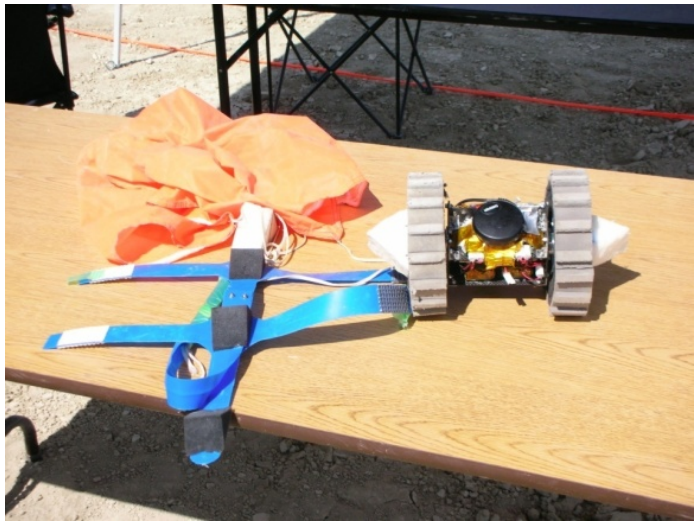
“CanSat” is an excellent tool

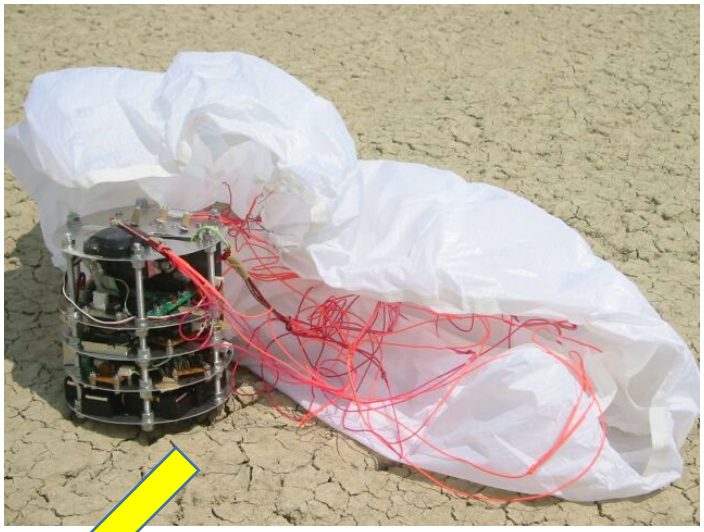
- Project management and team work
- System level design (weight/power budgeting, etc.)
- How to make “die hard” system
- Ground tests and operations from ground

Hands-on Training Tool: CanSat

Universities in Japan have been trained by CanSat.

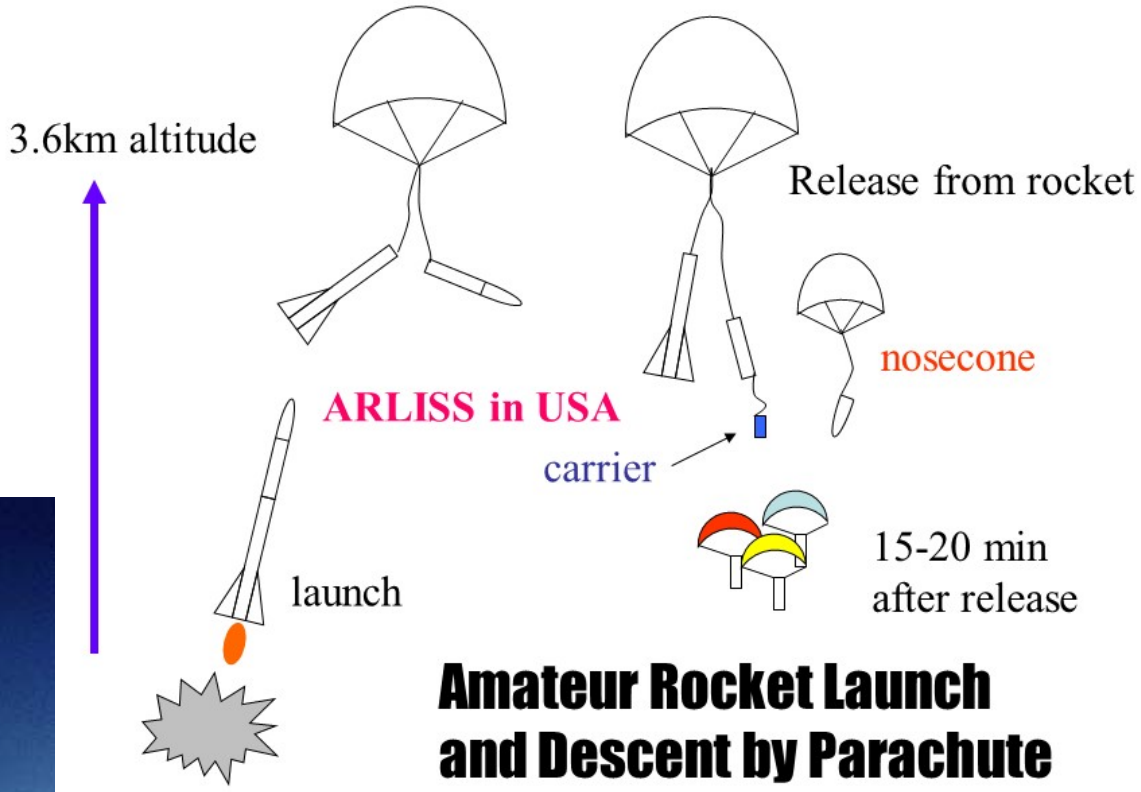






ARLISS: A Rocket Launch for International Student Satellites in Nevada, USA

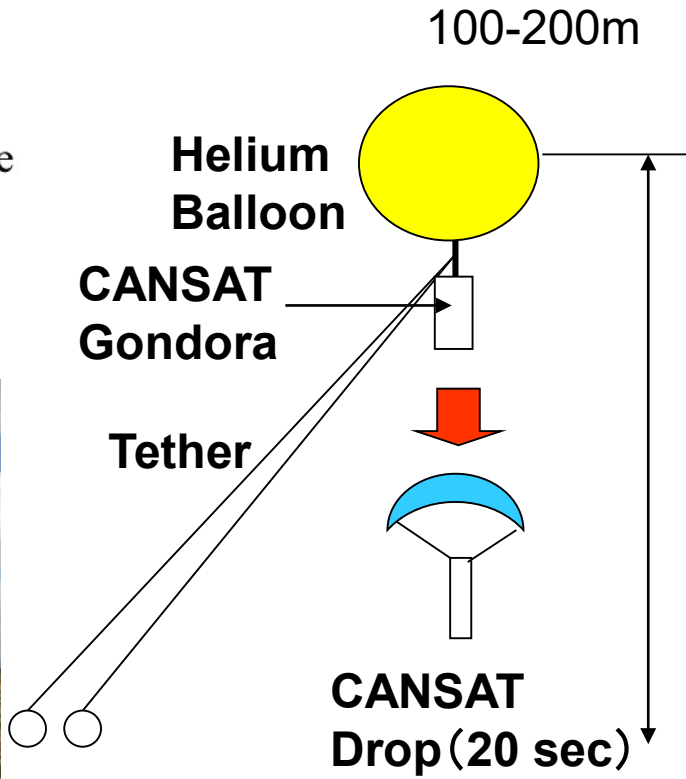
How to lift CanSat ?



Amateur Rocket Launch and Descent by Parachute

Drone or UAV are also used recently

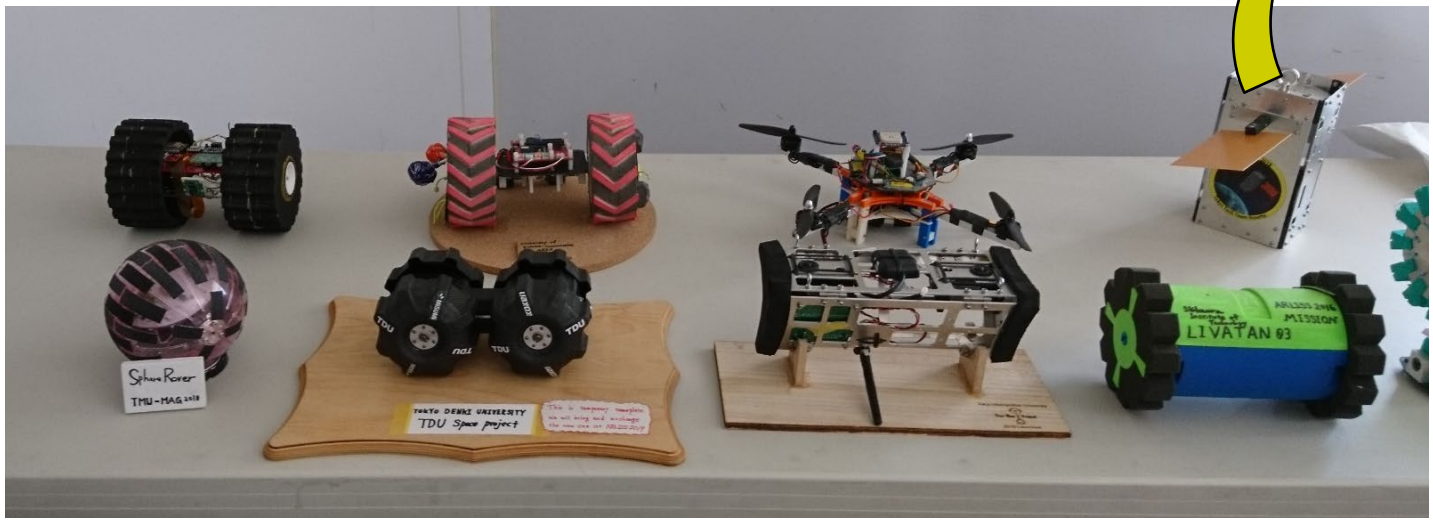
Simplest way: drop from high building

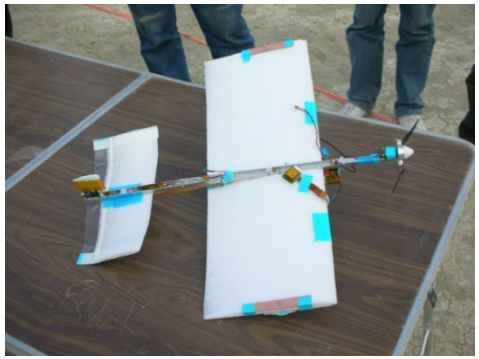


Example Mission “Comeback Competition”

CanSat International Competition in ARLISS

- Mission: to autonomously come back to the target point after release from rocket
  - Flyback-type vs rover-type





CLTP (CanSat education) History & Participants

CLTP1 (Wakayama Univ. in Feb-March, 2011)
12 participants from 10 countries, Algeria, Australia, Egypt, Guatemala, Mexico, Nigeria, Peru, Sri Lanka, Turkey (3), Vietnam.
CLTP2 (Nihon Univ. in Nov-Dec, 2011)
10 participants from 10 countries, Indonesia, Malaysia, Nigeria, Vietnam, Ghana, Peru, Singapore, Mongolia, Thailand, Turkey.
CLTP3 (Tokyo Metropolitan Univ. in July-August, 2012)
10 participants from 9 countries, Egypt (2), Nigeria, Namibia, Turkey, Lithuania, Mongolia, Israel, Philippines, Brazil.

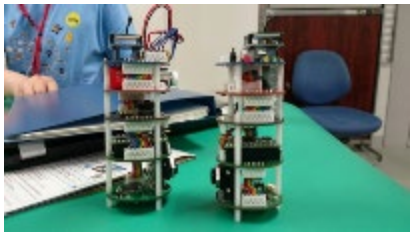
96 participants from 46 countries

<2013~ iCanSat Kit: CLTP4-7>

CLTP4 (Keio Univ. in July-August, 2013)
9 participants from 6 countries, Mexico(4), Angola, Mongolia, The Philippines, Bangladesh, Japan.
CLTP5 (Hokkaido Univ. in Sept, 2014)
7 participants from 5 countries, Korea (2), Peru, Mongolia, Mexico (2), Egypt.
CLTP6(Hokkaido Univ. in August, 2015)
8 participants from 8 countries, namely Angola, UN(Austria), New Zealand, Tunisia, Turkey, Egypt, Bangladesh, Mexico
CLTP7 (Hokkaido Univ. in Sep, 2016)
8 from 7 countries, namely Egypt, Myanmar, Peru, Nepal (2), Mongolia, Serbia, Dominican Republic

<2017~ HEPTA-Sat Kit: CLTP8-10>

CLTP8 (Nihon Univ. in Sep, 2017)
9 from 7 countries, namely Bolivia, Egypt, El Salvador, Malaysia, Nepal, Turkey
CLTP9 (Nihon Univ. in Aug, 2018)
8 from 6 countries, namely Argentina, India, Japan, Malaysia, Mongolia, UAE
CLTP10 (Nihon Univ. in Aug, 2019)
15 from 11 countries, namely Australia, Bhutan, Bulgaria, Cambodia, Colombia, Kenya, Morocco, Myanmar, Peru, Rwanda, Zimbabwe



6. Define the Target Outcome of the Project

Various Options for Satellite Development

You can buy CubeSat components from websites easily. How to mix purchased components and ones of your own design ?

1) Assemble purchased components with fixed mission (i.e.,"kit") , do ground test and launch/operation

Option 1-1) Add one original mission with your own designed component

2) Create your own mission, buy components to realize it, do ground test and launch/operation

Option 2-1) Design/fabricate a few components

Option 2-2) Design/fabricate all the components

Find adequate option considering your team's expertise and your target outcomes.

Expertise to be Obtained by Project

What can you learn in each option ?

Options	Mission creation	Architec-ture design	System Analysis	Sub system design	Project manage-ment	AI&T	Ground operation
1)					s	s	L
Purchased Kit + design/fabrication of one original mission by yourself							
1-1)	s	s	s	s	s	L	L
2)	L	L	L		L	L	L
Original mission with purchased components + some designed components							
2-1)	L	L	L	s	L	L	L
2-2)	L	L	L	L	L	L	L

Note) **AI&T** **A**ssembly, **I**ntegration and **T**est "s":small effect "L":large effect

Various Skills to be Obtained

CubeSat or satellite project will give you……

- ***Practical Training of Whole Cycle of Space Project***
  - Mission conceptualization, satellite design, fabrication, ground test, modification, launch and operation
  - Know what is important and what is not.
- ***Important Experiences on Engineering***
  - "Synthesis" (not analysis) to realize your mission
  - Feedbacks from the real world to evaluate design, test, etc.
  - Learning from failures (while project cost is small)
- ***Education in Project Management***
  - Four Managements: "*Time, human resource, cost and risk*"
  - Team work, conflict resolution, discussion, documentation
  - International cooperation, negotiation, mutual understanding

- ***Also contributes to other technological areas !***

7. Summary

Keep these in mind !

- Survivability in space is the most important.
  Imagine as many possible failures as you can and prepare countermeasures against them.
- “Reset” is an effective way to recover your satellite from anomalies. Please prepare effective ways to do “reset”.
- Start with very simple CubeSat. After your first success, you can step up to more sophisticated satellites.
- Study various knowledge, skills and project management before developing a satellite. CanSat type hands-on training is very effective!
- Define the target outcome of your project. Only the launch and operation of your first satellite is not enough. You can get something and continue it to your next project.
- Have fun ! This spirit will provide you with energy, endurance and never-give-up mind !