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/htsi/kibocube.html
University of Tokyo’s CubeSat Project “XI”

Survived for 17 years in orbit!
- Image by CMOS Camera onboard XI-IV -
17-year trend in space
- Li-ion battery voltage history -

If your satellite lives long, you can get various insights from operations.

Larger Internal Impedance
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%**

CubeSat Mission Status, 2000-present (271 spacecraft)

- **Mission Achieved**: 37
- **Mission In Progress**: 54
- **Early Loss**: 35
- **Did not function after release from rocket**: 88
- **Died soon after operation started**: 40
- **Unknown**: 14.8%
- **Launch Fail**: 6.3%
- **DOA**: 32.5%

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 (Electromagnetic 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

Mission Creation

Bread Board Model (BBM) Phase

Engineering Model (EM) Phase

Flight Model (FM) Phase

Launch & Operation

System level design

“Water flow” project management and lots of ground tests

Trial-and-error of detailed design

Radiation tests
Simple function tests on TableSat

Review Ground Tests

Assuring functions in space environment

Space environment tests (vibration, shock, thermal, thermal vacuum tests) with strong load (Qualification Test)

Fabrication as designed

Space environment tests (vibration, shock, thermal, thermal vacuum tests) with launch load (Acceptance Test)
“Table-sat” assures proper functionalities and connections between components
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
Combination of “High performance but may-be-weak” processor and “Low performance but very robust and space-proven” processor
One thoughtful idea to use “counter circuit” for reset mechanism

Command from ground

When Counter becomes full, it resets RX and OBC

“Counter reset” is possible by command from ground, which is possible only when RX and OBC are functioning correctly
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

- 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?

Simplest way: drop from high building

Drone or UAV are also used recently

Amateur Rocket Launch and Descent by Parachute

ARLlSS in USA

3.6km altitude

Helium Balloon

CANSAT Gondora

Tether

100-200m

15-20 min after release

Release from rocket

nosecone

carrier

launch

January 21, 2021

KiboCUBE Academy
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.

<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

96 participants from 46 countries

<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?*

<table>
<thead>
<tr>
<th>Options</th>
<th>Mission creation</th>
<th>Architecture design</th>
<th>System Analysis</th>
<th>Sub system design</th>
<th>Project management</th>
<th>AI&amp;T</th>
<th>Ground operation</th>
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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    | 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               |

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**Note:**

**AI&T** Assembly, Integration and Test  
“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!