KiboCUBE Academy

Lecture 02

CubeSat for Capacity Building

Kyushu Institute of Technology

Laboratory of Lean Satellite Enterprises and In-Orbit Experiment

Director, Professor Mengu Cho, Ph.D.

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

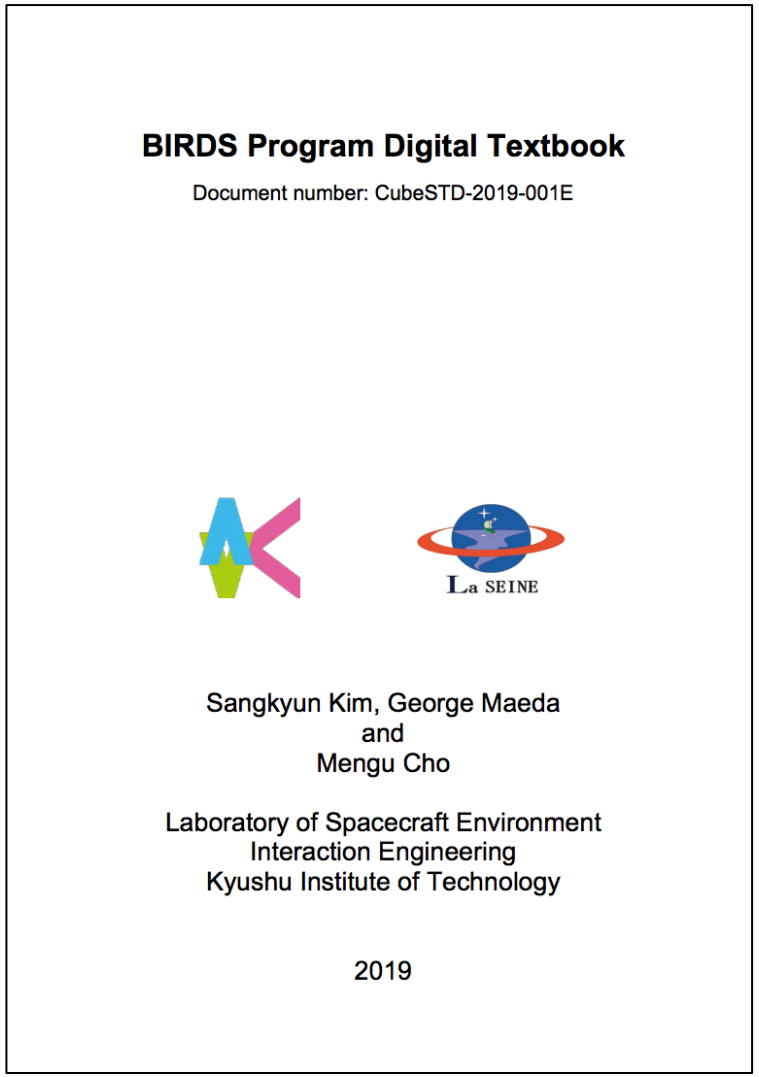
UNISEC University Space Engineering Consortium JAPAN

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

Contents

References

- BIRDS Program Digital Textbook
  - https://birds-project.com/mext/



BIRDS Program Digital Textbook

Document number: CubeSTD-2019-001E

La SEINE

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and
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Laboratory of Spacecraft Environment
Interaction Engineering
Kyushu Institute of Technology

2019

1. Lecturer introduction

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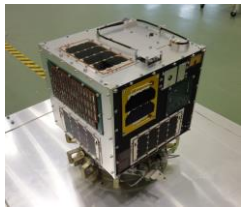
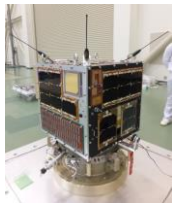
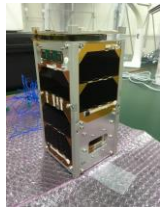
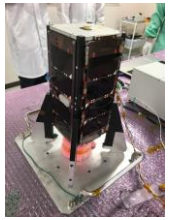






Mengu Cho, Ph.D.

Position:

2004 - Professor, Department of Space Systems Engineering*
Director, Laboratory of Lean Satellite Enterprises and In-Orbit Experiments **
Kyushu Institute of Technology, Japan
2021 – Visiting Researcher, Chiba Institute of Technology, Japan
2014 - Visiting Professor, Nanyang Technological University, Singapore
2013 - Coordinator, Nations/Japan Long-term Fellowship Programme, Post-graduate study on Nano-Satellite Technologies (PNST)

(*since 2018)
(**since 2020)

Correction: In video, I said that I have been working at Kyutech since 2004. But I have been working at Kyutech since 1996

Research Topics:
Lean Satellite, Spacecraft Environment Interaction

2. Demand for capacity building

2. Demand for capacity building

2.1 Small satellite proliferation

No.	Country	Satellite name	Launch Year
1	Columbia	Libertad 1	2007
2	Switzerland	SwissCube	2009
3	Hungary	Masat-1	2012
4	Romania	Goliat	2012
5	Poland	Pwsat 1	2012
6	Ecuador	NEE-01 Pegaso	2013
7	Estonia	EstCube 1	2013
8	Peru	PUCPSat-1	2013
9	Lithaunia	LitSat 1 LitaunicaSat 1	2014
10	Uruguay	Antelsat	2014
11	Iraq	Tigrisat	2014
12	Finland	Aalto 2	2017
13	Bangladesh	BRAC Onnesha	2017
14	Ghana	Ghanasat-1	2017
15	Mongolia	Mazaalai	2017
16	Slovakia	SKCUBE	2017
17	Latvia	Venta-1	2017
18	Kenya	1KUNS-PF	2018
19	Costa Rica	Irazu	2018
20	Bulgaria	EnduroSat One	2018
21	Bhutan	BHUTAN-1	2018
22	Jordan	JYAT (JO-97)	2018
23	Sri Lanka	Raavana 1	2019
24	Nepal	NepaliSat-1	2019
25	Rwanda	RWASAT-1	2019
26	Guatemala	Queztzal-1	2020
27	Slovenia	TRISAT	2020
28	Monaco	OSM-1 CICERO	2020

List of CubeSats launched as the first national satellite

2. Demand for capacity building

2.2 Issues of capacity buiilding activities

- Small satellites are ideal entrance for developing countries to join the space sector
- Demand for capacity building through small satellites
- Various training programs via agencies, companies and universities in space faring countries
  - Often tied with sales of satellites (big or small)
  - Not successful, especially if the training is done in agencies or companies
    - Lack of hands-on experience
    - Not covering the entire system life cycle of satellite
- Key points
  - Experience the **complete cycle** of designing, building, testing and operating through **hands-on**
  - Strategy for **sustainability** after the training

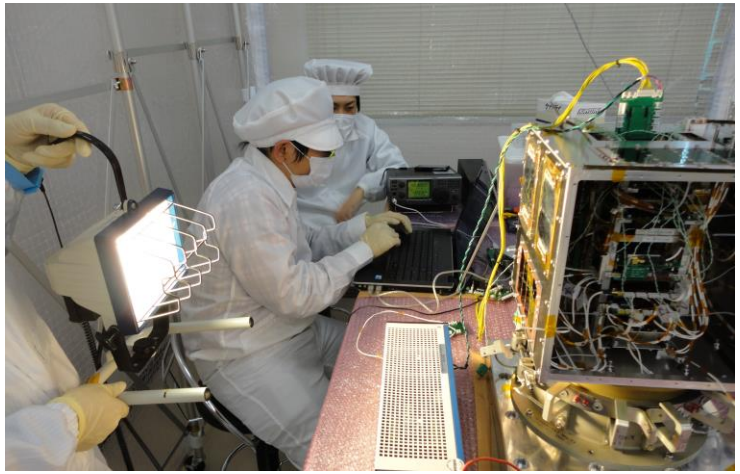
3. Capacity building activities at Kyutech

3. Capacity building activities at Kyutech

3.1 Space Engineering International Course (SEIC)

- Started in April 2013 at Graduate School of Engineering, Kyutech to support PNST

1. Research toward a Master or Doctoral degree
2. On-the-job training such as space environment testing workshop
3. Project Based Learning (PBL) through a space project
4. Space-related lectures in English



3. Capacity building activities at Kyutech

3.2 **UN/Japan Long-term Fellowship Programme**

- A part of United Nations Office of Outer Space Affairs (UNOOSA) Basic Space Technology Initiative (BSTI) since 2011
- 2011: Doctor on Nano-Satellite Technologies (DNST) initiated at Kyutech
  - 2 Doctoral students selected per year
  - Kyutech provided financial support
- 2013: **Post-graduate study on Nano-Satellite Technologies (PNST)** initiated
  - 2 Masters students selected per year
  - 4 Doctoral students selected per year
  - MEXT (Japanese government) fellowship support
- **2018 - : PNST 2nd and 3rd term**
  - 3 Masters students selected per year
  - 3 Doctoral students selected per year
  - MEXT (Japanese government) fellowship support
  - **Application Deadline: January 10, 2022 (for 2022 October admission)**

3. Capacity building activities at Kyutech

3.3 PNST/SEIC Student Composition

Country	Number of students	Country	Number of students	Country	Number of students
Nigeria	7	Vietnam	7	Paraguay	4
Ghana	4	Thailand	7	Mexico	3
Uganda	3	Philippine	7	Costa Rica	3
Egypt	3	Malaysia	5	Columbia	3
Zimbabwe	3	Indonesia	4	Peru	2
Sudan	3	Myanmar	2	Honduras	1
Algeria	2	Singapore	1	El Salvador	1
Ethiopia	1	Laos	1	Trinidad and Tobago	1
Kenya	1	Cambodia	1	Brazil	1
Namibia	1	China	1	Ukraine	2
Morocco	1	Mongolia	4	Romania	1
Turkey	3	Bhutan	6	France	9
Palestine	1	Bangladesh	4	Spain	2
		Sri Lanka	3		
		Nepal	3		
		India	1		

Distribution of foreign students enrolled up to 2021 October

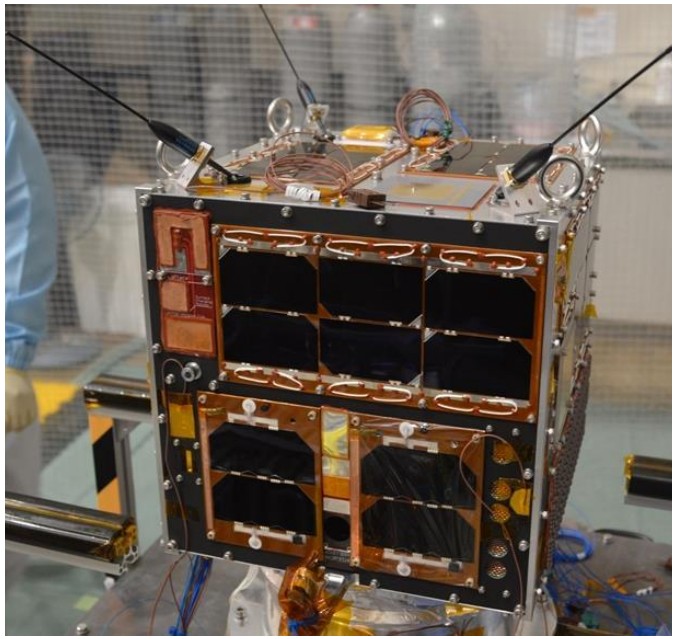
126 foreign students from 42 countries enrolled over 9 years

PNST/SEIC won Space Development Utilization Award (Minister of Foreign Affairs) in 2017

3. Capacity building activities at Kyutech

3.4 HORYU-IV Project (2013~)

This is a mock-up (not a real satellite)



Launched on Feb. 17, 2016

44 members from 18 countries
First and second generations of PNST/SEIC students

3. Capacity building activities at Kyutech

3.5 Kyutech meets Ghana

Visit by Dr. Donkor, All Nations University College, Ghana, to Kyutech (2015 5.21)

The idea for an international satellite project was born that night

3. Capacity building activities at Kyutech

3.6 BIRDS Program

Satellite program for non-space faring countries

Mission Statement

By successfully building and operating the first national satellite,
make the foremost step toward indigenous space program at each nation.

BIRDS-I (2015-2017)

JAPAN GHANA MONGOLIA NIGERIA BANGLADESH

BIRDS-II (2016-2018)

BHUTAN PHILIPPINE MALAYSIA

BIRDS-III (2017-2019)

SRI LANKA NEPAL JAPAN

BIRDS-IV (2018-2020)

PHILIPPINE JAPAN PARAGUAY

BIRDS-V (2020-2022)

JAPAN ZIMBABWE UGANDA

3. Capacity building activities at Kyutech

3.7 BIRDS program features

- 1U CubeSat constellation of
  - BIRDS-I: 5 satellites by **Bangladesh*, Ghana***, Japan, **Mongolia***, and Nigeria
  - BIRDS-II: 3 satellites by **Bhutan***, Malaysia and Philippine
  - BIRDS-III: 3 satellites by Japan, **Sri Lanka*** and **Nepal***
  - BIRDS-IV: 3 satellites by Japan, Philippine and **Paraguay***
  - BIRDS-V: 3 satellites by Japan, **Zimbabwe*** and **Uganda***
- Made by students at Kyutech
- 2 years from concept design to disposal
- Released from ISS
- Network operation by multiple ground stations

**** First satellite for the country***

Group photos of BIRDS-I, –II, –III, -IV and -V teams

3. Capacity building activities at Kyutech

3.8 Fit into 2 years

- A short-term goal
  - Build and operate satellites
    - Give the students **confidence** that they can do it
- Long-term goal
  - Students initiate their own space program in home countries
  - The full mission success
    - **The former students successfully build and operate the second satellite in their home countries**
- Let students learn **the entire process** of a satellite project from beginning to end
  - Witness each decision process and make decisions by themselves
- Fit the project within the degree timeline. 2 years longest
  - Selected 1U CubeSat and ISS launch as a platform
- ***What 1U CubeSat can do is limited. But it is more important to gain the confidence and the experience as the first step***

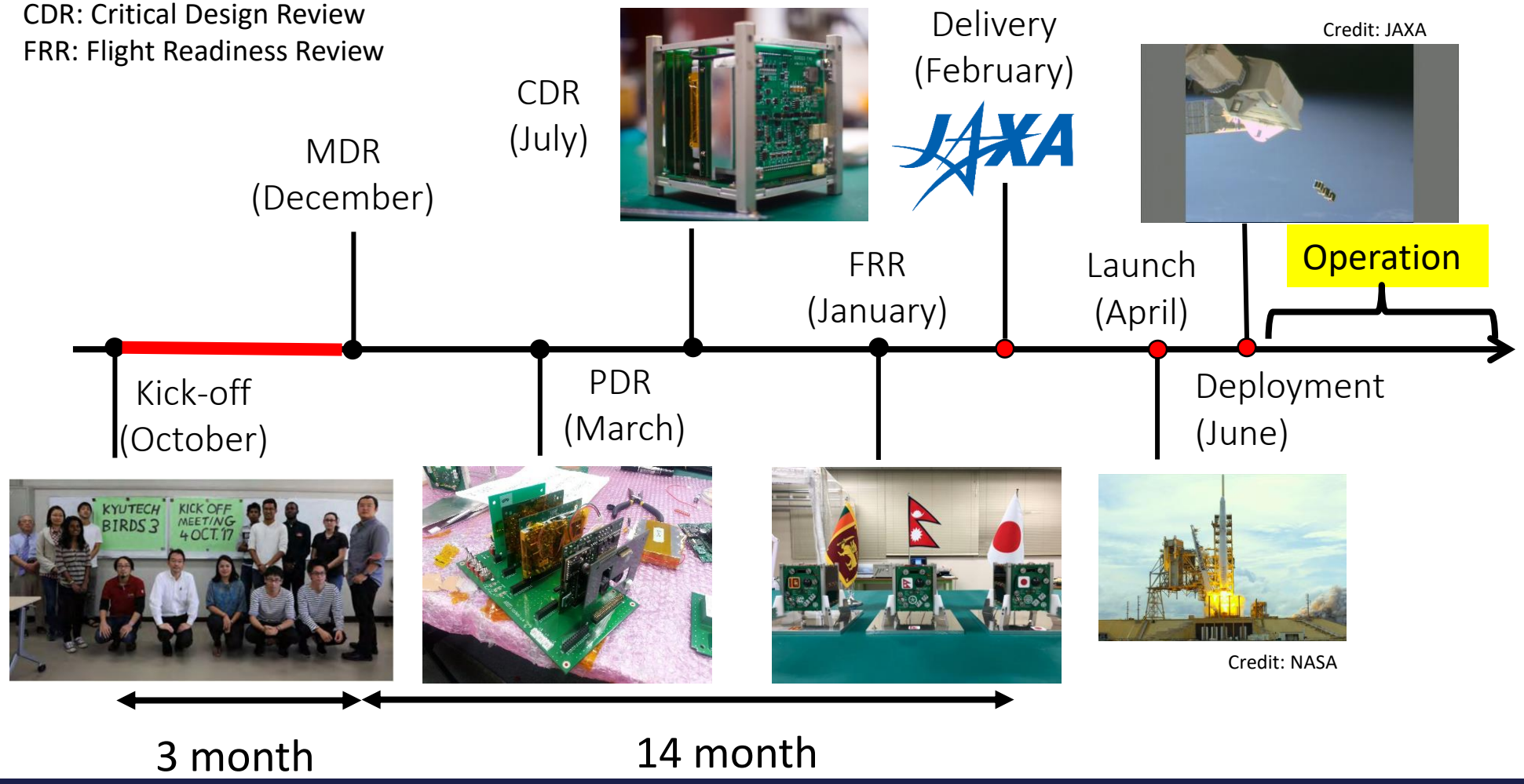
4. CubSat project timeline

4. CubeSat project timeline

4.1 What do we do in 2 years?

MDR: Mission Definition Review
PDR: Preliminary Design Review
CDR: Critical Design Review
FRR: Flight Readiness Review

Example of BIRDS projects



4. CubeSat project timeline

4.2 Mission definition (first three months)

- Do not make a satellite that you want. Make a satellite that people want.
- Three steps. Requirements. From Top to Bottom
- Top
  - What do country, people, society, economy, etc., need?
  - Space is not relevant.
  - Ranking of needs
  - Agriculture, energy, mining, fishing, society, security, ****
  - Prioritize the needs
- Can space help solve the problems?
  - Big satellite, small satellite, by any means.
  - Combination with ground, air (UAV) assets
  - Space can be only part of the overall solution
- Can we use CubeSat(s) as the solution?
  - Direct solution
  - Demonstration of technology or proof-of-concept
    - Key technology, Key idea

Go through this process at the beginning. No need to touch any hardware.

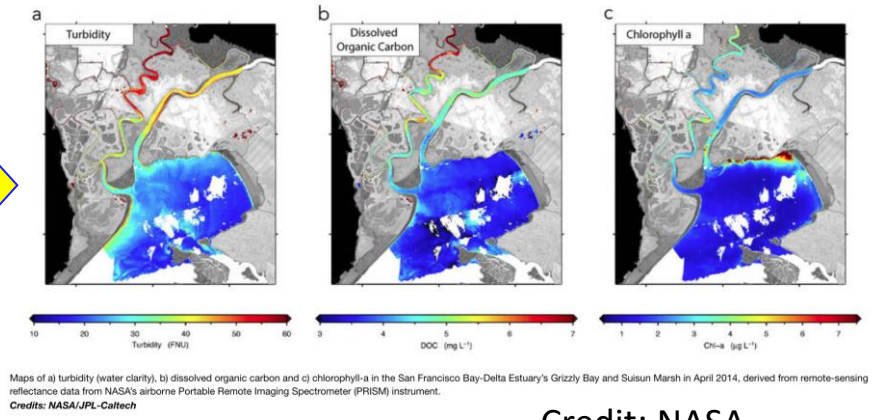
4. CubeSat project timeline

4.3 Mission definition (Example)

poverty
environment
safety
water
agriculture
mining
health

Drinking water

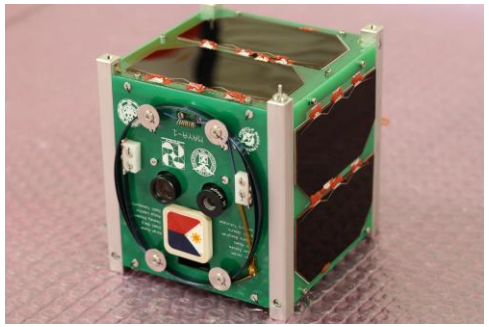
Water quality monitoring by satellite images



Maps of a) turbidity (water clarity), b) dissolved organic carbon and c) chlorophyll-a in the San Francisco Bay-Delta Estuary's Grizzly Bay and Suisun Marsh in April 2014, derived from remote-sensing reflectance data from NASA's airborne Portable Remote Imaging Spectrometer (PRISM) instrument.
Credits: NASA/JPL-Caltech

Credit: NASA

Credit: NASA



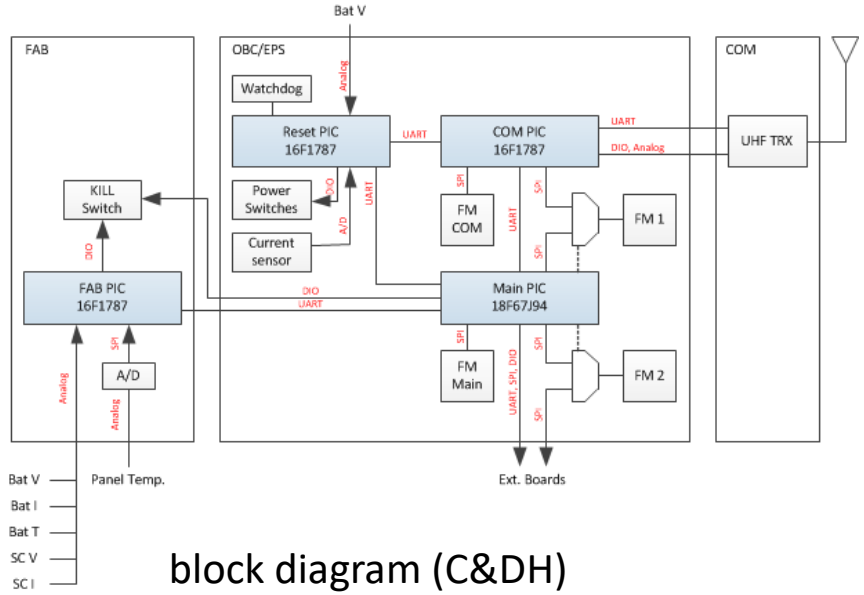
Multi-spectral observation of water resource

Domestic data analysis and distribution

4. CubeSat project timeline

4.4 Satellite configuration design

- Mission is defined
- How do we do the mission?
- Write the mission scenario
- Is the mission scenario feasible by 1U CubeSat?
- What components do we need?
- Do we buy the components or make them by ourselves?
- Can all the components fit into 1U volume?
- Draw the satellite system block diagram



block diagram (C&DH)

CAD design

4. CubeSat project timeline

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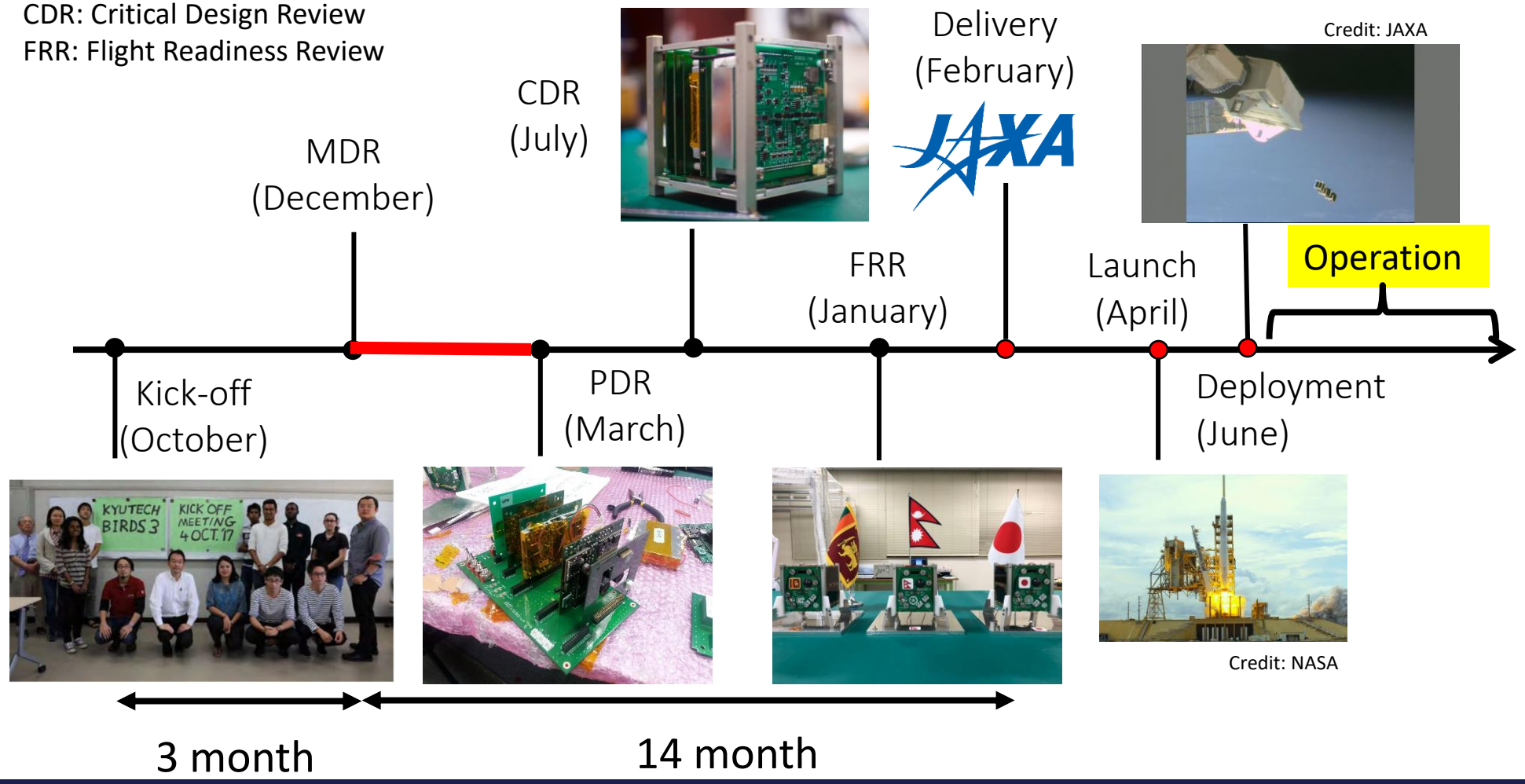
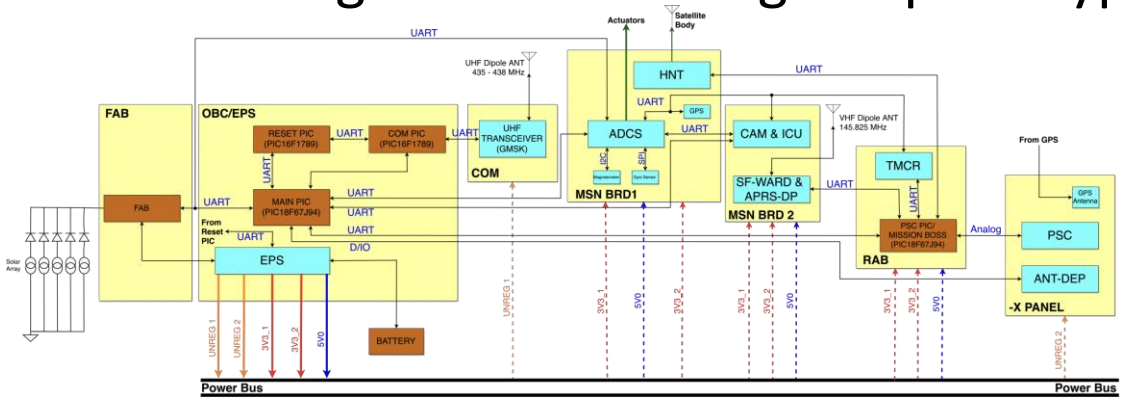


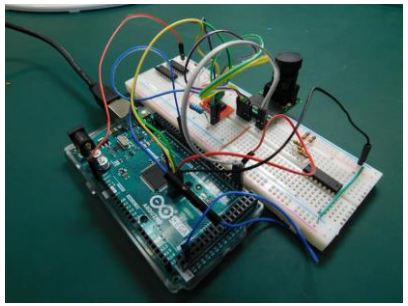
4. CubeSat project timeline

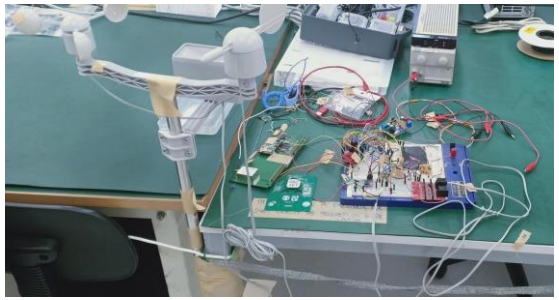
4.5 Proof of concept

- Make sure that the missions are possible by checking with actual hardware as much as possible
- Detailed satellite design before making the prototype (Engineering Model)

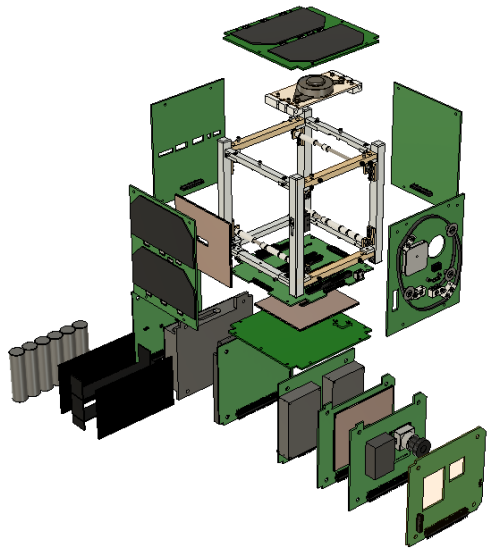


Detailed interface definition





Test with bread board models (BBM)



Detailed CAD model

4. CubeSat project timeline

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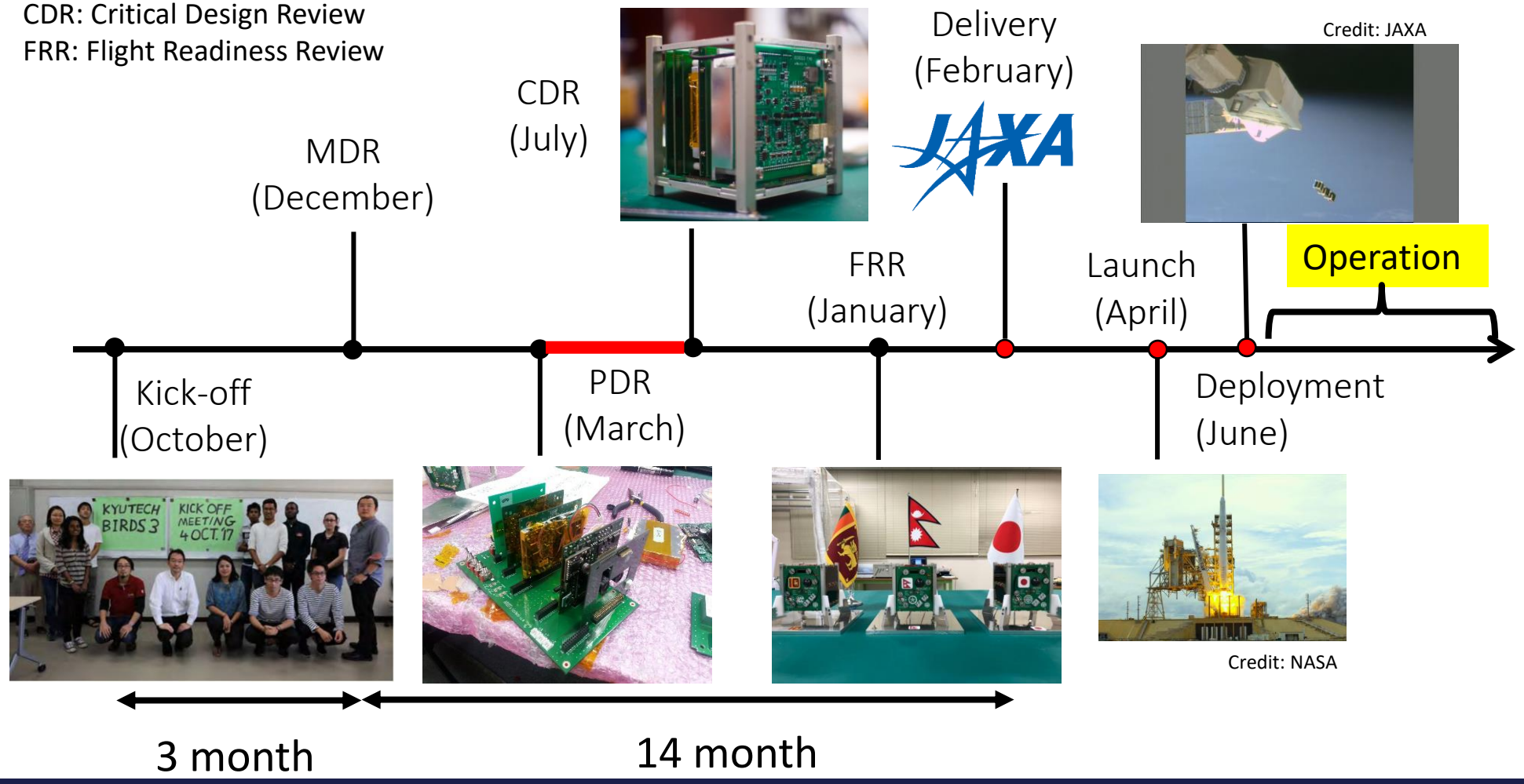
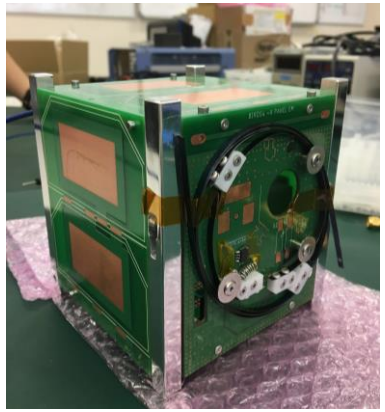
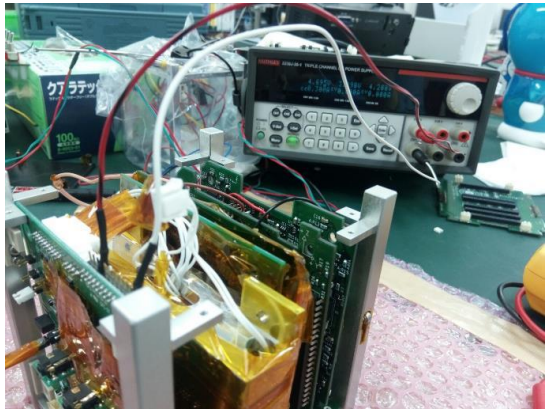
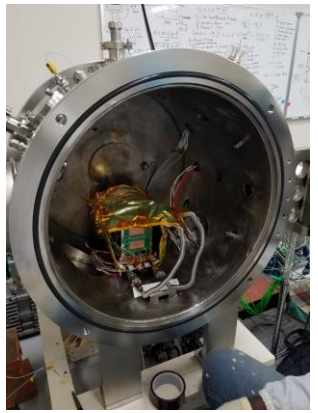
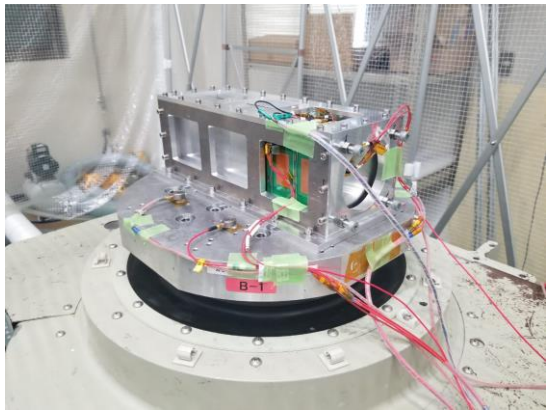
Example of BIRDS projects



4. CubeSat project timeline

4.6 Design verification by prototype

- Make a prototype (Engineering Model, EM)
- Verify that the satellite **system** design is good by checking
  - Functionality
  - Environment durability
- Uncover interface incompatibility issues
- Do not forget software development and the ground station
- Safety Review Phase 0/1/2 before moving to FM (takes at least one month)

Test with Engineering Model (EM)

4. CubeSat project timeline

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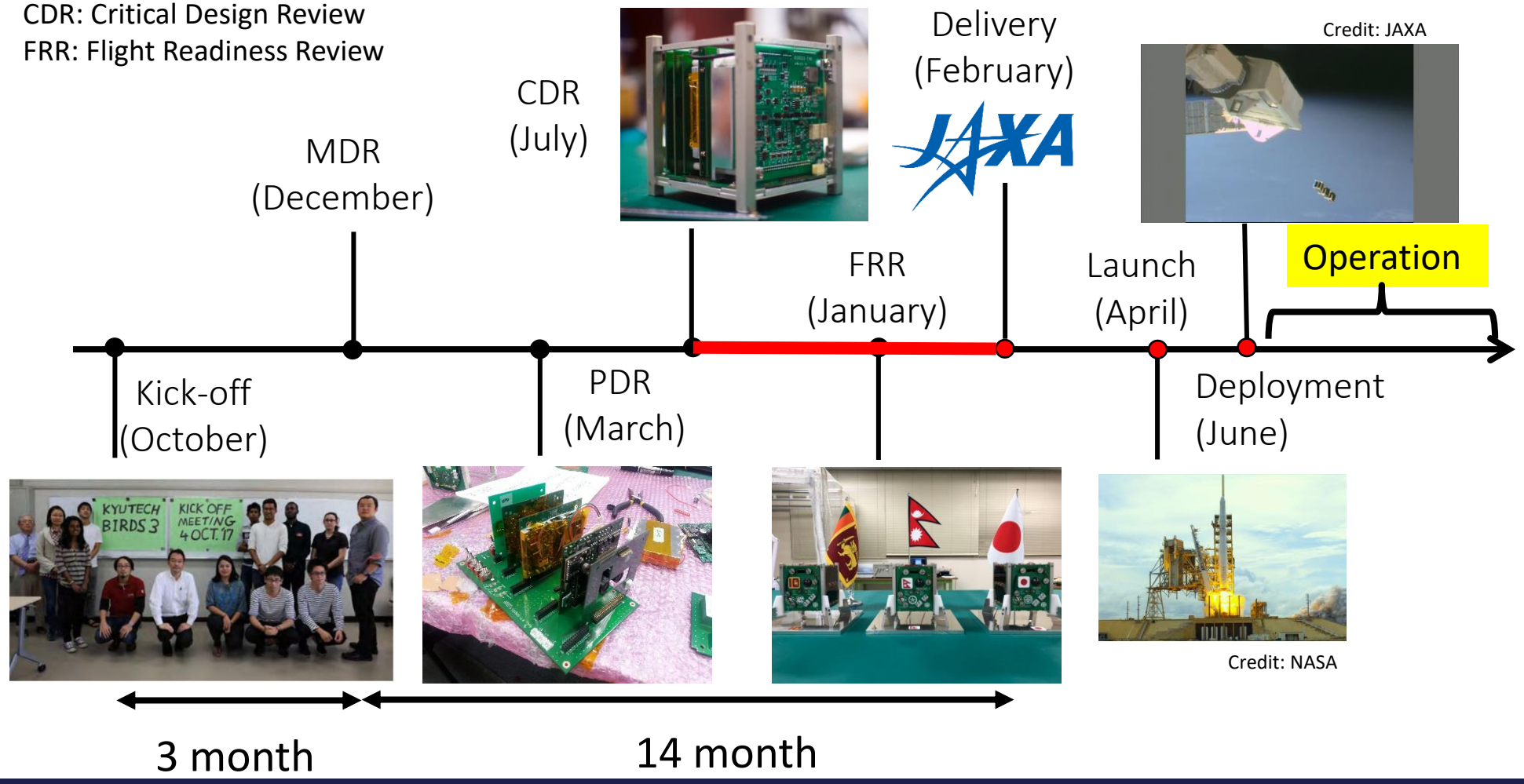
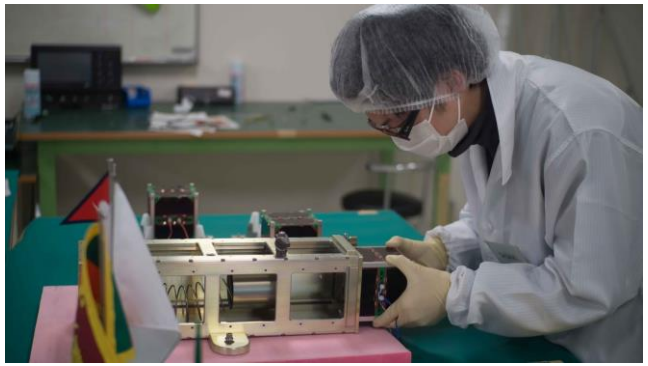
Example of BIRDS projects

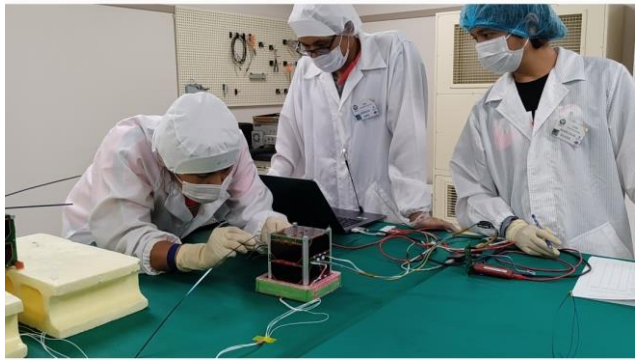


4. CubeSat project timeline

4.7 Making of flight models

- Make and verify flight models based on
  - Assembly documents
  - Testing procedures
- Make sure that the satellite was built correctly without
  - Workmanship flaws
  - Material flaws
- Do not forget about software testing
  - Run the flight software as long as possible
- Safety Review Phase 3 before delivery (takes at least one month)





4. CubeSat project timeline

4.1 What do we do in 2 years?

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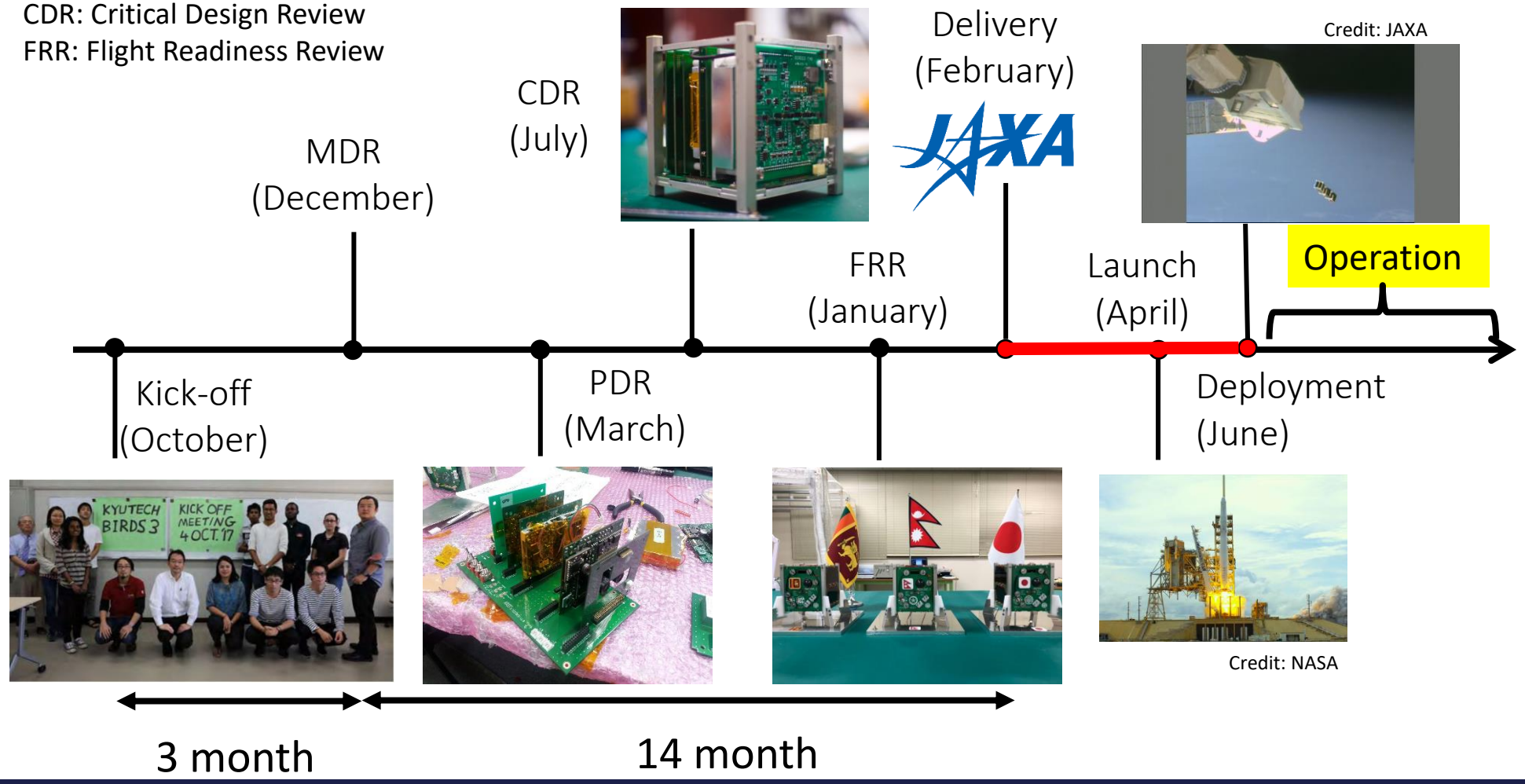
Example of BIRDS projects



4. CubeSat project timeline

4.8 Satellite operation preparation

- Make sure that the satellite can be operated from Day One
  - Mission operation plan
  - Ground station operation practice
- Do “lessons-learned” sessions
- ***Think about the next satellite***

4. CubeSat project timeline

4.1 What do we do in 2 years?

MDR: Mission Definition Review
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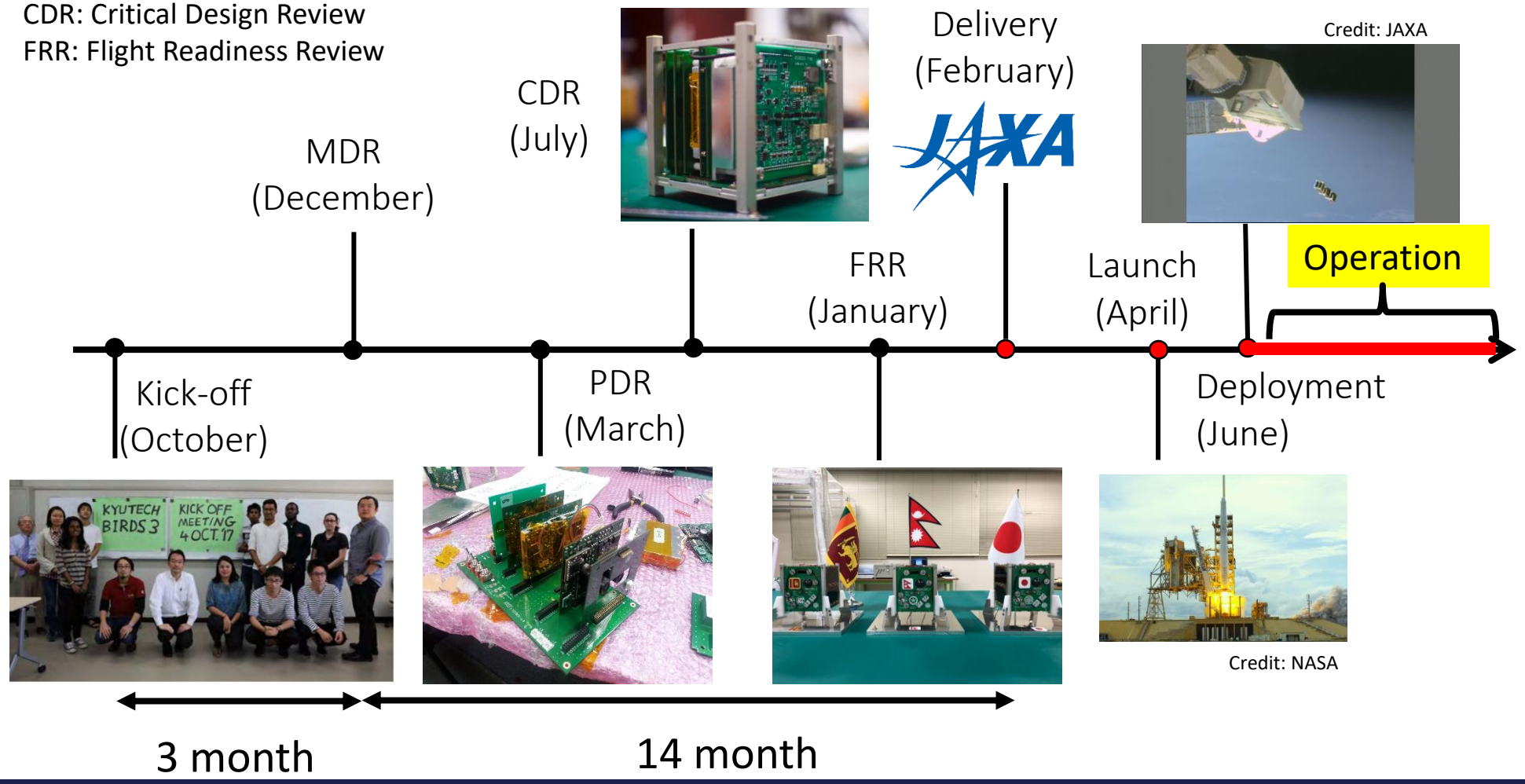
Example of BIRDS projects



4. CubeSat project timeline

4.9 Satellite operation

- Establish the communication link
  - Downlink & Uplink
- Do the main mission first
  - Satellite can fail at any time
  - So do not wait for a good day
    - Plan ahead
- Disseminate information about satellite status frequently
  - Outreach!
  - Let your country know that the satellite is working

5. Sustainability

5. Sustainability

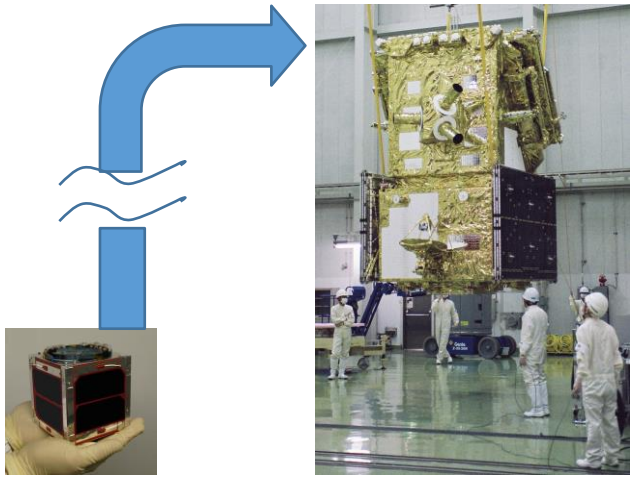
5.1 After KiboCUBE

- Your country's first satellite *must* not be the last satellite
- Do not lose the momentum acquired with the first satellite
  - **Retain the people who experienced the first satellite**
- The second satellite will face the challenge of funding, less enthusiasm, and others
  - Tell your country that space solutions are necessary and reachable
- Plan how to run a sustainable space program
  - Establish a long-term view of how the space program will benefit people in your country
    - This is the reason why the mission of the first satellite is important
  - Secure the anticipation of various stakeholders.
    - Mechanism to collect, discuss and prioritize the needs of various stakeholders
    - Sound judgement of technical and financial feasibility

5. Sustainability

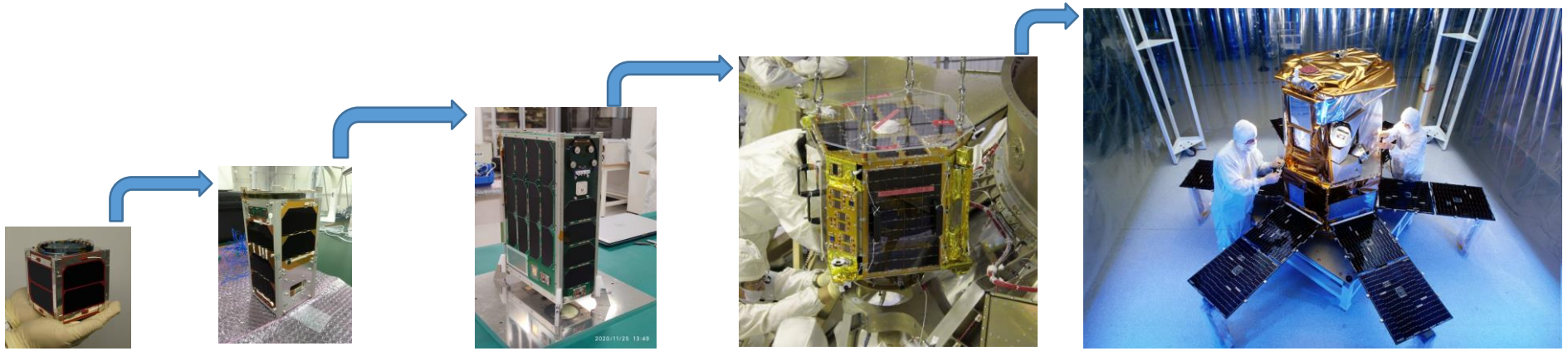
5.1 After KiboCUBE

It is not a good idea to attempt a giant leap



Credit: JAXA

Instead, proceed step-by-step -- and continuously



Credit: JAXA

Credit: NASA

5. Sustainability

5.2 Think as a program

2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021

BIRDS-1

BIRDS-2

BIRDS-3

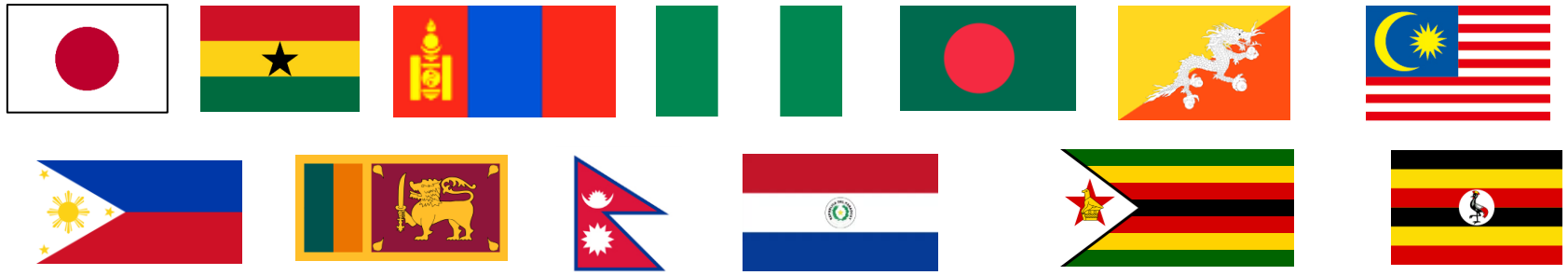
BIRDS-4

BIRDS-5

- Keep launching CubeSats in a series
- Learn from **operation** in space
- Reflect lessons into next generation
- Improve the overall reliability each time
- Cumulate **experience** in humans

5. Sustainability

5.3 Post BIRDS, Importance of networking



BIRDS member institutions are supposed to start their own space program

The BIRDS Network assists infant space programs on a mutual basis.

Human network

Ground station network

5. Sustainability

5.4 BIRDS graduates

After returning to their home countries, they are struggling but not giving up.

Mongolia

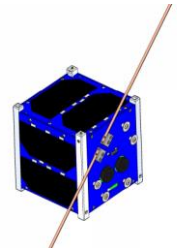
National University of Mongolia

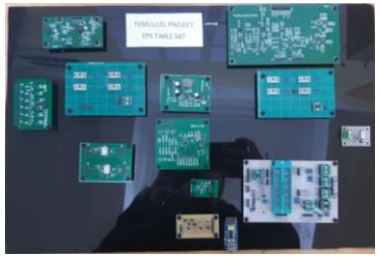
Bangladesh

Brac University

TEMUULEL(“Aspiration”) team

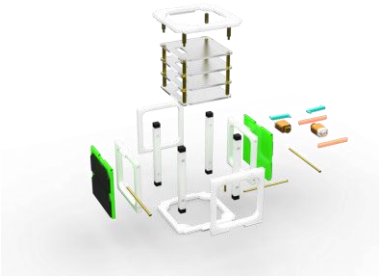
Structure



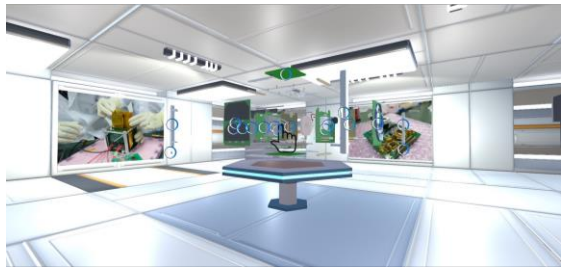


Power system

Establishment of Laboratory of Space Systems Engineering and Technology (LASSET)



Satellite training kit



Satellite Education and Learning Tools by Interactive Virtual Reality Game

6. Frequently asked question

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6.1 Funding

Q: How do we get funding?

A: Use your imagination. Don’t worry. For the country’s first satellite, you can expect multiple support. Government, university, university alumni, private sponsors, crowdfunding, donations, etc. You need to have a good mission to get funding. Just saying “this is our country’s first satellite” is not a compelling case.

6. Frequently asked question

6.2 Test facility

Q: We don’t have any testing facility. Where do we test?

A: Concentrate on the testing items which are really necessary.

1. Electrical interface test
2. Functional test
3. EMC test and End-to-End simulation test
4. Deployment test
5. Launcher/Spacecraft interface test (fit-check)
6. Thermal test
7. Vibration test

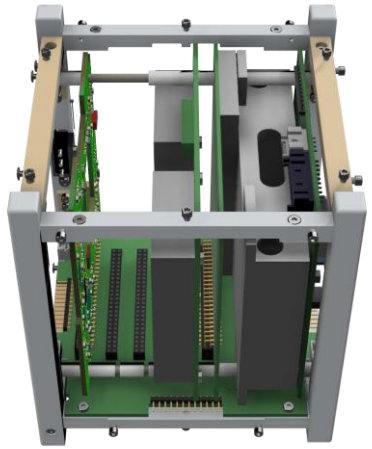
You should be able to do #1-#4 in your country. #5-#7 can be done in Japan before final delivery. Find a vacuum chamber in your country (check your university physics department, for example). I suggest that you shake the satellite/components with your own hands if you solder by yourself or use a cable made by yourself.

6. Frequently asked question

6.3 Buy or build?

Q: Should we purchase COTS components or make everything by ourselves?

A: I suggest you to buy COTS components for the basic satellite bus (e.g. computer, radio, power system) and concentrate on mission payload development. When you buy COTS components, I strongly advise you to buy from a single vendor as software interface issues can delay the project significantly. Also choose stuff that have flight heritage. I also suggest you to buy two sets. One set is for flight. The other set is for an engineering model, which can serve as the flight spare and also as a flat-sat model during operation.



CubeSat platform

7. Conclusion

7. Conclusion

- 1U CubeSat is the ideal tool for entry into space
- Going through the entire process of the satellite system life-cycle is important
  - From mission definition to operation in space
- The first satellite must not be the last satellite. Think of sustainability at all times.

Thank you very much.

[Disclaimer]
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