Program management for sustainable university CubeSat programs based on the experience of five generations of CubeSat projects, BIRDS program

Mengu Cho, Mariko Teramoto, Takashi Yamauchi,
George Maeda, Sangkyun Kim, Hirokazu Masui
Laboratory of Lean Satellite Enterprises and In-Orbit Experiments
Kyushu Institute of Technology, Kitakyushu, Japan

August 7, 2022
Small Satellite Conference, Logan, Utah, US

Issues of capacity building activities

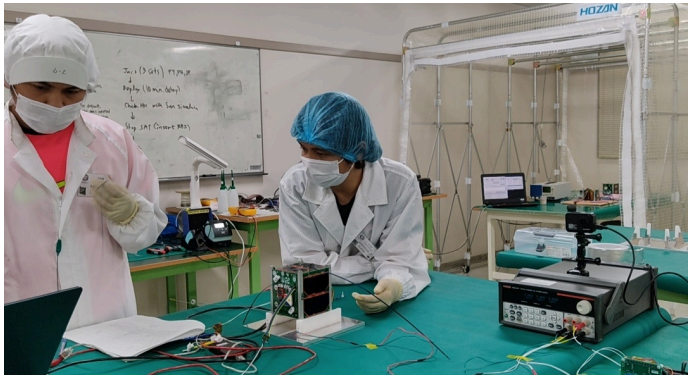
La SEINE

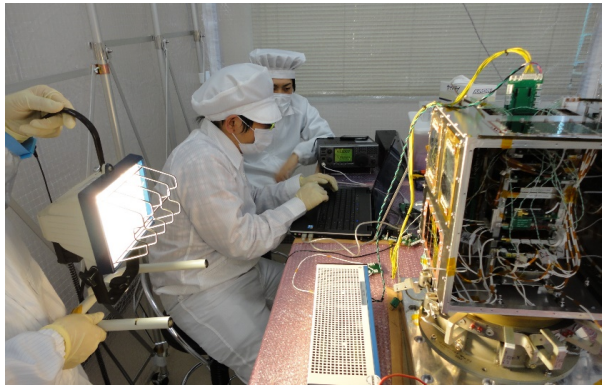
- Small satellites are ideal entrance for developing countries to join the space sector
- Demand for capacity building through small satellites
- Various training programs via agencies, companies and universities in space faring countries
  - Often tied with sales of satellites (big or small)
  - Not 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

Space Engineering International Course (SEIC)

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

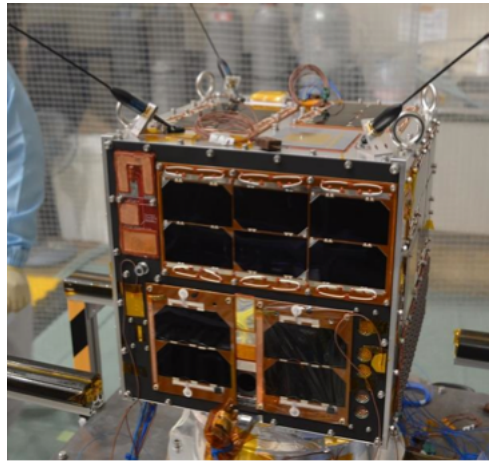
1. Research towards a Master or Doctoral degree
2. On-the-job training such as space environment testing workshop
3. Project Based Learning (PBL) through a space project
4. Space-related lectures in English





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 SEIC students

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

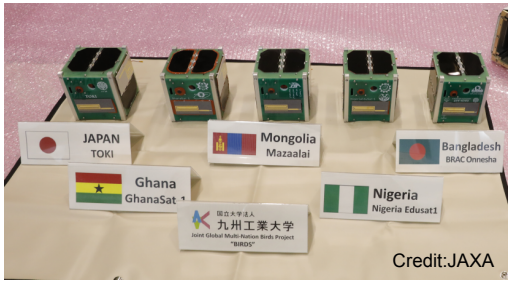
BIRDS Program

Satellite program for non-space faring countries

Mission Statement

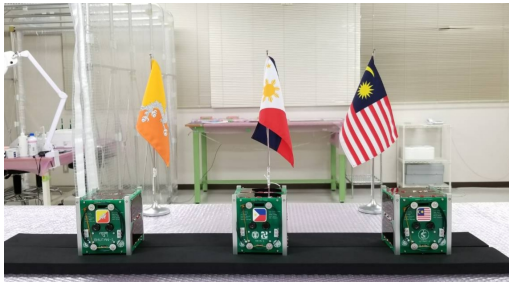
By successfully building and operating the first national satellite, make the foremost step toward indigenous space program at each nation.

BIRDS-I (2015-2017)



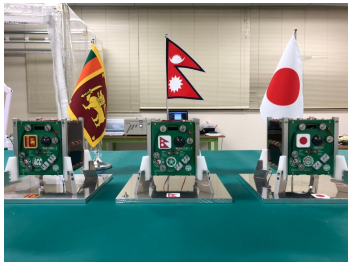
JAPAN GHANA MONGOLIA NIGERIA BANGLADESH

BIRDS-II (2016-2018)



BHUTAN PHILIPPINE MALAYSIA

BIRDS-III (2017-2019)

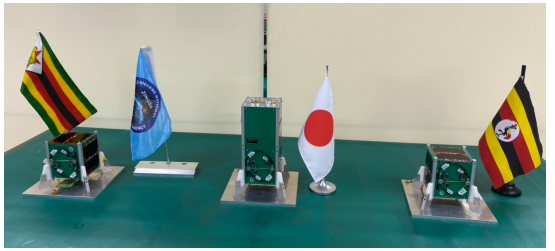


SRI LANKA NEPAL JAPAN

BIRDS-IV (2018-2020)

PHILIPPINE JAPAN PARAGUAY

BIRDS-V (2020-2022)



ZIMBABWE JAPAN UGANDA

BIRDS-1 was first called “Joint Global Multi-Nation Birds”. Later, it simply became “BIRDS”

BIRDS program

- BIRDS program is made of the following projects

1. Satellite projects
   - BIRDS-1
   - BIRDS-2
   - BIRDS-3
   - BIRDS-4
   - BIRDS-5
2. BIRDS network project
3. Open-Source project
4. Standardization project

BIRDS program missions

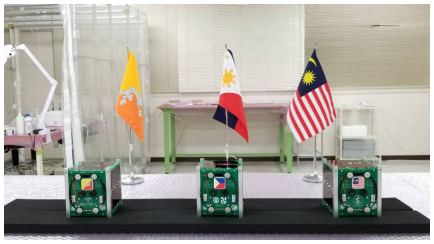
- Lower the entry barrier to space sector
  1. Support capacity building efforts of non-space faring countries
  2. Make satellite building easier
- Practice a new engineering education
  3. Human resource development through international joint satellite projects
  4. Learn systems engineering and project management through satellite development and operation

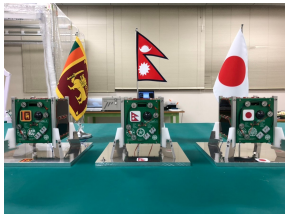
- When BIRDS-1 started, there was no programmatic view. It was just a satellite project.
- Initially #1 was the primary and #3,#4 were secondary. #2 came later after BIRDS-3.

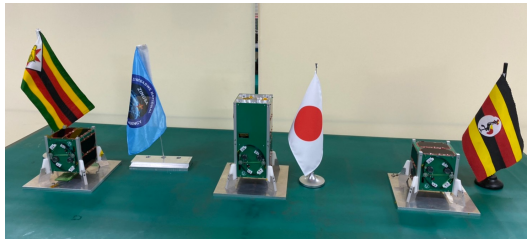
BIRDS satellite projects features

- 1U CubeSat constellations 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, **Paraguay*** and Philippine
  - BRIDS-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*







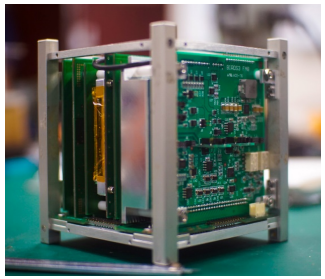
Group photos of BIRDS-I, –II, –III, -IV and -V teams

Fit into 2 years

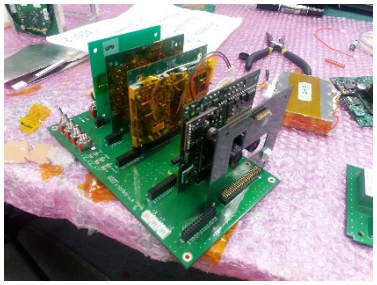
- A short-term goal
  - Build and operate satellites
    - Give the students **confidence** that they can do it
- Long-term goal
  - Students initiate their own space program in home countries
  - The full mission success
    - **The former students successfully build and operate the second satellite in their home countries**
- Let students learn **the entire process** of a satellite project from beginning to end
  - Witness decision-making processes and then make decisions by themselves
- Fit the project within **the degree timeline. 2 years** maximum.
  - Select 1U CubeSat and ISS deployment as the platform for this training

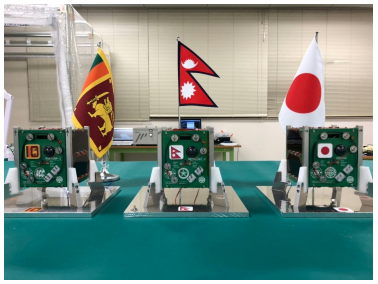
Fit into 2 years

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



Credit: JAXA





Credit: NASA

Kick-off (October)

MDR (December)

CDR (July)

PDR (March)

FRR (January)

Delivery (February)

Launch (April)

Deployment (June)

Operation

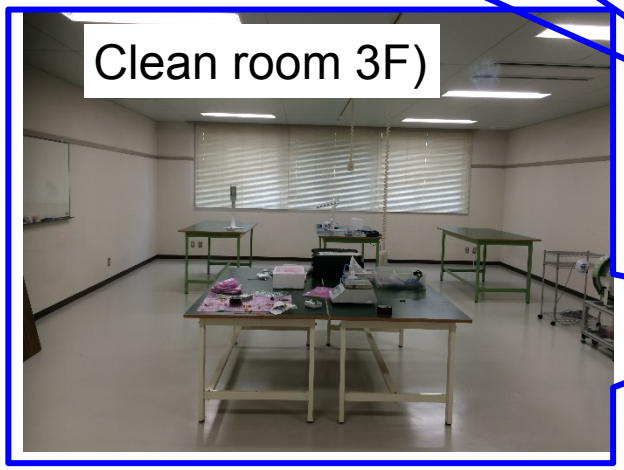
3 month

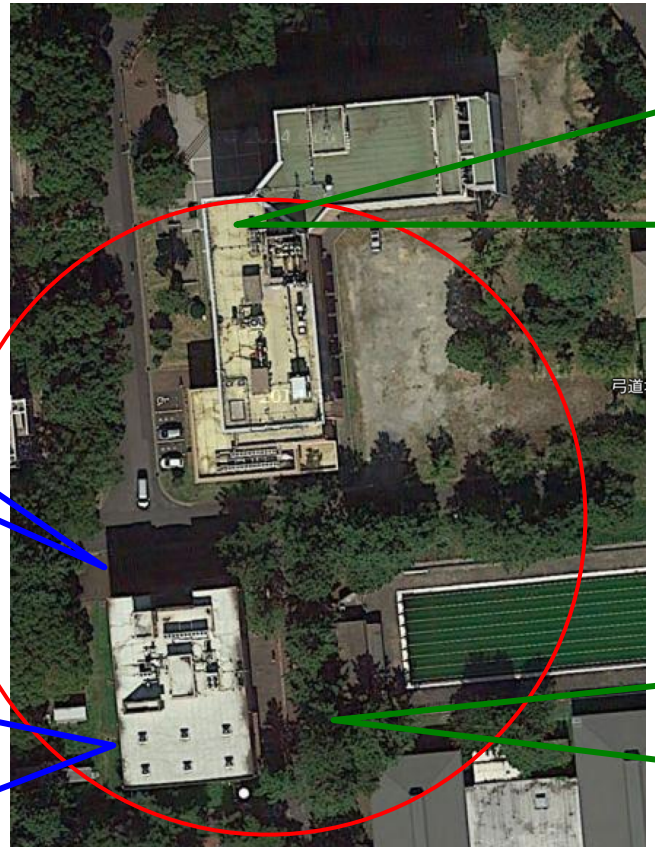
14 month

7 months and beyond

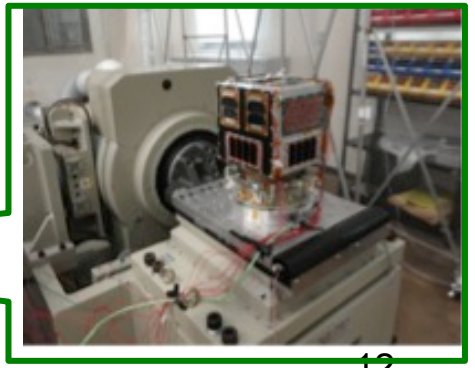
Fit into 2 years

Lean satellite approach was adopted to minimize the waste of moving and waiting





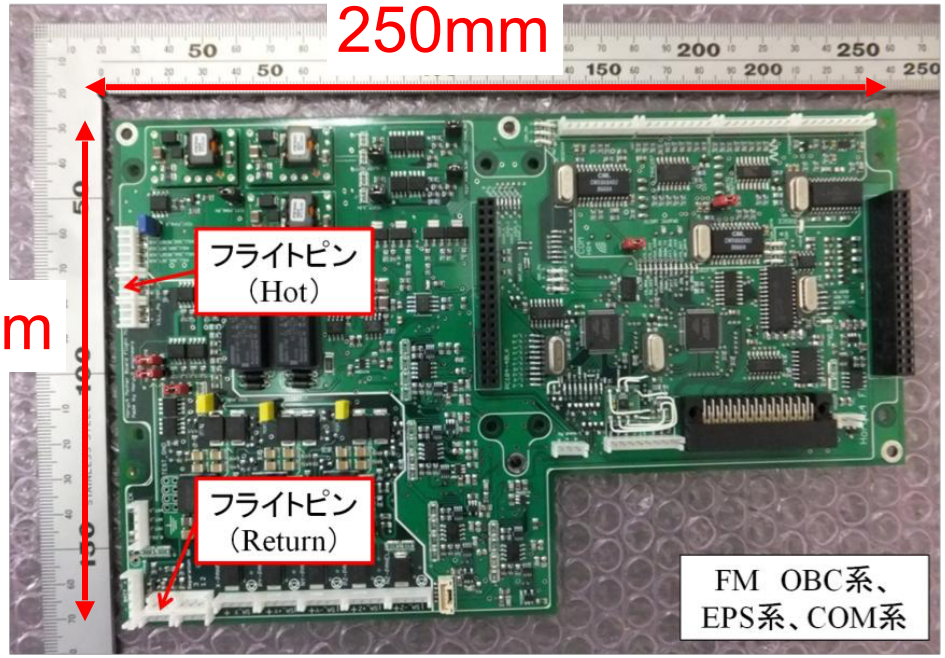
Test facility(1F)



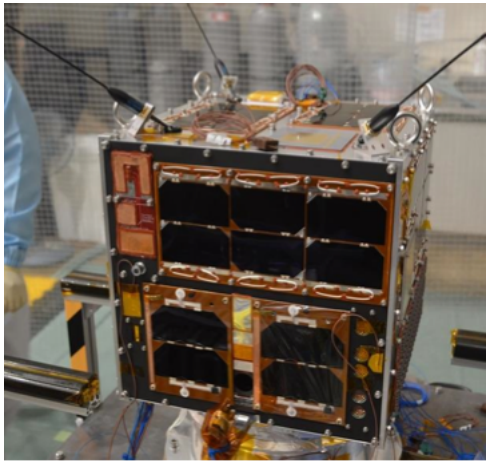
Radius 30m

Satellite design

The initial design (BIRDS-1) inherited already available ad flight proven in-house satellite bus



HORYU-IV

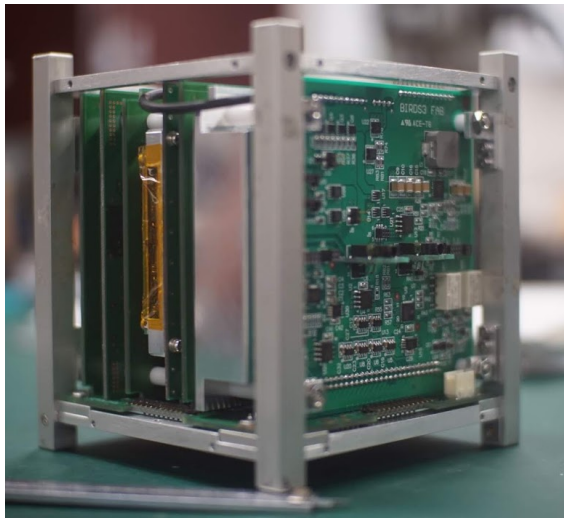


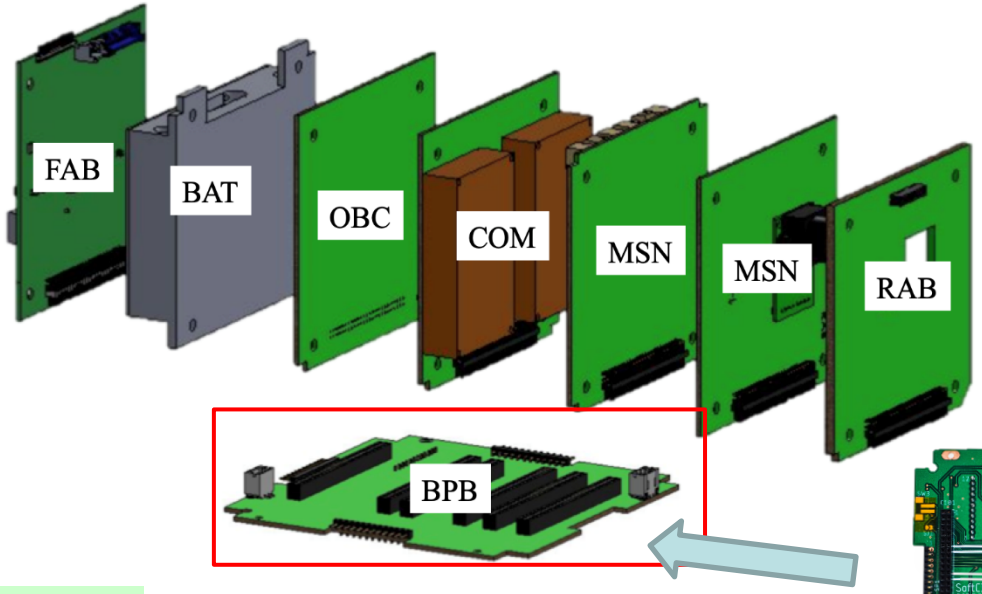
30cmx30cmx30cm

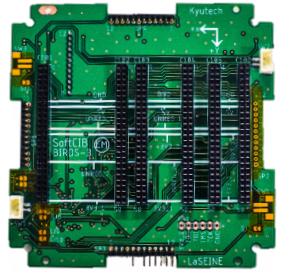
- The basic design inherited HORYU-IV (Launched February 2016/2)
- Changed 250mmx150mm PCB to 100mmx100mm
- Asked a professional company to re-layout and solder the parts

Satellite design

- Each satellite has the same design (per generation)
- Harnessless design
- Each satellite uses the same frequency (UHF/VHF amateur radio)



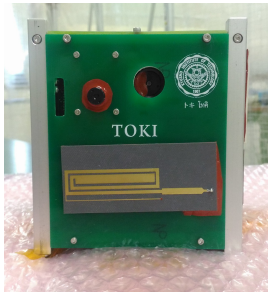
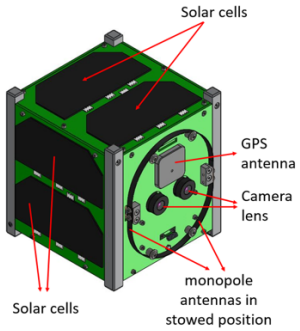
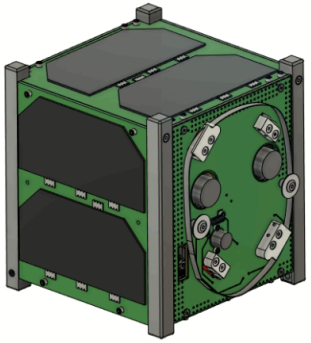
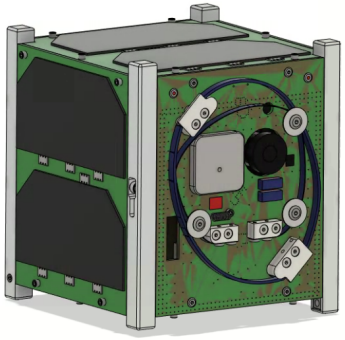
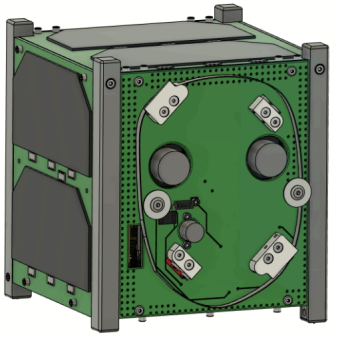




Easy assembly and disassembly

The satellite is designed to make the development time short even for satellite beginners

Evolution of BIRDS satellites

BIRDS-1	BIRDS-2	BIRDS-3	BIRDS-4	BIRDS-5
				
	Deployable antenna UHF uplink	Dipole antenna New OBC/EPS	3xDeployment switch	No rail switch

- BIRDS bus evolved by reflecting the lessons learned in the previous generations
  - Antenna
  - Internal noise
  - Power management
- External factors forcing design changes
  - IARU regulation
  - ISS safety requirements
  - Parts discontinuity
- Minor design change since BIRDS-3

Flight Heritage

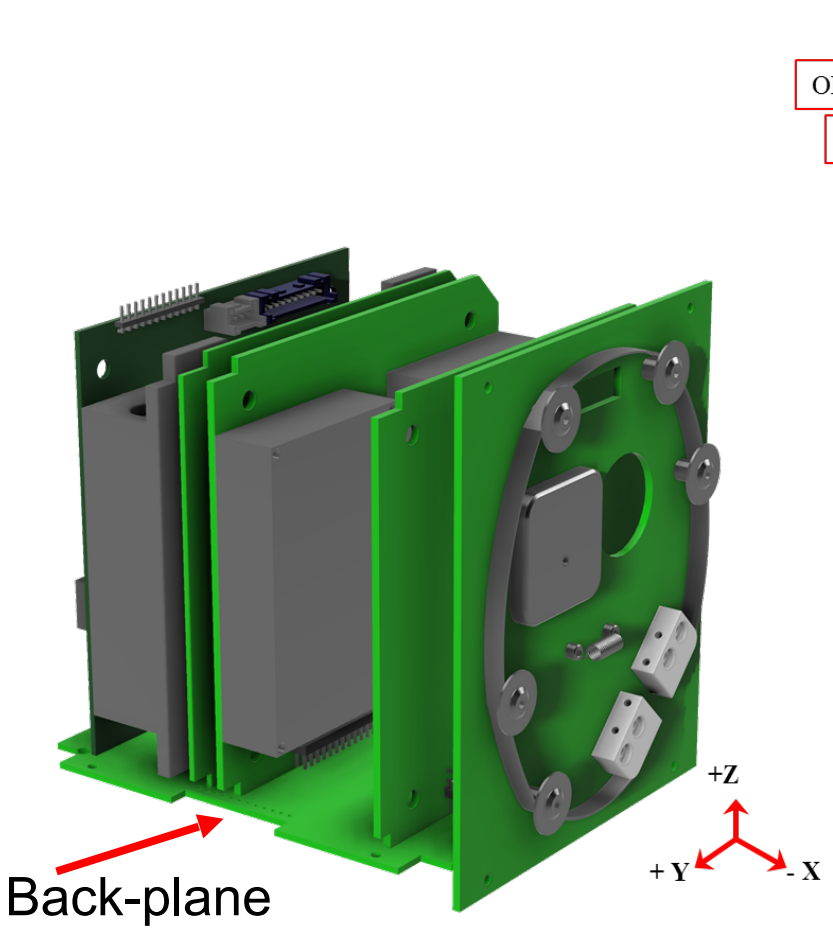
- BIRDS-1
  - CW beacon until reentry
  - Failed in uplink due to low gain of patch antenna
- BIRDS-2
  - Basic functions until reentry
  - Difficulty in UHF uplink due to internal noise from EPS
  - Modified version (BIRDS-2S) worked well in orbit
- BIRDS-3
  - Achieved the full mission success
  - Fully operational for two years until reentry
- BIRDS-4
  - Power budget issues for two satellites
  - One satellite remained and achieved the full mission success
- BIRDS-5
  - To be deployed into orbit in Fall 2022

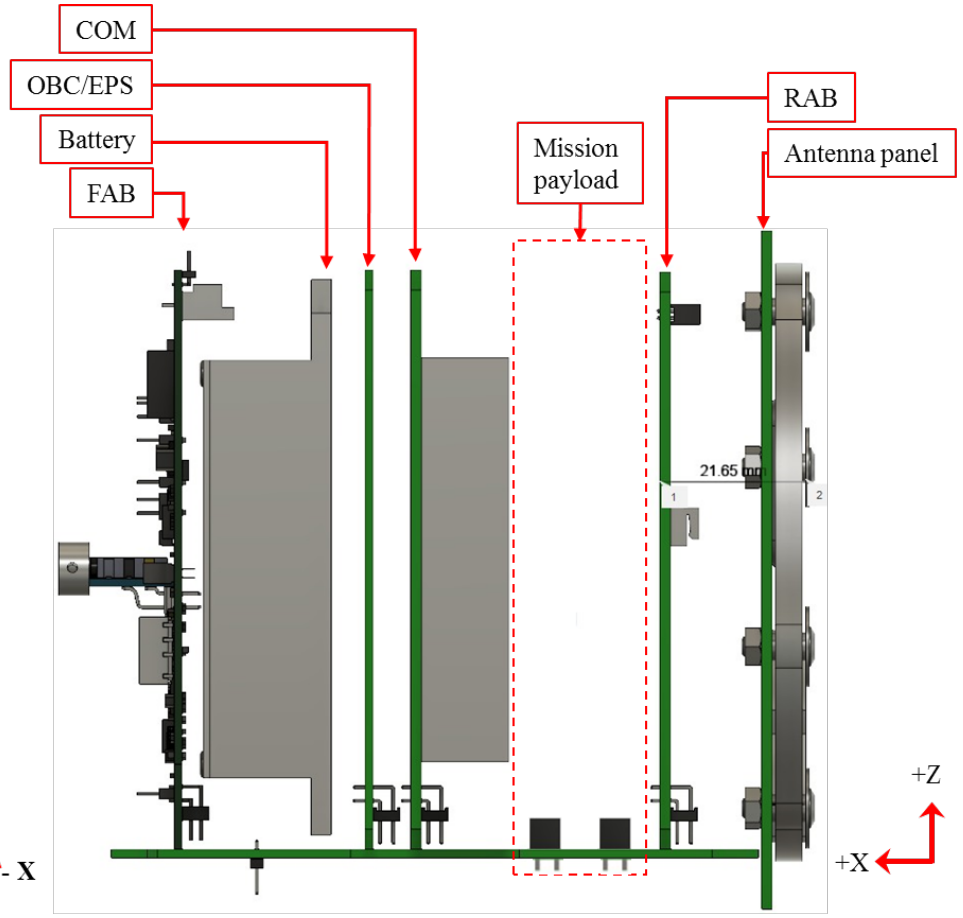
Photo of Sri Lanka by BIRDS-3

Photo of ISS by BIRDS-4

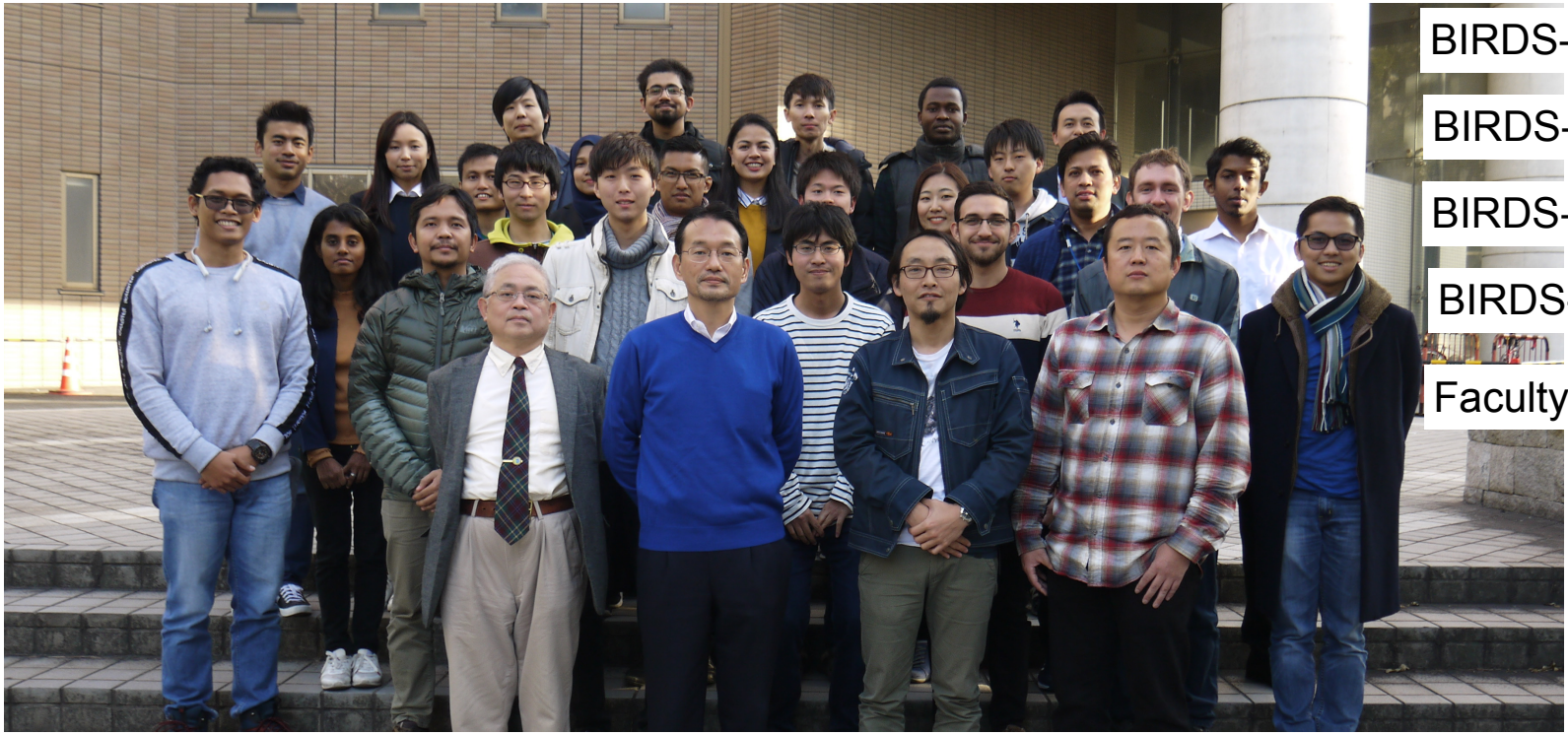
BIRDS BUS

- Two slots for mission payload PCB (86mmx90mm)
- Connected to back-plane board with 50-pin connectors
- UHF(up/down), Power, C&DH, Antenna, Structure, Umbilical and Solar Panels are fixed





Knowledge transfer and maintenance



Group photos of 4 generations of BIRDS students at BIRDS-4 kick-off

- "Collective intelligence" among the students by overlapping generations
- Secure fundings to run multiple satellite projects simultaneously
- Assistance of junior faculties and staff
- **Need "exit strategy"**
  - Open-source vs Commercialization

Why open sourcing?

- BIRDS-5 will be the last of BIRDS satellite projects
- We will move to the next stage
  - Promote second satellites built by former BIRDS students
    - True mission success of BIRDS program
- The easiest solution for the second satellites is to duplicate or modify BIRDS satellites
- Kyutech cannot maintain the satellite bus
  - Kyutech is not a company
  - If a company commercialize the BIRDS bus (it is still OK, if you want), it will be expensive
- The most affordable way is to let users work on the satellite by themselves
- Why don't we make others (non-BIRDS members) benefit from this initiative as well?
- The conclusion is "Open Source"

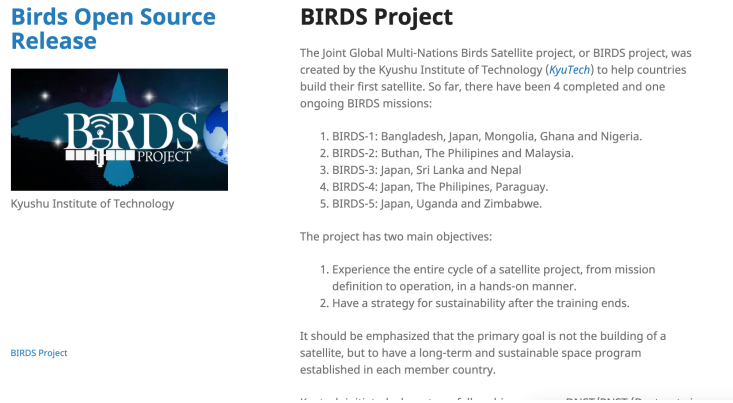
Sustainability!

What information to be open-sourced

- Basically everything
  - Technical Drawing (i.e. CAD files)
  - Source code (satellite and ground station)
  - PCB design
  - Assembly and testing procedure
  - Parts list
  - Test reports
  - Interface Control Documents
  - Textbook
- Currently, information about BIRDS-3 and 4 are available
- Coming soon
  - In-orbit results (temperatures, voltage, current, etc) of BIRDS-3 and 4
  - BIRDS-5 information
- MIT license is adapted (free to do anything as long as you acknowledge the original copyright)
- Currently there are 5 domestic and 4 foreign users

Open-sourcing Activities

- Monthly Webinar
  - 22:00-23:30 2nd Wednesday every month (JST)
  - Next one is August 10
- GitHub platform
  - https://github.com/BIRDSOpenSource
  - Telegram Chat
- Mailing list to announce events such as Webinars
  - To subscribe, access to
  - https://lean-sat.org/opensource/
  - Or send me an e-mail
  - cho.mengu801@mail.kyutech.jp
- For further information,
  - Google “birds opensource”



Conclusion

- Having a programmatic view on a series of satellite projects improves the mission success rate
- The BIRDS satellite bus has become mature and evolved as a good platform for academic satellite projects.
- Use of “collective intelligence” by overlapping the projects for know-how transfer lowers the burden on the principal faculty.
  - Need continuous funding
  - Needs an exit strategy for further sustainability such as open-sourcing
- To be sustainable as a university education program
  - Funding
  - Presence of junior staff dedicated in overseeing the daily project and serving as the knowledge database
  - Lowering the satellite hardware cost and the launch cost
    - Currently 4MJPY per satellite. Goal is to achieve less than 3MJPY.

Estimated cost to produce a 1U CubeSat

La SEINE

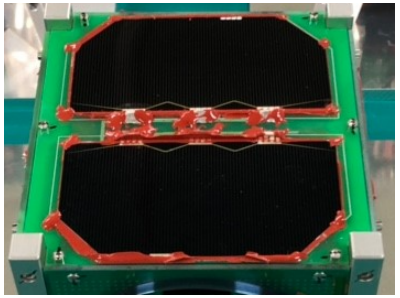
Item	Cost (MJPY)	Note
C&DH and EPS*	0.4	Procured from a company
UHF COM*	0.8	Procured from a company
Structure + fastener	0.8	Manufacturing outsourced
Battery	0.2	Ni-MH_2 (Eneloop by Panasonic)
Solar panels + Glue	1	Glue costs 0.5MJPY per kg
Backplane + Antenna panel	0.5	Manufacturing outsourced
Other small items	0.3	
Total	4	Equivalent to $33,000

**Provided by Japanese companies*

Costs are the case when purchased inside Japan
No mission payload
Keys to reduce the cost are to

- Develop UHF COM in-house
- Find non-space grade glue for solar panel

Goal is to achieve less-than 3MJPY



Solar panel w/ glue

UHF COM board