Open-sourcing 1U CubeSat platform for Education and Capacity Building

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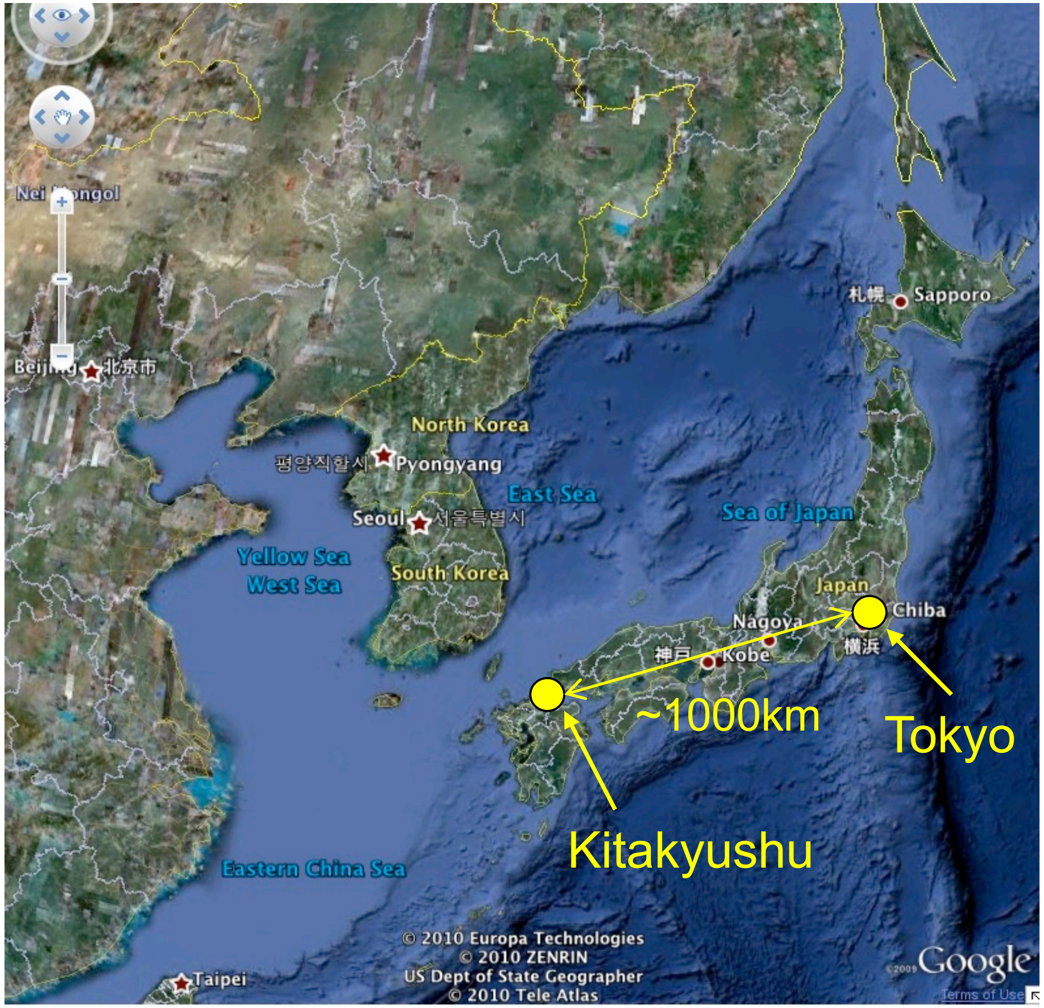
April 26, 2022

CubeSat Developers Workshop 2022

Kyushu Institute of Technology (Kyutech)

- A national university founded in 1909
  - 4,400 Undergraduate students
  - 1,700 Graduate students
  - 370 Faculty members
  - Engineering, Computer science, Life-science
- Located in the Kitakyushu region
  - Population of more than 1million


Nei Mongol
Beijing 北京市
North Korea
평양직할시 Pyongyang
Seoul 서울특별시
East Sea
Sea of Japan
Yellow Sea
West Sea
South Korea
札幌 Sapporo
Japan
Chiba
Nagoya
神戸 Kobe
横浜
~1000km
Tokyo
Kitakyushu
Eastern China Sea
Taipei
© 2010 Europa Technologies
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US Dept of State Geographer
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Google
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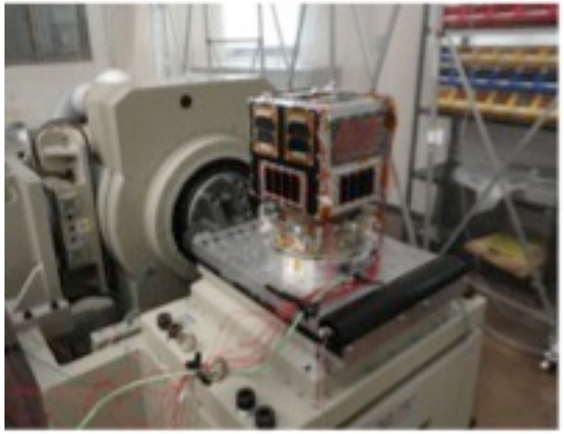
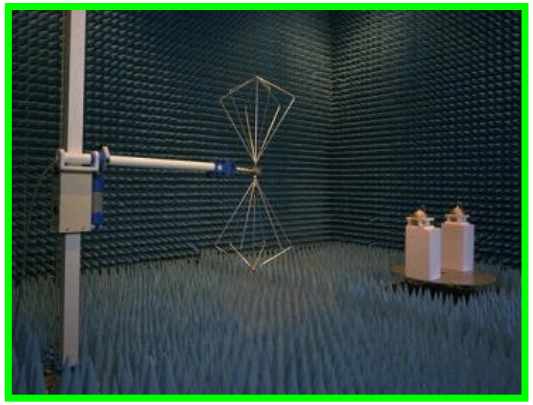
- **Space Engineering International Course (SEIC) since 2013**
  - English-based post-graduate program
- **Department of Space Systems Engineering since, 2018**
  - Undergraduate program given in Japanese

Center for Nanosatellite Testing

To be capable of doing all the tests for a satellite up to 50cm, 50kg



Vibration

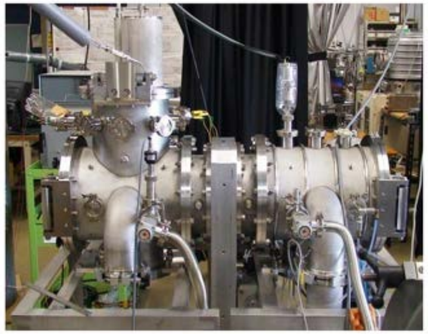


EMC & Antenna pattern

Pressure & Leak

Thermal vacuum

Assembly & Integration



Thermal vacuum

Thermal cycle

Shock

Outgas
(ASTM E595)

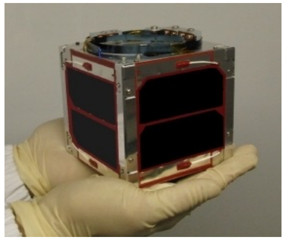
α&ε measurement

Conducted more than 400 tests for external users since 2010

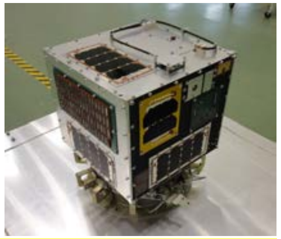
Space Development and Utilization Award (JAXA president award), 2022

Kyutech Satellite Heritage

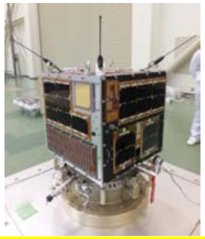
La SEINE



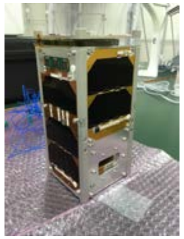
HORYU-1 (1U)
2006-2010
Not launched



HORYU-II
2010-2012
Launch 2012/5/18



HORYU-IV
2013-2016
Launch 2016/02/17

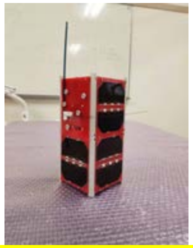


AOBA VELOX-III
2014-2016
ISS Release 2017/01/19

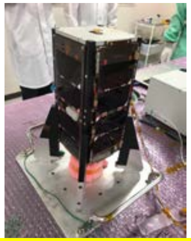
JAPAN
TOKI
Mongolia
Mazaalai
Bangladesh
BRAC Onnesha
Ghana
GhanaSat
Nigeria
Nigeria Edusat1
九州工業大学

BIRDS-I constellation
2015-2017
ISS release 2017/07/07

BIRDS-II constellation
2016-2018
ISS release 2018/08/10



SPATIUM-I
2016-2018
ISS release 2018/10/06



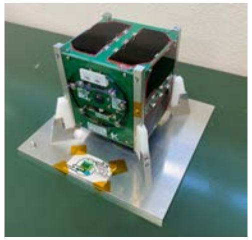
AOBA VELOX-IV
2016-2018
Launched 2019/01/18

BIRDS-III constellation
2017-2019
ISS release 2019/06/17

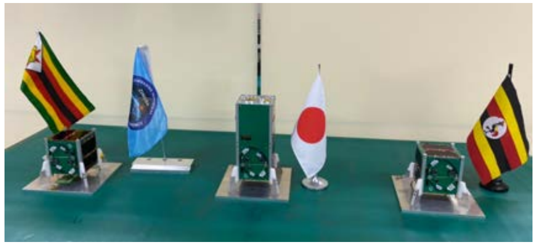
PHILIPPINES
JAPAN
PARAGUAY

BIRDS-IV constellation
2018-2020
ISS release 2021/03/14

KITSUNE
2019-2021
ISS release 2022/03/24



FUTABA
2018~2021
Launch, 2022



BIRDS-5J, -5Z, -5U
Launch 2022

MITSUBA
2022

22 satellites launched since 2012

Satellite name
Satellite development period
Launch/ISS release date

BIRDS Program

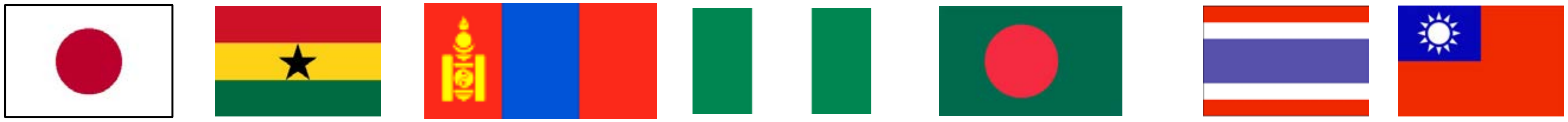
Satellite program for non-space faring countries

Mission Statement

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

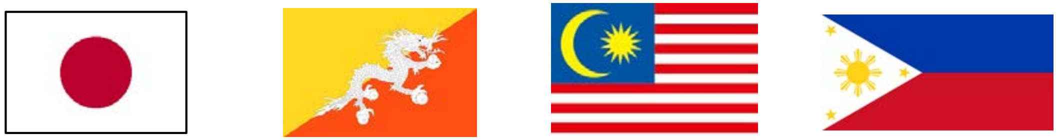
BIRDS-I (2015-2017)

JAPAN GHANA MONGOLIA NIGERIA BANGLADESH THAILAND TAIWAN



BIRDS-II (2016-2018)

JAPAN BHUTAN MALAYSIA PHILIPPINE



BIRDS-III (2017-2019)

JAPAN SRI LANKA NEPAL

BIRDS-IV (2018-2020)

JAPAN PARAGUAY PHILIPPINE

BIRDS-V (2020-2022)

JAPAN ZIMBABWE UGANDA

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

BIRDS program

- BIRDS program is made of the following projects
- Satellite projects
  - BIRDS-1
  - BIRDS-2
  - BIRDS-3
  - BIRDS-4
  - BIRDS-5
- BIRDS network project
- **Open-Source project**
- Standardization project

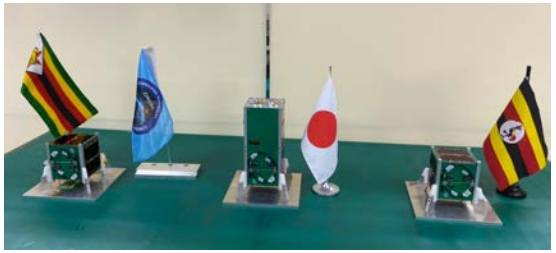
BIRDS satellite projects features

- 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, **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*

JAPAN
TOKI
Mongolia
Mazaalai
Bangladesh
BRAC Onnesha
Ghana
GhanaSat
Nigeria
Nigeria Edusat1
九州工業大学

PHILIPPINES
JAPAN
PARAGUAY



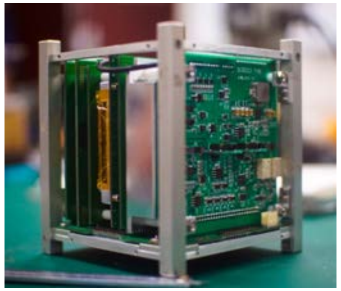
Group photos of BIRDS-I, –II, –III, -IV and -V teams

Fit into 2 years

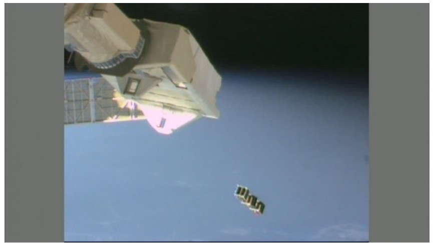
- A short-term goal
  - Build and operate satellites
    - Give the students **confidence** that they can do it
- Long-term goal
  - Students initiate their own space program in home countries
  - The full mission success
    - **The former students successfully build and operate the second satellite 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

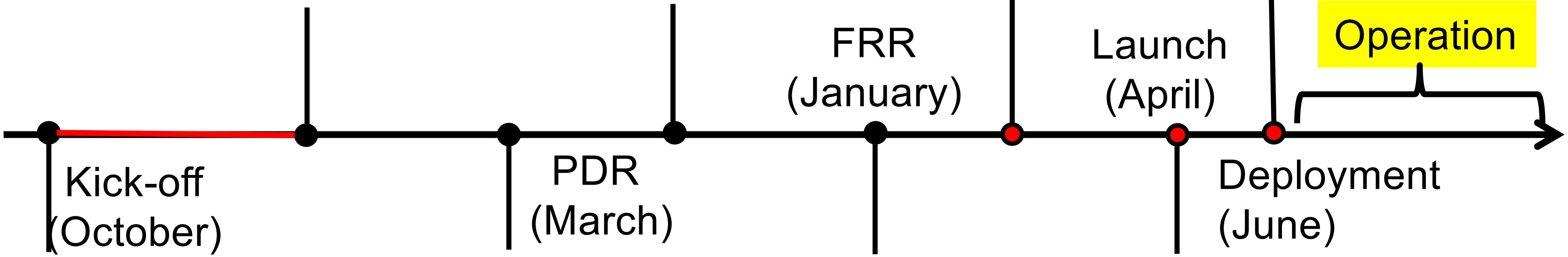
Fit into 2 years

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



Credit: JAXA




MDR
(December)
CDR
(July)
Delivery
(February)
FRR
(January)
Launch
(April)
Operation
Kick-off
(October)
PDR
(March)
Deployment
(June)

KYUTECH
BIRDS 3
KICK OFF
MEETING
4OCT.17

Credit: NASA

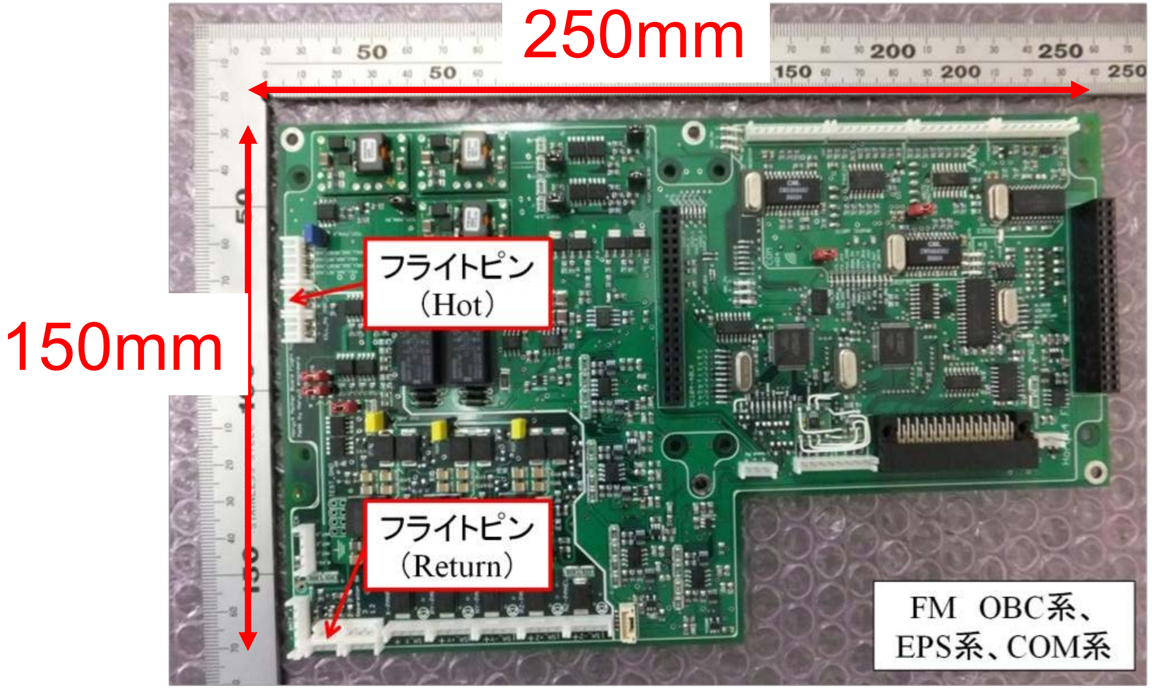
3 month

14 month

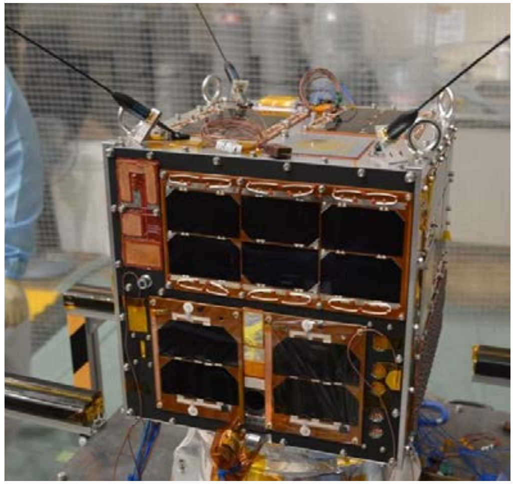
7 months and beyond

Satellite design

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


250mm
150mm
フライトピン（Hot）
フライトピン（Return）
FM OBC系、EPS系、COM系

HORYU-IV

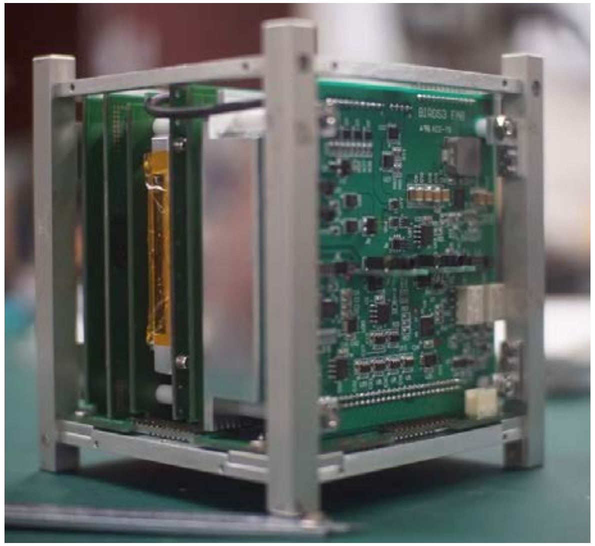


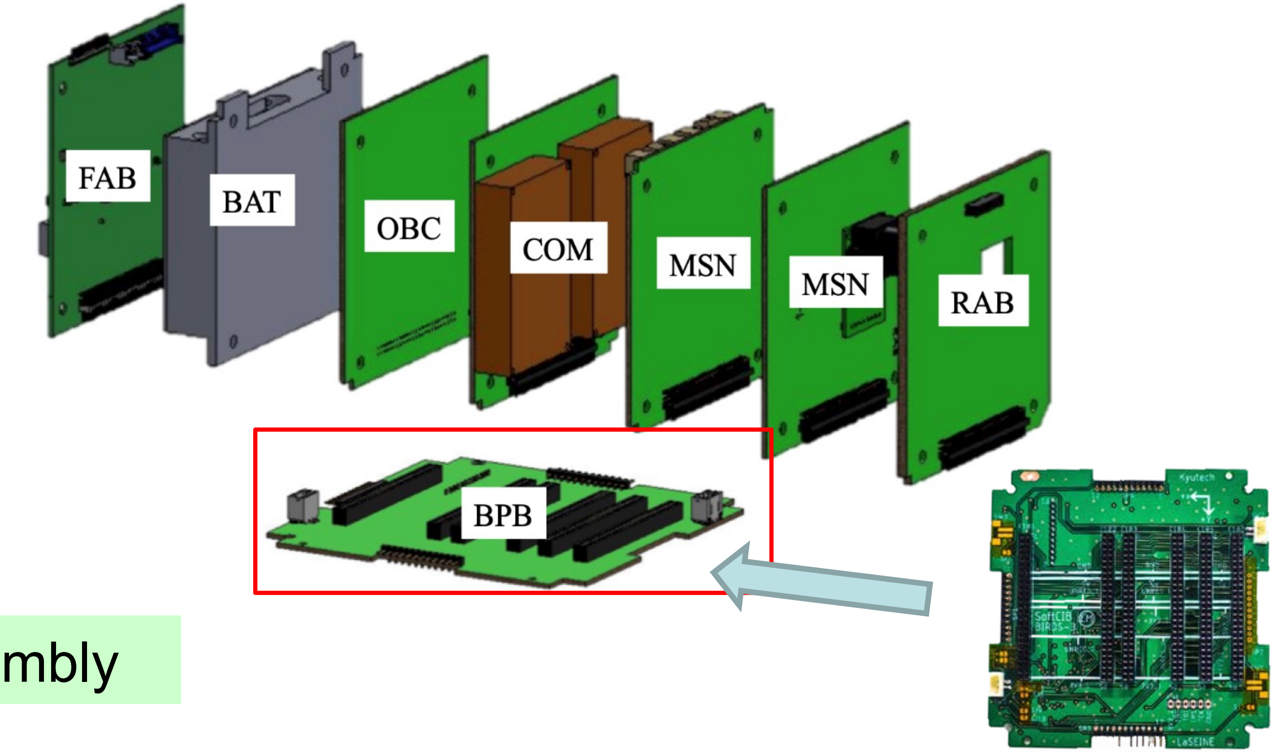
30cmx30cmx30cm

- 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)





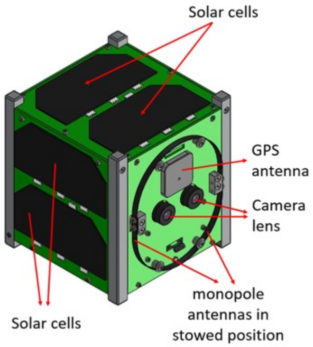
Easy assembly and disassembly

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

Evolution of BIRDS satellites

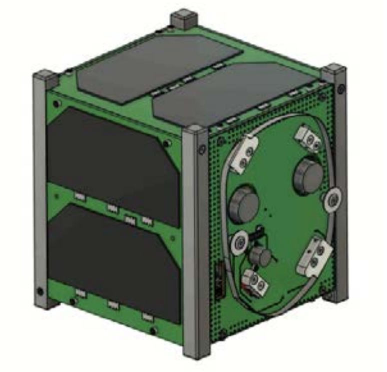
BIRDS-1

BIRDS-2


Solar cells
GPS antenna
Camera lens
monopole antennas in stowed position
Solar cells

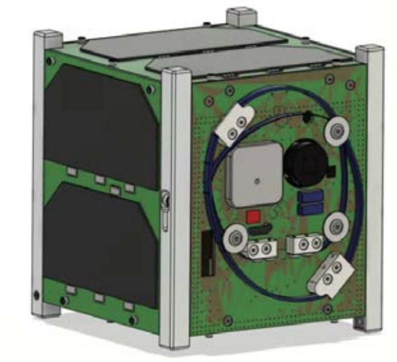
Deployable antenna
UHF uplink

BIRDS-3



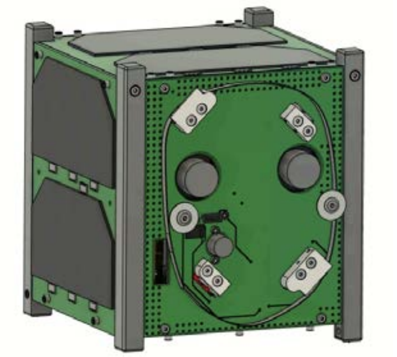
Dipole antenna
New OBC/EPS

BIRDS-4



3xDeployment switch

BIRDS-5



No rail switch

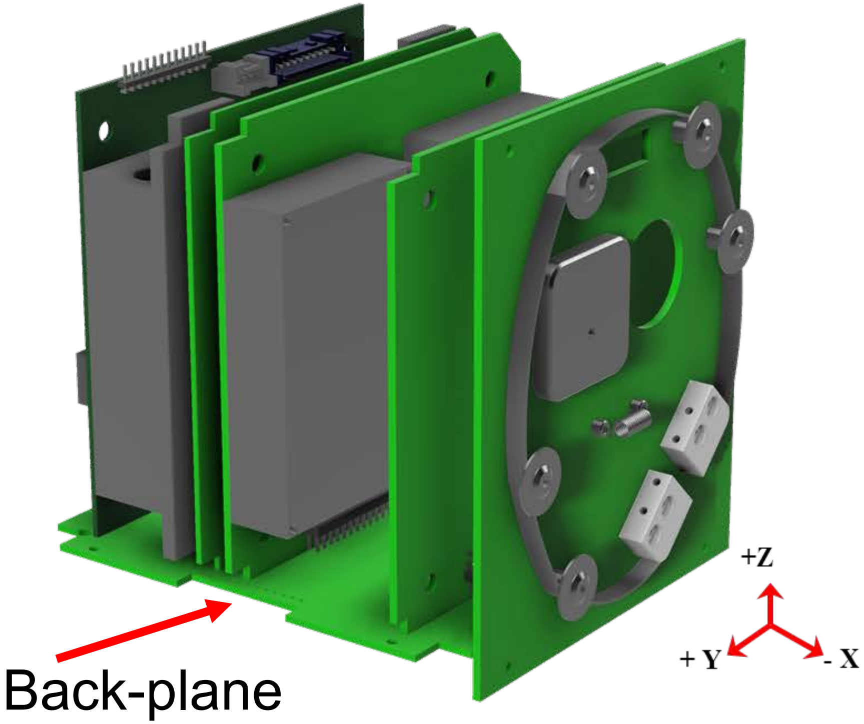
- BIRDS bus evolved by reflecting the lessons learned in the previous generations
- Minor design change since BIRDS-3
  - Mostly to adapt the changes of ISS safety requirements

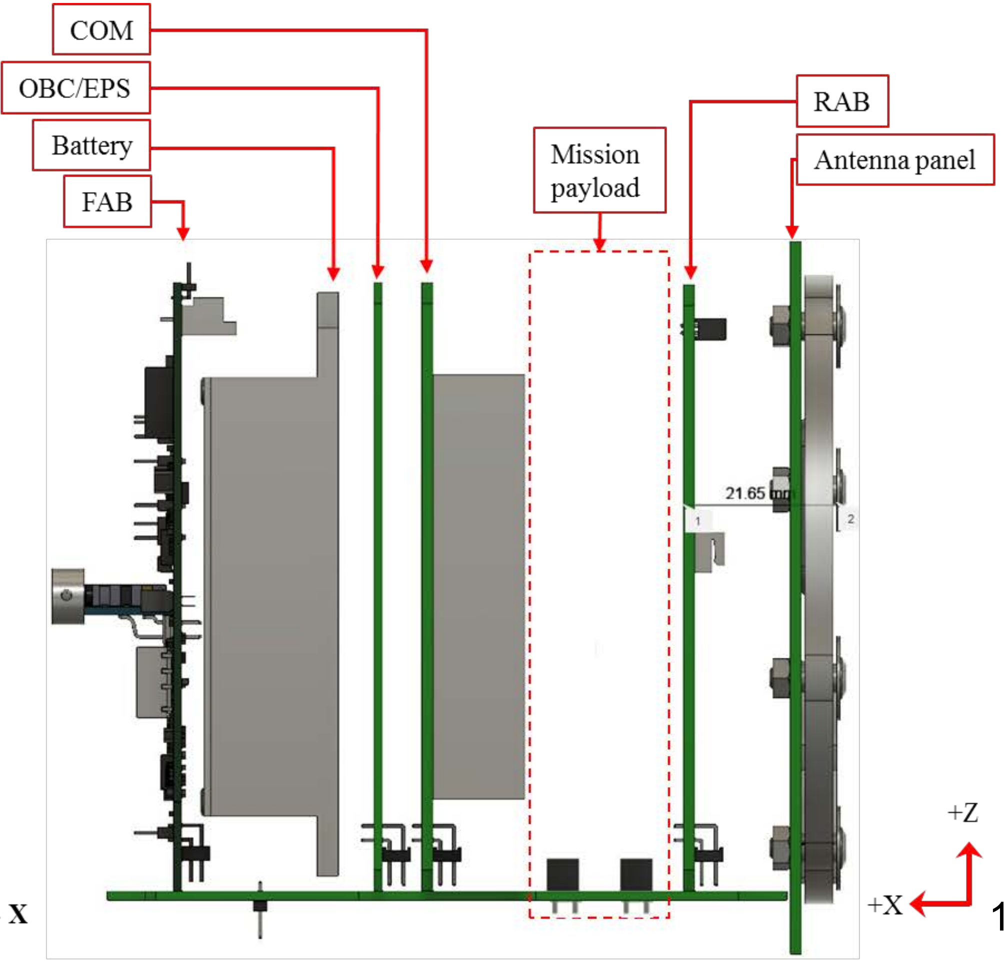
Flight Heritage

- 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 all the missions
  - Fully operational for two years until reentry
- BIRDS-4
  - Power budget issues for two satellites
  - One satellite remained and achieved most of the missions
- BIRDS-5
  - To be deployed into orbit in summer 2022

BIRDS BUS

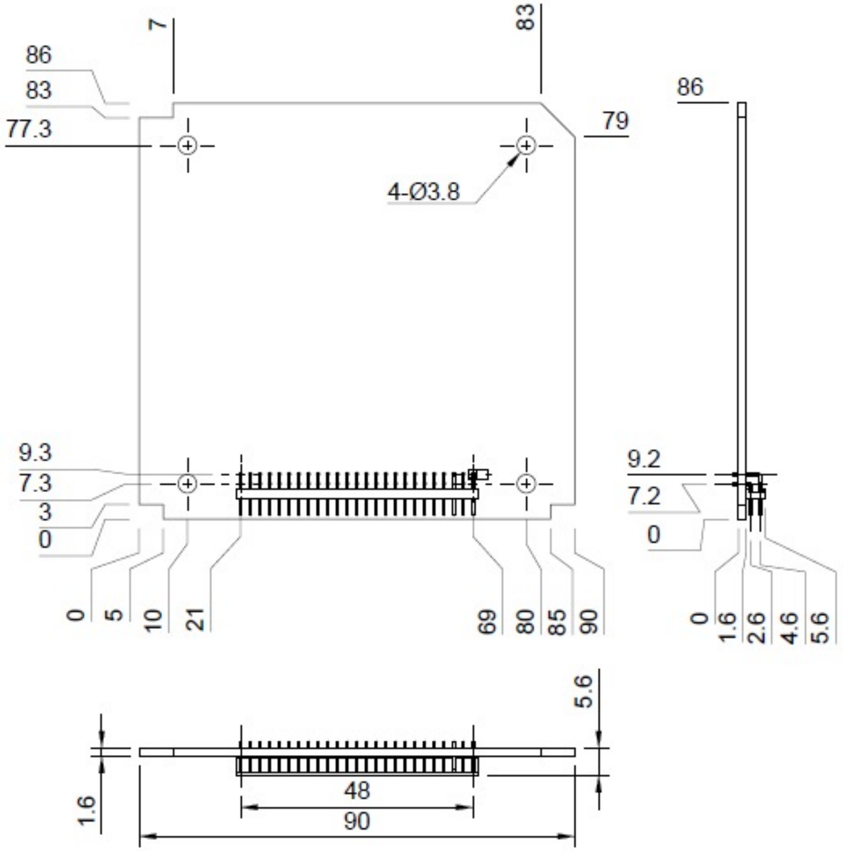
- Two slots for mission payload PCB (86mmx90mm)
- Connected to back-plane board with 50-pin connectors
- UHF(up/down), Power, C&DH, Antenna, Structure, Umbilical and Solar Panels are fixed


+Z
+Y
-X
Back-plane


COM
OBC/EPS
Battery
FAB
Mission payload
RAB
Antenna panel
21.65 mm
1
2
+Z
+X

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



Mission board dimension

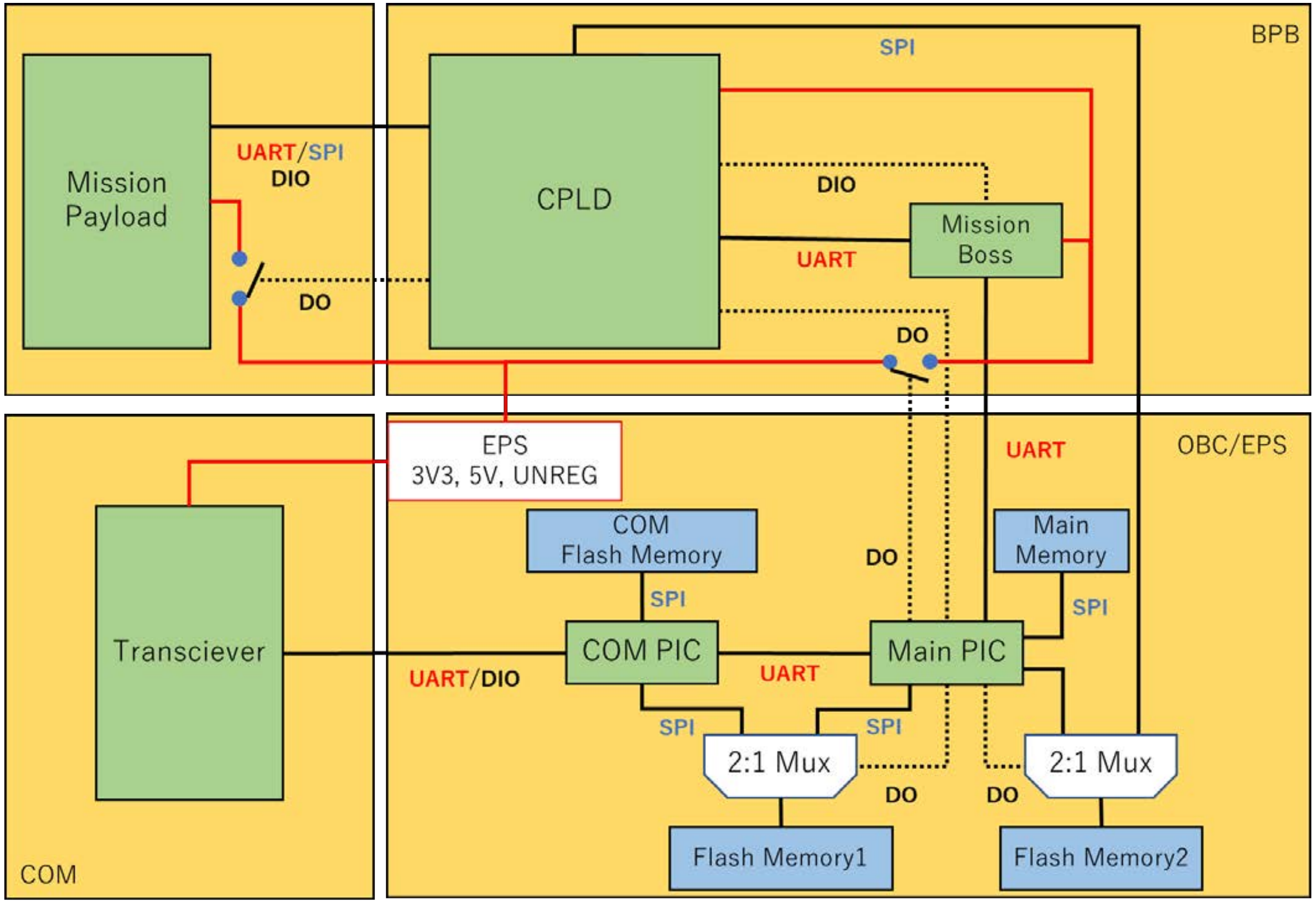
C105 (MSN-2)			
Signal Name	Pin Number		Signal Name
Prog GIO 1 Mission	1	2	Prog GIO 2 Mission
Prog GIO 3 Mission	3	4	Prog GIO 4 Mission
Prog GIO 5 Mission	5	6	Prog GIO 6 Mission
Prog GIO 7 Mission	7	8	Prog GIO 8 Mission
Prog GIO 9 Mission	9	10	Prog GIO 10 Mission
Prog GIO 11 Mission	11	12	Prog GIO 12 Mission
GND-SYS	13	14	GND-SYS
SUP 5V0	15	16	SUP 5V0
CPLD31	17	18	CPLD32
CPLD33	19	20	CPLD34
Analog3	21	22	Analog4
SUP UNREG 1	23	24	SUP UNREG 1
SUP 3V3 2	25	26	SUP 3V3 2
CPLD35	27	28	CPLD36
CPLD37	29	30	CPLD38
CPLD39	31	32	CPLD40
CPLD41	33	34	CPLD42
SUP UNREG 2	35	36	SUP UNREG 2
CPLD43	37	38	CPLD44
CPLD45	39	40	CPLD46
CPLD47	41	42	CPLD48
CPLD49	43	44	CPLD50
CPLD51	45	46	CPLD52
CPLD53	47	48	CPLD54
SUP 3V3 1	49	50	SUP 3V3 1

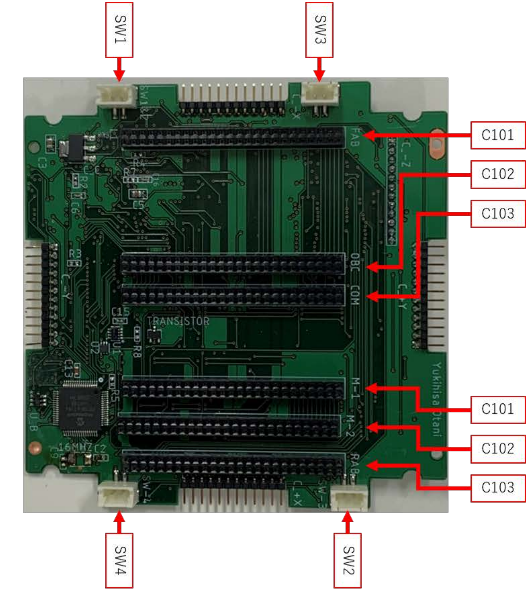
C106 (RAB)			
Signal Name	Pin Number		Signal Name
Prog GIO 1 Mission	1	2	Prog GIO 2 Mission
Prog GIO 3 Mission	3	4	Prog GIO 4 Mission
Prog GIO 5 Mission	5	6	Prog GIO 6 Mission
Prog GIO 7 Mission	7	8	Prog GIO 8 Mission
Prog GIO 9 Mission	9	10	Prog GIO 10 Mission
Prog GIO 11 Mission	11	12	Prog GIO 12 Mission
GND-SYS	13	14	GND-SYS
SUP 5V0	15	16	SUP 5V0
CPLD55	17	18	CPLD56
CPLD57	19	20	CPLD58
Analog5	21	22	Analog6
SUP UNREG 1	23	24	SUP UNREG 1
SUP 3V3 2	25	26	SUP 3V3 2
CPLD59	27	28	CPLD60
CPLD61	29	30	CPLD62
CPLD63	31	32	CPLD64
CPLD65	33	34	CPLD66
SUP UNREG 2	35	36	SUP UNREG 2
CPLD67	37	38	CPLD68
CPLD69	39	40	CPLD70
CPLD71	41	42	CPLD72
CPLD73	43	44	CPLD74
CPLD75	45	46	CPLD76
CPLD77	47	48	CPLD78
SUP 3V3 1	49	50	SUP 3V3 1

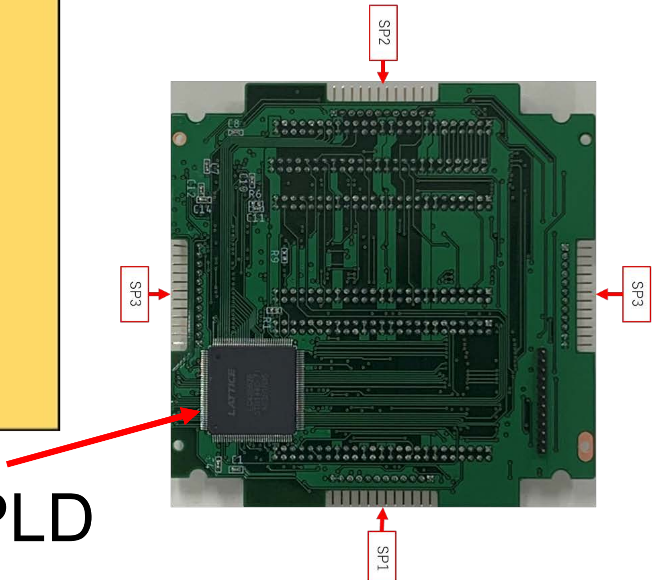
50-pin connector assignment

BIRDS BUS

Communication between mission payload and satellite bus is done through CPLD (Complex Programmable Logic Device) configurable by software


BPB
Mission Payload
UART/SPI
DIO
DO
CPLD
SPI
DIO
UART
Mission Boss
DO
COM
Transciever
UART/DIO
EPS
3V3, 5V, UNREG
OBC/EPS
UART
COM Flash Memory
SPI
COM PIC
UART
DO
Main Memory
SPI
Main PIC
SPI
SPI
2:1 Mux
DO
DO
2:1 Mux
Flash Memory1
Flash Memory2


SW1
SW3
C101
C102
C103
C101
C102
C103
SW4
SW2


SP2
SP3
SP3
SP1

CPLD

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”

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 (by summer 2022)
  - In-orbit results (temperatures, voltage, current, etc) of BIRDS-3 and 4
  - BIRDS-5 information

Licensing

- So-called “MIT license”

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Users

- Domestic
  - 2 universities
  - 2 high-school projects
  - 1 company
- International
  - 4 countries (former BIRDS students)
- The information is open to anybody including non-BIRDS countries

Estimated cost to produce a 1U CubeSat

Item	Cost (USD)	Note
C&DH and EPS*	4,000	Procured from a company
UHF COM*	8,000	Procured from a company
Structure + fastener	8,000	Manufacturing outsourced
Battery	2,000	Ni-MH_2 (Eneloop by Panasonic)
Solar panels + Glue	10,000	Glue (RTV S-691) costs 5K$ per kg
Backplane + Antenna panel	5,000	Manufacturing outsourced
Other small items	3,000	
Total	40,000	

**Provided by Japanese companies*

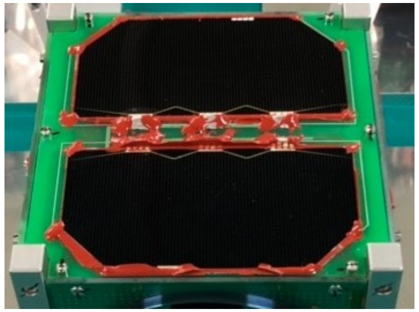
Costs are the case when purchased inside Japan

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 30K$



Solar panel w/ glue

Main Bus
COM

UHF COM board

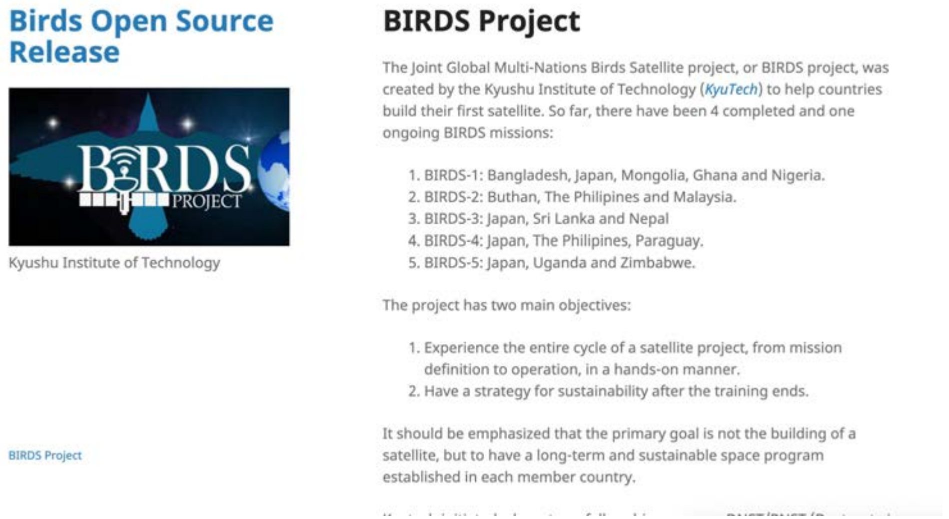
Estimated schedule to produce a 1U CubeSat

Timing	Milestones
D	Delivery of the satellite to the launcher
MonthD-1	Completion of FM hardware testing
MonthD-3	Completion of FM hardware procurement. Everything deliver and waits for assembly.
MonthD-6	Completion of EM testing
MonthD-10	Completion of EM hardware procurement. Everything deliver and waits for assembly.
MonthD-13	Feasibility of the conceived mission is confirmed Design of the EM is complete and order placement starts
Month D-A*	Mission profile of the satellite is decided

Aim to deliver a satellite in 15 ~ 18 months

Activities

- Monthly Webinar
  - 20:00-21:30 2nd Saturday every month (JST)
  - Next one is May 14
- GitHub platform
  - https://github.com/BIRDSOpenSource
  - Telegram Chat
- Mailing list to announce events such as Webinars
  - To subscribe, access to



Birds Open Source Release

Kyushu Institute of Technology

BIRDS Project

BIRDS Project

The Joint Global Multi-Nations Birds Satellite project, or BIRDS project, was created by the Kyushu Institute of Technology (*KyuTech*) to help countries build their first satellite. So far, there have been 4 completed and one ongoing BIRDS missions:

1. BIRDS-1: Bangladesh, Japan, Mongolia, Ghana and Nigeria.
2. BIRDS-2: Buthan, The Philipines and Malaysia.
3. BIRDS-3: Japan, Sri Lanka and Nepal
4. BIRDS-4: Japan, The Philipines, Paraguay.
5. BIRDS-5: Japan, Uganda and Zimbabwe.

The project has two main objectives:

1. Experience the entire cycle of a satellite project, from mission definition to operation, in a hands-on manner.
2. Have a strategy for sustainability after the training ends.

It should be emphasized that the primary goal is not the building of a satellite, but to have a long-term and sustainable space program established in each member country.

Conclusion

- Flight proven BIRDS Bus information is open-sourced
- Goal
  - Space programs in non-space faring countries have more solid basis in each country
  - Making satellite development easier, quicker and cheaper so that
    - More new people enter the space sector
    - More people benefit from the uses of outer space