



#### **Lessons Learned from BIRDS-I Constellation Mission**

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#### **Countries that launched 1-10kg satellites**





- Satellites affordable even to universities, small business, developing/ emerging countries
- Interest in capabilities for basic space technology development

### **Demands for Capacity Building**



- Small satellites are ideal entrance for developing countries to join the space sector
- Demands 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

Kyushu Institute of Technology (Kyutech) Space Engineering International Course (<u>SEIC</u>)



- Started in April 2013 at Graduate School of Engineering, Kyutech
- Research toward a Master or Doctoral degree
- On-the-job training such as space environment testing workshop
- Project Based Learning (PBL) through a space project
- Lectures in English
  - Space Systems Engineering, Satellite Engineering, Space Environment, Environment Testing, Power System, Structure and Material, Dynamics, Propulsion, Plasma, Semi-conductor, and more









As of October 2017, 19 countries 64 students (24 Japanese, 40 foreign students)

## 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: <u>Post-graduate study on Nano-Satellite Technologies (PNST)</u> initiated
  - 2 Masters students selected per year
  - 4 Doctoral students selected per year
  - MEXT (Japanese government) fellowship support
- 2018 2020: PNST 2<sup>nd</sup> term
  - 3 Masters students selected per year
  - 3 Doctoral students selected per year
  - MEXT (Japanese government) fellowship support
  - Application Deadline January 28, 2018

#### **Kyutech Satellite Heritage**











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

HORYU-II 2010-2012 Launched on 2012/5/18

Shinen-2 2013-2014 Launched on 2014/12/03

HORYU-IV 2013-2016 Launched on 2016/02/17

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Tenkou



JAPAN Mongolia Bangladesh Mazaalai TOKI Ghana Nigeria Nigeria Edusat1 GhanaSat 国立大学法人 九州工業大学

**AOBA VELOX-III** 2014-2016 ISS release 2017/01/19

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





To be launched

AOBA VELOX IV



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### HORYU-IV Project (2013~)





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



### BIRDS Program (2015~)



#### 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) NIGERIA BANGLADESH JAPAN GHANA MONGOLIA THAILAND TAIWAN . پ BIRDS-II (2016-2018) JAPAN BHUTAN MALAYSIA PHILIPPINE BIRDS-III (2017-2019) Sri Lanka Nepal JAPAN



#### **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\*
- 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



#### **Project Organogram**







#### **BIRDS** partners

- Except Bhutan, all the BIRDS partners are universities
- Each partner who owns a satellite pays
  - Launch cost (3,000,000 yen)
  - Hardware cost
  - Student cost (at least two students sent to Kyutech)
  - Ground station cost in each country
- Each partner is committed to initiate space education/ research program
  - BIRDS graduates form its core

### **Strategy for sustainability**



- BIRDS program aims at fostering university space programs in non-space faring countries
- Often a national space program suffers disruption because of political and economical disturbance
- University space program is immune to the external disturbances.
- To start with the minimum budget, a university is an ideal place.
  - CubeSat chosen as a training platform.
  - Affordable enough at university budget level
- The university space program cannot grow forever.
  - Need to hand over the national space program to the government or companies
- Even after handing over the big projects to the outside body, the university still can continue its own space research and education
  - Need to provide the human resource to the national space program 13

#### **Educational aspects**



- A short-tem goal
  - Build and operate satellites
    - Give the students confidence 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 processes 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

### **System Configuration**

- Modularized and Less harness design.
- All satellites share same frequency (UHF/VHF).
- Using Backplane style used in UWE-3.
- Multi functional single board.











#### **BIRDS-I** Configuration







- Deployable UHF\_9600bps
- Patch UHF\_1200bps
- **(a)** VHF Patch Antennas;
- Battery (3 series 2 parallel)
  - Ni-MH batteries, 10 solar cells;
- Passive attitude control system
  - hysteresis damper and
  - permanent magnet;

### **BIRDS ground station network**



#### BIRDS constellations are operated by a network of GSs in BIRDS partners



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#### **BIRDS ground station network**



#### Satellite missions BIRDS-I BIRDS-II



- Take a picture of participating countries
- Digi-singer for outreach
- Single Event Latch-up detection
- Determination of satellite precise location
- Atmospheric density measurement
- Constellation operation via ground station network



Patch antenna

- Take a picture of participating countries
- Packet communication relay between amateur radio people
- Store & Forward
- Demonstration of COTS GPS device
- Single Event Latch-up Detection
- Measurement of Earth magnetic fields



Deployable antenna

#### **System Development**





### Lean Satellite Approach



- The BIRDS program experiments the lean satellite approach
  - Lean satellites seek to deliver value to the customer (the enduser or the purchaser) or the stakeholder at minimum cost and in the shortest possible schedule by minimizing waste.
- When the students continue the space program in their home country, they have to adopt a lean approach so that the program can run with a small team and a minimum cost.
- In the BIRDS program, the overall satellite development activity can be done within a radius of 30 m.
- The students are encouraged not to use e-mail unless they need to broadcast to all the team members.

#### Waste minimization



• Minimize waste of "waiting" and "moving"



#### **BIRDS** Network



- Human network
  - Formed during intensive two years project by "living under the same roof"
  - Assist the infant space programs survive the hard time
- Ground station network
  - The backbone of the inter-university network
  - Enable constellation operation in future
    - Space research using a small satellite constellation generating scientific outputs

# Cross-Border Inter-University Collaboration

- Mission
  - "To advance the peaceful use of outer space for the benefit of humanity by using a network of universities conducting space research and education"
- Each member institution of the BIRDS Network will launch its own space research and education program.
- Annual workshops
  - Japan (2016), Ghana (2017), Mongolia (2018), Bangladesh (2019) and so on...



BIRDS workshop 2017 @Ghana



#### **Outreach Activities**





2017 Diversity Award





#### Satellite delivery on February 8, 2017



Launched successfully to ISS on June 4, 2017



#### Released successfully to orbit from ISS on July 7, 2017





#### BIRD-M JG6YJQ / BIRD-G JG6YJP CW Beacon

② FRIDAY, JULY 7, 2017 ▲JA0CAW ● LEAVE A COMMENT

#### 21:12 UTC



Heard beacon signals from all the five satellites

Patch antenna gain was much worse than expected





Baterry Voltage [mV]





As of September 20, trying to establish uplink communication



#### **GEDC** Airbus Diversity Award



BIRDS-I project manager, Tejumola Taiwo (Nigeria)

BIRDS project won 2017 GEDC (Global Engineering Deans Council) Airbus Diversity Award out of 45 entries from 18 countries as a successful example of using **diversity** to effectively conduct **engineering education** 







So many news coverage



### **BIRDS-II and BIRDS-III status**

- BIRDS-II
  - Reflect many lessons learned from BIRDS-I
  - Currently EM phase
  - FM completed in early 2018
  - Released from ISS in spring 2018
- BIRDS-III
  - Kicked-off in October 2017
  - Japan, Sri Lanka and Nepal



#### Engineering Model of BIRDS-II

#### **Preparation for future**



- Once students go back to the home countries, they will face
  - Huge expectation from all over the country as a space expert
  - Asked what the country should do to advance the country's space program
- They have
  - Chance
    - of achieving what you want
  - Risk
    - of not meeting the people's expectation
- Students need to prepare in advance
- 6-month long sessions to prepare 10 year strategic space plan of each country to be presented to stakeholders
- Combined with space policy & law



### **Team Future plans**



- Students returned back home and became faculty members in their countries
  - Regenerate experience and innovative ideas at home.
    - Learn to use limited resources at home.
- Make the second satellite at home.
  - Ghana, Mongolia, Bangladesh
  - Do not lose momentum
- Support one another and share ideas.
  - Build on the network established.
  - Share best practices and lessons learned.

### **BIRDS-I lessons learned**



- As a constellation satellite program
  - Thorough design verification before moving to flight model
  - Quality assurance of each flight model
  - Decision on whether making every stakeholder happy or guaranteeing that at least one satellite will work
  - Scale merits lower the hardware cost
- As an international satellite program
  - Proper supervision to avoid crucial conflict of cultural backgrounds among team members
  - Careful about different commercial practices in each country
  - Different levels of frequency regulation and space treaty ratification

#### **BIRDS-I lessons learned**

- As an educational program
  - It was a very good educational opportunity for students.
  - But, to make the BIRDS program as a sustainable educational program to be done by a university
  - 1. Need to lower the hardware cost further
    - Fix the satellite bus design
  - 2. Need to lower the burden on each faculty
  - 3. Need to increase the number of students who can benefit
    - Currently only 2~3 students per satellite
    - Increase to 12 students per satellite
  - 4. Need to have documents to be used as textbooks
- These points will be addressed from BIRDS-III and -IV





### Conclusion



- BIRDS program is a unique capacity building program to foster space development and utilization capability in non-space-faring countries by
  - Making students experience the entire processes of a satellite project
  - Making networks to support the cross-border inter-university collaboration on space research and education
- The mission success criteria of BIRDS program
  - After graduation, students succeed in developing and operating the second satellite in their home country
  - BIRDS network will assist the infant space programs each other
- BIRDS workshop to be held once every year in member countries, Mongolia (2018), Bangladesh (2019)