

Challenges to spread space technology and bring diversity to the space sector through BIRDS Bus Open-sourcing activities

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Abstract: Kyushu Institute of Technology (Kyutech) launched the BIRDS program in 2015 to enhance space technology capacity in emerging countries, facilitating their initial satellite launches and promoting self-sufficiency in satellite development. Over five two-year projects, the program produced 17 CubeSats spanning five generations and enabled nine countries to launch their first national satellites from the International Space Station (ISS), thus fostering the democratization of space technology. To support global capacity-building, Kyutech shared the BIRDS BUS satellite design, adaptable for 1U, 2U, and 3U CubeSats and larger scientific missions, including lunar and astronomical endeavors. Kyutech graduates have subsequently led satellite projects in their home countries, advancing the institute's goal of broad space technology access. Presently, Kyutech collaborates with five Japanese and four international partners on satellite projects, leveraging open-source designs. To address operational challenges and further lower barriers to space engagement, Kyutech launched the BIRDS-X project, which includes mission boards and ground terminals competition for global use. A 2U satellite with the BIRDS BUS is planned for launch in 2025, along with a 6U satellite for more complex missions. The widespread use of the BIRDS BUS underscores Kyutech's significant role in promoting open-source space technology.

1. INTRODUCTION

The history of space development has developed against the backdrop of the Cold War between the United States and the Soviet Union, and since then, developed countries and major countries have taken the lead in promoting research and development of space technology. On the other hand, with the progress of practical use of small satellites such as CubeSats, an increasing number of countries are aiming to acquire satellite technology using CubeSats. Figure 1 shows the Nanosats Database[1] (<https://www.nanosats.eu/>), which is a database of small satellite launch records. As we can see from the figure, developed countries and countries that have been engaged in space development have a large number of launches, but although the number is small, Southeast Asia, South America, Africa also has a track record of

satellite launches, indicating that the technology of space, especially small satellites, is expanding around the world.

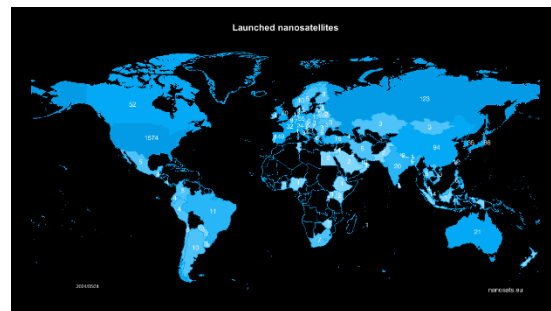


Figure 1: Number of small satellite launchers in the world (<https://www.nanosats.eu/>)

Against this backdrop, there is a growing demand for many emerging countries to embark on space development. Therefore, in 2015, Kyutech conceived the "BIRDS Program". Kyutech realized that these countries were not moving forward

because they did not have the necessary human resources to acquire satellite technology, let alone acquire it. With "the launch of the first national satellite" as a point of inspiration and motivation, the goal of the BIRDS program is to support such countries advance as their own technology by training cadres of engineers to have mastered the skills needed to design, build, and test the first satellites. It is an important premise that engineers return to their home countries and achieve the goal of (1) building a second satellite in their home country and (2) training other engineers in the process. If this process is repeated enough, they will gradually acquire human resources for a sustainable space program. Therefore, the central goal is not the first satellite itself, but rather the key goal is to connect it to the sustainable space program of the country that has just boarded it.

Since most of the students who participate in each BIRDS project are graduate students at the master's level, Kyutech has set the duration of the master's program to be two years. We aim to do it within two years. Over the course of these two years, they will design, build, test, and operate the 1U CubeSat under minimal faculty supervision. Since their satellites are launched before graduation, they also experience operations in orbit of satellites. This is an important factor in learning the entire satellite development process. With human resource development as the most important objective, the participating countries of the BIRDS program send two or three engineers to work on the first CubeSat project and in parallel to pursue a master's or doctoral degree in Kyutech's Space Engineering International Course(SEIC) program.

We have completed several projects, and the achievements of BIRDS BUS are accumulating. There was a growing need for a mechanism that would not only help countries and universities that want to

launch the first 1U CubeSat to be the first satellites to use this Bus technology, but also help lower the barrier for various organizations to enter space. As a result, we decided to release information on the open-sourcing of BIRDS BUS and focus on activities to encourage new stakeholders to enter space using this Bus technology.

2. BIRDS PROGRAM

2.1 Overview of BIRDS Program

The first satellite project, BIRDS-1, initiated in 2015. The mission statement of BIRDS-1 was to "successfully build and operate the first national satellite, and take a step towards each country's own space program." When BIRDS-1 began, there was no idea to conduct a series of satellite projects. However, with the launch of BIRDS-2 in 2016, the perspective of a continuous satellite program gradually emerged. Eventually, the BIRDS program began delivering multiple CubeSats almost every year since 2017. In this program, a total of 17 CubeSats were generated, which were deployed into space from the International Space Station (ISS) in five generations. All BIRDS projects and participants are presented in the table 1.

Table 1. The BIRDS Project and its Participants

project	Release Date	country
Bird-1	2017.7.7	Japan, Ghana, Mongolia, Nigeria, Bangladesh
Birds-2	2018.8.10	Bhutan, Malaysia, Philippines
BIRDS-3	2019.6.17	Japan, Nepal, Sri Lanka

Birds-4	2021.3.1 4	Japan, Paraguay, Philippines
Birds-5	2022.11. 6	Japan, Zimbabwe, Uganda
Bird-X	Winter 2025	Multiple Countries

2.2 Features of the BIRDS Program

Since the advent of small satellites, many non-space countries have tried to enter the space field through the development and operation of small satellites. Even before the BIRDS program, there were various training programs through institutions, companies, and universities in the countries that developed the space. They were often tied to the sales of satellites (large and small). However, many of them were not always successful in human resource development, especially if the training was conducted by an agency or company. The main reason for this was that the sale of goods (satellites) was the most important objective, and human resource development and capacity building were the second objectives. As a result, it often happened that the engineers who participated lacked practical experience, or their experience did not cover the entire life cycle of satellite systems. In addition, in many programs, there have been tragedies in which trainees have left space organizations after returning home because the space programs of non-space countries were not sustainable. Through these experiences, we believe that the key to a successful capacity building program is the following two points.

- Get hands-on experience with the entire design, build, test, and operate cycle
- Post-Training Sustainability Strategies

The short-term goal of BIRDS-1 was to build and operate satellites to give students the confidence that they could do

it. However, the long-term goal was for students to start their own space programs in their own countries. Therefore, the full mission success criterion for BIRDS-1 was for former students to successfully build and operate a second satellite in their country. Therefore, the emphasis was on getting students to learn the entire process of a satellite project from start to finish. Knowing what it takes to build and operate satellites, and what decisions they must make based on their own experience, makes it easier for them to start their own space program. By starting a small program on their own, they can make the program more sustainable without relying heavily on large support from the government.

For students to experience the entire lifecycle of the system, the project must fit within the two-year master's degree schedule. In order to fit in two years, we chose to deploy the 1U CubeSat and ISS as the platform for this training. The reason for the selection of the 1U CubeSat was obvious because it was the simplest satellite, and the deployment to the ISS was chosen because it had the opportunity to fly regularly once every three months on average and the launch coordination process could be standardized.

2.3 Development method of BIRDS Program

BIRDS program is experimenting with a lean-satellite approach[2] (<https://lean-sat.org/>). Lean Satellite aims to deliver value to customers (end users) or stakeholders in the shortest possible timeline at minimal cost by minimizing waste. We strive to achieve maximum reliability within budget and schedule constraints. To that end, we properly assess, prioritize, and mitigate risks to fit within a small budget and a short schedule. If students continue their space program in their home country, they should adopt a lean approach so that the

program can be run with a small team and minimal cost.

In the BIRDS program, all satellite development activities are carried out within a 30-meter radius of the campus. All team members are placed in one room where they will spend most of their time while on campus. The clean room is located next to their room, and the testing facility is downstairs. The operation takes place in the following buildings: To minimize the waste of waiting for a reply, students are advised not to use email unless they need to broadcast to all team members.

3. Development of BIRDS Bus

3.1 BIRDS' Legacy and development

Figure 2 shows the evolution of the BIRDS satellite. With each generation, it was necessary to change the satellite BUS.

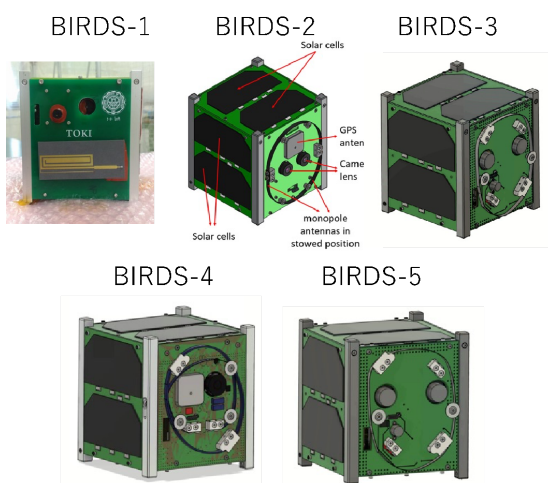


Figure 2: Evolution of the BIRDS satellite

The design of satellites has constantly evolved, reflecting flight results and adapting to changes due to external factors. Design changes could be implemented quickly because there was always an overlapping generation of students. When we started BIRDS-4 in 2018, all the members of BIRDS-3 were still in school. The members of BIRDS-2

were still in the majority, and there were only three members of BIRDS-1. Since BIRDS-2, it has become a tradition for new students to be taught directly by older generation students. If there are doubts about the design of the satellite, the student can immediately go to the advanced level. This system greatly reduced the burden on teachers, but as a result of relying too much on tutoring within students, two BIRDS-4 satellites were lost.

The strategy of the BIRDS program was to preserve the knowledge and experience of the students as a "collective intelligence" by superimposing several generations of satellite projects at the same time. Seniors teach the experience to juniors based on the results of the operation. This strategy requires funding to support multiple satellite projects.

It is important to continuously manage the project to always secure experience in the laboratory. For this reason, it is important to make continuous efforts to obtain partner institutions and external funding..

3.2 Expansion of BIRDS BUS

Its variations have also been used for other satellite projects, such as KITSUNE (a 6U CubeSat deployed from the ISS in February 2022). BIRDS/KITSUNE BUS has also been applied to other 2U and 3U also been applied to other CubeSats with slight modifications. As well as scientific missions such as lunar science mission called LEOPARD and the astronomy mission called VERTECS. Two years ago, we launched our latest BIRDS project called BIRDS-X. The project involves multiple countries due to the competition between the APRS Mission Board and the Ground Terminal (GT). By competing for mission boards, this is an initiative to lower the threshold so that anybody can participate in satellite projects from a

single board. Not only BIRDS BUS is a good starting point for emerging countries looking to build satellites domestically without starting from scratch, but the asset is being expanded to support the deployment of second and third more advanced missions at the same time.



Figure3. BIRDS-X Satellite

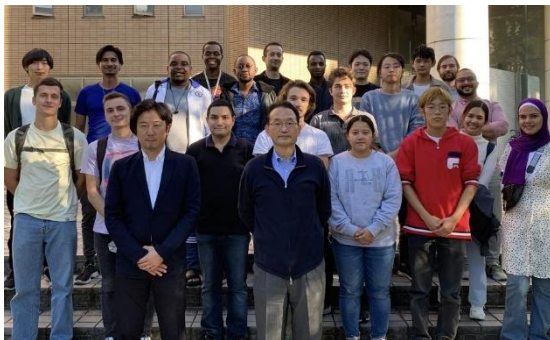


Figure.4 BIRDS-X project group photo taken in the fall of 2022

4. BIRDS Bus Open-Source Activities

This asset does not only support countries and universities looking to launch a 1U CubeSat as their first satellite, but also help lower the threshold for various organizations, including companies and institutions, to venture into space and take on further development missions. Therefore, we have decided to publish information on the open-sourcing of BIRDS BUS and focus on activities to encourage new stakeholders to enter the space sector.

Currently, the open-source project is actively pursuing not only BIRDS partners, but also people outside the BIRDS network. We started to have monthly meetings with former SEIC students during the pandemic. Many former students report the difficulties of promoting domestic satellite projects in their own country. The mission success criterion for the BIRDS program is that the second satellite will be built domestically by former BIRDS students. As a result, it turned out that the simplest solution for the second satellite is to duplicate or modify the BIRDS satellite, which they are familiar with. However, Kyutech is not a company, so it cannot maintain and operate satellite BUS. In addition, when it comes to companies that commercialize BIRDS BUS, it is expensive because it needs to make a profit. The most affordable way is to allow users to work on satellites on their own. We also wanted to make sure that other people (non-BIRDS members) could benefit from this effort. After that, we came to the conclusion that we would open source all the technical information related to BIRDS BUS.

We decided to post basically all the technical information related to the design of the satellite.

- Drafting (e.g. CAD files)
- Source code (satellites and ground stations)
- PCB Design
- Assembly and Test Instructions
- PARTS LIST
- Test Report
- Interface Control Documentation
- textbook

As of 2024, information about BIRDS-3, 4 and 5 is available on GitHub [3]. Also, the on-orbit results of BIRDS-3 and 4 (temperature, voltage, current, etc.) are posted on GitHub. In open-source activities, it is important to define a licensing policy. At BIRDS Bus open

source, we have decided to adopt so-called “MIT licence” which is the most flexible licensing option and can be leveraged by anyone as long as the user is aware of the source of information and can show it.

As of June 2024, there are five groups of Japan users using BIRDS BUS for satellite projects. Internationally, there are four countries that use the BIRDS BUS, all from the former BIRDS countries. This is made possible because BIRDS BUS is designed to serve as a CubeSat platform for a wide variety of mission payloads with minimal design changes to the satellite Bus. The information is open to anyone, including non-BIRDS countries. All information related to open-sourcing efforts is distributed on the portal site [4].

5. Conclusion

Kyutech recognized that many emerging countries were standing on the sidelines as the developed countries (space-developing countries) were making rapid progress in space development, as a global issue. The difference is large and is growing every year. In order to alleviate this technological and industrial disparity between the haves and have-nots of the United Nations, Kyutech decided to propose a means of starting space to non-space fairing countries, thereby initiating a series of positive chain reactions that would economically benefit such countries. Therefore, the concept of BIRDS has been endorsed by the countries listed in Table 1, some of which are still collaborating to develop space programs.

Launching their country's first satellite into space is an obvious achievement for everyone. This achievement has captured the imagination of the public in all BIRDS countries. With the support of public opinion in the direction of the wind, the government can allocate more funds to

space exploration. In addition, high-profile space achievements encourage the brightest and brightest young people to pursue careers in space science and engineering. In addition, if the base of human resources with space technology expands, BIRDS countries can realistically begin to develop their domestic space industry. These are necessary for the economic growth and prosperity of the state.

Through its open-sourcing activities, Kyutech will continue to reach out to students who have returned to their home countries after completing the project, countries that have not yet started space development. In addition, there is an increasing number of attempts by companies and organizations that are not related to space to acquire satellite technology and use it in their own services. In this way, by open-sourcing BIRDS BUS to other players who are thinking of entering the space program, we aim not only to encourage new entrants, but also to further develop these BIRDS program activities. We are utilizing the accumulated legacy to encourage activities that go beyond doing by ourselves. We aim to utilize BIRDS BUS and apply it to more advanced technology demonstrations and scientific missions, and to make it available to more players. This will also lead to a more sustainable development mechanism as a program of Kyutech's BIRDS BUS.

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6. REFERENCES

- [1] <https://www.nanosats.eu/> (accessed 30.08.24)
- [2] <https://lean-sat.org/> (accessed 30.08.24)
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- [4] <https://birds-project.com/open-source/> (accessed 30.08.24)