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International Collaboration Towards Cambodia's First Small Satellite Education Program - Lessons Learnt -

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ABSTRACT

Since 2019, students from the University of Tokyo (UTokyo) and the Institute of Technology of Cambodia (ITC) have collaborated to set up Cambodia's first small satellite education program. Around 30 students from both institutions have organized and taken part in joint educational activities, articulated around the development of a 1U CubeSat, which is planned to become Cambodia's first satellite. This paper presents lessons learnt so far during the cooperative education program. We first explain how students have led the collaboration between a mentor (UTokyo) and mentee (ITC) institution in different countries, mostly online due to the pandemic. We then provide transferable lessons on how to create a small satellite education program in a resource-scarce environment, based on the development of CubeSat training at the ITC. Finally, we present ongoing methods at the ITC to cultivate a supporting ecosystem for the new satellite education program. It is hoped that this paper will provide a useful reference point for other actors building a new and sustainable satellite education program with limited resources.

INTRODUCTION

Cambodia is a country located in the southern part of the Indochina peninsula, with a population of 17 million and a land area around half that of Japan. Cambodia does not own or operate any satellites, nor does it have a national space policy or agency.[1] On the other hand, since 2019, students at the Institute of Technology of Cambodia (ITC) have begun the country's first indigenous space development activities, by collaborating with students at the University of Tokyo (UTokyo) in Japan.[2] One outcome of this international partnership has been to establish Cambodia's first small satellite education program, with the goal of launching Apsara-1 – a 1U CubeSat set to become Cambodia's first satellite – in the near future.

This paper summarizes lessons learnt from creating the satellite education program.

The text is organized as follows. First, we provide a short history of the collaboration. Second, we review "iteration one" of the satellite education cycle. Third, we present the status of Cambodia's first CubeSat, developed by the education program's first student cohort. Fourth, we emphasize lessons which should be carried forward to future space education initiatives in other resource-scarce environments. Fifth, we explain our progress towards creating a supporting ecosystem for sustainable space education at the ITC and in Cambodia.

PROGRAM HISTORY AND STRUCTURE

In this section, we introduce the program timeline and participating stakeholders, and we explain our motivation to begin the international collaboration.

Timeline

The collaborative small satellite education program between UTokyo and the ITC began in February 2019. The program timeline to date is shown in Figure 1.

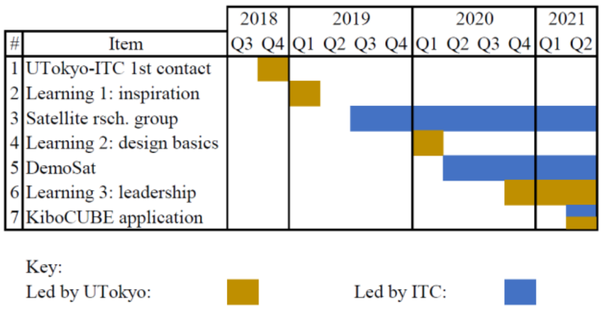

Figure 1: Timeline of education program

The program has comprised three collaborative teaching courses. UTokyo led the earlier learning activities ("learning 1" and "learning 2"), and a transition to co-leadership with the ITC has followed ("learning 3"). Each course has produced follow-on outcomes at the ITC. The courses trace out a full learning cycle, providing a gradual increase in duration and difficulty, to accompany learners from first exposure to space-related concepts through to systems engineering leadership in a real small satellite design project. The content of this first learning cycle, and its ongoing conversion into a yearly curriculum at the ITC, is described in more detail in the next section.

Members

Three research laboratories from two universities are currently part of Cambodia's first space education program. On the UTokyo side, the participating laboratories are the Kojiro Suzuki Laboratory and the Intelligent Space Systems Laboratory (ISSL), both based in or near Tokyo. The Dynamics and Control Laboratory (DCLab) is leading the development of the education program at the ITC, based in Phnom Penh.

UTokyo and the ITC have a mentor-mentee relationship in the educational partnership. UTokyo was responsible for initiating the first cycle of the education program, and continues to be responsible for providing supporting knowledge on space systems engineering, facility development, space regulations, and linkage with the sustainable development goals. The ITC is responsible for implementing subsequent cycles of the education program, securing funding to support students and learning activities, and leading the design and development of small satellites within the curriculum.

At both institutions, the program is coordinated either by graduate students or junior researchers, who are responsible for project management, curriculum design, and recruitment of participating students. Faculty members provide administrative support to facilitate students' initiatives, including funding. For example, a memorandum of understanding was signed between the DCLab and the ISSL to formalize the educational partnership.

The number and location of participating students and faculty members are shown in Table 1 and Figure 2. In addition to promoting technical capacity building, this collaborative education program has provided a platform for diverse multicultural exchange both within and beyond Cambodia.

Table 1: Participating students and supporting faculty members in each institution

Item	UTokyo	ITC
# of students	8	27
# of faculty members	3	3
# of nationalities (UTokyo) or Camb. provinces (ITC)	7	11

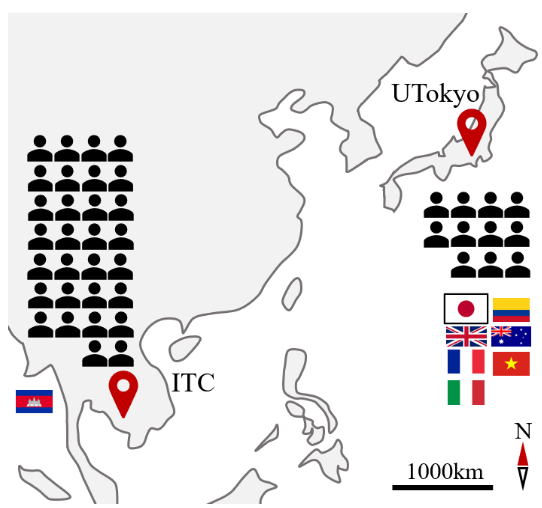

Figure 2: Location and number of program members (past and current)

For example, Cambodian members originate from 11 provinces: Banteay Meanchey, Battambang, Kampong Cham, Kampong Thom, Kampot, Kandal, Kep, Phnom Penh, Prey Veng, Siem Reap, and Sihanoukville.

Why Begin?

This collaborative small satellite education program was initiated for three reasons: (i) students in Cambodia and Japan were seeking new knowledge on space utilization, (ii) the program contributes to existing capacity at the ITC, (iii) the timing was good.

(i) Students were motivated on both sides. The program began in 2019 as a "Student Initiative Project"[3] led by five aerospace graduate students at UTokyo. The project members have existing expertise in small satellite design and space capacity building, which has included developing subsystems of the EQULEUUS nanosatellite (to be launched in November 2021 via the SLS)[4] and receiving training for CubeSat teaching. Members were motivated to share their experience with other aspiring space enthusiasts in the Asia-Pacific region, and Cambodia was shortlisted due to its novelty to the space field yet quite high technical skill base. In parallel, undergraduate students at the ITC have a history of participating in the Asia-Pacific Robot Contest ("Robocon")[5] organized by the Asia-Pacific Broadcasting Union (ABU), and as such already have an interest in taking up engineering challenges in electronics and communications. This combination of curiosity and initiative led to the start of the program.

(ii) The program contributes to existing capacity at the ITC. The ITC consists of seven faculties and graduate schools, and a Research and Innovation Centre (RIC) with five units. Two of these research units and graduate schools are Mechatronics & ICT, and Materials & Structural Engineering. For example, the DCLab specializes in four fields at the interface between these areas: artificial intelligence, the internet of things, robotics and autonomous navigation, and aeronautics. Gaining knowledge in small satellite engineering is expected to produce three favorable outcomes at the ITC: deepening the existing technical base in mechatronics and control; developing project management experience in advanced systems engineering transferable to other complex technical projects; and uncovering new research opportunities by creating connections between existing research areas. For this reason, the DCLab was enthusiastic to initiate the ITC's pilot small satellite education program.

(iii) Good timing. In April 2020, a Cambodian graduate in satellite engineering from Tohoku University in Japan entered the DCLab as a lecturer and founded a satellite research group. Most members joined the group after having received prior satellite engineering training provided by UTokyo. This fortunate timing, with coincident leadership on both sides from UTokyo and the ITC, was responsible for the fast and sustainable development of the education program.

DEVELOPING THE FIRST LEARNING CYCLE

The ITC's small satellite education program was developed in a step-by-step approach. The first cycle was led by UTokyo over two years. Based on lessons learnt from the first cycle, a yearly curriculum is being crafted by the ITC. This section overviews the development of the education program.

Hills Before Mountains

Tokyo in Japan and Phnom Penh in Cambodia share a similar topography. The cities are located in a large flat plain, delimited by a distant mountainous rim to the north and west. The development and content of the satellite education program share common features with this geography. They begin with short and basic teaching activities (i.e. the "plain"), progressively increasing in duration and difficulty ("hills"), before culminating in a real small satellite project (the "mountains"). We describe this "hills before mountains" approach in the following two paragraphs.

(i) "Hills before mountains" learning approach. Most students in Cambodia have little or no prior exposure to satellite development. Therefore, teaching must begin by combining two features: content which starts from the very basics, and an engaging format which captures students' interest. Once students have been inspired, the next step is to provide relevant knowledge on satellite operation and design. Finally, students are ready to "climb the mountain", and can be given leadership to apply their new knowledge and acquire management and systems engineering skills in a real small satellite project. The first cycle of this kind was led by UTokyo, and subsequent cycles will be led by the ITC.

(ii) "Hills before mountains" curriculum development. As this is the first small satellite education program in Cambodia, starting simple was also desirable in order to test the waters (e.g. to gauge students' interest, expected costs, response from the ITC, etc.) and to progressively build a relevant and efficient curriculum adapted to local needs and constraints. In developing this program, we emphasized an agile[6] methodology, seeking continuous improvement and promoting bi-directional exchange between learners and program leaders. The first learning cycle led by UTokyo in 2019-2021 will be improved upon in next iterations.

The three-step learning approach is presented in detail in the next subsections. The first iteration of the curriculum by UTokyo is described, followed by the improved curriculum designed by the ITC for the next teaching cycles.

Learning 1: Hands-on Open Days

Step one is to introduce learners, who are complete space engineering newcomers, to the basic concepts.

In the first iteration of the education cycle, UTokyo organized a two-day intensive lecture course in Phnom Penh in February 2019 covering the fundamentals of planetary exploration, propulsion, satellite technologies, and space applications for society.[2] The objective was to inspire undergraduates at the ITC, using interactive presentations, gamification, hands-on group work, and competitions. Figure 3 shows a group photo taken after a soft-landing challenge, which introduced participants to mission design and sensors for space applications.

Figure 3: Hands-on introduction to space activities with UTokyo and ITC members, in Phnom Penh

In the next iterations, the ITC will continue to offer an intensive course on the fundamentals of space engineering to interested ITC students. This will be led by the current space engineering team of the DCLab, with guidance from UTokyo on an as-needed basis. The purpose of the course will be to share space engineering knowledge, while at the same time introducing current space related DCLab activities to prospective new members for recruitment. Students who are interested to continue learning will be able to officially join the DCLab space engineering team after completing this introductory course.

The one-week course will be provided during the ITC's semester break (July to September), targeting second- and third-year undergraduate ITC students, with a focus on the mechanical and electrical engineering departments. Timing the course during the vacation is important, so that previous members will be available to transfer their knowledge to the next generation. The course structure will follow that initially provided by UTokyo, and will act as the first building block of a formal university-level space engineering curriculum at the ITC, which may evolve into a fully-fledged aerospace engineering department in the near future.

Apart from the above-mentioned course, DCLab members will also organize a small exhibition to showcase their space engineering projects at the ITC's orientation day – an open day during which each department at ITC promotes its activities – held annually in November. Through this event, we hope to create awareness about space engineering especially among freshmen who recently enrolled at ITC. Indeed, most new ITC entrants have limited knowledge about engineering. We expect that this exhibition will help students to realize for example that mechanical engineering is not limited to manufacturing, or fixing cars and air-conditioners, but can also be applied to new and exciting problems such as space applications.

Learning 2: CubeSat Design Workshop

Step two is to provide learners with practical knowledge on satellite operation, subsystem design, and modelling.

For the first iteration, UTokyo organized a five-day CubeSat workshop in March 2020, online due to the pandemic. The content included a crash course on satellite subsystem design, systems engineering, and project management. Undergraduate learners at the ITC were introduced to actual CubeSat development activities at UTokyo, and given supervised assignments related to mission design, hardware design, and flight software design.

Next editions of the workshop will be turned into a design competition. ITC will use the learning materials from the first CubeSat workshop offered by UTokyo, with two changes: the duration will be extended, and the content will be simplified. In addition, the curriculum will be adjusted to match the ability of each new member.

Specifically, before the competition begins, we will provide an assessment form to understand students' background knowledge and interests. We will then give tutorials with varying levels of technical difficulty (e.g. group reading and discussion on selected chapters of standard satellite engineering textbooks) to brush up their grasp of space engineering concepts on an as-needed and as-interested basis. We will also introduce satellite design concepts via common lectures.

Then, during the actual competition, participants will be required to form teams and experience project management by designing their own unique mock-up satellite (i.e. with most of the functions of a real small satellite, but not intended for operation in the space environment) over two months using available training tools at the DCLab. To promote skills exchange, current student members of the DCLab satellite team will become the team leaders and mentors of the newly formed teams. The starting point will be DemoSat, a 1U satellite training kit developed by the DCLab, shown in Figure 4. Each team will work to improve the baseline design by adding and/or changing features according to their team's mission objective. The final output of the competition will be field testing (e.g. CanSat-style drop test from helium balloon gondola, drone, or high building) and a presentation.

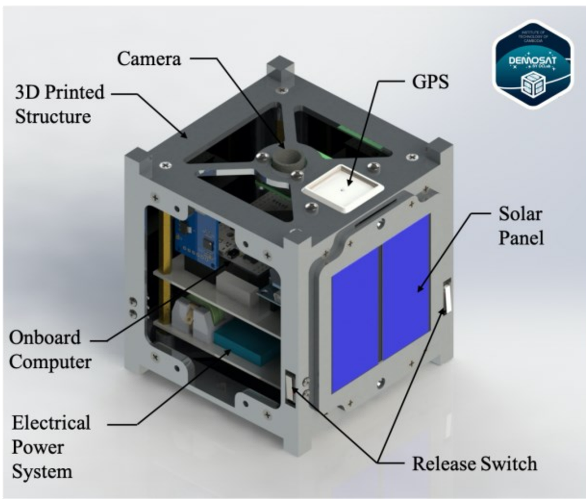

Figure 4: DemoSat – the satellite training kit by ITC

From our experience (see next subsection), effective teamwork and communication are crucial for success in a real satellite project. Therefore, this competition will be a chance to train participants before they join the DCLab's actual satellite development projects.

Learning 3: Leadership in a Real Satellite Project

The third step is to provide learners with the chance to implement their knowledge and develop design leadership skills in a real small satellite project.

For the first iteration, UTokyo organized a six-month CubeSat design challenge, from December 2020 to June 2021. Learners from both UTokyo and the ITC worked together under joint mentorship from junior researchers at the two institutions. The objective was to design an innovative yet feasible 1U CubeSat mission to address current socio-economic issues in Cambodia. The challenge covered the entire satellite design lifecycle, from mission objectives to mission requirements, subsystem design, and verification and validation. In addition, the ITC-UTokyo team went one step further by planning for actual development of the satellite, including performing risk management, creating a testing and assembly plan, setting up a work breakdown structure, ensuring adherence to relevant regulations, etc. The team summarized their proposal in an application for the KiboCUBE launch opportunity, provided by the United Nations Office of Outer Space Affairs (UNOOSA) and the Japan Aerospace Exploration Agency (JAXA).[7] If successful, the 1U CubeSat would become Cambodia's first satellite. More details follow in the next section.

Even if our application to KiboCUBE is not successful this year, we will use experiences and lessons learnt to reapply next year under ITC leadership (as opposed to UTokyo leadership this time). Regardless of the outcome, the ITC will create another CubeSat design challenge starting from November 2021, with newly recruited members. During the six-month challenge, current mission objectives will be updated if necessary, and the breadboard model (BBM) of our initial CubeSat proposal (Apsara-1) will be developed.

The duration of each new design challenge will roughly coincide with the duration of each development phase of the CubeSat (BBM, EM, FM). This means that each participating student will have the chance to experience the entire development process of a functioning CubeSat model, including design, assembly integration and testing (AIT), design reviews, etc. In addition, to promote the continuity of knowledge gained during the project, participating students will be given mentorship by past members to develop part of the CubeSat within their undergraduate final year projects, which means there will be a roll-over of skills between each cycle of the design challenge.

In summary, the first cycle of satellite education at the ITC has been completed, and a three-step framework has been set up to begin the next cycle. The core output of the first cycle is a 1U CubeSat design called Apsara-1, which is described in more detail in the next section.

CURRENT STATUS: CUBESAT CHALLENGE

This section presents the main technical achievement of the first cycle of the ITC's satellite education program: a 1U CubeSat design which may become Cambodia's first satellite. The online international collaboration method used to design the satellite is also discussed.

Design of Cambodia's First Satellite

This subsection introduces the key features of Apsara-1, a technology demonstration CubeSat with multi-spectral camera for land and water resource monitoring in Cambodia. The design was submitted to the KiboCUBE opportunity, for launch from the International Space Station (ISS) around 2024-25, and the results of the selection process will be announced later this year. If successful, and subject to funding opportunities, this would become Cambodia's first satellite.

(i) Mission objectives. The purpose of this mission is to demonstrate the ITC's ability to develop and operate a small satellite in space, and to utilize it for acquiring remote sensing data to support climate-event management and research in Cambodia. The minimum-level success requirement is to make contact with the satellite on orbit and to downlink telemetry. The nominal success requirement is to take an RGB picture of the Tonlé Sap lake – Southeast Asia's largest freshwater lake – and to downlink it to a custom-built ground station at the ITC, for outreach purposes. The challenging success requirement is to capture multispectral images of Cambodian land during the dry and/or wet season and downlink them in near real time to support climate research at the ITC and decision-making by Cambodian government stakeholders.

(ii) Satellite design. Apsara-1 with UHF antennas deployed is shown in Figure 5.

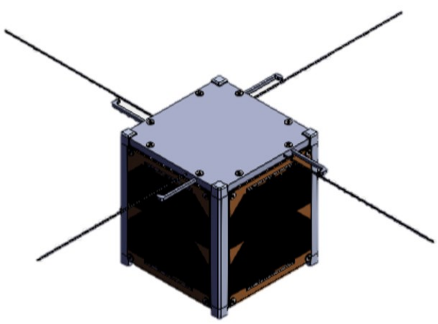

Figure 5: Apsara-1

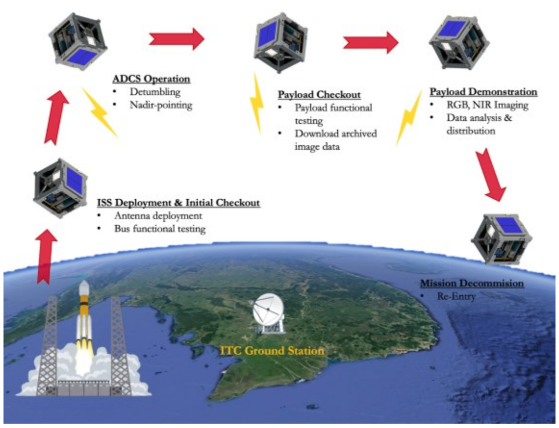

Figure 6: Apsara-1 concept of operations

Unique features of the 1.3kg, 1U CubeSat include a customized imaging payload, efficient onboard image processing, an in-house attitude control system, and a custom onboard orbit propagator. All subsystems will be developed (including from COTS components) by students at the ITC, during the next cycles of the small satellite education program. The planned concept of operations of Apsara-1 after release from the ISS is shown in Figure 6.

"Apsara" refers to a traditional Cambodian dance form (របាំទេពអប្សរា), which represents a prayer movement for fertility and rain. The association between Apsara and favourable climate conditions for agriculture and life reflects our remote sensing mission objectives.

Online International Collaboration Structure

Apsara-1 was designed via online collaboration between students at the ITC and UTokyo, jointly supervised by junior researchers (PhD students or early-career lecturers) from both institutions. The management structure used for collaborative design in this project was relatively successful, and in this subsection we share it with interested parties.

(i) Teamworking structure. There were ten project members in this cycle of the CubeSat design challenge, collaborating online in two countries. Efficient team-working was essential to cover all project areas. The online collaboration structure is shown in Figure 7.

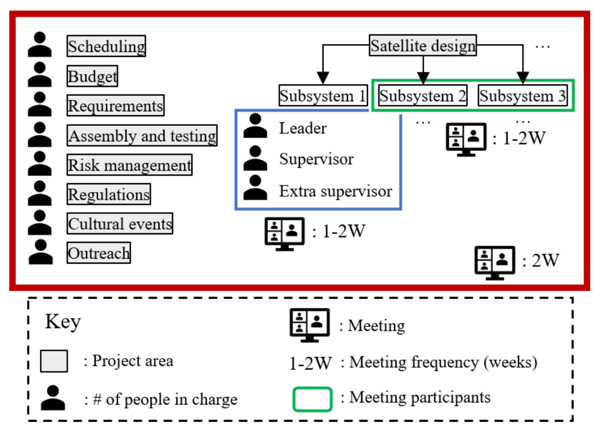

Figure 7: Online collaboration method for Apsara-1

The structure consists of four components: a distinction between mentors and participants; clear and reasonable responsibilities for all members; regular and focused meetings; and periodic review and allocation of tasks. These are described in detail in the next paragraphs.

Two categories of project members were defined: mentors, with prior experience in satellite design; and participants, with no or limited experience. A pamphlet introducing each member's personal and academic background was distributed to all members. This made it easier to understand who to contact for guidance on specific design areas. At the same time, to encourage all members and especially junior students to develop leadership skills, we decided to avoid a pyramidal

Table 2: Communication methods used in this project

Method	Purpose	Structure
Slack	Messaging, announcements, scheduling	One channel / subsystem. ・ One channel / project area. ・All channels public, except dedicated mentor channel. ・Emphasize messaging in channels over DMs.
Google Drive	Resource sharing, progress reports, meeting minutes, presentations	One folder / project area. ・ One sub-folder / subsystem. ・ Open access to all members.
Zoom	Internal meetings, progress reviews with external stakeholders	(Group photo at end of each meeting.)

management structure. Instead, we used a multi-layer horizontal approach. In the bottom layer, participants were given leadership roles for each of the CubeSat subsystems (see right part of Figure 7), as well as for non-technical project areas (e.g. outreach), to foster soft and hard skill development. In the second layer, each subsystem was assigned with a supervisor (i.e. mentor) to provide guidance and feedback. In the third layer, an extra supervisor (also a mentor) was assigned to each subsystem to bridge busy periods in the supervisor's schedule. We found that having three members working on each subsystem kept steady momentum while maintaining agility and avoiding overwork.

Meetings were designed around the mentor plus participant and multi-layer horizontal structure. Each subsystem team was responsible for organizing its own meetings (also a learning experience for students), usually every two weeks. When needed, subsystem teams were encouraged to hold inter-subsystem meetings (e.g. for interface design), also with a two-week frequency. The only meetings bringing together all participants were regular bi-weekly meetings (or BWMs): two- to five-hour long meetings during which participants presented their progress on each project area, and received feedback and comments from all other members. The BWMs allowed all members to gain a quick overview of recent updates from all project areas, and plan the next subsystem and inter-subsystem meetings. The BWMs were also used to set the next milestones for each subsystem. Finally, in addition to BWMs, biweekly mentor meetings were held in weeks without BWMs in order to discuss administrative matters mainly focusing on interfacing with external stakeholders and planning events (e.g. organizing review meetings with invited panelists, applying to the SmallSat Conference, adjusting the team-working structure, etc.).

Overall, this approach: was able to minimise unnecessary discussion time by involving only relevant members in each meeting; kept up momentum by allocating clear, realistic, and tracked responsibilities to all project members; and allowed students to develop leadership and project management skills by each being responsible for the design of one subsystem. In the next subsection, we describe the communication tools used to support team-working during this project.

Figure 8: Congratulations message from Slack for fluid communication during Apsara-1 project

(ii) Communication methods. The three main communication platforms used during this project are summarized in Table 2. The emphasis was on making all information as easily accessible as possible to all project members. We found that this facilitated inter-subsystem collaboration and allowed students to flexibly build knowledge on all aspects of the CubeSat design. Slack was used for communication during the project. All channels were made "public", and we encouraged all discussions to be conducted via channels rather than private messaging (see Figure 8). We made this decision after noticing that members were initially exchanging design updates privately, which made it difficult to keep an accessible progress record. Google Drive was used for file sharing, and Zoom was used for meetings. Zoom was also used to host cultural evenings, as described in the next section.

Global Team Building: Cultural Evenings

The collaborative ITC-UTokyo team which designed Apsara-1 consists of members from four countries.

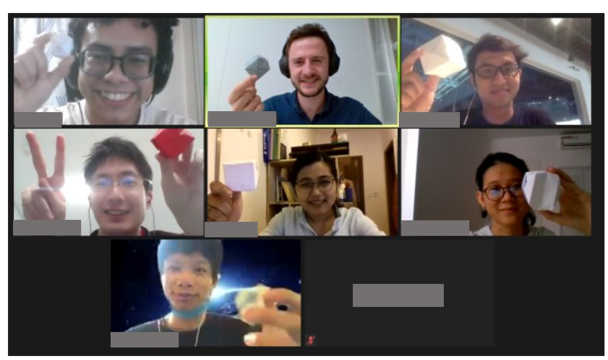

Figure 9: CubeSat origami workshop

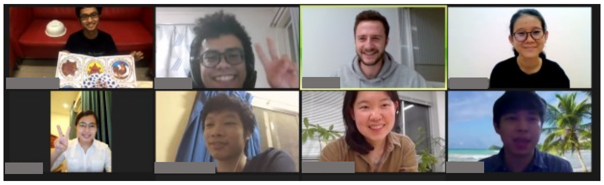

Figure 10: Khmer new year evening

We recognized in this diversity a chance to expand our understanding of different cultures (and to have fun!). After each BWM, we organized a one- to two-hour cultural evening during which members introduced their home countries or regions via interactive events compatible with available resources. For example, during the Japanese edition we held an origami evening (Figure 9), and for the Cambodia edition we played a popular Khmer new year game called Kla Kok (Figure 10). The cultural evenings were not only a platform for team building but also a chance to introduce our project to external stakeholders such as prospective members at ITC and friends at UTokyo.

In summary, during the first cycle of the small satellite education program at ITC, a CubeSat development framework emphasizing student leadership, information sharing, and cultural understanding was established. This framework will provide the basis for future real small satellite projects at ITC, including the Apsara-1 CubeSat.

LESSONS FROM 2-YEAR COLLABORATION

In this section, we summarize lessons learnt from the two-year ITC-UTokyo partnership towards Cambodia's first small satellite education program. The following items are intended as potential signposts for actors developing innovative small satellite education programs, especially with limited resources.

Start with Physical Before Online

The first lesson is to start with an in-person format before moving online. All ITC students who joined the online Apsara-1 development project in 2020-2021 had previously joined the physical hands-on workshop (see Figure 3) in 2019. Similarly, all UTokyo members who joined as mentors and participants had previously met the UTokyo project leader in person. This suggests that memorable in-person contact, especially at the beginning of a collaborative satellite education project, is important for sustainability. Our experience shows that once this initial contact has been established, further activities can smoothly continue online. At the same time, we benefited from the small time-difference (only two hours) between Cambodia and Japan.

Let Students Lead

The second lesson is to let students lead their own portions of satellite development activities, not limited to design but also including transversal project areas such as outreach, risk management, and cultural events. We started the "learning 3" phase of the education cycle with limited human resources for supervision. Therefore, it was not feasible to micromanage the entire process of small satellite design and education. Instead, by letting students take leadership in a horizontal, multi-layer management structure, they not only reduced the burden of oversight, but were also able to develop skills in negotiation, communication, and independent research, which are difficult to acquire in existing courses at ITC (and in fact, at UTokyo). These transversal skills will allow them to become the next generation of program managers within this collaboration, and beyond. At the same time, we realized the importance of BWMs to provide tacit feedback on individual leadership styles and encourage continuous improvement.

Mobilize Local Resources

The third lesson is to develop the education program locally, so as to keep the cost low and the content relevant to local needs. During the first learning cycle, UTokyo provided knowledge on small satellite development and education, but conversion into ITC satellite research activities ("satellite research group" in Figure 1) and teaching hardware (e.g. DemoSat) was performed entirely by ITC, using materials and methods available in Phnom Penh. In addition, during the collaborative development of Apsara-1, ITC and UTokyo independently bore all the costs (e.g. software, books) incurred on their sides, while using free resources when possible. Although funding remains a major constraint on satellite education at the ITC, this approach has allowed discussions to begin with Cambodian government stakeholders for identifying potential funding routes and to consider how small satellite development could be incorporated into national strategies to meet actual socio-economic needs in Cambodia. In the meantime, for now funding is still the main barrier to expand satellite activities at the ITC.

"Accordion Approach" for Collaboration

The fourth lesson is to combine short and intense administrative discussions between partnering institutions with longer periods of independent work: we call this the "accordion approach" to international collaboration. For example, during the development of Apsara-1, one-hour biweekly (i.e. every two weeks) mentor meetings were sufficient to exchange updates and set the next milestones for the collaboration.

Beyond Technology: Fostering Creativity

The fifth and final lesson is to incorporate a combination of technical and non-technical elements into the education program, so as to create a space for students to deploy their creativity. We found that students' motivation increased when we set up opportunities for them to coordinate outreach activities (e.g. creating a project website[8] and Facebook page[9]) and events (e.g. planning cultural evenings), and to produce external deliverables (e.g. application to KiboCUBE, this conference paper, etc.). These abilities – seldom taught in universities in Japan and Cambodia – will not only be valuable to extend the reach of Cambodia's satellite education activities, but will also be useful for students' future careers either in or beyond the space field.

In summary, the first learning cycle has provided several learning points which will be carried forward to the next iteration of the education program. The two major outstanding challenges for the continuity of space education in Cambodia are funding and human resources, which will be developed incrementally and patiently.

TOWARDS AN EDUCATIONAL ECOSYSTEM

At present, satellite education at the ITC is limited to one laboratory. In this final section we describe ongoing efforts to expand the education program within and beyond the ITC, for sustainability.

Linkage with Research at the ITC

Currently, there is already active research at ITC on climate and land resource management using remote sensing data[10] and GIS.[11] The Research and Innovation Center (RIC) is responsible for promoting research activities at the ITC, and two of its largest research units are Mechatronics & Information Technology, and Water & the Environment. The Apsara-1 CubeSat project bridges these research areas and shows that they are complementary. On one hand, Apsara-1 can contribute to land and climate management research by providing relevant remote sensing data collected from space. At the same time, projects in land and water resource research can help to develop current and future ITC satellite technologies by informing mission objective design, to serve the needs of Cambodia.

One example of this crossover is shown in Figure 11. The maps show the normalized difference vegetation index (NDVI) over Cambodia, computed from Sentinel 2 remote sensing data. The data from April-May 2020 and 2021 show minor differences. However, close observation reveals higher NDVI values in 2021 than in 2020, especially in Ratanakiri, Mondulkiri (two easternmost provinces), and Battambang (to the west of the Tonlé Sap lake). These areas are mostly covered by forests and agricultural lands, which means that their greenness is more strongly controlled by the amount of rainfall. The NDVI maps reflect that in 2020, Cambodia was hit by drought with a delayed rainy season,[12] whereas rainfall started earlier in 2021. At present, satellite remote sensing data for research at the ITC is obtained from external (e.g. open access) sources with limited controllability, and the Apsara-1 mission has been designed to provide tailor-made data designed to meet the ITC's (and other Cambodian stakeholders') needs.

Overall, this education program – apart from contributing to other ongoing research at the ITC via satellite development activities – is creating a precedent for challenging multidisciplinary research, which is still in its infancy at the ITC. The Apsara-1 project has been a chance for the ITC to expand its perspective and ambition across disciplines, and to increase research synergies for sustainability.

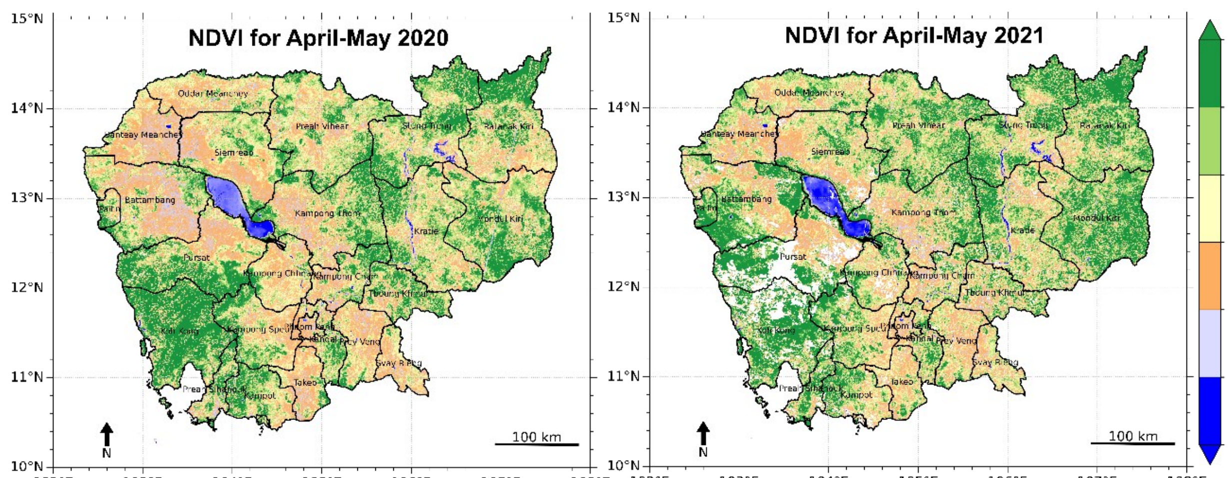

Figure 11: NDVI in Cambodia based on Sentinel 2 data, for the same calendar month in two consecutive years

Extending Space Education into Schools

(i) Purpose and expected benefits. For now, our small satellite education program has been conducted at the ITC. Now that we have found our footing, we would like to use our experiences as a vector to grow larger-scale human resources in the space sector in Cambodia. We believe that the first step is to raise awareness of the importance of space research and space technology utilization among the younger generation.

(ii) Outreach methods. We are planning to connect with high school teachers and students through three methods: training workshops, exhibitions, and internships. Based on our experiences, competitions such as CanSat projects (e.g. supported by DemoSat), are a good way to create incentives such as recognition, and also to grow passion and teamwork.

Firstly, we will reach out to students by visiting high schools to give presentations introducing small satellite knowledge and to recruit participants for a CanSat competition (see below). Due to the diversity of Cambodian participants in the ITC's satellite education program (see Table 1), we have an existing network to contact schools in various provinces. To accommodate the COVID-19 situation, we will start with an online format. Second, we plan to organize a national CanSat competition alongside the Air and Tech Show – an annual national exhibition recently created to promote aerospace engineering in Cambodia.[13]

Finally, we are going to offer short term internship programs to highschool students who want to get acquainted with research at university. Opportunities to experience research are few in Cambodia. The internship would let students understand what research is, and would allow them to learn by observing alongside researchers at the ITC. We believe that an internship program would not only boost participants' motivation (both within and beyond the ITC), but would also make research in STEM (not limited to space engineering) more accessible, triggering the interest of young talents both at highschool and at university. One challenge will be to provide financial support for students visiting Phnom Penh from the Cambodian provinces.

Involving Government and Industry

(i) Government exposure to research. Beyond connecting with researchers, students, and educators, we are also encouraging government members to take an interest in our satellite education program. For now, we have invited them to join our activities as observers. For example, several government officers joined design review meetings during the development of Apsara-1. In this way, we are creating awareness among the government about the usefulness of university research, which is slowly growing in Cambodia, as well as the specific attractiveness of satellite engineering. During discussions with government officers, we often need to start from the very basics of space engineering. We have learnt that these meetings – in which students are also learning – are also a good first entry point into space for government members. Moreover, after government members develop an understanding of our project, it may become easier to appeal to them to become our next funders.

(ii) Entrepreneurship for space education. Creating space education start-ups as spin-offs from our satellite education program at the ITC could be an effective way to achieve two objectives at once: to provide job opportunities to graduates, and to promote space education in Cambodia. Since there is no market demand in the upstream space-related field in Cambodia yet, we believe that start-ups focusing on education have the highest potential at this stage. We would like to initiate a start-up to provide space engineering courses and hands-on projects using made-in-Cambodia tool kits to high school students. In this way: high school students would be able to receive space engineering training (which would benefit them for future learning in any STEM field); university graduates from the ITC would have access to job opportunities; and space education would slowly gain momentum in Cambodia.

CONCLUSION

The ITC-UTokyo collaboration is not the only example of first-in-country space capacity building by UTokyo in the Asia-Pacific region. UTokyo contributed to the start of space activities in Indonesia in the 1960s.[14] Professor Hideo Itokawa (of "Pencil Rocket" fame) helped to design the Pameungpeuk rocket launching station, which remains active to this day. The site was used in 1965 to launch Indonesia's first sounding rockets, a core focus of the then-nascent Indonesian space agency (LAPAN).

56 years later, the ease of international collaboration for space education has dramatically increased. The development of Cambodia's first small satellite education program described in this paper embodies a new paradigm, demonstrating that the wide accessibility of space-related knowledge, the ease of online communication, and the numerous online tools for collaborative engineering projects mean that students with a limited budget can achieve what was previously limited to institutional leaders with institutional budgets.

Even so, funding and human resources remain the two major obstacles to the further development and extension of this education program, and we are trying to overcome these by increasing linkage with ongoing research at the ITC, as well as Cambodian industry and government. If we are able to work with these constraints – by mobilizing student leadership, drawing upon local resources, and fostering creativity – the 1U Apsara-1 CubeSat is poised to become Cambodia's first satellite in the near future.

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