Trans. JSASS Aerospace Tech. Japan
Vol. 19, No. 6, pp. 892-901, 2021
DOI: 10.2322/tastj.19.892
***Education Programs Report***

# Space Science and Technology Proliferation in the Philippines through Nationwide University Partnerships

By Mary Ann CONSTANTE,[1)] Frances Mara MENDOZA,[1)] Charleston Dale AMBATALI,[1)] Izrael Zenar BAUTISTA,[1)] Paul Jason CO,[1)] and Joel Joseph MARCIANO Jr.[1),2)]

[1)]*STAMINA4Space Program, University of the Philippines Diliman, Quezon City, Philippines*
[2)]*Philippine Space Agency, Quezon City, Philippines*

(Received July 12th, 2019)

This paper discusses the ongoing activities of the STEP-UP Project aimed at proliferating space science and technology in the Philippines. The STEP-UP Project is a research project funded by the Department of Science and Technology that undertakes the establishment of a university consortium on space science and technology applications. The consortium will serve as an avenue for nationwide and global collaboration for university-based space-related research activities. The institutions invited as founding members of the consortium are strategically located across the three major islands in the Philippines, serving as central hubs for cooperation and providing access to knowledge and facilities within their respective regions. Among the activities of the STEP-UP Project are the offering of a graduate track on nanosatellite engineering with hands-on development and testing of a 1U CubeSat that will be launched to an ISS orbit, the development and setup of amateur radio and satellite stations in partner universities, and the continuous enhancement and offering of undergraduate courses and trainings on space engineering. In proliferating space science and technology, the STEP-UP Project expands the human resources critical in sustaining the country's space activities.

**Key Words:** Space Education, University Consortium, CubeSat Development, Ground Station Network

## Abbreviations

| | | |
|---|---|---|
| ARSS | : | Amateur Radio and Satellite Station |
| BIRDS | : | Joint Global Multi-Nation Birds Satellite |
| DOST | : | Department of Science and Technology |
| PhilSA | : | Philippine Space Agency |
| SSTA | : | Space Science and Technology Applications |
| UNISEC | : | University Space Engineering Consortium |
| UPD | : | University of the Philippines Diliman |

## 1. Introduction

The Philippines reached milestones with the successful launch and operations of small satellites developed under the PHL-Microsat Program, a pioneering space research and development (R&D) program implemented by the University of the Philippines Diliman (UPD) and the Advanced Science and Technology Institute of the Department of Science and Technology (DOST-ASTI).[1)] Under the PHL-Microsat Program, three satellites were developed and successfully launched. Diwata-1 and Diwata-2 are 50 kg microsatellites launched on 2016 and 2018, respectively. Maya-1 is a 1U CubeSat developed as part of the BIRDS project[2)] and was launched on 2018. Through the development of these satellites, Filipino scientists and engineers gained experience on mission design, satellite development, testing, and operations. These were translated to training materials and undergraduate courses on space science and technology applications (SSTA).

Despite the Philippines' achievements through the PHL-Microsat Program, the country still lags behind its neighboring countries in terms of space assets and accomplishments. A good tool to present a snapshot of a country's development in its space sector is the Space Technology Ladder (STL).[3)] The STL consists a list of milestones that a country would follow as its space capabilities evolve. These milestones are presented in Table 1. The milestones are categorized in terms of the capability to launch satellites and to develop or own satellites in the Geostationary Orbit (GEO) or Low-Earth Orbit (LEO), and the success in establishing a space office or agency.

Table 1. The Space Technology Ladder (STL) by Wood and Weigel.

| # | Definition |
|---|---|
| 13 | Launch Capability: Satellite to GEO |
| 12 | Launch Capability: Satellite to LEO |
| 11 | GEO Satellite: Build Locally |
| 10 | GEO Satellite: Build through Mutual International Collaboration |
| 9 | GEO Satellite: Build Locally with Outside Assistance |
| 8 | GEO Satellite: Procure |
| 7 | LEO Satellite: Build Locally |
| 6 | LEO Satellite: Build through Mutual International Collaboration |
| 5 | LEO Satellite: Build Locally with Outside Assistance |
| 4 | LEO Satellite: Build with Support in Partner's Facility |
| 3 | LEO Satellite: Procure with Training Services |
| 2 | Space Agency: Establish Current Agency |
| 1 | Space Agency: Establish First National Space Office |

Figure 1 shows the evolution of space activities in select Southeast Asian countries as plotted using the STL. The

information presented in this STL was compiled from various sites and media outlets that are readily accessible in the public domain. For years before 2015, only the first milestones per level are presented. This STL does not discriminate between efforts initiated by the government, private sector, or academe.

It is evident from Fig. 1 that other Southeast Asian countries have invested in various space activities decades before the Philippines, and these countries remain active in their space efforts in the recent years. Another notable area where the Philippines fares behind its neighbors is in the establishment of an office or an agency that will handle the nation's space activities. Indonesia established its space agency, the National Institute of Aeronautics and Space (LAPAN), as early as 1963. On the other hand, Vietnam, Thailand, and Malaysia all have an appointed office or an established agency for space activities by 2005. The PHL-Microsat Program, which served as the Philippines' first state-sponsored space program, was only initiated in 2014, and the country's space agency, the Philippine Space Agency (PhilSA), was only officially established in 2019.

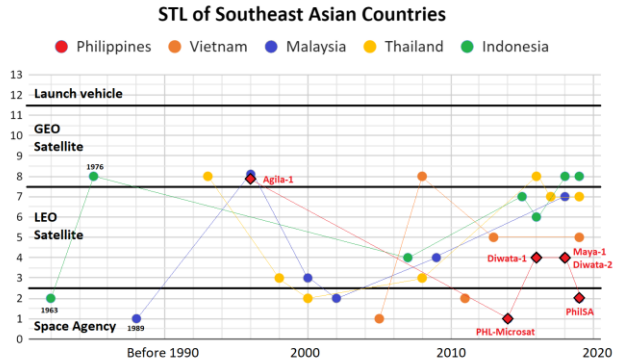


Fig. 1. Evolution of space activities in Southeast Asian countries.

Between the periods of establishing Indonesia's space agency to present, the country has amassed over a thousand employees.[4] The employee count in the Vietnam National Space Center (VNSC) is significantly lower than LAPAN's, at only around 120 staff. However, half of VNSC's staff holds post graduate degrees, and the agency remains very active in expanding its human resource by sending engineers to obtain advanced degrees in different universities.[5] Meanwhile, PhilSA is seen to source a significant fraction of its human resource from the PHL-Microsat Program that had around 60 personnel in its culmination in 2018.[6] Out of this pool of personnel, only 20% had hands-on experience in building parts of or of the whole satellite.

The involvement of other academic institutions in the Philippines' first space foray is also very limited—throughout its implementation, the PHL-Microsat Program was only able to involve UPD. Although there are other universities conducting space-related activities within the same period as PHL-Microsat, these efforts, albeit in a reduced scale, are not consolidated and coordinated with the program. In contrast, in more developed countries like Japan, a leading network of universities cooperating in space activities, the University Space Engineering Consortium (UNISEC) Japan, has over 50 university members and involves 15 private companies and over 900 students.[7]

It was shown that the Philippines still faces a wide gap between the available local expertise and the human resources required to broaden its SSTA activities. There still lie several challenges in raising awareness, engaging, and capacitating various sectors of the society on space-related activities.[8] Recognizing this, the Philippine government funded the Space Technology and Applications Mastery, Innovation and Advancement (STAMINA4Space) Program, the successor program of PHL-Microsat. Launched in the second quarter of 2018, the STAMINA4Space Program focuses on further developing the local expertise in space technology and applications to spur the development of high-value industries in the country and to address manifold needs in scientific earth observation for disaster risk reduction and management, resource assessment, environmental monitoring, and other applications.[9]

Among the components of the STAMINA4Space Program, the Space Science and Technology Proliferation through University Partnerships (STEP-UP) Project focuses on making space technology more accessible and more inclusive by providing local opportunities to learn space engineering and involving more sectors of the society. The project achieves this by engaging universities and institutions into building a nationwide university consortium that will serve as an avenue for instruction and research collaborations, and as a vehicle for the coordination of university-based activities in the field of SSTA locally and globally. Throughout the project's implementation until July 2022, STEP-UP aims to also identify the challenges in pioneering SSTA proliferation in the country.

This paper will discuss the specific activities taken by the STEP-UP Project towards expanding the pool of resources engaged in SSTA. Only the initial results will be presented along with observations on the results of implementation. The outcomes and long-term impact/s of the activities cannot be determined at this point. However, the activities presented along with the challenges encountered and the lessons learned from the initial phases of the project implementation may benefit other nations intending to build and strengthen their space capabilities. Among the different fields that can be addressed for capacity building, this paper focuses on the field of space engineering, which is the main thrust of the STEP-UP Project. The paper is organized as follows: Section 2 presents the basis of strategies for implementing the activities discussed in Section 3. Section 4 discusses the results of the project activities in terms of its human resource development targets, and Section 5 presents the challenges encountered by the team throughout its implementation. Section 6 gives an outlook for the Philippine's space agency and Section 7 gives conclusion to this work.

## 2. Conceptual Framework

There are three major concepts involved in the implementation framework of the STEP-UP Project, which are discussed in the following subsections.

### 2.1. University partnerships as avenue for collaboration

Universities play a major role in information dissemination and the facilitation of knowledge exchange. These institutions are key to sustaining the initial efforts in the SSTA sector, with its innate capability to reach the youth, interact with the society, and influence policy-making through research- and evidence-based recommendations. They can also be considered as knowledge hubs and the home of innovative R&D that the government, scientific community, and innovators can tap as valuable knowledge resources.

Partnerships between universities are an established approach to facilitate knowledge transfer on a larger scale and in a faster manner. In the Philippines, there are already several consortiums that have proven the effectiveness of engaging universities towards fruitful engineering R&D activities. The Engineering Research and Development for Technology (ERDT)[10] funded by the DOST is among the most active and prominent consortium in the country. The ERDT was established to address the need for quality engineers across different fields through human resource development programs, R&D support, and infrastructure development.

Furthering university collaborations across the globe is the University Space Engineering Consortium (UNISEC-Global).[11] UNISEC-Global is an international nonprofit body that links local UNISEC chapters around the world. Each local UNISEC chapter is independently managed and operated in their respective countries. A local UNISEC chapter can serve as a jump-off point for establishing a local university consortium and in participating in practical space projects in collaboration with local and foreign universities.

In its four-year implementation, the STEP-UP Project aims to engage at least one (1) partner university on each major island group in the Philippines. These universities, along with the STEP-UP team, will form the country's first university consortium on SSTA and serve as the regional point of contact for their respective areas, with faculty members as focal representatives for collaboration. These faculty members will lead space-related activities within their universities or in partnership with other universities or organizations. The course materials developed by the STEP-UP Project, which is further discussed in Section 3, will be shared to the university partners. Faculty members can build from or use these materials to offer space engineering courses and training to their students, local governments, and other institutions. This places the universities as the central hub for knowledge exchange between various sectors and aid them in their SSTA-related activities, programs, and applications that cater to their specific area or needs.

### 2.2. CubeSat as a tool for project-based learning

CubeSats have long been used by universities and institutions as a tool for teaching and providing a complete experience in satellite development from mission conceptualization to operations. Several programs such as the European Space Agency's Fly Your Satellite! (FYS)[12] and the National Aeronautics and Space Administration's Educational Launch of Nanosatellite (ELaNa)[13] were initiated to support CubeSat development activities of universities and even government agencies. The paradigm used in FYS and ELaNa are based on an open competition between aspiring teams.

The Kyushu Institute of Technology's (Kyutech) Joint Global Multi-Nation Birds Satellite (BIRDS)[1] Project is a cross-border satellite venture that aims to provide leverage to students from non-space faring nations through hands-on involvement in designing and developing CubeSats.[2] The project builds a cooperative network of universities by forming the students from different countries into a single group that develops identical 1U CubeSats. The goal is to capacitate these students in building space systems and go back to their home countries to help build the ecosystem for a space industry. To date, all graduates of the BIRDS Project either continued with their doctorate degree or returned to their countries to teach or work in government institutions related to space. The same long-term goal can be said for the STEP-UP Project as it aims to have the supported graduate students (scholars) join PhilSA, teach and start space-related projects, or establish spin-off companies from the research they did during their study.

In 2016, the Philippines joined the second generation of the BIRDS project, BIRDS-2, along with Malaysia and Bhutan. One researcher from the PHL-Microsat Program and one full-time engineer from the DOST-ASTI were sent to take graduate studies at Kyutech and participate in BIRDS-2. The project led to the development and launch of three identical 1U CubeSats for data collection and technology demonstration.[14] To date, one of the engineers has completed his Master's degree and has returned to DOST-ASTI at the same time providing assistance to the STEP-UP Project. The other one is currently completing his doctorate degree and is expected to return to UPD as a faculty member.

The STEP-UP team aims to replicate the success of other institutions utilizing CubeSats as a low-cost learning platform for developing human resources. While the goal of the project is to train as many graduate students as possible, the availability of funds to support scholarships and building satellites still remain a limiting factor. To add, the current human resource of the STEP-UP Project itself is also limited, with only five (5) full-time engineers engaged in different technical and capacity building activities of the project. Factoring these limitations, the STEP-UP Project aims to support at least nineteen (19) graduate students in local and foreign space engineering programs throughout its implementation.

### 2.3. Amateur radio in technology education

Amateur radio is a voluntary and non-commercial radio service that allows licensed operators to communicate and improve their technical skills in electronics. Amateur radio has been recognized in the past as an effective tool in teaching Science, Technology, Engineering and Mathematics (STEM) because it gives practical experience and allows engagement with fellow amateurs.[15] In relation to this, satellite communication using the amateur radio band has shown to be an innovative and practical way to introduce students to space technology through hands-on communication with these satellites. Amateur satellites pave the way for low-cost but effective means of teaching students how to build devices suitable for space communications.[16]

[1] The BIRDS project is supported by the JSPS Core-to-Core Program, B. Asia-Africa Science Platforms.

In the Philippines, an Amateur Radio and Satellite Station (ARSS) was established under the PHL-Microsat Program. The ARSS supports terrestrial and satellite communications in the amateur bands. These capabilities enable the station to host courses, seminars, and internships, which promote awareness, interest, and involvement on amateur satellites and radios. The ARSS also became an avenue for students to develop and test projects related to satellite and radio communications such as antenna design and antenna rotator controller development.[17)]

The STEP-UP Project will build on the success of the ARSS in engaging the youth in different space activities. Yearly, the STEP-UP Project will target at least eighteen (18) undergraduate students enrolled in space engineering electives or involved in satellite tracking and operations utilizing the ARSS. The founding members of the consortium will be enabled with the same capability by establishing a ground station in their universities.

## 3. Status of Implementation

Conducting activities in the field of SSTA is a challenge to every developing country as several groups question the benefits of this advanced field over responding to socio-economic problems. For this reason, the STEP-UP Project aligned its initial set of activities to various strategies that have a direct impact to the community, while at the same time maximizing and fast-tracking the proliferation of SSTA in the country. These strategies are discussed in the next subsections.

### 3.1. Establishment of a university consortium on SSTA

The archipelagic setting of the Philippines entails challenges in streamlining knowledge transfer through seminars and hands-on activities. As such, in addition to technical capability, the geographical location of the universities became a major consideration in the selection of potential co-founders of the consortium. Given these, three universities, one from each of the major islands in the Philippines, were invited to join UPD in establishing the consortium. These universities are the Holy Angel University (HAU), University of San Carlos (USC), and Mindanao State University-Iligan Institute of Technology (MSU-IIT). The location of these universities, shown in Fig. 2, provides strategic coverage in the provision of local knowledge hubs and access to space engineering expertise and facilities. It is also worth noting that the co-founding members are a mix of privately owned and state universities, which provides an interesting vantage point in terms of policies, challenges, and best practices for implementation, and inclusive and diverse membership and network.

To create an immediate network locally and globally, the university consortium shall build its foundation as a local chapter of UNISEC, the UNISEC Philippines, which was officially approved in June 2019. UNISEC-Global's structure and activities coupled with the country-specific needs and challenges shall be used as the basis for the terms of the memorandum of understanding (MOU) of the local university consortium. The terms, expectations, and limitations that will arise from the discussions with the co-founding members will be incorporated in the MOU.

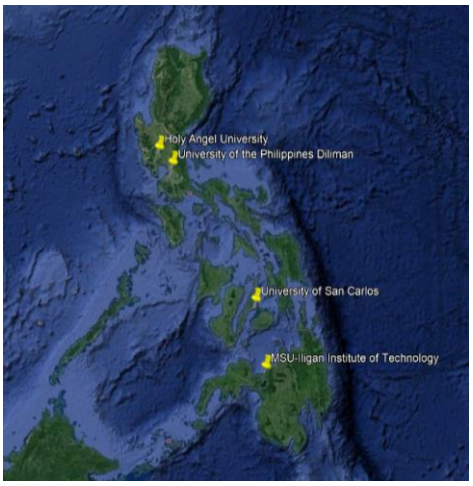


Fig. 2. Geographic location of the co-founders of the consortium.

In February and April 2019, the STEP-UP team visited HAU and USC, respectively. The visit included meetings on the establishment of the consortium and a site survey for the potential location of an amateur radio and satellite station. The meeting and visit provided insights and initial data on the challenges of these universities and the support they need. However, more data are necessary, and in order to identify and collect information on possible contributions of the partner university to the consortium, a survey form was developed via Google Forms. The survey aims to inform the initial terms of the consortium, gather information on the technical requirements for the ARSS, and identify further collaborations and possible joint activities under the consortium.

In May 2019, a draft MOU was crafted and sent to the three universities for review. The MOU was finalized in September 2019 and signed by all parties in February 2020, with the delay being attributed to the further review of each university's legal offices and the back and forth shipment of the documents for signing. With the signing of the MOU, UNISEC Philippines was officially established. Some of its current members attended the 7th UNISEC Global Meeting in November 2019 in Tokyo, Japan, and presented the regional report for UNISEC Philippines. During the global meeting, UNISEC Philippines was also acknowledged as a local chapter of UNISEC Global.

Apart from the co-founding members, three university applications were approved by UNISEC Philippines in January 2020, expanding the membership to a total of seven universities. To date, the STEP-UP Project continues to send invitations and cater to applications of different institutions to UNISEC Philippines.

### 3.2. CubeSat technology transfer and development

The STEP-UP Project partnered with the DOST Science Education Institute (DOST-SEI) to provide scholarships that will cover the expenses for graduate studies while the STEP-UP Project covers the costs of CubeSat development and launch. Three (3) foreign scholarships for the participation in BIRDS-4 and eighteen (18) local scholarships in UPD were allotted for the STEP-UP Project. The local scholarships were divided into two batches, one started in January 2019 and the other in August 2020.

The Filipino team sent to join BIRDS-4 is composed of a

researcher from the STEP-UP Project, a faculty member from Mapua University, and a faculty member from Adamson University. The members are taking their doctorate degrees, and, upon completion, are expected to develop and teach courses and lead space technology research in their home universities. The members of the BIRDS-4 team are shown in Fig. 3. The overlap in the implementation of each generation of BIRDS project allowed effective technology transfer between teams, enabling the BIRDS-4 project to take on more ambitious missions such as active attitude control, store-and-forward, and the use of the satellite structure as an antenna.

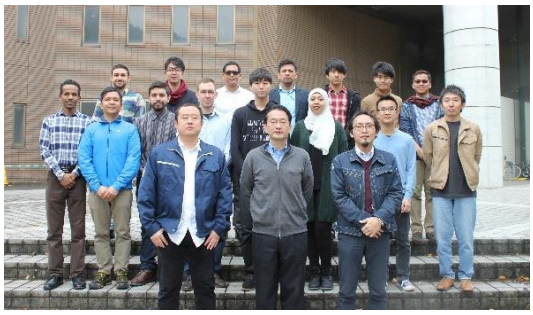

Fig. 3. BIRDS-4 members with Kyutech professors.

To fast-track SSTA proliferation, there is a need to provide more accessible opportunities to learn satellite development in the country. Recognizing this, the STEP-UP Project instituted a local graduate track on nanosatellite engineering at UPD Electrical and Electronics Engineering Institute (UP EEEI). The nanosatellite engineering track augments the existing graduate program at UP EEEI with specialized courses on SSTA. A sample plan of study is presented in Table 2.

Table 2. Plan of study for Master of Science in Electrical Engineering.

| Year 1 | |
|---|---|
| Semester 1 | |
| Course No. | Course Title |
| EE 298 | Introduction to Satellite Development |
| EE 290 | Directed Studies |
| EE 298 | Satellite Communications |
| Semester 2 | |
| Course No. | Course Title |
| EE 298 | Space Environment and Tests |
| EE 290 | Directed Studies |
| EE xxx | Elective |
| Year 2 | |
| Semester 1 | |
| Course No. | Course Title |
| EE 298 | Orbital Mechanics |
| EE 290 | Directed Studies |
| EE 296 | Seminar |
| Semester 2 | |
| Course No. | Course Title |
| EE 300 | Thesis |

The nanosatellite engineering track includes hands-on development, tests, and operations of a 1U CubeSat that will be launched to an ISS orbit. This format is patterned to the BIRDS program. The development of the CubeSat is credited through directed studies that are distributed over the duration of the graduate program.

For the first batch of the graduate track, the BIRDS-2 bus was used as the reference bus of the local 1U CubeSats. This was done to speed up and ease the development time of the satellite. The design and materials for the CubeSat development is acquired through a cooperative research agreement with Kyutech. The second batch will implement a similar strategy but will use the developed BIRDS-4 bus.

To date, the first batch of scholars completed the assembly of the satellite's engineering model and is scheduled for the space environment test. A photo taken from the kick-off meeting attended by the STEP-UP Scholars, STAMINA4Space Program Members, and DOST officials is shown in Fig. 4. The STEP-UP team's internal screening for the second batch was already completed and the shortlisted applicants were requested to proceed with the application to the UPD's National Graduate School of Engineering (NGSE). The UPD NGSE screens all the applicants to different graduate engineering degrees based on university criteria and will be STEP-UP's basis on who will be admitted to the scholarship program.

Fig. 4. STEP-UP scholar's kick-off meeting.

Among the notable observations in the implementation of the graduate track was the high increase in the applicants after the first batch was offered and publicized. During the first batch, only sixteen (16) submitted applications to the scholarship program. This increased to fifty (50) applications in the second batch, indicating how much the project has attracted more people into studying space science and technology.

Figure 5 shows the breakdown of the background of the applicants to the scholarship for the first and second batch. The graph shows a very limited representation from the academe, which is the main target of the program. Among the possible reasons for the low count of applicants coming from the academe will be discussed in Section 5. On the other hand, there is a high interest from the government institutions and the industry. This is optimistically viewed as an indication of potential space projects within these groups or a step towards building a space industry in the country. The number of fresh graduates also indicate a good outlook of the younger generation to gear their career towards the space sector in the country with its upcoming space agency.

Finally, despite the nanosatellite engineering track being tied to an electrical and electronics engineering institute, the degree profile of the accepted applicants for the first batch and the endorsed applicants for the second batch shows a good diversity as presented in Fig. 6. Notably, for the second batch,

45% of the endorsed applicants come from other courses including Mechanical Engineering, Physics, Computer Science, and Secondary Education.

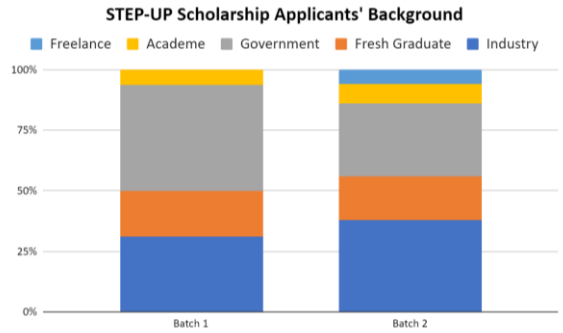


Fig. 5. Distribution of scholarship applicants based on background.

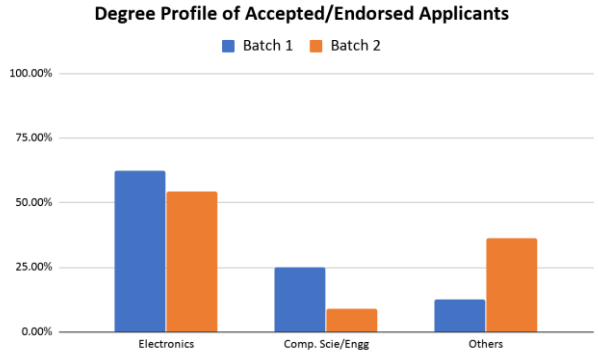


Fig. 6. Distribution of scholarship applicants based on degree.

### 3.3. Undergraduate activities on amateur radio and satellite engineering

The STEP-UP Project targeted two sets of undergraduate students in its implementation—students within UPD, which the team has more access to, and the students from the university consortium, which were accessed through their faculty representatives.

#### 3.3.1. Undergraduate elective and student engagement within the university

Under the PHL-Microsat Program, an introductory course on satellite systems was developed and offered to undergraduate students.[17] Recognizing the effectiveness of the undergraduate course in engaging students and attracting them to the field of SSTA, the STEP-UP Project leveraged on this and further improved the course offering. Among the changes implemented include:

- Addition of remote sensing topics and hands-on exercises
- Addition of a laboratory component dedicated to cansat design, development, and testing
- Elevating the level of difficulty through enhanced missions and providing full flexibility in the design and development

With these enhancements, the course was able to attract students outside the electrical and electronics engineering field such as mechanical and geodetic engineering students. This enabled cansat groups to have multiple disciplines that interact to further optimize the design of their cansat.

Apart from regular undergraduate courses, the STEP-UP Project also caters student trainees and assistants, and involves them in project activities such as satellite tracking and operations utilizing the ARSS. Through STEP-UP's joint activities with the students, the ARSS is now capable of receiving weather data from NOAA satellites in addition to VHF and UHF satellite communications.

#### 3.3.2. Establishment of a ground station network

A network of ARSS was set up in HAU, USC, and MSU-IIT. These stations shall be used to provide hands-on opportunities to conduct space activities for students and faculty outside UPD. A simplified block diagram of the ARSS kit installed in the three universities is shown in Fig. 7. Each ARSS kit is composed of a computer running a satellite tracking software, an antenna with a rotator and controller, an SDR subsystem receiver, and a handheld radio.

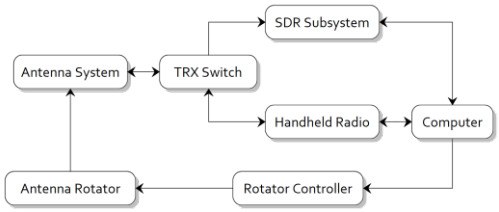


Fig. 7. Block diagram of the ARSS kit.

The STEP-UP team conducted site visits to the three universities to assess the location of the stations and identify the needs for sustaining its operations. As a counterpart requirement, the recipient of the ARSS kits shall sign a memorandum of agreement indicating their consent to the following terms. These requirements were deemed necessary in setting up, maintaining, enhancing, and ensuring utilization of the ground stations.

- The university shall identify a faculty adviser and students who will set up, operate, and maintain the station
- The university shall provide a laboratory space to house the equipment and antenna, and shall shoulder operations costs such as electricity and security
- The university shall forge a partnership with the Philippine Amateur Radio Association (PARA) for promoting and ensuring utilization of the station, and for the creation of an Amateur Radio Club
- The university shall be given access to the ARSS kit designs and the flexibility to review the design and encourage enhancements on the ARSS kit, thereby supporting student projects and researches
- The university shall keep records/logs of ground station operations and satellite tracking activities
- The university shall report issues or damages to the station, along with investigation of the cause of failure

To date, the ARSS installation was already completed in USC and MSU-IIT. Figure 8 shows a completed setup in USC. Apart from installing the kits, the STEP-UP team also conducted training and provided manuals for setting up and operating the station.

Fig. 8. ARSS setup and training in USC: (left) Antenna tower; (top-right) Laboratory setup; (bottom-right) Participants to the ARSS training.

### 3.4. Space awareness raising and outreach activities

As the capacity building component of the STAMINA4Space Program, the STEP-UP Project has been an integral part in information dissemination and proliferating knowledge on SSTA, in close coordination and cooperation with the DOST and other project components of the STAMINA4Space Program. Seminars, technical talks, and training were conducted on amateur communications, space engineering, and small satellite development.

In March 2019, the STEP-UP Project hosted a lecture series on small satellite development, with notable resource persons from Kyutech. Over 400 high school, undergraduate, and graduate students, researchers, faculty members, and representatives from the government, industry, and other sectors attended the lecture series. Future lectures are being planned and requested by various institutions and organizations.

During the 4th Philippine Showcase of Space Technology in April 2019, the STAMINA4Space Program demonstrated Diwata-2's Amateur Radio Unit (ARU) payload and opened its services to the amateur radio community. The service announcement was attended by members of the Department of Information and Communications Technology, PARA, AMSAT Philippines, Armed Forces of the Philippines, and amateur radio enthusiasts. A media event was held separately in May 2019, where about 50 media representatives participated.

Due to the interest garnered for the ARU, requests for seminars and training were received by the project. To date, the STEP-UP Project has conducted trainings for various organizations, which has reached a total of over 150 participants. The project also remains open to internships and immersion programs within and outside UPD. These programs will be expanded to industry members in the future.

Apart from students, researchers, faculty members, and a select number of representatives from the government, members of the media are regularly updated and invited on project activities and events. Tapping the media amplifies the reach for awareness raising activities and has proved to be significant in proliferating SSTA in the country. Through media features on the graduate program under the nanosatellite engineering track, an increase in the application not only to the second batch but also to UNISEC Philippines has been noted. There has also been an increase in the number of engagements, such as views, shares, mentions, followers, likes, and messages, on the various social media accounts being managed by the STAMINA4Space Program, including the UNISEC Philippines Facebook page.

## 4. Discussion

The summary of the STEP-UP Project's current accomplishments in terms of human resource development are presented in Table 3.

Table 3. Summary of STEP-UP accomplishment.

| Categories | Targets | Short Term Results |
|---|---|---|
| Faculty members from other universities | At least one faculty member per major island enlisting commitment as university representative to build the consortium | 4 university representatives: UPD and HAU (Luzon), USC (Visayas), MSU-IIT (Mindanao) founded UNISEC Philippines; 3 additional university representatives joined UNISEC Philippines |
| Graduate Students | At least 19 graduate students on SSTA locally and abroad | 3 PhD students in Japan; 2 MS students in Taiwan; 8 MS/MEng students in UPD; 11 MS/MEng applicants endorsed to UPD |
| Undergraduate Students within UPD | At least 18 undergraduate students per year enrolled in an SSTA elective or involved in SSTA activity | At least 60 students enrolled in SSTA elective; At least 15 students engaged as student assistant or advised for thesis |
| General Public | At least 200 participants in various outreach activities per year | At least 3000 participants from various presentations, tours, exhibits, trainings and immersions |

As shown in Table 3, the STEP-UP team has met and has already exceeded its target numbers in only 21 months of implementation. These statistics are expected to increase further as the project continues implementation for its remaining 27 months.

Since the STEP-UP Project is still halfway on its implementation, the impacts of its activities are still difficult to see. There are, however, notable cases that are already worth mentioning as accomplishments in this paper. One of the factors explored that contributed to these generated impacts is the level of exposure to the project activities, which are presented in Table 4.

Although the results presented in Table 4 are still preliminary, it can be seen that the level of exposure to space activities has an effect on the outcomes of the project. The activities that involved longer exposure to the project such as the graduate program and the project-based engagements are seen to generate more tangible outcomes. However, there are several factors that still limit achieving success in these long-term goals, which are presented in Section 5. On the other hand, although

there is an evident increase in the interest and awareness to the program, which manifested in the increase of applicants from the first to the second batch of the nanosatellite engineering track, the outcome of these activities in terms of people trained over the people returning to the project to seek engagements or initiate space projects remain low at 1 in every 100 people trained. The factors explored contributing to this are also presented in Section 5.

Table 4. Observations on the outcomes of the STEP-UP activities.

| Exposure | Observations and Impacts |
|---|---|
| Through public talks / training / media and other awareness raising initiatives | Typical duration: 1 hr lecture to 1 day<br>Evident increase and regularity of requests for training and presentations. The number of applicants in the first batch to the second batch of the graduate program increased from 16 to 50. |
| Through short term training but with reinforcement through ARSS network | Typical training duration: 8 hrs/day for 2 days<br>At least 50 students and faculty from HAU, USC, and MSU-IIT were given training on amateur radio and satellite operations. Interest is seen from these groups to further expand their space activities |
| Through undergrad elective within UPD | Typical duration: 3 hrs/week for 16 weeks<br>No known case yet of application to STEP-UP Project or space related activity. |
| Through project based engagement within UPD | Typical duration: 30 hrs/week for 16 weeks<br>83% of students that graduated are known to pursue space activities |
| Through graduate track in nanosatellite engineering | Typical duration: 40 hrs/week for 16 weeks<br>All the current 13 graduate students expressed intent to either join the space agency, return to their home institution to spearhead space projects, or to teach in their home universities |

## 5. Challenges in Implementation

As a pioneering effort in proliferating space science and technology in the Philippines, several challenges were encountered. These are discussed in the following subsections.

### 5.1. Coordination and sustainability of the consortium

The establishment of the consortium on SSTA received warm response from the initial list of universities invited. However, despite the smooth coordination and meetings, and proactive contact with different academic institutions in the country, challenges are still present in the establishment of the university consortium. These include:

- Difficulty in identifying the specific expertise and facilities, and valuation of contributions of universities;
- Geographical challenges as the consortium aims to involve universities nationwide;
- Lack of faculty and students or representatives in some universities and possibly taking on more work;
- Budget and funding sources; and
- Sustainability after the STEP-UP Project ends.

From the survey forms handed to UNISEC Philippines members and applicants, it was found that most universities have similar challenges and support needed to further their respective SSTA-related activities. These include the lack of human resources (e.g. resource persons, researchers, subject matter experts, etc.), financial resources (e.g. travel funding for conferences), facilities/laboratories, research/publication materials, training, and network. While these can be complemented by the STEP-UP Project, it is worth noting that the STAMINA4Space Program is only funded under a grant from the DOST and also has limited resources and implementation duration. Options for further funding are available through the DOST, and the STEP-UP Project can serve as a link not only to DOST but also with other institutions from its established network.

As the STEP-UP Project is operating on limited resources, this also adds to the challenge of expanding membership under UNISEC Philippines. There is no provision for a full-time secretariat for UNISEC Philippines and the management for the membership is being handled on top of administrative and technical tasks of team members.

As a new field in the country, most universities are not yet familiar with how to get started with their own space-related activities. Therefore, incorporating the ARSS network and CubeSat development are effective jump-off points for collaboration within the consortium. However, ultimately, the sustainability of the consortium will rely on the capacities of the member universities and schools to continuously support their activities. This will be one of the major items that must be addressed among the members of the university consortium.

These challenges and limitations are identified through the two-year implementation of the STEP-UP Project. The first UNISEC Philippines meeting is planned in 2021 and the activities, leadership once the project ends, expansion of membership, collaboration and partnership, and future plans will be discussed and consolidated to come up with the consortium's sustainability plan.

### 5.2. Employment limitations in joining the nanosatellite engineering program

Valuing the role of universities in proliferating SSTA in the country, the faculty members were among the main targets of the nanosatellite engineering track. However, since universities also have regulations on who can be allowed to take study leaves, the STEP-UP Project received low number applications from the academe. In both the first and second batch, all applicants from the academe are employed as lecturers or instructors who are not yet allowed to take a study leave and who will have to submit their resignation if they get into the program.

The same limitation is true for applicants from the industry and some government agencies. In the first batch, only five (5) of the sixteen (16) applicants are allowed to take study leave and all of them are representatives from the government. In the second batch, only ten (10) of the fifty (50) applicants are allowed to take study leave and all of them are also representatives from the government.

### 5.3. Sustaining satellite development activities under the nanosatellite engineering track

Sustaining the development, test, and launch of the CubeSats under the nanosatellite engineering track at UPD after the STEP-UP Project still remains a big challenge. While the courses established under the graduate track can be

continuously offered beyond the implementation duration of the STEP-UP Project, the funding secured for CubeSat-related activities is only for two batches, with each batch developing two 1U flight models.

Currently, DOST-SEI provides financial support for the tuition and miscellaneous fees, stipends, research grant, travel costs, and satellite test costs. The cost of satellite parts, development, and launch is covered by the STEP-UP Project. In order to continue the support for satellite development beyond the termination of the STEP-UP Project in 2022, there is a need to institutionalize a complete scholarship package through DOST-SEI. However, the total resulting cost of this scholarship package is beyond the capacity that can be provided by DOST-SEI at this time.

One approach to lower the amount needed for the scholarship package is by localizing the satellite components and utilizing local industries for satellite fabrication. Currently, the STEP-UP Project has not yet deeply explored engagement of the private sector in its activities, something that needs to be prioritized in the next half of the project implementation. Aside from the potential to lower component and development costs, this may also eliminate or reduce shipment costs and customs duties. The processing time and costs of importing and exporting satellite components still remains among the major challenges in the project execution.

Through the PHL-Microsat Program, facilities to support satellite testing and assembly such as thermal vacuum test chamber, full anechoic chamber, and clean booth were established in the Philippines. However, a vibration test machine, which is critical to assess readiness for launch, is not yet available in the country. Having local access to this machine will also reduce shipment costs, customs duties, and travel expenses of staff and students going abroad for testing.

### 5.4. Building the ground station network

The limitations in the resources meant that the STEP-UP Project had to limit the number of institutions that will receive the ARSS kits, and include, as a qualification, the capability of the institution to support the technical and logistical responsibility of operating and maintaining the ARSS. This hinders the proliferation of the technology especially to institutions with limited technical and financial resources.

### 5.5. Procurement delays

One of the major challenges in the R&D activities and in the implementation of the undergraduate courses is the delay in the acquisition of needed components. There is a large overhead cost in processing parts procurement under government terms, regardless of whether or not these components can be easily sourced in the country.

To circumvent this challenge, one approach is to purchase and stock various components whether or not they will have an immediate use. The disadvantage of this approach are possible wastes and unutilized components. Another, but an inefficient, approach is to incorporate a long lead time for parts procurement in the development timeline.

### 5.6. Awareness on ongoing space-related activities

Among the most notable observations during the initial phases of the implementation of the project is the very low awareness of the activities on SSTA even since the PHL-Microsat Program started. This low awareness limited the number of applicants to the first batch of the graduate track on nanosatellite engineering to only sixteen (16). However, after the media coverage of the first batch of scholars admitted to the program, the number of interested applicants already doubled even without the release of the call for applications to the second batch.

Within the country, there are already many universities that started their space-related activities. However, with the absence of platforms to consolidate and coordinate these efforts, these activities become isolated and unknown to other universities that may be able to contribute or utilize their results. The university consortium targets to address this by linking universities conducting related researches, and by setting up symposia where the members can share their ongoing activities and invite others for collaboration.

### 5.7. Generating tangible outcomes from training and outreach activities

Despite the wide reach of the STEP-UP's activities, the generated spin-off space projects or applications received from its trained participants remain low. There are several factors that may contribute to this. First, with the PhilSA still under establishment, only the STAMINA4Space Program and DOST-ASTI offer employment that will involve satellite development. The nature of position under STAMINA4Space may not be appealing to most degree holders. As the program is project-based, the offered positions are contractual with no opportunity for tenure and no employment benefits. These types of projects also typically expire every three years. Second, there still remains limited resources to practice the knowledge acquired from the training activities of the project. In the absence of hands-on opportunities or tools to conduct their own space activities in their home institutions, the learnings from these outreach activities remain underutilized.

## 6. The Philippine Space Agency in Supporting Local Space Education

In the absence of a space agency, the Philippines started its space efforts through government projects implemented by different universities and agencies. However, to consolidate and sustain these activities, there is a need to have a dedicated government entity that leads and directs the country's efforts in this field.

In May 2019, the Philippine Senate passed a bill on the creation of the PhilSA, which was signed into law on August 8, 2019. Republic Act No. 11363 (RA 11363) or the "Philippine Space Act" stipulates that the Philippine Space Development and Utilization Policy "… will embody the country's central goal of becoming a space-capable and space-faring nation within the next decade" through the establishment of "capacity building measure for human resources development." The STEP-UP Project aims to contribute to this by establishing a pool of experts in SSTA through the exchange of knowledge with members of the university consortium, R&D collaborations, and learning sessions on the design and development of CubeSats, including the nanosatellite engineering track and workshops/seminars.

The role of the academe has been recognized in the proliferation of SSTA and predefined in RA 11363. Under Section 8, III, the PhilSA is called upon to collaborate with universities, industries, and other institutions in performing basic and applied R&D relating to SSTA and promote the growth of space S&T through R&D. Specifically, Section 8, IV outlines initiatives for education and capacity building, which include "(a) establish programs that would develop space education and promote public awareness; (b) provide grants and contributions in support of programs or projects relating to scientific or industrial space R&D and application of space technology; and (c) provide services and facilities for the use by entities conducting academic R&D relating to SSTA."

Although the PhilSA is newly established, the STAMINA4Space Program is considered as a stakeholder by PhilSA. The program has already started reporting and coordinating activities to PhilSA, in addition to the periodic reporting to the DOST. The experience of the STEP-UP Project, and the STAMINA4Space Program as a whole, is feeding into the further development of SSTA-related activities. It is hoped that these experiences and results are significant contributions and be integrated into future SSTA programs under PhilSA.

## 7. Conclusion

The PHL-Microsat Program succeeded in building the foundation of space science and technology in the Philippines. The challenge for its successor, the STAMINA4Space Program, is to sustain and proliferate the gains from the country's initial space activities. The STEP-UP Project under the STAMINA4Space Program addresses this need through the strategies discussed in the paper. The quantitative and qualitative metrics used to assess how much of the objective were already attained are also presented.

The establishment of the UNISEC Philippines served as a vehicle in coordinating nationwide activities in SSTA and led the country's participation in global SSTA activities. The consortium offers a central platform for student and faculty exchange, provide expertise on space science and engineering, and link and foster local and global partnerships among member universities for joint research and sharing of available facilities. To extend the coverage of the consortium even in its early stages, the selected co-founding members of the UNISEC Philippines cut across the three main islands of the country, serving as a knowledge hub in their respective regions. To encourage collaboration among members of the university consortium, the STEP-UP Project initiated activities that can later on be incorporated as regular activities of the consortium. Among these is the offering of a graduate track on nanosatellite engineering, which involves hands-on design, development, and testing of a 1U CubeSat that will be launched to an ISS orbit. The STEP-UP Project also developed a customized set of equipment for amateur radio and satellite operations. These kits are installed at the university co-founding members of UNISEC Philippines, promoting amateur radio and space technology among the students and even faculty members.

Despite the high interest and cooperation of various institutions in the proliferation of space science and technology in the country, the STEP-UP Project still encountered several challenges. These include limitations in the technical and logistical resources, procurement delays, and sustainability of the activities beyond the implementation duration of the project.

## Acknowledgments

The authors would like to extend its gratitude to the Philippine Department of Science and Technology (DOST), to the DOST - Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD), and to the DOST - Science Education Institute (DOST-SEI) for providing full support to the STAMINA4Space Program. The authors would also like to thank the members of the UNISEC Philippines, the Kyushu Institute of Technology in Japan and its BIRDS project supported by the JSPS Core-to-Core Program, B. Asia-Africa Science Platforms, and the researchers, staff, and consultants of the STEP-UP Project and the STAMINA4Space Program.

## References

1) PHL-Microsat Program, http://phl-microsat.upd.edu.ph/about (accessed April 1, 2019).
2) Joint Global Multi-Nation Birds, https://www.birds-project.com (accessed March 24, 2019).
3) Wood, D., Weigel, A.: Charting the Evolution of Satellite Programs in Developing Countries—The Space Technology Ladder, *Space Pol.*, **28** (2012), pp. 15–24.
4) SDM LAPAN, https://www.lapan.go.id/page/sdm-lapan (accessed April 10, 2020).
5) Phuong, V.: The Need of Remote Sensing and the Development of Earth Observation Satellites in Vietnam, Presentation during the Hokkaido Summer Institute, Sapporo, Japan, 2017.
6) PHL-Microsat Internal Report, 2018.
7) Cho, M.: UNISEC Japan Activity Report, 2018.
8) Department of Science and Technology (DOST)-PCIEERD: PHL Space Development Report 2018, DOST, 2019.
9) STAMINA4Space: Official Statement on the "PHL-Microsat Program" Being Renamed to "STAMINA4Space Program," Press Release, 2019.
10) National S&T Human Resource Development thru Engineering Research and Development for Technology (ERDT), 2016.
11) UNISEC-Global Terms of Reference, http://www.unisec-global.org/termsofreference.html (accessed April 1, 2019).
12) CubeSats and Education: The Fly Your Satellite! Program, http://www.esa.int/Education/CubeSats_and_Education_the_Fly_Your_Satellite!_programme (accessed March 24, 2019).
13) CubeSat Launch Initiative, https://www.nasa.gov/content/about-cubesat-launch-initiative (accessed March 24, 2019).
14) Pradhan, K., Pauline, F., Maeda, G., Kim, S., Masui, H., and Cho, M.: BIRDS-2: Multi-Nation Cubesat Constellation Project for Learning and Capacity Building, 32nd Annual AIAA/USU Conference on Small Satellite, Logan, Utah, USA, 2018.
15) Lennon, E.: Amateur Radio in the STEM Classroom, Techdirections, April 2016, pp. 11–12, 21–23.
16) Newport, J.: Amateur Satellites as a Vehicle for Satellite Communication Education, Seminars of the United Nations Programme on Space Applications, New York, USA, pp. 145–151, 2004.
17) Constante, M., Cansino, P., Bautista, I., Bajaro, G., Talampas, M., and Marciano, J.: Capacity Building in Space Technology in the Philippines through the PHL-Microsat Program, 31st International Symposium on Space Technology and Science, Matsuyama, Japan, 2017-u-12, 2017.