Evaluating Japanese university-led space technology development and utilisation capacity building programmes in emerging countries

新興国における宇宙技術の開発・利用に関する我が国の大学等による人材育成支援活動の評価

STIG SPACE POLICY REPORT NO.1

Science, Technology and Innovation Governance (STIG) Education Programme

Graduate School of Public Policy

The University of Tokyo

March 2021

The **Science, Technology and Innovation Governance (STIG) Education Programme** was established in 2012. It is a University of Tokyo programme that harnesses specialised graduate school-level education in the humanities and the sciences. STIG fosters human resources who can lead science and technology governance with knowledge of the science, technology, and innovation (STI) policymaking process in each field and knowledge of the evidence-building methods required to draft and implement STI policy. Specifically, the programme advances both education and research activities primarily aimed at fostering policymaking specialists, STI researchers and research and development management specialists.

In recent years, the STIG Education Programme has developed a strong expertise in international space affairs, including space safety and sustainability, space security, and space technology development and utilisation in developing countries.

Funding source

The research presented in this report was funded by the Ministry of Education, Culture, Sports, Science and Technology's (MEXT) *Science for REdesigning Science, Technology and Innovation Policy* (SciREX) programme.

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Foreword

Since its establishment in 2012, the Science, Technology and Innovation Governance (STIG) Programme has been active in the promotion of evidence-based policymaking. With this report, providing the first comprehensive assessment of the role of universities in space technology development and utilisation capacity building programmes with emerging countries, STIG proposes its first major work on space policy, at the crossroads of knowledge management, higher education policy and science diplomacy.

Funded by the *Science for REdesigning Science, Technology and Innovation Policy* (SciREX) programme of the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT), this study was conducted as a "co-evolutionary" research project, in which academic researchers work hand-in-hand with MEXT officials. Beyond producing high-quality academic research, such projects aim to have a direct impact on the ministry's activities.

Implementing the ambitious while pragmatic recommendations made in this report, result of two years of intensive data collection and analysis, would have a great impact on the ability of Japanese universities to continue to spread space technology development and utilisation knowledge around the world, and would contribute to maximising the diplomatic and industrial benefits such activities bring to Japan as a whole.

This first STIG Space Policy Report will be followed by many, contributing to STIG's vision to become the primary independent academic think-tank on space policy in Japan and in Asia.

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Executive Summary

This report presents the results of a two-year study on the role of Japanese universities in space technology development and utilisation capacity building, conducted by researchers of The University of Tokyo in collaboration with officials of the Office for Space Utilization Promotion of the Ministry of Education, Culture, Sports, Science and Technology (MEXT). Based on an initial research proposal from the MEXT, the team of researchers decided to make a detailed research plan to analyse the role played by Japanese universities, compare them with the best international practices, and propose to the ministry different scenarios for reform. The project was funded by the MEXT's *Science for REdesigning Science, Technology and Innovation Policy* (SciREX) programme.

Scope and objectives of the project

This research project studies the central role of universities in the establishment of space technology development and utilization capacity building programmes for the benefits of developing countries. In this report, it is defined as the ensemble of projects, training programmes, institution-building, enactment of laws, policies and strategies, facilitating the development of space capabilities in support to the achievement of domestic social and economic goals.

In close coordination with the MEXT officials having proposed the initial research topic, we identified a number of policy issues that needed to be addressed in order to meaningfully cover the question of university-led space technology development and utilisation capacity building. We then derived five initial research questions, answered throughout this report:

1. How to evaluate the success of a space technology development and utilisation capacity building programme?
2. What are the strengths and weaknesses of a "Japanese way" of individual university-led space technology development and utilisation capacity building?
3. What schemes can be developed at national level to combine the strengths of each Japanese university for space technology development and utilisation capacity building, in a sustainable way embedded in higher education policies?
4. How can these schemes be designed and funded to promote the involvement of small and mid-size universities in space technology development and utilisation capacity building programmes with developing countries?
5. What are the most appropriate institutional layouts and timeframes for such schemes?

Activities conducted for the project and outputs

The approach adopted in this study mostly consisted in collecting as much data as possible from past and current Japanese university-led space technology development and utilisation capacity building programmes, as well as comparable foreign initiatives. The data was collected through literature review, offline or online interviews, participation in international conferences and workshops, as well as during field visits of universities, laboratories and private capacity building service providers. Overall, the activities conducted as part of this project were:

- Interviews of Japanese capacity building providers in Tokyo in April-May 2019.
- Interviews of Japanese and foreign capacity building providers and recipients during the International Symposium on Space Technology and Science, in Fukui, Japan, in June 2019.
- Data gathering field trip to the United Kingdom, Italy and the Netherlands to interview capacity building providers in June 2019.
- Field visit at the Kyushu Institute of Technology to investigate their flagship BIRDS programme in August 2019.
- Interviews during the International Astronautical Congress in Washington, DC, in October 2019.
- Interviews and a workshop during the Asia-Pacific Regional Space Agency Forum in Nagoya in November 2019.
- Based on the data collected, a lot of analytical work during most of 2020.
- Final workshop to get feedback from experts in January 2021.

Based on this work, we generated the following outputs, mirroring the aforementioned research questions:

1. A precise mapping of Japanese university-led space technology development and utilisation capacity building programmes, which was the core request of the MEXT administrators, most existing programmes being carried out independently by university laboratories, with minimal coordination with the government.
2. A comparative analysis with equivalent international initiatives, in order to assess the specificities of the Japanese approach, with its strengths and weaknesses.
3. Three thematic chapters analysing (1) the diplomatic role of capacity building programmes, in a context of rise of Chinese initiatives competing with Japanese universities' traditional roles, (2) their educational effectiveness and (3) the impact of the COVID-19 pandemic on such activities.
4. Various policy recommendations at national and university levels in order to address the weaknesses identified.

Areas for improvement and final recommendations

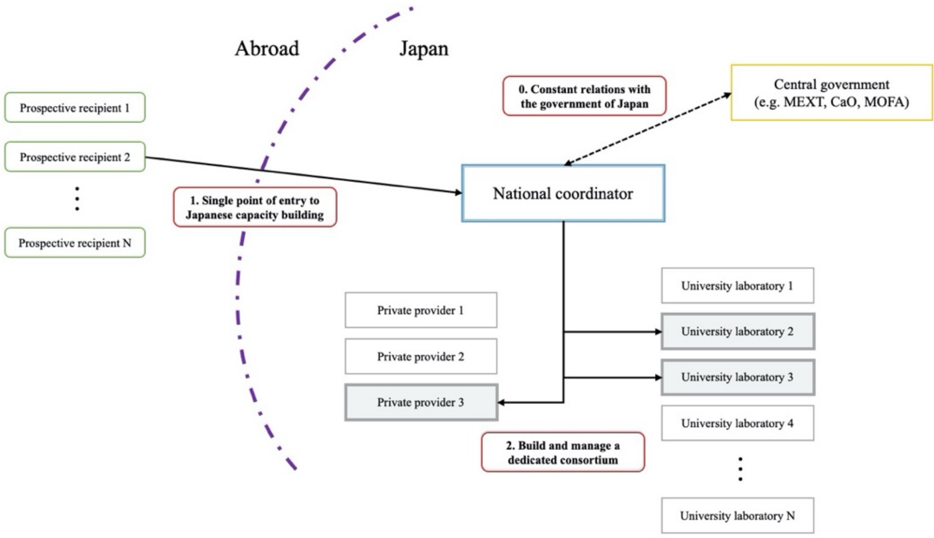
Apart from the numerous strengths and benefits of Japanese university-led space technology development and utilisation capacity building, we identified 11 needs, listed below:

- Need 1: national coordination mechanism to identify and combine the most appropriate capacity building providers, according to the needs for the recipient
- Need 2: more small satellites testing centres across Japan
- Need 3: national point of contact to connect prospective recipients with prospective donors
- Need 4: national repository of capacity building know-how
- Need 5: extract programmes from their dependency on each professor
- Need 6: the government should develop a national strategy on space cooperation with developing countries, to inspire partnerships
- Need 7: the government should not have a too strong direct involvement in partnerships as it could frighten foreign partners
- Need 8: ensure affordable satellite deployment opportunities for all Japanese universities
- Need 9: enhance intra-university coordination leveraging all relevant departments of the university, to include social sciences in capacity building programmes
- Need 10: ensure that the knowledge transferred will be retained before initiating a programme
- Need 11: facilitate responsibility sharing with private contractors

We then proposed four core recommendations in order to address those needs.

Recommendation 1: national coordination mechanism for capacity building providers

The first and main recommendation of this report is the establishment of a national coordination mechanism for capacity building providers, in the form of an independent non-profit organisation.



This mechanism would provide a series of benefits by serving as (1) a single point of contact for prospective recipients, (2) a body of expertise to evaluate the quality of requests and create appropriate consortia allowing smaller and private providers to participate, (3) a centralized repository of capacity building knowledge and on the space development level of foreign countries and (4) an advisory body to recommend a national strategy regarding space partnerships with foreign countries. However, the main challenge of such mechanism is to promote coordination while ensuring a healthy competition among potential providers as some projects can lead to very large funding opportunities.

Recommendation 2: internal schemes to foster capacity building programmes in Japanese universities

This report's second recommendation is to strengthen internal coordination in Japanese universities involved in capacity building programmes, in order to (1) reinforce the role of university headquarters in capacity building programmes usually conducted independently by specific laboratories, (2) leverage all departments and institutes within the university to provide comprehensive capacity building packages and (3) foster the development of university spin-off companies.

Recommendation 3: establishing geographic poles for satellite assembly and testing in Japan

The lack of satellite assembly and testing facilities in Japan is hampering the proliferation of small satellite development programmes and consequently the emergence of new space technology development and utilisation capacity building providers. We therefore recommend increased governmental support for the establishment of satellite assembly and testing facilities, in collaboration with local universities, with an emphasis on the northern half of Japan, unable to benefit from the equipment available at the Kyushu Institute of Technology.

Recommendation 4: regulatory and/or promotional tools available to the MEXT

Finally, this report recommends the MEXT to use some of its regulatory and promotional tools in support to universities providing space technology development and utilisation capacity building programmes. In particular, we strongly insist on the necessity to work with JAXA to maintain affordable small satellite deployment opportunities for Japanese universities. We also recommend the MEXT to develop funding targeted to international capacity building for space technology development and utilisation, in other words *space education official development assistance*.

概要

本レポートでは、文部科学省研究開発局宇宙開発利用課宇宙利用推進室と東京大学の研究者による 2 年間の共同研究プロジェクトの成果を報告する。本研究プロジェクトでは、宇宙技術の開発利用のための人材育成支援活動における日本の大学の役割について検討を行った。研究チームは、文部科学省からの研究提案に基づいて、日本の大学が宇宙分野の人材育成支援活動において果たしている役割を分析し、それらを国際的な成功事例と比較することで、政策再編のためのさまざまなシナリオを提案することを目的に詳細な研究計画を作成した。本研究プロジェクトは、文部科学省の科学技術イノベーション政策における「政策のための科学」推進事業（SciREX）によって資金提供されたものである。

研究プロジェクトの範囲と目的

本研究プロジェクトでは、途上国の利益に資する宇宙技術の開発および利用のための人材育成支援プログラムの確立における大学の役割について調査を行った。本レポートでは、宇宙技術の開発利用のための人材育成支援活動を「国内の社会的・経済的目標の達成に資する宇宙分野で活用可能な能力の開発、及び、関連する制度の構築、法律の制定、政策や戦略の策定を促進するためのプロジェクトや研修プログラムの総体」と定義する。

本研究においては、当初の研究トピックを提案した文部科学省の行政官と緊密に連携しつつ、日本の大学による宇宙技術の開発利用のための人材育成支援活動が抱える問題に効果的に対処するための多くの政策課題を特定し、次の 5 つのリサーチクエスチョンを導き出した。

1. どのように宇宙技術の開発利用のための人材育成支援プログラムの成功を評価するか。
2. 各大学による「日本式」の人材育成支援活動に見られる強みと弱みは何か。
3. 大学による宇宙技術の開発利用のための人材育成支援活動の強みを日本の高等教育政策の中に持続的なかたちで位置づけていくために、どのような国内スキームを形成することができるか。
4. 途上国への宇宙技術の開発利用のための人材育成支援プログラムに中小規模の大学の関与を促進するため、どのような国内スキームを設計することができるか。また、そのような国内スキームのために、どのような資金提供を行うことができるか。
5. そのような国内スキームにとって、最適な制度設計と期間はどのようなものか。

プロジェクトのために実施された活動と成果

本研究では、主に過去および現在の日本の大学による宇宙技術の開発利用のための人材育成支援プログラム、ならびに、諸外国における同様の取り組みについて、可能な限り多くの情報を収集した。これらのデータは、既存の文献のレビュー、オフラインまたはオンラインでのインタビュー、国際会議やワークショップへの参加、大学や研究所あるいは民間の人材育成支援サービスの提供者などへの現地視察を通じて収集された。このプロジェクトの一環として実施された活動は次のとおりである。

- 2019 年 4 月から 5 月：日本における人材育成支援プログラムの提供者へのインタビュー（於：東京）
- 2019 年 6 月：福井県で開催された宇宙技術と科学に関する国際シンポジウム（ISTS）に参加した際に実施した国内外の人材育成支援プログラムの提供者と受容者へのインタビュー
- 2019 年 6 月：イギリス、イタリア、オランダの関係機関への現地訪問、諸外国における人材育成支援プログラムの提供者へのインタビュー
- 2019 年 8 月：BIRDS プログラムを実施している九州工業大学への現地視察
- 2019 年 10 月：ワシントン DC で開催された国際宇宙会議（IAC）でのインタビュー
- 2019 年 11 月：名古屋で開催されたアジア・太平洋地域宇宙機関会議（APRSAF）でのインタビューとワークショップの開催
- 2020 年：収集したデータに基づく分析
- 2021 年 1 月：研究成果について専門家からフィードバックを得るための最終ワークショップの開催

こうした調査分析に基づき、前述のリサーチクエスチョンも踏まえながら、本プロジェクトでは、次のような研究成果を生み出した。

1. 文部科学省の行政官の要請に基づき、日本の大学による宇宙技術の開発利用のための人材育成支援プログラムの全体像についてマッピングを行った。それにより、国内における既存のプログラムのほとんどは、大学の研究室が独自に実施しており、政府との調整は最小限にとどまっているという特徴があることを明らかにした。
2. 諸外国における同様の事例との比較分析によって、日本の大学による取り組みの特徴を明らかにし、その長所と短所を評価した。
3. 次の３つの観点からテーマ別の分析を行った。（1）台頭する中国のイニシアティブも念頭においた日本の大学による人材育成支援プログラムの外交的役

割、（2）教育効果、および（3）このような活動に対する新型コロナウイルス感染拡大の影響。

4. 本研究で特定された弱みを改善するための国内および大学レベルでのさまざまな政策提言を行った。

改善すべき課題と提言

本研究では、日本の大学による宇宙技術の開発利用のための人材育成支援活動の改善に向けた 11 のニーズを特定した。

ニーズ 1： 受容者のニーズに応じて、最も適切な人材育成支援の提供者を特定し、組み合わせるための国内の調整メカニズム

ニーズ 2： 国内における小型衛星の試験のための拠点の拡充

ニーズ 3： 将来の受容者と提供者をつなぐための全国的な連絡窓口

ニーズ 4： 人材育成支援のためのノウハウの蓄積と集約

ニーズ 5： 個々の大学教授に依存したプログラムからの脱却

ニーズ 6： 途上国との宇宙協力に関する政府による国家戦略の策定

ニーズ 7： 海外のパートナーを尻込みさせないよう政府による直接的関与を避けること

ニーズ 8： 国内のすべての大学にとって手頃なコストで利用できる人工衛星の軌道配置の機会を確保すること

ニーズ 9： 人材育成支援プログラムにおいて、社会科学も含め、大学内のすべての関連部門を活用するための学内連携の強化

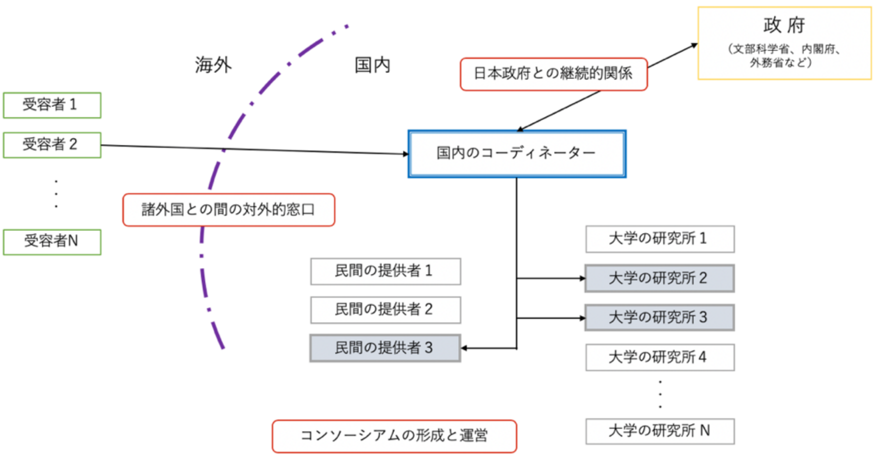
ニーズ 10： プログラムを開始する前に、移転された技術や知識が適切に保持されることを確認すること

ニーズ 11： 民間業者との責任分担を促進すること

そして、これらのニーズに対応するため、次の 4 つの政策提言を行った。

提言 1：人材育成支援プログラムの提供者のための国内調整メカニズムの形成

第一に、本研究における最も主要な提言は、人材育成支援プログラムの提供者のため国内の調整メカニズムの確立である。また、そのような調整メカニズムは、独立した非営利団体の形態であることが望ましいと考えられる。



このメカニズムは、次のような機能を果たすことによって、さまざまな利点をもたらすことができると考えられる。すなわち、（1）将来の海外の受容者との対外的な連絡窓口、（2）途上国のニーズを評価するための専門知識の体系化、および、より小規模な民間の提供者も参加できる適切な枠組みの形成（3）人材育成支援活動および諸外国の宇宙開発レベルに関する一元化された情報の蓄積と集約、そして（4）諸外国との宇宙分野でのパートナーシップに関する国家戦略を勧告する諮問機関としての機能である。ただし、一部のプロジェクトが非常に大きな資金調達の機会を得る可能性があるため、潜在的な提供者間の健全な競争を確保しながら連携を促進することが大きな課題となる。

提言 2：日本の大学における人材育成支援プログラムを促進するための学内スキーム

第二の提言は、（1）従来は特定の研究所が独立して実施してきた人材育成支援プログラムにおける大学本部の役割を強化するとともに、（2）包括的な人材育成支援のパッケージを提供するために、大学内のすべての学部および関係機関の活用を促し、また（3）大学のスピンオフ企業の発展を促進するため、人材育成支援プログラムにおける大学内部の連携を強化することである。

提言 3：衛星の組み立てとテストのための国内拠点の拡充

衛星の組み立ておよび試験のための施設が少ないことは、日本における小型衛星開発プログラムの発展を妨げる要因の一つとなっており、結果として、宇宙技術の開発利用のための人材育成支援活動の発展を妨げている。したがって、第三に、特に九州工業大学で利用可能な設備の恩恵を受けられない日本北部を中心に、地方の大学と協力して、衛星組み立ておよび試験のための施設を拡充するための政府の支援を強化することを提言する。

提言 4：文部科学省が大学に提供できる政策ツールの充実化

そして第四に、文部科学省が宇宙技術の開発利用のための人材育成支援プログラムを提供している大学を支援するために利用できる政策ツールの充実化を図ることを提案する。特に、JAXA と協力して、日本の大学が低コストで利用できる超小型衛星の軌道放出機会を維持していくことを強く提案する。また、国際的な宇宙技術の開発利用のための人材育成支援を対象とした資金提供、つまり、「宇宙教育のための政府開発援助」について検討することを提言する。

ACKNOWLEDGEMENTS

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In addition, we are grateful to the Executive Committee of the Asia-Pacific Regional Space Agency Forum (APRSAF) for inviting us to organise our mid-term review workshop during the 26th APRSAF, held in Nagoya, Japan in November 2019.

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List of Abbreviations

ACAE	Central American Association of Aeronautics and Space
AIT	Assembly, integration and testing
APRSAF	Asia-Pacific Regional Space Agency Forum
BIT	Bandung Institute of Technology
DLR	German Aerospace Centre
DOST	Department of Science and Technology
DOST-ASTI	DOST's Advance Science and Technology Institute
GISTDA	Geo-Informatics and Space Technology Development Agency
IAC	International Astronautical Congress
IAF	International Astronautical Federation
ISISPACE	ISIS - Innovative Solutions In Space
ISS	International Space Station
ISSL	Intelligent Space System Laboratory
ISTS	International Symposium on Space Technology and Science
J-SSOD	JEM Small Satellite Orbital Deployer
JAXA	Japan Aerospace Exploration Agency
JEM	Japanese Experimental Module
JICA	Japan International Cooperation Agency
KAIST	Korea Advanced Institute of Science and Technology
KHTT	Know How Transfer and Training
Kyutech	Kyushu Institute of Technology
LAPAN	National Institute of Aeronautics and Space (Indonesia)
LaSEINE	Laboratory of Lean Satellite Enterprises and In-Orbit Experiments
METI	Ministry of Economy, Trade and Industry
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MIC	Ministry of Internal Affairs and Communication
MOFA	Ministry of Foreign Affairs
MUT	Mahanakorn University of Technology
NPO	Non-profit organisation
NSPO	National Space Organization
ODA	Official development assistance
PhilSA	Philippines Space Agency
RESTEC	Remote Sensing Technology Centre of Japan
RSA	Rwanda Space Agency

RURA	Rwanda Utilities Regulatory Authority
S&F	Store-and-forward
SaTReC	Satellite Technology Research Centre
SciREX	Science for REdesigning Science, Technology and Innovation Policy
SSC	Surrey Space Centre
SSTL	Surrey Satellite Technology Limited
STI	Science, technology, and innovation
STIG	Science, Technology and Innovation Governance
TEC	Institute of Technology of Costa Rica
TICAD	Tokyo International Conference on African Development
TU Berlin	Technical University of Berlin
TU Delft	Technical University of Delft
UKSA IPP	UK Space Agency International Partnership Programme
UNAH	National Autonomous University of Honduras
UNCOPUOS	United Nations Committee on the Peaceful Uses of Outer Space
UNISEC	University Space Engineering Consortium
UNOOSA	United Nations Office of Outer Space Affairs
UP	University of the Philippines
VAST	Vietnam Academy of Science and Technology
VNSC	Vietnam National Space Centre

LIST OF PROJECT MEMBERS AND CONTRIBUTORS

Disclaimer: Although administrators of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) have been involved in the design and development of this study, the views and opinions expressed in this report are those of the writers only (underlined below) and do not necessarily reflect the official policy or position of the MEXT or The University of Tokyo.

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CHAPTER 1: INTRODUCTION AND DEFINITIONS

This study project was funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) as part of its *Science for REdesigning Science, Technology and Innovation Policy* (SciREX) programme. Every year, under the SciREX programme, the MEXT issues a call for proposals based on a list of research topics proposed by various offices in the ministry. Interested universities and research institutes can therefore submit research proposals, which are then revised during joint discussions between the proposing office and interested researchers.

Proposed in the autumn of 2018 by the MEXT's Office for Space Utilization Promotion, this project expressed the administrators' desire to get a precise picture of the role played by Japanese universities in space technology development and utilisation capacity building and to identify areas of improvement. Based on this initial proposal, our team decided to make a detailed research plan to analyse the role played by Japanese universities, compare them with the best international practices, and propose to the ministry different scenarios for reform.

The official project title was "Empirical research contributing to the examination of the domestic framework supporting Japanese university-led space technology development and utilisation capacity building programmes for the benefits of developing countries" or in Japanese: 新興国における宇宙技術の開発・利用に関する我が国の大学等による人材育成支援活動のための国内枠組みとその展開可能性の検討に資する実証的研究.

This introductory chapter is organised as follows: (1) the rationale and purpose of the project, (2) the activities conducted as part of the study, (3) the classification of projects analysed here and (4) the outline of the report.

1. Rationale and purpose of the project

This section introduces the overall rationale and goals of the study project and clarifies its scope.

1.1. What is space technology development and utilisation capacity building?

The core of this study is the role played by Japanese universities in space technology development and utilisation capacity building. But what is it?

There are numerous definitions of capacity building, or capacity development. The definition used in this report is the one developed by the United Nations Office for Disaster Risk Reduction:

> The process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals. It is a concept that extends the term of capacity-building to encompass all aspects of creating and sustaining capacity growth over time. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems and the wider enabling environment.[1]

In the field of space technology development and utilisation, capacity building means the ensemble of projects, training programmes, institution-building, enactment of laws, policies and strategies, facilitating the development of space capabilities in support to the achievement of domestic social and economic goals. Among the projects reviewed in this report, it can include, among many others:

- Joint satellite development projects, in order to transfer satellite design, assembly, integration and testing knowledge from established space powers to aspiring ones.
- The installation of satellite ground stations in developing countries in order to benefit from complimentary data available from advanced foreign satellites (e.g. Landsat, ALOS), and associated trainings.
- The establishment of centres for geospatial data analysis, in support of local needs.
- The joint drafting of national strategies, policies and laws in order to form the basis of a sustainable space programme in aspiring spacefaring countries.
- The organisation of space technology development and utilisation education programmes in the target countries or in universities in the donor country.

As we demonstrate in this report, capacity building can and should take various forms, in order to be adapted to the specific situation of the recipient to reach full efficiency, while also corresponding to the goals and interests of the donor.

1.2. Scope and research goals

This research project investigates the central role of universities in the establishment of space technology development and utilisation capacity building programmes for the benefits of developing countries. Our first venture into this topic was to identify specific policy issues in relations with university-led space capacity building and to derive research questions from them.

In close coordination with the MEXT administrators having proposed the research topic, we identified a number of policy issues that needed to be addressed in order

[1] 'Capacity', United Nations Officer for Disaster Risk Reduction, accessed 26 November 2020, https://www.undrr.org/terminology/capacity.

to meaningfully cover the question of university-led space technology development and utilisation capacity building:

- Japanese university-led space technology development and utilisation capacity building contributes to emerging and developing countries and their universities.
- While space technology development and utilisation capacity building is an important activity regarding Japanese space technology exports and more generally space business extension, it is also a meaningful educational and research activity in terms of international cooperation. In this context, space capacity building is worthwhile for Japanese universities themselves based on the nature of the university while being also effective for Japan as a whole (all-Japan strategy). However, existing Japanese university-led space capacity building programmes with developing countries are seen as independent initiatives from these universities, not as a comprehensive Japanese government policy. It is important for the MEXT to give a national coherence to these various efforts.
- However, it has not been identified how space technology development and utilisation capacity building programmes contribute to donor universities themselves in terms of education and research, and university management.
- Moreover, relations between universities headquarters and laboratories involved in space capacity building are, especially in the case of small and mid-size universities having limited resources, critical for the success of the programmes. In order to promote the involvement of such universities, for example to improve their international attractivity and to increase their access to external sources of funding, it is necessary to develop a precise scheme clarifying role-sharing between all internal actors. It is therefore important for small and mid-size universities to develop a strong strategic vision regarding international cooperation projects.
- As for big universities, which are leading most of existing space technology development and utilisation capacity building programmes in Japan, laboratories tend to act with a certain freedom. It would be preferable for the long-term sustainability of such programmes to be integrated in a university-wide strategy, highlighting the important role of university headquarters.
- In addition, the actual contributions of such capacity building programmes to recipient countries and to universities have never been evaluated, as well as their significance compared to similar activities of other countries.
- Although there are various practices accumulated over the years, the methodology of space technology development and utilisation capacity building has not been established yet and such programmes suffer from a lack of sustainability and mid to long-term perspective.
- Finally, space capacity building programmes being labour intensive, they require the involvement of many actors in Japanese universities, in particular students. However, for students in aerospace engineering, participating in such international cooperation programmes does not provide any clear career

benefit considering the existing aerospace engineer career path in Japan. Identifying and promoting clear and attractive international cooperation career paths for Japanese aerospace engineers would contribute to solving this issue.

Based on the aforementioned policy issues, we designed five initial research questions, answered throughout this report:

1. How to evaluate the success of a space technology development and utilisation capacity building programme?
2. What are the strengths and weaknesses of a “Japanese way” of individual university-led space technology development and utilisation capacity building?
3. What schemes can be developed at national level to combine the strengths of each Japanese university for space technology development and utilisation capacity building, in a sustainable way embedded in higher education policies?
4. How can these schemes be designed and funded to promote the involvement of small and mid-size universities in space technology development and utilisation capacity building programmes with developing countries?
5. What are the most appropriate institutional layouts and timeframes for such schemes?

1.3. Approach for data collection

The approach adopted in this study mostly consisted in collecting as much data as possible from past and current Japanese university-led space technology development and utilisation capacity building programmes, as well as comparable foreign initiatives. The data was collected through literature review, offline or online interviews, participation in international conferences and workshops, as well as during field visits of universities, laboratories and private capacity building service providers. The details of interviews and field trips is provided in section 2 below.

The data collected helped us to understand all the facets of space technology development and utilisation capacity building programmes: why were they started? With what resources? How were they appreciated by the recipient organisation? What was the involvement of the country’s central government? Are these programmes part of university-wide or government-wide strategies? Is it preferable to rely directly on university laboratories or establish a dedicated spin-off company? Etc.

Then, after understanding the subtleties of the issue, we defined and evaluated scenarios to enhance Japanese efforts in this field, relying on the team members expertise in public administration, in particular concerning the Japanese government.

1.4. Outputs

The concrete outputs of this study, mirroring the aforementioned research questions, are:

1. A precise mapping of Japanese university-led space technology development and utilisation capacity building programmes, which was the core request of the MEXT administrators, most existing programmes being carried out independently by university laboratories, with minimal coordination with the government.
2. A comparative analysis with equivalent international initiatives, in order to assess the specificities of the Japanese approach, with its strengths and weaknesses.
3. Various policy recommendations at national and university levels in order to address some of the weaknesses identified.
4. Finally, additional considerations on the impact of the COVID-19 pandemic on space technology development and utilisation capacity building programmes, which usually require a high level of hands-on involvement.

2. Timeline of the project and activities

This section briefly summarises the activities that have been conducted by the research team as part of this study. It includes numerous interviews, field visits of universities or private providers of capacity building services, international conferences and coordination meetings with MEXT administrators.

First year (FY 2019)

After the study project kick-off in April 2019, we focussed on understanding the current state of Japanese university-led capacity building by conducting interviews of prominent Japanese professors, both in Tokyo and during the International Symposium on Space Technology and Science, biennial Japanese international conference, last held in Fukui, Japan in June 2019. The first-year timeline (April 2019 – March 2020) is shown on figure 1-1.

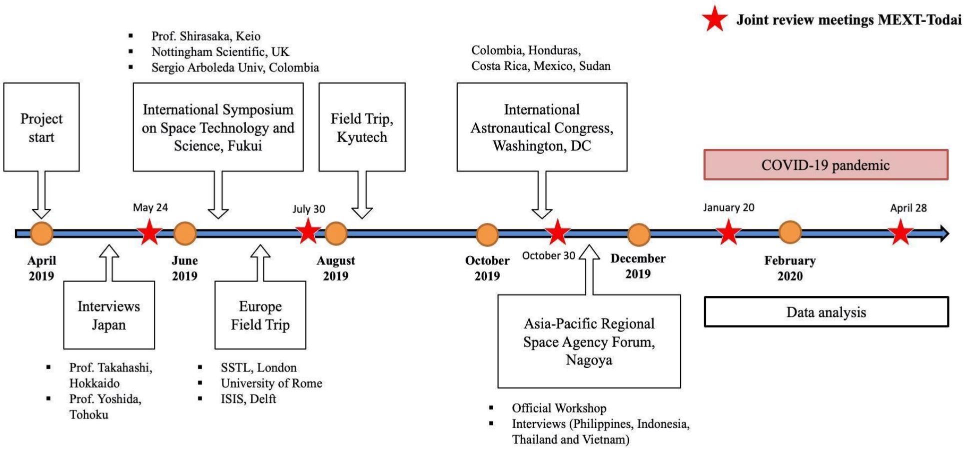

Figure 1-1. Timeline of the first year (FY 2019)

After initial interviews in Japan, we organised a large-scale data gathering field trip in Europe in order to investigate the role played by different capacity building providers and compare their history, motivations and activities with those of Japanese providers: Surrey Satellite Technology Ltd. in the United Kingdom, the Sapienza University of Rome and ISISPACE in the Netherlands.

Then, after a fascinating visit of the Kyushu Institute of Technology, to investigate their flagship BIRDS programme, we attended two major space conferences: the International Astronautical Congress (IAC) in Washington, DC and the Asia-Pacific Regional Space Agency Forum (APRSAF) in Nagoya, Japan. In both events, we conducted numerous interviews, mostly with capacity building recipients from Central and South Americas, Africa and Southeast Asia.

The APRSAF in Nagoya was a perfect opportunity for us to hold a workshop, on 26 November 2019, titled “Challenges to Academic Space Programs: The Function of Capacity-building in Promoting International Space Cooperation,” in order to share the initial results of our study, and to organise presentations and a panel with prominent experts of the Asia-Pacific region. After an initial keynote address by Dr Quentin Verspieren on the scope and purpose of the study and on the data collected so far, the first session, titled “Outcomes and Obstacles in the Existing Academic Space Programs,” welcomed presentations from Professor Shinichi Nakasuka of The University of Tokyo (also member of this study group), Mr Alex Da Silva of SSTL and Ms Rei Kawashima of non-profit organisation UNISEC. Then, session two, titled “Possible Mechanisms for Coordinating the Roles of Academic Institute, Government and Industry,” consisted in a panel with Professor Pham Anh Tuan, Director General of the Vietnam National Space Centre, Professor Joel Joseph Marciano, Director General of the Philippines Space Agency, Professor Toshinori Kuwahara of Tohoku University, Japan and Dr Mukund Rao of the National Institute of Advanced Studies, India.

Figure 1-2. Participants of the APRSAF workshop of 26 November 2019

The latter part of the first year was unfortunately impacted by the COVID-19 pandemic, preventing us to conduct additional data gathering field visits. We therefore focussed on analysing the great amount of data collected up to November 2019.

Throughout the first year, we had four coordinating meetings with the MEXT administrators in order to share the status of the project and gather their feedback.

Second year (FY 2020)

The second year having been entirely affected by the COVID-19 pandemic, we were prevented from conducting the data gathering trips that we had planned to Africa, South America and Middle East. Instead, we focussed on providing the best analysis from the data collected during the first year, which was completed by a few additional interviews. These interviews provided the bits of missing information necessary to complete our analysis. Figure 1-3 displays the timeline of the second and final year of the study (April 2020 – March 2021).

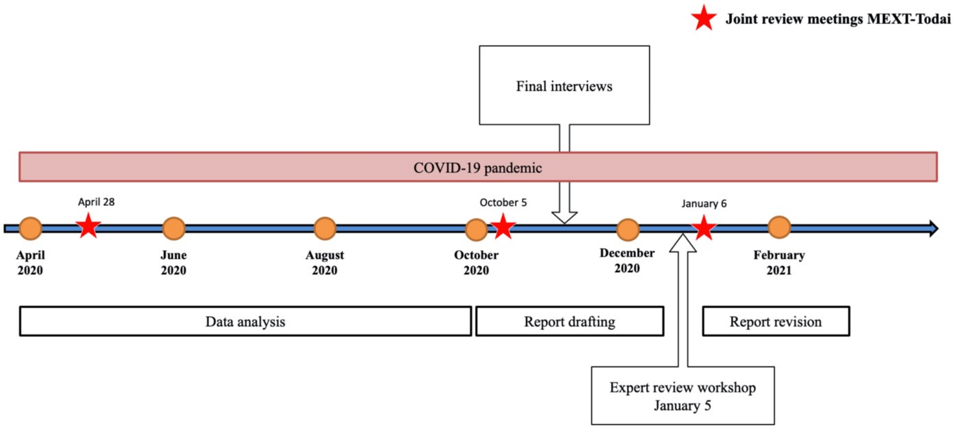

Figure 1-3. Timeline of the second year (FY 2020)

After completing the first draft of the report, we organised a review workshop with external experts, some of whom have been interviewed for the study. Based on their feedback and those of selected reviewers, the final version of this report was completed.

In addition to our existing plan, we decided to transform the COVID-19 pandemic from a challenge into an opportunity: how does such a worldwide situation impact capacity building programmes? Simple considerations were therefore added in the latter part of the second year.

Map of interviewees

As part of this study, we interviewed 30 stakeholders from 13 countries. Among them, 11 from four countries were on the donor side and 19 from 9 countries were on the recipient side of a capacity building programme. They are displayed on figure 1-4.

Figure 1-4. Map of interviewees

3. Classifying capacity building programs

This study has analysed 13 capacity building projects involving a variety of recipients and donors. Among these projects, we identified two types of recipients (universities or government agencies) and three types of donors (universities, university spin-off/out companies and large established corporations). It allowed us to classify studied projects using the matrix shown on figure 1-5.

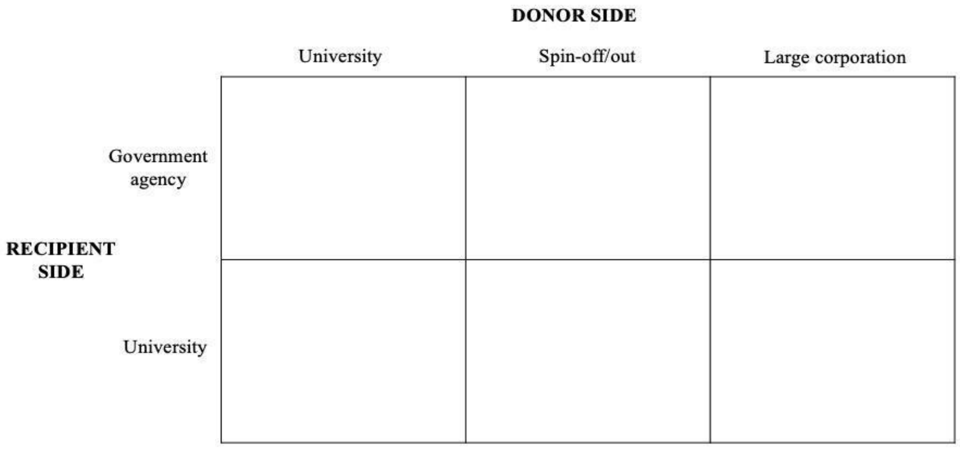

Figure 1-5. Classification matrix of capacity building projects

In addition to this matrix, we classified projects in this study based on our information source, whether we interviewed only one side (either donor or recipient), both sides, or a third party. Depending on the project, it was critical to hear from both sides to conduct a clear evaluation of its impact. Figure 1-6 displays the classification of the projects or entities analysed as part of this report and differentiate with a colour code the source of the data.

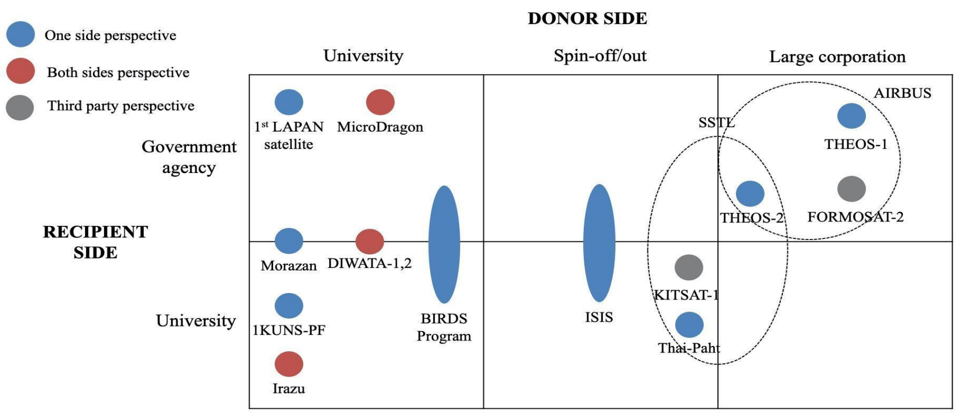

Figure 1-6. Classification of projects analysed in the study

4. Outline of the study

After the current introductory chapter, the study is organised as follows. First two chapters present an overview of space technology development and utilisation capacity building programmes conducted by both Japanese and foreign organisations.

Chapter 2 presents a detailed overview of the current state of university-led space technology development and utilisation capacity building programmes in Japan. Through four core examples, this chapter identifies the different motivations and philosophies of university laboratories providing such services, as well as the role played by different stakeholders: university headquarters, the central government and private contractors.

Chapter 3 then introduces the cases of foreign providers of capacity building services in Europe and Asia and draws lessons from them. One particular feature of foreign capacity building programmes in contrast with Japanese ones is that they tend to be primarily conducted by university spin-off companies rather than by the university laboratories themselves.

These two data-intensive chapters are then followed by three thematic chapters, focussing respectively on the diplomatic role of capacity building programmes, on their educational effectiveness and on the impact of the COVID-19 pandemic on such activities.

Chapter 4 provides a precise analysis of the diplomatic effectiveness of Japanese university-led capacity building programmes. After defining five specific criteria, the chapter lists the concrete diplomatic benefits provided by international capacity building for Japan as a whole and therefore the need for the central government to support such projects.

Chapter 5 evaluates the educational effectiveness of capacity building programmes by looking at the long-term retention of the knowledge transferred to recipient countries and draws good practices to be followed by Japanese providers.

Chapter 6 is a short chapter providing preliminary considerations on the impact of the ongoing COVID-19 pandemic on space technology development and utilisation capacity building activities.

Finally, **Chapter 7** presents all the conclusions of the report and the final policy recommendations of the research team. It starts by outlining the strengths of Japanese university-led capacity building programmes, as well as the benefits for universities to involve in such activities, before providing a fair and transparent assessment of the weaknesses of Japanese programmes. Finally, after deriving needs from those weaknesses, it introduces a series of four policy recommendations to address them.

CHAPTER 2: CURRENT STATE OF UNIVERSITY-LED CAPACITY BUILDING IN JAPAN

Japanese universities have been at the forefront of space technology development and utilisation capacity building in the last five years. From the Kyushu Institute of Technology's (Kyutech) BIRDS programme to The University of Tokyo's Intelligent Space System Laboratory's (ISSL) TRICOM project, numerous initiatives of Japanese universities – public or private, big or small – have helped developing countries to acquire their first satellite, capabilities for satellite operations or geospatial data analysis, a national space development strategy, etc. This chapter presents the current state of university-led capacity building in Japan by focussing on different features: nature of service provided, size and type of universities involved, motivations of professors having initiated the programmes, the roles of the private sector and the central government, etc.

1. Projects analysed in the study

In order to get the most precise understanding of the current landscape of Japanese university-led capacity building, we conducted a thorough evaluation of four programmes and projects:

- The **PHL-Microsat programme**, in which the Philippines obtained two remote sensing microsatellites, DIWATA-1 and 2, with the support of Hokkaido University and Tohoku University.
- The **MicroDragon project**, in which a consortium of five universities – The University of Tokyo, Keio University, Hokkaido University, Tohoku University and Kyutech – provided the Vietnam National Space Centre (VNSC) with a remote sensing microsatellite.
- The **RWASAT-1 project**, during which The University of Tokyo's ISSL helped Rwanda to develop its first satellite and a national space development strategy.
- Last but not least, **Kyutech's BIRDS programme**, which educated five generations of engineers and provided numerous developing countries with their first satellite.

These projects and programmes are further introduced below. The specificities of the projects and programmes are then developed in other sections and chapters when relevant.

Focus 1: PHL-Microsat

PHL-Microsat (pronounced *Phil-Microsat*) was a joint project of the University of the Philippines (UP) Diliman and the Philippines' Department of Science and Technology (DOST) that contributed to the deployment into orbit of two remote sensing microsatellites, DIWATA-1 and 2 and the acquisition of knowledge on satellite design, operations and geospatial data analysis, in collaboration with Hokkaido University and Tohoku University.

The programme was initiated by the Japanese side when Professor Yukihiro Takahashi met DOST Secretary Mario Montejo in 2013 and proposed to him a collaboration in order to support the development of satellite remote sensing capabilities in the Philippines. Then, in 2014, a Filipino delegation visited Hokkaido University. An important aspect of this collaboration is that it was initiated by the mission side, Professor Takahashi being specialised in optical remote sensing and developing cameras in his laboratory. Later, Professor Takahashi reached out to his former colleague Professor Kazuya Yoshida of Tohoku University, to ask for his support for satellite bus development.

The purpose on the Japanese side was primarily to get funding, development and deployment opportunities for Professor Takahashi's satellite remote sensing technologies, and on the Filipino side to build its capacities – in terms of human resources – in space and geospatial engineering and to obtain two advanced satellites for various applications such as monitoring the national territory (precise mapping) and islands (coastal areas), with a focus on disaster prevention and relief (typhoon), agriculture and ocean quality (for fisheries).

The four-year programme was entirely funded by the DOST's Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD), for a total of around USD 10 million. Tohoku University received USD 5 million and Hokkaido University USD 3 million (not including students/scholars' expenses). The programme's outcomes are the following:

- The joint development, in Tohoku University, of two 50 kg microsatellites, DIWATA-1 and 2, equipped with remote sensing instruments (cameras) jointly developed in Hokkaido University. DIWATA-1 was deployed from the International Space Station (ISS) on 27 April 2016 and DIWATA-2 was directly launched in orbit by a H-IIA rocket on 29 October 2018.
- The master's and doctoral studies of more than 20 Filipino students and engineers in Japanese universities from April 2015. Both Hokkaido University and Tohoku University welcomed around 10 students each.
- On the Filipino side, the development of a research infrastructure at UP Diliman and at the DOST's Advance Science and Technology Institute (DOST-ASTI), both in terms of physical infrastructure and organisational structure with thematic research groups.

- Technology (e.g. star sensor, attitude determination and control system) and knowledge transfer.

Focus 2: MicroDragon

The MicroDragon project was part of the long-term satellite development roadmap established by the Vietnam National Satellite Centre (VNSC, now Vietnam National *Space* Centre), shown on Figure 2-1. VNSC is one of the two Vietnamese entities involved in space technology development, along with the Space Technology Institute. Both are under the umbrella of the Vietnam Academy of Science and Technology (VAST).

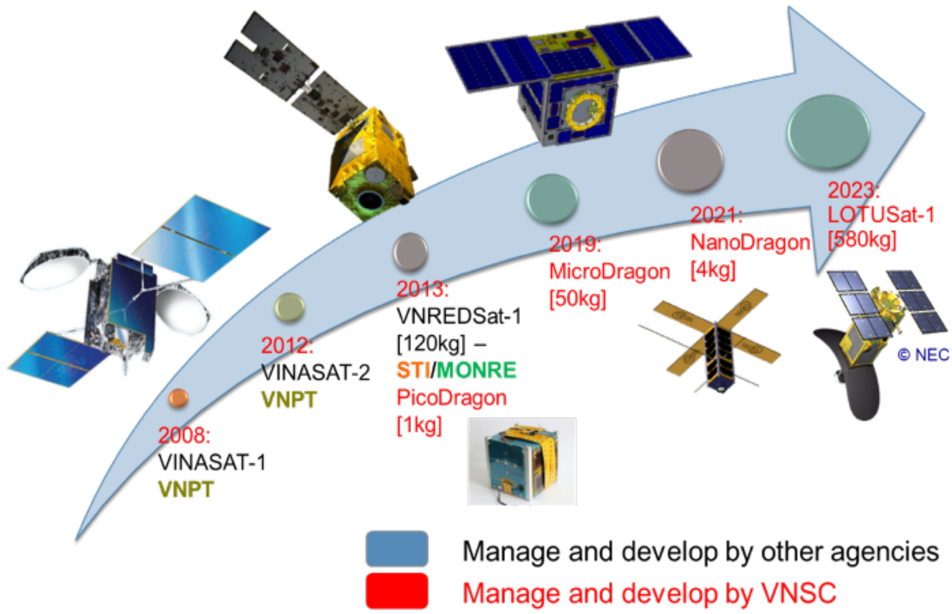

Figure 2-1. VNSC satellite development roadmap. Source: VNSC.

The MicroDragon project was part of a larger initiative of VAST called the Vietnam Space Centre (VSC) project, consisting in three goals: (1) build space technology development and utilisation facilities in Vietnam, (2) transfer satellite technology to Vietnam from advanced space nations and (3) build capacity among Vietnamese engineers.[2] The VSC project is partially funded through an official development assistance (ODA) loan granted by the Japan International Cooperation Agency (JICA) to the VNSC. In order to contribute to the achievement of points (2) and (3), VNSC Director General Pham Anh Tuan and Professor Nakasuka discussed a comprehensive capacity building package including sending VNSC engineers to study in Japanese universities and build a 50 kg remote sensing satellite.

[2] 'Vietnam Space Center Project', Vietnam National Space Center, 12 October 2015, https://vnsc.org.vn/en/projects/vietnam-space-center-project/.

Professor Nakasuka therefore gathered a consortium of five universities, including his university, The University of Tokyo, as well as Keio University, Hokkaido University, Tohoku University and Kyutech. This consortium was administered by a third party, alternatively PADECO Co., Ltd. and UNISEC (cf. Box 1). Thirty-six young engineers were then sent to Japan to follow master's degrees in partner universities and work on the design and development of MicroDragon, a 50 kg remote sensing microsatellite. Contracts were awarded in the form of contract research (委託研究) from VNSC, not collaborative research (共同研究).

After the launch of MicroDragon on 18 January 2019 as secondary payload on a Japanese Epsilon rocket, and after initial operations in Japan, the VNSC engineers returned to Vietnam to work on the LOTUSat radar satellite, developed in collaboration with Japanese satellite manufacturer NEC and final iteration of the national satellite roadmap.

The various participants of this project had different purposes. While VNSC was primarily motivated by education and human resources development, the Japanese universities involved were pursuing different goals: contributing to space education beyond Japanese borders, benefitting from the opportunity to join an ambitious project and receiving associated budgets, or supporting Japanese foreign policy goals in Vietnam. Although it seems that the participants benefitted from the project as a whole, issues arose from the handling of the consortium of five large universities. According to some professors involved in the project, it would have been preferable to work with less universities, or at least clarify from the start the exact repartition of responsibilities and authority. In particular, the centralisation in Tokyo, at Keio University and The University of Tokyo, of the latest phase of the project (satellite final integration and testing) was received negatively by partners in Hokkaido and Tohoku Universities.

Nevertheless, the MicroDragon project has achieved all its capacity building goals, such as:

- The design, development, integration and testing of a 50 kg remote sensing satellite by Vietnamese engineers.
- The successful operations of the satellite by Vietnamese engineers.
- The obtention of advanced knowledge and master's degrees by 36 Vietnamese engineers, now forming the backbone of VNSC's satellite development efforts (e.g. LOTUSat with NEC).

Box 1 – The University Space Engineering Consortium (UNISEC)

UNISEC is a non-profit organisation established in 2002 in Tokyo, Japan to "to support practical space development activities in universities and colleges, such as small satellites and hybrid rockets." It boasts a membership of 58 Japanese universities including all those cited in this report.[3]

UNISEC also established in 2013 an international NPO, called UNISEC-Global, composed of 21 local chapters and 70 points of contact, on all continents. As explained on its website, "UNISEC-Global's primary objective is to help create a world where space science and technology is used by individuals and institutions in every country, rich or poor, and offers opportunities across the whole structure of society - whether academic, industrial or educational - for peaceful purposes and for the benefit of humankind." Since 2017, UNISEC-Global is a Permanent Observer to the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS).[4]

Focus 3: RWASAT-1[5]

RWASAT-1 is a joint project of the Intelligence Space Systems Laboratory (ISSL) of The University of Tokyo through start-up Space Edge Lab. Inc. (now ArkEdge Space Inc.), of the Rwanda Utilities Regulatory Authority (RURA), and later on, of the Rwanda Space Agency (RSA), which involved the joint development and deployment of Rwanda's first satellite, RWASAT-1, as well as numerous forms of capacity building.

Following initial discussions between the governments of Rwanda and Japan in 2017-2018 with regards to capacity building in space technology development and utilisation, RURA expressed their desire to fund the development of Rwanda's first satellite and the training in Japan of selected Rwandan engineers. The ISSL having developed around the same time an innovative 3U store-and-forward (S&F)

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[3] 'What is UNISEC?', UNISEC 大学宇宙工学コンソーシアム, accessed 28 December 2020, http://unisec.jp/unisecen/abouten.html.
[4] 'About Us', UNISEC Global, accessed 28 December 2020, http://www.unisec-global.org/.
[5] Quentin Verspieren, one of the authors of this report, was manager of the RWASAT programme (including the RWASAT-1 project) at the Intelligent Space Systems Laboratory of The University of Tokyo and is an executive at Space Edge Lab. Inc. (now ArkEdge Space Inc.). A detailed description of the RWASAT-1 project is provided in: Quentin Verspieren et al., 'Store-and-Forward 3U CubeSat Project TRICOM and Its Utilization for Development and Education: The Cases of TRICOM-1R and JPRWASAT', *Transactions of the Japan Society for Aeronautical and Space Sciences* 63, no. 5 (2020): 206–11, https://doi.org/10.2322/tjsass.63.206.

communication satellite, called TRICOM, it was therefore decided to use it as the basis of RWASAT-1. In addition to the S&F communication system, RWASAT-1 was equipped with a multispectral camera, as decided during a mission idea contest held with Rwandan students in early 2018.

The satellite was developed from December 2018 to May 2019 by a joint Rwanda-Japan team at the facilities of the ISSL in Tokyo, as well as with industrial partners in Fukui Prefecture. It was then launched to the ISS onboard Japanese resupply vessel HTV-8 on 4 June 2019 before being deployed from the Kibo module on 20 November 2019. The project was mostly funded by RURA, although the initial technology development and diverse activities were supported by the Japanese government (e.g. Ministry of Economy, Trade and Industry, METI) and by Space Edge Lab.

In addition to the development and deployment of RWASAT-1, the outcomes of the project were:

- The training of three Rwandan engineers in Japan, who jointly developed the satellite with Japanese engineers of the ISSL.
- The organisation of diverse capacity building programmes in Kigali, Rwanda on nanosatellite design, remote sensing data utilisation and supercomputing.
- Joint satellite operations.
- Support for the development of a national space strategy, policy and law.
- Technology (e.g. bus system and S&F communication system) and knowledge transfer.

Focus 4: Kyutech's BIRDS

The Joint Global Multi-Nation Birds Satellite programme (colloquially known as BIRDS programme) is an initiative of the Kyushu Institute of Technology consisting in a series of two-year projects in which teams of three to four students (minimum two) design, assemble, test and operate a 1U CubeSat. Each team is related to a specific country. Table 2-1 shows the list of countries and number of students involved in the five generations of BIRDS projects organised by Kyutech.

Building on the *Space Engineering International Course* (SEIC) started by Kyutech in 2013, the initial BIRDS-1 Project was initiated in October 2015. The idea originated from a dinner between Kyutech faculty members and the president of the All Nations University in Ghana, who expressed his willingness to celebrate the 60th anniversary of the independence of Ghana with the deployment in space of the country's first CubeSat. After finding three students from Mongolia and three students from Bangladesh, BIRDS-1 was born. The BIRDS project started for purely educational purposes with the minimum possible cost: USD 120,000. The cost was later adjusted, from BIRDS 3, to USD 150,000. This money covers the cost of satellite hardware and its launch to the ISS.

Table 2-1. Five generations of BIRDS projects

Generation	Countries	Total number of students
BIRDS-1 (2015-2017)	Japan, Ghana, Mongolia, Nigeria and Bangladesh	15
BIRDS-2 (2017-2018)	Bhutan, the Philippines, and Malaysia	11
BIRDS-3 (2018-2019)	Sri Lanka, Nepal and Japan	7
BIRDS-4 (2019-2021)	Paraguay, the Philippines and Japan	14
BIRDS-5 (2020-2021)	Uganda, Zimbabwe and Japan	14

While BIRDS-1 counterparts were only universities, subsequent BIRDS projects included both universities and government agencies (e.g., Bhutan's Ministry of Information and Communications, Nepal's Academy of Science and Technology). Kyutech faculty members stressed the importance of international travels, international conferences (even in Japan) to initiate direct personal contacts with prospective recipients. They gave the example of the Seventh Tokyo International Conference on African Development (TICAD7), where Professors Cho and Maeda met high-level representatives from Uganda and Zimbabwe, now part of BIRDS-5. This was severely impacted by the COVID-19 pandemic as described in Chapter 6.

BIRDS-5 is currently expected to be the last iteration of the BIRDS programme under its current format. However, BIRDS is expected to continue by supporting past recipients for the domestic development of their second satellite and, more generally to ensure the long-term sustainability of their nascent domestic space programme.

Finally, thanks in large part to the BIRDS programme, Kyutech has been identified by space consulting company *Bryce Space and Technology* as the No. 1 academic operator of small satellites.[6] As of 2020, Kyutech had launched 18 small satellites into space – more than any other university.

[6] 'Smallsats by the Numbers 2020' (Alexandria, Virginia: Bryce Space and Technology, 2020), https://brycetech.com/reports/report-documents/Bryce_Smallsats_2020.pdf.

2. Different motivations and philosophies

Based on the four projects and programmes studied, we identified three main motivations from the points of view of Japanese universities.

2.1. Search for additional sources of funding and project opportunities

For numerous Japanese university laboratories working on innovative satellite components, it is critical to secure collaborations in order to, either get the necessary funding to develop a prototype, or benefit from an actual satellite launch to see their device tested in space.

As explained above, Professor Takahashi of Hokkaido University did not passively wait for an occasion to appear but created his own opportunity to send his satellite remote sensing components to space, in collaboration with his former Tohoku University colleague Professor Yoshida. He therefore obtained considerable budgets (around USD 3 million for the DIWATA programme) without which he could not have been able to achieve his laboratory's goals.

In addition to components and satellite development, Professor Yoshida mentioned the importance of external projects and associated budgets (around USD 5 million for the DIWATA programme) in order to hire new researchers as well as retain young scholars after the completion of their studies. Nevertheless, Professor Yoshida explained that he did not joined the DIWATA programme because he needed budget. He was however looking for project opportunities when Professor Nakasuka proposed to him to join the MicroDragon project.

Finally, to a lesser extent, RWASAT-1 was useful in further spreading an S&F communication technology developed at the ISSL during a previous project: TRICOM.

2.2. Involvement in international projects aligning with Japanese foreign policy goals

Professor Seiko Shirasaka of Keio University, one of the leaders of the MicroDragon project, explained to us that a collaboration between two countries or two governments, is more successful when built on existing "people-based" cooperation. In this context, he believes that educational collaborations, carried out by universities, are the most effective ways to build the foundations of long-term bilateral cooperation. He added that, as member of the National Space Policy Committee, he has to think about how, personally or through his work at the university, he can contribute to Japanese foreign policy objectives. In fact, the MicroDragon project was initiated by Professor Nakasuka, also member of the National Space Policy Committee, as part of a larger support of Japan to the Vietnam Space Centre project via JICA ODA.

The RWASAT project also originated from a larger government-to-government partnership. In fact, RWASAT is one of the numerous initiatives having been implemented by the Government of Japan to support the socio-economic development of Rwanda in recent years, seeing it as a key partner in Africa. For this project too, JICA has provided support, although much more punctual and modest than for MicroDragon.

These two examples raise the question of whether the government should provide more guidance or recommendations to universities on international partnerships. Interviewees from Keio University, The University of Tokyo and Kyutech have all expressed their desire to see the government – particularly the Cabinet Office's National Space Policy Secretariat – to identify potential partner countries. While universities are fully autonomous and it is up to professors to decide who they would like to partner with, Professor Shirasaka pointed out that only the central government has the knowledge, ability and workforce to see the "bigger picture", and to evaluate and classify potential partner countries based on numerous factors, including both the situation and needs of such countries as well as potential diplomatic benefits for Japan.

2.3. Primary focus on education

While the two previous motivations may have played a role, Kyutech's BIRDS programme was established with a strong focus on advancing space technology education worldwide. Compared to the other projects studied here, BIRDS is the only one in which the development and deployment of a satellite is a means, not the final goal. In fact, the choice to develop a 1U satellite is revealing. While applications of such a small satellite are extremely limited, the learning potential from its development is immense. In addition, the BIRDS programme has efficiently 'industrialised' the approach to capacity building, being able to accommodate a large number of teams while not having to sacrifice the quality of the education.

Other projects successfully managed to balance between advanced education and mission objectives, in other words between leaner or more complex satellites. The DIWATA programme chose to develop two 50-60 kg satellites, big enough to accommodate advanced payloads such as the remote sensing equipment developed at Hokkaido University. The complexity of a 50 kg system however makes satellite design and development education a bit less accessible than with a CubeSat. The RWASAT-1 project had a symmetrically different approach by focussing on a lean and accessible 3U CubeSat accommodating an S&F communication system but much more modest remote sensing equipment.

2.4. Correlation between motivation categories and universities/professors' characteristics

While the three main motivations presented above can be found in each of the projects studied in this report, in particular their emphasis on education – universities' primary mission, each carries more or less weight depending on universities and professors.

In particular, there is a clear distinction between The University of Tokyo and Keio University on the one hand and Hokkaido University – and Tohoku University to a lesser extent – on the other hand, with regards to the relations with the central government. During our interviews, it appeared that funding and project opportunities were not the sources of too much concern for the two academic mastodons that are The University of Tokyo and Keio University, which instead tend to focus on non-pecuniary benefits such as contributing to Japanese influence abroad, much in line with the key roles played by both Professor Shirasaka and Professor Nakasuka at the National Space Policy Committee. These views contrast heavily with those shared by Professor Takahashi of Hokkaido University, who believes that too much involvement of the central government can prove overwhelming in the context of international academic collaboration. According to his experience, in particular with the Philippines, counterparts in developing countries enjoy the simplicity of dealing with independent laboratories in Japanese universities rather than having to spend time and efforts in complex bilateral diplomatic processes involving Japan's heavy governmental bureaucracy.

As often mentioned in this report, Kyutech seems to offer the most balanced approach, carrying out its affordable programme with a great level of self-sufficiency while being in close contact with the Japanese government. In fact, during our visit of Kyutech's Tobata campus, Professors Cho and Maeda, architects of BIRDS, shared with us their desire to see the government providing a certain level of support, in line with Professor Shirasaka's comments quoted in 2.2. Although they do not advocate for a direct control or role of the government in capacity building programmes, they suggest the following form of support:

- The Cabinet Office should identify target countries and suggest a high-level governmental strategy on space collaborations with developing countries.
- The MEXT, as ministry responsible for higher education, should officially recognise the role of universities for the promotion of Japanese foreign policy, and support the internationalisation of universities. To this end, it could start by publicly recognising the capacity building projects presented in this report as significant achievements and help advertise them in the national press.
- The Ministry of Foreign Affairs (MOFA) should be more active in supporting the initiation of capacity building projects, in particular through its embassies. JICA's involvement could be beneficial, although it could send the wrong signal that the Japanese government would pay for the project.

3. The roles of university headquarters

All the projects studied in this report were initiated in full independence by professors and their laboratories but have received some form of support from university headquarters.

3.1. Independent decisions of university laboratories

While the projects studied in this report are described in terms of which university they involve, they were in fact initiated and fully carried out by independent laboratories, and the public or commercial partners that they chose – except for the BIRDS programme which scale prompted more involvement from Kyutech's headquarters. These laboratories are:

- The **Intelligence Space Systems Laboratory** (ISSL), led by Professor Shinichi Nakasuka, known in Japanese as Nakasuka-Funase Laboratory (中須賀・船瀬研究室), belonging to the Department of Aeronautics and Astronautics, Graduate School of Engineering, The University of Tokyo. Apart from independently conducting the RWASAT-1 project, it was involved in the MicroDragon project.
- The **System Design Methodology Laboratory** (システムデザインメソドロジーラボ), led by Professor Seiko Shirasaka, which belongs to the System Design and Management Research Institute, Graduate School of System Design and Management, Keio University. It was involved in the MicroDragon project.
- The **Space Exploration Lab** (宇宙ロボット研究室), led by Professor Kazuya Yoshida, belonging to the Department of Aerospace Engineering, Graduate School of Engineering, Tohoku University. It involved in the MicroDragon and PHL-Microsat projects.
- The **Space Mission Center** (宇宙ミッションセンター), led by Professor Yukihiro Takahashi, belonging to the Department of Earth and Planetary Sciences, School of Science, Hokkaido University. It was involved in the MicroDragon and PHL-Microsat projects.
- The **Laboratory of Lean Satellite Enterprises and In-Orbit Experiments** (LaSEINE, 革新的宇宙利用実証ラボラトリー), led by Professor Mengu Cho, belonging to the Department of Space Systems Engineering, School of Engineering, Kyushu Institute of Technology. Apart from independently conducting the BIRDS programme, it was involved in the MicroDragon and PHL-Microsat projects.

These laboratories can independently decide to involve in a project. For example, in the case of RWASAT-1, the project's agreement had four contracting parties: the RURA, represented by its director general, Space Edge Lab., represented by its CEO and two laboratories of The University of Tokyo, including the ISSL, represented by its director, Professor Nakasuka. Contracting this agreement required the sole signature of Professor Nakasuka and no official involvement of the department, graduate school or university headquarters.

3.2. The role of university headquarters (本部)

For what concerns the four projects studied here, university headquarters have been providing different forms of support, described below. This part does not include obvious contributions of universities, such as the provision of facilities or the remuneration of tenured faculty and permanent administrative staffs.

3.2.1. Space and university strategies

The importance of space technology development and utilisation varies from one university to the other. Although it is one department among many others in some of the largest domestic universities like The University of Tokyo, Tohoku University or Keio University, other universities have given a central role to space studies.

For instance, Kyutech's strategy and promotional documents put a strong emphasis on space engineering and robotics. Similarly, Hokkaido University headquarters have recognised space as one of the "main streams" of the university's educational and research activities.

3.2.2. Administrative support

Although they possess a deep technical expertise on their field, most of Japanese universities do not have the knowledge and manpower to deal with the legal, administrative and budgetary complexity of international cooperation programmes. To this end, university headquarters have been providing the following services:

- Legal consulting services during contract drafting and negotiation.
- Promotion of research achievements in different platforms (e.g. university website and social network accounts, local or national press) and in multiple languages by bearing translation costs. This also includes paying the salaries and expenses of employees devoted to the international promotion of the capacity building programmes (e.g. Professor George Maeda in Kyutech).
- Support the filing of patents.
- Handling of the organisation of visits of high-level foreign officials at the university (e.g. DOST Secretary de la Peña in Hokkaido University or numerous ambassadors in Kyutech).

3.2.3. Support to foreign students and trainees

Universities welcoming foreign students and trainees often provide support to facilitate their acclimatation into Japanese society. In the case of the MicroDragon project, Keio University headquarters provided the students with accommodations on Mita campus. In addition, most of universities have free Japanese language programs run by the headquarters.

4. The role of the central government

Overall, the central government plays a limited role in the initiation or the implementation of the projects, which often originate from the personal relationships of Japanese professors with foreign officials or academics.

4.1. Research and project funding

This section provides an overview of the different forms of funding support provided by various government agencies.

4.1.1. Ministry of Education, Culture, Sports, Science and Technology (MEXT)

The MEXT is the core organisation dealing with early technological research support, as well as infrastructure and personnel development, on which capacity building programmes are based.

First of all, most of the functioning budget of Japanese universities comes from the MEXT: facilities rental, faculty and researchers' salaries, equipment cost, etc. In addition to the annual guaranteed budget, there are numerous forms of project-based funding provided by the MEXT. In particular, most of the technologies involved in the projects studied in this report have been developed, at least partially, through Grants-in-Aid for Scientific Research (*kakenhi*) of the MEXT's Japan Society for the Promotion of Science (JSPS).

Finally, in the case of Kyutech, the MEXT has been providing funding (委託金) to (1) solidify and expand LaSEINE's satellite testing facilities, which are being used by numerous small satellite makers from Japan and abroad (USD 2-300,000 per year over 2014-2016) and (2) support the internationalisation of Kyutech satellite engineering education efforts (2017-2019). Finally, the JSPS has been providing around USD 100,000 per year for the organisation of annual international BIRDS workshops and other workshops used by Kyutech to continue developing knowledge among its network of current, past and future BIRDS participating countries.

4.1.2. Ministry of Economy, Trade and Industry (METI)

The METI has been providing two forms of financial support to some of the Japanese university-led capacity building projects reviewed in this report:

- The financing of innovative technologies via the New Energy and Industrial Technology Development Organization (NEDO), for instance for RWASAT-1's store-and-forward communication system.
- The support to the development of international standards for space technology. In particular, Kyutech is receiving a multiyear support to establish a worldwide community and organise workshops in order to set up the best standards for "lean satellites".

4.1.3. Japan International Cooperation Agency (JICA)

In the case of development collaborations with developing countries, ODA provided by JICA can play a core role in the projects' funding and overall success. Among the four projects studied here, JICA has been providing the following types of support:

- *Sovereign lending to the recipient country* to fund the whole capacity building programme in the case of MicroDragon.
- *Grant funding for projects* related to the development of innovative space data products, for example as part of the *Science and Technology Research Partnership for Sustainable Development* (SATREPS) in the case of Hokkaido University, using data from DIWATA-1/2.
- Scholarships, for instance as part of the African Business Education Initiative for Youth (ABE Initiative).
- Technical training in Japanese universities like the one received by Malaysian engineers in Kyutech.
- Technical assistance missions, for instance regarding the deployment of ground sensors or the drafting of a national space policy during the RWASAT-1 project.

4.2. Satellite deployment from the Kibo module of the International Space Station

Apart from the excellence and international inclination of its universities, one of the greatest strengths of Japanese space technology development and utilisation capacity building is the launch and deployment opportunities provided by the Japanese Aerospace Exploration Agency (JAXA) to selected universities.

As part of its activities for the promotion of the Japanese Experimental Module (JEM) ("Kibo") of the ISS, JAXA has established a Strategic Partnership programme with selected universities. Three strategic partners were selected based on their past expertise on microsatellite development: The University of Tokyo, Kyutech and the couple Hokkaido and Tohoku Universities. Having positioned the Kibo module as a technological development research base that supports scientific and technological innovation, JAXA created a standardised system for the deployment of microsatellites from Kibo, called the JEM Small Satellite Orbital Deployer (J-

SSOD). Through the Strategic Partnership, JAXA aimed to promote (1) Japanese university-led capacity building programmes with foreign organisations in order to sustain the worldwide demand for satellite release from Kibo and (2) to get feedback from the user side (universities) on the process and service of ISS deployment.

Concretely, under the umbrella of this Strategic Partnership, selected universities can contract Kibo deployment services at a discounted price, compared to the price charged by private companies operating Kibo deployments. The partnership expires at the end of FY2020 in March 2021, and the only way to deploy a satellite from the J-SSOD, even for Japanese universities, will be to contract one of the two commercial providers selected by JAXA: Space BD and Mitsui Bussan Aerospace. Considerations on the consequences of the expiration of the programme are presented in Chapter 7, section 3.2.2.

In addition to the discounted rates provided to Japanese universities, JAXA developed a partnership with the United Nations Office of Outer Space Affairs (UNOOSA) to organise a competition which prize is the complimentary deployment of a 1U CubeSat from the J-SSOD for an emerging space nation.[7]

4.3. Other forms of support

4.3.1. Strategy and diplomacy

As explained throughout section 2, although some universities tend to be wary of too much government involvement, most agree that a certain level of support should be provided, including for strategy and diplomacy.

The Cabinet Office has been providing a basic form of coordination with developing countries' governments and has contributed to the inclusion of the promotion of space technology development and utilisation capacity building in the programme of important international events such as the 7th Tokyo International Conference on African Development (TICAD7), during which numerous space actors connected with African leaders. For instance, Professors Cho and Maeda initiated first contacts with two of BIRDS-5's member countries – Uganda and Zimbabwe – during TICAD7.

As for "diplomatic" support, a few of the projects reviewed in this report have received some form of help from local Japanese embassies. The Japanese embassy in Manila provided advice but no concrete support for the initiation of the DIWATA cooperation. The On the other hand, the embassy of Japan in Rwanda has been very active in organising promotional events (receptions and press conferences) as well as high-level dinners with relevant officials (including

[7] 'KiboCUBE: UN / Japan Cooperation Programme on CubeSat Deployment from the International Space Station (ISS) Japanese Experiment Module (Kibo) "KiboCUBE"', United Nations Office for Outer Space Affairs, accessed 19 February 2021, https://www.unoosa.org/oosa/en/ourwork/psa/hsti/kibocube.html.

ministers), in part because RWASAT-1 was included in a larger scale bilateral cooperation. Finally, the role of embassies is sometimes more circumstantial: having heard about the BIRDS programme, the Government of Bhutan first contacted the Japanese embassy in Thimphu, which then connected it with Kyutech officials.

4.3.2. Export licences

The METI is the Japanese ministry in charge of export controls and as such, provides export licenses for space-related technologies, in accordance with the Foreign Exchange and Foreign Trade Act of 1949. In the case of the capacity building projects studied in this report, METI Trade Control Department officials have been providing useful support to universities regarding the complex administrative process involved. The METI has also been providing trainings in order to ensure that universities set up their own "security export control" policies.[8]

4.3.3. Frequency coordination

The Ministry of Internal Affairs and Communication (MIC) has supported frequency licensing and registration for most of the projects evaluated in this report (e.g. RWASAT-1, BIRDS).

4.3.4. Access to infrastructure

The final form of support provided to university laboratories by the central government concerns the access to advanced facilities, mostly for satellite operations and experiments.

The VNSC having issues/delays with the establishment of a satellite ground station to conduct MicroDragon's operations from Vietnam, a team of Vietnamese operators staying in Japan has been allowed to use (for a fee) the ground stations of the Institute of Space and Astronautical Science (ISAS), the space exploration arm of JAXA.

Similarly, the National Institute of Information and Communications Technology (NICT) of the MIC has been providing experimental equipment and facilities for the laser communication experiments of Tohoku University. The University of Tokyo has also benefited from similar facilities for other projects not addressed in this report.

[8] 'METI Launches E-Learning Program in Academic and Research Institutes in the Field of Security Export Control', Ministry of Economy, Trade and Industry, 29 May 2018, https://www.meti.go.jp/english/press/2018/0529_003.html.

5. Interactions of universities with the private ecosystem

The degree of interaction of university laboratories with private actors varies heavily from one project to the other, with some having a high level of vertical integration allowing them to develop, assemble and test satellites in-house (e.g. Kyutech) and those for which the university has partnered with a private company for the daily management of the project (e.g. RWASAT-1). A few examples are provided below.

The BIRDS programme is mostly dealt with internally, Kyutech having the capabilities and infrastructure to cover with all aspects of satellite development and capacity building. In fact, while other Japanese university-led projects presented in this report are not the core activities of laboratories involved, BIRDS has been an integral part of Kyutech's Laboratory of Lean Satellite Enterprises and In-Orbit Experiments (LaSEINE). Therefore, Kyutech's staffs and facilities are primarily devoted to the design, assembly and testing of the BIRDS CubeSats. Kyutech however works with private providers for specific components and services (e.g. Saga Mitsuishin for printed circuit boards, Addnics for communication components).

In the case of the two DIWATA satellites, their high-performance remote sensing cameras have been built by a private provider in close collaboration with the laboratory of Professor Takahashi in Hokkaido University. Specifically, while the early design of the camera was made at Hokkaido University, the detailed design and manufacturing were done by a small private company. Tohoku University has also been relying on Japanese manufacturers for the bus hardware development and procurement.

Finally, the case of RWASAT-1 is the only one managed by a private company, namely Space Edge Lab. While the project counted on the great expertise acquired by The University of Tokyo's ISSL, the primary Japanese contractor was Space Edge Lab., a spin-off of the ISSL, which dealt with the project from the beginning to the end.

CHAPTER 3. COMPARISON WITH OTHER DONORS AROUND THE WORLD

Although Japan seems to be the most active country in terms of university-led space technology development and utilisation capacity building with developing countries, other countries have also witnessed the development of such activities in their universities, under various formats. In fact, some foreign universities involving in small satellite-based education have progressively offloaded capacity building responsibilities to a commercial arm, often a spin-off company, which has allowed an increase of efficiency and scale. By comparing foreign practices to Japanese ones, we identify the comparative advantages of Japan as well as areas for improvement.

1. Overview of non-Japanese donor organisations analysed in the study

As part of this project, we investigated the case of four donor organisations, one being a university operating capacity building programmes similar with Japanese universities' (the University of Rome La Sapienza), while the three others are university spin-offs (Surrey Space Technology Ltd, ISISPACE and the Satrec Initiative).

Box 2 – University spin-off

The field of business administration includes various terms with more or less agreed-upon definitions such as *spin-off*, *spin-out*, *split-off* and *carve-out*, which may correspond to some of the cases addressed in this report.

In this report, we use the term *university spin-off* to describe any commercial venture created by former employees of a university laboratory, in a very general sense. It encompasses various formats such as ventures fully or partially owned by their mother-university (e.g. SSTL before 2008) as well as ventures which are financially independent but having kept close ties from their mother-university (e.g. SSTL from 2008) or not (e.g. ISIS).

Focus 1: University of Rome La Sapienza[9]

The University of Rome La Sapienza, founded in 1303, is one of the leading Italian research universities. Its prestigious faculty of engineering as had a long involvement in aeronautics and astronautics, including through the creation of the first aerospace research centre (*Centro di Ricerche Aerospaziali*) in Italy in 1959, strengthened by strong ties with the Italian Air Force. In fact, until the 1970s, the Italian law was allowing high-ranking generals to be university professors. For example, the father of the Italian space programme, Air Force General Luigi Broglio, head of the AF Engineering Corps (*Corpo del Genio Aeronautico*) was also the Dean of La Sapienza faculty of engineering. At the time, laboratories were shared between the air force and universities. Nowadays, La Sapienza can still receive grants from the military, but it is highly controlled by a department committee.

Thanks to its expertise in aerospace engineering and its close governmental connections, La Sapienza played a core role in an ambitious and long-term space technology development and utilisation programme organised by Italy for the benefit of Kenya. Soon after its independence from the United Kingdom, Kenya concluded a top-level bilateral cooperation agreement with Italy, ratified by both parliaments in 1963. This agreement included from the start elements of astronautical research.

As early as 1963, La Sapienza created and operated, in cooperation with NASA, the San Marco Equatorial Range in Malindi, Kenya, renamed in 2004 Luigi Broglio Space Centre (BSC) in honour of the late General Broglio and transferred to the Italian Space Agency (ASI). However, La Sapienza still retains telemetry and communication capabilities (three 2-meter antennas). At the same time, ASI took over Italian responsibilities with regards to space engineer research and education collaboration with Kenya. However, recognising its historical experience, ASI continues to officially delegate the provision of capacity building services to La Sapienza.

In fact, satellite development capacity building being included in the intergovernmental agreement, La Sapienza proposed to ASI a CubeSat project with the University of Nairobi, largest public institution in Kenya. This 1U CubeSat project, named 1KUNS-PF (1st Kenyan University NanoSatellite-Precursor Flight) resulted in the joint development of the first Kenyan-owned satellite, with all decisions being made by a joint committee of Italian and Kenyan professors. The project was then selected for the KiboCUBE programme (cf. Chapter 1, section 4.2 for more details), of which Kenya was the first beneficiary, which provided a good launch opportunity and a fixed timeline (very useful). 1KUNS-PF was deployed into

[9] Professor Hideaki Shiroyama and Dr Quentin Verspieren visited the University of Rome La Sapienza's Department of Engineering in Rome, Italy, in June 2019 and collected the information presented in this section.

space on 11 May 2018 from the Kibo module of the ISS by Japanese astronaut Norishige Kanai.

Professor Fabio Santoni, project leader, described the project as a mutual capacity building program, for both Kenya and Italy. Students exchanges happened on both sides, with 18 Kenyans studying in Rome over three years (4+8+6) and seven Italians going to Nairobi. Finally, in addition to teaching students, La Sapienza decided to focus on training Kenyan professors, in order to make sure that the knowledge would be retained at the University of Nairobi, and further spread over future generations of Kenyan engineers.

Key lessons learned from the case of the University of Rome, and directly applicable to the cases of large Japanese universities, are the following:

- University functions as agent (service provider) operating under a top-level bilateral government cooperation agreement.
- Collaboration with foreign government agencies (NASA, JAXA, etc.) is crucial.
- Training recipient country's professors to ensure that local universities retain knowledge.
- Involving recipient country's professors in decision-making to increase ownership.
- Exchanging students on both sides (but difficult to convince Roman students).
- Need to foster job opportunities for students in the recipient country/region (if not, they will leave the country or change their professional focus).

Focus 2: Surrey Space Technology Ltd. (SSTL)[10]

When Sir Martin Sweeting (SSTL founder) was PhD student and then research assistant at the University of Surrey's (UoS) electrical engineering department, he was tracking down amateur communication satellites. He decided to start a satellite programme, which was the first non-US university satellite with a free NASA launch. It benefitted from lots of small contributions from many companies. Around this time, the first microprocessors and memory components became available. Sweeting's satellite was the first microsatellite with a microprocessor and memory ("first modern microsatellite"), which facilitated worldwide data collection data.

The UoS was interested in the first two satellites but felt "forced" to do a third one. Therefore, in 1985, at the time of the second satellite, the UoS pushed Sweeting to create a spin-off company to make satellites with COTS technologies. SSTL was born, with initial investments from both the UoS and Sweeting himself. On the same year, the UoS started a space study programme.

SSTL quickly reached the same turnover as the UoS, but like for most aerospace companies, with irregular – though always positive – benefits. This variable cash

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[10] Professor Hideaki Shiroyama and Dr Quentin Verspieren visited SSTL headquarters in the United Kingdom in June 2019 and collected the information presented in this section.

inflow created issues with the UoS's charitable status. It therefore decided to sell SSTL and finally chose Airbus in 2008, among seven proposals. The shares were initially owned at 99% by Airbus and 1% by the UoS. Airbus now has full ownership of the company. A benefit for SSTL to be part of Airbus Group is the ability to rely on Airbus's "parental guarantee" for big projects – over USD 100 million, which were impossible with the UoS.

Even after the sale, SSTL maintains strong links with the UoS: Sweeting is executive chairman of both SSTL and the Surrey Space Centre (SSC), the UoS's space engineering department is partially funded by SSTL and Airbus, SSTL sponsors a professorship (head of the SSC), keeps a liaison officer at SSC and conducts joint research meetings. SSTL can therefore get intellectual property from UoS research. The SSC is currently the largest non-US postgraduate space research centre with 4 faculty members, a few research assistants and 70-80 postgraduate students.

As of the researchers' visit in June 2019, SSTL had 400 employees, launched 67 satellites (including 15 in commercial use), and 9 constellations. It is vertically integrated so everything can be done in-house. It also owns all its satellites' intellectual property so it can license its satellites/parts. SSTL has mostly two kinds of customers: (1) commercial actors purchasing a turnkey satellite and (2) actors wanting to learn everything about spacecraft studies, targets of the Know How Transfer and Training (KHTT) programmes. Other commercial activities of SSTL (e.g. satellite leasing, data sales, technology demonstration, etc.) are not addressed here.

SSTL's KHTT programmes cover all aspects of a space development programme. Usually targeting groups of 10 to 20 trainees, so project and subsystems responsibilities can be shared appropriately among them, KHTT programmes also include soft skills (e.g. project management), very important for the long-term sustainability of the recipient's future activities. SSTL can house 2 to 3 teams at a time. KHTT programme participations are sometime part of joint bids with Airbus (e.g. Thailand and Kazakhstan). In addition, KHTT programmes are linked with the SSC for degrees and trainings. The programmes are almost always funded by recipient countries, with two exceptions: (1) the UK Export Finance (UKEF) supported Turkey's BILSAT-1 training programme and (2) the UoS received money through UK Space Agency International Partnership Programme (UKSA IPP) to support Algerian satellite AlSAT-1b.

In terms of governmental support, SSTL tried to use UKSA IPP funding but it proved too complex. Moreover, IPP only funds 50% of the total cost of the project which is not adapted to hardware companies with important initial investments. The IPP is better suited to service companies with smaller costs (e.g. remote sensing data products). SSTL received small government support at its beginnings (a few £100k grants). It still does not get much support as SSTL is focussing on a commercial approach.

Key lessons learned from the SSTL case are the following:

- The status of private entity allows full vertical integration, intellectual property licensing and flexible response to customers' demands.
- Joint bidding scheme with Airbus is replicable with large Japanese companies
- Series of trainings should be planned, not a one-shot event.
- Teams of 10 to 20 trainees are optimal for small satellite capacity building projects.
- Training should include soft skills (in particular project management).
- The success of satellite projects is contingent on a good balance among the interests, needs and capabilities of academia, industry and the government.

Focus 3: ISIS - Innovative Solutions In Space (ISISPACE)[11]

ISISPACE was established in 2006 as a privately-owned spin-off of the Technical University of Delft (TU Delft) after student satellite project Delfi-C3. It focusses on the design and manufacturing of CubeSats, ranging from 1 to 16U (1-25 kg). ISISPACE is vertically integrated, including launch services, deployers and ground stations. It has working agreements with most of the major launchers in the world (Soyuz, Falcon 9, Vega, Dnepr, Long March, PSLV) and even signed a memorandum of understanding with Japanese commercial company SpaceBD for Kibo deployment services.

As of 28 June 2019, when we visited ISISPACE headquarters in Delft, The Netherlands, the company was responsible for 315 CubeSat launches (one third of all historical CubeSat launches), including 101 on a single PSLV (world record).

ISISPACE provides capacity building and knowledge transfer services on a purely commercial approach, at three levels:

1. Provide simple toolkits for power, communication, onboard computing, etc. (e.g. can emulate a full RF chain).
2. Platform development kit: integrated platform with various subsystems, including more high-end product for larger institutions.
3. Platform and turnkey satellites (1U S&F and 3U Remote Sensing): full satellite kit, usually for rich universities or state institutions.

Capacity building programmes conducted by ISISPACE include various training modules for design, assembly, integration and testing (AIT), and operations (including theoretical lectures, workshops and hands-on trainings) with numerous countries: Jordan, Thailand, UAE, Algeria and Brazil. Programmes are and can be provided either in ISIS or in the recipient country.

Importantly, ISISPACE does not receive any direct support from the government for its capacity building programmes, entirely funded by the recipient organisation on

[11] Professor Hideaki Shiroyama and Dr Quentin Verspieren visited ISISPACE headquarters in The Netherlands in June 2019 and collected the information presented in this section.

a purely commercial basis. It only indirectly benefits from partnerships with public organisations and occasional grants, such as:

- ISISPACE has ground stations in TU Delft and several research collaborations (with memoranda of understanding).
- Collaborations with Montpellier University (France) and the European Centre for Nuclear Research (CERN) for radiation studies.
- Grant for deployer development with a national institute in Netherlands.
- ESA grant for the development of educational kits.

Focus 4: Satrec Initiative[12]

Satrec Initiative is a major international provider of space technology development capacity building services based in South Korea. It was established in 1999 as a spin-off of the Satellite Technology Research Centre (SaTReC) of the Korea Advanced Institute of Science and Technology (KAIST), following successful satellite development projects.

KAIST's SaTReC was responsible for the development of the first Korean satellites. Established in 1989, it accumulated knowledge on satellite design and development, space science and remote sensing by sending students and engineers to the US, Japan and the UK (at SSTL). It then initiated a joint project with the University of Surrey to develop Korea's first satellite, KITSAT-1. Based on the model of KITSAT-1, SaTReC engineers developed KITSAT-2, first satellite built in Korea. Then, after developing KITSAT-3, Korea's first "indigenous satellite", SaTReC engineers founded Satrec Initiative with 100% of private funding.

Since then, Satrec Initiative has grown to become one the leading satellite manufacturers in Korea, involving in numerous domestic and international satellite projects, as well as one of the leading worldwide providers of space technology development capacity building services. In 2005, Satrec Initiative became the first Korean company to export a satellite, namely RazakSat to Malaysia. It has been conducting capacity building programmes with numerous countries in Southeast Asia, Middle East and Europe.

Satrec Initiative is the best example of a former recipient of capacity building having retained and expended the knowledge acquired to become one of the major capacity building services donors.

[12] A detailed history of Satrec Initiative is available in Sungdong Park et al., 'Journey of a Korean Small Satellite Company: From Space Technology Recipient to Donor', in *Proceedings of the 70th International Astronautical Congress in Washington, DC (IAC 2019)* (Paris, France: International Astronautical Federation, 2019).

2. Lessons and best practices from non-Japanese donors

Having provided an overview of capacity building practices from non-Japanese donors, what lessons can be useful for Japanese universities to enhance their impact and effectiveness?

The lessons of the University of Rome, reproduced here, are directly applicable to the case of Japanese universities, *a fortiori* large national universities having close ties with the central government:

- University functions as agent (service provider) operating under a top-level bilateral government cooperation agreement.
- Collaboration with foreign government agencies (NASA, JAXA, etc.) is crucial.
- Training recipient country's professors to ensure that local universities retain knowledge.
- Involving recipient country's professors in decision-making to increase ownership.
- Exchanging students on both sides (but difficult to convince Roman students).
- Need to foster job opportunities for students in the recipient country/region (if not, they will leave the country or change their professional focus).

Apart from the lessons of the University of Rome, the most interesting aspect of the case studies presented in this chapter is the reliance on university spin-offs to conduct capacity building. It therefore raises the issue of the comparative advantages of private providers of capacity building services versus universities and *vice versa*. What can and should be done by commercial providers? What can and should be done by universities? Although these questions are touched upon in most of the following chapters, below are a few good practices from private providers, directly extracted from the cases of SSTL, ISISPACE and Satrec Initiative.

The mandate of university laboratories is the education of students and the development of knowledge. They therefore cannot spend an excessive amount of time and resources to the provision of capacity building services. In fact, large projects such as MicroDragon cannot be dealt with by a single laboratory, often requiring the establishment of consortia including different large universities. Private ventures, on the other hand, can devote their full attention to customers and possess personnel and infrastructure adapted even to large-scale projects (e.g. satellites above 100 kg). Concretely, the comparative advantages of private providers are:

- Full vertical integration of satellite development capabilities, from design, manufacturing and testing to the provision of launch and deployment services.
- The presence of in-house legal and administrative experts able to deal with, for instance, international contracts, sensitive technology export licenses, frequency registration, etc.

- The ability to procure competitive and fast-tracked launch opportunities. In the case of ISISPACE, an official interviewed for this study explained that, thanks to the large number of satellites it produces or for which it procures launch services, the company has been able to conclude working agreements with most launch providers in the world.
- Joint-bidding opportunities with large satellite makers. SSTL in particular, being part of Airbus Group, can propose joint packages with its parent company: when Airbus Defense and Space sells a large satellite to a country, SSTL can, via the same agreement, be in charge of training dozens of local engineers.
- The ability to send experts abroad – at the recipient's facilities – for a long period of time, which is impossible in the case of university professors, researchers or students.

CHAPTER 4. DIPLOMATIC EFFECTIVENESS OF CAPACITY BUILDING PROGRAMMES

This chapter investigates the benefits generated by Japanese university-led space technology development and utilisation capacity building programmes for Japan as a whole. It starts by defining the criteria used to measure the programmes' diplomatic effectiveness before presenting their positive impact.

But why should the Japanese government care about the diplomatic impact of space capacity building programmes conducted by domestic universities? Although Japan is and has been the leader in this field, as proven in this report, it is being strongly challenged by the rise of Chinese capacity building initiatives. While the actual extent of Chinese activities is difficult to estimate due to the scarcity of information, some specific programmes have been under the spotlight. China's leading aerospace university, Beihang University (short for Beijing University of Aeronautics and Astronautics) established in 2014 the Regional Centre for Space Science and Technology Education in Asia and the Pacific (China), affiliated to the United Nations but fully funded by the Chinese government as the centre of its politics of influence in the regional space sector. In fact, since the 1990s, Beihang University has been attracting thousands of international students every year, primarily from developing countries, thanks to a generous scholarship policy. As explained on Beihang University's "International Education" webpage, scholarships available to international students are plentiful: "Chinese Government Scholarship (CGS), Beijing Government Scholarship, Beihang International Student Scholarship, Confucius Institute Scholarship, scholarships from enterprises, etc.".[13] Even in non-Chinese universities, Chinese students and scholars have largely taken over their Japanese colleagues: according to a Japanese professor often teaching at the International Space University, the number of Chinese registrants grew to around the third of annual cohorts, while Japanese students remain very few.

Without a strong reaction of the Japanese government and commitment to support domestic universities, China will undoubtedly become the main regional and international provider of space technology development and utilisation capacity building services in the coming years and reap all the benefits currently enjoyed by Japan. Although on a smaller scale and with less apparent competition with Japan, India has been advancing in terms of capacity building efforts, for example through the creation of a centre similar to the one in Beihang University: the Regional Centre for Space Science and Technology Education (India), affiliated to the United Nations.

[13] 'International Education', Beihang University, accessed 1 March 2021, https://ev.buaa.edu.cn/Admissions/International_Education.htm.

1. Evaluating diplomatic effectiveness

In order to measure the diplomatic effectiveness of Japanese university-led capacity building programmes, we defined the following criteria:

Impact on Japan's image abroad. To what extent the support provided by Japanese universities contributed to bettering the image of Japan as a whole, for instance thanks to positive press coverage or the assimilation of 'university support' to 'Japanese government support'?

Establishing long-term relationships. What role can play academic relationships in the development of strong and durable bilateral ties?

Impact on bilateral cooperation beyond space. How can bilateral cooperation for space technology development and utilisation contribute to the development of ties in other fields, for instance agriculture, information and communication technologies (ICT), and disaster management?

Grooming future leaders with ties with Japan. To what extent can the trainings received from Japanese universities help former trainees to reach a high level of responsibilities and influence in their home countries, therefore ensuring the existence of a foreign elite favourable to collaborations with Japan?

Developing new markets for Japanese companies. What is the contribution of university-led space technology development and utilisation capacity building programmes in the creation and obtention of new markets for Japanese commercial companies?

2. Positive impact of capacity building projects

This section identifies the positive impact of the Japanese capacity building programmes studied in this report, based on the aforementioned criteria.

2.1. Impact on Japan's image abroad

All the projects studied in this report have contributed to pioneering initiatives, including for some of them the development of the recipients' first national satellites. They were therefore highly publicised in local media. Often, the local press, while mentioning the name of the university or company having provided capacity building services, tends to deliver a simple message: 'Japan helped our country'. It is a typical case in which the independent action a single university laboratory can contribute to promoting the image of Japan as whole. In addition, the involvement of the local Japanese embassy or the local JICA office reinforces the understanding of the recipient country's population that 'Japan' is behind the support. Below are a few examples.

The RWASAT-1 project is a textbook example of such understanding. Although the existing government-to-government space cooperation between Rwanda and Japan is mostly non-existent (beyond a few signed letters of intents and memoranda of understanding), the collaboration programme between the Rwanda Utilities Regulatory Authority (RURA) and The University of Tokyo is almost exclusively described by national and regional news outlets as the "partnership between Rwanda and Japan",[14] or merely a project supported by "Japanese experts".[15]

The exact same demonstration can be made with the PHL-Microsat programme, the MicroDragon project and even more with the numerous BIRDS projects having received extensive coverage in numerous countries, in a scale well beyond any other Japanese university-led capacity building programmes.

2.2. Establishing long-term relationships

The role of academic partnerships in sustaining long-term bilateral relationships is particularly striking in the case of Japan. Although not the only country following such practices, the Japanese government is well known by its foreign counterparts for the high turnover rate of its bureaucrats. Japanese public officers, including diplomats, tend to follow job rotations of around two years, virtually resetting relations with foreign partners on a similar time pattern.

Conversely, Japanese university professors, thanks to the tenure system, retain their positions and responsibilities until retirement and are perfectly impervious to both the bureaucratic changes described above, and to larger political and diplomatic shifts in the country.

This is the case for most of the projects studied in this report: Professors Takahashi and Yoshida are maintaining close and durable relations with their Filipino counterparts, Professor Nakasuka has been working with Vietnam since the dawn of their satellite development roadmap and the BIRDS programme has even institutionalised the continuation of the relationship among BIRDS participant with an annual workshop and a plan for follow-up after BIRDS-5.

Going a bit further on the case of Philippines, Professor Marciano's great achievements with Japan (DIWATA-1/2 and BIRDS) were identified by experts interviewed for this report as part of the reason why he was appointed director general of the newly established Philippines Space Agency. The Filipino

[14] David Oni, 'Rwanda's First Satellite In Space Is Set For Release From ISS', Space in Africa, 14 October 2019, https://africanews.space/rwandas-first-satellite-in-space-is-set-for-release-from-iss/.
[15] Julius Bizimungu, 'Rwanda on Course to Establish Space Industry', The New Times | Rwanda, 10 August 2020, https://www.newtimes.co.rw/news/rwanda-course-establish-space-industry.

government apparently valued his role in maintaining close relations with academic partners in Japan.

2.3. Impact on bilateral cooperation beyond space

Space technology development and utilisation being closely intertwined with other fields, such as agriculture, disaster management, land management or environmental protection on the application side, or supercomputing, telecommunications, image processing or big data on the technical side, space cooperation programmes necessarily generate collaborations in other technical or scientific disciplines.

For instance, from the starting point of developing a small communication and remote sensing satellite, the RWASAT-1 project is responsible for the initiation of collaborations between Rwandan and Japanese entities for meteorological and hydrological studies, for the monitoring of infectious diseases, for the development of various environmental sensors, etc.

Exactly similar considerations can be found in other projects, such as the contribution of DIWATA satellites' data for agricultural ("world's detection of disease areas of banana plantations") or meteorology ("world's first precise 3D cloud model around the typhoon centre").

2.4. Grooming future leaders with ties with Japan

Human resource development is at the core of any capacity building programme. However, beyond transferring technical knowledge, there could be a benefit in organising the trainees' grooming into future leaders in their countries, for instance through English language, management or policy courses. In turn, when the former trainees will naturally be assuming high-level responsibilities in their home countries, it is likely that they will see in Japan – and Japanese institutions – a reliable and trustworthy partner.

This was well understood and implemented by Professor Shirasaka during the MicroDragon project. Apart from the main technical curriculum (engineering, design thinking, etc.), he set up English lectures and other forms of leadership development activities. Due, however, to the recent completion of the project, it is too early to see the concrete results of this initiative.

In the case of RWASAT-1 however, most of the project leaders and trainees were already appointed to prestigious positions for their pioneering role in the country's first satellite programme. The two main counterparts of The University of Tokyo – and Rwandan programme leaders of RWASAT-1, Georges Kwizera and Joseph Abakunda, were appointed as, respectively, the inaugural Chief Technical Officer and Chief Strategy Officer of the newly founded Rwanda Space Agency. Although seeing a direct causation would be excessive, Gaspard Twagirayezu, head of the trainee team, was appointed last year Minister of State for Primary and Secondary Education of the Republic of Rwanda.

The example of PHL-Microsat is also striking. The project leader, Professor Marciano, was recently appointed as the inaugural director general of the Philippines Space Agency – although he was already assuming a senior role as the director of a government agency – and numerous former students of Tohoku and Hokkaido Universities are now being promoted to senior scientific or engineering roles in the agency.

2.5. Developing new markets for Japanese companies

Capacity building programmes conducted by Japanese universities have proved useful to open new markets for Japanese space ventures, through two processes: (1) the creation of a market by introducing space technology development and utilisation in the recipient country, and (2) by directly promoting partnerships with specific Japanese space ventures.

As explained in Chapter 2, the MicroDragon project has been specifically designed as a steppingstone towards the joint development of advanced radar satellites (LOTUSat) by the Vietnam National Space Centre (VNSC) and leading Japanese satellite manufacturer NEC Corporation. The VNSC was unwilling to simply purchase satellites from Japan but wanted to include in the package an ambitious small satellite capacity building programme.

Similarly, different Japanese commercial providers were introduced to Rwanda as part of the RWASAT-1 project. Apart from the direct involvement of University of Tokyo spin-off Space Edge Lab. Inc, other companies have initiated discussions with the government of Rwanda such as Axelspace, fast-growing satellite remote sensing start-up based in Tokyo.

CHAPTER 5. EDUCATIONAL EFFECTIVENESS: KNOWLEDGE RETENTION IN RECIPIENT COUNTRIES

Setting up a capacity building programme to transfer knowledge and technology is one thing, retaining the knowledge is another. Through a combination of institutional building, and human resources and knowledge management measures, recipient countries can ensure a maximum level of knowledge retention, that would serve as the basis of future domestic projects. This chapter, after clarifying what we mean by education effectiveness, introduces the different knowledge retention strategies implemented by the recipients of the capacity building programmes studied in the report.

1. What do we mean by educational effectiveness?

In our first attempt to provide a definition to the concept of "educational effectiveness",[16] we focussed on its primary meaning which can summed up as the ability to effectively transfer knowledge from an entity that knows to an entity that wishes to learn. Evaluating this form of educational effectiveness is fairly straightforward in the cases of the capacity building programmes studied in this report: what was taught? How many students were trained? Did the recipient acquire the ability to develop a satellite on its own? Etc.

Based on our review of numerous cases, what appeared to be the most interesting aspect of educational effectiveness was not the raw quantity of knowledge acquired by the recipient but rather its ability to retain, employ and further develop this knowledge. In other words, apart from providing the recipient with new knowledge, did the capacity building programme empower the recipient, by allowing it to independently conduct its own space activities?

The cases presented in the next section illustrate the different approaches of recipient countries with regards to the long-term retention and development of the knowledge that they acquired. Several elements are analysed, such as:

- The existence of concrete knowledge retention strategies established by the recipient prior to the start of the capacity building programme.
- The inclusion by the donor, in the capacity building programmes, of teachings related to the long-term sustainability of the recipient's activities (e.g. policy, project management).

[16] We do not address here the different field of *educational effectiveness research*, which focusses on professor-to-student relations in the classroom, and associated teaching methods.

- The situation of the recipients several years after the programmes.
- The transformation from recipient to donor of space technology development and utilisation knowledge.

2. Different approaches to knowledge retention

Knowledge retention strategies vary greatly from one recipient to the other, with some managing to retain and expand the knowledge acquired through capacity building, while others almost go back to square one after several years. This section presents numerous good and bad cases of knowledge retention and draws useful lessons.

Focus 1: SSTL capacity building, comparison of Thailand (Thai-Paht) and South Korea (Satrec)

In the 1990s, two Asian universities received similar capacity building services from UK company Surrey Satellite Technology Ltd. (SSTL), both ending up producing a microsatellite, which was also their country's first satellite:

- In 1992, engineers from the Korea Advanced Institute of Science and Technology (KAIST), foremost engineering and science university of the Republic of Korea (ROK), were sent to SSTL to develop ROK's first satellite, KITSAT-1.
- In 1998, student and engineers from Thailand's Mahanakorn University of Technology (MUT) followed the same process and developed the microsatellite Thai-Paht.

However, although they followed the same programme, both universities embarked on a very different path, with KAIST ending up creating a competitor of SSTL, Satrec Initiative (see Chapter 3, section 1, focus 4), while the knowledge generated in the MUT mostly vanished. How can this be explained?

As extensively explained in an excellent paper written by the founder of Satrec Initiative, the capacity building programme conducted by SSTL with KAIST engineers and students was planned as the starting point of a progressive and long-term strategy aiming for the forming of indigenous satellite development capabilities in Korea.[17] The knowledge acquired during the development of KITSAT-1 – and during the studies of Korean students in other countries – was used and extended for the domestic manufacturing, a few years later, of KITSAT-2 and KITSAT-3. KAIST engineers then decided to consolidate the knowledge into a privately owned start-up company, therefore coupling the need to retain and expand the knowledge with the commercial survival of the newly established company. It has proved to be

[17] Park et al., 'Journey of a Korean Small Satellite Company: From Space Technology Recipient to Donor'.

extremely successful, Satrec Initiative now being a major space technology development and utilisation capacity building provider.

The MUT on the contrary had no such strategy in place when receiving support from SSTL. According to an interviewee involved in the project at the time, motivated neither by the desire to expand knowledge nor to the goal of setting up commercial activities, the development and launch of Thai-Paht was primarily aiming at the domestic and international promotion of the MUT, in a situation quite similar to the case of Colombia's Sergio Arboleda University presented later in this chapter.

Lessons that can be drawn from this comparison are:

- The need to include capacity building programmes within a long-term strategic vision, in order to make sure to build on the existing momentum.
- Tying the development of domestic capabilities with commercial imperatives, that is by conditioning a company's survival to the necessary retention and further expansion of the knowledge, has proved to be an effective motivation.
- The very limited and short-lived promotional benefits of launching a countries first satellite, if not part of a sustainable programme.

Focus 2: Airbus capacity building, comparison of Thailand (THEOS-1) and Taiwan (FORMOSAT-2)

Although this example concerns capacity building provided by a large corporation and neither by a university nor a university spin-off, focus of the study, it helps understand the importance of knowledge retention strategies.

In the 2000s, two countries purchased the same satellite from Airbus (still called EADS at the time) and received similar associated capacity building services:

- The Taiwanese National Space Organization (NSPO) purchased the large remote sensing satellite FORMOSAT-2, launched in 2004. NSPO is part of the National Applied Research Laboratories (NARLabs) under the administrative supervision of the Ministry of Science and Technology.
- Thailand's Geo-Informatics and Space Technology Development Agency (GISTDA) acquired THEOS-1 – almost identical to FORMOSAT-2, launched in 2008. GISTDA is under the administrative supervision of the Ministry of Higher Education, Science, Research, and Innovation, but also has in its Executive Board representatives from the Royal Thai Survey Department (Thai Armed Forces) and the Bureau of the Budget (Ministry of Finance).

Similar to the cases of Focus 1, while capacity building services were similar, their long-term outcomes are radically different:

- After the deployment in space of FORMOSAT-2, NSPO progressively built up its capabilities, including with the development of an indigenous large satellite, FORMOSAT-5.
- Conversely, GISTDA did not develop any domestic satellite since then. According to a GISTDA interviewee, part of the problem is that, out of 20 engineers and 20 students having been trained in France, only four are left in technical positions in GISTDA, with almost no retention of knowledge. In fact, when GISTDA engineers need help on THEOS-1, they usually contact their Taiwanese counterparts, who managed to keep and expand their knowledge.

How can these stark differences be explained? Having been unable to interview former NSPO trainees, we relied on literature review, which suggested that, like the case of Satrec Initiative, the primary reason of NSPO's success was the inclusion of FORMOSAT-2's capacity building programme within a long-term satellite development roadmap, having culminated with the domestic development of FORMOSAT-5.[18]

The case of Thailand however is precisely examined thereafter. For THEOS-1, 20 engineers were sent to EADS-Astrium facilities in Toulouse and 20 scholarship students were sent to French universities as part of the "THEOS training program". However, not having received any strict guidance, students registered for mathematics, aeronautics or civil engineering programmes, with only a single one focusing on space engineering. In addition to that, after the completion of the training programmes, GISTDA did not establish any knowledge retention mechanism, neither in terms of personnel management (as said above only four trainees retained technical roles until now) nor in terms of centralised knowledge repository or internal knowledge dissemination initiatives.

In addition to GISTDA's internal institutional failures, an interviewee also blamed the risk-averse nature of the Thai government, favouring short-term project success rather than long-term capacity building. Not allowing a project to appear as a failure, Thai government agencies tend to prefer turn-key solutions, at the expense of learning. In addition, in Thailand, all governmental projects have to be concluded within a single fiscal year. In fact, multi-year budgets are extremely complex to justify and obtain as they require the personal approval of the prime minister (Indonesia has a similar system requiring the supervising minister's approval).

Lessons that can be drawn from the comparison of the Taiwanese and Thai cases are:

- Again, the importance of long-term capacity development roadmaps.
- The need for concrete institutional knowledge retention strategies, including appropriate personnel management mechanisms, to ensure that former trainees contribute to further spreading the knowledge that they acquired.

[18] 'The Push to Develop Aerospace Technology', Executive Yuan (2.16.886.101.20003, 10 February 2020), https://english.ey.gov.tw/News3/9E5540D592A5FECD/46f4d4cc-ccea-4d22-874e-ecb93e5cf1b8.

- The damages of excessive risk-aversion. The maximisation of the mission's probability of success should not be done at the expense of capacity building.

Focus 3: MicroDragon

The MicroDragon project having been extensively described in Chapter 2, this section focusses on drawing lessons from the Vietnam National Space Centre's (VNSC) knowledge retention approach.

The MicroDragon satellite was developed as one stage of a long-term satellite development roadmap, expected to culminate with the manufacturing, in partnership with Japanese company NEC, of the advanced radar satellites LOTUSat. One strength of the VNSC's approach is to contractually force trainees to keep working at the centre at least until the completion of the roadmap (launch of LOTUSat in 2023) while also ensuring that they will have some real work to do afterwards. In particular, the future development of the LOTUSat satellites will involve numerous VNSC staffs, many of them having already acquired a strong knowledge – and advanced degrees – through the MicroDragon project: 48 for satellite development, 16 for operations, 34 for data processing. In total, around 100 staffs will participate in short-term stays in Japan.

In parallel with satellite development, data processing will start being taught in 2021 at Vietnamese universities by experts of the Remote Sensing Technology Centre of Japan (RESTEC), using data from the NEC's Asnaro-2 satellite, on which LOTUSat are based.

In addition, to further spread the knowledge acquired during the MicroDragon project, VNSC has educational contracts with three universities: the Vietnam National University, the Vietnam France University (also known as University of Science and Technology of Hanoi) and the Vietnam International University.

Overall, lessons that can be drawn from the case of MicroDragon are the following:

- Appropriate personnel management mechanisms need to combine contractually forcing trainees to stay in their agencies after the completion of capacity building programmes while parallelly ensuring that they have a reason to stay, that is a space-related job in their home country or organisation.
- In order to spread the knowledge domestically, the receiving agency can partner with local universities to have their engineers teach students, as well as welcome students as interns in the agency. In turns, it helps the agency develop a pool of competent prospective employees.

Focus 4: LAPAN's LAPAN-TUBSAT project[19]

LAPAN-TUBSAT is a CubeSat developed at the Technical University of Berlin (TU Berlin or TUB), by a team of engineers from the Indonesian space agency LAPAN, as part of a capacity building programme.

Willing to initiate a capacity building programme for some of its promising employees, LAPAN initially approached UK company SSTL after hearing about the case of Malaysia's TiungSAT microsatellite, launched in 2000. Based on LAPAN's initial requirements, SSTL provided a project budget estimation of around USD 10 million, which was ten times what LAPAN had expected and was willing to accept. After receiving a similar answer from the German Aerospace Centre (DLR), the latter recommended LAPAN to contact Professor Renner of TU Berlin, which had initiated in 1985 a university small satellite programme called TUBSAT, having already produced five satellites at the time (2002-2003).[20] TU Berlin proposed to LAPAN an all-inclusive proposal (stay, learning and satellite development) within the expected budget (USD 1 million). LAPAN therefore selected four young engineers following a very strict process (out of 60 applicants), to stay in TU Berlin for the duration of the project. In addition, a fifth trainee position was set up, with LAPAN engineers rotating every three months. The project was initiated in 2003 and the satellite launched in 2007.

Now, around 15 years after the project's completion, LAPAN has around 150 trained staffs devoted to satellite manufacturing with a 100 kg class clean room and vibration test facilities. The four initial trainees are all still in LAPAN, two having remained in the satellite manufacturing department while the two others have moved to other technical departments (remote sensing and rocket development).

According to one of the four main trainees interviewed for this study, the model of the LAPAN-TUBSAT project was followed by other countries (e.g. Singapore and China tried to work with TU Berlin), but without the same successful results. He explained it by the fact that 1) they did not select the best profiles and did not promote them quickly enough after the completion of the programme, and that 2) the key to capacity building is to build a strong relationship with the source of knowledge which has to open up. LAPAN trainees explained being still in very close contact with Professor Renner.

Commenting on 1), the interviewee explained that after coming back to Indonesia, the four trainees were given generous budgets and staff to go on with their research and keep the momentum. A new satellite programme was approved in 2008, the money came in 2009, and the satellite, fully developed in Indonesia but including foreign components, was ready in 2012 and launched in 2015 for free by India in

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[19] Unless otherwise referenced, the information in this section was obtained during an interview with a former LAPAN-TUBSAT capacity building programme trainee.

[20] 'TUBSAT', TU Berlin, Institute for Air and Space, 4 May 2016, https://www.raumfahrttechnik.tu-berlin.de/menue/forschung/abgeschlossene_projekte/tubsat/v_menue4/tubsat/.

exchange for using Indonesian islands for tests. LAPAN engineers were able to do it even without clean room and proper testing facilities ("almost clean room"). Now LAPAN teams are able to develop their own simple components.

Finally, in order to spread the knowledge that it acquired through capacity building programmes, LAPAN initiated a partnership with the Bandung Institute of Technology (BIT), the only aerospace engineering university in Indonesia. BIT students are usually hired in LAPAN but with limited space engineering knowledge. LAPAN therefore decided to contribute to their education by teaching and by welcoming them in LAPAN for their thesis or papers.

Knowledge retention lessons that can be drawn from the case of LAPAN-TUBSAT are the following:

- Trainees should be chosen following a strict selection process.
- Former trainees should be quickly promoted and given good working conditions in terms of budget, staff and equipment.
- Keeping a good relationship with the training provider allows to maintain knowledge transfer even after the end of the programme.
- Transfer knowledge to local students (BIT).

Focus 5: PHL-Microsat

There is no need to reaffirm the great contribution of the PHL-Microsat programme to the development of space capacity in the Philippines, in particular with the very appropriate combination of large, advanced satellites (DIWATA-1/2) with the leaner educational approach of the BIRDS programme (Maya satellites).

Apart from this intelligent combined approach allowing to develop capacity while conducting advanced missions, the most interesting feature of the PHL-Microsat programme is the effort made by its leader, Professor Marciano, to retain the staffs having been trained in Japan. Being unable to contractually force former trainees to stay at the University of Philippines because they had been hired under a fix-term project grant, he had to find a way to make them want to stay. He therefore established the well-named STAMINA4Space programme, modelled after Kyutech's BIRDS, in order to maintain the country's space development momentum by keeping his engineers busy and training more and more domestic students. In addition to this programme, he supported other trainees to become lecturers in national universities in order to transfer their precious knowledge to the next generation.

STAMINA4Space being a fix-term programme, it is viewed as a smooth transition towards the progressive build-up of the newly established Philippines Space Agency (PhilSA). While PhilSA was created as the outcome of a separate policy process led by Dr Rogel Mari Sese, the National SPACE Development Programme (NSDP), it is undeniable that the successful capacity building initiatives organised under the umbrella of PHL-Microsat have contributed to the agency's approval by the Congress and the nomination of Professor Marciano as inaugural director general. PhilSA is currently in the process of recruiting numerous employees, many of whom were pillars of the former PHL-Microsat programme.

The final point, strongly emphasised by Japanese professors leading capacity building programmes, is the great importance to have a local champion around which capacity building efforts can be based. In the case of the Philippines, the presence of Professor Marciano has been key in developing and cementing relations with Japanese universities as well as for the domestic development of research programmes – and PhilSA to some extent.

Overall, lessons that can be drawn from the case of PHL-Microsat are the following:

- Mechanisms to keep trainees after the completion of the capacity building programmes is indispensable to retain the knowledge. A combination of governmental (PhilSA) and academic job opportunities (STAMINA4Space or lecturers at the University of the Philippines) has proved extremely efficient in both retaining knowledge and spreading it to the next generations.
- The presence of a strong local champion is a facilitator of international relations and domestic institutionalisation of space development efforts. In addition, having a local champion with an academic tenure allows long-term continuity, independently from political changes.

Lessons from other projects studied in this report

In addition to the examples presented above, we reviewed additional case studies highlighting a few useful lessons.

Colombia's Libertad-1[21]

The Libertad-1 project, which ended with the development and launch of Colombia's first university CubeSat, was initiated to promote the newly established department of engineering of the Sergio Arboleda University. According to a former team member, the university headquarters having seen Libertad-1 more as publicity stunt rather than as the first step of a long-term space development strategy, lost interest in space activities soon after its launch, leading to the failure of researchers' and students' efforts to develop a second satellite, Libertad-2. Apart from reinforcing the aforementioned lesson that **when developing a CubeSat, one should already have planned and secured resources for a second or third one**, this example shows the **limitations of the common practice of 'advertisement' satellite projects**, like in the case of Thai-Paht.

[21] All the information presented in this section was obtained during an interview of Dr Jesus D. Gonzales-Llorente, former researcher at Sergio Arboleda University and member of the team having developed Libertad-1.

Costa Rica's Irazú[22]

Initiated by a team of volunteers of the Central American Association of Aeronautics and Space (ACAE, *Asociación Centroamericana de Aeronáutica y del Espacio*) in 2009, the Irazú 1U CubeSat project took a step further in 2013, when ACAE signed an agreement with the Institute of Technology of Costa Rica (TEC, *Tecnológico de Costa Rica*). While ACAE was in charge of strategic partnerships and funding, TEC became the technical and scientific co-lead. In TEC, the technical dimension of the project took off in January 2015 with a 4-year timeline. Approached by Professor Cho in 2014, TEC signed an agreement with Kyutech in 2016 for launch, testing, technical support and capacity building. According to Irazú's project manager Marco Gómez Jenkins, Kyutech was chosen based on its ability to provide a "full package", thanks to its extensive infrastructure and technical expertise, at an extremely competitive cost of USD 55,000. While the **full development happened in Costa Rica with Kyutech support**, tests have been conducted in Kyutech by two Costa Rica students (one master's and one PhD).

In order to retain capacity in Costa Rica and spread it further, a Space Systems Lab was created in TEC in mid 2017 (the first in Central America) so students can learn by operating Irazú. In addition, the **institutionalisation of space activities in TEC** allowed to have an official structure working with the country's Ministry of Science, Technology and Telecommunications for the establishment of a national space agency.

Central America's Morazán[23]

Building on the pioneering experience of the Irazú project, ACAE initiated in 2018 the Morazán CubeSat project. According to an ACAE representative whom we interviewed, while Irazú successfully completed its mission to create an enabling ecosystem and awareness on the need of space technology development and utilisation for the Central American region, Morazán aims to focus on **sharing knowledge with "Central American brothers" as well as partners around the world**. ACAE therefore secured partnerships with the University of Costa Rica (different from TEC), the National Autonomous University of Honduras (UNAH, Universidad Nacional Autónoma de Honduras) and the University of San Carlos in Guatemala, among others, as well as support from the Central American Integration System, a regional economic and political cooperation organisation (roughly equivalent of the ASEAN or the European Union).

Like Irazú, the Morazán project has concluded a partnership with Kyutech for testing and capacity building. At the time of publication of this report, one student

[22] All the information presented in this section was obtained from former members of the TEC team having developed Irazú, in particular by the project manager Marco Gómez Jenkins.
[23] All the information presented in this section was obtained from members of the Morazán project, met during the 2019 International Astronautical Congress in Washington, DC.

is supported by UNAH to study in Kyutech (currently remotely due the COVID-19 pandemic) and will be in charge of Morazán's environmental testing when the CubeSat will be sent to Kyutech (date yet to be decided). Morazán will then be deployed in space by JAXA for free, pursuant to Morazán's selection in the KiboCUBE programme.

3. General lessons on knowledge retention

Knowledge retention in recipient countries should matter to Japanese universities because even when capacity building programmes are fully paid for by the recipient, they consume Japanese resources: tax money funding the professors' tenures, the facilities and initial technology development costs; time of professors, researchers and students that can have been devoted to a better use; supported provided by government agencies for diplomacy, frequency registration, etc. The loss of the recipient's acquired knowledge is therefore an unacceptable waste of tax money and precious time. It is thus critical that Japanese universities check before starting the programme that appropriate measures are taken by the recipient to retain and develop the knowledge.

This section summarises the four most important 'good practices' to look for when evaluating a recipient's knowledge retention strategy. Conversely, we encourage donors to help recipients devise an appropriate approach based on these key lessons.

Good practice 1. Long-term space development roadmap

A common feature of all successful examples of knowledge retention, long after capacity building programmes were concluded, is the inclusion of each project, even minor, in a long-term space development roadmap. As bluntly explained by an interview: "when doing your first satellite, you should have secured the number two and the number three". With a pre-decided roadmap, every single knowledge development and acquisition activity is conducted for the achievement of short, mid or long-term goals.

On the contrary, an example of 'worst practice' is the unfortunately too common use of space development for promotion. Numerous universities have tried to bolster their domestic and international visibility with a CubeSat – often the first national satellite. However, a quick review of such practices clearly shows their very short-lived promotional effect and their nonexistence capacity building benefits, most space development programmes dying out after a few months of satellite operations.

Good practice 2. Ensuring job opportunities in the domestic space sector

The principal benefit of capacity building programmes is not technology transfer or the acquisition of a tangible piece of knowledge *per* se, it is the development of a skilled local workforce. The key question that needs to be answered by the initiators of a capacity building programme, on the recipient side, is: why do we need this trained workforce and what can the trainees do after the completion of the training?

When this question remains unanswered, then the knowledge is doomed to be quickly lost: trainees will find space-related jobs abroad or progressively lose their knowledge while working in another research or business sector. Even if the trainees are contractually forced to remain in the institution having paid for the capacity building programme, not working on a real project will lead to the progressive weakening of their abilities.

To ensure that the knowledge is retained, receiving organisations should have plans to keep the former trainees busy with satellite development projects, teaching at local universities, etc. To this end, the cases of the VNSC and of the University of the Philippines-Diliman provide excellent examples of good practices. This lesson is obviously closely interrelated to the first one. As explained by Professor Marciano is the speech that he delivered after his nomination as inaugural director general of PhilSA, his primary motivation is “to give a reason to Filipino space engineers living abroad to come back home”.

Good practice 3. Existence of a stable local champion

Recipient countries having a clearly identified local champion often prove successful in developing and maintaining a long-term space development vision. The best example is, once more, Professor Marciano, which has steadily led space technology development efforts in the Philippines for almost a decade. Other cases were mentioned during interviews, in South Korea (Professor Cho of KAIST) and Singapore.

In most cases, the local champion is a tenured university professor. It is in fact primarily thanks to the stability and long-term visibility provided by academic tenures, allowing its holder not to be affected too much by political changes.

Good practice 4. Partnerships between government agencies and local universities

The final good practice emphasised in this section is, in the case of government agencies having benefited from capacity building services, to further spread the knowledge through partnerships with local universities.

In the previous cases, the VNSC, the Philippine DOST and LAPAN have all encouraged their former trainees to teach space technology-related lectures in national universities, which provides a series of benefits: spread the knowledge, keep engineers busy if there is no current satellite project and finally ensure that their future employees, selected among taught students, will already possess a certain technical level.

Chapter 6. Impact of COVID-19 on capacity building programmes

The COVID-19 pandemic, by limiting long-distance travel for more than a year already, has strongly impacted international research and development collaborations, including space technology development and utilisation capacity building programmes. Due to the ongoing nature of the pandemic, its consequences are yet to be fully identified. This short chapter therefore provides preliminary considerations on the impact of COVID-19 on capacity building programmes through a few examples.

1. Academic and private providers: a very different situation

As extensively addressed in the next chapter, the respective strengths and weaknesses of academic and private providers of capacity building derive from commercial imperatives. While for university laboratories, capacity building programmes are occasional activities, commercial private providers depend on them for their survival.

By preventing international travel, the COVID-19 pandemic put a sudden stop to the core of any capacity building programme: hands-on training (in the recipient or donor organisations) and the installation of equipment in the recipient country. Concretely, this situation imposed the temporary suspension of existing programmes until travel can be resumed. Although some adaptation to the pandemic is feasible such as the organisation of online trainings or joint remote satellite operations, space technology development capacity building cannot be done online.

While inconvenient for universities, this situation did not disrupt their core activities (e.g. teaching, internal satellite projects), as budgets remained fairly stable throughout the pandemic, covering the majority of staffs, facility and equipment costs. Private providers however had to delay planned services and are struggling to recover costs for services already provided, as shown by the example of RWASAT-1 presented thereafter.

In addition, beyond disrupting the programmes themselves, the COVID-19 pandemic has strongly hampered the providers' outreach activities. Space technology development and utilisation capacity building being an expensive venture, often difficult to justify by universities or governmental agencies in developing countries, it needs to be based on a certain level of confidence between the donor and the recipient, confidence that can be built only after long, face-to-face discussions. In the case of Japan, it explains why most of the programmes were built upon existing solid relations between foreign officials and prominent

Japanese university professors. The example of the Kyushu Institute of Technology, presented thereafter, illustrates this point perfectly.

2. A few examples

This section provides three examples of capacity building programmes having been disrupted at various degrees by the COVID-19 pandemic.

2.1. Kyutech's BIRDS: importance of international travel to find participants

When asked what impact the COVID-19 pandemic had on Kyutech's BIRDS programme, Professor George Maeda, in charge of international relations and outreach, emphasised the role of physical international travel for the recruitment of BIRDS partner organisations and graduate students, "unavoidable to some extent".

In particular, he explained the importance of international conferences to meet prospective partners. It includes some of the largest space-related events such as the annual International Astronautical Congress, gathering for a week space experts and enthusiasts from almost all countries around the world, and other events focussing on international development. In particular, during the last Tokyo International Conference on African Development in 2019 (TICAD7), Professors Maeda and Cho were able to meet high-ranking officials from Uganda and Zimbabwe, both countries having since then joined BIRDS-5. Then, after initial contacts during conferences, it is often necessary to visit the prospective partner country in order to convince different domestic stakeholders of the benefits to join the BIRDS programme.

The worldwide cancellation of international conferences and the suspension of non-essential air travel has put a sudden stop to Kyutech's usual outreach initiatives, critical for the international promotion of the BIRDS programme and the discovery of future partners. The link among past and current participants was however maintained by switching the annual international BIRDS workshop online in 2020, until the improvement of the global health situation.

2.2. RWASAT-1: difficulties to fulfil contractual milestones

The example of the RWASAT-1 project is fairly common in any business area. The agreement between the three contracting parties, the Rwandan government, Space Edge Lab. Inc. and The University of Tokyo included specific tasks to completed and an associated payment calendar.

Payments being conditioned to the completion of a group of tasks, what happens when the provider completes only two thirds of them? This was the deadlock facing RWASAT-1 project members after the beginning of the COVID-19 pandemic. The

Rwandan side, being subjected to strict government rules was legitimately unable to honour – even partially – the payment deadline, while the provider, Space Edge Lab., was legitimately unable to provide additional services requiring the physical presence of Japanese experts in Rwanda. Only after the pandemic subsides can solutions be found to complete the project.

2.3. The University of Tokyo's support to the Institute of Technology of Cambodia

The final example of this chapter concerns a University of Tokyo student-initiated capacity building programme with the Institute of Technology of Cambodia (ITC).[24] In 2019, students of the Global Leader Program for Social Design and Management (GSDM) obtained funding to visit Cambodia and deliver the first-ever space engineering, law and policy course in the history of the country.

After the great success of this first training, which included numerous engaging hands-on group activities, it was decided to continue with an additional visit in 2020 in order to progressively accompany the ITC towards the development of Cambodia's first satellite. However, the advent in the meantime of the COVID-19 pandemic forced the University of Tokyo team to entirely rethink its educational approach, reducing hands-on activities to focus on online teaching.

Now, the project has been expanded thanks to the support of two laboratories of the university's department of aeronautics and astronautics. However, the COVID-19 pandemic limits its scope to satellite design, with the impossibility to work on an actual system for the foreseeable future.

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[24] All details on the initiation of the project are available in Maximilien Berthet et al., 'Student-Led Policy and Technical Capacity Building Program: The Road to Cambodia's First CubeSat', in *Proceedings of the 71st International Astronautical Congress, The Cyberspace Edition (IAC 2020)* (71st International Astronautical Congress, The Cyberspace Edition (IAC 2020), Online, 2020).

CHAPTER 7. EVALUATION OF JAPANESE CAPACITY BUILDING AND POLICY RECOMMENDATIONS

The final chapter of this report provides a precise analysis of Japanese university-led capacity building programmes and derives concrete policy recommendations from it. It is organised as follows:

- Section 1 lists the strengths of such programmes and differentiate those related to the academic nature of the provider and those specific to Japanese universities.
- Section 2 outlines the benefits for Japanese universities to engage in the provision of capacity building services.
- Section 3 identifies the weaknesses of Japanese university-led capacity building programmes and classifies them into structural, government-related and programmatic weaknesses. It then derives specific needs from each of the weaknesses.
- Finally, section 4 presents a series of recommendations aiming to address the needs identified in the previous section.

1. Strengths of Japanese university-led capacity building programmes

The strengths of Japanese university-led capacity building programmes can be divided into two types: those related to the fact the provider is a university and those to the fact that the provider is a *Japanese* university. Figure 7-1 illustrate this classification.

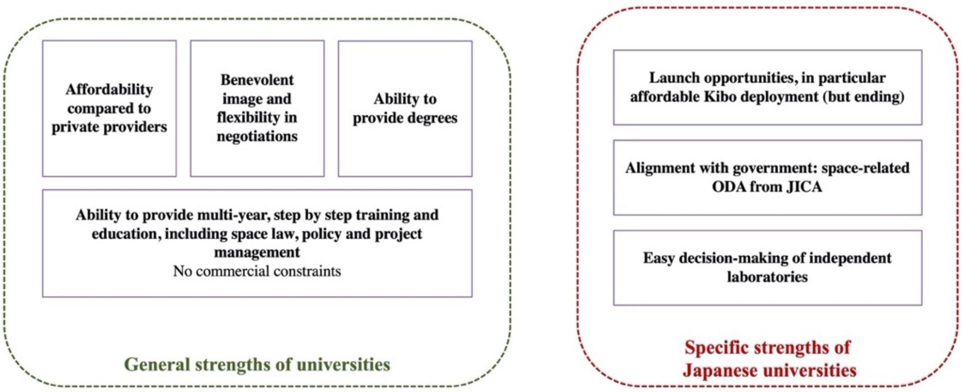

Figure 7-1. Classification of Japanese university-led capacity building programmes' strengths

1.1. Strengths of university-led capacity building

The academic nature of the service provider is responsible for a series of strengths, detailed below.

1.1.1. Affordability compared to private providers

Owing to their non-profit nature and to the fact that most of their basic costs are covered by their government (professors' tenures, facilities, etc.), universities have the ability to cut the price of their services down to the minimum, in particular by not including past technology development costs and core personnel costs.

In fact, when looking for a capacity building provider for its CubeSat project – later to be known as LAPAN-TUBSAT, LAPAN initially turned to Surrey Satellite Technology Ltd. (SSTL), which proposed a ten-million-dollar project based on LAPAN's requirements. This was ten times what LAPAN has planned and budgeted. LAPAN officials then turned to the German Aerospace Centre (DLR) which explained that, for a million-dollar budget, they would be able to provide only one advanced component, like a star sensor. However, they encouraged LAPAN to contact a professor at the Technical University of Berlin (TU Berlin), who agreed to provide capacity building services within the budget.

An interviewee from LAPAN summarised efficiently the fact that pure commercial providers tend to propose capacity building packages that are "too expensive, too big, too early" for emerging and budget-constrained agencies.

1.1.2. Benevolent image and flexibility in negotiations

Most recipients of capacity building programmes have justified their willingness to work with universities because of their benevolent image and flexibility in negotiations.

The universities' benevolent image was often equated to their absence of commercial motivation, owing to the fact that the fundamental objective of universities is the advancement of space technology development and education. On the other hand, recipients may doubt that the projects, budgets and timelines proposed by commercial providers are in their best interests.

Flexibility in negotiations relates to the fact that collaborations with universities are generally led by specific laboratories. It means that discussions involve a small number of counterparts and that the collaboration's approval process is usually short and straightforward. It was pointed out by Japanese professors interviewed for this study that recipient organisations wanted to work solely with universities, with limited involvement of the Japanese central government, that they perceived as complex, heavily bureaucratic and time-consuming.

1.1.3. Flexibility in project timeline and contents

Compared to pure commercial providers, universities, especially large ones, have the ability to provide comprehensive capacity building services going beyond science and engineering. One of the major takeaways of this report is the importance of project management, strategy, law and policy in the long-term sustainability of a space programme.

Although commercial providers could theoretically organise such comprehensive package, they could barely rival with the ability of major universities to leverage their numerous schools and departments. For instance, numerous components of The University of Tokyo independently possess world-class space knowledge with which no commercial provider can rival: the Graduate School of Engineering for satellite development and utilisation (Department of Aeronautics and Astronautics) and management (Department of Technology Management and Innovation), the Graduate School of Science for sensor development and data analysis, and the Graduate School of Public Policy for space law, policy and economics. Same considerations can be made for most of the major Japanese universities mentioned in this report.

In addition, owing to their commercial imperatives, private providers of capacity building services have limited tolerance for extended deadlines and stretched timelines. Universities, thanks to their stable budgets and the usually minor importance of external capacity building funding, can provide more temporal flexibility.

1.1.4. Ability to provide degrees

Finally, one major benefit of university providers compared to any other non-profit provider is their ability to sanction trainings with an actual degree (master's or PhD), element that has been strongly emphasised by numerous interviewees from recipient institutions.

1.2. Strengths of Japanese university-led capacity building

Owing to their intrinsic characteristics and their close proximity to the Japanese government, Japanese universities benefits from additional strengths with regards to the provision of space technology development and utilisation capacity building services.

1.2.1. JAXA-provided launch opportunities

As explained in Chapter 2, section 4.2, JAXA has been providing discounted rates for small satellite deployment from the Kibo module of the ISS to selected universities, as part of its Strategic Partnership Program.

These opportunities provided by JAXA were described by numerous Japanese professors interviewed in this study as one of the key enablers of their capacity building programmes. In particular, the high affordability of the BIRDS programme relies on the assurance of low deployment costs.

However, as further discussed in 3.2, the Strategic Partnership Programme expires at the end of FY2020 in March 2021, generating strong uncertainties for Japanese universities.

1.2.2. Alignment with Japanese government diplomatic goals

Capacity building projects aligning with specific diplomatic targets of the Japanese central government can benefit from different forms of support, in particular financial. Although official development assistance (ODA) tends to focus on traditional areas of development (e.g. infrastructure, agriculture, sanitation), the Japan International Cooperation Agency (JICA) has been one of the first and very few bilateral lenders supporting space technology development projects – space data utilisation projects are however more common.

The MicroDragon project has been fully supported by a JICA loan to the Vietnam National Space Centre as part of an ambitious bilateral cooperation framework aiming at the development of advanced satellite design and manufacturing capabilities in Vietnam. To a smaller extent, JICA has also been supporting other projects such as RWASAT-1 (in particular concerning the drafting of a national space policy to ensure the sustainability of the Rwandan space programme).

Apart from the specific case of Italy's capacity building programme with Kenya, not strictly speaking supported by ODA, we did not identify another example of bilateral or multilateral donor supporting space development programmes.

1.2.3. Easy decision-making of independent laboratories

An important finding on Japanese university-led capacity building programmes is the very high level of independence of university laboratories with respect to their university' headquarters, *a fortiori* at the largest national universities.

In fact, all international cooperation programmes studied here were initiated based on the sole decision of university professors. This is an important difference with the practices of most universities worldwide in which headquarters tend to exert a higher level of control over department-level or laboratory-level activities.

However, as discussed below in sections 3.1.3 and 3.1.4, the independence of Japanese university laboratories is a double-edged sword: while it simplifies negotiations and decision-making, it also creates a risky dependency on few individuals.

2. Benefits for universities to engage in the provision of capacity building services

Although the main beneficiary of capacity building services is the recipient, the donor can also benefit from engaging in such activities.

2.1. Previously mentioned motivations of Japanese universities

Although their primary motivation is the dissemination of knowledge, Japanese universities engaging in the provision of capacity building services can be motivated by specific gains such as the access to additional satellite project opportunities, the obtention of external funding complementing the resources provided by the Japanese government, etc. For a detailed overview of the motivations of Japanese universities to engage in capacity building, see Chapter 2, section 2.

2.2. Contribution to university branding and strategy

The positive impact of engaging in capacity building service provision on the overall university branding domestically and internationally was never part of the initial motivation of Japanese universities but has proved to be a major 'collateral' benefit.

The case of Kyutech is, in this regard, very revealing. Compared to Japan's large national – formerly imperial – universities such as The University of Tokyo or Kyoto University, Kyutech was less visible on the international stage. However, since the beginning of its BIRDS programme, Kyutech is now considered to be one the world leading universities for small satellite design, development, integration, testing and operations. Kyutech's prominent achievements were recognised by numerous prestigious international awards, such as:

- Kyutech was ranked first global small satellite operator in the category "Academic and Non-Profit" of Bryce Space and Technology's *Smallsats by the Numbers 2020*.[25] With 18 small satellites, Kyutech operates more small satellites than major space agencies like JAXA, ISRO, the DLR or ESA.
- Professor Cho received the International Astronautical Federation's (IAF) Frank J. Malina Medal, most prestigious space education award in the world, for his outstanding contribution.
- Numerous Kyutech students have been recognised as IAF Emerging Space Leaders for their pioneering contributions to advancing space technology development and utilisation knowledge in their respective countries.
- Finally, and most importantly, Kyutech received huge international press coverage in all the countries that it has supported in the development of their first satellite.

[25] 'Smallsats by the Numbers 2020' (Alexandria, Virginia: Bryce Space and Technology, 2020), https://brycetech.com/reports/report-documents/Bryce_Smallsats_2020.pdf.

The great success of the BIRDS programme has in turn influence the overall strategy of Kyutech, with space engineering now identified as one of the main fields of expertise of the university as a whole.

3. Weaknesses of Japanese university-led capacity building programmes and areas for improvement

Based on the overview of the current situation of Japanese capacity building programmes presented in previous chapters, we identified three main categories of weaknesses, defined thereafter: structural, government-related and programmatic.

3.1. Structural weaknesses of Japanese universities

Structural weaknesses refer to the environment surrounding capacity building programmes as well as their management and structural characteristics. For weaknesses related to the contents of the programmes, see 3.3.

3.1.1. Limitations induced by laboratory or university size

Being able to provide ambitious space technology development and utilisation capacity building programmes requires a large infrastructure, extensive human resources and a legacy of technology development. In addition, apart from technical and educational aspects, administrative tasks can be overwhelming (e.g. contract drafting, accounting, public relations, etc.).

As demonstrated in the four Japanese projects/programmes studied in this report, only large laboratories, housed in large and well-funded universities, have the ability to do capacity building programmes. In fact, even large laboratories sometimes need to team up and share the burden for the most ambitious projects, which can lead to managerial conflict, like in the case of the MicroDragon project. Smaller laboratories and smaller universities are doomed to be excluded from such ventures or enclosed into a supporting role if invited to join a consortium led by a larger laboratory.

Japan can boast a large number of small to mid-size universities having developed a deep expertise in a specific field. A small institute of technology working on specific communication components or a laboratory having developed an innovative camera could prove to be extremely valuable additions to a consortium of large universities. However, in the current situation, there is no platform or mechanism to highlight the comparative advantages of each prospective capacity building donor and combining different prospective donors into an efficient consortium. Everything is still done based on the personal connections of prominent professors.

Finally, in addition to fostering the participation of small and mid-size universities in space technology development and utilisation capacity building programmes, it would be valuable to integrate relevant commercial providers in the consortia.

Need 1: national coordination mechanism to identify and combine the most appropriate capacity building providers, according to the needs for the recipient

3.1.2. Lack of satellite testing infrastructure in universities

Japan currently suffers from a lack of small satellite testing infrastructure, which limits the development of small satellite projects across the countries. While Kyutech possesses comprehensive and advanced facilities, they are not sufficient to cover the demand of domestic organisations and international partners. Apart from Kyutech, there exist smaller facilities in the laboratory of Professor Torii on Waseda University's Kikuicho campus[26] and at the Industrial Technology Centre of Fukui Prefecture.

The lack of infrastructure can mostly be explained by two reasons:

1. The cost of the equipment itself and the difficulty to make a profitable, or at least sustainable use of the facilities. The development of facilities should therefore be made with the goal of pooling the resources of different universities or private companies.
2. The cost of the floor space. Testing facilities require extensive facilities, which is extremely complicated in some parts of the countries. In fact, during our field visit to Kyutech, Professor Cho explained to us that one important reason why he developed testing facilities in Kyutech and not in Tokyo was that the rent in Kyutech's Tobata Campus in Kita-Kyushu is around ten times cheaper than at The University of Tokyo's Hongo Campus is central Tokyo.

The Northern half of Japan, far from Kyutech, would strongly benefit from the establishment of joint testing facilities in the Tohoku region. Currently, the small number of satellite testing facilities is a bottleneck for the emergence of more small satellite development programmes in Japan. As said by Professor George Maeda of Kyutech, the creation of additional testing facilities across Japan could help the establishment of "numerous BIRDS-like programmes".

Need 2: more small satellites testing centres across Japan

3.1.3. Reliance on professors' personal connections

While personal connections are important for the initiation of university consortia for space technology development and utilisation capacity building programmes

[26] More information can be found here: https://www.waseda.jp/top/assets/uploads/2016/08/285efa0e6d58b82f8e9b4e0d748dbd9b.pdf

(e.g. Tohoku and Hokkaido Universities for PHL-Microsat and the five-university consortium for MicroDragon), they are even more critical for the initiation of partnerships with Japanese universities, from the perspective of recipient countries: Professor Nakasuka's experience with the VNSC during the PicoDragon project led to the realisation of the MicroDragon project, Professor Takahashi's personal encounter with DOST Secretary Montejo was the starting point of PHL-Microsat, etc.

In fact, with the exception of the BIRDS programme, the capacity building programmes studied in this report have all relied on the personal connections of Japanese professors, who initiated projects independently within their own laboratories. The BIRDS programme's situation is more nuanced as Kyutech is openly promoting it and encouraging motivated countries to submit an application. Therefore, past participants include organisations contacted by the Kyutech team while others have directly reached out to Kyutech (e.g. Bhutan during BIRDS-2).

Therefore, the main question is: how can a country without specific connections with prominent Japanese space engineering professors benefit from capacity building support? In the current situation, there is no systematic framework to connect interested countries with university laboratories willing to provide capacity building services.

Need 3: national point of contact to connect prospective recipients with prospective donors

3.1.4. Concerns on continuity and stability

As demonstrated in the previous section, the initiation of capacity building programmes is highly reliant on university professors' personal choices and decisions. In addition to the problems that it poses on domestic coordination and for foreign organisations without pre-existing personal relations with Japanese professors, this dependency on a few individuals endangers the continuity and long-term sustainability of Japanese university-led capacity building programmes. What if the professor leaves or is incapacitated? Most programmes would simply end, and the expertise acquired by a laboratory with regards to capacity building with developing countries would be lost.

Need 4: national repository of capacity building know-how

Need 5: extract programmes from their dependency on each professor

3.2. Government-related weaknesses

We identified weaknesses of Japanese university-led capacity building programmes directly related to the shortcomings of the central government.

3.2.1. Inadequate strategic vision of the central government

All the Japanese experts interviewed for this study regretted the inadequate strategic vision of the central government – in particular of the Cabinet Office's National Space Policy Secretariat – with regards to space technology development and utilisation cooperation with developing countries.

In fact, numerous professors consider that their capacity building activities could contribute greatly to the achievement of Japanese foreign policy goals by initiating pragmatic working relations with foreign countries bearing some interest for the Japanese government. However, what are the Japanese foreign policy goals with regards to space cooperation with developing or emerging nations? Which countries are diplomatic priorities? When trying to get an answer to these very basic questions, professors are faced with a void.

Based on the experience of some interviewees and of this report's authors, the Japanese Cabinet Office, instead of being proactive, tends to try to benefit from the *fait accompli* of projects initiated independently by universities. With even a minimum of strategic vision, the Cabinet Office could maximise the benefits for the country of this strong diplomatic tool that are Japanese university-led capacity building programmes.

However, it is critical to specify that strategic orientations developed by the government would serve as *recommendations* not as *instructions*, owing to the fact that Japanese universities are autonomous.

In addition, while support from the central government (e.g. strategic, diplomatic, financial) is much welcomed by Japanese universities, some professors pointed out that it should remain *only support.* According to their experience, a strong involvement of the central government could repel foreign partners, unwilling to deal with heavy Japanese bureaucratic processes.

Need 6: the government should develop a national strategy on space cooperation with developing countries, to inspire partnerships

Need 7: the government should not have a too strong direct involvement in partnerships as it could frighten foreign partners

3.2.2. Expiration of JAXA's Strategic Partnership programme with selected universities after FY2020

As part of this study, we expressed our concerns to JAXA regarding the expiration of the Strategic Partnership programme at the end of FY2020, and the huge impact it may have on university CubeSat programmes and therefore on the ability of Japanese universities to provide affordable space technology development and utilisation capacity building programmes to developing countries.

JAXA's answers to our concerns, obtained with the help of the MEXT administrators, are summarised in this paragraph. From FY2021, deployments from the J-SSOD will be mostly operated by commercial operators SpaceBD and Mitsui Bussan Aerospace, therefore realising the "promotion of economic activities on the low earth track including the ISS" described in the Basic Space Plan formulated in June 2020. However, recognising the contribution of the Strategic Partnership programme, JAXA is currently considering how to balance the plans for LEO commercialisation with the support to the development of skilled human resources in Japanese universities.

According to different interviewees, JAXA is considering continuing to offer discounted rates for project involving a foreign developing country. While it can seem attractive in the context of capacity building service provision, we think that this approach could prove highly detrimental to Japanese academic small satellite builders and operators. Under the Strategic Partnership programme, JAXA supports selected universities' satellite deployment, enabling them to support foreign countries. It therefore supports both the development of purely domestic academic capabilities in Japan as well as projects with foreign partners. However, the new approach supposedly envisioned by JAXA would sacrifice all purely domestic projects on the altar of international development. JAXA is a Japanese government agency with the mandate to expand space capabilities in the country. JAXA is not JICA and should basically work in the interest of Japanese stakeholders, *a fortiori* national universities, and not prioritise the needs of foreign countries at the expense of the vibrant academic small satellite community. Concretely, such approach could create highly unfavourable situations. In the case of BIRDS, for example, foreign teams would benefit from affordable deployment costs while Japanese teams would have to pay the full commercial rate.

However, even if its upholding would be a great news, JAXA's Strategic Partnership programme suffers from one important limitation: is it only granted to very few large universities (e.g. The University of Tokyo and Tohoku University) which according to JAXA's criteria, "have a track-record of releasing microsatellites".[27] It therefore bars other smaller universities to benefit from affordable satellite deployment contracts, unless they partner with the selected large universities.

This practice contradicts the spirit of small satellite development, which aims to provide affordable space education to everyone, regardless of the size, budget or historical prestige of the institution one belongs to. It seems also surprising for a public agency to grant preferential partnerships to selected national universities.

Need 8: ensure affordable satellite deployment opportunities for all Japanese universities

[27] In Japanese: 「超小型衛星放出の実績を有する大学」

3.3. Programmatic weaknesses

Programmatic weaknesses relate the contents of the capacity building programmes analysed in this study.

3.3.1. Excessive focus on engineering and science

As explained in section 1.1.3, universities have a strong comparative advantage in the provision of capacity building services thanks to the multifaceted expertise that they have in their various schools and departments.

However, in the current situation, social sciences are generally excluded, or at least underrepresented, in capacity building programmes, even though they have a key role to play in the long-term sustainability of the recipients' space activities. There are examples of space law and policy education in some of the programmes studied in this report (e.g. Dr Verspieren taught RWASAT-1's interns and Dr Werner Balogh teaches space law to students in Kyutech's Space Engineering International Course), but they remain marginal, partially due to the lack of internal coordination within large universities.

Need 9: enhance intra-university coordination leveraging all relevant departments of the university, to include social sciences in capacity building programmes

In the case of small universities not possessing the wide range of expertise existing in major national universities, then coordination needs not be internal but with other universities or private partners, hence further justifying **Need 1**.

3.3.2. Limited concerns about knowledge retention in recipient organisations

As demonstrated in Chapter 5 with numerous examples, although capacity building programmes are almost always successful in transferring knowledge to recipient organisations, there is very little concern from the donor's side regarding the ability of the said recipients to retain and develop this knowledge. Numerous reasons were identified such as the absence of long-term technology development and utilisation strategic vision when starting the capacity building project, of appropriate personnel and knowledge management strategies, etc.

But why would it matter for Japanese academic providers? It matters because even capacity building programmes fully paid for by the recipient consume Japanese resources: tax money funding the professors' tenures, the facilities and initial technology development costs; time of professors, researchers and students that can have been devoted to a better use; support from government agencies for diplomacy, frequency registration, etc. The loss of the recipient's acquired knowledge is therefore an unacceptable waste of tax money and precious time. It is thus critical that the definition of a strategy for the long-term retention and further development of the knowledge transferred is carried out before starting, or is included as an action item in the capacity building programme.

Need 10: ensure that the knowledge transferred will be retained before initiating a programme

For good practices on ensuring knowledge retention in recipient countries, see Chapter 5, section 3.

3.3.3. Limited involvement of the private sector

This final section does not concern a weakness *per se* but rather an area for improvement. Although most non-Japanese academic donors studied in this report made the choice to offload their capacity building activities to a spin-off company, Japanese programmes are all led by university laboratories. The only exception being the logistical and administrative support provided to capacity building projects of The University of Tokyo's Intelligent Space Systems Laboratory by its spin-off Space Edge Lab Inc. (now ArkEdge Space Inc.).[28] Based on the lessons of foreign providers, university laboratories can only conduct programmes limited in scale. Establishing a pure commercial service provider is a way to break these limits.

Beyond the use of university spin-offs to scale up activities, another issue concerns the involvement of private providers in university-led capacity building programmes. Most of the programmes develop satellites and components in-house with limited reliance on commercial providers. The right balance between what can and should be done by the laboratory and what can and should be done by a commercial contractor is an issue that each laboratory involving in capacity building should carefully consider. In turn, more interactions with private entities will support the development and strengthening of an ecosystem enabling the emergence of more small satellite programmes in Japan.

Need 11: facilitate responsibility sharing with private contractors

4. Recommendations

This report's final recommendations are mirroring the areas for improvement identified in the previous section, and incorporate the conclusions of chapters 4 and 5, focussing on improving, respectively, the diplomatic and educational effectiveness of Japanese university-led space technology development and utilisation capacity building programmes. Four main recommendations are provided below.

[28] Dr Verspieren, co-author of this report, is an executive at Space Edge Lab. Inc. and subsequently at ArkEdge Space Inc.

4.1. Establishing a national coordination mechanism for capacity building providers

Our first and main recommendation, addressing most of the needs identified in section 3, is the establishment of a national coordination mechanism for capacity building providers, as illustrated by figure 7-2. Although this framework was developed with space technology development and utilisation capacity building in mind, all the elements presented here can be applied to other fields of technological capacity building.

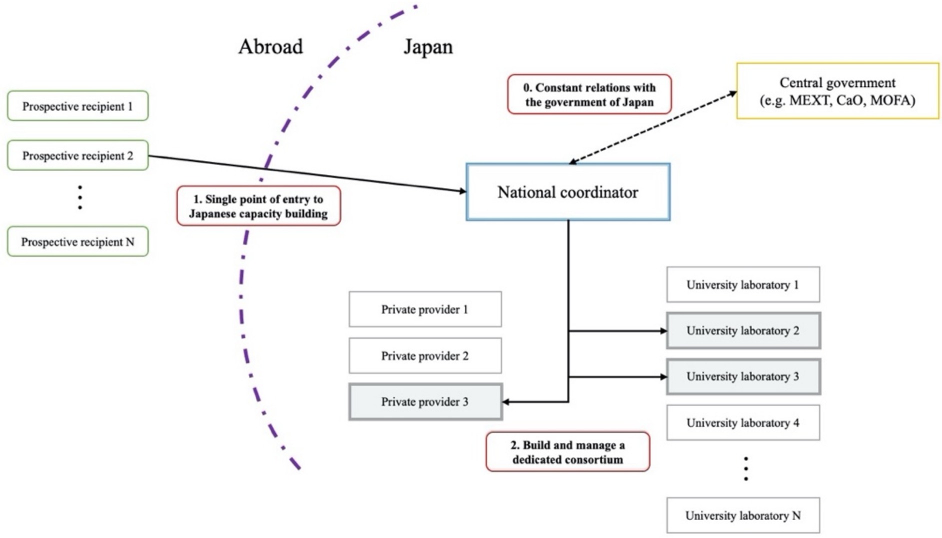

Figure 7-2. Simplified chart of the role of the national coordinator for capacity building

4.1.1. Benefits of the national coordination mechanism

The establishment of a national coordination mechanism would provide a series of benefits, addressing most of the needs identified in section 3, as shown below.

Benefit 1: coordination of all national actors

The primary benefit of the establishment of a national coordination mechanism is to facilitate the creation of consortia including potential capacity building providers otherwise excluded unless they had a direct connection with one of the leading actors of the field (e.g. The University of Tokyo, Kyutech). This includes smaller universities (**need 1**) and private companies (**needs 1 and 11**). In addition to connecting different types of actors, such a framework would also facilitate connections between mission experts and bus/hardware experts, like in the very successful collaboration between Hokkaido and Tohoku Universities.

However, coordination should not be done at the expense of competition. As highlighted by Professor Takahashi of Hokkaido University during the final review workshop, some capacity building projects can unlock important external funding for the provider, as was the case of Hokkaido and Tohoku Universities with the PHL-Microsat programme. Therefore, rather than merely building consortia, the coordination mechanism should organise a fair and open competition among different potential providers.

Benefit 2: single point of contact for prospective recipients

Apart from coordinating domestic players, the national mechanism would serve as a single point of contact for prospective recipients, whose opportunities to benefit from a capacity building programme is often contingent on existing personal connections with a Japanese university professor (**need 3**). In addition to facilitating the contacts between recipients and donors, the mechanism would possess enough expertise to evaluate the requests of prospective recipients before proposing them to prospective donors. It includes, for instance, making sure that the recipient has developed appropriate measures for knowledge retention and for the long-term sustainability of its nascent programme (**need 10**).

Benefit 3: centralised repository of knowledge

Due to the fragmented nature of Japanese university-led capacity building efforts, each new provider has to restart from scratch, without benefitting from the knowledge acquired by its peers. This report is the first attempt to collect and compile information, lessons and good practices from past programmes. A national coordination mechanism would serve as both a repository of capacity building know-how (**need 4**) as well as an information platform collecting data on the space development situation of developing countries (**need 6**), potentially supporting governmental strategy-making on collaboration with emerging space nations.

4.1.2. Legal status: government or independent non-profit?

After justifying the benefits of establishing a national coordination mechanism for capacity building arose the question of its legal status: should it a government or an independent non-profit organisation.

Based on our analysis as well as the unanimous feedback of experts consulted during the interview campaigns and the final review workshop, we recommend the establishment of the mechanism as an independent non-profit organisation.

The direct involvement and supervision of the government would not provide any particular benefit to both capacity building providers and recipients, but only to the government itself, which would be able to impulse partnerships with specific countries rather than others. However, an immediate downside of the involvement of the central government would be the reluctance of prospective recipients to deal with the Japanese bureaucracy, hence offsetting part of the apparent benevolence of academic providers of capacity building services (**need 7**).

On the other hand, an independent non-profit mechanism, that could be based on the successful example of the University Space Engineering Consortium (UNISEC), would provide a series of benefits. Thanks to its independence from the central government as well as its non-profit nature, the coordination mechanism would be perceived as benevolent from the perspective of recipients, without hidden political, diplomatic or commercial agenda. In addition, it would be seen as an independent source of unbiased knowledge about Japanese capacity building activities with developing countries. Finally, the central government itself could benefit from having a third-party platform for discussion among various ministries and agencies, apart from the sometime fastidious official interagency coordination processes (e.g. at the Cabinet Office) (**need 6**).

4.2. Internal schemes to foster capacity building programmes in Japanese universities

This report's second recommendation is to develop internal schemes to foster capacity building programmes and support innovation, within Japanese universities engaging in capacity building services.

Increased internal coordination in Japanese universities would provide a series of benefits for the provision of space technology development and utilisation capacity building services:

- Reinforced support of university headquarters to laboratories engaged in capacity building, in particular for internationalisation and communication (e.g. translation, press releases, organisation of outreach events).
- Inclusion of space capacity building in the strategy of the university as a whole, therefore removing the dependency of capacity building programmes on one single laboratory or professor (**need 5**).
- The ability to provide full capacity building packages including engineering, science, project management, law and policy, by leveraging the expertise present in the various schools and departments of the university (**need 9**).
- The university headquarters could support the establishment of spin-off companies from laboratories doing capacity building, following the example of Surrey Satellite Technology Ltd (**need 11**).

Reinforcing university headquarters' involvement may prove to be a very difficult objective in the case of large universities, in which dozens, if not hundreds, of world-class laboratories are shining in their respective fields. Professor Yoshida of Tohoku University and Professor Nakasuka of The University of Tokyo have explained that their respective headquarters have shown very limited interest in their activities and very little subsequent support (for instance to recruit one more assistant professor). They doubt that university headquarters would make a step towards them without clear signals sent by the central government and in particular the MEXT on the strategic importance of space technology development and utilisation capacity building for the country's diplomacy.

4.3. Establishing geographic poles for satellite assembly and testing in Japan

The shortage of satellite testing facilities has been identified in this report and by the experts consulted for this study as one of the major factors limiting the emergence of more university small satellite projects in Japan and therefore of associated capacity building programmes.

We therefore advise the government to fund the establishment of additional small satellite testing infrastructure (**need 2**), in particular in the northern half of the country, far from the equipment available in Kyutech and in selected centres in Kansai (Fukui Prefecture) and Kanto (Waseda University). This could be done in collaboration with a local university (e.g. Tohoku University).

Due to the heavy initial establishment costs, governmental support would be indispensable. The maintenance costs of the facilities would be covered by the existing demand for satellite testing, and sustained by the future demand generated by the small satellite projects that additional pieces of testing infrastructure will enable.

As said by Professor Maeda of Kyutech, more testing facilities would allow the positive emergence of BIRDS-like programmes across Japan.

4.4. Regulatory and/or promotional tools available to the MEXT

Apart from the three previous areas of recommendations that would require a coordinated effort of government, commercial and academic stakeholders, specific measures can be independently taken by the MEXT in order to promote and facilitate university-led space technology development and utilisation capacity building programmes with developing countries.

4.4.1. Funding targeted to international capacity building

When asked what forms of governmental support would be the most beneficial to their capacity building activities, most Japanese university professors answered: “scholarships, more scholarships and again, scholarships!”.

We therefore recommend the MEXT to create, in addition to its existing generalist scholarship programs (e.g. embassy or university MEXT research scholarship), official development assistance (ODA) grants dedicated to space education.

Such activities would perfectly embody the dual nature of the ministry. Having been established in 2001 by the merger of the former Ministry of Education and the former Science and Technology Agency, the MEXT retains two identities, which in this case, would cover, respectively university/education policy, and science and technology development and diplomacy. As demonstrated throughout this report, space technology development and utilisation capacity building with foreign countries is at the interface of these two missions of the MEXT.

4.4.2. Maintaining affordable J-SSOD small satellite deployment opportunities after FY2020

The final recommendation of this report concerns the future of affordable J-SSOD small satellite deployment opportunities, one of the major comparative advantages of Japanese university-led space technology development and utilisation capacity building programmes. We identified four possible scenarii and advise the MEXT to discuss their applicability with JAXA.

Scenario 1: maintaining JAXA's Strategic Partnership after FY2020, without change

The first scenario is simply to maintain JAXA's Strategic Partnership with selected universities beyond FY2020, without modification. While it would be satisfying as the current existing partners are the universities deploying the most CubeSats in Japan, in particular as part of capacity building programmes for the benefit of developing countries, the choice of only three large universities constitutes as, explained in section 3.2.2, an inappropriate breach of the principle of equity of government support to all universities.

Scenario 2: maintaining JAXA's Strategic Partnership after FY2020 and expanding the membership

The second scenario addresses the breach of equity inherent to the existing Strategic Partnership by allowing any university to join it, and therefore benefit from affordable deployment opportunities.

Scenario 3: direct contract with JAXA for affordable deployment

The third scenario generates the same results as the second one but removes an unnecessary step. Under the current situation, to benefit from affordable J-SSOD deployment, selected universities need first to conclude a strategic partnership agreement with JAXA before signing a deployment contract (including a discounted rate) for each satellite launch. We recommend removing the first step, in other words the Strategic Partnership agreement itself, to allow all universities to directly sign an affordable deployment contract when necessary.

Scenario 4: subsidising contracts made with commercial providers

The fourth and final scenario concerns a point raised by JAXA interviewees when proposing scenarii 1 to 3: giving preferential treatment to specific universities would violate the commercialisation agreement conclude by JAXA with SpaceBD and Mitsui Bussan Aerospace. Apart from the fact that the argument contradicts JAXA's apparent plans to provide preferential rates to foreign partners, a simple way to circumvent it would be to provide discounted rates through commercial providers.

In fact, according to some information that we collected, most of the deployment cost charged by SpaceBD and Mitsui Bussan Aerospace is the cost that JAXA charges to them for using the J-SSOD. It would therefore be extremely simple for JAXA to charge commercial deployment services providers less when they work with Japanese universities.

Table 7-1. Impact of the recommendations on the needs derived from the weaknesses of Japanese university-led capacity building programmes

	Need 1	Need 2	Need 3	Need 4	Need 5	Need 6	Need 7	Need 8	Need 9	Need 10	Need 11
4.1. National coordination mechanism for capacity building providers	N/A										
Scenario 1: Government-led national coordination mechanism	○		○	○	○	○	×			○	○
Scenario 2: Independent non-profit national coordination mechanism	○		○	○	○	○	○			○	○
4.2. Internal schemes to foster capacity building programmes in Japanese universities					○				○		○
4.3. Establishing geographic poles for satellite assembly and testing in Japan		○									
4.4. Regulatory and/or promotional tools available to the MEXT	N/A										
4.4.1. Funding targeted to international capacity building	Beneficial for capacity building programmes beyond specific needs										
4.4.2. Maintaining affordable J-SSOD small satellite deployment opportunities after FY2020	N/A										
Scenario 1: maintaining JAXA's Strategic Partnership after FY2020, without change								×			
Scenario 2: maintaining JAXA's Strategic Partnership after FY2020 and expanding the membership								○			
Scenario 3: direct contract with JAXA for affordable deployment								○			
Scenario 4: subsidising contracts made with commercial providers								○			

Positive impact: ○ Negative impact: ×

APPENDIX. DETAILS OF THE FINAL REVIEW WORKSHOP

Date	5 January 2021
Time	13:30 – 15:30
Place	Online (Zoom)
Participants (titles omitted)	*Project members* ▪ Hideaki Shiroyama, The University of Tokyo ▪ Shinichi Nakasuka, The University of Tokyo ▪ Quentin Verspieren, The University of Tokyo ▪ Yuichiro Nagai, Nihon University *MEXT administrators* ▪ Emiko Ishida, Yokohama City Board of Education *Guest experts* ▪ Mengu Cho, Kyushu Institute of Technology ▪ George Maeda, Kyushu Institute of Technology ▪ Kazuya Yoshida, Tohoku University ▪ Toshinori Kuwahara, Tohoku University ▪ Yukihiro Takahashi, Hokkaido University ▪ Rei Kawashima, UNISEC
Agenda	13:30 – 13:40 Opening remarks and presentation of the project (Shiroyama) 13:40 – 14:25 Presentation of the work and conclusions of the study (Verspieren) 14:25 – 15:20 Free discussion among participants 15:20 – 15:30 Wrap-up and closing remarks (Shiroyama)

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