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Cooperation and Capacity-building of Asia-Pacific Countries for Space Exploration

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Abstract

Although space exploration is repeatedly characterized as an endeavor uniformly accessible to all humans, few countries since the USA and USSR/Russia in the mid-1900s have had the economic and geopolitical capacities to develop into major space-faring nations, causing inequalities in space-based utilities and development. While many partnerships and capability-sharing agreements have been formed to assist with capacity-building, there are still specific niches and sensitivities that can only be addressed through sovereign capability development. Recently, however, coordinated efforts via private or state partnerships have opened opportunities for emerging and non-space-faring nations to participate in space exploration. In the Asia-Pacific (APAC) region, several frameworks exist for collaborative missions through cooperation and knowledge-transfer. Further expanding this ecosystem involves crucial considerations in the hows and whys of participating in space exploration. Efforts in characterising specific entry points into these cooperative frameworks must be made, leveraging the unique assets of a country. A set of recommendations was drafted during the four-day Asia-Pacific Space Generation Online Workshop 2020 wherein these issues were discussed through working groups composed of university students and young professionals from the APAC region. Three core aspects of regional collaboration for space exploration were identified. These include: (1) space-based data exploitation; (2) uncrewed space exploration; and, (3) crewed space exploration. In data exploitation, element standardisation is critical to lower barriers for entry and easing clear international regulations drafting, development of APAC satellite sensor suite; boosting AI and Big Data Value-Chain Distribution; and shared-formulation model for capacity-building programs. For uncrewed space exploration, collaboration can be found through joint space projects initiated by the APAC space-faring nations such as Japan, India, and China; early competence-development through scalable regional space exploration competitions; development of a multi-nation satellite, both as a platform for knowledge-transfer and sustained collaboration; and popularization of spin-in technologies to gain public support for exploration. For human space exploration, regional collaboration can spring from leveraging the rich geography, history, and culture of the APAC nations. To accomplish this, grassroot-level curriculum should be developed and integrated with easy analogue missions. Fundamental cross-border research on APAC-specific aspects of health, psychology, and diversity should also be done to address the current lack of data, with particular emphasis on the Asian and female physiology. These identified facets should allow a coherent drafting for a proposed framework of cooperation that will eventually lead to economic development of these nations and strengthen geopolitical relations.

Keywords: space exploration, regional cooperation, APAC, capacity-building

Chapter 1: Introduction

The emergence of new business models, fresh developmental frameworks, and unique multi-sectoral entry points to space exploration evidently spurred the rise of space exploration initiatives in the Asia-Pacific (APAC) region making it a noticeable player in the past half-century! No longer is space exploration monopolized by Western space-fairing world powers, but Asia-Pacific nations have also demonstrated aggressive efforts to join the *"space race"*. However, as such ambitions often require colossal resources, only three countries in the region have full-fledged space exploration capabilities, namely China, Japan and India with mature economies such as Thailand, Singapore, South Korea, and Australia not far behind. This is due to the fact that there is still a large gap in terms of which nation possesses the capabilities to be involved in space exploration.

According to a 2018 data published by Euroconsult, expenditure in space programs have largely increased in the last half-decade, with several APAC countries included in the global top spenders for space programs. These APAC nations include China ($5.8 B), Japan ($3.1 B), India ($1.5 B), South Korea ($ 593 M), Australia ($ 272 M), and Indonesia ($ 205 M) [28]. The highest expenditure and lowest expenditure of these APAC top spenders represent 107.41 % and 3.80 % respectively of the 2018 *average* GDP of the entire region ($5.4 B) [. This clearly shows the wide gap in terms of how much nations are willing to and can invest for space exploration!

In the APAC region, motivations for space programs are largely due to governments putting up their indigenous infrastructure to cater to their nation's needs from disaster management, to economic development, to national security. This theme on the primary use of space technology is common amongst APAC nations, which eventually made it obvious to these government units that their nations' endemic needs far outpace their efficiency to build space technology solely on domestic capacity and resources. As of date, emerging space nations have largely banked on forms of collaborative or cooperative strategies either with advanced space-faring countries or with local and international private partners to create solutions:

- The Philippines has been working with Japan for knowledge transfer for building satellites leading to the development of Diwata-1, Diwata-2, Maya-1, and Maya-2 [27].
- Malaysia strengthened its framework for enlisting the private sector to pursue space technology initiatives so as to share the costs [22] along with shared-infrastructure arrangements with other nations such as Thailand, Indonesia, and Singapore. Cooperative strategies also include maintaining existing agreements with other countries for launching, to leave room to focus on other space applications instead of building their own launching capabilities [12].
- Interestingly, Indonesia has laid down a long-term master plan to incubate homegrown space capabilities to future-proof their nation in case of volatility in international relations. However, officials have shown that the plan for a *commercial equatorial space port* will be a cooperative work with a commercial partner [29].

Due to the intricacy of space exploration, most APAC countries bank on cooperative or collaborative initiatives to participate. Currently, the cooperative ecosystem in the region is a bifurcation scheme in which the two primary leaders are China (APSCO) and Japan (APRSAF). The fact that there exists cooperative frameworks does prove the desire to create a regional *institution* to promote cross-border activities for space exploration. There are notable differences in both each framework's priorities and approaches, differences which can be taken as a driver for innovation. However, some may view it as more of a competitive effort to draw smaller nations to one's side, a rather counterintuitive effect as to what a *cooperative* framework should be promoting. Nevertheless, both initiative's existence and experience demonstrate that in the APAC region, pooling in capabilities through healthy cooperation definitely paves the way to more fruitful space exploration activities.

Understanding regional cooperation for space exploration for the APAC region was one of the key subjects discussed during the Asia-Pacific Space Generation Online Workshop (APSGOW) 2020 which was hosted by the Space Generation Advisory Council (SGAC). Conducted last November 2020, the workshop was meant to gather perspectives of students and young professionals on different aspects of space and its sustainable use. One out of the four working groups engaged in discussing the current state and future possibilities of cooperative space exploration in the APAC region by involving a gender-balanced group composed of 19 delegates (10 males and 9 females) representing ten (10) Asia-Pacific countries from both technical and non-technical backgrounds.

Regional cooperation for space is a multifaceted action. Thus, for the working group whose discussions are summarized in this paper, the focus was limited to **space exploration** alone with scope limited to the Asia-Pacific region's cooperative ecosystem. From hereon, the delegates defined space exploration as any space activity that involves any form of *human's presence*, utilization of any assets, or activities intent to pave the way to go beyond the Earth's atmosphere. As such, discussion for creating the set of recommendations for regional cooperation for space exploration in the APAC region was divided into a) uncrewed space exploration, b)human space exploration, and c) space-based data exploitation. These three (3) subgroups were determined as the proper way to adopt such that it partitions well but with good generalizability the aspects of space exploration, allowing the discussion to be focused but encompassing.

For each aspect of space exploration, the working group worked on answering the following focal questions:

a) What **niche area** of space exploration **can be contributed to by emerging or non-space actors** (e.g. Mars or Moon analog mission in desertic areas of central Asian countries)?

b) How would participation in an advanced neighbour's space exploration program b**enefit an emerging or non-space country**?
c) How can **national capacities be encouraged** to consider technological developments for space exploration specifically in non-space-faring countries?

Ultimately, each sub-group is meant to inspect in detail the above-mentioned questions with regards to nurturing a regional cooperative ecosystem **by presenting sets of recommendations tailored for each** aspect (the three sub-groups) of space exploration aspect's and its unique paradigms, its nuances, or its demands as has been demonstrated in the past or is currently seen. The delegates also determined that the following key stakeholders are common across all the aspects and they play a crucial role in developing regional cooperative efforts: Academia, Industry, National Space Agencies, and Non-Government Organizations (NGOs). Thus, summarized in this paper would be the set of recommendations for each of the three aspects, the rationale behind these recommendations, and the call to action. The recommendations were drawn out of a focus-group discussion framework These recommendations drafted by the working group are aimed to provide insights to the relevant stakeholders as to how the current regional cooperation looks, and what are the necessary innovations to existing frameworks towards a sustainable use of outer space.

Chapter 2: Methodology

2.1. Organization and Structure

This study's Focal Group Discussion (FGD) was a gender-balanced working group of nineteen (19) participants representing ten (10) different countries across the Asia-Pacific region, who attended the Asia-Pacific Space Generation Online Workshop (AP-SGOW) 2020 organized by Space Generation Advisory Council (SGAC). The working group's participants were from diverse cultures, and various (STEM and non-STEM) fields with common interest in space. The discussions were carried out on an online platform and led by two moderators. The moderators led the direction of the discussions through the enumerated *focus questions* described in the previous section. The working group was then subdivided into three subgroups: [1] uncrewed space explorations, [2] human space explorations, and [3] space-based data exploitation. The participants chose their subgroups according to their preferences.

2.2. Adopted Concept

Focus group discussion (FGD), a qualitative method and essentially social in its structure, is the primary method for this study. An FGD aims to better understand how a group of individuals with common experience or traits think or feel about a topic. These commonalities form the creating *groups* in the sociological sense which is an accommodating environment that permits participants to impart points of view without obligating participants to vote or hit consensus. Subsequently, meticulous and systematic analyses of the discussions produce insights and clues as to how an idea or opportunity is perceived by the participants [6].

2.3. Stakeholder Involvement and Research

Each subgroup had a representative, a young professional in the space industry and an active member of SGAC, who undertook the duty of reporting the minutes of each meeting. The subgroups developed their answers highlighting key areas such as law and policy, education and outreach, economic development, technology development, international cooperation, and workforce development. Each member in a subgroup contributed with data collection through various sources from scientific journals and articles, or their experience related to the subject. These subgroups also worked out the commonalities between each subgroup, and provided a diversified opinion across subgroups to improve the recommendations. Data were also obtained from insights of experts who are already engaging through space-related cooperation and capacity-building activities in the APAC region. These experts were Dr. P.V. Venkitakrishnan, *Director of Capacity Building Programme Office, Indian Space Research Organisation (ISRO) Propulsion Complex* as our working group keynote speaker, and two subject matter experts, Ms. Nandia Shatar, *Foreign Affairs Officer of the Mars-V Project at the Mongolian Aerospace Research and Science Association (MARSA)*, and Ms. Soyoung Chung, *Coordinator of the International Space Exploration Coordination Group (ISECG), Korea Aerospace Research Institute (KARI)*.

The preliminary study was presented during the online workshop. All of the comments, suggestions, and recommendations coming from the other participants/audience were all noted and considered valuable to the study. Afterwards, the whole working group virtually met to consolidate and filter out all the ideas or suggestions, then finally arriving at these satisfactory '*preliminary recommendations*'. The recommended processes for regional cooperation were presented along with other nuances often considered when planning regional cooperation and the potential way to address them. All of the preliminary recommendations from the preliminary study were then brought forward into consideration by the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS)-UNOOSA and other Space cooperation organizations in the Asia Pacific region after the online workshop.

Chapter 3: Results and Discussion

3.1. Uncrewed Space Exploration

The approach proposed in this section leverages the unique advantages of each country to exchange technical expertise and strengthen regional relationships. The recommendations below extend far beyond just the technical aspects of space education and human resource development in non-space faring and emerging-space nations.

3.1.1. Capacity-building from an Economic Perspective

One of the main differences between space-faring nations and emerging space or non-space faring nations is the development and socio-economic situation of the country, (i.e. the Gross Domestic Product or GDP index). According to the International Monetary Fund (IMF), the GDP measures the monetary value of final goods and services produced in a country in a given period of time [5]. GDP is important because it gives information about the size of the economy and how an economy is performing. The growth rate of real GDP is often used as an indicator of the general health of the economy, including the national budget allocated for its space sector's development and collaboration activities.

As an example, the flowchart below in *Figure 1* recommends a series of possible space-related projects for collaboration, with increasing complexity and technical challenge from left to right. The aim of this series is to establish a local national space capacity across the space value chain through collaborative efforts. Note that different nations may face different challenges to realise each step (eg. geographical constraints).

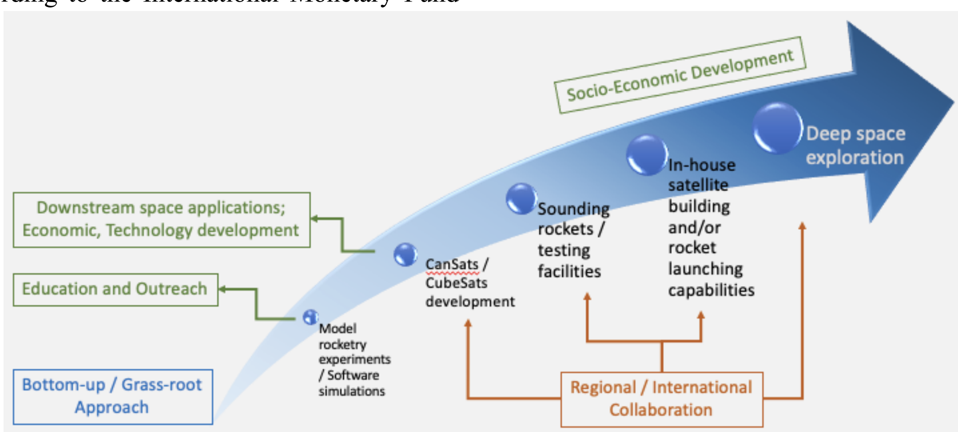

Figure 1: A flowchart illustrating a series of project-based capacity building in increasing complexity for countries of various GDP to be involved in.

Starting with a bottom-up approach, governments and NGOs from emerging space nations can organize small satellite launch competitions taking inspiration from NASA's *CubeSat Launch Initiative Program*. This program has enabled university students to launch their CubeSats and payloads in space through a ride-share in one of NASA's rocket launches to the International Space Station [30]. Similarly, space-faring nations in APAC can offer a ride-share to student-built small satellites to make space more accessible for non-space faring nations. Other similar projects might include establishing a high-power rocketry competition and designing Mars or lunar rovers. Through small scale and frequent involvement, the society will start adopting it as a norm, therefore spreading awareness, interest, and further education.

The second level onwards involves more technology research and development, progressing from student projects to professional work. The academia and the industry starts playing an increasing role where small practical collaborative projects can be initiated, with support from its country's space agency. Internship opportunities could be offered to graduates and young professionals from the non-space faring nations [9][37]. Moreover, organising cooperative training sessions for fresh graduates like UNNATI organized by ISRO [36] that provides a theoretical course on satellite technology and hands-on training on satellite assembly can help in human resource development. In these types of collaborations, we also need to assess how the space-faring nations can gain benefits by allocating their resources to the non-space faring nations. Even though the non-space faring nations do not have the required expertise in the space industry, they can have better resources in other adjacent fields like manufacturing, materials, remote sensing or software development, which can also be spin-in to the space industry.

A successful example of project-based capacity building through collaboration was when Malaysia collaborated with Korea to build the RazakSAT [26] and was launched into orbit as the first commercial payload of SpaceX's Falcon 9 rocket. Although it was a CubeSat, that collaboration has spun out many expertise such as satellite engineering, ground post-processing of imagery data, mission analysis, launch procurement and contracts, etc. On a relevant note, the government or the space agency also played a major role in the successful collaboration by having suitable space law and policy in place to facilitate the industry's collaborative efforts. This emphasizes the need to have a flexible national space act that can encourage and empower other players in the space ecosystem to pursue space exploration.

3.1.2. Capacity-building through Multi-nation Satellites

The use cases of satellites apply to both space-faring and non-space faring nations regardless of their status in the satellite industry. From acquiring several technical advancements like an efficient point-to-multipoint distribution and increasing connectivity to rural areas to applying earth observation tools to monitor various problems, satellites promise more than just technical prestige [1]. However, non-space faring nations struggle to obtain the required license, funds, and insurance to launch their own satellites. The procurement and processing is far more challenging than the technical or engineering problems.

The proposal to establish a multinational satellite can eliminate these problems. The space-faring nations can host to build a micro-satellite bus, that acts as an adapter where-in the non-space faring nations can attach their payloads without having to spend resources on developing an entire satellite. This helps to solve two problems: a) the space-faring nations can take the burden of licensing and securing insurance since they already have pre-established policies and b) the non-space faring nations can invest resources on creating a payload relevant to their context. For example, a country like Thailand could design payloads that can detect illegal fishing [8] and an earthquake-prone country like Nepal can have payloads that can control the functionality of transponders to detect earthquake waves or have high-resolution cameras to detect the earthquake victims [10].

This type of collaboration requires a high-level contribution from the participating space agencies, academia, industries, and NGOs. The policy makers should be well aware of the potential and limitations of their own space laws. The space agencies must communicate with one another about their space laws and whether having a multi-national satellite demands any amendments. For this purpose, a workshop should be designed specifically for the policy makers so that they can establish a *standard Memorandum of Understanding (MoU)* to initiate such collaborations. The end goal should be to design a flexible space act so that the nations involved can collaborate without the intervention of the ongoing geopolitical issues.

Similarly, academia can chime in to impart educational resources to enable the workforce to develop such payloads. The ideas for payloads can be curated with the help of various NGOs specializing in market research and value-creation to solve the ongoing challenges. Whether the payloads are necessary for solving environmental issues like climate change or helping farmers develop agricultural mapping, the NGOs would know best when it comes to identifying the needs of their nations. In the development process of the payloads, the industry can help with acquiring raw materials, manufacturing, and shipping the payloads for assembly.

3.1.3. Capacity-building through Deep Space Exploration

The most established space-faring nations have specific space strategies for their successful space missions in terms of economic perspective, law and policy, and international relationship with clearly defined rationale. The emerging space and non-space faring nations should confirm that their strategies are appropriate considering the *common rationales* [17] providing benefits to society, facilitating socioeconomic development, increasing national prestige, gaining scientific knowledge, enhancing national security, fostering technical innovation, and inspiring younger generations [14]. Rationale is significant because it strengthens the national prestige and technical advancements. Australia was an active space nation in 1960s, but in 2000s, it became an example of a lack of rationale and non-active space nation. The Australian government established a clearly defined space strategy and policy to become an active space nation, and formed Australian Space Agency in 2018.

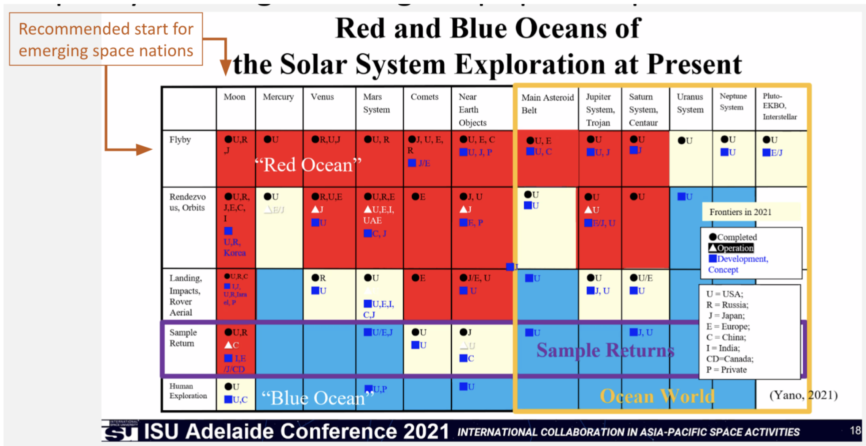

Figure 2: A table for red and blue oceans of the solar system exploration at present.

The sample return mission is included in the blue oceans and technologies present on the left side of *Figure 2* above and it increases in complexity as we go down the list. To operate a mission in the Blue Ocean, the flyby mission should happen first, but development of all required technologies for sample return mission might not be realistic for the non-space faring nations. Flyby missions are recommended for the emerging space or non-space faring nations while MoU/MoC should be promoted for knowledge transfer with APAC countries that have developed or conceptualized specific missions. For example, Japan and China could help in one or more technologies listed in order to achieve sample return missions since they are the most involved in space exploration. JAXA encourages international cooperation as the JAXA Hayabusa2 mission was accomplished and was supported by the Australian Space Agency, with the Department of Defence. Australian Space Agency played a significant role in re-entry within the WPA (Woomera Prohibited Area) by improving the accuracy of GPS navigation.

After the emerging space nation has a concrete strategy, the government and national space agency could use partners such as APRSAF and APSCO. Their participants are not all of each nation's space agency, but it includes universities, private companies and non-space related government offices [7].

The academic institutions could contribute in conducting knowledge-based online webinars and courses to provide certification in space education. Training and placement opportunities, competition or research involvement from doctoral projects could be a beneficial way to equip the next generation of young professionals.

Industry plays the development of space activities by assisting in manufacturing, research and development of the part for uncrewed space exploration. The space agency should identify the most relevant national company to collaborate with and support them to obtain necessary financial resources and knowledge transfer. This can help to establish the win-win scenario, especially in economic perspective from establishing space clusters.

3.1.4. Capacity-building through the Involvement of AI and Robotics

The nature of the space and satellite industry presents a quintessential use-case for Artificial Intelligence (AI). Some examples of application for AI in satellites and robotics include but are not limited to: In-Orbit Collision Avoidance Manoeuvres [4]; Near Earth ventures such as Abiotic Resource Extraction [3]; Mega satellite constellation Responsive Operations and Space Traffic Management [16]; Active Debris Removal [4]; Autonomous Navigation for rovers [3].

The APAC region should shift their mindset to start thinking and integrating AI as an opportunity for them to enter the space industry which won't involve huge investments as compared to building satellites. Potential developments in manufacturing, spacecraft control and coordination through AI would ease the challenging constraints on operators, government and agencies as well as boost productivity and growth in the downstream satellite industry which would in turn enable to drive down consumer costs, foster innovation, provide solutions to the issue of space debris and guarantee certainty for operators who find network coordination increasingly complex.The utilization of AI and robotics would enable deep space explorations which need to be carried out in remote, potentially hostile environments.

A strong legal framework should be laid down inorder to prevent the misuse of AI. This can be achieved by gathering a team of space lawyers from various countries in the APAC region and educating them on the potential issues and assigning them separate tasks to tackle those issues. Measures can be taken for space object registration. One of the drawbacks in the APAC region is the lack of capability and expertise to develop the AI-related projects for uncrewed space missions so the academic institutions across the region could form a network to work in collaboration so that they could develop joint courses for students in the region to get a deep insight into the AI technology. Thus, the gained knowledge could be used in developing a successful project for space explorations. Organization of collaborative AI-based projects by space agencies. For example, establishing an AI and robotics innovation hub in collaboration with APAC countries to generate income and boost profitability in numerous ways for the developing countries in the APAC region [35]. NGOs should organise forums to gather experts in the AI field around the region to discuss those issues and how to tackle them through regional cooperation [11].

3.1.5. Summary

Table 1. Summary of recommendations for APAC regional cooperation for uncrewed space exploration.

	Rationale	**Recommendations**	**Call to Action**
Economic Perspective	Different countries have different financial capabilities.	Involve in space cooperation and capacity building according to a nation's financial capability.	A series of project-based capacity building through cooperation, starting from a bottom-up approach for emerging space and non-space faring nations.
Building a multinational satellite	A lower cost of entry for emerging space nations	More complex project development (eg. launch) can be first handled by space faring nations	Governments of old and new space nations collaborate and take ownership of different aspects of the project. The key is for technical exchange of knowledge.
Deep Space Explorations	Encourages technological and economic development	To have a structured strategy for pursuing deep space exploration	Public-private partnerships and across the APAC regional collaboration to start with Blue Ocean space missions for building capacity.
AI for Satellites and robotics	Identification of potential areas where AI could be applied by the APAC countries.	Promoting utilization of AI in the region enabling driving down consumer costs, fostering innovation and boosting productivity, use of AI to build robots to explore hostile environments.	Different stakeholders have several duties vested in their respective areas of concern to promote using AI in the APAC region via regional cooperation.

3.2. Human Space Exploration

For human space exploration, APAC regional collaboration can be cultivated through the following recommended framework whose key points are summarized in *Table 2*.

Table 2. Summary of identified points from the FGD on collaborative human space exploration in the APAC region.

Questions	**Identified Points**
Why *should we pursue human space exploration in the APAC?*	Human space exploration ● provides a positive feedback loop for research

	and economic growth ● provides opportunities to learn from the diversity of APAC nations ● provides potential for educational outreach from primary school to university
***What** are the gaps the APAC can help address?*	The APAC region allows for cross-border research on these aspects of human space exploration: ● Health, psychology, and nutrition ● Unique diversity in age, gender, and culture ● Isolation effects
***How** can APAC accomplish this?*	Extreme environments unique in the APAC region provide potential sites for analogue missions, which include: ● Desert regions ● Aquatic regions ● Mountainous regions ● Technological free-zones ● Other sites for analogue facilities

The benefits of an investment in human space exploration research can be seen as a positive feedback loop – a phenomenon in which the product of a process increases the rate of that process – for APAC countries. *Figure 3* clearly illustrates this concept in which an initial investment for space research leads to a rising workforce which, in turn, leads to economic growth for the country. This growth further develops the space industry in that country, leading to more available resources for space research.

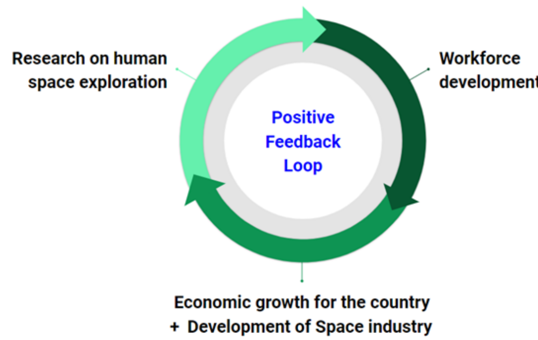

Figure 3. Potential positive feedback loop from an investment in space-related research

3.2.1. Cultural Diversity

The APAC region has a high degree of cultural diversity, which resulted from the fusion of foreign influences and indigenous ethnic culture, over thousands of years. Across the region, historical traditions and progressive ideas have successfully managed to coexist in harmony. Rich architecture, cuisine, and lifestyle techniques - especially those that involve self-sufficiency, e.g. isolated tribal communities, or adaptation and survival in extreme environments - are among some of the unique aspects of the culture of the APAC region. This abundance of diversity would certainly provide a valuable asset to space exploration, including potential resource opportunities in learning.

3.2.2. Educational Outreach

Inspiring the next generation of space enthusiasts is key in sustaining the progress seen so far with space exploration. In this regard, it is important that educational outreach be conducted via public engagement in all levels of school, from primary school to university. Some recommendations include: (1) inviting specific astronauts from the region to share their experiences (e.g. So-yeon Yi from KARI); (2) developing school curriculum to drive a more non-discriminatory interest in the field; and, (3) organizing various levels of analogue missions open to interested participants and thus increasing engagement in space.

At the university level, students in science, engineering, arts, and the social sciences are equally crucial for a more holistic approach in space. Indeed, as space is a multidisciplinary endeavor, this wide spectrum of educational backgrounds is necessary for viable future space colonies. Promoting studies in multiple technical areas, such as in space medicine, materials science, and artificial intelligence, as well as non-STEM areas like in group psychology, system management, and even interior design are therefore imperative for this purpose. Furthermore, workforce development can be sought through various competitions in, for example, spacesuit and space city designs. An opportunity to work with the space industry can serve as prizes for these competitions, therefore significantly increasing interest for space.

These can be executed by encouraging institutions to create opportunities or even just short-term programs where students or even young professionals can work on a project or initiative that allows participation from the diverse disciplines within the university, or across other educational units too! Such execution (acting as a solid demonstration) at the grassroot level will normalize the idea of the reality of the *multidisciplinary requirements for space exploration* that most people are not fully-aware of.

3.2.3. Potential Research and Analogue Sites

Some of the most important priorities in human space exploration is the need for basic research studies in its multidisciplinary facets. The APAC region provides a unique opportunity to be at the forefront of cross-border research on health, nutrition, psychology, and diversity. Short and long-term studies on these factors are imperative, with an emphasis on addressing the lack of data on astronauts with Asian and female physiology.

Analogue missions in the diversified natural environment of the APAC region can provide another key contribution for human space exploration. Virtually all types of terrain can be found in the region, with climate encompassing tropical to temperate zones and topography encompassing the highest peaks in the Himalayas to the deepest ocean floors in the Pacific. Thus, a determination of potential sites for analogue missions, including desert, aquatic, and mountain areas must be made. Table 3 lists some of these that have already been sites of multiple analogue missions. With these missions, duration tests on human survival can be performed in extreme conditions on aspects in health, nutrition, and crew psychology. Technological free-zones within these analogue facilities can further be developed in conducting research on human-robot and mission support interactions, in-situ resource utilization (ISRU) projects, and other in vitro, in vivo, or in silico studies.

Table 3. Some analogue mission sites in the APAC region.

Country	**Site**	**Description**	**Analogue Missions**	**Ref.**
Nepal	Kagbeni, Mustang	An analogue mission to train an international multidisciplinary team living and working in isolated and confinement environments on the Himalayas mountains.	Mars Medical Mission Analogue	[19]
Oman	Dhofar region	A mission to conduct experiments preparing for future human Mars missions in the fields of engineering, planetary surface operations, astrobiology, and the natural sciences.	AMADEE-18 Mars Simulation Mission	[2]
Mongolia	Gobi Desert	A project to establish an international center of science, technology and innovation that consists of Mars comprehensive training academy, space exploration and development free-zone and satellite city for tourism.	MARS-V	[18]

3.2.4. Issues on Geopolitics and Funding

Despite many successes, challenges still persist in obtaining adequate funding for research in human space exploration - especially when it comes to emerging space nations in the APAC region. In such a scenario, focusing on the direct benefit to society by considering not only space-based applications but also terrestrial applications could help with justifying research proposals. Potential economic returns should also be studied and proposed, especially with marketable technologies that have resulted from basic research. Furthermore, with space-related research, applications can usually be also found in disaster management and emergency food development, AI-controlled mechanisms, waste management, and special medical technologies like portable ventilation systems. Such arguments would facilitate acquisition of funding by giving a context to local governments with direct impact.

3.3. Space-Based Data Exploitation

Space-based data is data that has been collected from space, about space, or can be used to develop space-based capabilities. The APAC region's diverse demography and unique geography can be greatly invested for space exploration. The strength of this region lies in the large workforce, information technology and proximity to Earth's equator.

Presented as follows are recommendations on the niche areas of space-based data exploitation where emerging and non-space actors can contribute in, such as development of alternative navigation methods, machine learning-based data-processing platforms, easy access to data, frameworks for usage of space data, ground station networks, and workforce training. The group discussed the multiple ways in which these nations can enter and actively be involved in the global space sector and at the same time meet their domestic needs by skills training and employment.

3.3.1. Standards Development: Data & Hardware

For data collected by the APAC to be used most effectively, standard practices should be adopted to reduce the barrier of entry for those seeking to use it. An example would be the Cubesat standards, published as ISO 17770:2017 (Space systems — Cube satellites) in the International Organization for Standardization (IOS). It has dramatically lowered the barrier to entry for emerging space nations through clarity of development for installation. Similar standards on microsats, software, and data standards can make space more open [15].

To enable closer APAC regional cooperation, further standards can be adapted across microsatellite hardwares and space-based data. Specifically, a set of standards more easily allows cross-training of skilled space workforces between APAC space-faring and non-space-faring nations. Companies and entrepreneurs are more likely to use the available data gathered to solve problems or issues when the need arises. Lowering the barrier to entry allows for not only national agencies, but also private companies in the APAC region to join New Space. Students can access resources developed by neighboring countries without worrying about compatibility, which takes additional skill to tackle - further lowers barriers to entry. With standards, it is easier to make regulations on, e.g. sustainable space & deorbiting, security of data, etc. For data collected by the APAC to be used most effectively, standard practices should be adopted to reduce the barrier of entry for those looking to use it.

3.3.2. APAC Satellite Constellation

APAC should jointly develop a satellite constellation to tackle uniquely regional issues e.g. natural disaster monitoring and response, tropical weather and agriculture, etc. The technology transfer of satellite engineering capabilities between space nations in APAC and emerging space nations may help develop the satellite constellations in the long run. Each country needs only one or two satellites and can specialize in specific types or components; collectively the region will have a full-sensor-suite. Eventually, this joint APAC project helps each nation develop a niche capability, and the workforce that comes with it from technology transfer. This endeavor can provide an opportunity for every emerging and non-space nation to have access from component-level engineering to satellite integration. Such an undertaking makes for good university projects, and can be supported by the media to excite younger students about space. In effect, this joint project will force each nation to examine (or if not, formulate) its space policies to ensure international cooperation is taken into account.

3.3.3. AI & Big Data Value Chain Distribution

New Space data is moving into being data-rich. To exploit this for regional interests, every nation will need to build capability in this domain, and each nation is currently at a different starting point. The AI value chain spans from manual labelling for training datasets up to developing and running models. Every APAC nation can have a part to play depending on their current technological level [31].

Nations can serve different parts of the analytics value chain to reap immediate economic gain, while slowly developing capability in higher parts of the value chain. Leverage low labour costs in various emerging nations [34].

Similar to training in satellite engineering and hardware, regional projects give opportunities for nations to cross-train and build market niches. Skills built in data exploitation are highly transferable and make a nation empowered and more competitive in today's economic landscape [21]

School curriculum should emphasize computer and mathematical literacy, especially towards machine learning and data science, which are highly crucial for the progress of space-based data exploitation [20].

Foreign dignitaries, policy makers, and other influential people must also be well-knowledgeable and/or skilled up to heavily influence their decision-making related from an AI perspective..

3.3.4. Space Situational Awareness in Asia-Pacific

APAC should raise more about the benefits in space sciences and applications, through collaboration and cooperation, within Asia-Pacific countries to eventually reduce dependency on western commercial space tracking data.

Developing the local capability in APAC to track satellites boosts national security, for example the subject of space debris which increases the possibility of orbital collisions, for all countries in the region while building the tech industry capacity.

APAC's geographic diversity allows for broad sensor networks to track space objects. Data sharing agreements allow each space-faring/space-emerging nation to have a much more robust SSA capability than their own borders would allow.

As space becomes more crowded, the importance of space situational awareness increases. Having the foundational cap for SSA opens the door for the region to a greater diversity of space-related jobs in the near future. At present, the only nations/regions with well-developed SSAs are the United States of America (U.S. Strategic Command (USSTRATCOM) Space Surveillance Network and U.S. Strategic Command (USSTRATCOM) Space Surveillance Network), Japan (JAXA Space Situational Awareness Systems), and Russian Federation (Russian Military Space Surveillance Network (SKKP), and European Union (ESA SSA Programme).

In tandem with workforce development, being plugged into a global network for space situational awareness will open up future economic activities for the region, e.g. innovative business solutions to space debris mitigation. Showing students satellites in the night sky is always a good way to capture the imagination. For one's own nation/region to have the sensing and tracking capability indigenously adds a level of national pride.

Increasing the global capability of SSA will aid policymakers in crafting sustainable space regulations, as it provides assurance around enforcement capability [32, 23, 24, 33, and 25].

3.3.5. Summary of the Recommendations

In summary, the group recommends the following:

- A jointly developed APAC Satellite Sensor Suite to tackle the regional issues such as natural disaster monitoring and response, tropical weather, agriculture, etc, and reduce reliability on American and European satellite fleets.
- Set up a Asia Pacific group to work on space policy and legal framework
- Aim to encourage national capacities and technological developments by harvesting the unique skill sets

Table 4. Summary of recommendations for APAC regional cooperation for space-based data exploitation

	Standards Development: Data & Hardware	**APAC Satellite Constellation**	**AI & Big Data Value Chain Distribution**	**Space Situational Awareness in Asia-Pacific**
Technology	Easier for emerging and non-space nations to enter	All nations rapidly gain tech capability	Distribute labor-intensive vs research-intensive workload in AI	Tracking satellites boosts nat'l security and build tech industry
International Cooperation	Standard law and tech enables regional sharing of resources	Skill boosting and transfer between APAC nations	Not a zero-sum economic endeavor between nations	Diverse APAC geography and data sharing would give robust SSA capability
Workforce Development	Enable cross- training across countries		Learn from other nations and climb up value chain (as labor-intensive parts of AI gradually	Diversity in skill sets across multiple aspects of the space value chain

Education and Outreach			become obsolete)	Showing satellites to the students, and increase national pride
Economic Development	Easier for private sector to enter	Tools can be built/sold/used from the data from these satellites	Countries with different Economic strengths reap diff part of value chain	Open up future economic activities for the region, e.g. space debris mitigation
Law & Policy	Greater standardisation allows for clearer regulation	Nations can monitor their own regional issues	Regional decision-making enabled by AI. Not limited to advanced nations.	Aid lawmakers in crafting sustainable space regulations and assurance around enforcement

Chapter 4: Conclusions

This working group brings forth the past, present and future of space exploration and regional cooperation in the Asia-Pacific region. The main objectives for the working group were to identify the on-going climate of regional cooperation and devise recommendations for future cooperation in the key areas. Space technology in this region has historically been employed for social benefits in the major space nations such as China, India, and Japan, while the contributions of the emerging space nations have been limited to cooperation with these major nations.

This working group composed of interdisciplinary young professionals and students from ten nations, with the help of two subject matter experts, discussed various aspects of uncrewed and human exploration as well as space-data based data exploitation. The stakeholders playing crucial roles in the development of regional cooperation were identified and the focus questions were addressed.

The recommendations and the call for actions were drafted by each of the subgroups. The Uncrewed Space Exploration subgroup recommended bridging the gap between the space-faring and emerging space nations by capacity building through advancements in technology, education, joint multi-nation satellites, AI, IT and robotics industry. The Human Space Exploration subgroup recommended a framework to leverage on the unique advantages of their surroundings, diverse culture, geography and human resources of the region in order to address the gaps in the research of human performance in space. They also presented a holistic model to show how active investment in space exploration by the emerging space nations will lead to positive economic growth. They also touched upon the geopolitical conflicts in the region that often pose hurdles in cooperation activities between the nations. The Space-based Data exploitation subgroups recommended the development of technologies and policies for the ease of data sharing between the nations. They propose the standardization of both hardware and software to enable collective workforce training for the emerging and non-space faring nations. Technological developments for space exploration could lead to creating market opportunities for useful data products that do not already exist, data processing and acquisition expertise can be transferred to space data,by retraining already existing workforce and skills.

Thereafter, an assessment should be done on the possible spin-in technologies that would be useful to the global space exploration industry trends. To summarise, the Table 5 below provides a non-exhaustive list of the advantages local industry players have and the potential contribution of each advantage to the future of regional cooperative space exploration.

Table 5: A non-exhaustive list of advantages in the APAC to contribute in areas of Space Exploration

Industry advantage	Potential areas of contribution to the space sector
Technical Advantage	
CNC machining/ Milling/ Construction/ Mining Industry	• In-space Manufacturing / 3D Printing in Space • In-situ Resource Utilisation

Manufacturing of electrical & electronic products (eg. semiconductors)	● Radiation tolerant / Radiation hardened electronics; ● Mass production of electronics for meeting the demands of large satellite constellations.
Fabrication of Apparel & Textile	● Fabrication of astronaut suits (in-flight or spacewalk) ● Light-weight thermal insulator sheets
Automotive industry	● Robotic hardware manufacturing for Moon and Mars space missions
Information Technology	● The development, implementation and maintenance of systems to produce, store, organize, analyze, model, simulate and communicate space-based data
Geographical Advantage	
Deserts	● Analogue robotic missions: ● Ideal testing ground terrain for uncrewed robotic missions to Mars. (Eg. Mars-V Initiative)
Equatorial	● The most cost efficient in terms of the rocket fuel needed to launch things into space
Remote areas / High-Altitude grounds	● Suitable for establishing Ground Stations to increase coverage and communication with satellites
Diverse climatic conditions	● Weather monitoring and response to natural disasters as a preparation for robust human settlements on other planets
Diversity Advantage	
Cultural diversity and advantages	● Promote diversity and inclusion within the space work environment

Emerging space and non-space faring nations should consider leveraging on the unique advantages of their surroundings, be it technical or geographical advantages, or otherwise. Additionally, all the subgroups emphasized on spreading awareness about the benefits of space to the society and its role in inspiring the future generations. The working group recommends SGAC to provide an active interaction platform for Asia Pacific representatives at international gatherings like GLEX, IAF, ISECG, etc.

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