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Assessing the Bottlenecks for a Sustainable Framework for APAC Regional Cooperation for Space Exploration

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Abstract

An indisputable aspect of increased participation in space exploration is the cultivation of a sustainable cooperative ecosystem. Governments recognize the importance of a space program, yet only six APAC countries have fully-realized independent space capabilities, and only a handful have space presence. Cooperative frameworks have been devised but participation is seemingly unsustainable. These multiple regional initiatives (currently, a bifurcation scheme) actually portend the existence of regional division with competition impeding a truly "institutionalized mechanism". Difference in each initiative's primary goal and the promotion of own interests not necessarily towards regional cooperation has shown negative impacts towards institutionalization. Over the years, several leaders of space cooperation have turned inwards, increasing focus on exhibiting space capabilities and advancing space for military interests. Is this increased inward focus accompanied by a parallel increase in cooperative initiatives? Close analysis of existing national space policies can tell whether their legal infrastructure itself already provides room for propagating cooperation, or are they only focused inwards, on developing their own capacities? Sustainable cooperation is difficult if member-states have varying development status, varying priorities in national or space interests, or varying accessible resources. For a space exploration regional cooperative framework, are these the only bottlenecks, or are they only the evident ones with more imperative issues lurking behind? At a quick glance, it can be deduced how most cooperative frameworks drive technical discussions and educational programs (which can only go so far as theory) but very few promote hard-core tech-transfer or space hardware collaborations, which is deemed a critical determinant of how a country is able to participate in joint space explorations. An added dimension to these bottlenecks are seemingly unrelated ingredients (seldomly seen as directly affecting regional cooperation) such as the public's perception of space exploration as an expense vs. investment, the expectations from space activities, and the lapses in science communication. These aspects are relevant since public perception and support impact the pushing-forward of space policies where regional cooperative interests are possibly laid down. Lastly, there are recurring points tagged as primary bottlenecks. However, do past cooperative frameworks demonstrate observable restrategizing over these issues? Or do the same points pop up in every bottleneck discussion and remain unsolved to this day? Common themes such as geopolitics, diplomacy, diverse socio-economic environments, cultural differences, etc. remain. Why do they remain as hindrances to regional cooperation? Does the current ecosystem support sustainable space development in the future?

Keywords: space exploration, regional cooperation, bottlenecks, space policies, APAC region

I. Introduction

The regional economy for space exploration in the Asia-Pacific (APAC) region has been shown to consistently grow over the last decade. Space exploration is still considered a resource-demanding initiative for most APAC countries. However, the existing **cooperative frameworks** have made it possible to increase overall participation for space exploration. The Global Space Economy in 2019 amounted to $366B, according to the analytics and engineering firm BryceTech [1]. An open-source data-intensive report released by Space in Africa has shown that over the past three years alone, public

investments for space in Asia and Oceania combined has grown about 16%, from $13.34B in 2018 to $15.45B in 2020.This constitutes an 18.47% share of the global space budget in 2018 and 21.54% share in 2020 [2]. The same report attributed the region's overall boost of space activities to China's evident growing space investments.

Participation in space activities has increased for the past decade with more countries (who were previously non-space faring nations) now having a presence in space. Lao PDR for example put up their first satellite (LaoSat-1) in 2016 [11]. Cambodia also started talks with China for a satellite project [12], along with LigerSAT being put forward by local students as the country's first satellite [13]. Timor-Leste, having very limited internet access, relies on foreign satellites and has no plans yet for a space agency [14]. However, they've already approved initiatives for space applications to address climate risks, and build climate resilience by enhancing early warning systems for meteorological or climate hazards [15]. Yet another example is Brunei cooperating with India for ground stations (telemetry, tracking, and command stations) and launch vehicles [16]. Myanmar has recently collaborated with Japan for their first satellite (Lawkanat 1) launched this 2021 [17]. Bhutan's Bhutan-1 is the country's first satellite launched this 2021 and was also developed by Bhutan engineers in Japan [18].

These examples prove the rise of participation in space activities in the APAC region. This rise can be attributed to several factors: i) cooperative projects allowing low-barrier to entry participation of emerging space economies, ii) increased and accelerated realization of economic benefits of space due to COVID19, iii) consistent indigenous push for SSTA[1] for national security [3], iv) emergence of relatively new models for space activities tailored to APAC as a result of region-specific studies (not using Western data), and v) changes in public awareness on SSTA and its benefits towards life on Earth.

Along with the rise of space activity in APAC, the NewSpace era has observed a push towards a more sustainable space than ever before. With the *Space for the Sustainable Development Goals (Space4SDGs)* initiative launched by the UNOOSA, many other independent and non-profit organisations have also joined in to emphasize the importance of sustainability for space. Several trends observed are:

1. Rise in LEO satellites due to democratisation of CubeSats demands a sustainable use of the space environment. Some examples of such NewSpace companies are Astroscale, ClearSpace, D-Orbit, and SSTL debris removal technologies.
2. Advancement in solar system exploration technology and the ambitions to go back to the Moon as well as Mars demands a longer duration of human space travel. The Artemis programme headed by NASA, along with 11 supporting countries have come to an agreement on the principals around exploration of space, such as transparency, interoperability, release of scientific data, sustainable use of resources, safe disposal of debris, and prevention of harmful human interference.
   Quoted from NASA: "*The Artemis Accords will describe a shared vision for principles, grounded in the Outer Space Treaty of 1967, to create a safe and transparent environment which facilitates exploration, science, and commercial activities for all humanity to enjoy.*"
   The vision statement above has touched upon three important areas of an industry: Economy, Social, and Environment, which are the three key pillars of sustainability widely recognised across the world.
3. The Luxembourg government has implemented policies to support companies pursuing in-space mining technologies
4. The New Zealand government has been progressive and agile in policy making to further support their space industry's growth
5. JAXA has been pushing on the idea of Blue Ocean and Red Ocean development for both new and old space players to collaborate towards a more sustainable space exploration (crewed and uncrewed alike)

In the APAC region, along with the rapid increase of participation in space activities, are the emergence of new conditions and challenges that come with regional cooperation for space exploration. This paper focuses on identifying the bottlenecks that present themselves as primary blockers for a truly institutionalized and sustainable regional cooperation for space exploration. This focus is meant to map out previous and existing challenges that remain unsolved, and a preview of how these can be potentially addressed. In light of these identified bottlenecks, an evaluation of sustainable development for regional cooperation is also presented.

It is to be highlighted that this paper aims only to diagnose what are the bottlenecks that cut across the region, but will not prescribe specific solutions just yet. It is relevant to identify the bottlenecks in order to paint a picture of what the prevailing circumstance is from which evaluated and strategized solutions will later be expounded on a separate manuscript.

[1] *SSTA = space science and technology applications*

Identifying bottlenecks involves a systematic review of underlying factors and extracting relationships between these factors with the general subject. Thus, this paper adopted a **Multi-Perspective Analysis** by looking through three different lenses to evaluate past and existing regional cooperative frameworks for space exploration in APAC. Such an approach allowed the comprehension of what exactly are the dominant themes. In order to perform this type of analysis and identification, the following **three-tiered approach** was adopted:

1) Understanding what makes an *effective* and *sustainable* regional cooperation,
2) Using that characterization to identify *key considerations* for a truly institutionalized regional cooperation for space exploration, and
3) Lastly, employing these findings to analyze and identify the *specific bottlenecks* that need to be addressed for an effective and sustainable cooperative space exploration in the APAC region.

This approach was applied to parse through potential bottleneck identifiers in these two perspectives: i) past frameworks and organizational perspective, and ii) geopolitical perspective. A literature review was done based on the above aspects in order to analyse to what extent the past and current existing frameworks fulfill the sustainability and effectiveness of space exploration activities in the region. This literature review also generated the data required to do the mapping and evaluating of the components being considered in each perspective.

This straightforward approach allows a linear and easy to visualize interpretation. As such, Section 2 summarizes the general characterizations of regional cooperatives that are deemed effective and sustainable. The second half of the section presents it in the context of space exploration. Sections 3 to 5 summarizes the identified bottlenecks in each of the three perspectives enumerated above by providing examples and extrapolated evaluations. The content of Section 6 is a preview of the potential workarounds for these bottlenecks from a general point-of-view, with specifics intended for another elucidation.

II. Characterizing Effective and Sustainable Regional Cooperation for Space Exploration

Frameworks establishing regional cooperation have long been promoted to achieve maximum participation of member states, optimized resource utilization, and sustainable development. However, the evaluation of their effectiveness and sustainability for the purpose of building new frameworks has been challenging. For the most part, case studies doing so to strategize for the Asia-Pacific's cooperative frameworks often employ data of developed countries whose landscape politically, culturally, and economically are disparate to that of APAC [4]. With new studies conducted over the past decade mostly such as those conducted by the Asian Development Bank (ADB), the United Nations Economic and Social Commission for Asia and the Pacific [6], the Asia-Pacific Economic Cooperation (APEC), UN Industrial Development Organization [5], and many others, it is possible to extrapolate the key characteristics of how frameworks for regional cooperation in the APAC region to pre-evaluate its effectivity and sustainability:

1) The presence of **strategy addressing dynamic human resources** by designing the cooperative framework with mechanisms to prioritize human resources by accounting for impacts of migration, labour export, or labour distribution.
2) Designed with a **pipeline based on the region's landscape** and **integrating the connectivities of the pipeline's elements**. The latter simply means that it should be a strategy that fully encapsulates the need to streamline the process but also recognizes the spill over of the results of one over the other. Ideally, the pipeline somewhat mirrors something like this: *Human Resource > Socio-Economic Development > Sustainability Considerations by Alleviating Environmental Stress > Data-Sharing Capabilities > Enabling Truly Regional Solution.*

   This is particularly important to consider as some past frameworks demonstrated **parallel implementations** of projects from each of the above components, instead of a pipeline-like implementation. Due to the existence of spillover impacts, parallel strategy may result in a relatively inefficient/ineffective and unsustainable framework. For example, initiating large scale socio-economic development cooperative projects without first strategizing on how to address human resource challenges may result in a failed implementation.
3) Has a **strategy to mobilize unutilized funding** which does not merely rest in free trade agreements, but also promotes local planning to tap into unutilized funds such as savings that are not invested. This can further be strengthened by enabling vibrant trades, creation of deep regional supply chains and networks, and shaping attractive investment opportunities meant to kickstart fund mobility locally, then in the region.

4) **Avoids further sub-regionalization** and is designed **with freedom to engage in inter-organizational cooperation**. Sub-regionalization refers to creating cooperative frameworks in APAC that causes participation in each to be effectively mutually exclusive, counter-intuitive to being a regional cooperation. This can be done by making sure that each co-existing framework also provides room to work with other cooperative frameworks through as simple as bilateral agreements at the least.
5) Effective and sustainable regional cooperative frameworks **should always strive towards regional self-sustainability.** Promoting and supporting development of indigeneous and interconnected expertise, components of the ecosystem is a way to go here. This also creates the deep regional chains mentioned in the previous point.

The above characterizations work in general for any regional cooperative framework in APAC being shaped for sustainable development. Thus, it would therefore make sense to contextualize these and make it tailored for characterizing effective and sustainable cooperation for space exploration. The following are the key considerations:

1) The cooperative framework must first **address the dynamic landscape of human resource development** by prioritizing training and knowledge sharing or transfer (i.e. education) before any technology transfer of SSTA.

   This shall be of properly designed priorities **appropriated** for the particular aspect of space exploration being initiated. There is therefore a need to enumerate key space exploration areas, to identify needs, and to perform roadmapping or landscaping before initiating any cooperative projects.

   As and where necessary, the HR development programme should ideally prepare all parties involved with the necessary knowledge to maintain such a cooperative framework as long as the cooperative activity is still within the interest of all parties. For example, policy making skills, international relations, financial literacy, environmental awareness, etc.

2) The cooperative framework should **prioritise SSTA for socio-economic development** instead of lucrative space exploration missions.

   The nature of the APAC region geographically and socially presents many challenges when considering regional cooperation. One of the first steps towards sustainability involves improving human lives and in the APAC region the key areas are in communication and connectivity, disaster prediction or mitigation (not just management), and navigation.

   At a national level, governments should already have committed towards a continuous nation-wide socio-economic development independent from such regional cooperative frameworks. As such, engaging in space-related regional cooperation would be a ‘bonus’ and hopefully act as an accelerator to whatever socio-economic development goals the nation has planned out.

3) APAC cooperation for space **should strive to maximize lessons learned from past similar initiatives within or without the cooperative framework or organization to avoid duplication**. As is further elucidated in the following sections, the current nature of regional cooperation for space exploration prompts mutual exclusivity in terms of member state participation. This results in projects with overlapping and repetitive missions.

   However, **duplication is not necessarily fruitless**. Proposed frameworks should involve feasibility studies and discussions specifically geared to address duplication, and learn from previous initiatives to optimize all aspects of the mission such as capacity building and resource allocation for that new similar project. The existence of repetitive development programmes can be leveraged to **promote training and exposure at a faster rate**. More members are able to participate and obtain similar knowledge, regardless of which cooperation they initially join up with. This allows members to extract benefit from cooperative activities in similar scale as those who joined the first or original project, now being duplicated but with optimizations based on historical study.
4) In the context of space exploration, **it will become a truly regional solution if the implementation is also region-wide.** This rather simplistic idea is often challenging to implement. One way to kickstart such is the emergence of data/knowledge sharing projects instead of simply technological development projects here and there. By making the decision-making tools powered by space

exploration to be a repository of contributions of APAC states, economic integration through SSTA will proceed much more smoothly.

It is highly advised that the initial planning, strategy development, policy creation already accounts for region-wide implementation of the initiative. Considering a regional perspective when only during the implementation (and not before) may have deviated outcomes as only by the end would it be realized that member states have varying objectives. Accounting for these differences during planning results in a more inclusive and calculated cooperation.

One recommended way to do this is to start as early as when a country is doing surveys and assessing what policies to craft for their development plans. The national strategies should already incorporate regional and even international-wide cooperation. National strategies should already consider timelines of when are they ready to cooperate, how will they be cooperating, what are specific areas of cooperation is to their national interest, who to cooperate at the right time when things start maturing, etc.

5) Must be aligned with the UN 17 Sustainable Development Goals of the 2030 Agenda for Sustainable Development

Any mention of developing a sustainable framework in any sector **should contribute, in part, to one or more of the recognized 17 Sustainable Development Goals (SDGs)**[2] of the United Nations (UN). This universal 15-year Agenda brings into culmination decades of international work and highlights the importance of integrating the SDGs such as ending poverty while, at the same time, stimulating economic growth and tackling climate change [8].

While space science, technology, and data are not explicitly mentioned when talking about sustainable development, their potential in supporting the SDGs is understandably vast. Space science includes the fields of astronomy, aerospace engineering, space medicine, and astrobiology. Space technology refers to Earth observation, remote sensing, satellite communication, as well as satellite positioning. Using these technologies, real-time data information from any location can be provided, supporting any policy decision that is essential in monitoring SDG indicators[2]. The United Nations Office for Outer Space Affairs (UNOOSA) highlights these space applications, emphasizing the role of space-based technologies in countless areas of priority, including climate change and disaster management, among others [8]

From the multiple space activity examples above, it is important to appreciate that whatever cooperative activities identified and agreed within the sustainable regional framework, there is a high possibility that it can be related to one or more of the 17 SDGs.

6) Must have specific direct or indirect benefits on Earth, including benefits from technology offshoots

Developments in scientific research and innovative technologies can yield practical applications on Earth. Of particular interest to the Asia Pacific is food security. In this regard, agricultural output and environmental conditions (among others, rainfall, soil, and drought) can be monitored in real time, providing accurate data that can be analyzed to enhance production and profitability. They can also be used to predict the output of a particular country or region, giving the local government and decision makers time to properly act on potential food shortages. While it is true that the utilization of space data is currently limited to developed nations, the rise of private enterprises and open-access geospatial data are driving down costs, stimulating widespread adoption across the world. Current efforts are dedicated to data sharing and improving the capabilities of countries to analyze the large sets of data from satellites [9].

Other specific benefits include applications in health (telemedicine, disease surveillance, and health mapping), disaster risk response (Earth observation for early warning systems, detection and monitoring disaster risks for natural hazards), environmental management (Earth observation to monitor environmental conditions, managing natural resources, and tracking deforestation and pollution), and improving connectivity (delivery of tele-services for information cascade, education,

[2] Identified and adopted by all UN Member States in 2015, the 17 SDGs, with a total of 169 associated specific targets, are at the heart of the UN 2030 Agenda for Sustainable Development, which calls for an ambitious global effort in acting on the most critical, interconnected issues on the economy, society, and environment.

and medicine via satellites or other aerial devices).

Finally, extensive research in space technologies can spillover to public benefit and consumption. For example, battery storage capabilities have become more robust due to research originally for space applications. Efficient batteries may lead to an overall increase in mainstream adoption of renewable energy sources. Novel techniques in welding that were used in assembling rocket fuel tanks can be stronger, safer, and more environmentally friendly. Strict safety standards in space are also being adapted in many terrestrial industries, such as in the food, aviation, and automotive industries [9].

7) Must address the challenges in costs and widespread adoption

Many countries, regardless of their developed/emerging status or if they have a national space agency/policy, have benefitted from space applications. For example, in the APAC region, Laos, Myanmar, the Philippines, and Vietnam have managed to launch their own satellites. As discussed previously here, extensive research in these technologies originally intended for space can be applied in more terrestrial cases like in agriculture, health, environmental management, and energy. Investing in research and education contributes to increasing scientific knowledge, creating new opportunities for innovation and infrastructure [10]. Barriers to entry have also lowered due to increased data sharing and open-source availability. Costs have also been driven down as a result of automated prediction models from machine learning and big data science. Crowdsourcing has also become an attractive option to expand opportunities and fill data gaps for the different applications.

However, many hindrances still remain for fully maximizing space. One of these is the general lack of awareness and experience in space technology benefits. This may be due to the relative novelty of space which can be seen as a niche requiring a higher degree of specialization. Any step towards space utilization should therefore be focused on space promotion and de-"eliticization". Furthermore, although investment is an integral initiative for developing country capacities, sensitivities must first be made by tackling public opinions which, if not fully and properly addressed, will hinder progress and equal distribution. For example, space programmes and agencies are not necessarily required to use space-based technologies and data, and may, in fact, draw criticism for improper budget allocation. It is therefore important that investment in space is discussed in consideration of other areas of priorities of the country as well as how the benefits of space can be more inclusive for the entire population. Other challenges include the insufficient number of experts to build local capacities for using space technologies, still-restrictive data access, lack of standardization, and regulation and governance of space.

III. Perspective 1: Past Frameworks and Organizational Structure Analysis

Identifying bottlenecks requires evaluation of what has been and or being done, and extrapolating points of discussion from these records. This evaluation is done through the seven (7) General Dimensions of Effective and Sustainable Regional Frameworks for Space Exploration described in Section 2.

Table 1. *Understanding the bottlenecks for regional cooperation from the past frameworks and organizational structure perspective*

	ASIA-PACIFIC SPACE COOPERATION ORGANIZATION (APSCO)	ASIA-PACIFIC REGIONAL SPACE AGENCY FORUM (APRSAF)	COMMON BOTTLENECKS
1) MECHANISM TO ADDRESS HR CHALLENGES	The Data Sharing Service Platform (DSSP - operating since 2012) was initially implemented but did not yield the expected results. **The reason was determined to be the un-addressed human resource challenges.** After three months of on-site training for remote sensing applications, the project	The Sentinel Asia (SA) initiative is a prime example of how **capacity development** has been made to be at the **forefront of considerations when pursuing cooperative projects**. For example, the hazard map for the Mo River in Bhutan, created through the Advanced Land Observing Satellite	Cooperative projects do operate with considerations about technical capacity and financial difficulties. However, **recognition of the challenges to human resources is NOT enough**. Instead, there's a general need to acknowledge and lay down specific and comprehensive strategies to capacitate human resources for the success of the cooperation.

	got successful application results as expected.	(ALOS) imagery was characterized with community-level capacity dev't for it to become successful.	
2) INCLUDES SOCIO-ECONOMIC (SE) DEV'T AS PRIORITY	The Space Network and Interconnection of Ground Systems initiated by APSCO demonstrates a vital role in SE dev't as seen through the Joint Small Multi-Mission Satellite (SMMS) constellation in its value for enhanced data retrieving opportunity that resulted in a wider coverage sustainable earth observation system as a result of multilateral participation of member states with evident willingness for their satellites to join the swarm.	The demand to immediately address escalating improper management of the fragile environment in APAC prompted several cooperative projects such as the Space Applications For Environment (SAFE) Project which leverages vast amounts of satellite data. After transitioning from bilateral to multilateral collaboration, SAFE was able to fast track its initiatives. Despite no clear/rigid declaration of its priorities, the strategy accounts for the need to address environmental challenges for the sake of improving the socio-economic sector in the region as intensified climate hazards have risked livelihoods.	It is common in the APAC region that space is used more for economic development over prestigious exploratory activities. Participation in cooperation is motivated by each member states' **unique socio-economic requirements**. In the context of existing frameworks, there needs to be an active pursuit of optimizing mission requirements based on these unique requirements of member states. This is easier said than done especially for multilateral agreements. However, such step for cooperative frameworks can spur more participation as each party gets to have a definitive objective in joining.
3) STRATEGY TO MAXIMIZE PAST SIMILAR PROJECTS TO AVOID TOTAL DUPLICATION	The current nature of APSCO and the other existing regional cooperative framework for space exploration in APAC results in a seemingly "mutually exclusive" participation of its members. This sometimes results in duplication as member states are only allowed to participate under one corporation and not both.	Overlap of the projects for addressing natural disasters do exist. Instead of publishing research articles, APRSAF has carried out its Sentinel Asia (SA) and has applied satellite technology to assist its member organizations to manage natural disasters in the Asia-Pacific region.	There is a beauty to allowing similar projects to be pursued under different cooperations. However, the bottlenecks stem from **absence of co-existence** in terms of framework designs. If a framework **has strict treaty-based design, it leads to the sub-regionalization outcome** which may or may not be entirely good. On one end however, frameworks designed to co-exist may leverage the project duplications as sources of lessons learned, optimization data, or feasibility reviews.
4) ROADMAP FOR REGION-WIDE IMPLEMENTATION	The DSSP is a primary program shaped out of multiple collaborative projects (often multilateral). Algorithm and project outcomes were shared amongst member states.	APRSAF carries out its Sentinel Asia (SA) and applies satellite technology to assist its member organizations to manage natural disasters in the APAC region. From 2006 to 2018, APRSAF had used its Emergency Observation Request System of the Sentinel Asia (SA) to accept 333 requests for assistance from its member countries, and 289 of them have been successfully activated to provide data and products to its members in support of their disaster management in practice.	Most cooperations are bilateral in nature due to their temporal efficiency. However, such projects also (not always) tend to look at Country A - Country B implementation and rarely cast out a plan to implement regionally. The **allure of temporally efficient pursuit of bilateral agreements may be a bottleneck in this dimension**. Recently, there's been an observable transition to actively do multilateral cooperations. However, yet another layer to this bottleneck is that **most developing countries have no intentions yet or do not know how to craft a strategy for such multilateral cooperation to happen** while also protecting their sovereign interests. This bottleneck also lies in the same plane as that on challenges on human resources for each country, particularly that of policy making for regional cooperation.
5) ALIGNS WITH UN SDGs	The DSSP project has enabled to bring a lot of benefits in most of the areas such as disaster mitigation, atmosphere monitoring, forestry and agriculture which in turn result in alleviation of environmental stress.	Space Applications for Environment (SAFE) Livelihood of people in the region is always challenged by various natural disasters, mostly due to extreme climate events. Changes in the global climate intensify climate hazards, amplifying the risk on societies, and these risks further escalate with improper management of the fragile environment. Having acquired a vast amount of satellite data since the launch of Earth observation satellites, studies and research have shown the benefit of	Currently, the existing regional cooperative frameworks work well with promoting the use of space technology for improving life on earth, most especially for socio-economic benefits of the participating states. However, regionally, **the bottleneck comes from lack of the cooperative framework's dedicated initiatives to align public perception (misconception at that)** on top of the technical projects being pursued. Within the space community itself, the notion of SSTA for earth is well-understood, but the misconception that space exploration is a luxury still persists because the public views it as "a venture reaching for the stars, a venture we can't afford". Usual arguments lay down

		satellite observation in understanding environmental changes and climate change related issues, as well as in monitoring earth's environment from local to global levels effectively and objectively. The use of space technology (specifically Earth observation satellites) enables global and long-term monitoring of environmental changes.	how space expenditure could instead be poured into solving global warming, mitigating impacts of climate change, improving agriculture, etc. Clearly, these are misconceptions as it has been proven time and again how space exploration has been directly used for exactly these purposes, or kickstarting offshoot applications redirected to these very applications.
6) IDENTIFIES TECH OFFSHOOTS FOR LIFE ON EARTH	As a part of the project space network and Interconnection of Ground Systems, APSCO ground stations network was established for enhancing data retrieving opportunity, data accessibility and space asset manageability. The network was an integration of the existing, well established ground station system and other upgraded/ newly built stations in member states. In parallel, the network for shared space development infrastructure which included the Assembly, Integration and Test (AIT) facility, will play a central role to support space capacity building, experience, know-how sharing and hands on technology transferring APSCO Member states. Application was also an important part of the program. Several applications of the remote sensing satellite and Data collection satellite system will be designed, developed and deployed based on member states' requirements.	Kibo-ABC is a collaborative program established by the Space Frontier Working Group (SFWG) of APRSAF, aiming to promote the utilization of the Japanese Experiment Module "Kibo" on the International Space Station in the Asia-Pacific region and to share and build on the outcomes of Kibo utilization.	In the case of the APAC region, as space exploration is meant mostly for socio-economic purposes, **there is little to no bottlenecks in terms of participating for cooperation for the sake of tech offshoots**. Existing data-sharing capabilities and their results are examples of how space exploration is often maximized by member states to extract value from it by identifying applications that extend beyond their original mission's target.
7) ACTION PLAN TO TACKLE COST AND WIDESPREAD ADOPTION	Ka-Band rain attenuation modeling project established a database from collected Ka-band beacon Ka-signals and related meteorological data and developed a rain attenuation model that links the rain process and its atmospheric effects. A diversity site switching algorithm was developed for continuity and reliability of communication link. Ultimately, the model and algorithm have been shared among APSCO Member States for practical applications for their countries.	The Agromet project was initiated and implemented as a SAFE multilateral project in 2018. This activity aims to develop a mechanism and a system to share agrometeorological information to help the region, particularly to improve agriculture information services in the region.	

Observe how identifiable bottlenecks in each dimension are interconnected to each other. For example, in terms of achieving region-wide implementation of cooperative projects, there's a need to address bottlenecks with human resources such as in policy-making. Similarly, bottlenecks in avoiding duplication are met with challenges in terms of strict treaty-based agreements or unique socio-economic requirements of each participating nation. These interplay of dimensions showcase how sustainable and effective regional cooperative frameworks has to be approached from multiple perspectives. As such, to add another layer of cognizance to existing bottlenecks for regional cooperation for space exploration in the APAC region, the undeniably impactful perspective on geopolitics has to be taken account (supporting the mention of each member states' need to protect

sovereign interests while engaging in cooperative agreements).

IV. Perspective 2: Geopolitical Analysis

On top of the bottlenecks that already exists within the cooperative framework themselve, APAC states are also met with geopolitical challenges (either nationally or regionally) that may pose a difficulty in engaging with regional cooperation for space exploration. Geopolitics is a rather difficult thing to navigate in the region given the diversity and uniqueness of each states' objective. Regional integration is only achievable if existing geopolitical bottlenecks can either be worked around or resolved totally. It is easier said that done but the following identified layers of bottlenecks will be the basis of a resolution to be presented in a separate manuscript.

	IDENTIFIED GEOPOLITICAL BOTTLENECKS
1) MECHANISM TO ADDRESS HR CHALLENGES	In nations where a space policy does exist, significant effort is laid down to identify the areas of development or application for space technology or space exploration missions for the interest of socio-economic development (inclusive of disaster mitigation, communication, connectivity, etc), and national security. However, a comprehensive pipeline or roadmap addressing human resources penned down as part of the national space policy is often missing. These challenges remain bottlenecks as there's no specific strategy to account for the dynamic mechanisms of human resource (pertaining to the fluctuations in labour force as an effect of migration, labour export, and or labour redistribution). If national space policies do identify this key dimension alongside the areas of development or applications, it will act as a solid ground for the take-off of being able to easily participate in regional cooperation for space exploration as participation is now easier with a technically-equipped human resources.
2) INCLUDES SOCIO-ECONOMIC DEV'T AS PRIORITY	Singapore is uniquely identifiable as one that demonstrates prioritization of lucrative space exploration activities that includes novel research and development on emerging technology such as quantum payloads, micro-thrusters, etc. This is due to its wealth, which is not the same for most of the APAC region. For the most part, cooperation in the region does indeed prioritize socio-economic development using space exploration. This is generally attributed to the existence of shared social problems such as common disasters affecting livelihoods, shared problems on connectivity, amongst others. Despite the existence of common SE problems in the region, each is keen to nurture self-reliance for SSTA for socio-economic dev't but also for national security. The need to achieve sovereign security desires in parallel to regional cooperation even on common socio-economic requirements poses a bottleneck.
3) STRATEGY TO MAXIMIZE PAST SIMILAR PROJECTS TO AVOID TOTAL DUPLICATION	In line with the individual sovereign interests of the countries in the region, duplication is unavoidable. Moreover, the majority of the space policies set up each nation to compete in commercial markets to provide space services. Competition is long proven to be beneficial in terms of development and innovation, and even to market stability. However, this can be a bottleneck in terms of regional cooperation that involves data-sharing, standardization, or efficient knowledge transfer. Learning from similar projects of different countries will also be difficult if national security is of main concern. In order to give room for healthy cooperation, similar projects need to be shared for learning purposes and avoiding total duplication, expecting different results.
4) ROADMAP FOR REGION-WIDE IMPLEMENTATION	Due to aforementioned unique requirements (not just socio-economically but also geopolitically, financially, and technologically), APAC countries often look at bilateral arrangements as much favourable. In most cases, this yields outcomes, but in the context of regional cooperation (as a region instead of as nation-to-nation), the bottleneck persists.
5) ALIGNS WITH UN SDGs	Identification of key development areas for national space policies does draw a clear long-term plan for the country's space program. Public support is often required to push forward for the approval of a space policy, especially in country's where there's still no national space agency. This is where the bottleneck exists. For a country to be able to participate in regional cooperation, there needs to exist or at least a plan to materialize a sustainable space development strategy. If such a plan or national space agency exists at a national level, regional cooperation would be more efficient for that country. This bottleneck should be approached with how public support can be effectively garnered to push for that national plan by actively showcasing the impacts of such space policy in alignment with the UN SDGs on top of national security benefits being promised.
6) IDENTIFIES TECH OFFSHOOTS FOR LIFE ON EARTH	As has been mentioned previously in this paper, space exploration for many countries in the region also centers around national security applications. "Geopolitical boundaries" have solidified their definitions as of late due to rising conflicts on territories. This led to most national space policies highlighting national security applications to fast track political acceptance of the space policy. At

	times, this is effective. The bottleneck exists in this hyperfocusing on a singular area of application but rare mention of its potential impact on other areas. If policies (it does not need to be the national space policy itself) are also crafted by forecasting offshoot impacts, much as mentioned in #5, the policy provides a direction into the pursuit of space development for the state. If these are determined, the nation will be able to strategize on opportunities of cooperation that they can either initiate themselves (by looking at their neighbours' foreign policies), or participate in as per their requirements.
7) ACTION PLAN TO TACKLE COST AND WIDESPREAD ADOPTION	Majority in the region are emerging space-faring nations, without full space capabilities and are eager to participate in regional cooperations. The objective of such participation also often revolves around minimizing resource-demands for them. Cooperation provides a means to lower the barrier-to-entry to space activities. However, over-reliance on such benefits may be unsustainable. There is a need for each country to strategize on pursuing space activities that may also demand expense from every participant. This seems counter-intuitive to the benefits of regional cooperation, but having such a strategy promotes a long-term sustainability in being able to participate in regional cooperation for space exploration especially in initiatives which may spur offshoot applications that is of unique interest to a country's specific use-case (pursued outside the scope of the cooperation). This however is met with a bottleneck at a national level, politically at that. Countries whose space activities rely heavily on foreign sponsorships and can scarcely afford the threshold of participation for space activities are at risk of unsustainably pursuing space cooperation. There's a need to promote increased financial allocation for space activities, at a national level.

Note how the points made in the previous perspective (past frameworks) are also echoed in the geopolitical perspective. The two perspectives provide a preliminary look into how bottlenecks for regional cooperation for space exploration can be identified as for the most part, the two are interlinked! Establishing this link can aid in identifying workarounds, or characterizing what would make cooperation efficient and sustainable.

These commonalities are taken into account at the end of this paper, where the General Dimensions of Effective and Sustainable Regional Frameworks for Space Exploration is revisited.

V. Preview of Getting Around Bottlenecks for a Sustainable Regional Cooperation for Space Exploration in the APAC Region

This section provides a brief guideline for countries that wish to advance further in a sustainable manner in space exploration, by overcoming the various bottlenecks highlighted above. A series of steps are needed, the first of which is to recognise and critically assess the current capabilities and market of a country or a region for collaboration interest. This includes the environmental considerations of the nation, the political intentions and strategy of growth for a nation, the key driving economic factors of a nation, as well as the social wellbeing of the citizens and degree of inequalities.

Next, the drafting of a realistic and practical sustainable development strategy is important, starting with the creation of a nation's very own sustainable goals (economy goals, social goals, environmental goals, etc). At this stage, external and third party consultants are crucial to ensure an unbiased and objective view towards sustainable strategy planning. Awareness workshops on shifting of mindset, changes in policies to have incentivised programmes, adoption of new infrastructures and facilities, and a push for commercial buy-in are all aspects that should be considered in the strategy.

Lastly, active engagement with international and local NGOs as well as partnership for regional collaboration should be built based on a shared vision and goals from the well-defined sustainable development strategy. This ensures a minimal level of commitment and accountability when collaborative activities are executed in line with the strategy drafted. In the following paper of this series, more information as well as the foundation of a sustainable framework will be shared.

VI. Conclusion

Identifying existing bottlenecks for effective **and** sustainable regional cooperation for space exploration is essential for drafting recommendations on it. Two perspectives were adapted in this paper: the past frameworks and organizational structure analysis, and the geopolitical analysis. For each, seven dimensions were evaluated to paint the picture of bottlenecks for achieving an effective and sustainable ecosystem of regional cooperation. The two perspectives and the seven dimensions demonstrated how bottlenecks are for the most part interlinked and proves how solving one may result in effectively hitting multiple challenges at the same time.

Due to the identified interdependence of the dimensions and perspectives, the characterization of effective and sustainable regional cooperation for

space exploration is hereby revisited, and here are the key elements or considerations directed to a party[3]:

1) Have the intentions or currently developing or have already crafted a sustainable development strategy at a national level. Or, have historical evidence of past successful ventures in space but are no longer active today.
2) Commits to a continuous human resource development
3) Commits to a continuous socio-economic development
4) Displays or practices the mindset or attitude to listen and adopt better practices, feedback, guidelines, or recommendations provided by its industry, NGOs, and the local grassroot community.
5) Observes a certain level of political / legal / regulatory stability. This is crucial for ensuring such regulation acts as enablers for innovation, investments, breakthroughs, new infrastructures, new developments, and new cooperation can be formed.
6) The society or community of the nation is willing to take necessary risks, new research and developments, and engage in innovation. There has to be a culture of innovation or entrepreneurial ecosystem in place.

and here are the key elements or considerations that are directed at a regional-level:

7) The regional cooperative framework must be built from parties that have a common goal or a shared vision. The shared vision or common goal could be a subset of each parties' national sustainable development strategy.
8) The cooperative framework must benefit all parties involved and such benefits must be in-line with the national development strategy crafted by each individual party. In other words, a win-win situation for all involved.
9) The cooperative framework must contain a good cooperative strategy planned that:
    a) Considers sustainability from an economic, social, and environmental perspective
    b) Aligns with the UN SDGs
10) The execution of a good cooperative strategy planned must have:
    a) Considered the sustainable impact from an economic, social, and environmental perspective
    b) Been aligned with at least one of the UN SDGs

[3] The list takes a country as an example of a 'party' but it doesn't have to be a nation. A party can also refer to a particular organisation.

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