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New Framework for the Utilisation of Space Technology: Effective Collaboration amongst Industry, Academia, and Government to Contribute to ASEAN's Socio-Economic Development

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Foreword

ASEAN countries are facing diverse challenges in disasters such as heavy rain and earthquakes, environmental problems such as forest fires and air pollution, and marine problems such as illegal fishing and coastal erosion, and these social issues are slowing down socio-economic activities in ASEAN.

Space technologies such as satellite remote sensing are expected to be used in solving these social issues. Currently, there is an active movement to shift services that utilise space technology from government-led to private-sector initiatives. Furthermore, by promoting the development of solutions and business implementation using space technology, we can address common social issues in the ASEAN region. It is expected that it will contribute to solving the problem and promoting local industry.

Based on this understanding, an ERIA study project 'Study on a New Framework for the Utilisation of Space Technology: Effective Collaboration amongst Industry, Academia, and Government to Contribute to ASEAN's Socio-Economic Development' was conducted in 2023–2024 and explores a new framework in adopting space technology, ranging from infrastructure deficits to policy gaps, funding limitations, skill shortages, regulatory weaknesses, and reliance on foreign technology.

To implement such a framework, four selected pilot projects for Examination and Trial of Problem-Solving Methods in the ASEAN Region were conducted: (1) ASEAN Maritime States (Maritime Surveillance), (2) Indonesia (Peatlands), (3) Indonesia and the Philippines (Coastal Erosion, Environmental Conservation), and (4) Viet Nam (Disaster Monitoring). Those projects showed creation of blueprints for solutions utilising new space technologies like Remote Sensing with AI, synthetic aperture radar (SAR), small satellite constellations, and so on.

Furthermore, this report covers the patent landscape in ASEAN's space technology innovations, though largely driven by academia, with limited private-sector engagement. We hope that this report proves useful to the ASEAN, the participating states, and stakeholders who work with the ASEAN by guiding the utilisation of space technology to the more connectivity of ASEAN states.

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ASEAN	Association of Southeast Asian Nations
ERIA	Economic Research Institute for ASEAN and East Asia
E-DISC	ERIA Digital Innovation and Sustainable Economy Centre
GNSS	Global Navigation Satellite Systems
GISTDA	Geo-Informatics and Space Technology Development Agency
LAPAN	National Institute of Aeronautics and Space (Indonesia)
VNSC	Viet Nam National Space Center
MYSA	Malaysian Space Agency
PhilSA	Philippine Space Agency
EEZ	Exclusive Economic Zone
PoCs	Proofs of Concept
SAR	Synthetic Aperture Radar
THEOS	Thailand Earth Observation System
ICT	Information and Communication Technology
AI	Artificial Intelligence
IoT	Internet of Things
HPC	High-Performance Computing
R&D	Research and Development
MRV	Measurement, Reporting, and Verification
STDP	Space Technology Development Programme
JAXA	Japan Aerospace Exploration Agency
NASA	National Aeronautics and Space Administration
ESA	European Space Agency

Executive Summary

The ASEAN region faces numerous socio-economic challenges, including natural disasters, environmental degradation, and technological disparities. To address these issues, space technology, particularly satellite remote sensing, has emerged as a vital tool due to its wide coverage, periodicity, and resilience against surface obstacles. This study explores a new framework for effectively utilising space technology through collaboration amongst industry, academia, and government, aiming to contribute to ASEAN's socio-economic development while enhancing ASEAN–Japan cooperation.

ASEAN nations face diverse challenges in adopting space technology, ranging from infrastructure deficits to policy gaps. Key areas of concern include funding limitations, skill shortages, regulatory weaknesses, and reliance on foreign technology. Each country has unique priorities and needs: Singapore excels in data processing for urban planning, maritime security, and sustainability but faces constraints in infrastructure and workforce development. Viet Nam prioritises disaster resilience, agriculture, and maritime monitoring, requiring investment in radar technology and policy frameworks. Thailand focuses on disaster management and agriculture, making strides with recent advancements in Earth observation satellites. Indonesia leverages space for agriculture and environmental monitoring but needs significant investment in satellite technology and skill-building. Malaysia and the Philippines are emerging players addressing deforestation, disaster resilience, and maritime security but are constrained by limited funding and infrastructure. Meanwhile, Cambodia, Lao PDR, and Timor-Leste remain foundational nations heavily reliant on external partnerships, requiring capacity building in workforce, infrastructure, and regulatory frameworks.

The study segments ASEAN nations into categories based on their technological maturity: Technological Innovators (e.g. Singapore), Established Capability Nations (e.g. Viet Nam, Thailand, Indonesia), Emerging Nations (e.g. Malaysia, Philippines), and Foundational Nations (e.g. Cambodia, Lao PDR, Timor-Leste). Enhanced regional collaboration is essential to share expertise, resources, and infrastructure effectively. The patent landscape reveals growth in ASEAN's space technology innovations, though largely driven by academia, with limited private-sector engagement. Comparative analysis with developed nations highlights gaps in scale, industry readiness, and innovation intensity, underscoring the need for stronger R&D investments and supportive policy frameworks.

To maximise the potential of space technology, ASEAN–Japan partnerships should be strengthened to leverage Japan's advanced space expertise. The framework proposes developing localised solutions tailored to each country's socio-economic and environmental challenges, enhancing private-sector engagement, funding mechanisms, and talent development. Establishing a comprehensive regional framework for data sharing, technology transfer, and collaborative initiatives is also crucial. By addressing these strategic areas, this study emphasises the transformative potential of space technology to tackle ASEAN's socio-economic challenges and foster sustainable development through effective international collaboration.

Background

In ASEAN countries, numerous significant social challenges exist, including droughts, floods, earthquakes, landslides, tsunamis, forest fires, red tides, air pollution, haze, illegal fishing, coastal erosion, environmental degradation, and river pollution. These challenges are shared amongst ASEAN nations and contribute to the stagnation of their socio-economic activities. Addressing these issues is of paramount importance for ASEAN's development.

To confront this wide array of terrestrial and maritime societal challenges, the utilisation of space technology – particularly satellite remote sensing possessing attributes like 'wide coverage,' 'periodicity,' and 'resilience against surface obstacles' unaffected by ground conditions – has gained recognition for its efficacy across various demonstration cases. Further technological advancement, expanded solutions, and broader adoption are expected to enhance its impact.

Promoting the adoption of space technology, along with the derived solutions and their business implementations, can effectively address common social challenges within the ASEAN region. This contribution aids in the development of the region's socio-economy and fosters regional connectivity.

In Japan, the extensive history of space development has led to the accumulation of diverse and advanced space technology solutions and use cases across academia, industry, and government circles. Many of these solutions are considered relevant for addressing the aforementioned social challenges within the ASEAN region. Collaborative implementation of these solutions across ASEAN nations can elevate socio-economic development, amplify regional connectivity, and contribute to the advancement of ASEAN–Japan cooperation.

Effectively implementing space technology and solutions to resolve ASEAN's challenges necessitates international collaboration involving not only universities, research institutions, and providers with expertise in space technology, but also local governments and corporations (the demand side) directly facing on-site challenges. Collaboration amongst academia, industry, and government is of utmost importance. Achieving this collaboration and realising ASEAN–Japan partnerships in the space sector requires an integrated approach. This approach entails involving stakeholders such as Japanese government agencies, universities, businesses, and organisations with space technology expertise, along with stakeholders from the respective areas facing challenges and potential business partners. Collaborative efforts encompass joint seminars, proofs of concept (PoCs), and satellite data utilisation system verification projects.

Against this background, the objective of this research is to come up with the ASEAN–Japan Space Technology Utilization Framework to be used for the expansion of the effective use of satellite data in the ASEAN region. As a part of this effort, the newly established Digital Innovation and Sustainable Economy Centre at ERIA (E-DISC) will provide a platform for the development and implementation of the framework.

Chapter 1

Challenges and Needs in the ASEAN Region

With the diversification of economies, the uniqueness of geographies, and the uneven developments of technologies, the ASEAN region is an interesting environment for understanding the dynamics related to the adoption and usage of remote sensing and space technology. The section that follows reflects the results from an interview survey carried out amongst stakeholders in the ASEAN countries, encompassing government officials, leaders of industry, and academicians, regarding identification at the country level of the challenges and needs for utilisation of remote sensing technology. These results raise important questions about shared regional priorities and country-specific gaps in infrastructures, expertise, and policy.

1. 1 Challenges

A. Singapore

1. Infrastructure Constraints

Singapore is a small country with limited natural resources, with an area of about 734.3 km^2 as of the end of December 2022. This fundamentally inhibits it from developing extensive, large-scale satellite manufacturing and launch infrastructure. While Singapore indeed excels in small satellite technologies, its capacity remains limited in comparison with countries providing full-fledged satellite ecosystems. There is a further investment in the infrastructure enhancements that are required since increased demands for real-time data remote sensing create immense pressures on the highly developed ground stations and data centers that are in Singapore.

2. Funding Limitations

Funding space technology in Singapore always depends on private sector co-funding and limited government resources and budgets for high-risk ventures, long-term activities in particular. While generally spearheading innovation through public–private partnerships, the venture capitalists in space ventures normally dishearten private investment all the time.

3. Skill and Workforce Development

Singapore's workforce has a strong competency in data science and analytics, but an adequate supply of specialists for satellite engineering, orbital mechanics, and cutting-edge remote sensing technologies does not exist. The current demand for processing and analysing satellite data far outweighs the availability, and that is very challenging. On the other hand, minimal hands-on training opportunities with satellite operation further indicate industry–academia collaborations, as well as custom programmes.

4. Policy and Regulatory Framework

Singapore's regulatory environment for space activities is still evolving. Singapore currently lacks a comprehensive national space law that covers space activities, including satellite launches, remote sensing, and space resource utilisation. This absence creates legal uncertainties, particularly for private sector participants who require clear regulations for liability, licensing, and compliance with international treaties. While satellite communications are regulated by the Infocomm Media Development Authority (IMDA), broader space activities remain underdeveloped in regulatory terms. Balancing strict data protection rules with the need for international data sharing would further complicate the situation. Therefore, comprehensive legislation and governance structures will have an important role to play in eliminating such gaps.

5. Dependence on Foreign Technology

Singapore is, indeed, termed as a techno powerhouse but in terms of acquisition of data and provision of satellite launch services, it relies heavily on foreign suppliers. The absence of huge infrastructures in the country to support satellite operations lends further dependence on external sources for the major components and data. Investments in localised R&D and establishing regional partnerships with shared resources could be helpful to insulate the potential vulnerabilities created by such dependence regarding data access and control.

6. Awareness and Industry Engagement

Remote-sensing applications and their associated space technologies are not commonly in the knowledge of the public and industries. The tech-savvy areas of Singapore have already embraced these technologies, but other fields such as agriculture and urban planning have yet to do so. Demonstration projects and outreach campaigns can show them the actual value of space technology for solving critical issues in a relevant way.

7. Data Autonomy

Singapore's position as a data hub is paradoxically coupled with its dependence on external satellite data sources. While the nation excels in processing and analysing data locally, the reliance on international satellite operators for raw data undermines its autonomy.

B. Viet Nam

1. Infrastructure Constraints

In Viet Nam, the space infrastructure is developing; large-scale applications are still underdeveloped. It has launched the Earth observation satellite VNREDSat-1, amongst others, but has limited capacity with regard to satellite manufacturing, advanced data processing facilities, and dedicated launch infrastructure. Finally, ground station networks should be extended to receive more real-time data and cover more areas, especially coastal and rural regions.

2. Funding Limitations

Government funding for space technology and remote sensing is limited and even linked to international grants or specific projects for the short term. Although Viet Nam has gained significant foreign investment for its technology industries, space ventures are usually underfinanced because of their high risks and long payback periods. This is further exacerbated by a lack of private sector involvement. Targeted funding opportunities, public–private partnerships, and tax incentives for companies investing in space applications can help to fill this funding deficit.

3. Skill and Workforce Development

Viet Nam faces a shortage of specialised talent in satellite engineering, data analytics, and geospatial applications. While universities and research institutes are producing a growing number of graduates in STEM fields, opportunities for hands-on training in space technology remain limited. This gap is particularly evident in emerging applications such as AI for remote sensing and maritime monitoring. Strengthening academic programmes, industry internships, and research collaborations can help build the skilled workforce needed to advance the sector.

4. Policy and Regulatory Framework

Viet Nam still lacks a comprehensive legal framework to regulate its growing space activities. The current policies are fragmented, addressing specific aspects such as satellite operations or data sharing without an overarching governance structure. Issues like liability, intellectual property, and international compliance remain ambiguous.

5. Dependence on Foreign Technology

Viet Nam relies heavily on foreign technology for satellite components, launches, and advanced data processing tools. While the country has developed capabilities in small satellite operations, it remains dependent on international partners for high-resolution satellite imagery and critical technologies. This dependence limits Viet Nam's autonomy in space operations and can delay data access during critical situations.

6. Awareness and Industry Engagement

Awareness of the potential applications of space technology and remote sensing amongst industries and the general public is limited. Sectors such as agriculture, fisheries, and urban planning have yet to fully adopt these technologies despite their clear benefits. This lack of awareness hampers demand for innovation and investment in space applications. Conducting targeted outreach programmes, pilot projects, and workshops can demonstrate the value of remote sensing in addressing Viet Nam's key challenges.

7. Data Autonomy

Viet Nam's capacity to independently collect and process satellite data is limited, forcing reliance on external sources for high-resolution imagery and analytical tools. This dependency poses risks to data sovereignty and operational efficiency, particularly during emergencies such as typhoons or flooding. Expanding domestic satellite programmes and exploring joint satellite missions with international partners can enhance Viet Nam's data autonomy.

C. Thailand

1. Infrastructure Limitations

Thailand's space infrastructure, while more advanced than some of its regional peers, still faces limitations in scaling to meet growing demands. The country relies on external providers for satellite launches and advanced data processing capabilities. While GISTDA operates several satellites, including THEOS-1 and THEOS-2, the coverage and resolution of these assets are insufficient for the wide range of applications needed, especially in disaster-prone and rural areas.

2. Funding Constraints

Funding for space technology in Thailand remains a challenge. Although the government has made significant investments in satellites and geospatial technology, the resources allocated are often insufficient to cover long-term projects or large-scale infrastructure upgrades. Furthermore, private sector participation in funding space initiatives is limited due to the perceived high risk and unclear returns on investment.

3. Skill and Workforce Development

Thailand faces a shortage of highly specialised professionals in satellite engineering, remote sensing analytics, and AI-driven geospatial applications. While GISTDA has led efforts to train personnel, the demand for skilled talent far exceeds the supply. Additionally, the lack of widespread access to hands-on training and practical experience in satellite operations creates a gap in readiness for advanced technological projects.

4. Policy and Regulatory Framework

The lack of a comprehensive legal framework governing space activities is a significant barrier to Thailand's progress. Current policies are fragmented, with limited clarity on issues such as data privacy, satellite licensing, and liability. Moreover, there is insufficient regulation to encourage private sector participation or ensure compliance with international standards.

5. Dependence on Foreign Technology

Thailand relies heavily on international partnerships for satellite components, launch services, and high-resolution data. While THEOS satellites provide valuable insights, many applications depend on data sourced from international providers, which can limit autonomy and create vulnerabilities during geopolitical tensions.

6. Data Autonomy

Thailand's reliance on external sources for essential satellite data hampers its ability to independently collect and process high-resolution imagery. Such dependency can delay responses in emergencies such as floods or droughts where real-time data is of prime importance.

7. Awareness and Industry Engagement

Public and industrial consciousness of the potential uses of remote sensing is still very low. While disaster management and agriculture have widely adopted these technologies, urban planning and infrastructure development are still not exploiting their full potential.

D. Indonesia

1. Infrastructure Limitations

Indonesia's space infrastructure is still developing but remains insufficient to meet the country's vast geography and economic sectors. The country lacks indigenous launch facilities for domestic satellites, thereby making it dependent on international launch service providers, which adds costs and limits the country's sovereignty. Moreover, Indonesia's ground station network is not adequate to receive and analyse data in real-time, especially in remote and disaster-prone areas. Current satellites, such as LAPAN-A3, have yielded very useful data, but they lack the capability to deliver high-resolution imagery that is essential for critical applications such as disaster management and resource monitoring.

2. Funding Constraints

Research and development in space technology has rather low funding. The funding for space activities is relatively less in volume compared to other industries. The research and development funding on space is under 1% of the GDP, much lower than what has been allocated in other nations with advanced space programmes. Such limited funding does not help in the achievement of any significant progress in space technology and infrastructure such as the development of spaceports. Satellite technology development is slow. The slow pace of indigenous satellite development and launching signifies a lack of focus and investment in building domestic capacities. This limitation doesn't allow investment in infrastructure such as developing and launching satellites and building state-of-the-art research facilities. Additional budgetary support is critical to building Indonesia's autonomy in space technology.

3. Skill and Workforce Development

There is a scarcity of special talent in Indonesia in the field of satellite engineering, geospatial analysis, and data-driven applications of remote sensing. The remote sensing and space technology workforce is very limited, and unevenly distributed in the country. The majority of the professionals are found to be in urban centers, and most rural and disaster-prone areas lack representation. There is a vast lack of trained professionals to help drive the development and operational aspects of space technology. Opportunities for hands-on training in satellite operations and advanced data processing remain limited.

4. Policy and Regulatory Framework

The Indonesia Government views space technology more like a supporting system than any

specialist one. Space technology rarely seems to be significant in terms of discussion, issues, or any agenda items from national priorities. There is mostly a tendency in the heads of political leadership to talk about other vital issues around economic development, healthcare, and education. This lack of political prioritisation may inhibit the space sector from growing and consequently limit its potential contributions towards national development. This view influences policy decisions and the provision of resources, which in turn slows down the development and mastery of space technologies in the country. Policy frameworks guiding activities in space are not nearly as strong or detailed compared to those of other sectors such as agriculture or manufacturing in Indonesia. Although there are fundamental laws and strategic regulations, for example, the Space Act No. 21 of 2013, policies lack the supporting detailed measures needed to establish fast development in the space sector. The Space Act has a legal framework for conducting space activities but does not provide similar levels of support and incentives as other sectors. The regulatory environment that will have to be developed to facilitate the growth of a local space industry is underdeveloped. Critical areas in satellite launches, space traffic management, and commercial space activities are not even well regulated. This forms a regulatory gap that leads to uncertainty and might deter one from investing or innovating in the space sector. For example, the Space Act encompasses varied issues in the conduct of space activities that range from safety, security, and even international cooperation; however, it lacks definite provisions in regulation over commercial space activities or on traffic management issues.

5. Dependence on Foreign Technology

Indonesia is presently dependent on space data and technology from other countries. The dependence on external sources for essential satellite data, including weather forecasting and disaster management, exposes Indonesia to strategic vulnerabilities during geopolitical tensions, which may restrict its access to this data. Using foreign satellites risks privacy breaches and unauthorised data usage, thus undermining Indonesia's sovereignty in data. This dependence also strangles the emergence of native industries and discourages indigenous scientists and engineers from acquiring advanced skills in satellite technology. Even in the case of institutions like BRIN, making efforts to promote indigenous satellite systems, these are inferior in comparison to satellites acquired from other technologically superior nations in terms of quality and performance; hence, unused and foreign data is preferred.

6. Data Autonomy

Indonesia is unable to independently gather, process, and interpret satellite information; thus, there exist enormous risks to data sovereignty. Although some of the satellite data emanates from LAPAN's satellites, the use of high-resolution imagery from external satellites hampers the system and leaves many applications vulnerable to disasters such as landslides, poor urban planning, and environmental mismanagement that increase costs due to lack of immediate access.

7. Awareness and Industry Engagement

In Indonesia, the low public awareness and understanding of the benefits of space technology pose a peculiar challenge, considering the country's needs for disaster resilience, agricultural optimisation, and environmental monitoring. Most Indonesians, including private sector stakeholders, do not understand how space technology directly impacts their lives and industries. This lack of understanding translates into insufficient public enthusiasm and, in turn, weak political will to prioritise funding for space initiatives. For the private sector, the market demand for space-based solutions reflects the same gap. Industries like agriculture, forestry, and urban development often underutilise remote sensing and geospatial tools, perceiving them as costly or nonessential because of a lack of awareness about their potential cost-saving and efficiency-enhancing benefits. This limits partnerships and investments in space technology, slowing innovation and economic integration in these sectors.

E. Malaysia

1. Infrastructure Limitations

Malaysia's space infrastructure is underdeveloped, but it has little scale and capabilities in size for the country's full requirements. Lack of a domestic launching facility on satellites forces them to opt for international satellite launch companies that increase satellite launching timeframes and costs. The coverage provided by ground station networks lacks seamless real-time data capture and analysis, especially in larger-scale applications like disaster response and environmental monitoring.

2. Funding Constraints

Space technology and remote sensing initiatives in Malaysia are underfunded primarily due to limited government budgets, with low private sector engagement. Most rely on international grants or partnerships, which can create dependence and limit autonomy. Companies perceive space technology as a risky investment, thus underfunding innovation and application development.

3. Skill and Workforce Development

Malaysia has a strong potential workforce, though there is a lack of specialised talent in satellite technology, geospatial analytics, and AI applications for remote sensing. Even though MYSA and the leading universities have initiated building expertise through developed programmes, it is still too small in scale to support the rising demand. There is also limited practical training in advanced satellite engineering and real-time data processing.

4. Policy and Regulatory Framework

Lack of comprehensive and unified space policy to steer the development of space activities and remote sensing applications in Malaysia. Satellite operation, data privacy, and licensing are not well-defined, which hinders innovation and private sector participation.

5. Dependence on Foreign Technology

Malaysia depends on international vendors for satellite parts, launching services, and high-level data analytics. Even though Malaysia has been doing a good job in small satellite development, such as RazakSAT, the advanced technology and high-resolution imagery mainly originate from overseas. This leaves the country to rely extensively on foreign entities to effectively operate critical applications such as disaster response and environmental monitoring.

6. Data Autonomy

Malaysia's domestic satellite capabilities are limited and, therefore, cannot collect and process high-resolution satellite data independently. This makes the country vulnerable to data sovereignty and operational efficiency risks, especially in times of emergencies.

7. Awareness and Industry Engagement

Public and industrial awareness of how remote sensing can be useful remains underdeveloped. This notwithstanding, disaster management and environmental conservation continue to adapt to these technological advances, while agriculture, forestry, and urban development still remain largely untapped industries for remote sensing.

F. Philippines

1. Infrastructure Limitations

The Philippines' space infrastructure is in the very early stages of development. The country has only been able to launch microsatellites such as Diwata-1 and Maya-2 but lacks the capacity to manufacture large-scale satellites and facilities for launching them. Ground station coverage is limited, particularly in rural and disaster-prone areas, which hampers the timely collection and analysis of remote sensing data.

2. Funding Constraints

Funding remains a significant challenge for the Philippines' space technology initiatives. Although the government has made strides in supporting PhilSA, resources are often insufficient to cover the long-term development and operational costs of advanced satellite programmes. The private sector has also shown limited investment in space technology due to the high perceived risk and lack of immediate returns.

3. Skill and Workforce Development

The Philippines faces a shortage of highly trained professionals in satellite technology. geospatial analytics and AI-driven remote sensing applications. While PhilSA has initiated programmes to develop local talent, opportunities for hands-on training and practical exposure to advanced satellite operations are limited. Additionally, the availability of specialised academic programmes in space-related fields is low.

4. Policy and Regulatory Framework

The regulatory environment for space activities in the Philippines is still evolving. While the Philippine Space Act provides a legal foundation, there are gaps in implementing comprehensive policies for satellite operations, data privacy, and industry engagement. Clearer guidelines are needed to regulate private sector participation, ensure international compliance, and streamline data-sharing protocols.

5. Dependence on Foreign Technology

The Philippines remains heavily dependent on foreign technology for satellite development, data acquisition, and launch services. While collaborations with international partners such as JAXA, NASA, and ESA have been instrumental, this dependence limits the country's autonomy in managing critical applications like disaster response and maritime monitoring.

6. Data Autonomy

The Philippines' reliance on external satellite data sources poses challenges for data sovereignty and operational efficiency. During emergencies like typhoons or volcanic eruptions, delays in accessing critical data can hinder response efforts.

7. Awareness and Industry Engagement

Public and industry awareness of the benefits of space technology and remote sensing remains low in the Philippines. While sectors such as disaster management and agriculture have begun to adopt these technologies, industries like fisheries, urban planning, and forestry are still underutilising them.

G. Lao PDR

1. Infrastructure Limitations

Lao PDR has limited infrastructure for space technology and remote sensing. The country does not have domestic satellites, ground stations, and data processing facilities, and it relies on external sources for critical data. Internet and technological infrastructure in rural areas are also limited, which restricts the processing and utilisation of remote sensing data for practical applications.

2. Funding Constraints

The developing economy and reliance on international aid for large-scale projects limit funding for space technology in Lao PDR. Most initiatives rely on grants or regional partnerships, focusing on immediate needs rather than long-term capacity building. Private sector investment in space technology and remote sensing is virtually nonexistent, as these areas are perceived as low priority compared to other development needs.

3. Skill and Workforce Development

Lao PDR suffers from a shortage of skilled professionals in space and satellite technology, geospatial analysis, and data interpretation. Largely due to insufficient opportunities for education in the field of STEM, Lao PDR does not have specialised programmes focused on space and remote sensing; these factors impede the growth of the workforce. Lack of training facilities and hands-on opportunities restrict local expertise.

4. Policy and Regulatory Framework

Lao PDR currently does not have any coherent policy framework for the use of space technology and remote sensing. The lack of specific space laws or policies on the proper use of satellite data concerning privacy, international cooperation further complicates adopting and regulating the technologies.

5. Dependence on Foreign Technology

The country is highly reliant on foreign sources for satellite data, technology, and expertise. It is incapable of developing or operating its own satellites and relies on the international organisations or neighboring countries for remote sensing data. Thus, this dependency reduces Lao PDR's ability to effectively deal with national priorities and is faced with challenges in accessing data when it needs to respond to emergencies.

6. Data Autonomy

The limited ability to collect and process data domestically hampers Lao PDR' control over its geospatial and environmental information. Such reliance on external sources delays responses to critical issues like floods, deforestation, and agricultural monitoring.

7. Awareness and Industry Engagement

Awareness of the possible applications of remote sensing and space technology is low amongst government agencies, industries, and the public in Lao PDR. Although international organisations have introduced some projects on agriculture and environmental monitoring, the wider application of these technologies is still limited.

H. Cambodia

1. Infrastructure Limitations

Cambodia lacks the infrastructural setup that is fundamentally required for space technology and remote sensing. This country has no domestic satellite ground station or any advanced facility for data processing. Consequently, this country is completely dependent on foreign sources of geospatial data. The absence of IT infrastructure in rural and remote regions restricts the availability of the benefits of remote sensing.

2. Funding Constraints

Because the space technology and remote sensing sector is still relatively new for Cambodia, as a developing country, this sector receives little to no financial contributions. Sources of funds depend on international grants or some regional agreements focused on specified projects rather than building a long-term capability. Fund injection from the private sector comes close to nil because investing in space-related projects involves too much and returns so little in the short-term.

3. Skill and Workforce Development

Cambodia has few professionals experienced in satellite technology, geospatial analysis, and remote sensing applications. As a result, there are few opportunities for STEM education and training in space-related fields, and the fact that hands-on learning facilities are limited further hampers the development of a well-trained workforce.

4. Policy and Regulatory Framework

Cambodia does not have any specific policy or regulatory framework on space technology and remote sensing. This situation creates uncertainty for investors and hampers the organised adoption of these technologies. Data privacy, satellite licensing, and international cooperation are still some of the issues that have not been addressed.

5. Dependence on Foreign Technology

Cambodia is fully dependent on foreign technology and expertise for accessing satellite data, designing remote sensing applications, and conducting technical operations. In this regard, the dependency of the country restricts its ability to solve its problems uniquely.

6. Data Autonomy

Cambodia's incapacity to collect and process geospatial data on its own limits the ability of the country to manage natural resources, track disasters, and enhance agricultural practices. Reliance on other sources of data makes emergency responses late and increases costs on accessing critical information.

7. Awareness and Industry Engagement

Public and industry awareness of applications and benefits of space technology and remote sensing is low in Cambodia. Even though some efforts have been put into introducing remote sensing in agriculture and forestry sectors, there are still immense potentials untapped in infrastructure planning and disaster resilience sectors.

I. Timor-Leste

1. Infrastructure Limitations

In Timor-Leste, the lack of stable infrastructure and necessary facilities makes it challenging to establish ground stations, satellite communication networks, and processing facilities for remote sensing data. Satellite data may mostly depend on the services offered by international organisations on some occasions, resulting in time-lag effects or holes and a lack of site-specific data for particular localised applications.

2. Funding Constraints

The state of Timor-Leste, being small, with economic development issues also makes satellite missions highly priced. Satellite launching, development, and running demands an amount of financial investments. Timor-Leste is a developing nation that should first prioritise healthcare, education, and basic infrastructure. Such a small national budget places limitations on the capacity to support R&D projects toward technological advancements, meaning such projects must rely on donor funds or regional collaboration for support. The lack of dedicated funding also deters investments in necessary infrastructure, such as laboratories or geospatial data centres or innovation hubs that enable the adoption and innovation of remote sensing technologies. Furthermore, the financial constraints create a limitation on the resources available to the government towards funding specialised education programmes and scholarships or training sessions regarding geospatial technologies that can limit local expertise-building capabilities and make the nation dependent on external support mechanisms for remote sensing projects.

3. Skill and Workforce Development

Space technology and earth observation require a workforce highly skilled in the operation of satellites, data analysis, and geospatial technology. In Timor-Leste, the technical workforce will be limited because there lacks proper education and training at specialised levels in space sciences and related fields. In this country, very few universities and technical institutes offer courses in the areas of remote sensing or geospatial analysis, resulting in a lack of skills to be utilised for the management of projects involving remote sensing. In the policy-making area, strategic planning, and incorporation of remote sensing data into national development plans, a lack of skills is identified. The country faces a problem in terms of providing consistent training due to the lack of trainers or mentors who are experienced in this specialised field, besides limited resources. International cooperation by agencies, NGOs, and regional groups helps fill this gap. However, it normally means time and resources cannot coincide with the country's most urgent needs. There also is the problem of holding onto the trained person; even if training were to be made available, professional people will seek abroad more lucrative packages, greater facilities, and more R&D facilities than in neighbouring countries.

4. Policy and Regulatory Framework

Timor-Leste still needs a formalised national policy dedicated to the space sector. Without a defined strategy or legal framework, efforts to develop remote sensing capabilities lack direction and face inconsistent funding. The absence of policy also weakens coordination across sectors and limits the country's ability to attract international partnerships, secure funding, and manage data effectively. Political factors constrain the flow of technological support and expertise. Regional cooperation often depends on stable political relationships, and shifts in these dynamics can disrupt existing agreements and future collaborations. Such shifts can slow down infrastructure development or compromise ongoing projects, challenging long-term planning for space capabilities. Timor-Leste is starting to develop a space policy by learning from Malaysia in legal and policy formulation.

5. Dependence on Foreign Technology

Accessing, managing, and sharing remote sensing data across different sectors remains challenging due to underdeveloped digital infrastructure. Remote sensing data has cross-sectoral applications, but coordination between government departments and sectors is often limited. A lack of standardised data-sharing protocols further complicates the exchange and utilisation of geospatial data across sectors like environmental monitoring, agriculture, and disaster response. The absence of centralised data repositories or geospatial information systems (GIS) hinders data-driven decision-making and reduces the potential benefits of remote sensing technologies in national development.

Currently, geospatial data management in Timor-Leste is overseen by the National Directorate of Geospatial Data (DNDG) under the Ministry of Planning and Strategic Investment. The DNDG is working to address these challenges and plans to develop a Geospatial Data Center in the near future. This center aims to enhance data accessibility, improve coordination between sectors, and establish centralised repositories for geospatial information. These efforts are expected to facilitate more effective decision-making and amplify the role of geospatial technologies in achieving national development goals.

6. Data Autonomy

Accessing, managing, and sharing remote sensing data across different sectors is also challenging due to an underdeveloped digital infrastructure. While remote sensing data can be applied across various sectors, coordination amongst different government departments is often limited. Standardised data-sharing protocols further complicate the exchange and utilisation of geospatial data across sectors such as environmental monitoring, agriculture, and disaster response. The absence of centralised data repositories or geospatial information systems (GIS) hinders data-driven decision-making and reduces the potential benefits of remote sensing technologies in national development.

7. Low Awareness and Industry Engagement

Low public awareness in Timor-Leste limits the development of space and remote sensing technology. This is evident in the lack of government support, investment, and community engagement. The public generally views space initiatives as costly and not urgent, influencing political priorities and market demand. Consequently, community participation and technology adoption remain low. Without public demand, educational programmes and policy development progress slowly, which perpetuates a limited capacity and growth.

1.2 Needs

A. Singapore

Singapore, the small but ambitious city-state, has recognised the massive potential of remote sensing and space technology in addressing the challenges unique to it, to support its vision as a Smart Nation. While the country pushes forward on all its initiatives, key needs have emerged in the realm of space-based technologies.

Environmental monitoring has become a primary concern for an island country due to susceptibility to climatic changes, and due to the constant threat posed by rising sea levels, Singapore needs higher satellite data about its coast lines. Land Authority of Singapore has already taken the initiatives in adopting space and ground technologies by mapping the territories and in monitoring the differences in ground height, so crucially important for shielding the coastlines of that country from erosion.

In the heart of the city, space technology is very important in urban planning and development. The Electronic Road Pricing (ERP) system, which is a core component of Singapore's traffic management, relies on Global Navigation Satellite Systems (GNSS) to provide real-time traffic information and improve overall transport planning. This technology is not just about easing congestion; it's an integral part of Singapore's Smart City vision.

A high performing, dynamic marine-related segment of Singapore's economy greatly benefits from the impact of space-based innovations. On satellite-based maritime communications like VHF Data Exchange System (VDES) are amongst the investments made towards enhancements in ship-to-ship and ship-to-shore communications. It should then be able to lengthen coverage and enhance traffic management in the marine context-things that matter especially because Singapore is known as an important maritime hub.

Singapore is committed to sustainability in its use of space technology. The country is building capabilities for carbon Measurement, Reporting, and Verification using satellite data, an essential tool in its arsenal against climate change. The country is also using satellite technology in agricultural applications and pollution monitoring, which addresses the concerns of the nation about food security and environmental quality.

In the national security and defense area, Singapore does not stand still. All-weather, day-and-night radar imaging capability demonstrated by the development of DS-SAR satellites shows commitment to enhancing the country's defense capabilities through space technology.

Looking to the future, Singapore is making significant investments in the state-of-the-art space technologies of Very Low Earth Orbit (VLEO) satellites and Quantum Key Distribution (QKD) satellite solutions. These will enable greater earth observation capabilities and secured communications, positioning Singapore as one of the world leaders in the development of space technology.

The Space Technology Development Programme (STDP), with its substantial investment of S$150 million, underscores Singapore's commitment to nurturing its space industry. This programme aims to develop space capabilities that support critical domains such as aviation, maritime, and sustainability while exploring emerging opportunities in the space economy.

With ongoing investment in the development of its space capabilities, remote sensing and space technology are no longer mere luxuries but are more like necessities for a nation like Singapore. They start protecting the shores, then urban management, secure communication systems, and boost the economic activities that are driven from there, and they play an important role in weaving space technology into Singapore's present and future and enable the small island nation to punch above its weight on the global level.

B. Viet Nam

Viet Nam, a country of multiple landscapes and huge potential in natural resources, identified the vast opportunities created by remote sensing and space technology to meet its problems, as well as enable the realisation of its strategic goals. As the country accelerates its space missions, several key needs appear for space-based technologies.

Due to its vulnerability to natural disasters and climate change, monitoring of the environment has emerged as a high priority activity in the country. Having such a long coastline with massive marine resources, advanced satellite data are required by Viet Nam to monitor its coastal areas and marine ecosystems As a leading organisation using space technologies, the VNSC is at the forefront of using such technologies in water quality monitoring, coral reef mapping, tracking of marine pollution, and coastal landform changes.

Space technology, though crucial for the optimisation of agriculture, is an important element in Viet Nam's economic hub. Data from remote sensing is being used for vegetation indices, crop health checks, and irrigation requirement. This allows farmers and policy makers to make better-informed decisions on the crop selection, water management, and sustainable farming, as it aligns with food security goals of Viet Nam.

Viet Nam's investment in radar satellite technology is a response to the need for all-weather, day-and-night imaging capabilities. The country will launch its first radar satellite, LOTUSat-1, in early 2025. This 600kg satellite will be able to detect objects as small as 1 meter on Earth, regardless of weather conditions or time of day. Dr Le Xuan Huy, deputy director general of the Viet Nam National Space Center, was underlining the significance of such technology, ‘Whereas optical satellites cannot photograph or take pictures when the day is cloudy, foggy, and during poor visibility, radar satellites can get pictures in all such adverse weather conditions.

Viet Nam's huge EEZ covers almost 750,000 km^2 and requires robust monitoring capabilities. The country's investment in SAR satellites, such as the LOTUSat-1 and LOTUSat-2 projects, is motivated by the need to effectively monitor this vast maritime area.

Another important need for Viet Nam is the development of its domestic space capability. Over the years, Viet Nam has been investing not only in human resource development but also in small satellite development, construction of infrastructure, and other activities as part of its efforts. The development of satellites with a ground station system-the Viet Nam National Space Center-reflects the country's ambition in building its own technology capabilities for space.

As Viet Nam continues to invest and develop its space capabilities, the country is not indulging in remote sensing and space technology as a luxury but necessity for this forward-thinking nation. From protecting its coastlines to managing its agricultural lands from monitoring its vast marine territories to driving technological innovation space technology is woven into the fabric of Viet Nam's present and future developmental strategies.

C. Thailand

As an ethnically, geographically, and geologically rich country, the nation is now aware of the extraordinary potential remote sensing and space technology hold in answering their unique set of challenges toward supporting national development goals. As Thailand continues to thrust forward into its space enterprise, here are a number of high-priority needs in space-based technologies.

Environmental monitoring is of paramount importance because the country is susceptible to natural disasters and climate change. Advanced data from space are needed to vigilantly monitor its environment, and carbon dioxide level monitoring should be on top. The Geo-Informatics and Space Technology Development Agency (GISTDA) has spearheaded the utilisation of space technologies for gathering important environmental data.

In the heart of Thailand's economy, agriculture plays a very important role, and space technology has become an indispensable tool for optimising agricultural practices. Crop health monitoring, yield estimation, and loss assessment are all being done with the help of remote sensing data. The RIICE project, covering Thailand and other Southeast Asian countries, exemplifies the country's commitment to satellite technology in agricultural management.

The need for comprehensive earth observation capabilities has been an incentive for Thailand to invest in satellite technology. The successful launch in October 2023, THEOS-2; it is Thailand's second earth observation satellite, marks a historical landmark in the country's pursuit of space ambitions. It will provide high-definition photographs and precision geoinformatics, assisting the natural resource monitoring, smart agriculture, and disaster prevention and response.

The development of domestic space capabilities is also recognised by Thailand. In fact, the country has been investing in the human resource development and infrastructure building of space. Launching THEOS-2 jointly designed by Thai and British engineers is a sign that Thailand is ambitious enough to enhance its indigenous space technology capabilities and foster international cooperation in this field.

Disaster response and management is another critical need for Thailand's remote sensing and space technology efforts. The country is using SAR technology to help rapidly assess damage caused by natural disasters like earthquakes, floods, and landslides. This is crucial for a country prone to various natural hazards.

As Thailand continues to invest in and develop its space capabilities, it is evident that remote sensing and space technology are no longer luxury items but rather a requirement for this forward-thinking country. From protecting its environment and managing its agricultural lands to responding to disasters and driving technological innovation, space technology now plays a key role in the development strategies of present and future Thailand. The country's efforts in this field aim not only to respond to its immediate needs but also to position Thailand as a key player in the regional and global space technology landscape.

D. Indonesia

Indonesia, the world's largest archipelago with more than 17,000 islands, has realised its potential through remote sensing and space technology in addressing specific challenges facing it and promoting its development objectives. Since the nation continues to aggressively pursue space endeavors, various key needs have emerged concerning space-based technologies.

The country's wide diverse landscapes, along with vulnerabilities towards natural disasters, led environmental monitoring to become top on the list. It has been the need for advanced satellite data in its expansive coastlines, marine ecosystems, and natural resources of Indonesia. The LAPAN or the National Institute of Aeronautics and Space has been spearheading this task of utilising space technologies, water quality monitoring, and coral reef mapping, tracking pollution in the marine world, and identifying changes on the coastal landforms.

Agriculture is a crucial part of Indonesia's economy, while space technology has emerged as one of the indispensable tools to optimise farming practices. Crop health monitoring, yield estimation, and potential loss assessment are being executed using remote sensing data. That helps farmers and policymakers have a proper choice about crops, water management, and sustainable farming in favor of food security for Indonesia.

The need for all-around Earth observation capability has driven Indonesia's investment in satellite technology. It has set ambitious targets for its satellite sensing capabilities by planning to develop and launch a national earth observation satellite in the 500 kg class by 2030. This satellite will carry optical cameras and synthetic-aperture radar (SAR) sensors, providing all-weather, day-and-night imaging capabilities crucial for a country prone to cloud cover and various natural hazards.

Indonesia's huge Exclusive Economic Zone requires strong monitoring capacity. Investment in satellite technology by Indonesia aims to enhance its capability to effectively monitor its vast maritime area, combat illegal fishing, and ensure the sustainable management of its marine resources.

In terms of developing its domestic space capability, Indonesia has also shown such necessity. It has taken time in the development of human resource, small satellite development, and space infrastructure building. A constellation of 19 satellites comprising very high-resolution imaging satellites, synthetic aperture radar satellites, and low Earth orbit satellites is under development from the Indonesian Space Agency or BRIN. This shows Indonesia's intent to construct its own space technology capacity while not depending on satellites elsewhere.

Thus, it is quite evident that Indonesia continues to invest and develop its space capabilities: remote sensing and space technology are no longer luxuries but necessities for this forward-thinking nation. From protecting coastlines to managing agricultural lands, from monitoring vast marine territories to technological innovation, space technology is woven into the fabric of Indonesia's present and future development strategies. The country's efforts in this area aim to not only answer the needs of the country immediately but also position Indonesia as a significant player in the regional and global space technology landscape.

E. Malaysia

Malaysia, with its diversified ecosystems, rapidly urbanising cities, and focus on sustainable development, has unique requirements in remote sensing and space technology to pursue national priorities. These priorities are linked with disaster management, environmental monitoring, agricultural optimisation, and infrastructure development.

One of the key needs of Malaysia is in environmental monitoring and conservation. With vast areas of tropical rainforests and significant biodiversity, Malaysia will require high-resolution satellite imagery to monitor deforestation, trace changes in land use, and combat illegal logging in the country. These will be critical tools for preserving Malaysia's natural heritage and meeting its sustainability and carbon reduction goals.

Other critical aspects include disaster management, where floods, landslides, and coastal erosion are always devastating features in the country. These tools can also be part of real-time data input into early warning systems to complement response efforts and help in critical information for recovery planning. The fact that Malaysia uses agriculture as a stabilising factor in its economy necessitates the use of precision agriculture tools. Satellite-based monitoring can optimise crop health management, track pest infestations, and ensure efficient use of water and fertilisers. These technologies can help boost productivity while reducing environmental impacts.

Malaysia, as a rapidly urbanising country, is facing demands for efficient urban planning and infrastructure management. The need for remote sensing technologies to monitor urban sprawl, manage traffic congestion, and ensure sustainable infrastructure development in cities like Kuala Lumpur will increase in the future. These technologies contribute to smart cities, aligned with the vision of digital transformation in Malaysia. Malaysia's geographical position along the global shipping route, especially on the maritime front, has been a significant reason for the importance of coastal and marine monitoring. Fisheries management, illegal activities like piracy or illegal fishing, and security in the maritime front all require satellite technology.

To achieve such objectives, Malaysia will be needed to invest in next-generation satellites as well as expand its domestic satellite programmes under the Malaysian Space Agency, MYSA. What is needed are satellites designed precisely for Malaysia's environmental and geographical needs. Increasing the efficiency of real-time data acquisition and processing will necessitate the expansion of the ground station network. Workforce development in Malaysia also requires great efforts in developing experts in satellite engineering, geospatial analysis, and AI-driven remote sensing applications. Building partnerships between universities, government, and private industries can support this goal and bring forth a pool of skilled talent. Malaysia must enhance its indigenous R&D capabilities and participate in international collaborations to engage in technology transfer for reducing dependency on foreign technology. This would gradually allow the country to be self-sufficient in manufacturing satellites and in advanced data analytics. Lastly, a strategic space policy and regulatory mechanism should be in place to attract participation from the private sector, guide data management, and decongest satellite operations. This would allow Malaysia to integrate remote sensing and space technologies in furthering its sustainable development thrust, enhancing the resilience to disasters, accelerating economic growth, and thus putting itself at the lead of ASEAN.

F. Philippines

The Philippines' unique geography and extensive coastline, coupled with its vulnerability to disasters, make the country have huge needs for remote sensing and space technology that would contribute to addressing the national priorities, which are mostly disaster management, environmental protection, agricultural optimisation, and sustainable development.

Disaster preparedness and resilience form one of the foremost needs for the Philippines. Given that it lies along the Pacific Ring of Fire, there is always the experience of typhoons, earthquakes, and volcanic eruptions in the country. Hence, real-time satellite data helps in tracking these hazards to issue early warnings for preparation and to support responses. Remote sensing technologies will further help in post-disaster assessments so that communities will quickly recover.

High dependency on agriculture as a source of economic activity in the country makes precision farming tools critical. Remote sensing can make critical inputs into soil health, crop conditions, and water resource management, and thus increase productivity while decreasing environmental impacts. These are important for food security, especially in a country dependent on its agricultural output. The monitoring of coastal and marine is also another pressing need. The Philippines, being one of the countries in the world with the longest coastline and having a vast maritime zone, must face issues such as illegal fishing, marine conservation, and territorial disputes. Satellites can improve the management of marine resources, monitor biodiversity, and ensure maritime security.

Other needs come in through urbanisation and infrastructure development. For example, the continuous growth of cities such as Manila would necessitate the need for high-resolution geospatial data in planning urban development, managing traffic flow, and monitoring infrastructures. This, therefore, aids the country in building smart cities toward meeting modernisation targets. The Philippines needs domestic extended satellite capabilities to meet all its needs. While Diwata-1 and Maya-2 are examples of excellent microsatellites launched within the country, this programme needs next-generation satellites in terms of high-resolution capacity and real-time acquisition to better service the population over the archipelago through efficient data processing at well-strengthened grounds.

Workforce development is another critical area. The Philippines needs to create a pool of skilled talents in satellite technology, geospatial analysis, and AI-driven data processing. In this regard, partnerships with the Philippine Space Agency, universities, and private industries can be used to support local expertise and innovation. Reducing dependence on foreign technology is equally important. The Philippines relies heavily on international partners for satellite launches, data acquisition, and advanced processing tools. Investment in indigenous R&D and technology transfer agreements can foster self-reliance and provide access to critical technologies in times of emergencies.

Last, a full-fledged space policy is needed to guide the satellite operations, data governance, and private sector participation in the country. It will spur investment, streamline operations, and help utilise space technology for national development.

Meeting these needs can assist the Philippines in fully utilising remote sensing and space technology to enhance disaster resilience, agricultural productivity, marine resources management, and sustainable growth in cities.

These developments will allow the country not only to build capacity within itself for the challenges being faced uniquely but also gain a more significant role globally and in the region's space related endeavors.

G. Lao PDR

Lao PDR is a landlocked country with an agrarian economy and rich resource base. Some unique challenges of this country can be addressed through remote sensing and space technology. These are important technologies in support of the country's priorities in disaster management, sustainable agriculture, environmental conservation, and infrastructure planning.

Disaster monitoring and resilience should be one of the immediate needs of Lao PDR. Most rural communities are adversely affected during floods, landslides, and droughts which seriously impact agricultural productivity in rural areas. The potential early warning systems, in situ monitoring, and assessment following a disaster will better provide disaster preparedness and response with remote sensing instruments.

Agricultural optimisation is another pressing need, as agriculture is a cornerstone of Lao PDR' economy and livelihoods. Remote sensing technology can provide insights into soil health, crop conditions, and water resource management, helping farmers improve yields and adapt to changing weather patterns. These tools are vital for ensuring food security and supporting economic stability.

Strong environmental monitoring capabilities are essential in the rich biodiversity and high forest cover of Lao PDR. Remote sensing will be applied to monitor deforestation and land-use changes and assist in managing protected areas. The capabilities will give effective support in preventing illegal logging, maintaining ecological balance, and fulfilling international commitments towards sustainability and climate action.

The growing need for infrastructure development in the country also emphasises the necessity of high-resolution geospatial data. Remote sensing technology can be used to support land use planning, urban development, and infrastructure monitoring, making sure that projects are sustainable and resilient to environmental challenges.

Consistent access to high-quality satellite data will be necessary to meet such needs in Lao PDR. This can be done through partnership with international satellite providers and regional initiatives, allowing the country to capitalise on remote sensing for national priorities. Investment in basic infrastructure, like ground stations and data processing centers, would also be essential to enhancing the ability to collect, analyse, and make use of satellite data. Capacity building is also an important area. Lao PDR requires a competent workforce in geospatial analysis, satellite technology, and remote sensing applications. ASEAN partners can be of particular assistance through collaborative programmes with universities and international organisations in establishing training initiatives to build local expertise.

In present times, the country still relies majorly on imported technology and other expertise hence the relevance of technology transfer and exchange for knowledge with partners. Relations with Thailand and Viet Nam along with others and various organisations will support Lao PDR step towards domestic capacities in this scope of space and remote sensing technology.

Lastly, the country needs a holistic space policy and regulatory framework that integrates remote sensing into its national development strategy. This should address issues on data governance, privacy, and public–private sector collaboration in an environment that fosters investment and innovation.

By answering these needs, Lao PDR will be able to tap the full potential of remote sensing and space technology for better disaster resilience, optimised agriculture, conservation of natural resources, and sustainable development. These efforts will enhance the country's capability in tackling major issues while contributing to regional collaboration and growth in the ASEAN context.

H. Cambodia

Cambodia, richly endowed with natural resources and having an agricultural dependency that renders the country vulnerable to climatic changes, has major needs for remote sensing and space technology to support national development goals. These are in the areas of disaster management, sustainable agriculture, environmental conservation, and infrastructure planning. Disaster monitoring and resilience are urgently needed for this country, as the people face frequent floods and droughts that impact their lives and agriculture in the worst ways possible. Real-time satellite imagery and remote sensing tools will thus be crucial in developing an early warning system and helping in disaster response planning as well as recovery efforts for Cambodia in reducing the negative impacts of natural hazards as well as protecting vulnerable people.

The other important area is agricultural optimisation. As an agrarian economy, Cambodia needs satellite-based precision agriculture solutions to monitor crop health, optimise water usage, and increase productivity. These tools will help farmers adapt to the changing weather patterns and ensure food security in the face of climate change.

Cambodia's biodiversity and forest cover also call for strong environmental monitoring capabilities. It is through remote sensing that deforestation can be traced, illegal logging activities monitored, and protected areas conserved. These capabilities are very important in maintaining ecological balance in Cambodia and in satisfying the country's commitments to environmental sustainability.

Other needs of Cambodia are fast urbanisation and infrastructure development. This technology can support high-resolution geospatial data in aspects of urban planning, monitoring of infrastructure, and managing land use to ensure the sustainability of development. Hence, these technologies are of huge significance in managing urban sprawl as well as improving infrastructure within a growing city like Phnom Penh. One of the requirements for meeting these needs is access to reliable satellite data of high resolution. Developing partnerships with regional and international satellite providers can ensure the availability of critical information at any time. In addition to this, Cambodia needs ground stations and data processing centers as foundational infrastructure that will help in real-time analysis of data and application.

Another major need is building capacities. To tap the available satellite data and remote sensing technologies, Cambodia needs training and development programmes that would generate competent workforce. Alliances with universities, international organisations, and other countries in the ASEAN would be necessary for education and training programmes in geospatial analysis and satellite technology. Cambodia needs to rely on transfer and sharing of knowledge in a partnership to gradually build home-based expertise, reducing external dependence. Neighboring countries such as Thailand and Viet Nam, as well as international organisations, can be used to support Cambodia in developing a solid foundation for remote sensing.

Cambodia requires an integrated space policy and regulatory framework that would enable it to integrate remote sensing and space technology into its national development strategy. Such a framework should cover data governance, privacy, and private sector engagement in a way that creates an investment- and innovation-friendly environment. In so doing, it can strengthen its disaster resilience, optimise its agricultural practice, conserve its natural resources, and promote sustainable urban development by utilising remote sensing and space technology. This is likely to result in a strong performance of the country toward the attainment of development goals as well as contributions to regional and global initiatives in space technology.

I. Timor-Leste

Timor-Leste, also known as Timor-Leste, is a developing country with an essentially agrarian economy and extreme vulnerability to climate-related challenges, remote sensing, and space technology to meet its development priorities. These technologies are essential to strengthening disaster resilience, improving agricultural productivity, and conserving natural resources towards supporting sustainable development. Probably, the biggest need that Timor-Leste has is disaster monitoring and management, for this country frequently experiences floods, landslides, and droughts. This country needs real-time satellite data and remote sensing, such as providing enhanced early warning systems and better disaster preparedness with guidelines for recovery. This will aid in minimising the social and economic consequences of disasters on rural communities. Within the agricultural sector, it sustains most of the population in Timor-Leste. Precision agriculture tools are indispensable in the agricultural sector as they make important insights related to soil conditions, water availability, and crop health possible so that farmers may use the resources better and increase the yield. This is important for Timor-

Leste as changing weather patterns and lack of modern agricultural techniques continue to be challenges. The rich coastal and marine resources of Timor-Leste speak to the importance of monitoring the coast and environment. Remote sensing can support sustainable fisheries management, monitor coral reef health, and take action against illegal fishing, which are important for conserving marine biodiversity and achieving food security. The rugged terrain and limited infrastructure also underscore the need for geospatial data in planning and development. High-resolution satellite imagery will be needed to map land use, areas of infrastructure development, and the efficient management of natural resources. Such tools may be used in guiding national planning efforts so that development projects are sustainable and resilient. Timor-Leste should have access to high-quality satellite data through regional and international satellite providers on a consistent basis to meet these needs.

Building basic infrastructure, such as ground stations and data processing facilities, will be crucial in meeting local priorities for the real-time collection and analysis of data. Capacity building is also an important area in that Timor-Leste will have to invest in education and training programmes that can build a skilled workforce, ready to tap into the uses of satellite and remote sensing technologies. Training programmes can be developed with the collaboration of international organisations, universities, and ASEAN neighbors. Technology transfer and knowledge-sharing partnerships must be developed for the Timor-Leste nation as it heavily depends on foreign technology and needs to gradually decrease dependence on external sources. Such collaborations with countries like Australia, Indonesia, and other ASEAN members would allow access to expertise and resources and promote regional integration. Therefore, space policy and strategy must integrate remote sensing into the Timor-Leste national development framework. The policy must involve data governance, private sector participation, and facilitation of collaboration with international and regional partners. Timor-Leste can capitalise on remote sensing and space technology to augment disaster resilience, improve food security, conserve its resources, and support sustainable development by solving these needs. All this will not only enhance the nation's strength in trying to solve such unique issues but also will place the country as one of the active participants amongst the members of regional as well as global collaborations about space technology.

It is vital to raise public awareness about the potential benefits of space and remote sensing technology, focusing on its practical applications in everyday life (e.g. improved agriculture, disaster response). Incorporating Space Science into education (school curricula) to foster early interest amongst students, building a foundation for the next generation of space scientists, engineers, and data analysts.

Timor-Leste is strengthening its geospatial capabilities to address disaster management, agriculture, and infrastructure planning. The 2013 National Registration System (SNC) programme, with a budget of US$57.2 million, aimed to modernise land registration and positively impact local communities, although further transparency, evaluation, and capacity building are still required.

The National Directorate of Geospatial Data (DNDG) has taken significant steps to enhance geospatial management by acquiring drones and establishing eight new Continuously Operating Reference Stations (CORS). These stations have provided technical training for local staff and equipped them with advanced tools, including GNSS RTK. DNDG's collaboration with academic institutions for joint field data acquisition training in GNSS CORS strengthens knowledge transfer. In contrast, partnerships with public institutions ensure data-sharing mechanisms that align with institutional needs.

Despite these efforts, Timor-Leste needs help scaling geospatial capabilities due to limited infrastructure and resources. Increased international support and partnerships are essential to enhance data accessibility, modernise tools, and establish robust data management policies. These efforts would strengthen the integration of geospatial technologies into national strategies, boosting climate resilience, disaster preparedness, and sustainable development.

Timor-Leste has implemented geospatial data management through collaborations with local institutions, NGOs, and international agencies. Key initiatives include JICA's 1:2,000 Scale Topographic Map, road geodatabases under the R4D Program, LiDAR data for planning by the Basic Sanitation Directorate, cadastral data management by the Land and Property Directorate, and mangrove mapping by UNDP. These efforts demonstrate the critical role of geospatial data in supporting infrastructure, conservation, and disaster preparedness.

Despite progress, Timor-Leste needs further international support to address capacity, infrastructure, and data-sharing systems gaps. Expanding collaborations with global organisations could enhance workforce training, modernise geospatial tools, and establish centralised data systems, enabling the country to tackle environmental challenges better and achieve sustainable development goals.

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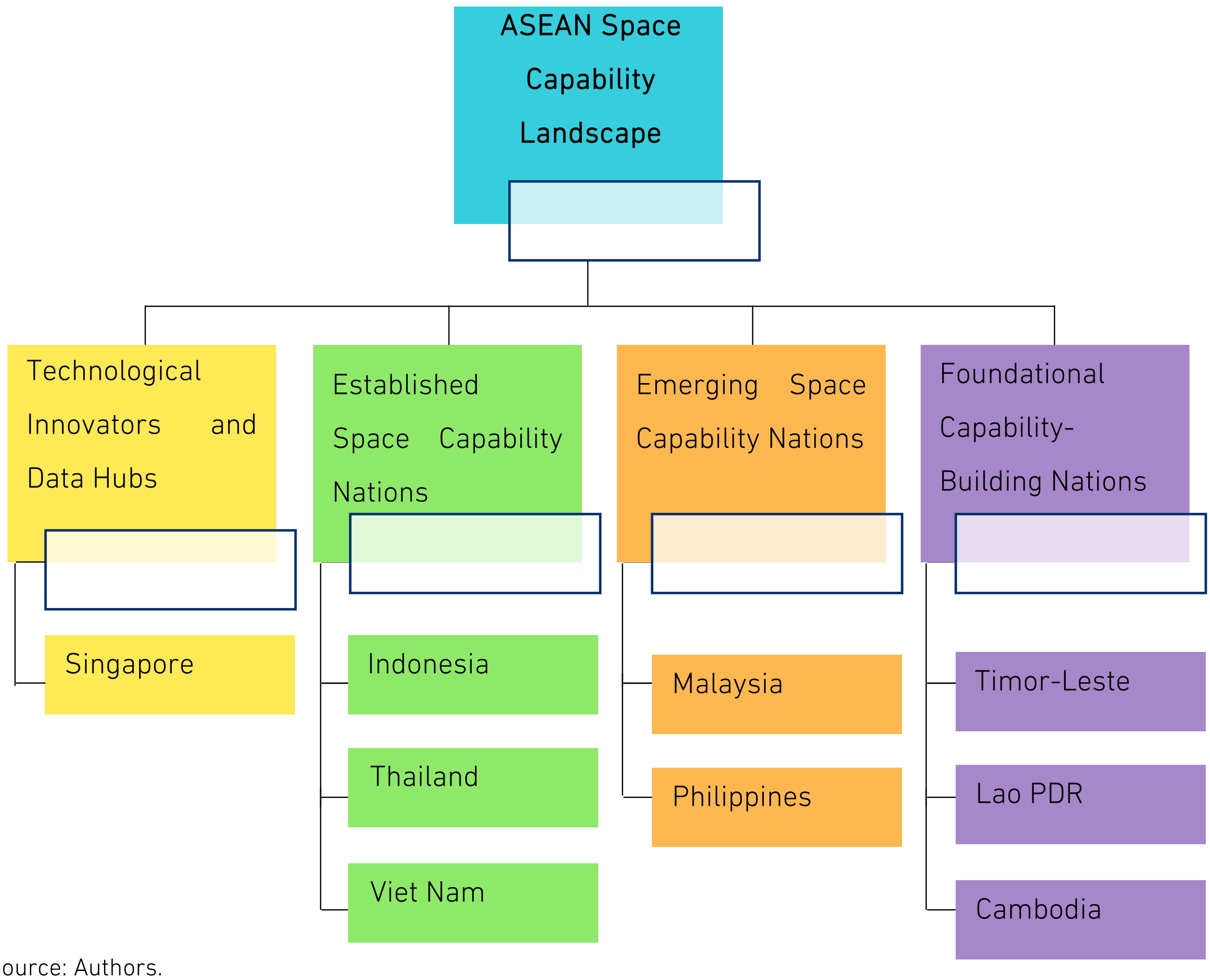
Chapter 2

Segmentations in Remote Sensing and Space Technology

The ASEAN region exhibits varying degrees of maturity in remote sensing and space technology, each of the member states reflecting different priorities, capabilities, and available resources. For this better perspective, the countries can be categorised into four broad groups: Technological Innovators and Data Hubs, Established Space Capability Nations, Emerging Space Capability Nations, and Foundational Capacity-Building Nations, all of which are distinctly characteristic and focus on areas different from each other, each having a specific development need.

Figure 2.1. ASEAN Space Capability Landscape Segmentation



Source: Authors.

The segmentation criteria provide a framework for assessing the advancement and competencies of ASEAN nations in remote sensing and space technology. Each criteria represents a vital facet of technical and operational advancement, delineating the strengths, problems, and objectives of each group.

Infrastructure assesses the physical and technical resources of each organisation, including satellite manufacturing facilities, ground stations, and data processing centers. Technological innovators such as Singapore emphasise data processing proficiency but lack satellite infrastructure, while nations with established space capabilities embrace superior physical infrastructure and want to enhance it. Nations with emerging space capabilities are establishing fundamental satellite infrastructure, whereas foundational nations depend significantly on foreign assistance owing to their limited infrastructure.

Funding and Sustainability evaluates the financial resources and stability of space initiatives. Innovators possess substantial financing avenues dedicated to research and development, whereas established nations often benefit from consistent support. Emerging Nations encounter fiscal limitations, depending on high-impact initiatives, while Foundational Nations rely on foreign assistance and grants, grappling with the challenge of securing stable financial backing.

Data Autonomy assesses the capacity of nations to independently manage satellite data. Innovators analyse data locally while relying on global sources for satellite information. Established Nations exhibit limited autonomy, but Emerging and Foundational Nations are significantly dependent on other sources for data collection and processing.

Skill and Workforce Development emphasises the technical proficiency and talent reservoir within each group. Innovators use exceptionally proficient experts in artificial intelligence, data science, and analytics. Developed nations cultivate specialised expertise in satellite technology, while emerging nations prioritise basic skill development. Foundational Nations depend on fundamental training programmes often conducted by foreign collaborators.

Policy and regulatory frameworks reflect the sophistication of governance in space endeavors. Innovators front with progressive policies about data privacy and cybersecurity. Developed nations have created structures for satellite operations and collaborations. Emerging Nations continue to enhance their policies, but Foundational Nations depend on international norms because of inadequate domestic frameworks.

The applications of remote sensing assess the extent of practical use. Innovators use remote sensing for advanced applications such as IoT and urban planning. Established nations use it in several areas, including disaster response and agriculture. Emerging Nations prioritise high-impact sectors, while Foundational Nations concentrate on fundamental applications like environmental monitoring.

International Partnerships examine collaborative and resource-sharing methodologies. Innovators prioritise strategic alliances for innovation, Established Nations balance partnerships with independence, Emerging Nations rely on collaborations for technological access, and Foundational Nations depend significantly on partnerships for essential requirements. Data processing capabilities assess the complexity of data management. Innovators thrive with sophisticated analytics, while Established Nations maintain modern data centers. Emerging Nations are enhancing their capabilities, whereas Foundational Nations conduct fundamental studies with constrained processing equipment.

The Regional Role & Collaboration examines contributions to the collective development of ASEAN. Innovators serve as data centers and technological facilitators. Established Nations spearhead regional projects, Emerging Nations engage as active collaborators, while Foundational Nations largely serve as beneficiaries.

Table 2.1. Criteria for Segmentation

Criteria	Technological Innovators & Data Hubs	Established Space Capability Nations	Emerging Space Capability Nations	Foundational Capacity-Building Nations
Infrastructure	Limited satellite infrastructure; strong data processing focus	Established satellite & ground station; expansion focus	Building foundational infrastructure; partial satellite programmes	Minimal infrastructure; relies on external data and support
Funding and Sustainability	Strong funding; R&D-focused	Generally stable funding	Limited funding; reliant on specific high-impact projects	Primarily foreign aid and grants; struggles for consistent funding
Data Autonomy	Relies on external satellite data; data sovereignty in processing	Partial autonomy in data collection; some reliance on international sources	Dependent on international sources; building towards partial autonomy	Dependent on international sources
Skill & Workforce Development Focus	Highly skilled in data science, AI, and analytics	Developing specialised skills in satellite engineering and data processing	Building foundational skills; limited specialisation	Basic training and education through international programmes
Policy & Regulatory Frameworks	Strong policies on data privacy, cybersecurity, and ethical AI use	Advanced policies for satellite operations, data	Developing comprehensive policies; early-	Limited policy framework; early-stage development relying on

		security, and partnerships	stage implementation	international standards
Applications of Remote Sensing	Advanced applications for urban planning, environmental monitoring, and IoT	Diverse, including disaster response, agriculture, and urban planning	Targeted applications for high-impact areas like disaster resilience and agriculture	Basic applications, primarily environmental monitoring and land use
International Partnerships	Focus on innovation and data processing expertise	Strategic collaborations; technology transfer emphasis on autonomy	Heavy reliance on partnerships for technology and data access	Partnerships primarily for data access, training, and support
Data Processing Capabilities	Highly developed data processing and analytics capabilities	Advanced data centers & HPC; growing real-time data processing	Limited processing capacity; gradually building infrastructure	Basic processing capabilities; limited to fundamental analyses
Regional Role & Collaboration	Key data hub and tech innovator, sharing processed data and expertise	Leaders in ASEAN; drive regional initiatives and data-sharing efforts	Active in ASEAN collaboration, usually as partners, not leaders	Primarily beneficiaries in regional collaborations; limited ability to contribute

Source: Authors' analysis based on ASEAN Secretariat Reports (2020-2024); Singapore Land Authority (2018); Economic Research Institute for ASEAN and East Asia (ERIA) Digital Innovation Reports; institutional data from GISTDA, LAPAN, MYSA, NUS, PhilSA, RUPP, SSTA, VNSC, CNSP, ITC, LSRP, NUOL, INCT , and UNTL.

2.1. Technological Innovators and Data Hubs

Country: Singapore

Singapore is a global leader in data processing, analytics, and smart city applications. Despite the very limited physical space and no domestic manufacturing or launch capabilities for its own satellites, Singapore has been able to position itself as the regional hub for satellite data management and advanced technology integration. The country focuses on applications such as urban planning, maritime security, and environmental sustainability, which is leveraged through its strength in AI, IoT, and geospatial analytics. While Singapore relies heavily on overseas sources for satellite data, it stands out in local processing and application of satellite data to meet national and regional requirements. The strong public–private collaboration model coupled with its highly skilled and capable workforce are the power drivers behind Singapore's innovations. Nevertheless, Singapore's future must be built more on its data sovereignty to improve its satellite capabilities and expand its highly specialised workforce to maintain its competitive advantage.

2.2 Established Space Capability Nations

Countries: Indonesia, Thailand, Viet Nam

These countries have established domestic space programmes and are actively leveraging remote sensing for disaster resilience, agricultural productivity, environmental monitoring, and urban planning. National agencies like LAPAN (Indonesia), GISTDA (Thailand), and VNSC (Viet Nam) have spearheaded satellite launches, ground station networks, and research initiatives. These countries are specifically oriented towards disaster management, since their geographies make them very prone to natural hazards like floods, typhoons, and volcanic eruptions. These countries are developed but still have to depend on foreign launches of satellites and high-resolution images for certain applications. Moving forward requires increasing domestic capabilities in manufacturing satellites, augmenting ground station infrastructure, and fostering public–private partnerships to fuel innovation. In addition, ASEAN regional cooperation opens the ways to the sharing of resources and capabilities.

2.3. Emerging Space Capability Nations

Countries: Malaysia, Philippines

Malaysia and the Philippines will soon become a space actor in the ASEAN Space Ecosystem. They developed national space agencies MYSA in Malaysia and PhilSA in the Philippines with already launched satellites. Areas that are prioritised in capability development include disaster management and mitigation, environmental monitoring and tracking, and maritime domain awareness. Malaysia, with its rich biodiversity, requires remote sensing for monitoring the deforestation process and sustainable development; meanwhile, the Philippines utilises space technology to monitor its coast and control fisheries, which is an area of great importance for it with its vast maritime zone. However, both face problems in reducing their reliance on foreign technology and in establishing indigenous satellite R&D capacities. They also have to encourage more private sector participation and enhance their policy frameworks to attract investment and talent. Workforce development and capacity building are still necessary to achieve sustainable growth and self-reliance.

2.4. Foundational Capacity-Building Nations

Countries: Cambodia, Lao PDR, Timor-Leste

These countries are at the initial stages of adopting remote sensing and space technology and are focusing on foundational capacity building. Heavily reliant on international satellite data and partnerships, they primarily use remote sensing for disaster management, agriculture, and environmental monitoring. In Cambodia, it is used to combat deforestation and optimal agricultural practices, while Lao PDR utilises satellite data for flood management and resource mapping. In Timor-Leste, which is still a developing nation, it is vital for disaster preparedness and agricultural productivity for its rural communities. These countries are facing serious infrastructure gaps in the ground stations and data processing centers and have to rely on regional cooperation to access data and expertise. Building capacity through education, training, and technology transfer is essential for these countries to establish their remote sensing capabilities. Basic regulatory frameworks can be developed, and partnerships within ASEAN can also be fostered to help integrate these nations into the regional space ecosystem.

The division of ASEAN nations according to their remote sensing and space technology competencies underscores the variation in technical sophistication, operational emphasis, and developmental objectives throughout the region. This classification offers a systematic comprehension of each group's strengths and weaknesses, facilitating the development of customised tactics that correspond to their specific requirements. By means of strategic investments, capacity enhancement, and regional partnerships, ASEAN countries may jointly elevate their space technology proficiencies, guaranteeing that even fundamental states gain from shared knowledge and resources. By addressing gaps in infrastructure, financing, and workforce development, while fostering international collaborations, the region may strengthen its resilience, sustainability, and leadership in remote sensing applications. This segmentation provides a basis for comprehending the intricate relationships of local and regional processes, directing future efforts towards a unified and creative ASEAN space ecosystem.

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Chapter 3

Patent Landscape of Space Technology and Remote Sensing in ASEAN

This chapter examines the patent landscape surrounding space technology and remote sensing in ASEAN countries. Although the sector is developing, there are significant obstacles to transforming technological advancements into industry-ready applications. In contrast to leading economies, where innovation is primarily driven by industry, in ASEAN, it is researchers and universities that propel progress. This focus on academic-driven innovation has resulted in a limited number of solutions that are ready for the market, with the private sector demonstrating a relatively low level of involvement and technological readiness.

Patents are a prominent data source for assessing technical development, invention, and innovation. Patents pertain to economically viable inventions, which are often nearer to market implementation and practical applications than those described in academic articles. In this regard, patent analysis is an essential instrument for evaluating the region's technical readiness and industrial applicability.

The patent data used in our research was obtained from the Derwent advancement Index (DII), which functioned as the principal source of patent information, providing a comprehensive and organised basis for analysing technical advancement in remote sensing applications throughout ASEAN. DII, as an internationally acknowledged database, offers comprehensive, standardised patent information that improves the credibility and depth of our studies.

We classified patents according to technical domains and geographical contexts via DII. This allowed us to methodically examine the innovation environment, identifying critical areas of advancement and nascent trends. The database's incorporation of standards from initial patent papers and classifications enabled cross-comparative analysis, assuring uniformity in understanding innovation intensity across many domains.

Essential indicators from patent numbers and application dates were retrieved to assess filing patterns and innovation intensity. This statistic enabled us to evaluate technical output and the relative significance of various applications, while filing dates were examined to determine recency and pinpoint growing areas of interest.

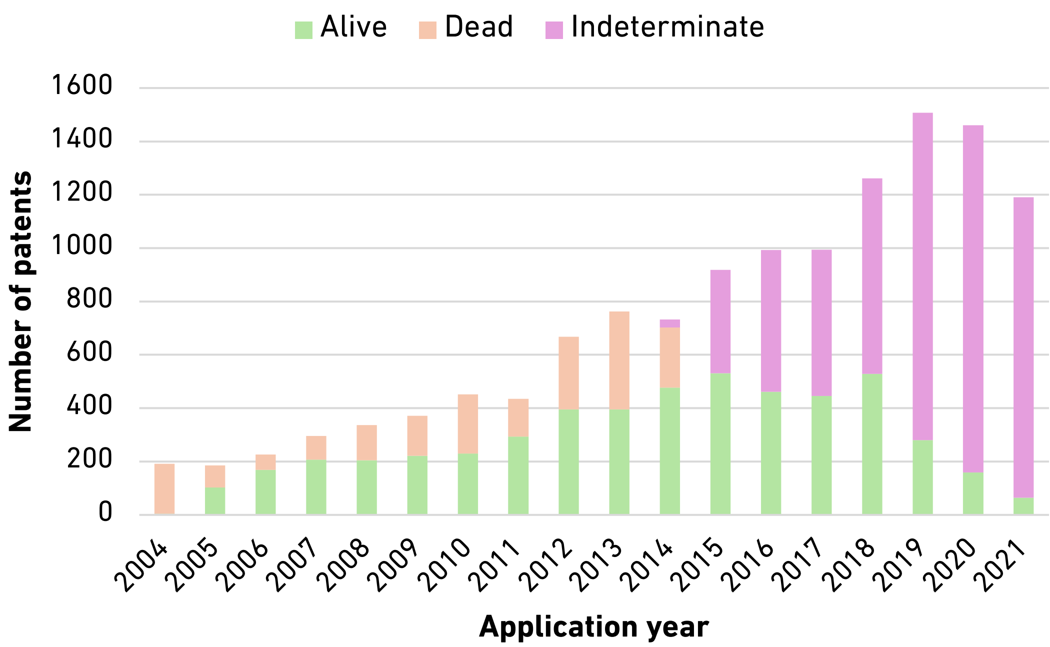
Utilising DII's extensive dataset, we developed an Innovation Maturity Matrix to graphically illustrate the advancement and acceptance patterns of several remote sensing applications. This matrix delineates critical zones, including Current Hot Topics, Better-Explored Areas, Emerging Interests, and Static Development, so illustrating the innovative status and future potential of each application.

DII's capacity to categorise patents into families enhanced our research, providing a comprehensive perspective on technical advancements and minimising duplicates in patent tallies. This thorough methodology has enabled our research to provide practical insights for policymakers and stakeholders, directing resource distribution and strategic planning for technical progress in ASEAN. This story characterises DII not just as a data source but as an essential facilitator of practical insights into technology innovations in space and remote sensing applications. The comprehensive patent landscape technique and patent searches are presented in Appendix A and B.

3.1 Patent Trends in ASEAN's Space Technology Sector

The patent landscape in ASEAN from 2004 to 2024 showcases the region's growth, evolution, and recent challenges. The data highlights significant trends in patent filing activity, shifts in application statuses, and the influence of external factors on innovation. It captures ASEAN's dynamic journey toward becoming a global hub for technological and intellectual property development. Between 2004 and 2019, ASEAN experienced a remarkable increase in patent applications. Starting with just 191 applications in 2004, the numbers steadily climbed to 1,507 by 2019. This period of expansion reflects the region's increasing focus on research and development, driven by growing economies, government support for innovation, and active engagement in international trade and technology.

Figure 3.1. Number of patent applications in ASEAN



Source: Author`s analysis based on patent data from Derwent Innovation Index.

This was further supported by the increased emphasis of nearly all sectors in developing countries on intellectual property rights in agriculture and manufacturing as well as emerging technologies such as renewable energy and digital innovation. The leaders in patent filings were ASEAN nations including Singapore, Malaysia, and Thailand, and other nations, including Viet Nam and Indonesia, were gaining remarkably. Throughout the years, the state of patent applications has seen change, keeping with region-specific administrative practice and strategies.

- Active Patents: The active or 'Alive' patents steadily increased year by year from 2004 and reached its peak in the year 2015 to 531. This indicates a healthy trend of keeping patents alive for possible commercial use and technological development. However, starting from 2015 onwards, the figures dipped rapidly and hit as low as 5 active patents by 2024. The falling trend may indicate changes in priorities of patentees or difficulties in keeping the patent alive.
- Dead Applications: Between 2004 and 2014, 'Dead' applications – patents no longer maintained or expired were a significant category, peaking at 367 in 2013. However, after 2014, this category disappeared from the data, possibly due to changes in classification practices or better strategies to extend patent lifecycles.
- Indeterminate Applications: The creation of the 'Indeterminate' category in 2014 was watershed moment in the classification of patents into status categories. This new category increased exponentially, making up 2020 data with 1,302 applications classified as Indeterminate. This trend may indicate a growing wait time for patents to be processed or that there is uncertainty at the approval or maintenance stages. However, from 2020 onwards, the Indeterminate applications trended downward, similar to the decline in patent activity.

Although 2019 is the year in which the patent filings for ASEAN reached its highest level, the following years are considered to be lower than those of the year 2019. For example, in 2023, only 308 applications were reported, and for the year 2024, only 63 applications were recorded. This rapid decrease might be due to the effect of external causes like economic disturbances, COVID-19, or changed innovation directions. The decline in 'Alive' patents over the past years also indicates difficulties in keeping active filings or sustaining interest in the protection of intellectual property.

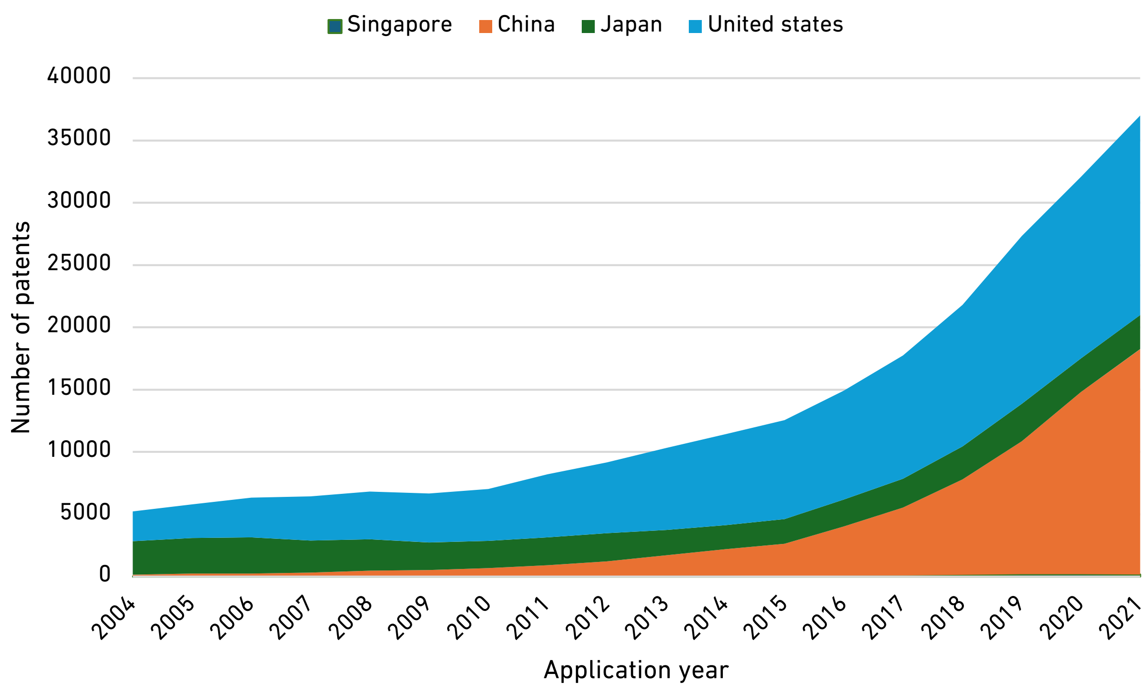
The data for ASEAN is indicative of its potential as an innovation hub during its peak years but calls for renewed efforts in reviving patent activity in the region. Strong intellectual property frameworks, addressing the delay in processing, and the value of active patents should be emphasised to keep innovation going. Encouraging cross-border collaboration, investing in R&D, and supporting startups and SMEs in filing and maintaining patents can help ASEAN regain its momentum. ASEAN patent growth is slow and steady, growing from 19 in 2004 to 50 in 2023. It reveals that ASEAN countries do not focus on quantity but rather on quality because most patents are associated with niche innovations.

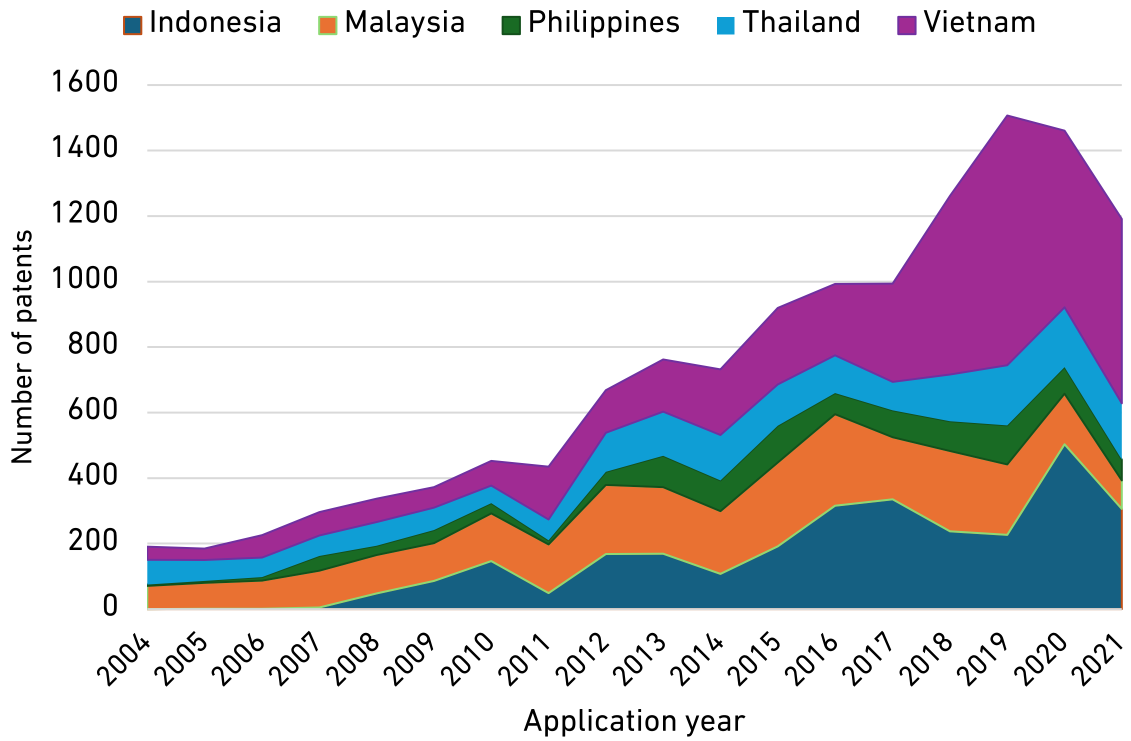
3.2 Innovation Dynamics in ASEAN: A Comparative Analysis with Developed Countries

The ASEAN region, on the whole, has had a remarkable growth over the last two decades with respect to patent activity; however, there are conspicuous imbalances within the region as well as when benchmarked against developed countries like the United States, Japan, and the rapidly developing China. Each of the member nations of ASEAN depicts its own pattern of innovation and reflects the national priorities of the country, its economic conditions, and investments in research and development (R&D). Nonetheless, if compared with the developed nations, which, notwithstanding this unprecedented growth of filing patents, are already more massive and faster at scale in innovation, these ASEAN countries, particularly Singapore, still have quite long-scale gaps in terms of preparedness of industries as well as output in innovations as compared to developed countries, like Japan, the United States, and China.

The United States tops the global chart, with 130,302 patents filed from 2004 to 2021, driven by huge investments by the private sector, strong IP frameworks, and world-class R&D infrastructure. Similarly, Japan has consistently remained innovative by the interaction of industry with academia to keep the innovational fires burning, which stood at 43,920 patents. China too has been a major disruptor to become a very significant peer competitor to the United States. With 71,289 patents filed.

Figure 3.2. Comparison of Patent Applications Between Developed Countries and ASEAN Countries





Source: Author`s analysis based on patent data from Derwent Innovation Index up to 3 December 2024.

Singapore stands as a forerunner within ASEAN for innovation and technology. As the country has been relatively small in size, it regularly tops its peers with well-endowed infrastructure, a reasonable R&D expenditure level at 2.2% of GDP, and all-around supportable policy regimes. Indeed, most nations across ASEAN cannot manage more than 1% of their GDP towards research activities. Private enterprise is dominant in patent-filing in Singapore; this clearly manifests a mature system that should promote commercialisation and the adoption of ideas into the industrial world. The state has emphasised technologies that carry a high impact, namely ICT, clean energy, and biotechnology, moving it closer to developed world standards such as Japan or the United States.

This can be coupled with an excellent international collaboration that helps sustain this very important ecosystem. For example, Singapore's Global Innovation Alliance connects its research institutions and businesses with global partners. Singapore, on the other hand, with tens of thousands of annual filings, can still keep up with these superpowers, especially now as it targets strategic industries and emerging technologies, positioning the country as a regional innovation hub. However, its smaller population and market size put a cap on the overall scale of patent activity compared to developed nations.

Viet Nam has become the second most significant contributor to patent filings within ASEAN, at a total of 4,234 applications between 2004 and 2021. Viet Nam's growth is very striking after 2016, when filings started going up rapidly, peaking at 563 applications in 2021. Targeted initiatives by the government for encouraging research and development along with the increasing role of universities are factors that have promoted innovation. Viet Nam's success reflects a nation working to meet the pressing local challenges of agricultural development, manufacturing efficiency, and climate resilience through technological advance. The country's achievements are impressive at the regional level but, on a different scale and output, represent a clear contrast. It indicates the initial stages of Viet Nam's innovation journey, with limited involvement from the private sector and commercialisation.

Malaysia, on the other hand, presents a case of steady, moderate progress with a total of 2,905 patent filings. The country's innovation trajectory peaked in 2016 with 279 filings, demonstrating consistent efforts to strengthen its technological landscape. Malaysia has benefited from strong government initiatives, such as investments in R&D hubs, technology parks, and grants for innovation projects. All this have pushed innovation in fields such as IT, biotechnology, and clean energy. However, compared to Japan, Malaysia has far lower numbers. Japanese filings annually range between 2,000 and 3,000 patents a year. This comparison clearly speaks of the need for greater private sector engagement and greater innovation beyond the academia wall of Malaysia.

In Indonesia, an emerging force in ASEAN's innovation ecosystem is identified in the patent landscape. Having in aggregate 2,899 patents Indonesia filing counts have risen significantly after the period of 2015 while reaching its peak of 503 patents in 2020. This trend represents rising science, technology, and digital infrastructure as a motive for the economic growth drivers of Indonesia. Agriculture improvement through innovation, energy management efficiency, and urban planning techniques are at the core and a critical part of the priorities being set for Indonesia. Despite this momentum, Indonesia's innovation ecosystem is still developing against the United States, whose better private-sector participation, greater strength in intellectual property frameworks, and higher R&D spending have supported sustained innovation supremacy.

Patent activity also grows more gradually for Thailand, which filed 1,921 patents over the period. The country's filings peaked in 2019 at 184 patents, driven by government efforts to promote digital transformation and innovation in agriculture and renewable energy. Thailand's slower pace, especially when compared to regional leaders like Viet Nam or more developed nations, underscores the difficulties in fostering a more vibrant innovation ecosystem. Participation from industry is still limited, and the adoption of technology often struggles to go beyond initiatives led by the government. On the other hand, the Philippines has encountered significant challenges, managing to file only 1,023 patents over a span of 17 years. Although the country saw a peak in 2013 with 96 filings, the overall trend has been lackluster. Issues such as insufficient research funding, infrastructural deficiencies, and a sluggish technology transfer process have prevented the Philippines from making more progress. Unlike developed economies, the innovation ecosystems in the Philippines are characterised by strong collaboration between academia and industry, along with substantial investments in research and development activities.

To bridge this gap, ASEAN countries need to make a concerted effort in making academia–industry collaboration stronger and more effective, R&D investments higher, and encouraging policies that promote private innovation. Singapore is a best practice example of how innovation can be sustained through an excellent policy environment, strategic focus, and international partnerships. By learning from these lessons, the ASEAN nations can propel their technological development forward.

3.3 The Key International Patent Classification (IPC) in ASEAN

Remote sensing and space technologies are some of the basic needs for managing regional problems such as climate change, urbanisation, disaster management, and utilising resources with sustainability in ASEAN countries. The classification by the system of International Patent Classification reveals the diversity and depth in the technological innovations and understanding the diversification of advancements. This analysis is relevant in determining which technologies ASEAN countries are focusing on. This patent analysis reveals 9 primary IPC codes that comprise the innovation on image processing, sensing systems, climate adaptation, and digital communication technologies. These are significant areas to be used to promote the support of ASEAN priorities on monitoring changes to the environment, resource utilisation optimisation, and adaptation to climate change impacts.

Technologies falling under the broad categories of G06V (Image or Video Recognition or Understanding) and G06T (Image Data Processing or Generation, in General) form the basic frameworks of remote sensing innovation. These classifications include image analysis advancement, pattern recognition, and visualisation, which form an essential basis for the interpretation of satellite and aerial imagery. These technologies are used in countries like Indonesia and Malaysia, which are highly concerned with deforestation, to detect and monitor changes in forest cover. Similarly, countries that experience rapid urban growth, such as the Philippines and Viet Nam, rely on image data processing to track urban sprawl, assess infrastructure needs, and plan for sustainable development.

This is the urgency of dealing with climate change, as embodied by the Y02A (Technologies for Adaptation to Climate Change) classification. In the case of countries such as Viet Nam and the Philippines, which are more vulnerable to rising sea levels and extreme weather events, the innovations in this area serve as critical tools in monitoring climate variables. Remote sensing technologies enable the adaptive strategies involved in coastal management, disaster mitigation frameworks, and sustainable urban planning.

Technological advancements in sensing systems fall under G01S-Radio Navigation and Distance Measurement-and G01J-Measurement of Light Characteristics. Radar, LiDAR, and multispectral imaging systems categorised under these codes are widely applied in topographical mapping, vegetation health monitoring, and disaster impact assessments.

In Indonesia, land-use changes and biodiversity conservation in protected areas require the same. For example, with LiDAR technologies, fine resolution in surface mapping is available. For urban development and environment monitoring purposes, this capability becomes particularly important.

There is growth in the utilisation of remote sensing data processing as applied in the classification of G06F. That being said, since the adoption of big data and AI, ASEAN countries also increasingly use methods for the processing of data for enhancing resource management capabilities. Countries like Thailand and Viet Nam have incorporated these innovations into precision agriculture, enabling farmers to monitor crop health, predict yields, and enhance resource efficiency. Similarly, real-time environmental monitoring systems rely on advanced data processing to inform decision-making during natural disasters and environmental crises.

Supporting this technological ecosystem are new developments in H04L, Transmission of Digital Information, and H04W, Wireless Communication Networks. These classes underline innovations in data transmission and communication systems that ensure free sharing of geospatial information. For ASEAN countries, such technologies therefore enable regional collaboration in disaster response and environmental monitoring while allowing real-time data across borders for coordinated actions.

Beyond the environmental and urban applications, there are great benefits for the agricultural industry, which remains at the center of ASEAN's economic pillar. Technologies under A01B Soil Working in Agriculture allow precision farming: remote sensing data is processed to enhance soil management, optimised crop monitoring, and greater productivity. In Viet Nam, Thailand, amongst other nations, innovations such as these are critically important to resolve food security issues while advocating for agriculture sustainability.

The broader application of remote sensing in resource exploration falls under E21C, which deals with mining or quarrying, and G01B, which pertains to measuring surface characteristics. ASEAN countries rich in natural resources, such as Indonesia and Malaysia, apply these technologies in identifying and managing mineral deposits while ensuring sustainability and environmental compliance.

Other classifications from the IPC include Y02D, Climate Change Mitigation in ICT, and G06Q, ICT for Administrative and Commercial Purposes. These emphasise innovations in energy-efficient systems and integration of ICT into decision-making processes. Such advancements help support the efforts of ASEAN towards reducing greenhouse gas emissions while implementing smart city initiatives that have geospatial data as drivers for urban planning and resource management.

The patent trends in these IPC codes indicate that ASEAN places more emphasis on innovations that solve direct environmental, agricultural, and urbanisation problems. For instance, image processing (G06V, G06T) and sensing systems (G01S, G01J) are essential for the remote sensing of deforestation, climate change tracking, and disaster-prone region mapping. Similarly, data processing (G06F) and communication technologies (H04L, H04W) indicate real-time analytics and data sharing for informed decision-making in all sectors.

3.4 Who Owns Space Technology and Remote Sensing Patents in ASEAN?

Patent applicants denote the legal entities possessing the intellectual property rights to technical advances. Table 3.1 highlights the Top 10 Assignees in the domain of space and remote sensing technologies, categorised by the quantity of patent applications submitted. These candidates are at the forefront of the field, guiding the trajectory and momentum of technical advancement.

Table 3.1. Top 10 Assignees of space and remote sensing technologies in ASEAN

Assignee	Patent Applications	Percentage (%)
Samsung Electronics Co. Ltd	189	26.95%
Huawei Technologies Company Ltd.	107	15.26%
Qualcomm Inc	93	13.26%
Sony Group Corp	58	8.27%
Nokia Corporation	47	6.71%
Natural Science & Technology Dev Agency	44	6.28%
Microsoft Corporation	40	5.71%
Tencent Holding Ltd	39	5.56%
Canon Inc	34	4.85%
Panasonic Holding Corporation	28	3.99%

Source: Author`s analysis based on patent data from Derwent Innovation Index up to 3 December 2024.

The distribution of patent applications indicates a concentrated innovation environment, with a few dominating entities responsible for a significant number of innovations. Samsung Electronics Co. Ltd. stands as the leading entity, with around 27% of total patents, demonstrating its robust dedication to innovative technologies in remote sensing, potentially including imaging systems, AI integration, and sophisticated sensors.

Huawei Technologies Company Ltd. follows Samsung, possessing 15% of the patents, indicative of its emphasis on telecommunications and AI-driven applications. Qualcomm Inc., accounting for 13%, is a significant contributor, highlighting advancements in sensor development and connection essential for remote sensing.

Additional significant contributors are Sony Group Corp. and Nokia Corporation, together contributing more than 15% of the patent applications. Their proficiency in imaging and communication technology guarantees ongoing enhancement of remote sensing capabilities. Research institutions, such the Natural Science & Technology Development

Agency, are crucial, underscoring the significance of universities and government-backed organisations in promoting innovation.

The minor position but significant entities such as Microsoft Corporation, Tencent Holding Ltd., Canon Inc., and Panasonic Holding Corporation conclude the top ten. These firms concentrate on specific developments, like data analytics, cloud solutions, and optical imaging technologies.

The concentrated form of the patent landscape signifies a dominant leadership position undertaken by the primary assignees. The participation of an extensive range of organisations guarantees a broad spectrum of advances, enhancing several applications within the fields of space and remote sensing. This distribution illustrates a dynamic ecosystem in which industry leaders and academic institutions collaboratively influence the development of remote sensing technology.

3.5 Comparative Analysis of Remote Sensing Specialisation Between Developed Countries and ASEAN Nations

The analysis of regional specialisation in remote sensing technologies highlights the significant differences between developed countries such as Japan, United States, and China and the emerging contributions of ASEAN nations, including Singapore, Indonesia, Malaysia, the Philippines, Thailand, and Viet Nam. The number refers to a country's specialisation index, measured by the proportion of patent families in a specific area divided by the total number of patent families originating from that location. The color key is applied in contrast to the mean value of the region. While ASEAN countries show growing strengths in targeted areas, developed nations exhibit broader technological mastery, deeper integration of advanced methodologies, and superior infrastructure, positioning them as global leaders in remote sensing innovation.

Table 3.2. Regional Specialisation index of patent

	Specific area	Indonesia (%)	Malaysia (%)	Philippines (%)	Thailand (%)	Viet Nam (%)	Region (%)
Image pre-processing	Calibration	1.33	1.83	1.55	1.43	1.83	1.64
	Atmospheric	0.77	0.39	0.57	1.10	0.71	0.70
	Filtering	8.64	9.19	5.86	8.57	10.18	9.02
	Radiometric	0.00	0.05	0.00	0.00	0.00	0.01
	Masking	1.58	2.91	2.12	2.42	1.87	2.17
	Mosaicing	0.15	0.16	0.08	0.00	0.36	0.19

	Specific area	Indonesia (%)	Malaysia (%)	Philippines (%)	Thailand (%)	Viet Nam (%)	Region (%)
	Harmonisation	0.22	0.29	0.08	0.84	0.24	0.34
	Geometric	0.25	0.26	0.24	0.11	0.08	0.18
Image storage	Cloud storage	0.46	0.45	0.65	0.04	0.26	0.34
	Big data	0.00	0.05	0.00	0.07	0.12	0.06
Image processing	Artificial intelligence	2.82	1.86	2.36	1.68	3.18	2.47
	Clustering	1.61	1.34	1.14	1.72	3.14	2.00
	Classification	3.87	4.79	3.42	5.31	4.11	4.38
	Detection	24.95	33.88	24.41	29.60	18.44	25.82
	Segmentation	4.64	5.89	3.99	11.72	5.04	6.22
	Feature extraction	0.09	0.03	0.00	0.00	0.08	0.05
	Data fusion	0.09	0.05	0.00	0.00	0.00	0.03
	Coherence	0.28	0.16	0.16	0.22	0.32	0.24
Image sensor	Multispectral	0.15	0.08	0.00	0.07	0.08	0.09
	Hyperspectral	0.09	0.18	0.00	0.04	0.02	0.08
	SAR	0.12	0.05	0.08	0.04	0.04	0.06
	Lidar	0.31	0.08	0.24	0.07	0.20	0.18
	Thermal	2.17	4.14	3.01	5.53	3.87	3.81
	Aerosol	0.43	0.13	1.06	0.51	0.24	0.36
Image post-processing	Accuracy	13.49	11.26	12.45	11.06	13.63	12.50
	Elevation	0.84	0.52	1.22	0.59	0.58	0.67
	Enhancement	10.49	8.67	12.61	7.07	11.19	9.85
	Land Use	0.00	0.00	0.00	0.04	0.04	0.02
	Land Cover	0.06	0.00	0.00	0.00	0.00	0.01
	Terrain	0.22	0.24	0.00	0.07	0.46	0.26

	Specific area	Indonesia (%)	Malaysia (%)	Philippines (%)	Thailand (%)	Viet Nam (%)	Region (%)
Applications	Agriculture	0.84	0.31	0.81	0.92	0.77	0.70
	Telecommunication	6.31	3.77	7.32	2.89	8.35	5.83
	Urban planning	1.45	0.84	1.71	0.70	2.10	1.40
	Marine	0.40	0.24	0.00	0.04	0.16	0.19
	Fisheries	0.40	0.08	0.49	0.18	0.28	0.26
	Security	2.75	2.20	3.42	0.99	2.14	2.18
	Disaster	0.28	0.03	0.41	0.04	0.06	0.12
	Mining	0.90	0.26	0.65	0.15	0.32	0.42
	Renewable energy	0.87	0.47	1.38	0.59	1.03	0.81
	Public health	1.64	0.58	3.09	0.81	1.19	1.21
	Forestry	0.40	0.31	0.33	0.15	0.24	0.28
	Climate	0.53	0.34	0.24	0.15	0.22	0.30
	Water resource	1.08	0.63	0.90	0.88	1.09	0.93
	Infrastructure	2.01	1.02	1.95	1.61	1.71	1.61

[blue] higher than the region mean
[yellow] lower than the region mean
[white] in the range of the region mean
Source: Authors, based on patent data from Derwent Innovation Index up to 3 December 2024

	Specific area	China (%)	Japan (%)	Singapore (%)	United States (%)	Region (%)
Image pre-processing	Calibration	14.02	2.11	3.16	3.34	6.70
	Atmospheric	2.16	0.28	0.19	0.30	0.92
	Filtering*		9.21	7.68	7.52	5.34
	Radiometric	0.15	0.00	0.00	0.02	0.06
	Masking	10.47	4.23	2.07	3.52	6.02
	Mosaicing	1.00	0.36	0.26	0.35	0.57

	Harmonisation	0.51	0.21	0.32	0.19	0.30
	Geometric	2.23	0.61	0.45	0.55	1.13
Image storage	Cloud storage	7.48	0.44	1.29	2.52	3.75
	Big data	3.73	0.05	0.13	0.08	1.31
Image processing	Artificial intelligence*		3.58	10.78	11.11	5.71
	Clustering	13.46	1.50	3.29	3.01	6.23
	Classification*		12.59	13.82	10.10	7.23
	Detection*		15.43	9.17	8.74	7.23
	Segmentation*		14.01	13.11	9.41	7.23
	Feature extraction	3.55	0.32	0.06	0.26	1.39
	Data fusion	2.16	0.01	0.06	0.09	0.77
	Coherence	1.24	0.68	1.36	1.31	1.15
Image sensor	Multispectral	1.95	0.10	0.13	0.43	0.88
	Hyperspectral	3.26	0.05	0.71	0.54	1.36
	SAR	4.40	0.55	0.45	0.38	1.78
	Lidar	1.05	0.22	0.52	1.45	1.05
	Thermal	4.20	6.73	1.74	2.45	3.97
	Aerosol	0.16	0.02	0.06	0.04	0.08
Image post-processing	Accuracy*		8.55	7.36	7.11	5.01
	Elevation	1.31	0.42	0.32	0.35	0.69
	Enhancement*		7.74	8.72	10.39	6.28
	Land Use	0.15	0.02	0.00	0.02	0.06
	Land Cover	0.10	0.01	0.00	0.02	0.04
	Terrain	1.48	0.18	0.52	0.39	0.72
Applications	Agriculture	1.84	0.22	0.13	0.41	0.85
	Telecommunication	2.90	1.61	2.32	3.71	2.98
	Urban planning	1.50	0.33	0.77	0.77	0.93
	Marine	0.45	0.02	0.00	0.03	0.17

Fisheries	0.57	0.08	0.13	0.06	0.24
Security	0.82	0.04	0.39	0.39	0.46
Disaster	0.77	0.10	0.13	0.05	0.30
Mining	0.55	0.07	0.39	0.19	0.29
Renewable energy	0.43	0.04	0.06	0.06	0.18
Public health	2.91	0.63	1.81	1.78	1.91
Forestry	2.27	0.22	0.39	0.27	0.94
Climate	3.14	0.54	0.06	0.52	1.41
Water resource	1.58	0.07	0.06	0.05	0.57
Infrastructure*		5.83	5.62	5.72	3.80

[blue] higher than the region mean
[yellow] lower than the region mean
[white] in the range of the region mean
*The region mean calculation excluding China, given the significant higher number of patent by the country
Source: Authors, based on patent data from Derwent Innovation Index up to 3 December 2024

Developed countries lead across multiple categories with a balanced and comprehensive approach to remote sensing technologies. Japan stands out for its leadership in image processing, particularly in detection (15.43%), classification (12.59%), and segmentation (14.01%). These areas reflect Japan's emphasis on high-precision image analysis, which is essential for applications such as urban planning, resource management, and disaster mitigation. Japan's specialisation in thermal sensing (6.73%) highlights its commitment to advanced sensor technologies for monitoring climate and disaster-related challenges. However, Japan's contributions to data storage infrastructure, such as cloud storage, remain limited compared to China and the United States.

The United States, in contrast, demonstrates a balanced and comprehensive approach to remote sensing specialisation. With strong contributions in artificial intelligence (11.11%), classification (10.10%), and enhancement (10.39%), the United States integrates advanced technologies across all domains. It maintains significant leadership in cloud storage (2.52%), lidar technologies (1.45%), and telecommunications (3.71%), reflecting its robust infrastructure for large-scale data processing and global connectivity. This versatility allows the United States to support diverse applications, including disaster management, climate resilience, and smart infrastructure development.

China, for instance, dominates areas such as calibration (14.02%), masking (10.47%), and cloud storage (7.48%), underscoring its focus on handling large-scale datasets and enhancing foundational image pre-processing methods. China's strong investments in clustering technologies (13.46%) further demonstrate its capability to analyse massive data volumes, which are critical for environmental and infrastructure applications.

However, China lags behind in more advanced AI-driven image processing, where countries like Japan, Singapore, and the United States excel.

Singapore, as a developed economy within ASEAN, excels in artificial intelligence (10.78%), classification (13.82%), and segmentation (13.11%). These strengths reflect Singapore's strategic investment in integrating AI and machine learning for practical applications like smart urban planning, public health management, and security enhancement. Additionally, Singapore's focus on enhancement technologies (8.72%) highlights its ability to improve data quality, ensuring actionable insights across diverse applications. While Singapore leads in AI adoption, it contributes less to sensor technologies like SAR and thermal imaging, where Japan and China dominate.

In comparison, ASEAN countries display specialisation in specific areas aligned with regional priorities and immediate development goals. Indonesia demonstrates its strength in detection technologies (24.95%) and accuracy in post-processing (13.49%), reflecting its focus on infrastructure planning and national security. However, Indonesia's limited contributions in AI-driven processing and sensor technologies indicate opportunities for growth, particularly in areas where developed countries excel.

Malaysia emerges as a leader within ASEAN in detection (33.88%), showcasing its capacity for environmental monitoring and resource management. Malaysia also contributes to masking (2.91%) and classification (4.79%), but its minimal focus on sensor technologies signals the need for further investment in areas like thermal imaging and SAR. Similarly, the Philippines stands out in enhancement technologies (12.61%) and public health applications (3.09%), emphasising its use of remote sensing for disaster response, health monitoring, and security challenges. Despite this, the country's focus on advanced AI and data infrastructure remains limited.

Thailand shows notable strengths in segmentation (11.72%) and thermal sensing (5.53%), reflecting its commitment to addressing climate resilience and disaster management through remote sensing. These technologies are particularly relevant for Thailand's urban planning initiatives and climate monitoring efforts. Viet Nam shows relative balance across all categories with significant specialisations in telecommunications (8.35%), accuracy (13.63%), and artificial intelligence (3.18%). Viet Nam's renewables and water resource management emphasise long-term sustainability goals and short-term economic priorities.

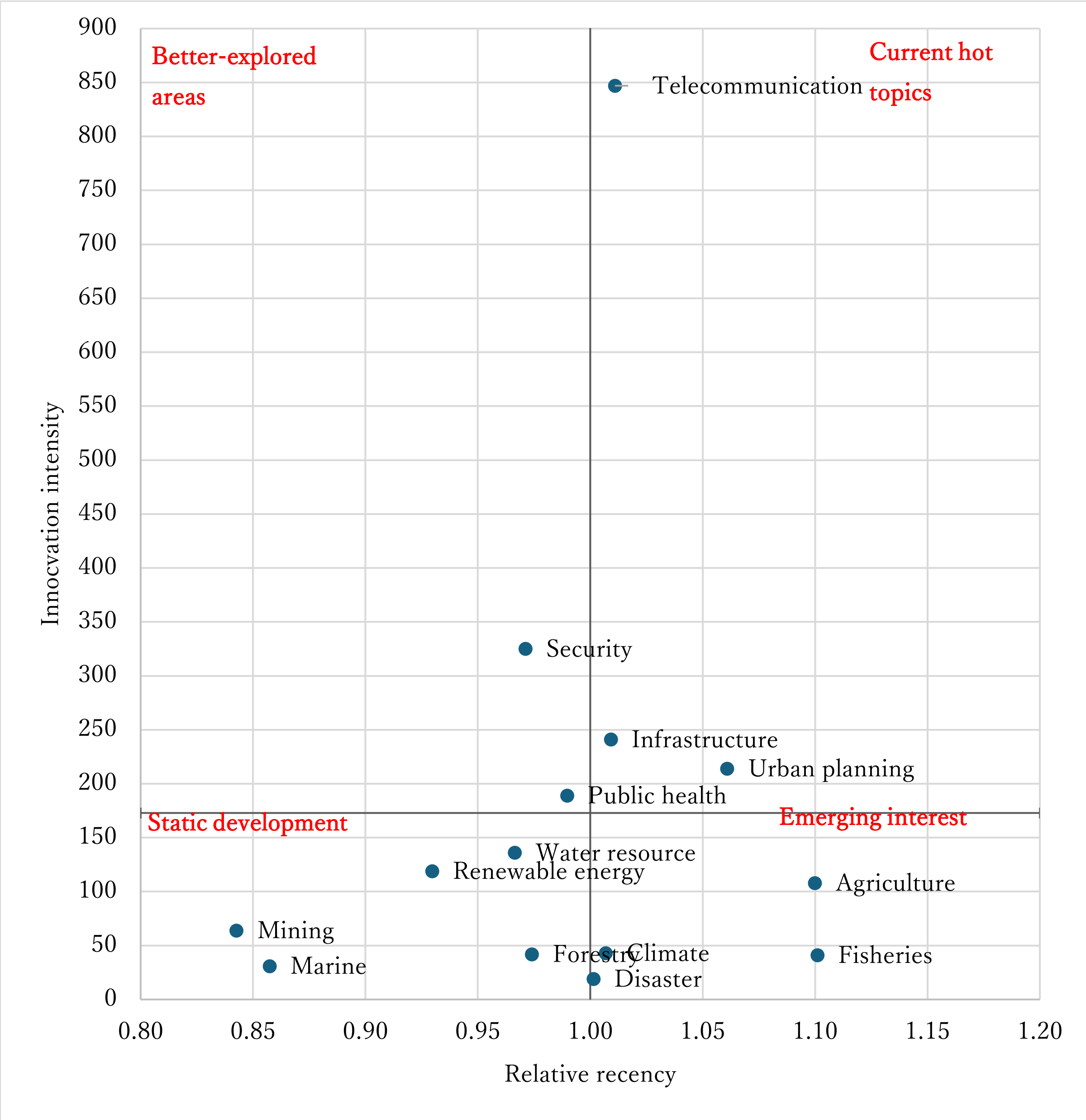
The salient difference between developed countries and ASEAN nations is specialisation breadth and depth. In contrast, the developed countries will hold out to possess equidistance in the fields of preprocessing, image processing, sensor technologies, and applications under strong private-sector involvement backed by AI integration and high-end data infrastructure. Meanwhile, ASEAN countries will depict niches like detection in Indonesia and Malaysia, enhancement in the Philippines, and segmentation in Thailand while holding no panoramic expertise across the technological realms. Developed countries have invested more in AI-driven analysis, sensor fusion, and large-scale cloud infrastructure, whereas ASEAN nations are lagging behind in these fronts and mainly rely on conventional detection and accuracy methods, constrained by infrastructure and funding.

To bridge the technological gap, ASEAN nations have to invest in artificial intelligence, advanced sensor technologies, and big data infrastructure that would upgrade their remote sensing capabilities. ASEAN regional cooperation and knowledge diffusion with the developed countries would push for a faster pace, helping nations like Indonesia, Viet Nam, and Thailand to mainstream these advanced methods into national priorities. The comprehensive approach of China, Japan, and the United States can teach the ASEAN countries to advance from the current specialisation, moving toward broader innovation ecosystems for addressing global challenges such as climate change, infrastructure development, and disaster resilience.

3.6 Technological Innovation of Remote Sensing Application in ASEAN

To understand the technological innovation of remote sensing applications in ASEAN, the Innovation Maturity Matrix can be designed to visually classify remote sensing applications based on their innovation intensity and relative recency. Here's how the scatterplot and its key zones can be described. The scatterplot categorises remote sensing applications based on two parameters: innovation intensity (y-axis) and relative recency (x-axis). This comparative analysis highlights four key zones: Current Hot-Topic, Better-Explored Areas, Emerging Interest, and Static Development, reflecting the technological progress, adoption trends, and future potential of each application.

Figure 3.3. Innovation Maturity Matrix in ASEAN



Source: Author`s analysis based on patent data from Derwent Innovation Index up to 3 December 2024

3.6.1 Current Hot-Topic

Telecommunication is at the top-right of the chart, where it is found to be the most prominent area, with high innovation intensity along with recentness. Telecommunication's strong presence reflects its essential role in enabling satellite-based communication, global connectivity, and advanced signal infrastructure. This focus highlights the critical importance of remote sensing in supporting real-time data transmission, broadband services, and telecommunication networks worldwide. In addition, urban planning and infrastructure sit closer to the center, reflecting moderate innovation intensity and recency. These fields indicate the increasing use of remote sensing in smart city planning and urban development, especially when it comes to infrastructure surveillance, especially in developing countries where urbanisation is experiencing rapid growth.

3.6.2 Better Explored

The better-explored zone in the scatterplot shows zones of high innovation intensity, with relatively established progress: significant technological advances over the years and wide-ranging applicability. Applications in that zone are mature; the technological aspects of remote sensing have already been developed, tested, and integrated into practical applications by different industries.

Security is one of the key areas in the more explored zone, showing greater innovation intensity. Applications in security involve surveillance, monitoring borders, and defense systems, with technologies such as high-resolution imaging, LiDAR, and radar systems frequently used. The maturity of the innovation in security reflects long-standing importance in safeguarding national interests and addressing geopolitical challenges.

In addition, public health is also present in this area, but with less innovation intensity. Remote sensing has become increasingly relevant in monitoring environmental factors that affect health, tracking disease outbreaks, and supporting health resource allocation. Its presence reflects growing integration with healthcare strategies, particularly in regions vulnerable to environmental health crises, where geospatial technologies assist in early interventions and risk assessment.

3.6.3 Emerging Interest

Emerging interest areas in the bottom-right quadrant reflect applications that show relatively new developments but with lower innovation intensity, which implies growing attention and, therefore, potential for growth.

Thus, focus comes on agriculture as well and shows that the utility of remote sensing technology was gradually increasing in precision agriculture, crop health monitoring and resources optimisation. It revealed with new innovations, that global changes through food security are an uphill battle and need sustainable production from agriculture. Recently seen advancements include the utilisation of high-resolution satellite imagery alongside AI-driven analytics for detecting soil health, predicting the crop yield, and controlling or regulating irrigation.

Fishery similarly presents itself as an emerging sector in which remote sensing technology assumes an important role for supporting the monitoring of ocean health, optimisation of aquaculture, and the evaluation of fishing activities. Such innovations, like thermal and multispectral imaging, enable the detection of fish stocks, the monitoring of aquatic ecosystems, and support sustainable fishing.

The current issues also intensify global environmental concerns regarding the monitoring of climatic effects and disaster management. Of these, tracking the progression of climate change patterns forms the basis for applications on observing extreme weather patterns as well as assessing the disaster effects, creating room for earlier intervention

programmes. Satellite-based sensor capabilities and radar system configurations therefore play a central role during early warning phases, hence in post-disaster activities, especially within susceptible geographical entities.
These emerging fields reflect a growing emphasis on leveraging remote sensing technologies to address pressing societal and environmental challenges, offering significant opportunities for future innovation and investment.

3.6.4 Static Development

The bottom-left quadrant, labeled as Static Development, highlights areas that exhibit slower technological advancements and lower innovation intensity. Despite their importance, these fields have not experienced significant breakthroughs in recent years, indicating stagnation in innovation and application.
Mining and ocean utilisation remain unchanged, showing how remote sensing has traditionally been used for resource discovery and oceanic observation. As remote sensing technologies such as multispectral imaging and LiDAR are used in detecting mineral deposits and observing maritime activity, innovation intensity in mining and ocean utilisation has stalled. There is little adoption of advanced tools such as artificial intelligence and sensor fusion into transformative solutions that would further enhance efficiency and sustainability.
On similar grounds, forestry and climate disaster management have scant progress since they are imperative to solving environmental sustainability issues and promoting climate resilience. Remote sensing has been utilised in deforestation monitoring for decades; and tracking forest health, monitoring disasters' impacts still has inadequate technological investment and breakthrough. Slow innovation prevents them from dealing with deforestation and climate-induced disaster challenges along with ecosystem deterioration.
Applications like renewable energy, as well as water resources, are placed in a middle category within the stagnating development zone, at an average pace but slightly lower than new areas like agricultural sector. Remote sensing technologies, including satellite imagery and topographical analysis, are already being applied to solar site identification, hydrological mapping, and water resource optimisation. However, these fields remain underutilised, with untapped opportunities for greater innovation and integration of advanced technologies such as machine learning, real-time monitoring systems, and sensor networks.

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Chapter 4

Examination and Trial of Problem-Solving Methods in the ASEAN Region

4.1 Pilot on Disaster Management (Synspective) – InSAR analysis for Disaster Management

4.1.1 Objective and Overview of the Pilot

Southeast Asia experiences serious landslides and floods every year, partly due to climate change, and Synspective believes that SAR satellite-based solutions can mitigate the damage caused by these disasters. Therefore, the objective of this project is to create sustainable solutions to prevent land subsidence and other disastrous by-products.

In particular, in Viet Nam, the demonstration country for this study, subsidence-related issues exist in both urban and mountainous areas. The usefulness of SAR satellite-based solutions in demonstration sites with different characteristics will be clarified.

Figure 4.1. Social Issues in Viet Nam

Source: Nguyen (2016); Viet Nam News (2019); Viet NamNet (2020); VN Express (2023)

4.1.2 Implementation Scheme/Role of Each Organisation

In this pilot project, Synspective formed a team with other companies and organisations to conduct the demonstration to achieve the goals mentioned above and to expand business efficiently.

Synspective Inc.

- Japanese startup manufacturing and operating SAR (Synthetic Aperture Radar) satellites constellation (StriX)
- Overall project management and provide solutions and analysis to utilise SAR satellites.

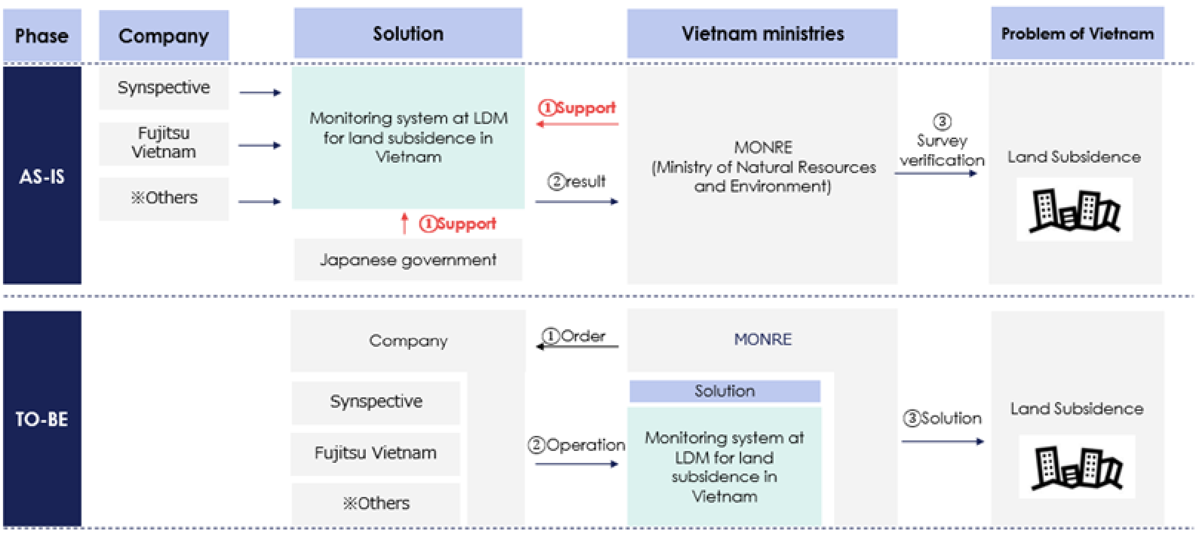
National Remote Sensing Department Ministry of Natural Resources and Environment, Viet Nam (NRSD)

- Carry out remote sensing activities for natural resource monitoring, environmental protection, disaster prevention, socio-economic development, security, and defense in Viet Nam.
- Advise to choose a target area for analysis and provide feedback about SAR satellite-based solutions.

Fujitsu Viet Nam Ltd.

- A wholly owned subsidiary of Fujitsu Limited, it offers comprehensive, integrated IT, telecommunications, and network solutions.
- Support for Synspective and NRSD discussions, support for local programmes

Figure 4.2. Project Structure



Source: Synspective Inc. (2024).

4.1.3 Technologies, Model, and Algorithms Applied to the Pilot

Data used in the project

Suitable SAR satellite data were selected based on the characteristics of the demonstration site. The first demonstration site, Ho Chi Minh City, has little vegetation and is hypothesised to experience high frequency of subsidence, so we chose Sentinel-1, a SAR satellite owned by ESA (European Space Agency).

On the other hand, Gia Nghĩa, which was selected as the second demonstration site, is a mountainous area with a lot of vegetation, so we chose ALOS-2 with L-band and a SAR satellite operated by JAXA (Japan Aerospace Exploration Agency).

Figure 4.3. Area of Interest and Satellite conditions

1. Ho Chi Minh City

Sentinel-1 data availability for Ho Chi Minh City

Area size	956 km2
Analysis period	Jan 2022 – Dec 2023
Image availability	Sentinel-1
Ascending	60 (Path 128)
Descending	54 (Path 18)

2. Gia Nghĩa

ALOS-2 ScanSAR data availability for Gia Nghĩa

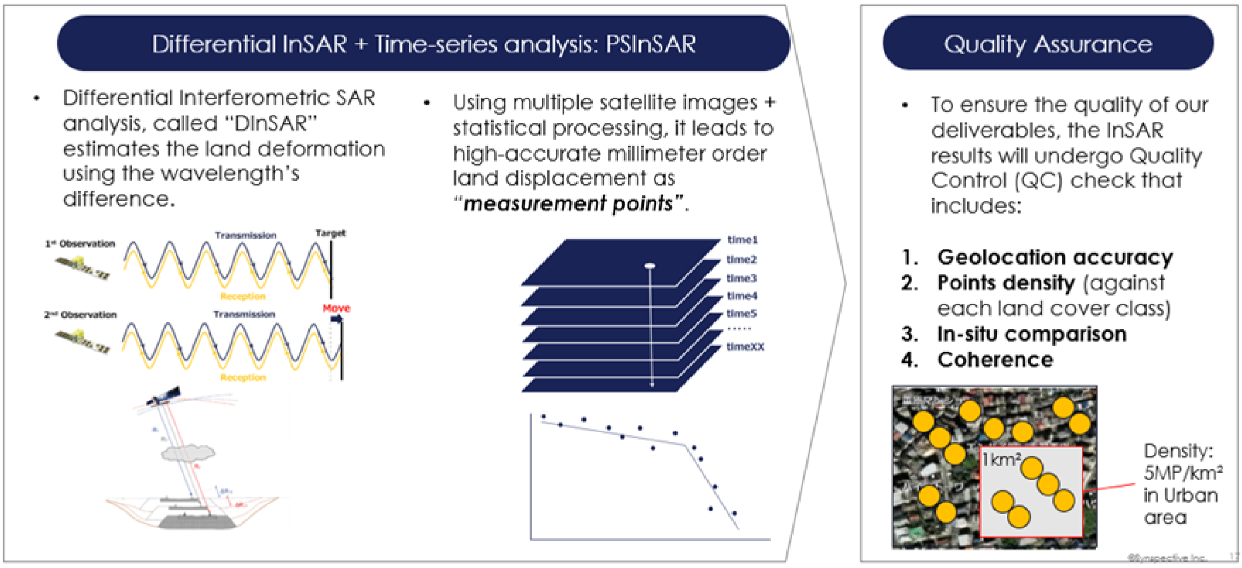
Area size	339 km2
Analysis period	Jan 2022 – Dec 2023
Image availability	ALOS-2
Ascending	-
Descending	31 (Path 34)

Source: Synspective Inc. (2024).

Analysis method

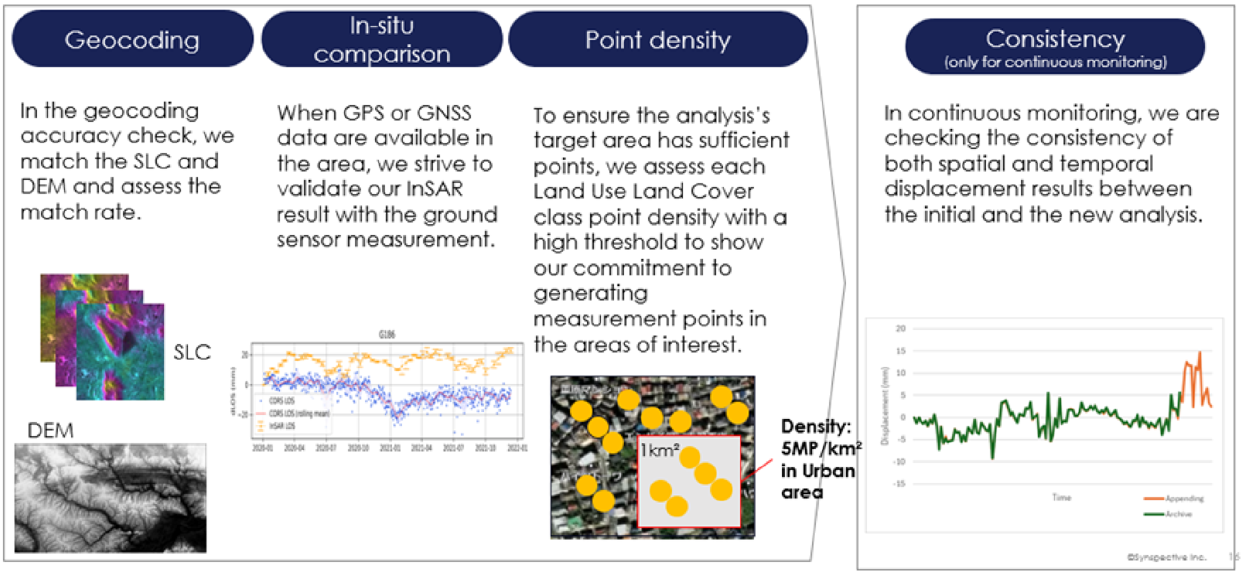
SAR satellite data has information such as intensity and phase, and this demonstration utilised an analysis method that can analyse ground deformation using phase data. In particular, the service used by Synspective in this project is based on Persistent Scatterer Interferometric Synthetic Aperture Radar (PSInSAR) technology, which enables time-series analysis of ground deformation using multiple SAR satellite images.

Figure 4.4. InSAR analysis



Source: Author`s based on Japan Aerospace Exploration Agency (2019)

Figure 4.5. InSAR analysis Quality Assurance



Source: Synspective Inc. (2024).

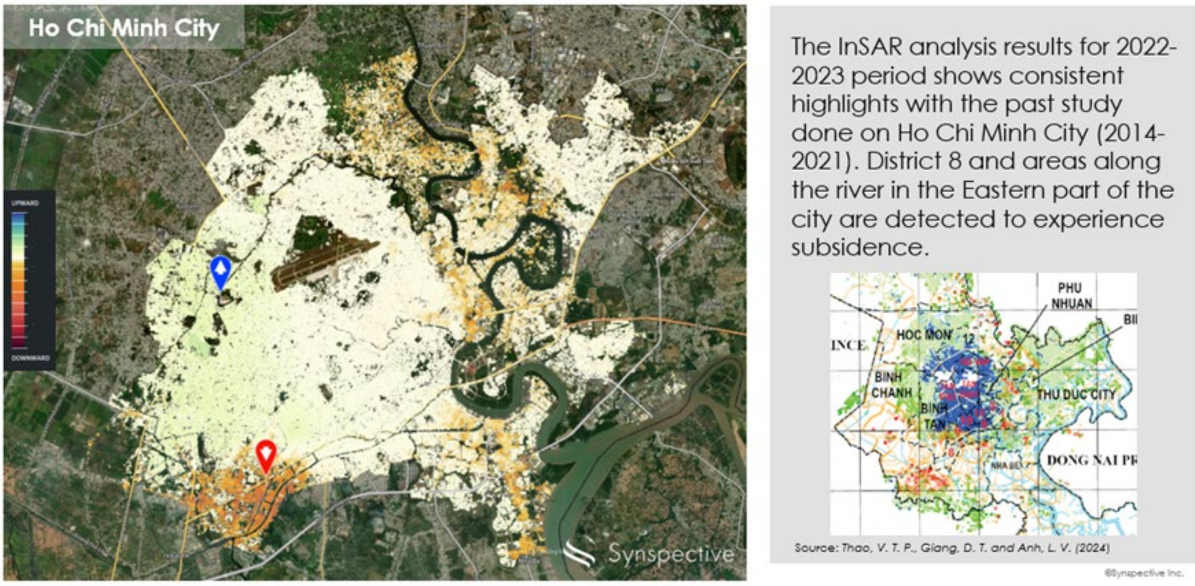
4.1.4 Current Results of the Pilot

Ho Chi Minh City

We detected subsidence more than 10.0 mm/year in a lot of areas in Ho Chi Minh city.

- Both due to natural causes and human activities, the subsidence level in Ho Chi Minh is growingly concerning. Groundwater extraction is primarily the water source for household needs due to low coverage of the water provision system.
- Urbanisation exacerbates the rate of extraction that leads to a forecast of > 20mm/year for the upcoming years.
- Underground urban infrastructure is constructed with poor management and lack of monitoring of the holistic area.

Figure 4.6. LDM analysis of Ho Chi Minh City

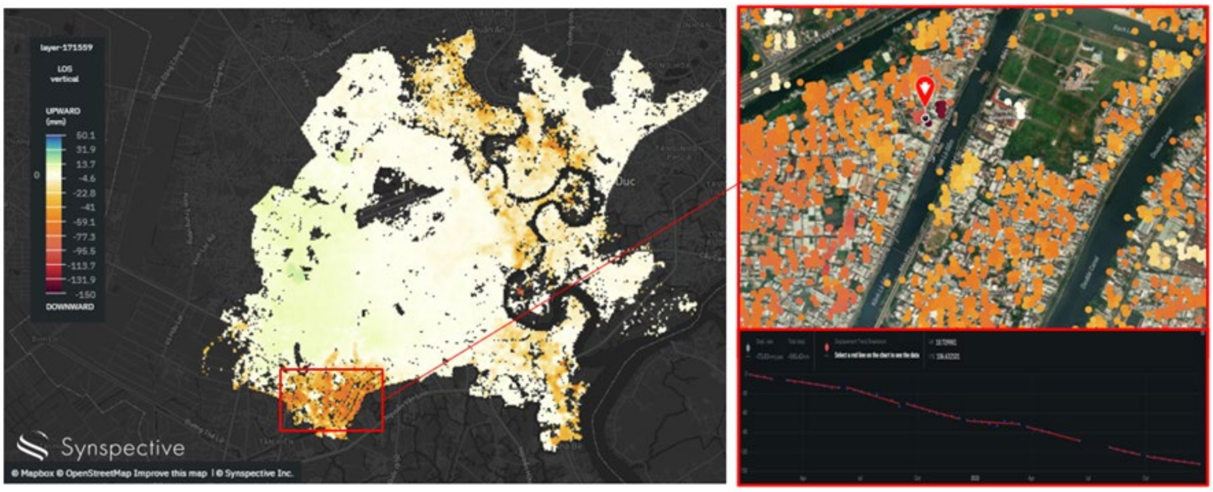


Source: Synspective Inc. based on Thao et al. (2024)

District 8

District 8 displays the highest level of subsidence with maximum displacement rate at approx. 74 mm/year and in total subsiding as much as 145.6 mm within 2022–2023. This result is consistent with a research paper. Binh Tan and District 8 were completely using water derived from boreholes. Combined with the population density, the subsidence we observed here might be caused by the same reason.

Figure 4.7. District 8 analysis result



Source: Synspective Inc. (2024).

East districts (District 2, 7, Binh Thanh, Thu Duc, and 12)

In general, the districts along the river/canal experience high subsidence rate except District 1. The districts that are being passed by the river and experiencing high subsidence are District 2, 7, Binh Thanh, Thu Duc, and 12.

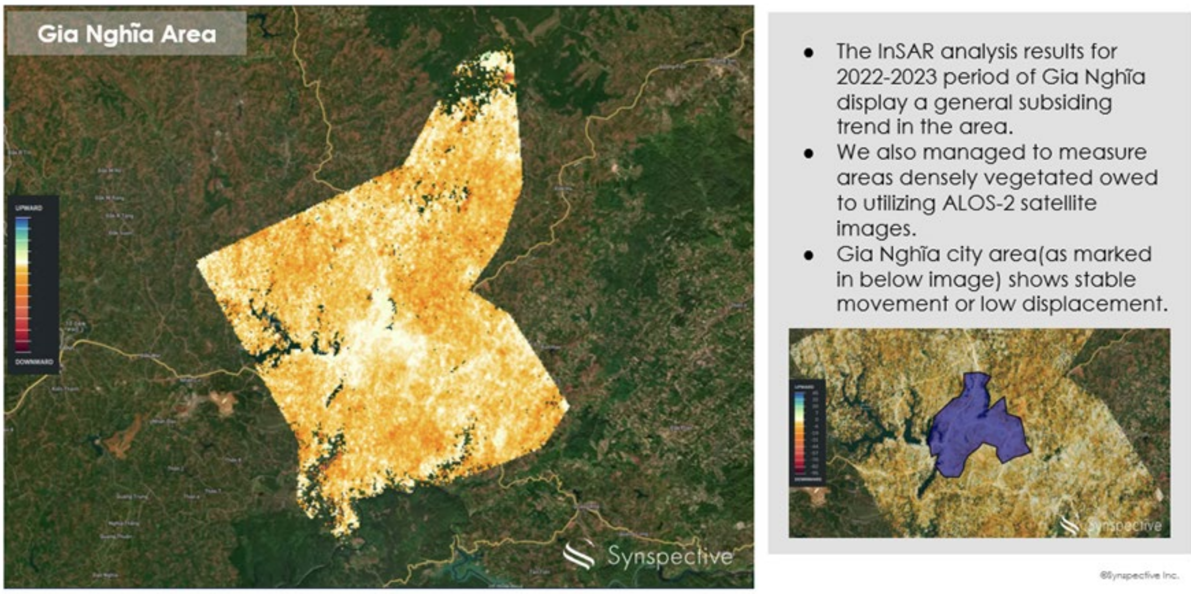
It's difficult to determine the cause just from these results. Still, several researchers indicate that on top of rising sea levels, human activities and increasing population are potentially major contributing factors to further sinking of the areas. Resource extraction and sedimentation should be investigated along with the geological features of the area.

Gia Nghĩa Area

Thanks to ALOS-2, regardless of the mountainous area with abundant vegetation, the ground movement was captured. Gia Nghĩa city area (as marked in Figure 4.8) shows stable movement or low displacement.

On the other hand, we detected continuous subsidence trends observed over a wide area.

Figure 4.8. Gia Nghĩa Area



Source: Synspective Inc. (2024).

Achievements of the project

Through this pilot project, Synspective and the team achieved two essential goals.

First one is presenting usefulness of the solutions to users such as Viet Nam, NRSD. SAR satellite-based solutions are still a new technology with limited opportunities to confirm their usefulness. Thanks to this ERIA study, Synspective and NRSD started to dig deeper into the planning necessary for implementation of SAR satellite solutions.

The second achievement is strengthened partnership amongst NRSD and Fujitsu Viet Nam. We Signed MOU with the National Remote Sensing Agency of Viet Nam and Fujitsu Viet Nam to Enhance Natural Disaster Preparedness, Natural Resource Management, and Economic and Social Development. Also, NRSD's recognition on our solutions value was confirmed, we started framing Next Phase of Coop that enables NRSD to feel and steer the solutions towards their system implementation.

Figure 4.9. Synspective, Viet Nam National Remote Sensing Department, and Fujitsu Viet Nam Sign MoU

Source: Synspective Inc. (2024).

4.1.5 Challenges and Solutions toward Operational Use

While this demonstration presented the usefulness of the SAR satellite utilisation solution, the following issues exist.

- One pilot project is not enough to obtain results to enable customers to make a decision to use the service.
- Project with one agency is not enough to understand the challenges of field use.
- LDM, SAR satellite-based solution, alone is not very effective to monitor all possible situations.

Solving these challenges will require the support of governments and international organisations that support long-term demonstrations and the participation of many companies and organisations.

4.1.6 Expected Schedule until Operational Use

Through this pilot project, we were able to demonstrate the effectiveness of monitoring ground displacement in urban and suburban areas of Viet Nam using SAR satellites. As part of the commercialisation of subsidence monitoring utilising SAR satellites, we aim to organise the administrative operations of Vietnamese government agencies, including NRSD, regarding subsidence (such as investigations, monitoring, and administrative measures against water extraction). Additionally, we plan to implement projects to verify the effective use of SAR satellite monitoring for each use case, clarify its administrative effectiveness, and explore the possibility of obtaining direct budget allocations from the Vietnamese government. While the effectiveness of SAR satellites was demonstrated in this project, NRSD and the Vietnamese government have limited budgets, making it challenging to secure funding for further demonstrations. Therefore, we are considering utilising support from the Japanese government and other sources to proceed with demonstration projects.

The ground displacement monitoring technology used in this demonstration has applications not only for subsidence but also for infrastructure facilities, energy and natural resources, construction projects, and landslide monitoring. In Japan, some of these applications have already been commercialised. Based on the achievements of subsidence projects and domestic use cases, further expansion of these applications is expected in Viet Nam.

Furthermore, the Viet Nam Remote Sensing Department has shown significant interest not only in our SAR analysis technology but also in the immediate and high-frequency monitoring capabilities enabled by our small SAR satellites, which provide high-resolution data. They have expressed specific needs in areas such as disaster monitoring, environmental protection, and natural resource management.

Although no specific projects for implementation have been initiated yet, we are considering project execution with the support of Japanese government.

Proposed Timeline:

2025:

- Subsidence: Organise SAR satellite utilisation methods for Vietnamese administration and begin verification of SAR satellite use tailored to specific use cases.
- Small SAR Satellites: Initiate concrete discussions for utilisation.

2026:

- Subsidence: Conduct verification of SAR satellite use tailored to specific use cases and request budget allocation from the Vietnamese government.
- Small SAR Satellites: Demonstrate the use of small SAR satellites for disaster-related use cases.

2027:

- Subsidence: Secure commercial contracts under the Vietnamese government's budget.

- Other Use Cases: Discuss expanding use cases for ground displacement monitoring.
- Small SAR Satellites: Demonstrate small SAR satellite use for disaster-related and additional use cases.

2028:

- Subsidence: Continue commercial contracts under the Vietnamese government's budget.
- Other Use Cases: Demonstrate utilisation of other use cases for ground displacement monitoring.
- Small SAR Satellites: Demonstrate small SAR satellite use for disaster-related and other use cases, and request budget allocation from the Vietnamese government.

2029:

- Subsidence: Continue commercial contracts under the Vietnamese government's budget.
- Other Use Cases: Secure commercial contracts for other use cases in ground displacement monitoring.
- Small SAR Satellites: Obtain commercial projects under the Vietnamese government's budget.

4.1.7 Estimated Market and/or Revenue Scale after Operational Use

The counterpart for this project and the primary user agency within the Vietnamese government, NRSD, has an annual budget of approximately 500 million yen in 2024. Currently, the remote sensing market is maintaining an annual growth rate of 14.8%, projected to expand to 3.7 trillion yen by 2027 and 7.4 trillion yen by 2032. Additionally, NRSD's budget has grown approximately 1.5 times from 2022 to 2024, and it is anticipated to exceed several billion yen within the next few years. Furthermore, Synspective's business in Viet Nam is not limited to NRSD; it is also expected to extend to other agencies within the Ministry of Natural Resources and Environment (MONRE), other ministries, and the Viet Nam National Space Center (VNSC). As a result, the market potential is estimated to be in the range of several billion to 10 billion yen. Synspective's ground displacement monitoring service is provided at a cost of several million to tens of millions of yen, depending on the monitoring target, in Japan. If our service is adopted as a monitoring system and used to monitor areas within Viet Nam requiring observation for subsidence, the revenue scale is expected to be in the range of tens of millions to 100 million yen. Additionally, if ground displacement monitoring for other targets and small SAR satellite monitoring are commercialised, the total revenue scale is anticipated to reach several hundred million to one billion yen.

Projected Revenue Scale:

- 2025–2029: Several tens of millions to 100 million yen annually
- 2030–2034: 500 million to 1 billion yen annually

4.2 Pilot on Maritime Observation/Surveillance (ArkEdge Space/JSS)

4.2.1 Objective and Overview of the Pilot

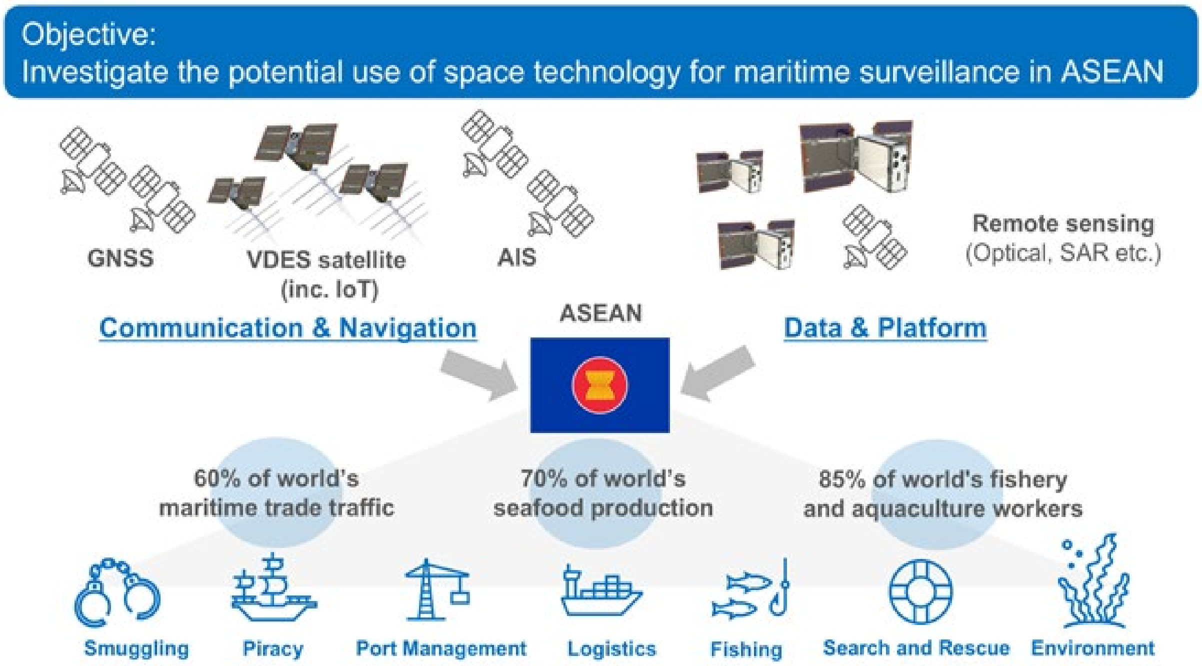
The objective of this pilot project is to examine the potential for using space technology to address the maritime issues facing the ASEAN region, particularly maritime surveillance in the region, which supports the global maritime transport and fishing industry.

Many of the ASEAN member countries are amongst the countries with the longest coastlines in the world, and the Asian region accounts for 70% of the total global marine product production and 85% of the world's fishing and aquaculture workers[1]. Also, 60% of maritime trade passes through Asia, and it is estimated that the South China Sea accounts for one third of the world's shipping[2]. In particular, the Straits of Malacca, which separates the Malay Peninsula and Sumatra Island, and the Singapore Strait, which connects to the southeast of the Straits of Malacca, are amongst the world's most important choke points, linking the Pacific and Indian Oceans. In recent years, security conflicts in the South China Sea have become more apparent, and the stable development of the maritime sector in the region is becoming increasingly important, both economically, socially and politically.

Through interviews with experts from the Philippines, Thailand and Indonesia, we found out that the maritime issues in the ASEAN region are diverse including illegal, unreported and unregulated (IUU) fishing, armed robbery such as piracy, smuggling, terrorism and kidnapping, logistics, environmental issues and search and rescue. One of the challenges facing the Philippines is that it can be vulnerable to illegal acts by vessels because it does not have an established archipelagic sea lane, and it is difficult to manage the large volume of traffic. In Thailand, the fishing and tourism industries are thriving. The expert from Thailand mentioned that there are challenges in logistics management and search and rescue, including tourists.

The demand for maritime surveillance will increase in response to these issues, but it will be not easy or cost-effective to constantly monitor activities on the ocean, which has a wide area and limited infrastructure, especially in areas far from the coast. Satellites are efficient for observing a wide area at regular intervals, and there are expectations for the use of satellite technology in maritime surveillance. ArkEdge Space (hereinafter called AE) and Japan Space Systems have been in dialogue with its counterparts in the ASEAN region. In this pilot project, we investigated the potential contribution of space technology to solve the issues of maritime in the region. We demonstrated the visualisation of maritime situations with the case of piracy attacks by our geospatial information platform which can be also used for understanding illegal activities at sea, for example IUU fishing.

Figure 4.10. Objective and Overview of the Pilot Project



Source: ArkEdge Space Inc. (2024).

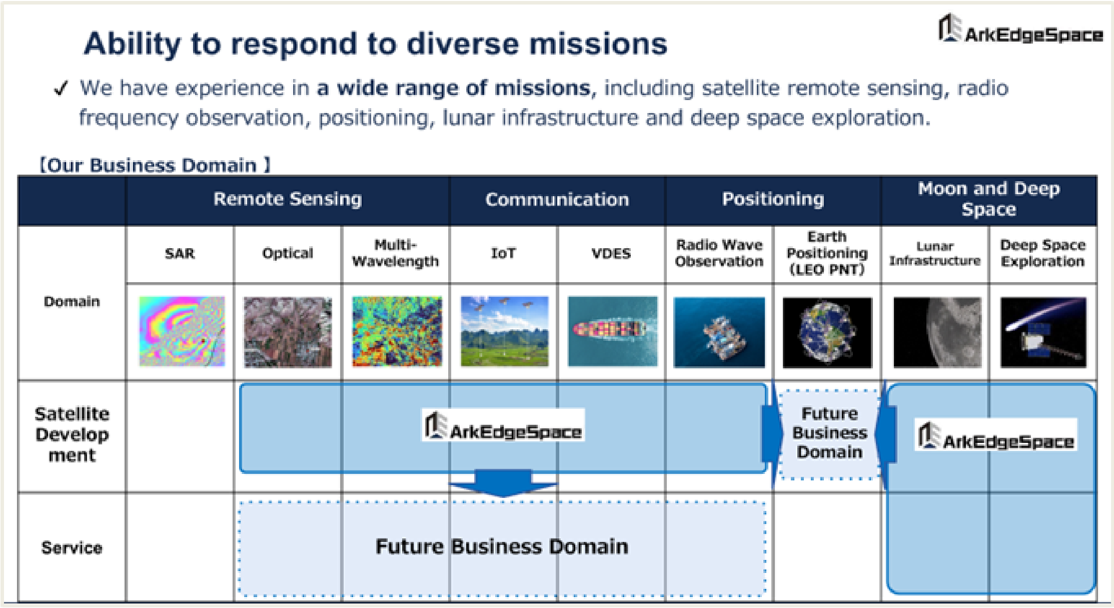
4.2.2 Implementation Scheme/Role of Each Organisation

AE is a startup company founded in 2018 as a spin-off from the University of Tokyo. We design, develop and operate micro-satellites, provide software, ground station operation and capacity building services across a wide range of business areas as shown in Figure 4.11.

AEWe is specialised in micro-satellites, which have the advantage of being able to be launched quickly and flexibly to meet needs at a cost of less than 1/100th of that of conventional large satellites. By deploying a large number of satellites called satellite constellations, it can communicate or collect data at high frequency. Taking these advantages of micro-satellites, AE aims to provide a better understanding of maritime situation to users such as coast guards, port management authorities, marine logistics companies, marine insurance companies, fisheries companies, search and rescue authorities and government officials through the visualisation by our geospatial information platform which has the data collected by remote sensing, VDES (VHF Data Exchange System) and satellite IoT communication.

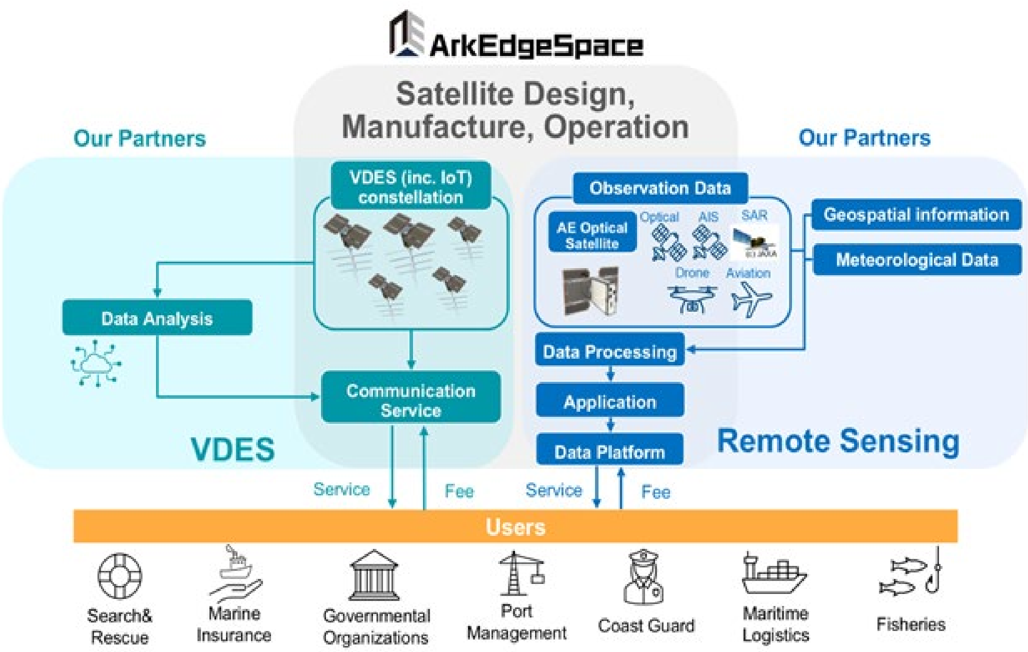
By combining Earth observation data and various other data with a user-friendly web data platform, AEwe aims to visualise various oceanographic information. In addition to joining the Satellite VDES Consortium as a founding member in 2022 to promote the implementation of satellite VDES with partner companies, AE is also working on business development with IHI Corporation and LocationMind Inc. as one of a Key and Advanced Technology R&D through Cross Community Collaboration Program by Japanese government. In this project, AE is mainly responsible for the design, manufacture and operation of the VDES satellites, and plans to launch the satellites sequentially from 2025 onwards, aiming to expand its coverage. AEWe will also collaborate with local partner companies as necessary for service customisation and localisation.

Figure 4.11. Business Domain of ArkEdge Space Inc.



Source: ArkEdge Space Inc. (2024).

Figure 4.12. Overview of our maritime situational awareness service



Source: ArkEdge Space Inc. (2024).

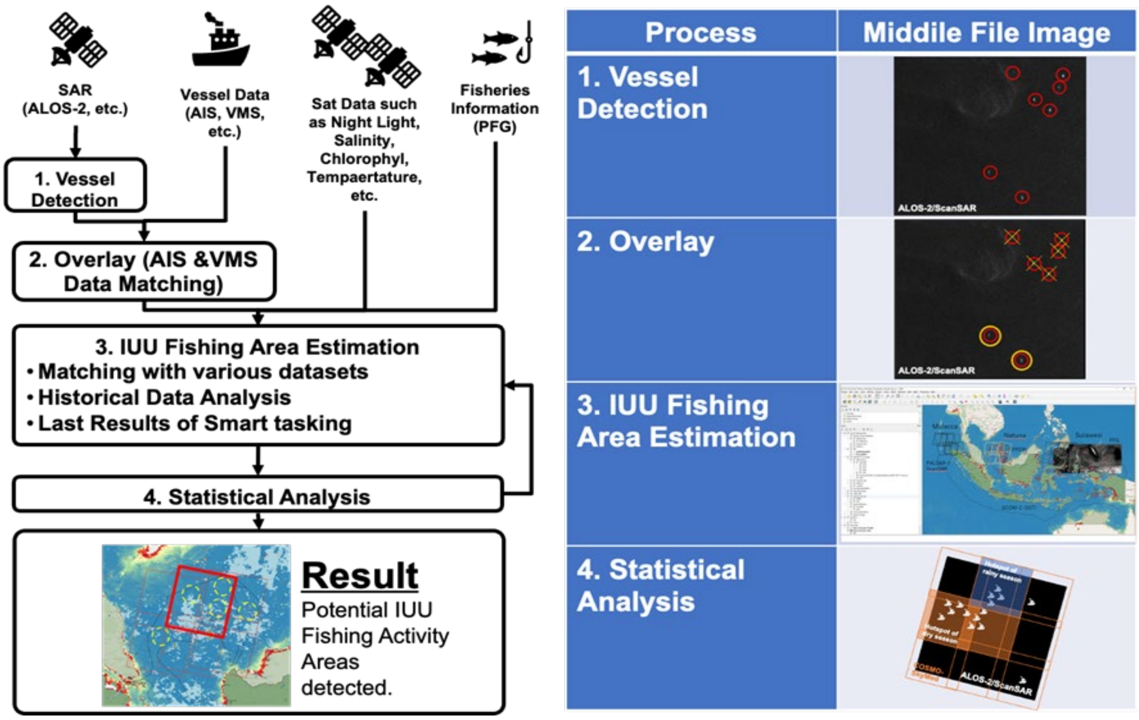
4.2.3 Technologies, Model, and Algorithms Applied to the Pilot

Algorithms of the satellite data analysis for estimated IUU fishing areas

Algorithms of the satellite data analysis for estimated IUU fishing areas were designed as following steps:

1. Extract vessels from ALOS-2/PALSAR-2 data,
2. Overlay vessel data such as AIS and VMS data on analysed satellite data,
3. Overlay multiple analysed satellite data such as night lights by SUOMI, sea surface temperature by GCOM-C, and potential fishing areas by Indonesian members,
4. Consider historical data,
5. Consider last results of satellite data analysis, and
6. Apply statistical calculations for estimating potential IUU fishing areas.

Figure 4.13. Concept of satellite data analysis for estimating IUU fishing areas



Source: Japan Space Systems (2024)

Through the practical pilot project, project members faced an issue: PALSAR-2/ScanSAR covers the wide area as much as 350.5 km * 355 km, and it is able to observe in the Indonesian territories efficiently and effectively. According to some articles and dialogues, however, the average size of IUU fishing vessels in Indonesia was smaller than 20 m which is also smaller than 50 m resolution of PALSAR-2/ScanSAR. Experts prepared and asked the local fishermen to operate a small fishing vessel (its length was 17.6 m, Figure

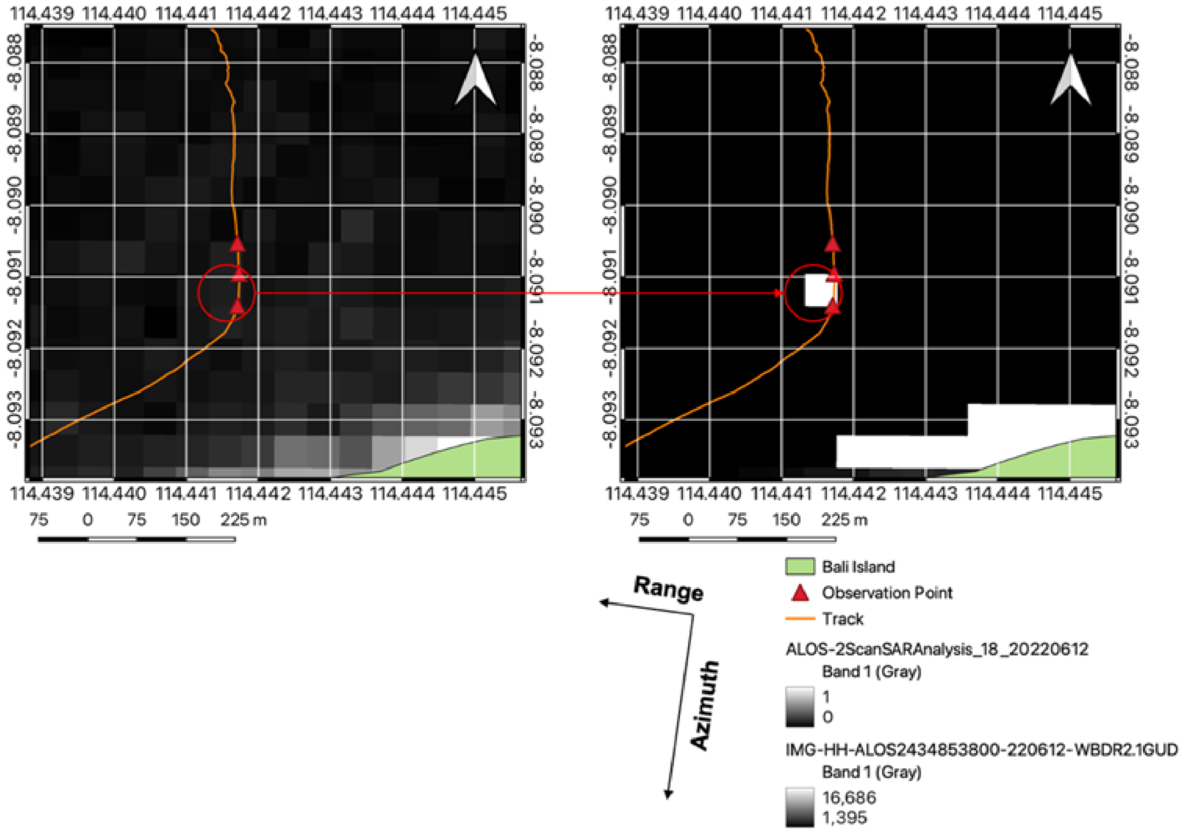
4.14) with GNSS devices, and the vessel was observed by PALSAR-2/ScanSAR mode on June 12, 2022. Experts downloaded and analysed the data image after the observation, and they extracted the shadow of the vessels from the image (Figure 4.15). The abilities of PALSAR-2/ScanSAR for monitoring IUU fishing activities in Indonesian oceans were shown, and the significance was huge through the demonstration. This demonstration was only one of examples for showing the abilities of PALSAR-2/ScanSAR for monitoring IUU fishing activities. If budgetary and time are permitted, observations using multiple fishing vessels under the fishing operations would be demonstrated in future activities, and experts would like to deepen their knowledge about satellite data analysis techniques, characteristics of IUU fishing activities and abilities of PALSAR-2/ScanSAR.

Through the demonstration, abilities and utilities of PALSAR-2/ScanSAR for monitoring IUU fishing activities were shown, and the results had huge impacts on not only the Project but also the field of remote sensing data analysis.

Figure 4.14. The target vessel. Experts had supports by the local fishermen in Perancak

Source: Japan Space Systems (2024)

Figure 4.15. A power image of PALSAR-2/ScanSAR

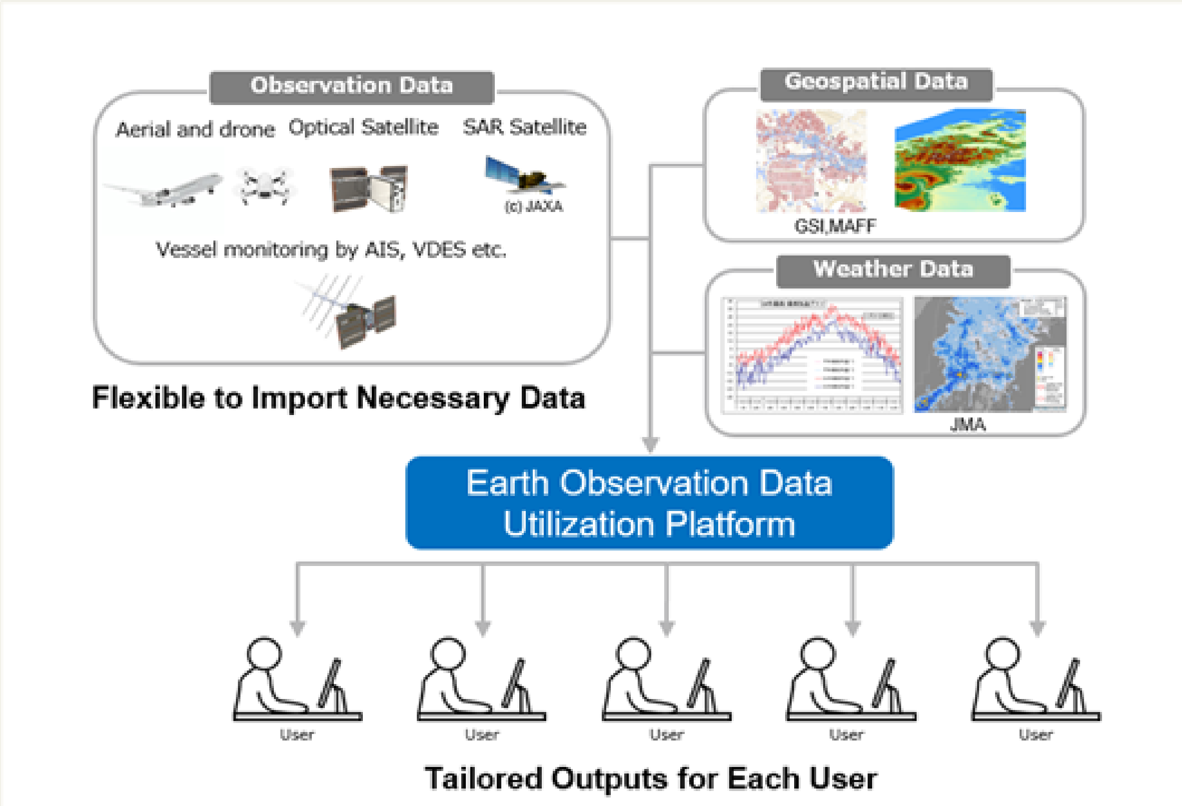


Note: (left) and the result image (right). An orange line showed the track of the vessel. The vessel operated to the north from the south. Red triangles showed start, center and end of observation times by PALSAR-2/ScanSAR. The shadow of the vessel was difficult to be recognised on the power image, but it was detected as 1 pixel by data analysis. The geographic coordinate system of the images is WGS84.
Source: Japan Space Systems (2024)

Geospatial information platform and VDES technologies

There are potential needs for visualising the movement of ships and various other information in the vast ocean areas for maritime situational awareness. AE is developing a geospatial information platform and aims to provide a service that visualises marine information by combining various data according to user needs. Although many satellite data platforms provide a variety of data, in many cases users need to select and analyse the data they need by themselves, and this requires specialist knowledge. The AE's geospatial information platform is designed to be easy for non-specialists to use, with a simple user interface and a tailored service that only provides the data each user needs.

Figure 4.16. Concept of our geospatial information platform service



Source: ArkEdge Space Inc. based on Japan Aerospace Exploration Agency (JAXA), Geospatial Information Authority of Japan (GSI), Ministry of Agriculture, Forestry and Fisheries (MAFF) and Japan Meteorological Agency (JMA) (2024).

Also, according to the Cabinet Office of Japan, the four approaches to strengthening maritime domain awareness are: 1. information collection systems, 2. information integration and sharing systems, 3. international cooperation and collaboration, and 4. information utilisation. Amongst these approaches, the satellite VDES, which is being developed by AE, is considered as one of the means of constituting the information collection systems.

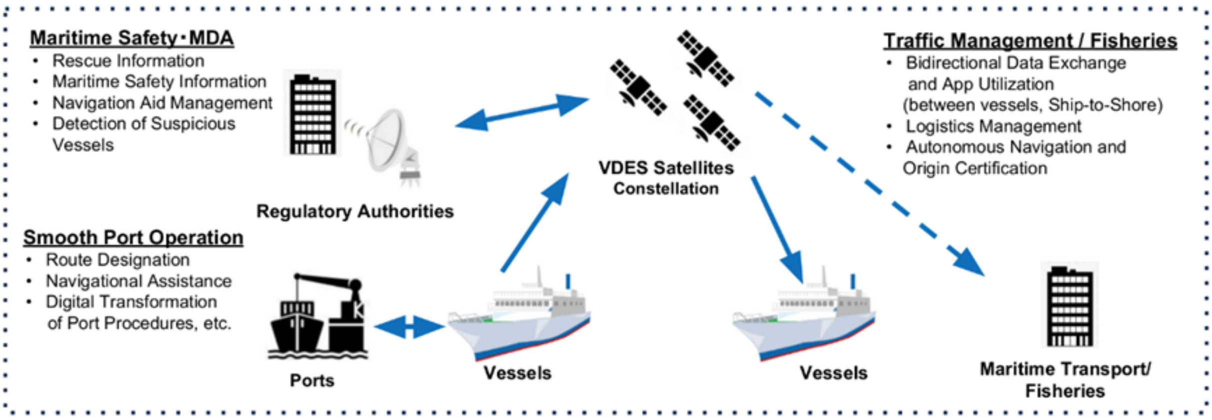
The methods and accumulated data for comprehensively understanding ships moving across vast expanses of ocean are not sufficient. Automatic Identification System (AIS) is a system that is currently used for ship information. In 2002, the International Convention for the Safety of Life at Sea (SOLAS Convention) made it compulsory for some ships to be equipped with AIS, and its use is expanding to include safety navigation, maritime security operations, and coordination related to port operations.

However, since AIS is based on the premise of exchanging information over short distances at sea (around 20 km), there are many gaps due to signal collisions when satellites receive AIS signals from ships. In addition to the lack of real-time data, the intentional cutting of AIS signals and signal spoofing make it difficult to obtain highly reliable data. Furthermore, it is only possible to broadcast (simultaneously broadcast) information such as the ID, position and speed of the ship in short distance, and it does not support two-way communication.

Under these circumstances, the allocation of the necessary frequency bands for VDES satellites was decided at the International Telecommunication Union's World Radiocommunication Conference in November 2019. VDES will contribute to preventing spoofing through a robust network, and the use of satellites will overcome the communication distance problem and enable real-time coordination of offshore operations on a global scale. In addition to AIS, VDES has added the function of the transmission of multi-purpose data with a larger communication capacity to create a network with two-way communication, which is defined as Application Specific Message (ASM) and VHF Data Exchange (VDE).

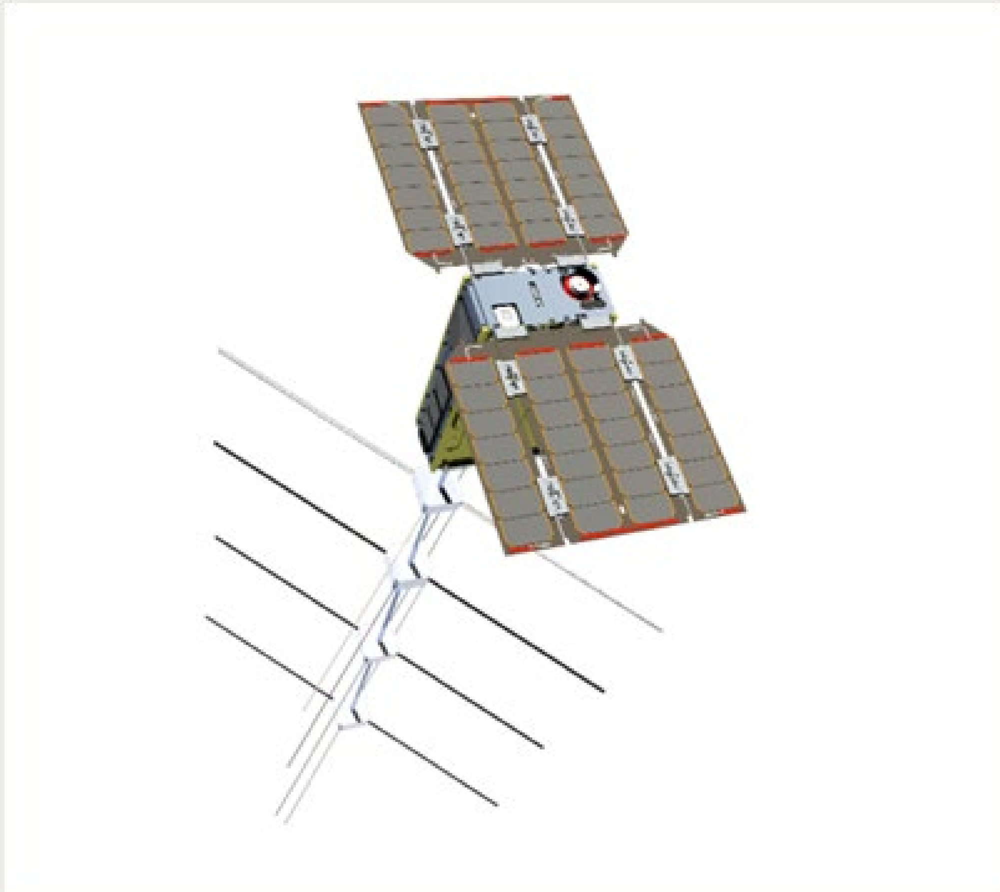
Various VDES use cases are being considered, and the guidelines for VDES by International Association of Marine Aids to Navigation and Lighthouse Authorities propose for example search and rescue communications, maritime safety information, maritime traffic management, and chart distribution. AE aims to provide services in major waters around the world by deploying a VDES satellite constellation, and also to meet needs such as understanding maritime conditions by collecting information from IoT buoys and other devices by equipping the satellites with IoT functions.

Figure 4.17. Concept of VDES system



Source: ArkEdge Space Inc. (2024).

Figure 4.18. Our VDES Satellite (AE VDES 1st Gen.)



Source: ArkEdge Space Inc. (2024).

4.2.4 Current Results of the Pilot

Satellite data analysis and dead reckoning of AIS/VMS data

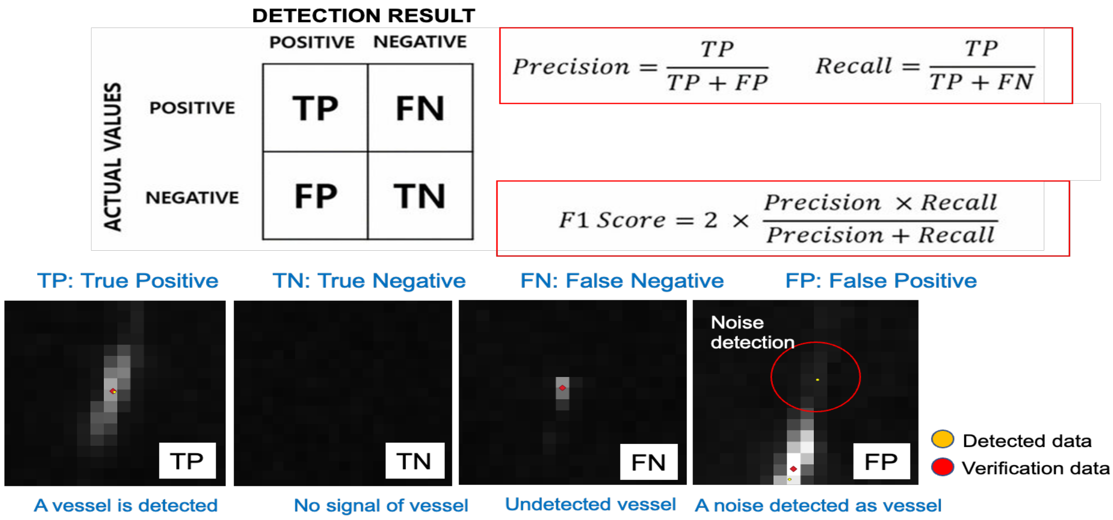
Members of the practical pilot project worked on verifications of the satellite data analysis results. Members prepared 3 steps: 1) verification of vessel detection results by satellite data analysis; 2) verification of dead reckoning of AIS and VMS data; and 3) verification of correlation between results of satellite data analysis and dead reckoning of AIS/VMS data.

Members of the practical pilot project compared results of systematic and manual analysis as the first verification of satellite data analysis. The threshold was set as low to collect as many possibilities as system was able to. This step was the first activity of the process, and all possibilities had to be applied to the next for enhancing accuracies of estimations.

Intervals of VMS data were an hour. Estimating the vessel activities, times and positions was serious issues for selecting legal and illegal vessels. Members calculated position gaps between the true positions of AIS/VMS data and estimated position by the dead reckoning method. They also applied Lamber-Amdoyer methods for calculating distance of 2 points on the spheroid and used all effective records. Members also plotted which was about correlation between Δd (distance gaps) and Δt (time gaps) for showing corrections.

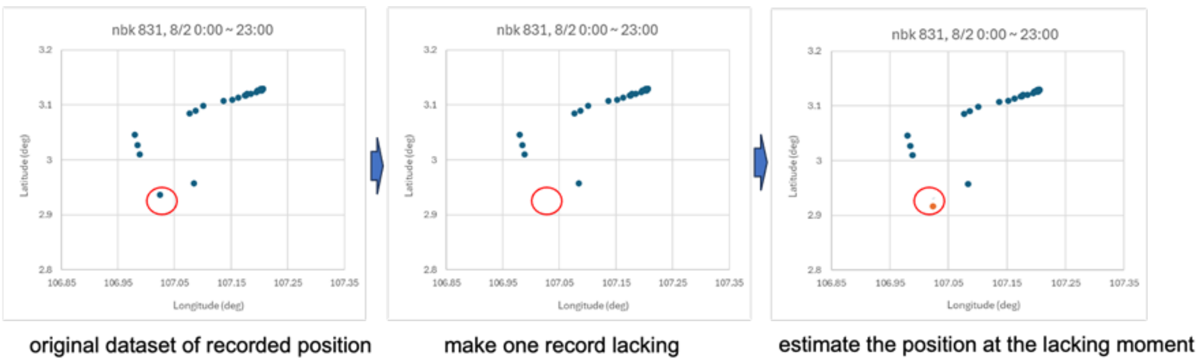
Moreover, members of the practical pilot project contributed to show certainly of the total analysis results between satellite data analysis and dead reckoning. They overlayed and plotted Δd (distance gaps) and Δt (time gaps) of both results of satellite data analysis and dead reckoning.

Figure 4.19. Verification of Vessel Detection by Satellite Data Analysis



Source: Consortium of Japan Space Systems, JGI, Inc., Remote Sensing Technology Center of Japan, & PASCO Corporation (2024).

Figure 4.20. Verification of Dead Reckoning



Source: Consortium of Japan Space Systems, JGI, Inc., Remote Sensing Technology Center of Japan, & PASCO Corporation (2024).

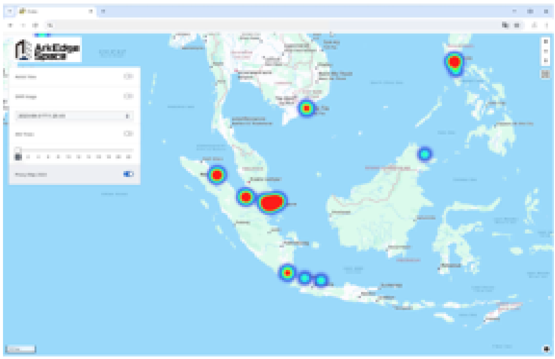
Geospatial information platform superimposing optical data, SAR data, and AIS data

Piracy is one of the serious issues facing the ASEAN region. According to the 2024 report on piracy and armed robbery against ships published by the International Chamber of

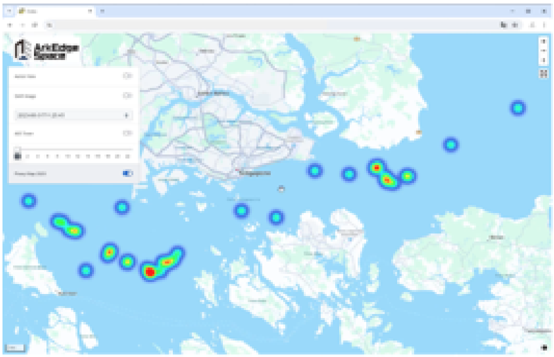
Commerce's International Maritime Bureau, there were 120 cases of piracy and armed robbery against ships in 2023. In fact, 67 incidents, which is about 55% of all maritime armed robberies worldwide, occurred in Southeast Asia, with 37 incidents, which is about 30% of all incidents worldwide, reported in the Singapore Strait in particular.[4] The Singapore Straits is a geopolitical gateway for many commercial ships, and anti-piracy measures in the ASEAN region will be essential for global trade and the economy.

As a measure against piracy, AEwe attempted to visualise the traffic and pirate activities in the region using our geospatial information platform. By superimposing optical data, Synthetic Aperture Radar (SAR) data, and AIS data on a map and displaying the sailing routes along a timeline, you can easily grasp when and where incidents occurred by pinpointing pirate information. The specific procedure is shown below.

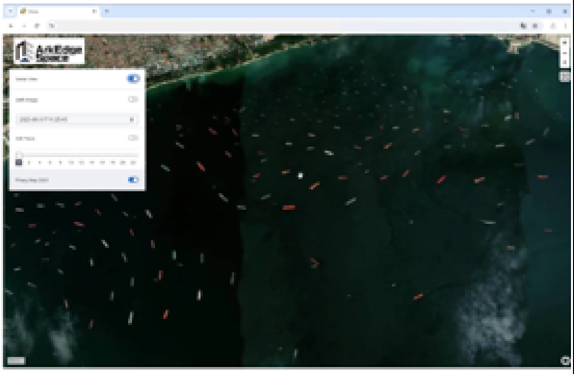
Figure 2.21 Copernicus Sentinel | ICC Commercial Crime Services |



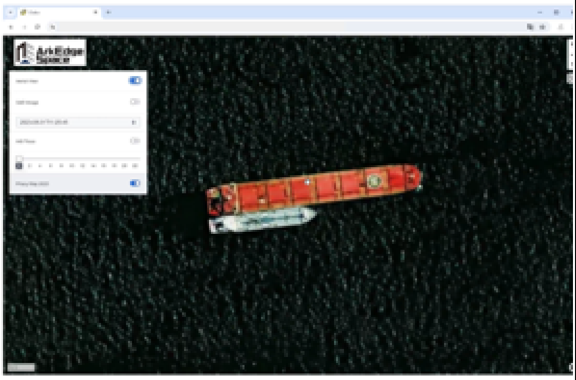
1. Displaying the hotspots of pirates in Southeast Asia



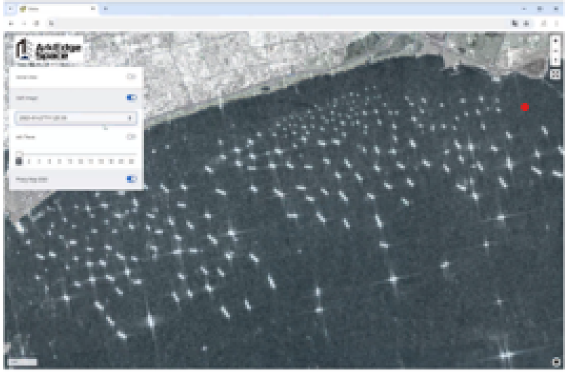
2. Enlarging the area around the Singapore Strait



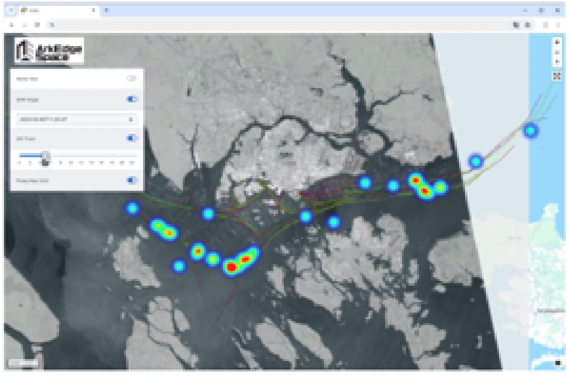
3. Optical data is also available



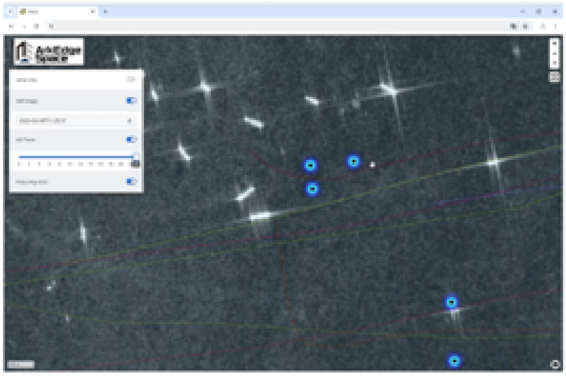
4. High-resolution optical data allows identifying ships



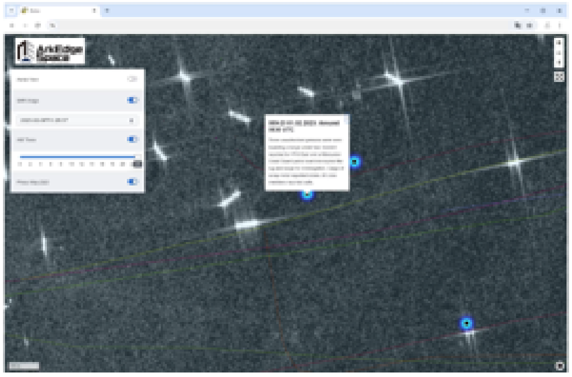
5. SAR data is also available



6. The combination of AIS data enables the display of a ship's trajectory along a timeline



7. Displaying pirate attacks as spots



8. Displaying pirate information (date, time, and details of the incident) by clicking on it

Source: ArkEdge Space Inc. based on MapLibre, Copernicus Sentinel and ICC Commercial Crime Services (2024)

In the future, AEwe aimsaim to provide services to stakeholders in the maritime sector by visualising ocean conditions using a combination of the geospatial information platform, VDES and communication data from satellites, remote sensing data such as optical and SAR images, and processing by artificial intelligence. In addition to preventing piracy, there are various other possible uses, such as collecting IoT data from buoys to provide information on wave height and other maritime conditions or using it to detect suspicious vessels in maritime security operations.

4.2.5 Challenge and Solutions toward Operational Use

The practical pilot project showed the abilities of ALOS-2/PALSAR-2 data for vessel detections and effectiveness of satellite data analysis for estimating potential IUU fishing areas. The outputs, algorithms of satellite data analysis and satellite data infrastructure were installed as a part of systems for KKP, and they were operated. The practical pilot project achieved its original goal, and cross-sectional operation amongst fields of marine affairs would be the next achievement, such as applying and cooperating amongst ASEAN countries.

In developing the geospatial information platform, it is necessary to consider cost reduction by evaluating the optimal usage through comparison and combination with ground technology such as drones and ground sensors, and by improving the efficiency of change detection using artificial intelligence. The development of the VDES satellite will require further reductions in cost and lead time to build a constellation. From a technological perspective, it will also be necessary to improve the efficiency of communication functions, develop high-performance onboard processing functions that can extract useful information from large amounts of data in orbit, and develop advanced data analysis algorithms on the ground. In addition, it will also be necessary to make global policy making regarding the mandatory installation of VDES and its implementation in society. Although the SOLAS Convention made the installation of AIS mandatory for some ships in 2002, it is limited to ocean-going ships and domestic ships over a certain tonnage, and not for fishing boats and small ships. At the International Maritime Organization meeting in June 2024, it was agreed that the installation of VDES would be made optional in conjunction with AIS. It is expected that this will be reflected in the revised SOLAS Convention, which is scheduled to be issued in January 2028. It is necessary to form a norm while collaborating with other organisations to make the installation of VDES mandatory. Furthermore, there are also potential needs to promote policies to make it mandatory for all ships, including those that are not covered by the convention, to install VDES, such as by formulating rules for the introduction of simplified VDES.

4.2.6 Expected Schedule until Operational Use

Through the pilot project, detections of IUU fishing activities were developed with ALOS-2, AIS and VMS dataset combinations. Satellites are effective for monitoring widely, but real-time monitoring is required for surveillance activities. Proceeding with activities such as designing and developing satellite constellations, equatorial orbits and operations through international cooperation are the next steps for enhancing abilities of satellite utilisations for monitoring IUU fishing activities in ASEAN.

The development of the geospatial information platform is aimed to be commercialised after 2025. AEThe company will establish methods for detecting and analysing changes, develop analysis technology using artificial intelligence, and continue to make further improvements while implementing demonstration projects that utilise the platform. The results obtained in this process will be reflected in our satellite development and launch plans, and AEwe will continue to improve and streamline data acquisition.

The development of marine surveillance using VDES is being carried out as part of the ‘Development and Demonstration Project of Maritime Situational Awareness Technology Based on a Constellation of VDES Satellites’ project, which has been adopted as Key and Advanced Technology R&D through Cross Community Collaboration Program by

Japanese government. The project will run for eight years from FY 2022 to FY 2029 and will involve research and development of satellite technology for comprehensively collecting ship movement information from space, as well as data platform technology for integrating and sharing maritime information via two-way communication. AE We will launch and demonstrate our satellites from 2025 onward and plan to implement them after the R&D phase.

4.2.7 Estimated Market and/or Revenue Scale after Operational Use

The global market for marine situational awareness is expected to be worth around US$2.2 billion in 2024 and US$2.74 billion in 2029, with a growth rate of 4.45% between 2024 and 2029.[5] The Asia-Pacific region is expected to grow the fastest in the marine situational systems market.[6] In addition, the size of the marine communications market in 2024 is estimated to be about US$6.5 billion, and it is expected to reach about US$10.9 billion by 2029 at a growth rate of 11%.[7] Similarly to the maritime situational awareness market, the Asia-Pacific region is expected to be the fastest-growing segment of the maritime analytics market between 2022 and 2027, due to factors such as the increased use of waterways for transportation and satellite communications as well as rising government initiatives. Based on this, we estimated the market size in 2036 will be about US$4 billion for the maritime situational awareness market and US$21 billion for the maritime digital transformation market. We expect to acquire markets in the growing ASEAN region in the future. We will continue to develop technology and make proposals to companies, customers, governments, etc. in Japan and overseas, aiming to expand our services toward the full-scale commercialisation of our geospatial information platform and VDES.

4.3 Pilot on Peatland Management (Sumitomo Forestry/Kokusai Kogyo)

4.3.1 Objective and Overview of the Pilot

Utilisation of Satellite Technologies for Future Peatland Management

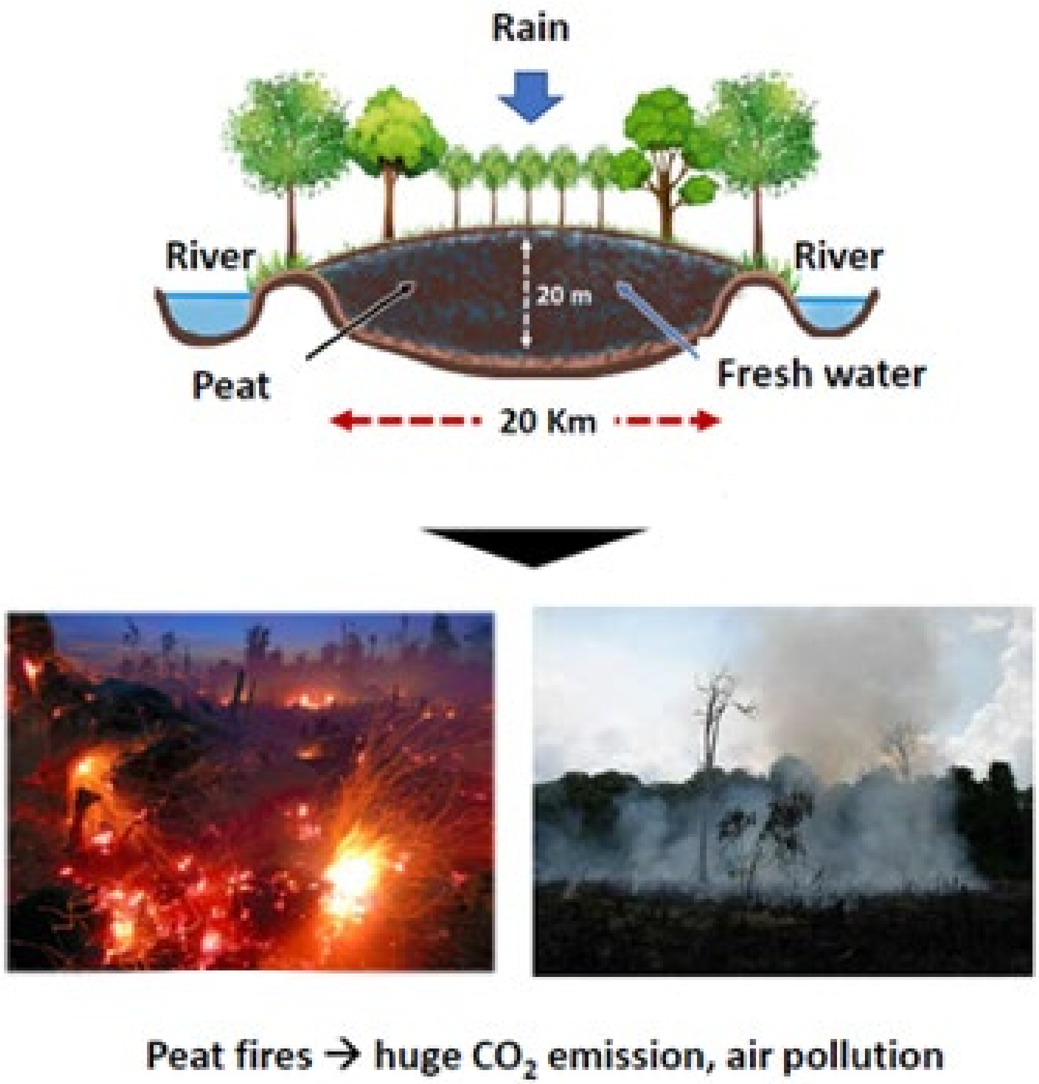
Tropical peatlands cover about 82 million hectares worldwide and are mainly found in the Amazon in South America, the Congo in Africa and Indonesia. Tropical peatlands are mainly composed of more than 90% water, and peat is formed from plant matter that has accumulated over a long period of time. Tropical peatlands are covered with high densities of highly diverse flora and fauna, which means they have a significant impact on the planet. Therefore, if peatlands are not properly managed or if fires occur, the ecosystems of all peatlands will be destroyed and there is a possibility of various risks (CO_2 emissions, economic losses, health hazards, etc.) to human life.

The conservation of tropical peatlands is crucial in responding to global climate change. Sumitomo Forestry has been preventing peat fires and promoting tree growth in West Kalimantan, Indonesia, by controlling groundwater levels. We call this method of peatland water management 'Water reserved peat management'.

Water reserved peat management requires a lot of data, such as groundwater levels, topography and vegetation, and is very costly in terms of time and effort (Figure 4.22). UAV and satellites can be used to efficiently collect data over large areas of forest and peatland. However, verification of the collected ground data is essential for the practical application of remote sensing technology.

To rapidly promote the proper management of tropical peatlands and contribute to climate change mitigation, high-precision, wide-area measurement and assessment technology combining satellite observation technology and ground data is needed.

Figure 4.22. Importance of tropical peatland



Source: Sumitomo Forestry Co., Ltd. (2023).

Figure 4.23. Field survey in west Kalimantan

Source: Sumitomo Forestry Co., Ltd. (2016).

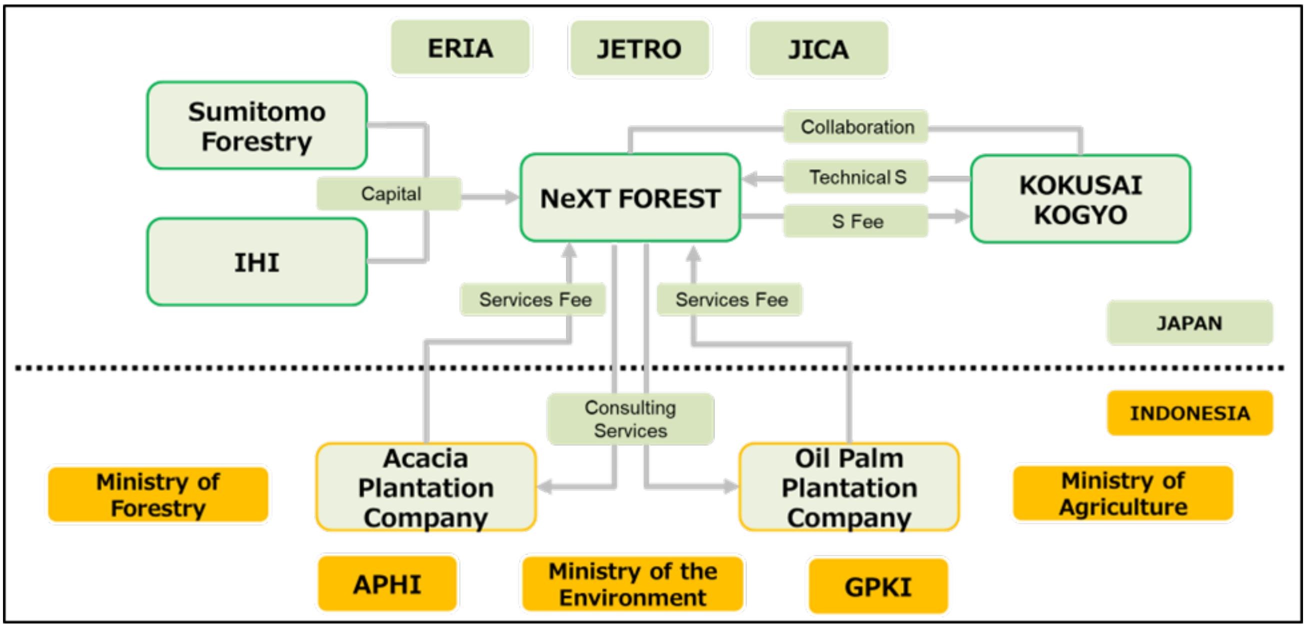
4.3.2 Implementation Scheme/Role of Each Organisation

NeXT FOREST and KOKUSAI KOGYO are exploring collaboration, aiming to achieve a balance between the environment and economy in peatland plantations (Fig 3)

- NeXT FOREST measures ground data for peatlands, forestry, and agriculture.
- KOKUSAI KOGYO analyses data acquired by satellite and UAV.
- NeXT FOREST and KOKUSAI KOGYO combine their data to create higher-value data and solutions.
- NeXT FOREST provides peatland management consulting services to peatland management companies in Indonesia. If necessary, we will coordinate with the Indonesian government and related organisations.

- The content of the consulting services varies from high environmental value theme, such as water level management and reducing the amount of fertiliser used in peatlands, to high economic value theme, such as increasing yields and yield forecasting.
- The project will be promoted as a team, with the cooperation of ERIA, JETRO and JICA as necessary.

Figure 4.24. Concept of our future project implementation structure



Source: Sumitomo Forestry Co., Ltd. (2023).

4.3.3 Technologies, Model, and Algorithms Applied to the Pilot

Utilised ground data and satellite data

- Acquiring data on the ground requires a lot of time and money.
- The data acquired by satellite and UAVs would not be very accurate
- To carry out more accurate measurements over a wide area, it is necessary to combine ground data, UAV data and satellite data (Fig 30).

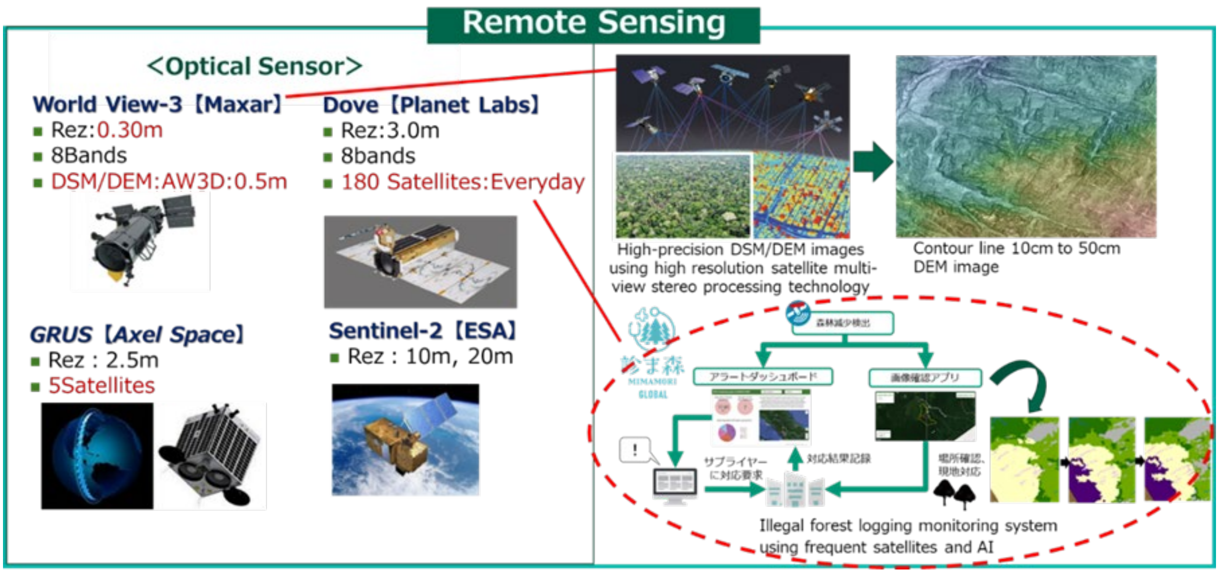
Figure 4.25. Data set in tropical peatland and remote-sensing technology

Source: Sumitomo Forestry Co., Ltd. (2022).

In Tropical peatland and forest by Optical Sensor

- MAXAR satellite has a resolution of 30cm, and its data can be used to create a 50cm resolution DSM,DEM, which allows us to build a detailed terrain model of peatlands.
- PLANET satellites have a resolution of 3m, and their constellation of 180 satellites enable 24/7 observation to monitor illegal logging in and around peatlands.
-

Figure 4.26. Main Satellite Systems in tropical peatland and forest by Optical Sensor

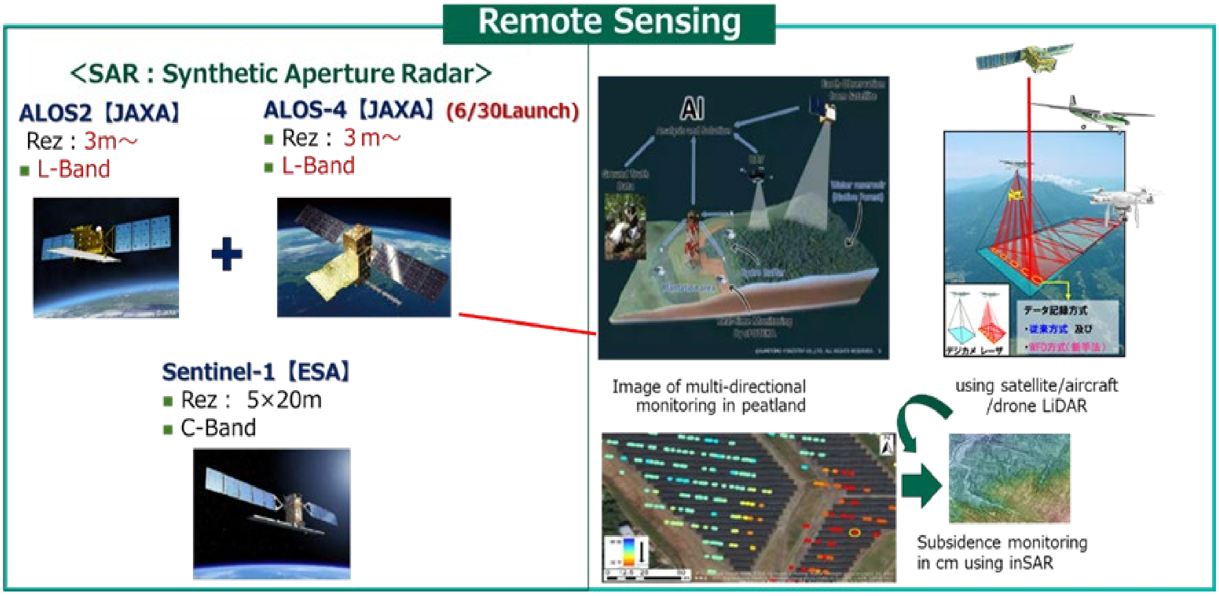


Source: KOKUSAI KOGYO Co., Ltd. (2023).

In tropical peatland and forest by SAR Sensor

- The SAR satellite can observe even under clouds or at night.
- In addition, satellite interferometric processing can be used to observe changes of ground surface level from the past observation.
- In addition to ALOS2, which is currently operated by Japan's JAXA, the next-generation ALOS4 was launched on June 30th. While maintaining the same resolution, it can return to the same location about 20 times a year to take an image, and is expected to be useful for observation in tropical regions. It is also expected that ALOS2 and 4 will be able to perform interference.

Figure 4.27. Main Satellite Systems in tropical peatland and forest by SAR Sensor

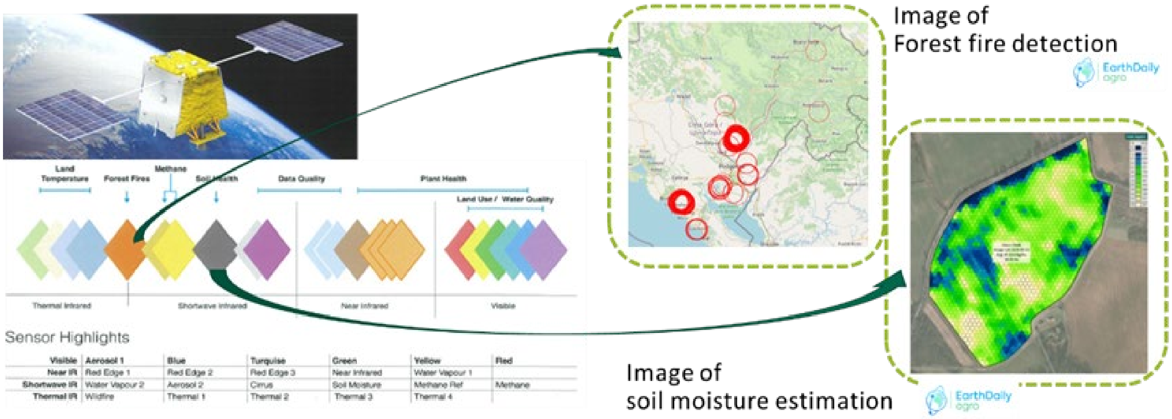


Source: KOKUSAI KOGYO Co., Ltd. (2023).

Forest fire detection and soil moisture estimation by satellite

- In recent years, several satellite systems have been planned that will have many bands. For example, it is becoming possible to detect forest fires using daily thermal images with a resolution of 120m
- The SWIR wavelength is effective for understanding the height of groundwater and soil moisture content, which are important for palm tree growth, and it is possible to monitor soil moisture content on a daily basis.

Figure 4.28. Forest fire detection and soil moisture estimation by satellite



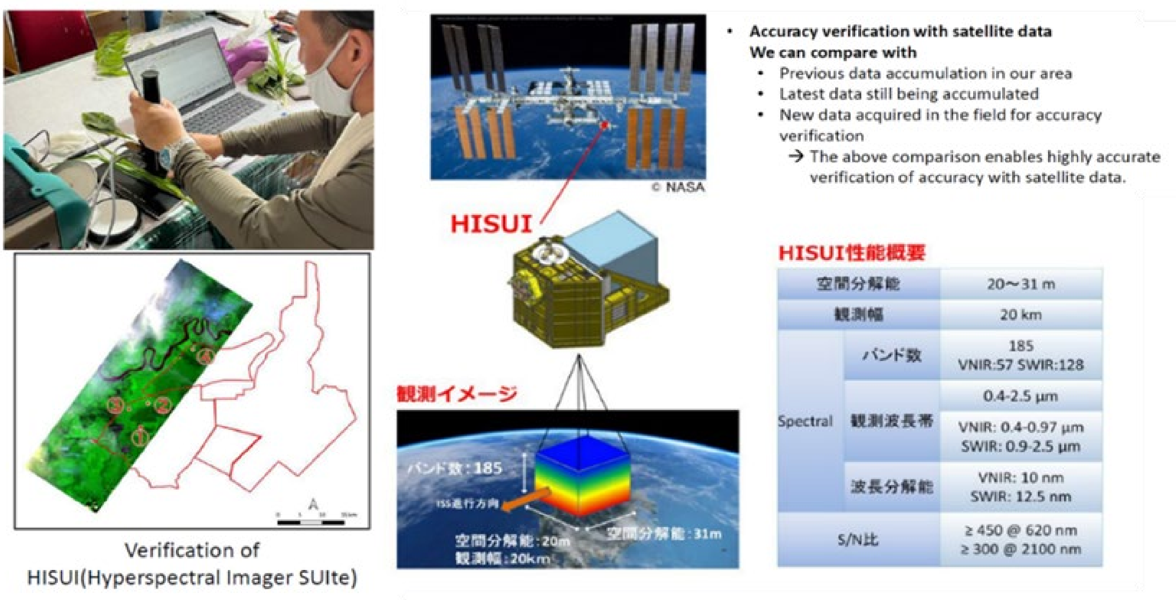
Source: KOKUSAI KOGYO Co., Ltd. (2023).

4.3.4 Current Results of the Pilot

Hyperspectral data by HISUI(ISS)

- Identifying tree species through ground truth survey is essential to know the forest components, but there is a potential to identify the tree species by hyperspectral data.
- By combining data from the hyperspectral sensor installed on the ISS with data acquired by contact-type sensors, it is possible to accurately determine the forest type.

Figure 4.29. Use case of hyperspectral satellite image to identify tree species

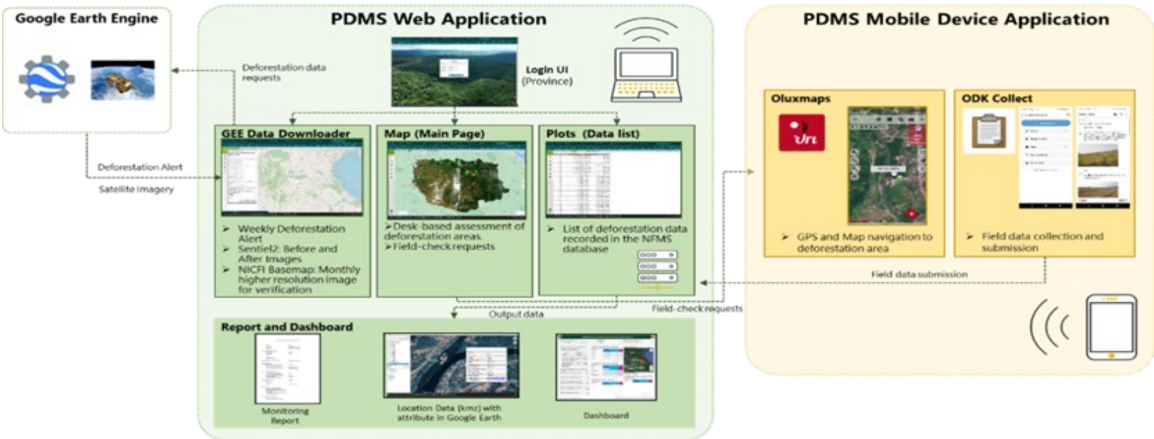


Source: Sumitomo Forestry Co., Ltd. (2024) & KOKUSAI KOGYO Co., Ltd. (2023).

Near Real-Time Forest Monitoring

- Provincial Deforestation Monitoring System (PDMS) is near real-time deforestation monitoring tool based on satellite imagery and field verification
- Enhance forest monitoring and forest law enforcement to control illegal land conversion. Provide more accurate deforestation data for forest monitoring

Figure 4.30. Near Real-Time Forest Monitoring in Lao by satellite

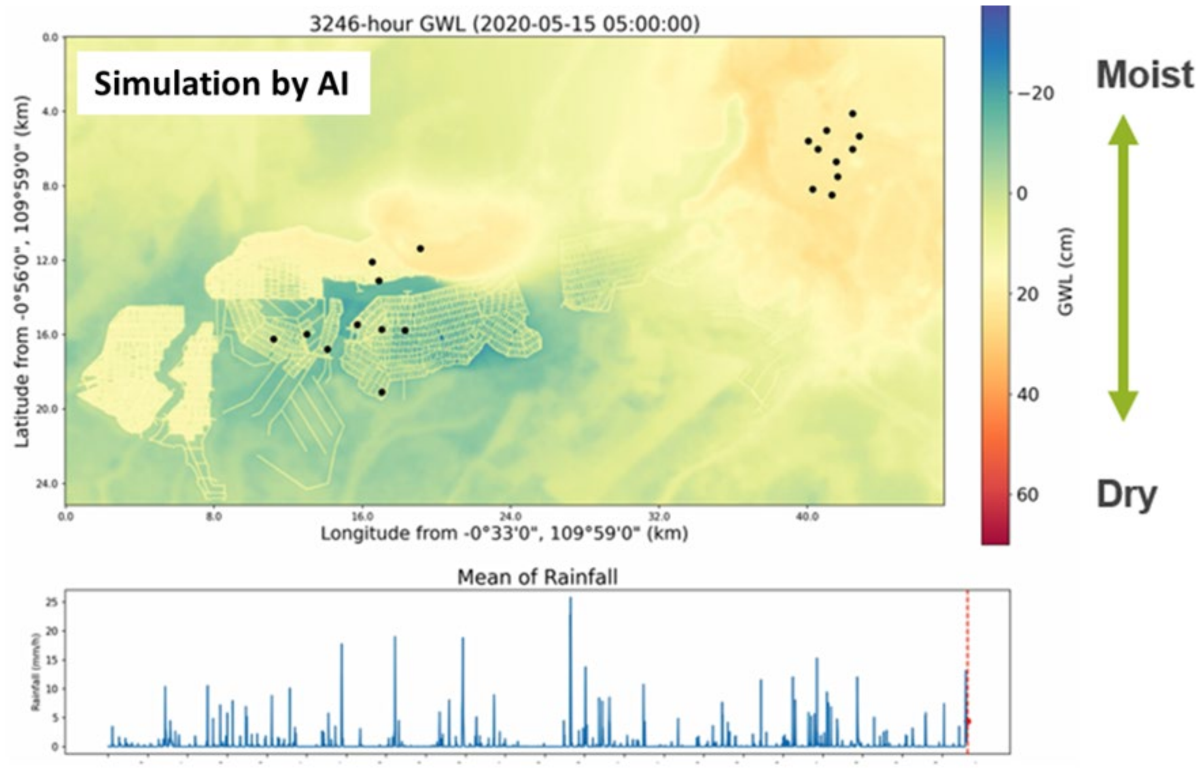


Source: KOKUSAI KOGYO Co., Ltd. (2023).

Predicting the groundwater level in peatlands using AI

- It is difficult to control groundwater levels in peatlands, and it is particularly difficult to maintain adequate groundwater levels during the dry season.
- We have developed an AI model that predicts future groundwater levels by combining big data collected by ground survey, such as an actual ground water level, topographical information and meteorological data, with satellite data.
- The AI model can predict groundwater levels up to seven days in advance.
- Additionally, combination with highly accurate rainfall forecast enable the prediction more accurate in the future.
- The AI model is expected to help prevent peat fires by preventing the over-drying of peatlands during the dry season.

Figure 3.31 AI model to predict groundwater level in SFC's peatland

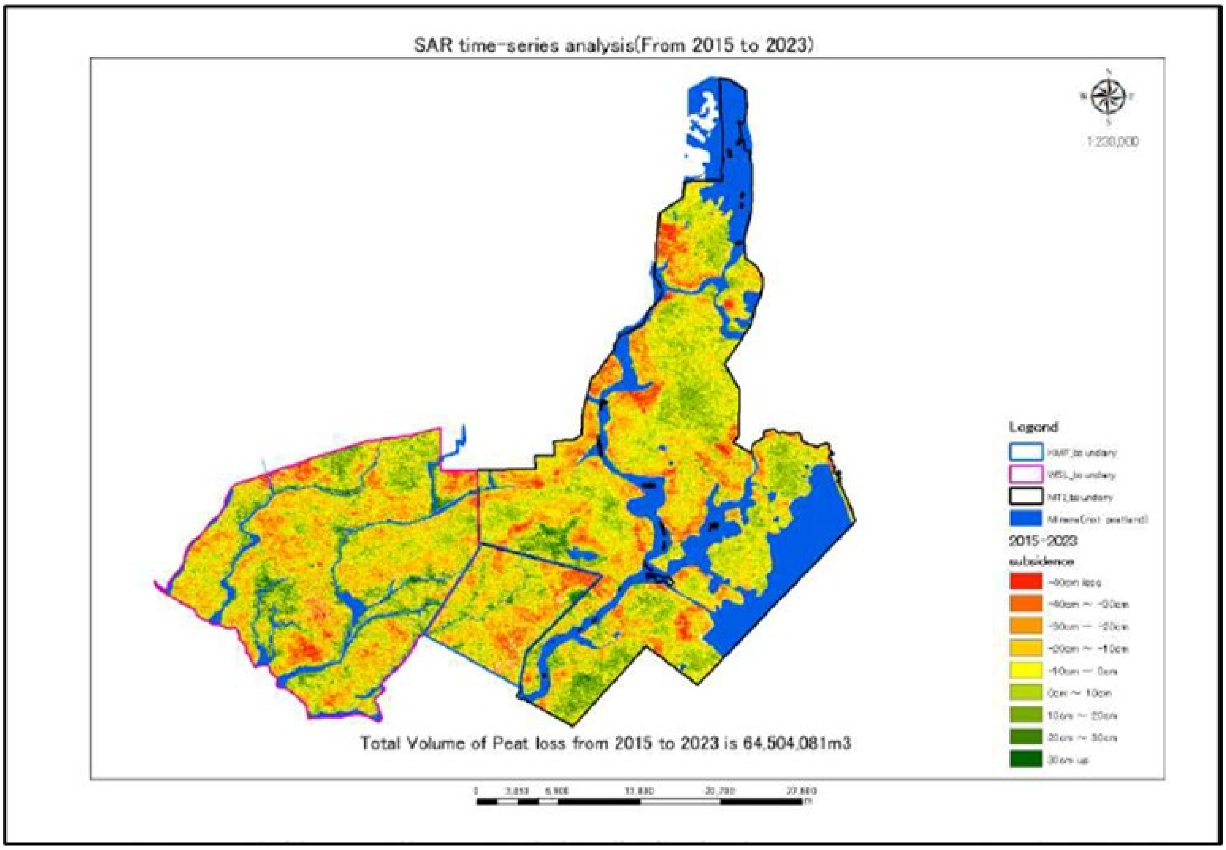


Source: Sumitomo Forestry Co., Ltd. (2023).

Estimation of CO_2 emission, using ALOS-2

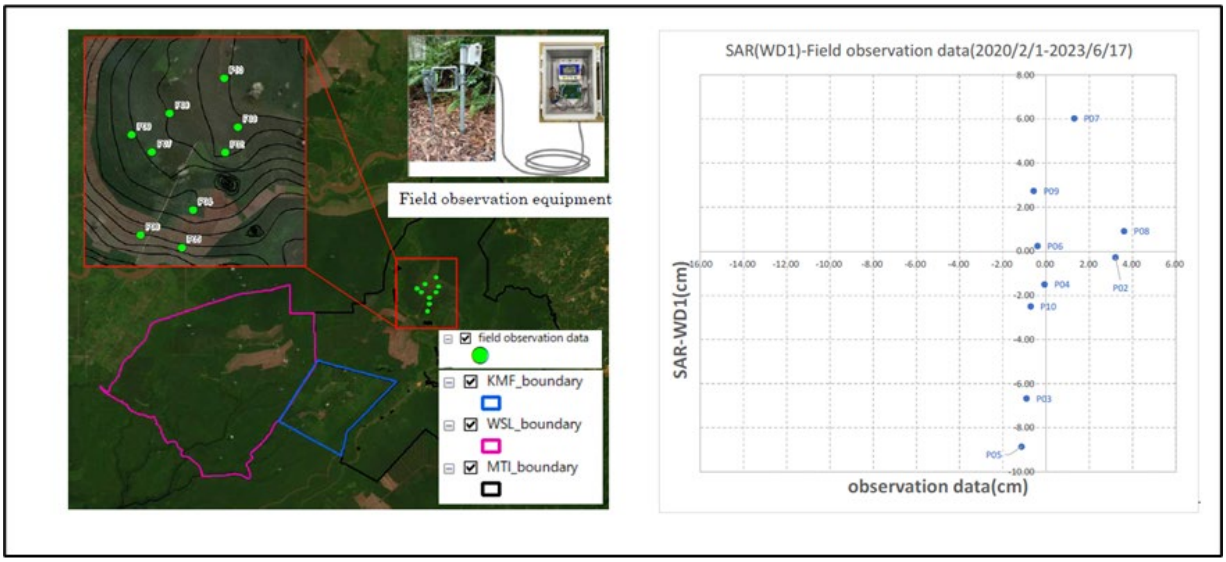
- SAR data is not only unaffected by weather in tropical regions, but is also able to detect the difference of ground surface level of the same point by different timing within a few centimeter accuracy. In other words, measurement of this ground subsidence (equivalent to organic matter reduction from peat) means that SAR satellites have the potential to measure CO_2 emissions.
- We have installed a subsidence meter on the ground to directly measure the amount of peat subsidence per hour. By comparing this ground data with JAXA's ALOS-2 (SAR) data, we found that although there are slight differences in the amount of peat subsidence between the ground data and the satellite images, it is possible to estimate the amount of CO_2 emissions between two points in time (Figures 4.32 and Figure 4.33).

Figure 4.32. Peat subsidence accumulation distribution (2015 to 2023)



Source: Sumitomo Forestry Co., Ltd. (2022)

Figure 4.33. Ground measurement and correlation between ground data and satellite image



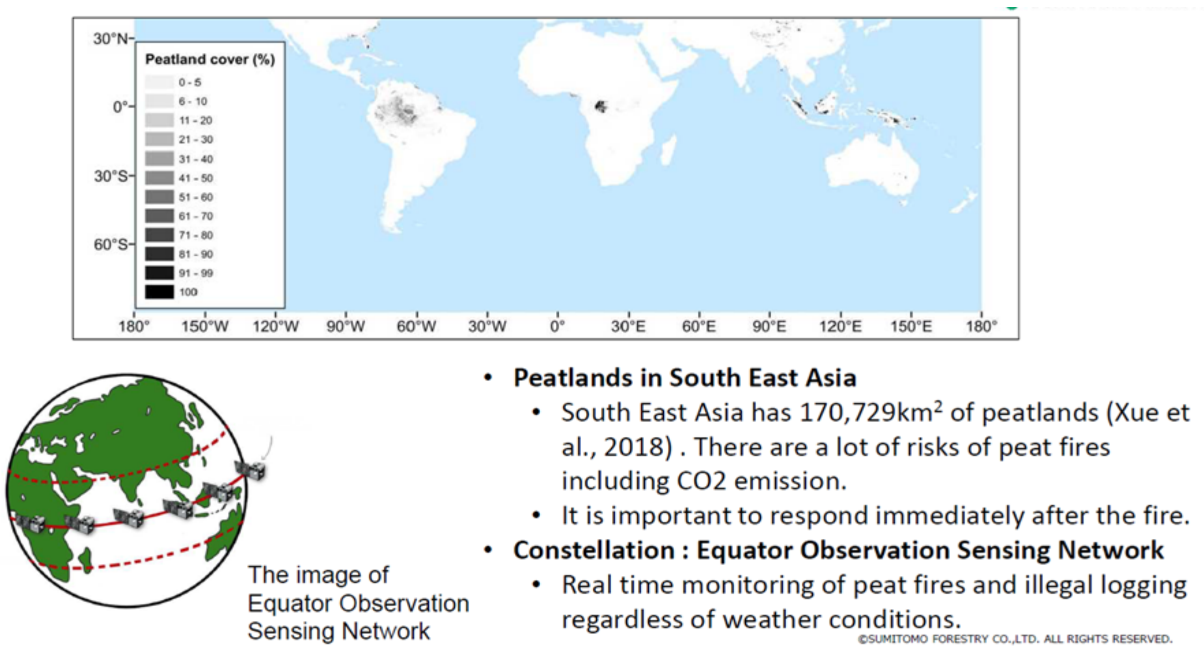
Source: Sumitomo Forestry Co., Ltd. (2022)

4.3.5 Challenge and Solutions toward Operational Use

Enhancing the value of Nature – Fusion of ground and space data (Figure 4.34)

- Plantation company on peatlands understand the environmental value of peatlands, but economic incentives are required to allocate their financial resources for peat conservation.
- To manage peatlands properly, it is necessary to obtain highly accurate and comprehensive data quickly.
- Building a constellation of many small satellites in an equatorial orbit will increase the frequency of imaging and the possibility of collecting cloud-free data.
- However, since the cost of satellites opration is high, a lot more actual use by cliant is required.
- We, KOKUSAI KOGYO and Sumitomo Forestry, would like to contribute to both economic development and environmental protection in the ASEAN region by implementing initiatives that balance environmental protection and increased productivity in peatlands using satellite data.

Figure 4.34. Future concept of constellation in tropical regions



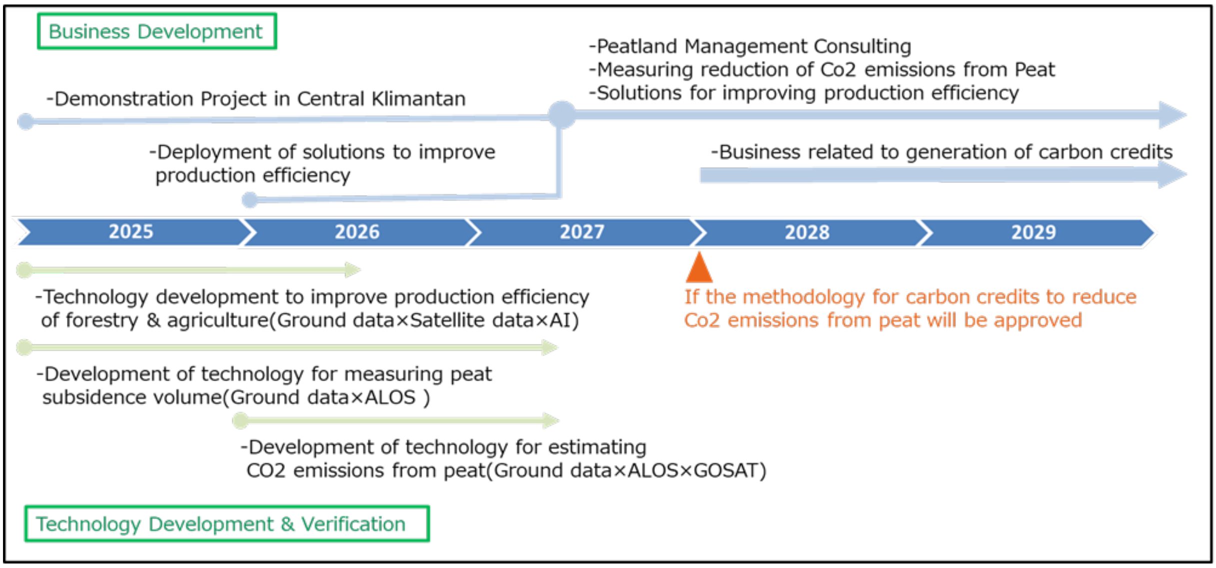
Source: Sumitomo Forestry Co., Ltd. (2022)

4.3.6 Expected Schedule until Operational Use

Aim to commercialise the technology in 2027 after conducting development and verification

- 2025: Start a demonstration project to restore peatlands in Central Kalimantan and develop a data service to improve production efficiency in the forestry and agriculture. Develop technology to measure peat subsidence using SAR.
- 2026: Deploy solutions to improve production efficiency and start developing technology to estimate CO2 emissions from peatlands.
- 2027: By adding peatland management consulting to the existing solutions we have already developed, we will be able to increase our profits.

Figure 4.35. Schedule for operational use

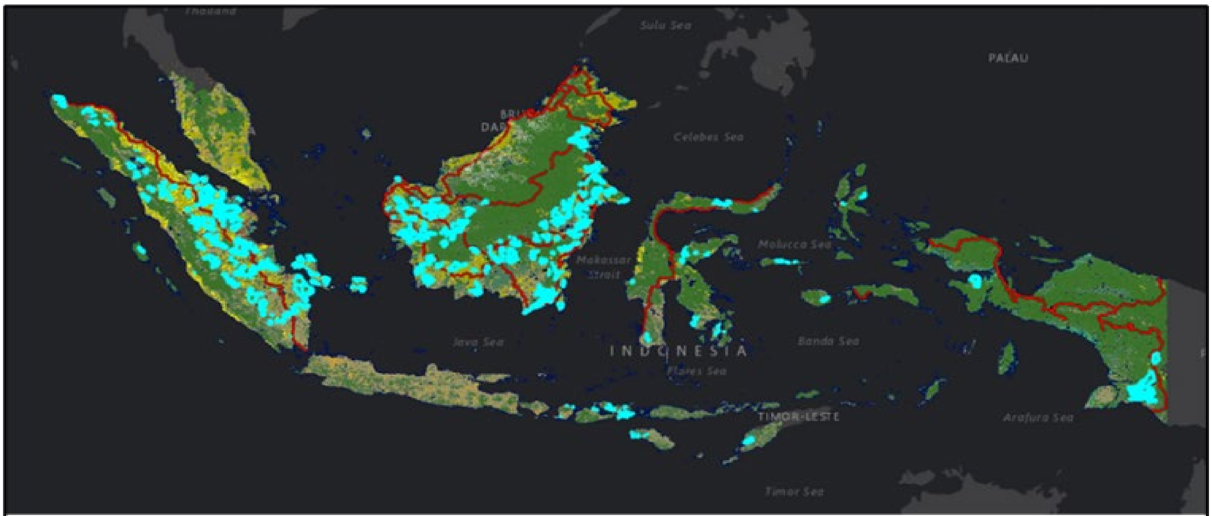


Source: Sumitomo Forestry Co., Ltd. (2024) & KOKUSAI KOGYO Co., Ltd. (2023)

4.3.7 Estimated Market and/or Revenue Scale after Operational Use

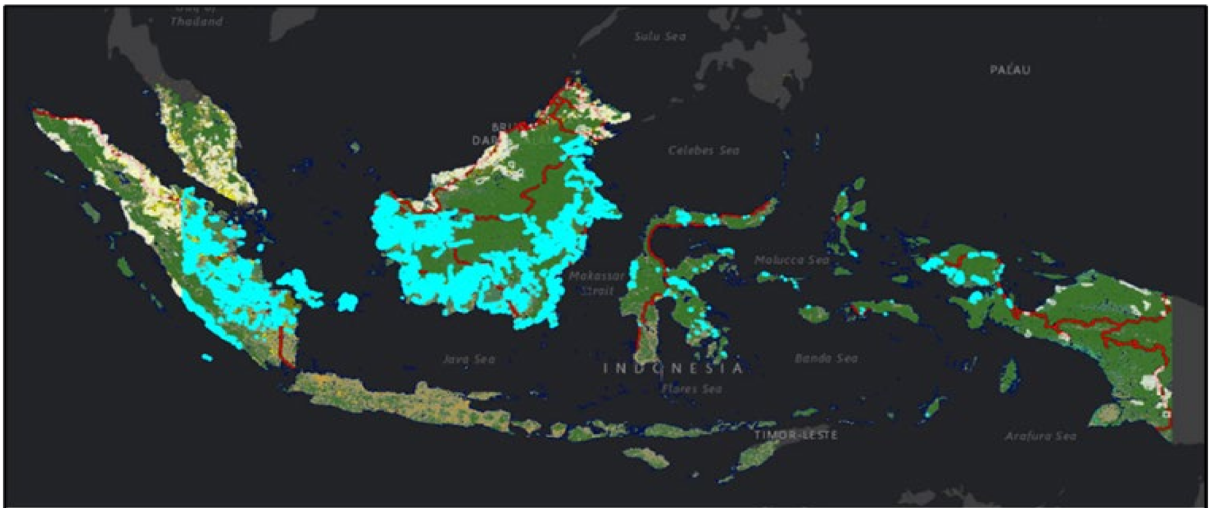
- The market we are targeting is Acacia plantations and palm oil plantations in peatland of Indonesia
- Of the above land uses, plantations that exist on peatland are shown in Figure 4.36.
- Total area of peatland pulp log plantation in Indonesia is equivalent to 2,641,457 ha and peatland oil palm plantation is 2,353,743 ha as well.

Figure 4.36. Potential area of our consulting service



Plantation area for pulpwood in Indonesia :11,196,609ha

Of the above, plantations on peat land :2,641,457ha



Plantation area for Palm in Indonesia :19,977,110ha

Of the above, plantations on peat land :2,353,743ha

Source: Sumitomo Forestry Co., Ltd. (2023)

4.4 Pilot on Coastal Management (Yamaguchi University)

A. Spatial Analysis of Coastline Change and Vulnerability Assessment to Sea Level Rise

4.4.1 Objective and Overview of the Pilot

Climate change, with its associated rising sea level and possible increases in the frequency and/or intensity of storms and changes in wave climate, can be expected to significantly increase the risk of coastal erosion and flooding in most coastal locations, especially in low-lying areas. Bali Province is a well-known tourist destination dependent on sun-and-beach recreation activities. However, about 86 km or 20% of the length of the existing beaches has been eroded, and environmental degradation has occurred due to natural factors and human activities. As a natural coastal defense system, beaches are important in reducing coastal erosion risks. Thus, their retreat and eventual disappearance increase their vulnerability to hazardous events. In addition, beach narrowing threatens beach environmental services critical to tourist destinations' economy since recreational activities depend on the beach backshore. Considering the threat of sea-level rise in coastal areas and on small islands, it is necessary to conduct a study to determine the degree of vulnerability experienced by a coast since measuring vulnerability is a fundamental phase towards effective risk reduction.

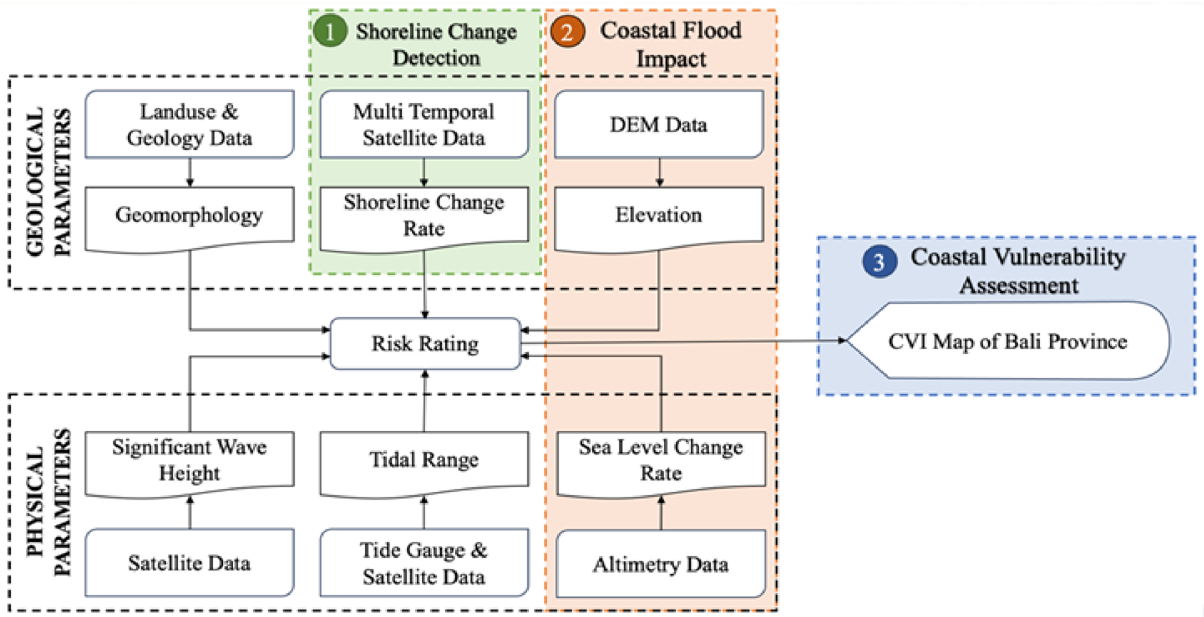
Objective: is to investigate and assess the vulnerability of the Bali Province coast to the effect of coastal erosion, which specifically involves:

- To determine the physical parameters in the area that are necessary for evaluating coastal zones vulnerable to sea level rise;
- To identify the area submergence in different sea level scenarios based on the derived annual sea level rise rates;
- To analyse the dynamic changes in shoreline position from satellite images.

It also serves as a model initiative to address pressing issues related to coastal management, using a multidisciplinary approach.

- Scope: the project targets vulnerable coastal areas facing challenges such as erosion.
- Key actions: conducting baseline studies using satellite imagery and field surveys
- Technological integration: advanced tools and climate models are employed to track temporal shoreline changes, evaluate environmental impacts, and forecast future scenarios.

Figure 4.37. Overview of the work



Source: Hastuti & Nagai (2024).

4.4.2 Implementation Scheme/Role of Each Organisation

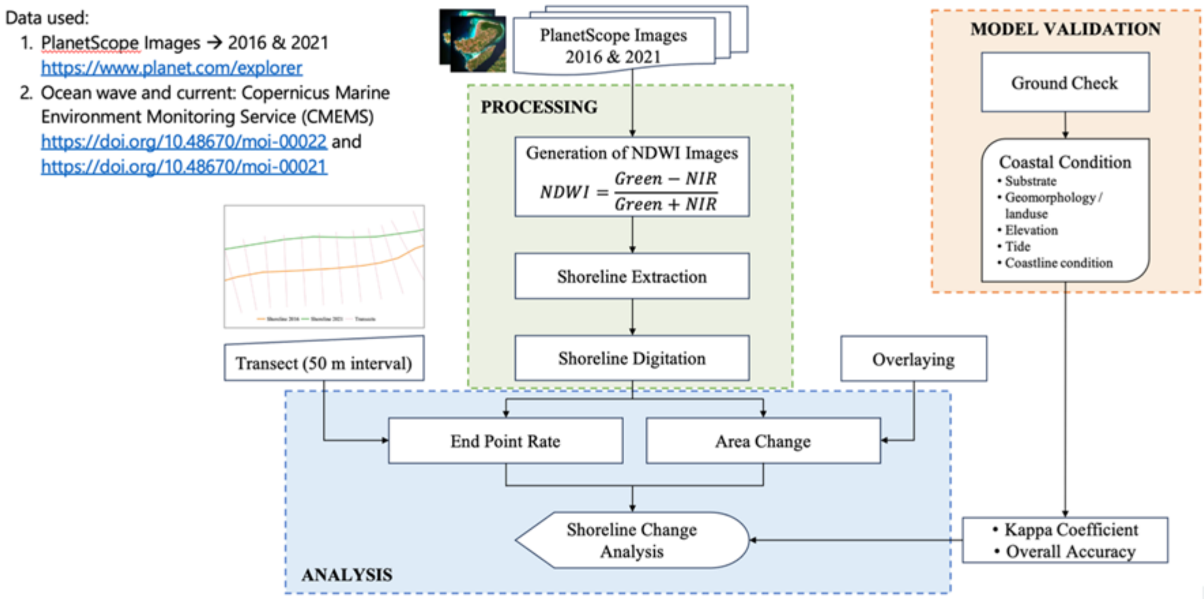
- Central Government Authorities (e.g. Ministry of Marine Affairs and Fisheries, Ministry of Public Works and Public Housing, National Agency for Disaster Countermeasure): provide monitoring and evaluation to ensure adherence to national coastal management goals, allocate budgets and ensure funding for the project; and develop national policies and regulations for sustainable coastal management.
- Local Government (e.g. Bali Province): facilitate participation and awareness campaigns for local communities and conduct regular surveys and reports on environmental and socio-economic impacts.
- Research Institutions (e.g. IMRO) and Universities (e.g. Yamaguchi University): create predictive models for shoreline change, erosion rates, or flood risks; carry out baseline surveys and environmental impact assessment; and train local authorities and stakeholders in monitoring and management techniques.
- Private Sector and International Agencies: supply equipment such as remote sensing tools, GIS software, etc.; offer expertise and grants or loans for sustainable coastal development; organise workshops, training sessions and/or conferences for knowledge transfer.

4.4.3 Technologies, Model, and Algorithms Applied to the Pilot

Remote sensing technologies, such as satellite imagery and drone-based surveys, are integrated with GIS to analyse shoreline changes, land-use patterns, and erosion-accretion dynamics.

- **Shoreline Change:** Models like the Digital Shoreline Analysis System (DSAS) are employed to quantify shoreline change rates using End Point Rate (EPR). The change rate was calculated by dividing the perpendicular distance between the two shorelines by the time difference between the measurements.

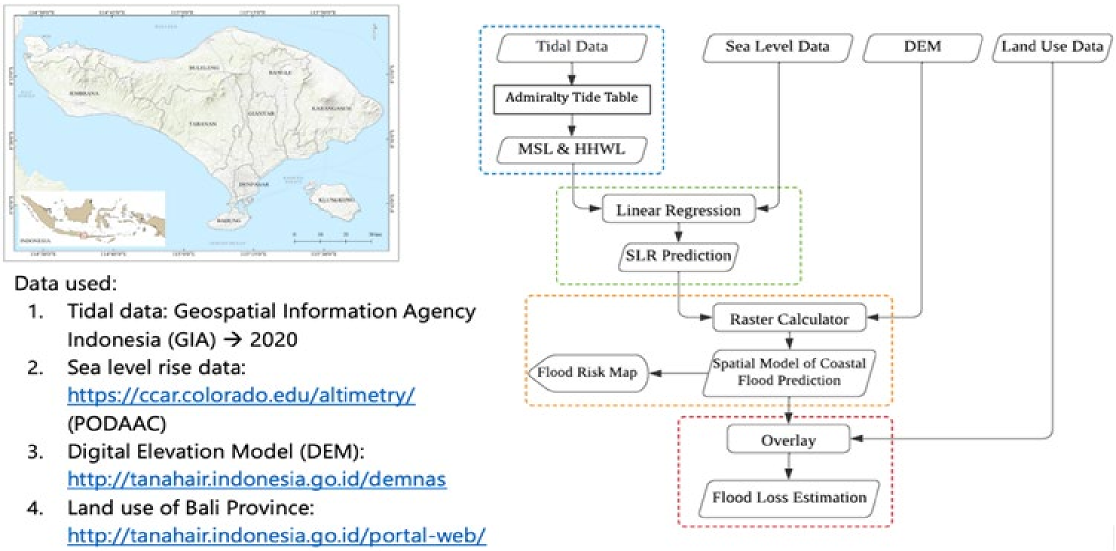
Figure 4.38. Shoreline change detection workflow



Source: Hastuti & Nagai (2024).

- **Coastal Flooding:** The flood prediction is carried out by mapping the predicted sea level rise on DEM data. The coastal areas that have the same height as the sea level will be determined as the inundated area. Furthermore, the flood loss estimation is obtained from the result of overlying inundation polygons with spatial information of land-use. This is the calculation of direct damage of any land-use which have economic value based on water depth.

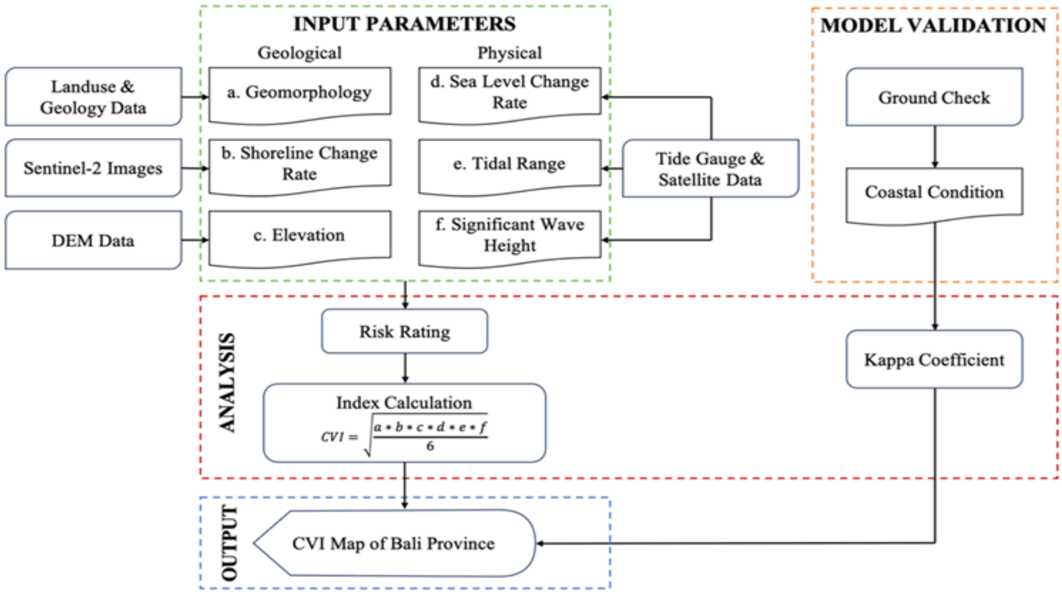
Figure 4. Workflow: coastal flooding impact assessment



Source: Hastuti & Nagai (2024).

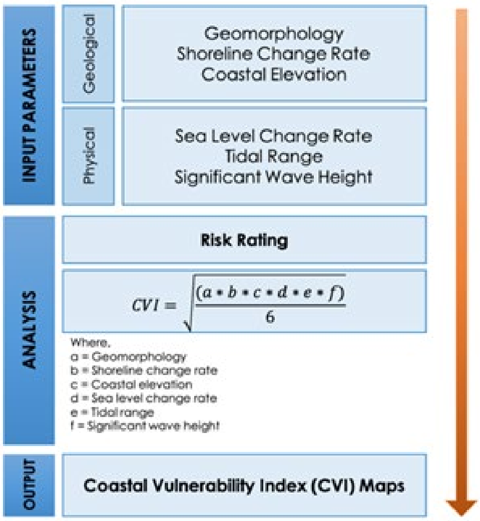
- **Coastal Vulnerability:** Coastal vulnerability was calculated using the Coastal Vulnerability Index (CVI), which is one of the most commonly used and simple methods to assess coastal vulnerability to sea level rise, mainly due to erosion and/or inundation. Each parameter was processed to get the value and those values will classified into the risk rating, which indicates its contribution to vulnerability.

Figure 4.40. Workflow: coastal vulnerability assessment



Source: Hastuti & Nagai (2024).

Figure 5.41. Data sources of input parameters for the coastal vulnerability assessment



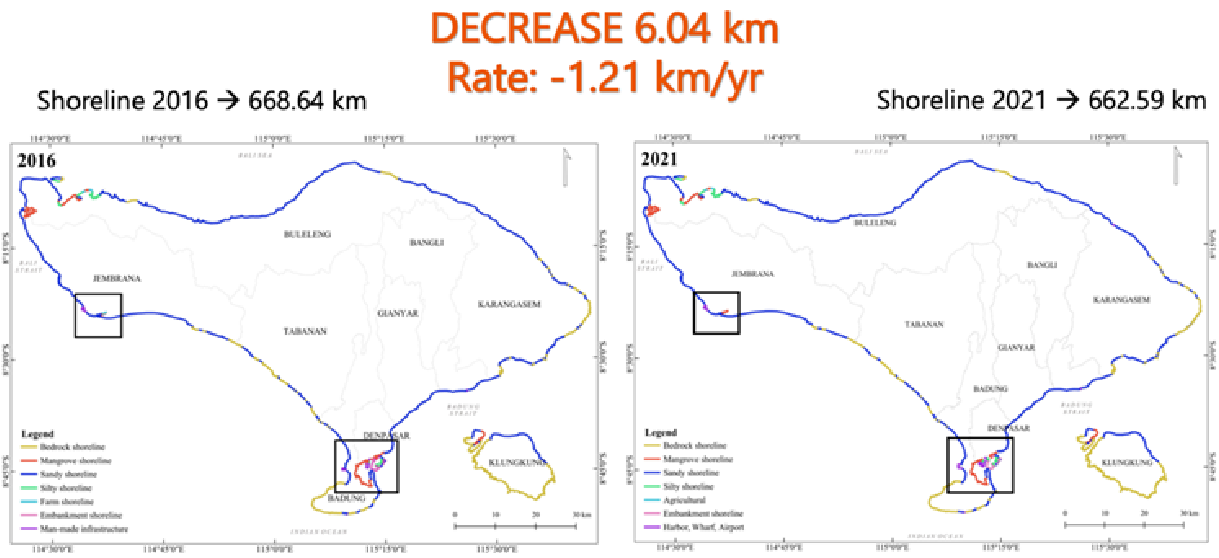
Parameter	Resolution	Period	Data Sources
Geomorphology	scale 1:25k	2000	Thematic map https://portal.ina-sdi.or.id/downloadaoi/
Shoreline change rate (m/yr)	10 m	2015 2019	Sentinel - 2A https://earthexplorer.usgs.gov/
Elevation (m)	0.27 arcsecond (~8.1 m)	-	DEM Imagery by BIG tides.big.go.id/DEMNAS/
Sea level change rate (mm/yr)	1/6th deg (~18.5 km)	1992 - 2019	Tide gauge & satellite altimeter data https://ccar.colorado.edu/altimetry/index.html
Tidal range (m)	-	1998 - 2019	Tide gauge http://tides.big.go.id/pasut/index.html
Significant wave height (m)	0.2 deg (~22.2 km)	1993 - 2019	Marine Copernicus https://marine.copernicus.eu

Source: Hastuti & Nagai (2022).

4.4.4 Current Results of the Pilot

- Rapid erosion is emerging as a major concern in Bali Province, primarily driven by human activities and coastal hydrodynamics. And the southern part of Bali is more vulnerable to erosion than the northern part
- Artificial shorelines have increased net land due to human interventions such as land reclamation and infrastructure development.

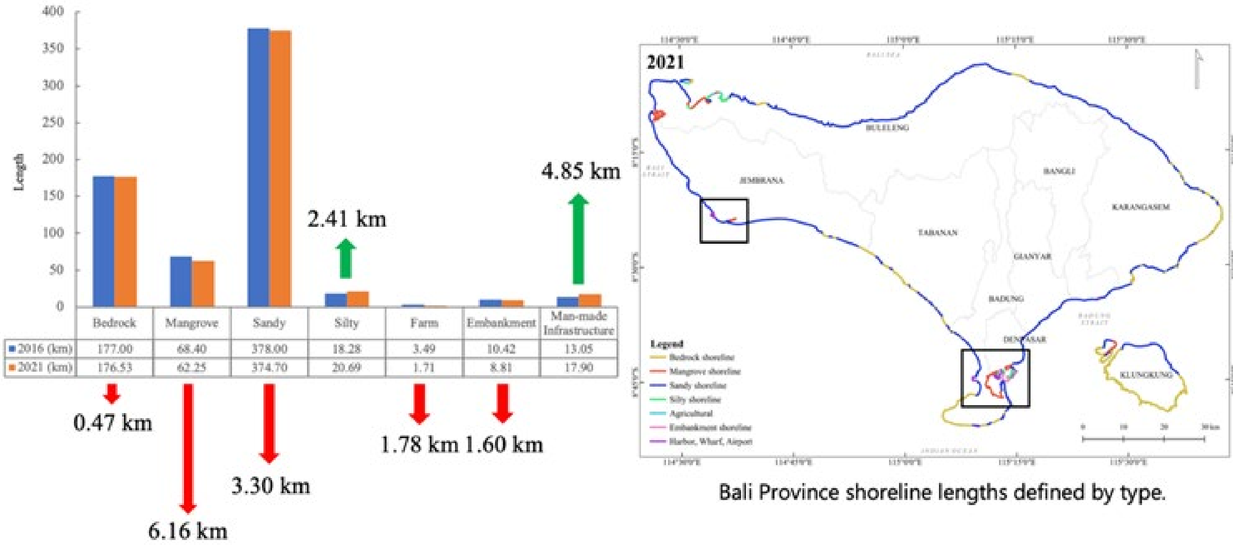
Figure 4.42. Shore-type changes (part 1)



Bali Province shoreline lengths defined by type between 2016 and 2021.

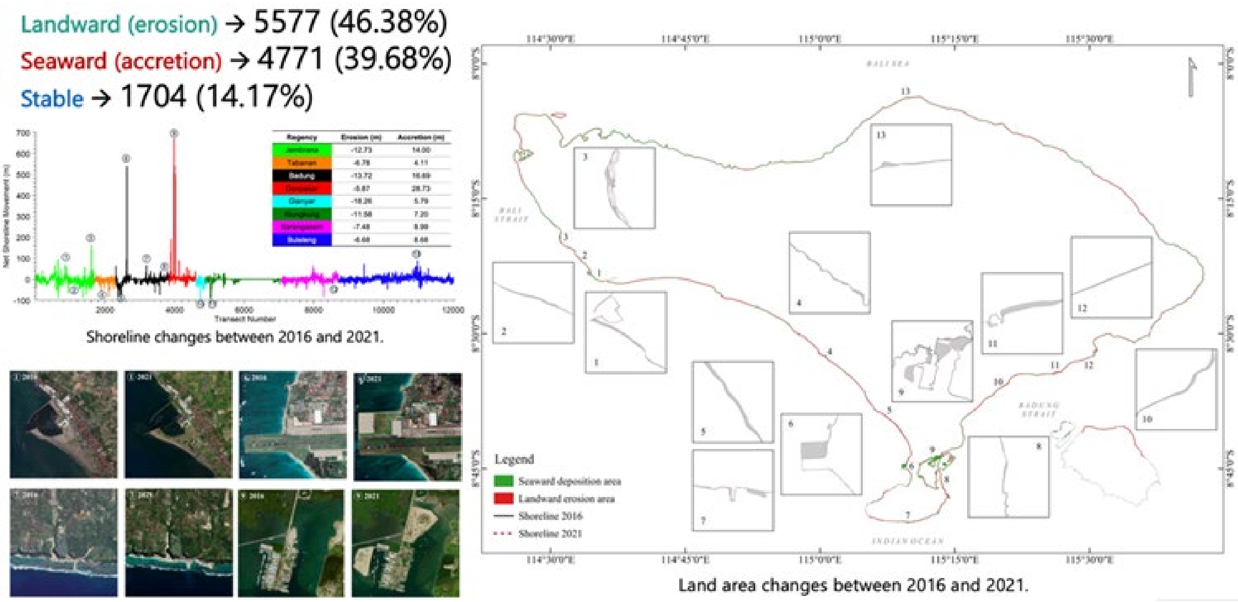
Source: Hastuti & Nagai (2024).

Figure 4.43. Shore-type changes (part 2)



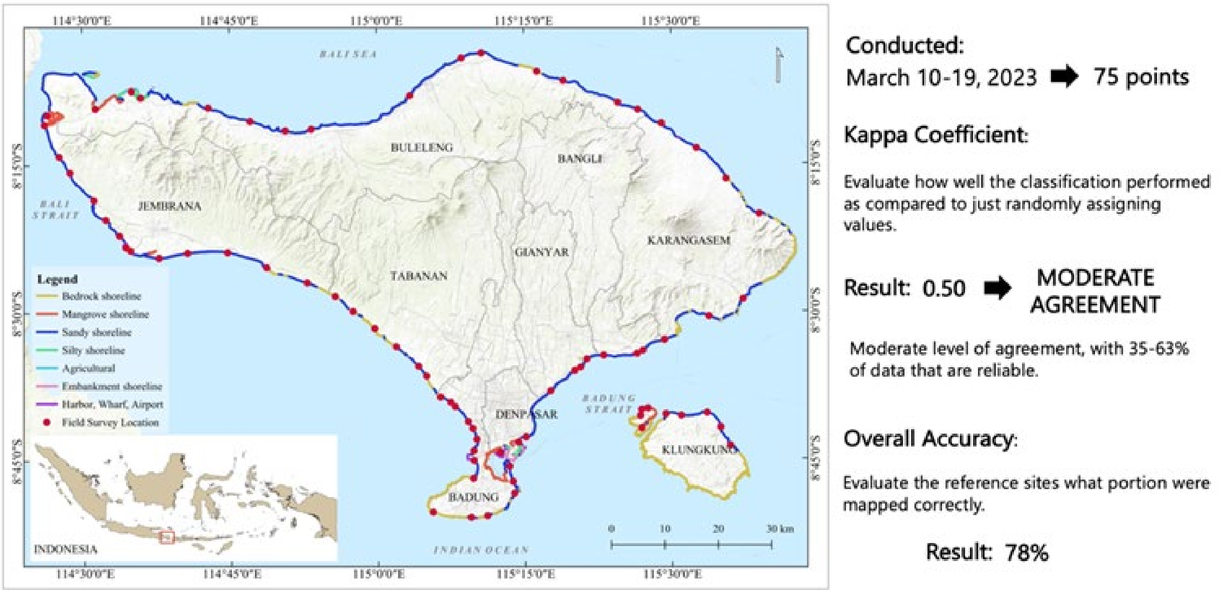
Source: Hastuti & Nagai (2024).

Figure 6. Shoreline and coastal area change rate



Source: Hastuti & Nagai (2024).

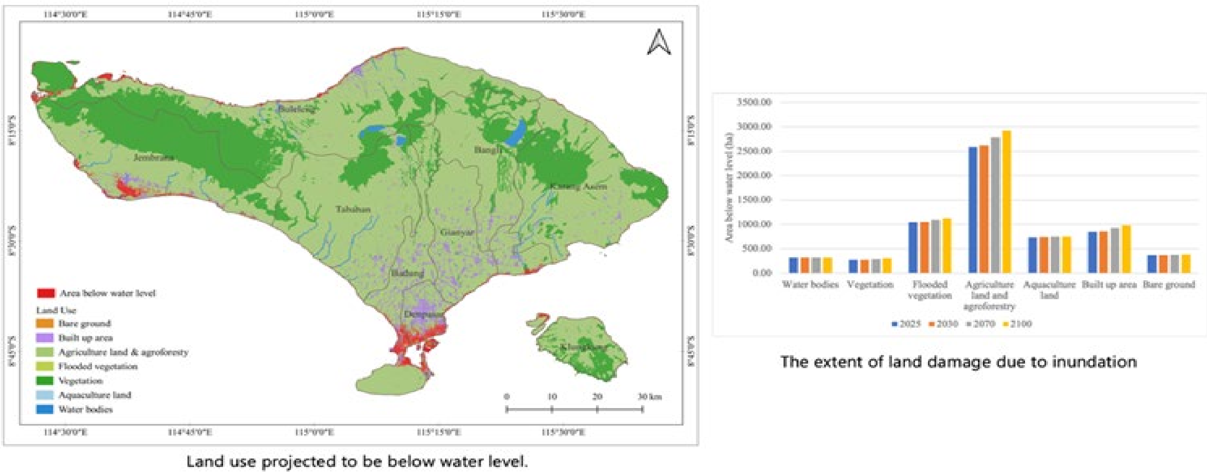
Figure 4.45. Result validation from field study



Source: Hastuti & Nagai (2024).

The trend of rising sea level drives the extent of coastal flooding, and it is estimated that a total of 7176.46 ha area of Bali Province will be below the water level in 2100.

Figure 4.46. Flood loss estimation

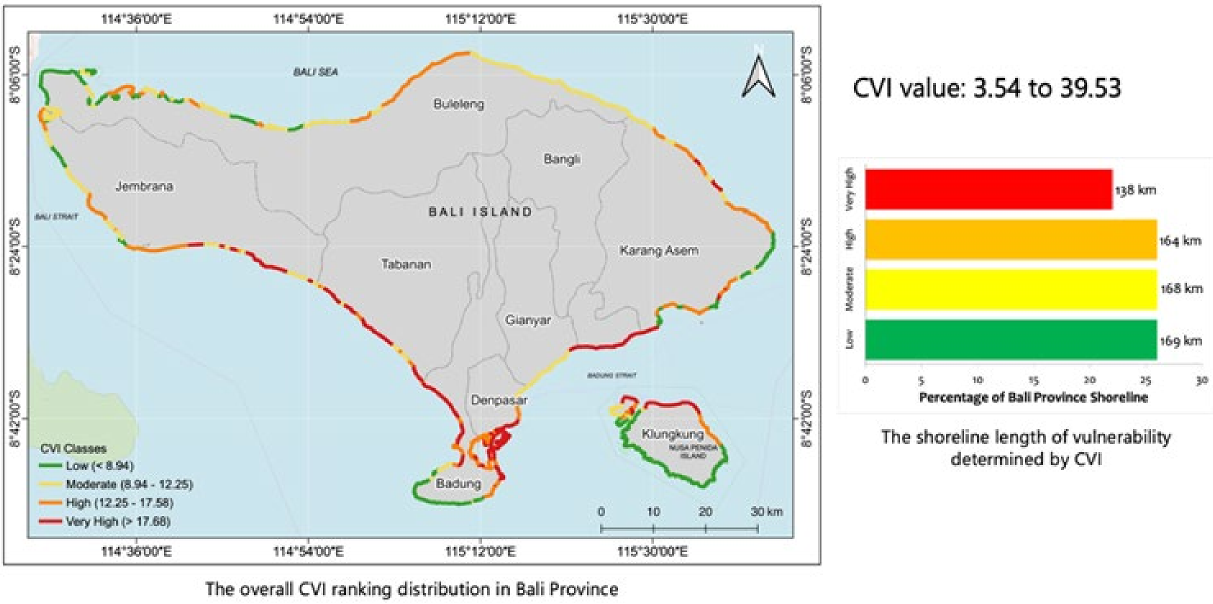


Source: Hastuti & Nagai (2024).

- The coastal vulnerability assessment can be done by the Coastal Vulnerability Index (CVI) to measure the risk level of coastal areas in Bali Province in an efficient way, considering physical and geological variables.
- The southern part of Bali Province is the most vulnerable area compared to the northern part.

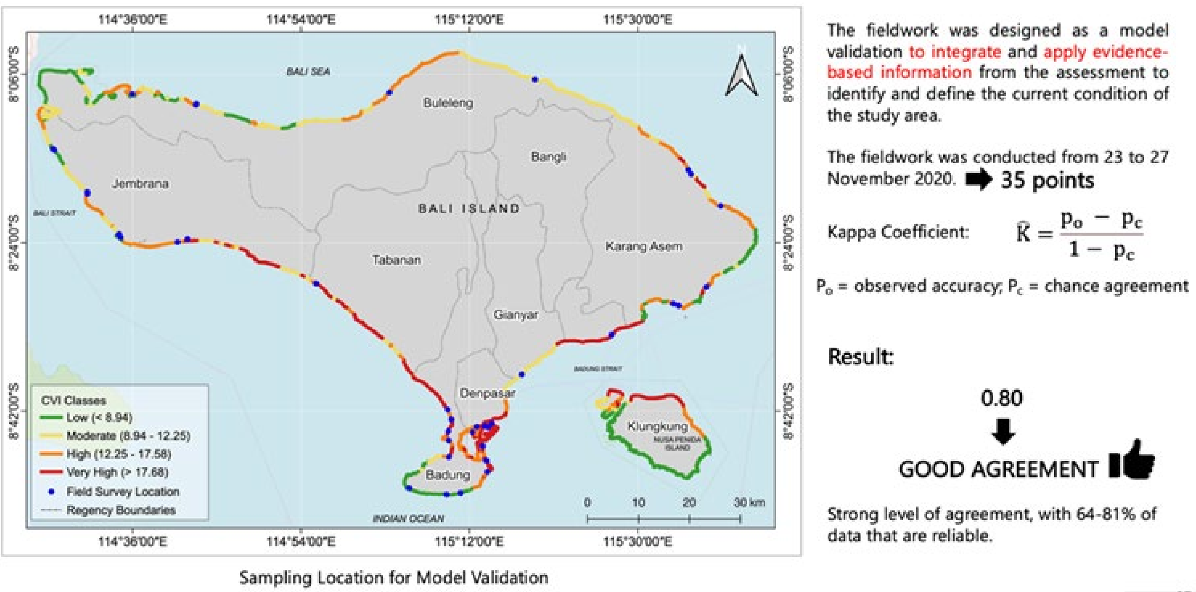
- Geomorphology, shoreline change, elevation, and significant wave height are the significant variables determining the coastal vulnerability level in Bali Province.

Figure 4.47. Coastal Vulnerability Index of Bali Province



Source: Hastuti, et al. (2022).

Figure 4.48. Model validation from field survey



Source: Hastuti, et al. (2022).

4.4.5 Challenges and Solutions toward Operational Use

Shoreline change detection is challenging due to the dynamic nature of the coastal environment, inconsistent data quality, and technical limitations in detecting methods. Issues like temporal, and spatial variability, various types of geomorphology, and algorithmic sensitivity to noise complicate accurate monitoring. To address these, innovative solutions include using advanced machine learning models for precise shoreline extraction, leveraging high-solution multi-temporal data for subtle change detection, and automated workflows to improve efficiency.

4.4.6 Expected Schedule until Operational Use

The operational implementation of this project is outlined in five key phases:

1. Preparation Phase (1–3 months), focuses on defining project goals, acquiring necessary data (e.g. satellite imagery, historical record, tidal information), and setting up preprocessing protocols.
2. Algorithm Development and Testing Phase (3–6 months), involves designing and validating models (e.g. machine learning, DSAS) to ensure accurate shoreline analysis.
3. Implementation Phase (6–12 months), applies these models at test sites and refines methodologies based on feedback.
4. Operational Deployment Phase (12–18 months), ensures large-scales implementation, real-time monitoring, and customisation for local needs.
5. Evaluation and Optimisation Phase (3–6 months), review system performance, integrates feedback, and develops long-term strategies and policy recommendations, enabling continuous improvement and operational reliability.

4.4.7 Estimated Market and/or Revenue Scale after Operational Use

The estimated market and revenue scale for coastal erosion modeling and vulnerability assessment after operational use deployment is highly dependent on factors like regional requirements, local government budgets, and the economic value of coastal areas. Typically, such tools offer significant economic benefits, including:

- Cost saving in disaster mitigation: governments can save millions by proactively addressing erosion and vulnerabilities rather than reacting to disaster.
- Informed infrastructure investments: insights from coastal vulnerability assessments can help prioritise investments in protective infrastructure like seawalls or mangrove restoration, optimising resource allocation.
- Tourism and real estate preservation: protecting coastal areas ensures the longevity of revenue from tourism and stabilises coastal property values.
- The market for analytics and consulting services: companies offering coastal modeling services, software, or training can expect substantial demand from municipalities, disaster management agencies, and private industries like insurance.

Estimating revenue for coastal erosion modeling and vulnerability assessment using remote sensing technology in a 100 sq km area of Bali Province, we can align it with the region's economic reliance on tourism which has economic benefits from tourism up to US$3.5 million in 2017, the following considerations apply:

1. Tourism prevention benefits

- Cost savings on infrastructure damage: coastal modeling can help mitigate erosion impacts, potentially saving $500,000 – $1,000,000 per year in areas with high-value infrastructure by preventing damage.
- Tourism and economic activity preservation: by protecting coastal regions, local governments can maintain tourism and economic activities. For a 100 sq km coastal area with active tourism, revenue protection could range between $300,000 – $700,000 annually.
- Disaster management efficiency: early detection and mitigation using remote sensing can reduce emergency response costs, potentially saving $100,000 – $600,000 annually.

2. Costs and revenue from service implementation

- Model implementation costs: establishing a remote sensing-based erosion model for 100 sq km typically costs $50,000 – $150,000, depending on data sources (e.g. Landsat is free, while high-resolution private data like Planet Labs costs more).
- Revenue from licensing or sharing services: local governments can license datasets and models to private stakeholders (e.g. real estate or fisheries industries), generating $50,000 – $100,000 annually.

3. Long-term benefits

- Over 5 years, integrating these technologies could lead to cumulative savings or revenues ranging from $2 – $5 million, considering avoided damages, sustained economic activity, and additional revenue streams.
- Target clients: Local government, fishermen, Real estate, Insurance company, Port, commercialised activity, tourism industry.
- Service: coastal assessment and monitoring, technology (method, system), technical expertise (consultation), workshop.

B. A Study on the Construction of Seagrass Bed Distribution Map in Honda Bay, Palawan, Philippines through Depth Index Algorithm Using Satellite Constellations and Field Observations

4.4.8 Objective and Overview of the Pilot

This research mainly focuses on developing a methodology to map seagrass beds in Honda Bay, Philippines, derived from PlanetScope satellite images. Seagrass beds play an important role in marine ecosystems as they protect from erosion and floods, food supply, water purifiers, and shelter for juvenile fishes. Aside from this, seagrass absorbs and stores carbon through photosynthesis. The carbon that seagrass stores in its system is called 'blue carbon' and has been in various research in recent years due to its importance in climate change mitigation.

Recently, seagrass habitats have been constantly decreasing due to pollution, climate change, and man-made activities. Monitoring seagrass beds is necessary for scientists and government institutions to plan and prevent further loss of this coastal habitat properly. This will not only ensure the survivability of the marine ecosystem but will also help alleviate the effects of climate change. This research utilises a method to detect seagrass beds from pixels of optical images of the PlanetScope satellites.

PlanetScope offers a daily capture of images in any part of the world due to its multiple satellite constellations constantly orbiting our planet. PlanetScope also provides high-resolution satellite images having approximately 4 meters of ground sampling distance. Several pre-processing techniques were applied to the images before calculating the depth index and classifying the images to determine which band combination is suitable for detecting seagrass beds.

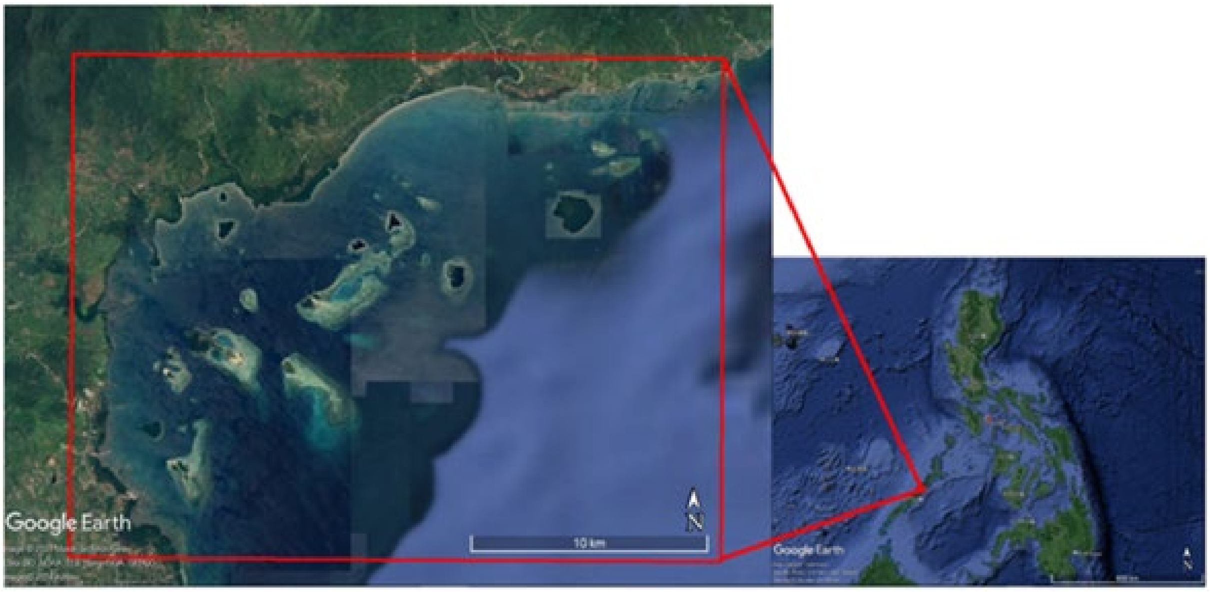
4.4.9 Implementation Scheme/Role of Each Organisation

Through the collaboration and discussion with Director Ariel C. Blanco of the Space Information Infrastructure Bureau of the Philippine Space Agency, Honda Bay was selected as the research area of interest because of the abundance of seagrass in this area.

Prior to the survey activity, Prof. Ayin M. Tamondong of the Department of Geodetic Engineering of the University of the Philippines-Diliman gave the researchers a lecture on how to identify the seagrass species in Honda Bay, and how to properly conduct the survey plan.

This research will significantly contribute to the constant monitoring of the seagrass environment by these research institutions in the Philippines.

Figure 4.49. Honda Bay, Palawan, Philippines (Google Earth Images, Maxar Technologies)

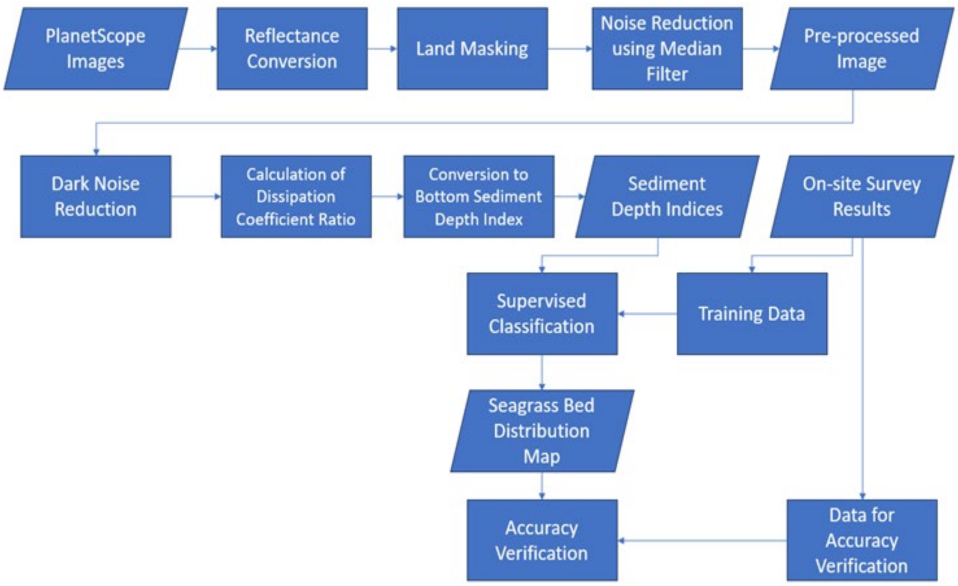


Source: Hirota & Nagai (2024).

4.4.10 Technologies, Model, and Algorithms Applied to the Pilot

This research follows the workflow shown in the figure below. Several pre-processing techniques were applied to the PlanetScope satellite image to ensure the quality of the assessment.

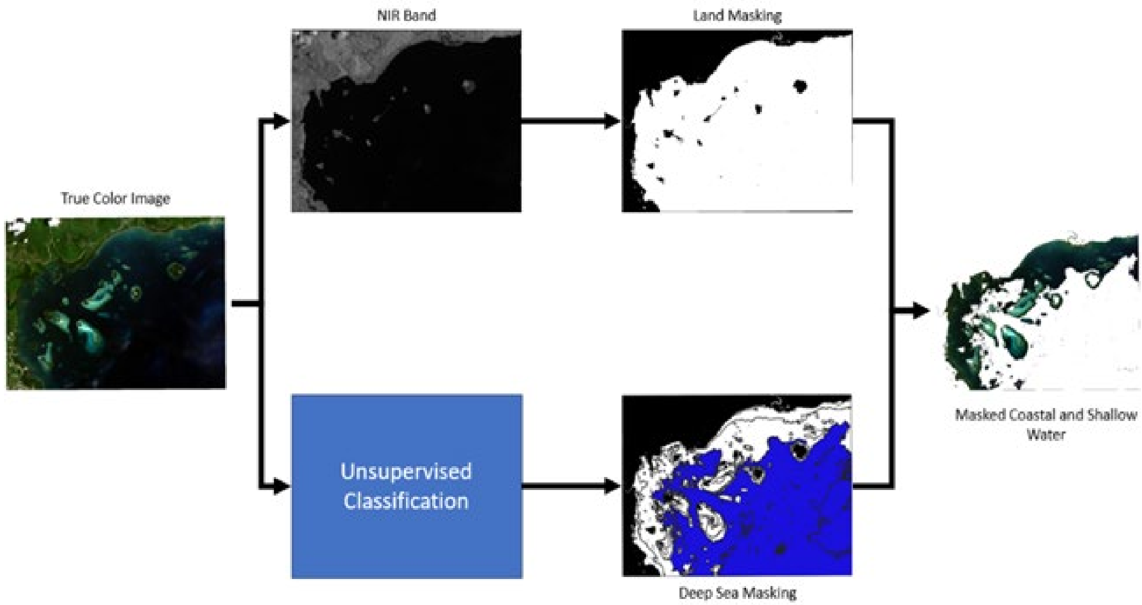
Figure 4.50. Research Workflow



Source: Author`s based on the Research Methodology of Hirota & Nagai (2024).

For this research, a PlanetScope image of Honda Bay from September 10, 2023, was used. This satellite image was then pre-processed to remove noises that would affect the quality of the assessment. The land and deep-sea pixels were masked from the image to accelerate the algorithm's processing time. The image's Near Infrared (NIR) band was used to mask the land pixels, while an unsupervised classification was used to mask the deep-sea pixels. From this masked image, the remaining noises, the dark water pixels, were removed using the dark noise reduction where a minimum pixel value was set for each band in the image.

Figure 7.51. Land and Deep Sea Masking



Source: Authors based on the Land and Deep Sea Masking Methodology of Hirota & Nagai (2024)

This research uses the Depth Index algorithm published by Lyzenga in 1981 to estimate the sediment at the sea surface using satellite images. This algorithm assumes that if the bottom quality is the same, the bottom reflectance ratio of two different bands is constant. This algorithm does not require depth information instead it uses the ratio of the dissipation coefficients from two bands in a satellite image. These dissipation coefficients can be used to compute the depth invariant index. The depth invariant index indicates what kind of feature can be found on the bottom surface of shallow waters.

The dissipation coefficient ratio is the slope of the regression line calculated from the scatter plot between the natural logarithmic values of the pixels from a combination of two bands. The points used for the regression were made using a point cloud with 50 m intervals. The depth invariant index was calculated from the coefficients derived from the correlations of the pixel values from the bands.

The calculated depth invariant indices were then classified using the Minimum Distance Supervised Classification using ground verification data gathered from a field survey in Honda Bay. Lastly, an accuracy assessment of the classification was conducted to determine which band combination mapped the seagrass bed effectively.

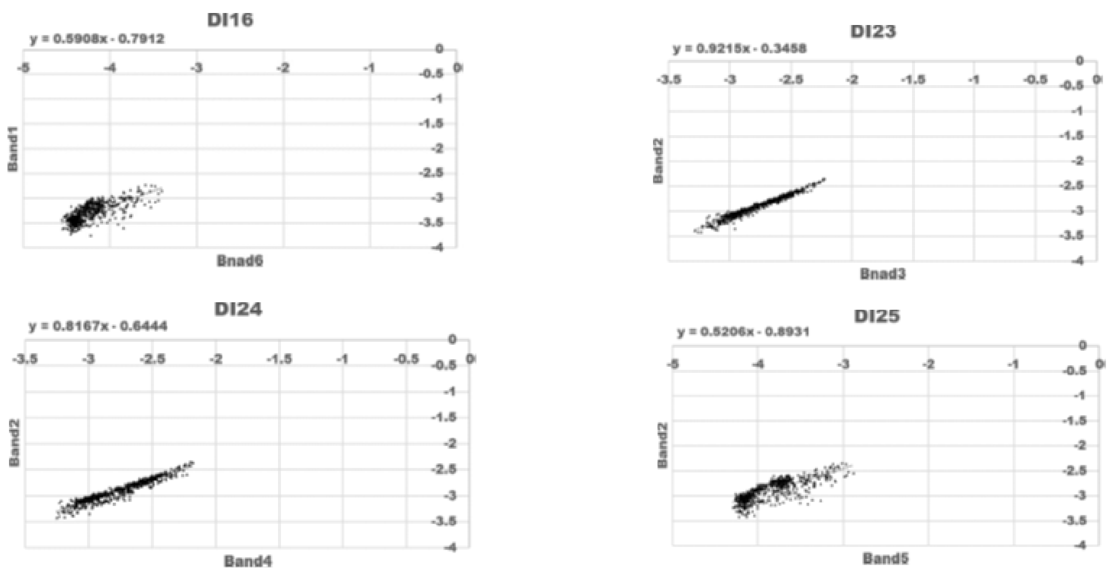
Figure 4.52. Honda Bay, Palawan Fieldwork

Source: Hirota & Nagai (2024).

4.4.11 Current Results of the Pilot

The graphs below show some of the results in the regression of the scatter plot created from the pixel values from the point cloud.

Figure 4.53 The regression of the scatter plot created from the pixel values from the point cloud



Source: Hirota & Nagai (2024).

The table below shows the slope of the regression line, which is the dissipation coefficient, and the correlation coefficient (R^2) which signifies the strength of the correlation between the two bands.

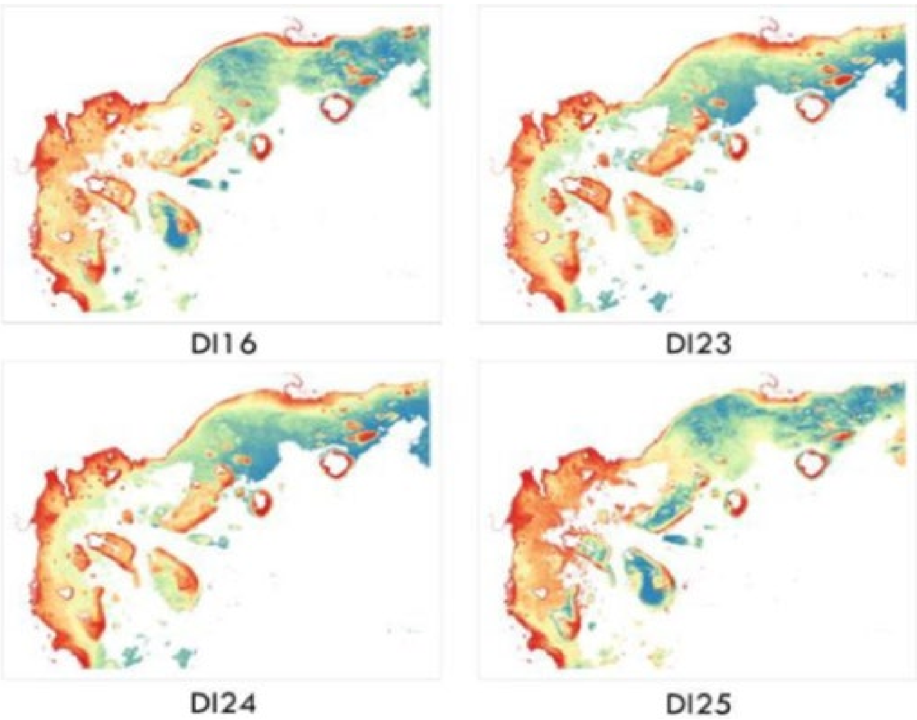
Table 4.1. The slope of the regression line

Band Combination	Dissipation Coefficient	Correlation Coefficient
DI 16	0.591	0.706
DI 23	0.921	0.977
DI 24	0.817	0.951
DI 25	0.521	0.784

Source: Hirota & Nagai (2024).

The depth invariance indices were calculated using the equation above. The figure below shows some of the sample results. To make the information visually legible, the contrast was enhanced by manual stretching and pseudo-color classification, a classification based on the difference in values was applied to the image.

Figure 8. Depth Index Maps



Source: Hirota & Nagai (2024).

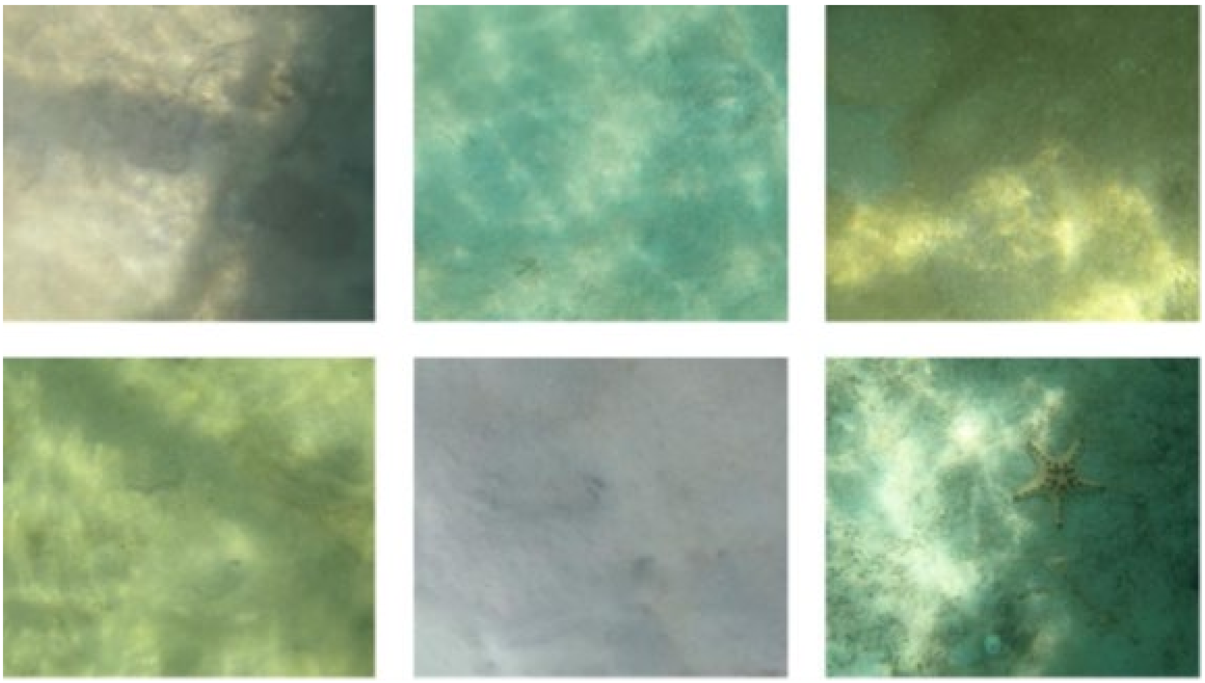
228 survey points have been extracted from 7 locations in Honda Bay. In the figure below, the red dots indicate the locations where the readings have been recorded.

Figure 4.55. Location of Survey Points

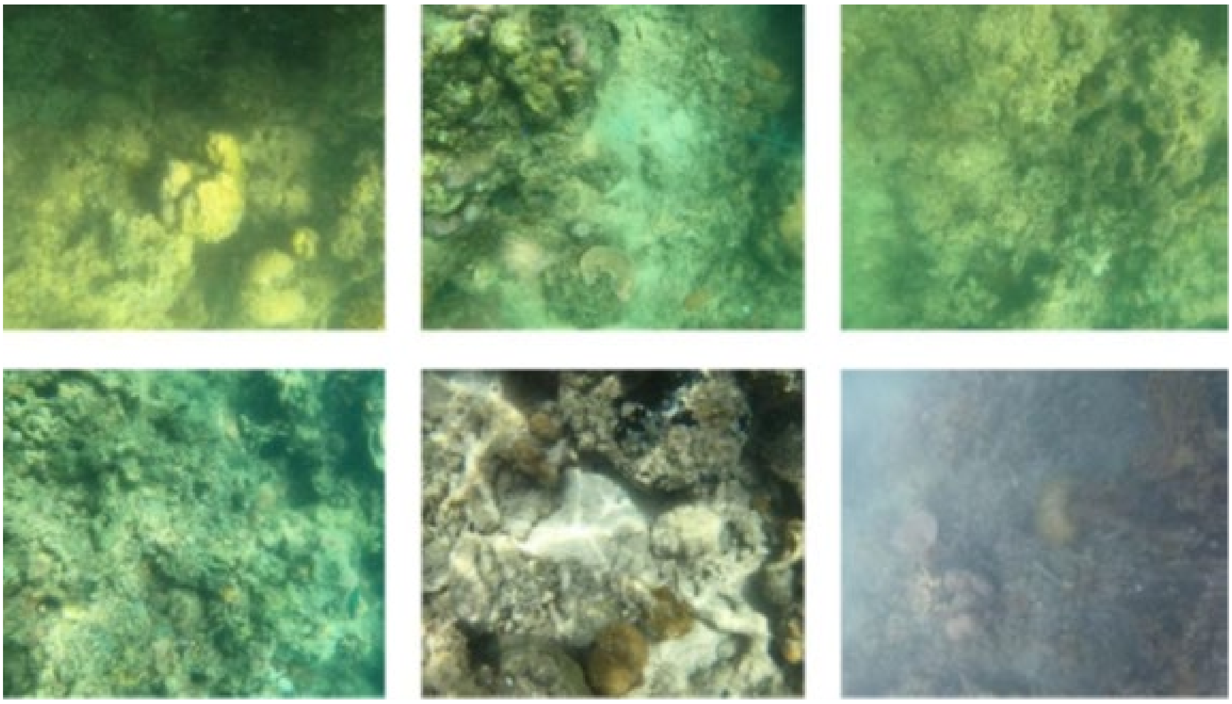
Source: Hirota & Nagai (2024).

Sand and gravel, corals, and seagrass are the three types of sediments that were identified in the area.

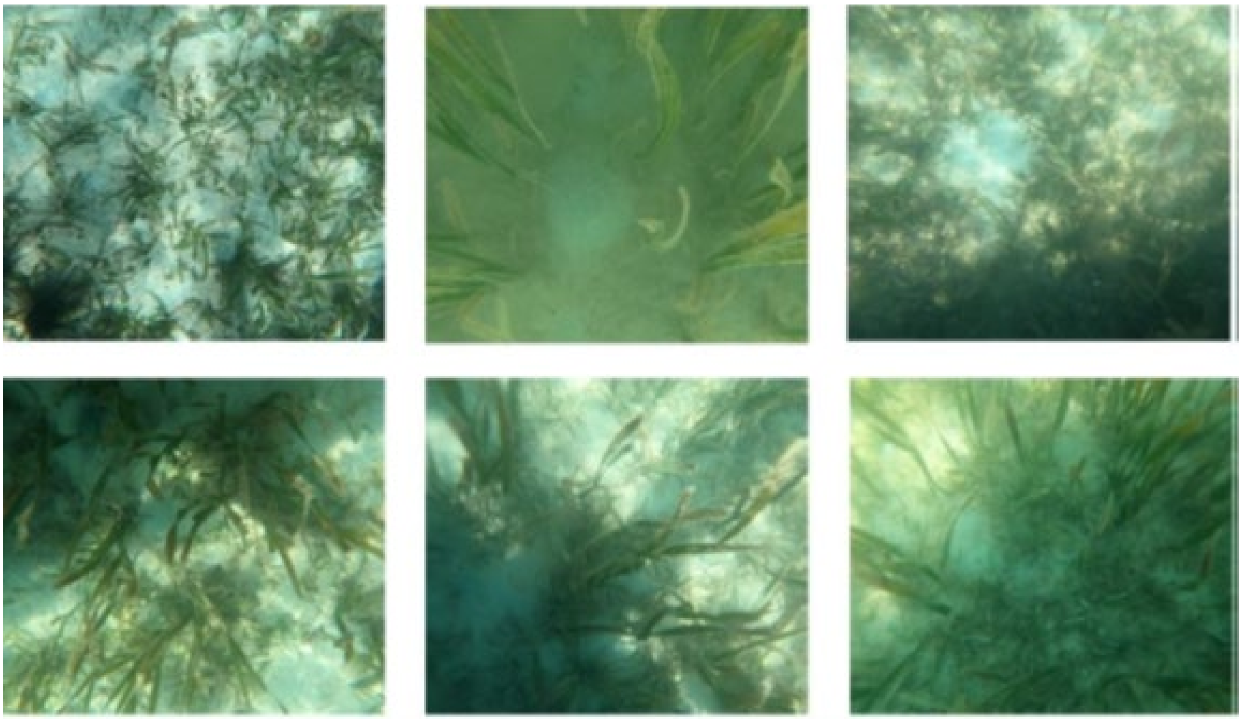
Figure 4.56. Types of sediments



Sand and Gravel



Corals

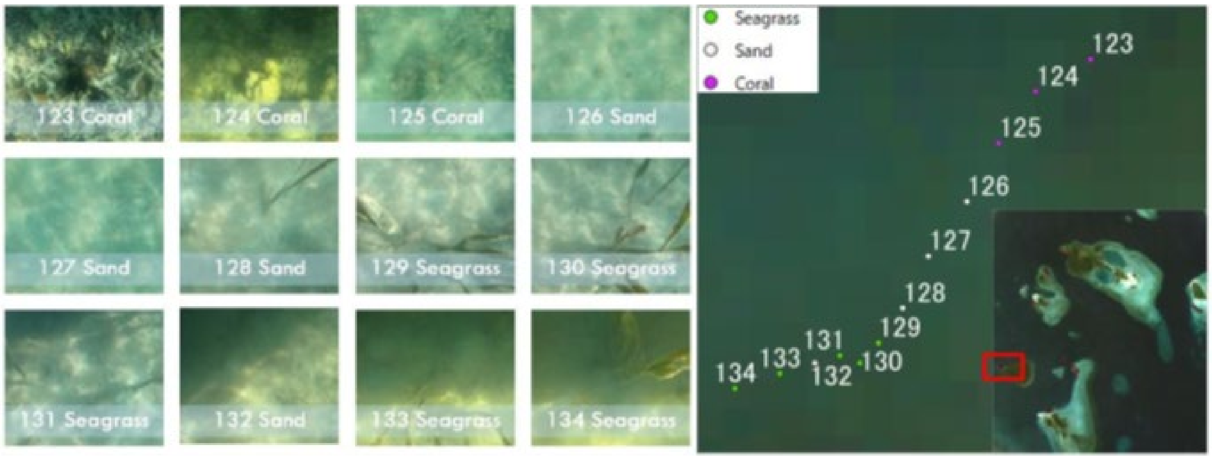


Seagrass

Source: Hirota & Nagai (2024).

Shown in the figure below is an example of how the point data were classified into these three categories.

Figure 4.57. Survey Points in Honda Bay, Palawan



Source: Hirota & Nagai (2024).

From the 228 points, 76 points were selected to be part of the training data for the classification, and 152 points were selected for the accuracy verification. The distribution of these points is shown in the table below.

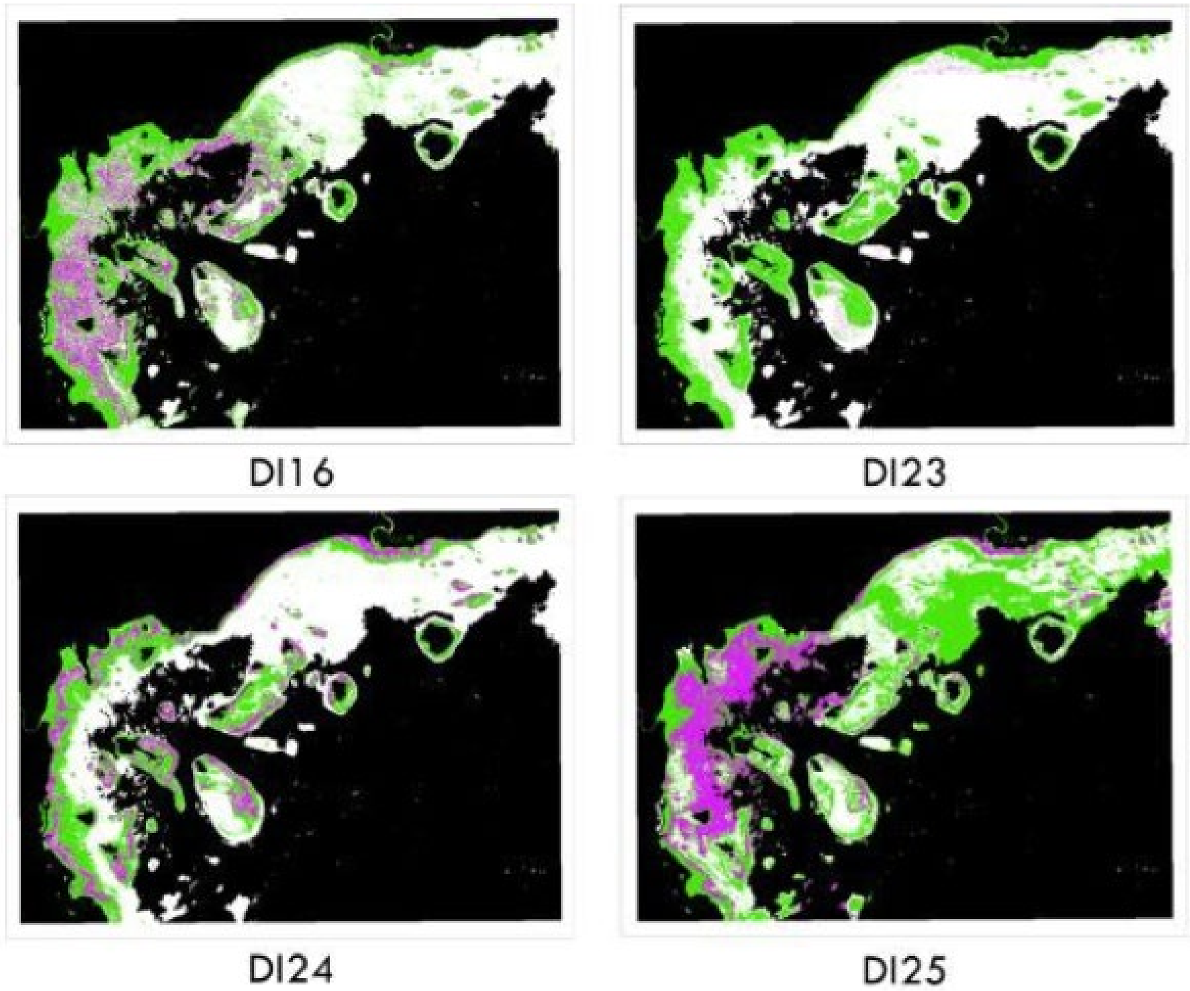
Table 4.2. Training data for the classification

Category	Training Data	Accuracy Verification	Total
Seagrass	37	75	112
Sand/Gravel	26	51	77
Coral	13	26	39
Total	76	152	228

Source: Hirota & Nagai (2024).

The figure below shows an example of the results of the supervised classification of the depth invariant indices. The white areas are classified as sand and gravel, the purple areas are classified as corals, and the green areas are classified as seagrass.

Figure 9. Classification Results



Source: Hirota & Nagai (2024).

Out of all the 15 band combinations, the combination of Band 2 (Blue) with a wavelength of 465–515 nm, and Band 4 (Green II) with a wavelength of 547–583 nm was able to construct a seagrass bed distribution map with an accuracy of 73 %. This band combination was able to properly map the local seagrass distribution in general. The depth invariance index from this band combination can be used to map seagrass beds for monitoring and environmental conservation.

4.4.12 Challenge and Solution toward Operational Use

Even though the seagrass bed distribution map of Bands 2 and Band 4 displayed the highest overall accuracy, there were many misclassifications of seagrass as corals, and sand and gravel as coral, resulting in low user accuracy. This is due to the similarity of spectral reflectance characteristics between seagrass and corals. The figure below shows an image of a bottom sediment with seagrass and coral in the same habitat. The mixing of spectral properties of these two organisms is highly possible.

Figure 10. Bottom Sediment with Seagrass and Coral

Source: Hirota & Nagai (2024).

The solutions to this problem, other than ground verification survey, include using a higher resolution satellite sensor, and by using hyperspectral satellite sensors. By using higher-resolution satellites, the ground sampling distance will be lower which means the areas of interest will be more thorough. Lastly, using hyperspectral satellite sensors, the spectral reflectance characteristics of these organisms will be more definite due to the multiple number of bands of about 300 compared to using multispectral sensors which are commonly 4 to 9 bands only.

4.4.13 Expected Schedule until Operational Use

The operational implementation of this project is outlined in four key phases:

1. Preparation Phase (1–3 months) – This phase will plan the project's scope and congregating satellite images and in situ data. Gathering the necessary permits to conduct the research and field survey is also included in this phase.
2. Algorithm Development and Testing Phase (3–6 months) – This phase will be used to test the suitability of the algorithms and models of the research to the area of interest. Proper adjustments in the algorithm from the results of the experiments will be implemented before deployment.
3. Operational Deployment Phase (12–18 months) – This phase is the project's operational period. Its duration may vary depending on the contract.
4. Evaluation and Optimisation Phase (3–6 months) – This phase focuses on evaluating, assessing, and improving the algorithm. It will help optimise the project's methodologies for its next implementation.

This project can be applied not only in the Philippines but also to other countries that require mapping their seagrass habitats.

4.4.14 Estimated Market and/or Revenue Scale after Operational Use

1. Target Market

The system developed for mapping seagrass habitats has diverse applications and can cater to several markets globally:

- Environmental Conservation Organisations:
    - NGOs focused on marine ecosystem preservation.
    - Government agencies responsible for coastal and marine biodiversity management.
- Climate Change Initiatives:
    - Carbon offset programmes emphasising ‘blue carbon’ storage.
    - International bodies involved in climate mitigation policies (e.g. UNFCCC, IPCC).
- Coastal Development and Management:
    - Developers requiring environmental impact assessments (EIAs).
    - Coastal zone planners managing seagrass and coral ecosystems
- Academic and Research Institutions:
    - Universities and laboratories focusing on marine ecology and satellite remote sensing.
- Commercial Enterprises:
    - Fisheries and aquaculture industries interested in sustainable practices.
    - Tourism operators dependent on the health of marine ecosystems
- Global Market Potential:
    - Coastal nations with significant marine biodiversity and seagrass habitats (e.g. Indonesia, Australia, Maldives, and the USA).

2. Revenue Streams

The potential revenue streams for the operational system include:

- Data Subscription Model:
    - Providing regular seagrass mapping data to clients (e.g. $5,000–$10,000 per area per year).
- Custom Mapping Services:
    - One-time mapping projects tailored to specific needs (e.g. $20,000–$50,000 per project).
- Licensing the Algorithm:
    - Licensing the Depth Index Algorithm and classification model to other institutions or governments (e.g. $10,000–$30,000 per license).
- Consultancy and Training:
    - Offering consultancy services and capacity-building workshops for using the system (e.g. $10,000 per workshop).

- Collaboration with Carbon Markets:
    - Partnering with carbon credit platforms to quantify and monetise 'blue carbon' storage for clients.
- International Projects and Funding:
    - Securing funding from global environmental initiatives such as the Green Climate Fund (GCF) or partnerships with organisations like the World Bank and Asian Development Bank.

3. Estimated Market Size

Based on the applications and the markets:

- **Global Market for Blue Carbon Initiatives**: Estimated at $50 billion annually by 2030, growing at a CAGR of 13%.
- **Marine Ecosystem Services Market**: Projected to exceed $25 billion by 2027.
- **Coastal Zone Management Market**: Estimated at $15 billion by 2025.

If the system captures just 1% of this combined market:

- **Potential Revenue**: $90 million annually.

4. Operational Revenue Projections

For a regional implementation in the Philippines and nearby Southeast Asian countries:

- **Initial Year** (Pilot Phase): $100,000–$200,000 (focused on research institutions and NGOs).
- **Expansion Phase** (Years 2–5): $500,000–$1 million annually through data subscriptions, custom services, and carbon offset projects.
- **Global Scalability** (Post-Year 5): $5 million+ annually, targeting international partnerships and multi-country implementations.

By creating a scalable and reliable system, the Honda Bay pilot project can become the foundation for a highly profitable and impactful business model in environmental monitoring and management.

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Chapter 5

Research and Investigation Toward Collaborative Schemes for Industry–Academia–Government Cooperation and the Development of a Framework for Space Technology Utilisation in the ASEAN Region

5.1 Investigating Examples of Industry–Academia–Government Collaboration Schemes in Developed Countries

A. Japan

In Japan, the government, academia, and industry can collaborate in effectively pushing the frontiers of space technology. JAXA, for one example, has been more dominant in space research for long years but succeeds a bit better through its very good partners, such as universities, in partnerships.

JAXA heads Japan's efforts toward space, spearheading highly notable missions such as Hayabusa to explore asteroids and its participation in the International Space Station with the Kibo module. Its achievements significantly helped in expanding knowledge into space science and revealed how technology in Japan has an extraordinary ability in the discovery of space. To conduct these areas, such as satellite technology, space robotics, and astrophysics, JAXA is in partnership with University of Tokyo and Kyoto University, amongst others. Their contributions are crucial to Japan's space missions' scientific foundation, focusing on development of new technologies and raising the capabilities of exploration. The role of the private sector must also be mentioned. Companies such as Mitsubishi Heavy Industries and NEC Corporation collaborate with JAXA in terms of satellite and launch-vehicle development. JAXA also promotes the use of space-based technologies in private industry, helping Japan position itself as a major player in global space arena, especially on communications satellites.

Japan has nurtured a rich industry–government–academia collaboration particularly in remote sensing and space technology. This synergy has led to an innovative culture and many breakthroughs, too. In March 2024, the Ministry of Economy, Trade and Industry (METI), in cooperation with the Cabinet Office (CAO), the Ministry of Internal Affairs and Communications (MIC), and the Ministry of Education, Culture, Sports, Science and Technology (MEXT), set up the Space Strategy Fund. This fund, under the administration of the Japan Aerospace Exploration Agency (JAXA), offers private companies strong, multi-year support in the development of space-related technologies. This move is reflective of the government's intention to boost the space industry with constant investment in finance.

Technology Licensing Organizations, or TLOs, have been established in Japan to bridge the gap between academic research and industrial application. These entities help the researchers in universities to file patents and further enable the transfer of such technologies to the private sector, which accelerates the commercialisation of the academic innovations. A good example of open innovation is the Space Avatar Project. This project is a collaboration between a startup company, a research institute, and a local government. This shows how different entities can be brought together to create innovative technologies and services, in accordance with the Japanese government's growth strategy that focuses on such synergies.

The University of Tokyo has been a key player in Japan's space efforts. In 1970, the university made history by launching Ohsumi, Japan's first satellite, using domestically developed solid-propellant Mu rockets. This was a defining moment in Japan's space exploration journey and underscored the role of universities and other educational institutions in advancing space technology. Japan is also very active in international cooperation, for example, in Earth CARE, a collaborative project between ESA and JAXA, aimed at observing and characterising clouds and aerosols, together with their reflected and emitted radiation. This mission exemplifies the spirit of multilateral cooperation amongst nations in addressing global environmental challenges. Through these multidisciplinary teams, Japan continues to advance its remote sensing and space technology sectors, fostering collaboration between industry, academia, and government to drive innovation in addressing both national and global issues.

B. United States

In the United States, the government plays a very significant role in promoting collaboration between industry and academia, particularly through agencies such as NASA and the Defense Advanced Research Projects Agency (DARPA). These organisations foster innovation by using mechanisms such as Cooperative Research and Development Agreements (CRADAs), which facilitate partnerships between academic institutions and private industry. CRADAs will allow government researchers to collaborate with industry experts on focused projects, bringing together resources and expertise to solve complex challenges. It benefits both sides: the government agencies obtain practical industry knowledge and the latest technological advancements, whereas private companies can access the research funds of the government and be informed about what the national space priorities are. The agencies also provide research grants aligned to national objectives, ensuring innovation is channeled towards the country's broader needs. Through these agreements and funding initiatives, the U.S. government is therefore critical in advancing space technology by breaking barriers to collaboration, providing necessary resources, and ensuring that research is transitioned from the lab into real-world applications.

Over a relatively brief period, the United States developed a strong ecosystem that allowed collaboration between government, industry, and academia in pushing innovations related to remote sensing in space technology research. Innovations driven by this collaborative entity continued to strengthen national security, thereby increasing our understanding of many scientific realities. In June 2023, the U.S. Space Systems Command (SSC) launched the COSMIC center in Chantilly, Virginia. This is an outreach programme for the commercial industry, government agencies, allied partners, and academic institutions. COSMIC seeks to reduce the time and expense of inserting commercial technologies and services into the U.S. Space Force and therefore increase its power. The center demonstrates the commitment of the government to commercial innovation by leveraging academia and industry. The TAP Lab is a collaborative endeavor between the U.S.

The collaborators of this initiative include Air Force Space and Missile Systems Center, the University of Colorado Boulder, Lockheed Martin, and many more. Through this, the usage of remote sensing data is upgraded by the promotion of collaboration amongst academics, industries, intelligence communities, defense sectors, and civil communities. TAP Lab equips stakeholders in developing innovative tools and applications that help improve the analysis and sharing of remote sensing information. Research opportunities exist by way of engaging universities to tackle the challenging issues associated with space that the United States Space Force has set forth. This will include topics such as smart sensing, machine learning to ground-based remote sensing satellites, and quantum sensing for location and electromagnetic field detection. They work together with top academic researchers, drawing from unique expertise, to create cutting-edge capabilities that ensure America's space operations stay one step ahead of any peer competitor.

The USGS conducts extensive research in remote sensing, focusing on environmental monitoring, land use, and natural resource management. Collaborations with academic institutions and industry partners enhance the development of remote sensing technologies and methodologies, providing critical data for informed decision-making.

MIT Lincoln Laboratory engages in research and development of advanced satellite systems for space situational awareness and Earth observation. Collaborating with government agencies, industry, and academia, the laboratory focuses on innovative solutions to ensure the United States' continued use of space for communications, navigation, and remote sensing.

Established to address military, intelligence, environmental, and civil concerns, the Remote Sensing Center brings together expertise from various departments. It collaborates with government, academia, and industry partners to develop and exploit remote sensing systems for air and space applications, contributing to national security and scientific advancement.

This project is a joint effort amongst the University of New Hampshire, Sonoma State University, and Howard University, forming part of NASA's Interstellar Mapping and Acceleration Probe (IMAP) student collaboration. The mission aims to understand Earth's polar upper atmosphere's response to particle precipitation and solar wind forcing. It is a multidisciplinary team of undergraduate students, hence showcasing educational collaboration in space research.

The ISS National Lab was designated as a U.S. National Laboratory in 2005. It is undertaking research in life sciences, physical sciences, technology development, and remote sensing. This will serve a broad range of academic, government, and commercial users to promote the collaboration of industry–academia–government in microgravity research and technology development.

In October 2024, the aerospace startup Sceye teamed up with NASA and USGS to deploy high-altitude platforms for monitoring wildfires and storms. This collaboration uses solar-powered airships equipped with earth observation sensors, thus serving as a cost-effective alternative to traditional satellites and aircraft. The partnership aims to enhance the collection of data and improve forecast accuracy during environmental events, which shows the potential of industry–academia–government collaboration in climate challenges.

C. China

China has led in setting up industry–academia–government collaborations in its remote sensing and space technology sectors. This was achieved through strategic initiatives and partnerships, creating an ecosystem bridging innovation, research, and policy for both national and global impact. One of the most typical examples is the Dragon Programmed, launched in 2004 by European Space Agency (ESA) together with China's National Remote Sensing Center as an initiative under the Ministry of Science and Technology. It represents one of the best and characteristic examples of international cooperation and how it may be capitalised for scientific as well as practical purposes. Through this programmed called Dragon, European and Chinese scientists are able to come into joint research in environmental monitoring, resource management, or disaster response by using satellite data from Earth observation. This project not only contributes towards furthering China's capacity with regard to the utilisation of satellite data but also ties it closer to global scientific communities.

Another example of multilateral cooperation in space science is the China Seismo-Electromagnetic Satellite Mission, or Zhangheng. This mission is a collaborative effort between China, Italy, and Austria, whose focus is on monitoring electromagnetic fields and plasma parameters for the study of seismic phenomena. The project is a synergy between the China National Space Administration (CNSA), the China Earthquake Administration (CEA), and academic institutions. It is a great example of synergy between government agencies and academic research in pursuing scientific breakthroughs. In terms of infrastructure, SGIIN is a perfect example of China's plan to build a coherent information system based on space. SGIIN was approved by the 13th Five-Year Plan, integrating the fields of satellite communication, remote sensing, and navigation. It's a mega-engineering project with government agencies, research institutions, and industry leaders' cooperation, thus demonstrating how large-scale projects can become hubs for innovation and talent development.

This is further emphasised by the fact that China is gaining prominence in remote sensing all over the world. In improving the technological capability of the nation, China embarked on a joint satellite launching with other countries, particularly Brazil and Ethiopia. Amongst these moves was resource monitoring and management through environmental support in a partnership that existed between the two in its CBERS programme. Besides, via the China Platform of Earth Observation System, remote sensing data is shared across the world and therefore advances science globally as well as across its coasts.

D. European Space Agency (ESA)

The European Space Agency (ESA) is at the forefront in encouraging long-term cooperation between industry, academia, and government. At the center of this partnership is the Technology Research Program (TRP), aimed at driving innovation into space-related technologies. The TRP encourages universities and research centers to submit proposals based on ESA's strategic goals, thus establishing a mutualistic relationship in which the academic institutions provide cutting-edge research and ESA offers funding to make such ideas become a reality.

The third objective of TRP is to close the gap between the academies and industries by especially developing linkages between universities and SMEs. This link between universities and SMEs can be a starting point in developing the knowledge-exchange and technology-transfer mechanisms between research and actual practice. Practically, researchers from academic institutions have knowledge from industrial experience, which can be tapped by industry by adopting innovative research as an initiator for the development of new products and improving technological abilities.

Beyond TRP, the Academic Research Pilot Initiative at ESA plays a key role in mapping and harmonising space research across Europe. It builds capacity within the universities through fostering a powerful network of institutions that would work towards common space exploration goals. All this has made ESA build a collaborative ecosystem that nurtures technological advancement, strengthens the space workforce, and encourages multi-sector partnerships that lead to space missions and technologies no one would have thought possible.

Besides the TRP programme, The European Space Agency (ESA) has established various regional cooperation frameworks amongst its member states to advance space and remote sensing technologies. These frameworks promote shared efforts in research, development, and application, ensuring that all member states benefit from the collective expertise and resources.

1. European space policy coordination

The European Space Policy Coordination framework ensures a unified and strategic approach to space activities across the European Union (EU). This framework aligns the space programmes of individual member states with broader EU objectives, maximising resources and expertise. The collaboration between the European Space Agency (ESA) and EU member states supports the development and operation of key initiatives like Galileo, Europe's satellite navigation system, and Copernicus, a leading Earth observation programme.

This coordination enhances Europe's capabilities in space exploration and technology, ensuring competitiveness on the global stage. It also ensures mutual benefits, where member states contribute to and share the outcomes of advancements in areas such as navigation, climate monitoring, and security. By pooling funding and expertise, the framework fosters innovation and reduces redundancy, making Europe a stronger and more efficient player in the global space sector.

2. ESA earth observation envelope programme (EOEP)

The ESA Earth Observation Envelope Programme (EOEP) is a flagship initiative designed to advance Earth observation capabilities, addressing scientific, societal, and economic challenges. The programme supports the development, deployment, and operation of diverse Earth observation missions, fostering innovation and flexibility. Central to EOEP are the Earth Explorer missions, which focus on understanding critical aspects of Earth's systems, including climate dynamics, atmospheric processes, and hydrology. Additionally, the programme complements Europe’s Copernicus initiative by supporting contributing missions that enhance the quality and scope of Earth observation data. EOEP emphasises technological innovation, driving the development of advanced instruments and techniques to improve monitoring precision and expand observational capabilities. A key focus of the programme is ensuring open access to Earth observation data, enabling scientific research, informed policymaking, and commercial applications. Through these efforts, EOEP reinforces Europe’s leadership in Earth observation, equipping member states to address global challenges such as climate change, disaster management, and sustainable development, while delivering valuable insights for science and society.

3. European space operations centre (ESOC) collaboration

The European Space Operations Centre (ESOC), located in Darmstadt, Germany, serves as the operational heart of the European Space Agency (ESA). It is a hub for managing satellite operations, including launch coordination, orbital control, and ground communication systems. Member states collaborate through ESOC to ensure the efficient operation of ESA's diverse portfolio of missions. This centralised framework streamlines efforts, reduces redundancy, and leverages shared expertise to maintain high standards of operational excellence. By pooling resources and technical capabilities, ESOC supports missions ranging from Earth observation to deep space exploration, strengthening

Europe's presence in space. This collaborative model enhances mission reliability and fosters innovation in satellite operations and technology development.

4. ESA regional innovation clusters

ESA's Regional Innovation Clusters, including its network of Business Incubation Centres (BICs) in countries like Germany, France, Italy, and the Netherlands, play a vital role in fostering innovation and economic growth. These clusters create collaborative ecosystems by connecting academic institutions, industries, and government bodies to develop advanced space-based applications. A key focus of these clusters is leveraging remote sensing technologies to address real-world challenges, such as enhancing precision agriculture, optimising urban development solutions, and supporting climate monitoring. By providing funding, mentorship, and technical expertise, ESA's BICs empower startups and researchers to transform cutting-edge space technologies into market-ready solutions. This approach not only stimulates regional development but also ensures that member states capitalise on ESA's resources and expertise to drive innovation, strengthen local economies, and contribute to Europe's global leadership in space technology applications.

5. EUMETSAT–ESA cooperation

Meteorological cooperation between ESA and EUMETSAT represents a pivotal aspect of Europe's space efforts. ESA focuses on the development of advanced meteorological satellites, including the MetOp series and the Sentinel missions, which are part of the Copernicus programme. Once these satellites are operational, EUMETSAT takes responsibility for managing data operations, ensuring the continuous delivery of high-quality weather and climate data. This partnership enables precise weather forecasting, climate monitoring, and long-term environmental research, providing essential insights for scientific, industrial, and policymaking purposes. By combining ESA's expertise in satellite design and EUMETSAT's proficiency in data management, this collaboration benefits all participating countries, strengthening Europe’s capabilities in meteorology and climate science. It also ensures the seamless integration of space-based observations into global systems for better environmental management and disaster resilience.

6. Integrated applications promotion (IAP) programme

The Integrated Applications Promotion (IAP) Programme highlights ESA's commitment to collaboration and innovation by supporting projects that combine remote sensing data with other technologies, such as telecommunications and navigation, to address critical societal challenges. This programme fosters the development of integrated solutions in areas like smart cities, where advanced technologies improve urban management and sustainability, as well as disaster resilience, by enhancing early warning systems and response strategies. Through targeted funding and technical expertise, the IAP Programme empowers member states to implement innovative applications that drive sustainable development and improve the quality of life for their citizens. By bridging multiple technological domains, the programme exemplifies how space-based capabilities can be harnessed to create tangible benefits for society, ensuring that ESA's advancements resonate beyond the scientific community and directly impact everyday lives.

7. ARTES (advanced research in telecommunications systems) programme

The ARTES (Advanced Research in Telecommunications Systems) Programme is a key ESA initiative aimed at fostering innovation in satellite communication technologies. Through ARTES, ESA supports the development, deployment, and commercialisation of advanced telecommunications solutions, enabling member states and industries to stay at the forefront of this critical sector. The programme offers a flexible structure that encourages collaboration between ESA, industries, and national agencies, facilitating projects at various stages, from research and development to market-ready applications. ARTES has been instrumental in advancing technologies like high-throughput satellites, 5G integration, and secure communication systems, addressing both commercial and governmental needs. By promoting public–private partnerships and providing technical expertise and funding, ARTES ensures that European industries remain competitive in the global telecommunications market. It also drives innovation in areas like broadband connectivity, disaster management, and secure data transmission, delivering impactful solutions that benefit businesses and societies across Europe.

8. Climate change initiative (CCI) and regional partnerships

The Climate Change Initiative (CCI) is a pivotal ESA programme that advances climate research by generating consistent, long-term climate data records from satellite observations. This initiative enables comprehensive monitoring of key climate variables, such as sea level rise, greenhouse gas concentrations, and ice cover changes, providing critical insights for understanding and addressing climate change. European research institutions collaborate under the CCI framework to analyse this data, enhancing the region's capacity to monitor climate trends and develop adaptive strategies. ESA further supports these efforts through workshops and data-sharing platforms, ensuring that the data and findings are accessible to researchers, policymakers, and stakeholders across the globe. By fostering regional partnerships and promoting the widespread use of high-quality climate data, the CCI strengthens Europe's leadership in climate science and its ability to address global environmental challenges effectively.

9. European space research and technology centre (ESTEC) partnerships

The European Space Research and Technology Centre (ESTEC), based in the Netherlands, is the technical hub of the European Space Agency (ESA) and a cornerstone of European space innovation. It offers state-of-the-art facilities for the design, testing, and integration of space technologies, enabling the successful development of missions across domains such as Earth observation, satellite communication, and planetary exploration. Member states collaborate at ESTEC, leveraging its advanced infrastructure and technical expertise to ensure excellence in mission development and execution.

This partnership model promotes the exchange of knowledge and skills, enhancing technological capabilities across Europe. By serving as a central hub for research and innovation, ESTEC not only drives the success of ESA's projects but also reinforces Europe's leadership in the global space industry. To further strengthen cooperation, ESA encourages joint scientific missions and data analysis efforts amongst member states. Examples include collaborative research under the Horizon Europe framework and the shared operation and data usage of missions like Swarm, which studies the Earth's magnetosphere, and Aeolus, which provides global wind profile measurements. These initiatives combine expertise and resources to advance cutting-edge research, fostering innovation and maximising the impact of European space science.

Through these frameworks, ESA demonstrates the power of regional cooperation, allowing its member states to achieve shared goals in space and remote sensing. By pooling resources, aligning policies, and fostering innovation, ESA ensures that all member states contribute to and benefit from Europe's leadership in space exploration and Earth observation.

E. United Kingdom

The UK exemplifies the potential of government-driven initiatives to encourage collaboration in space. Central to this is UK Research and Innovation, which has developed a specific framework for collaboration that joins government, academia, and industry in partnerships that have mutual benefits. One exemplary example of this collaboration is the Harwell Campus, which is ranked as one of the leading hubs of space organisations globally. There are more than 100 high-tech companies present at the Harwell Campus; some of these include organisations involved in the development of satellites, Earth observation, and other related space enterprises. The facilities are class-leading, including the National Satellite Test Facility, thus allowing the companies to carry out all testing and developments within the campus. Strong partnerships amongst the academic and government institutions as well as private enterprises can ensure that their research is put into reality very fast. Furthermore, the appointment of a sector champion for space by UKRI is crucial in streamlining coordination amongst the various councils that manage research, innovation, and technology funding. This role unifies all stakeholders – academia, industry, and government, working together to enhance the UK's space capabilities. UKRI has streamlined and strategically planned to make the UK a leader in space technology innovation.

The UK Academic Expertise Portal, funded by the UK Space Agency, is a much-needed resource linking academic and industry partners in the UK space sector. The principal purpose of the AEP is to map the UK's academic capabilities in that field, thus helping businesses and government agencies find institutions that have the appropriate expertise for their specific projects. The portal further allows industry players to source potential collaborators or access ongoing research that could advance their project by creating a database of scholarly resources. It is also a show of university facilities, and this simply makes it easy for the business to secure the kind of infrastructure necessary for development and research work. This centralised platform facilitates the start of collaborations and fosters innovative partnerships between academia and industry to promote the commercialisation of cutting-edge research and accelerate the development of new space technologies.

For researchers, the AEP provides an opportunity to present their work to a much wider audience, thereby reaching industry partners and getting support for future projects. Therefore, by strengthening these bonds, the portal is facilitating the development of a much stronger and collaborative space ecosystem in the UK.

F. Australia

Australia has utilised collaboration effectively in the promotion of its space endeavors. In 2018, it launched the Australian Space Agency. It serves as a core component of Australia's space policy, hence leading and guiding space-related activities. This strategic vision fosters partnerships amongst the government, universities, and private industry, allowing Australia to improve its space capabilities. Leading universities in the area, such as the University of Sydney and the University of Melbourne, are pushing new frontiers in fields related to satellite communications, space medicine, and exploration. They have joined forces with the Australian Space Agency to develop new technologies and facilitate global space missions. Take an example in Australian universities in regard to advanced space instrument creation and data analysis methods – a critical element of both exploration and Earth observation missions. Regarding industrialists, companies such as Fleet Space Technologies and Inmarsat have contributed significantly through satellite communications and space-based observation about Earth in collaboration with analytics data. The involvement of the private sector in the space industry has played a vital role in reforming Australia's position in the space arena and turning it into a major force in the region. Also, Australia's partnerships with international space organisations, like NASA and the European Space Agency, enhance its space sector. Through these collaborations, the Australian Space Agency ensures that Australia remains at the forefront in the development and exploration of space technology.

5.2 Investigating Examples of Industry–Academia–Government Collaboration Schemes in ASEAN Countries

A. Singapore

Singapore Space and Technology Association (SSTA) is at the foundation for cooperation between the government, industry, and academia within the country's space sector. The leading associations comprise this space, hence allowing all types of stakeholders involved in the space ecosystem to get integrated and form associations to engage with each other.

This collaborative framework involves the Singapore Economic Development Board (EDB) and the Agency for Science, Technology and Research (A*STAR), which provide funding and encourage research. The agencies make it conducive to space technology development; the universities, such as National University of Singapore (NUS) and Nanyang Technological University (NTU) bring in the expertise in satellite systems, space communications, and Earth observation.

NUS's Center for Remote Imaging, Sensing and Processing (CRISP) has played an important role in the improvement of space science and technology, particularly concerning satellite technology and remote sensing applications. On the other hand, NTU's Earth Observatory of Singapore (EOS) examines climate change and natural hazards through the use of data from satellites. Private sectors, such as companies like SES S.A. space engineering specialists in association with universities, bring research to reality for the commercialisation of space-based solutions for telecommunications and environmental monitoring. This is also how Singapore has developed the thriving space ecosystem that unifies research, technology commercialisation, and national policies to support innovation in the space domain.

1. Space mission design and development programme

Singapore has developed a Space Mission Design and Development Program that encourages close cooperation between the government, academia, and industry in innovation and design of space missions, especially in satellite technology and space systems engineering. Under the programme, the Singapore Space Agency, a government body under the Ministry of Transport, is working with NTU and NUS. NTU's Space Systems and Technology Laboratory is working on satellite payloads design and mission simulation. NUS's CRISP is focused on small satellites design and testing. From these partnerships, satellite systems focusing on space exploration, remote sensing, and satellite communications are being developed.

The programme also has a collaboration with companies in the private sector including ST Engineering. This organisation significantly contributes to the fabrication of satellites and the other running aspects of space activities. ST Engineering's association with the TeLEOS series of Earth observation satellites epitomises the crucial collaboration that occurs between partners like this. This collaborative effort drives innovative advancements in technology, ensuring that Singapore's space sector stays competitive on a global scale.

2. Smart nation initiative and space technology applications

The Smart Nation Initiative represents the commitment of the Singaporean government to utilise technology to raise the quality of life of its citizens in tandem with sustainable development. This is through space technology and satellite-based data to improve urban planning, transportation systems, and environmental monitoring. The SNDGO supervises the programme on gathering and utilising space-based data for urban and environmental purposes. NTU's Earth Observatory of Singapore has partnered with SNDGO to employ satellite data to monitor the urban heat island, water resources, and air quality. Thus, remote sensing has become a very important instrument that is assisting Singapore in accomplishing its sustainability goals. Cooperative arrangements for delivering satellite data services include companies such as private ones like ST Engineering and SES S.A., providing service to applications in the area of a smart city. For instance, ST Engineering manufactures space-based communication systems enabling smart transportation solutions through live data for traffic management as well as route optimisation. SES S.A. is also engaged with IoT networks that rely on space-based communications to deliver much-needed connectivity to underserved communities. This fits well with the Singapore vision of integrating the technology of space into urban ecosystems to make those cities more efficient, more sustainable, and more responsive.

3. Satellites in environmental and agricultural monitoring

Besides smart city applications, satellite data has been used by Singapore for environmental monitoring and sustainable agriculture. The issues of climate change, biodiversity loss, and food security must be addressed by the government agencies, universities, and private companies in collaboration with each other.

The Ministry of the Environment and Water Resources and the National Parks Board, Singapore, have space-based data used to monitor land use, forestation, and biodiversity. A*STAR promotes technology in processing and analysing satellite imagery, offering data-driven solutions for the country in its natural resource management.

Efforts in this direction are contributed by universities such as NTU's Earth Observatory and NUS's CRISP, which work on research of satellite-based solutions for precision agriculture and environmental sustainability. Universities in these works develop remote sensing technologies to optimise land use, enhance crop monitoring, and improve water management practices.

ST Engineering and SES, other private sectors, will play important roles in making satellite-based communication and data analytics happen for precision farming and monitoring of the environment. Its contributions will ensure the commercial and impactful integration of space technology into agricultural and environmental management systems. It optimises agricultural productivity while monitoring climate change impacts and the sustainability of Singapore's natural resources, integrating satellite data with AI and IoT.

4. Singapore–India collaboration on space-based technologies

Singapore also collaborates with other countries, especially with India's ISRO, on space-based applications in disaster management, telecommunication, and agriculture. The collaborations include space technology exchanges, satellite data sharing, and joint research on Earth observation.

The Singapore Space Agency (SDA) and ISRO have been working together to develop early warning systems for natural disasters using satellite imagery. There are collaborations between academic institutions in Singapore, such as NUS and NTU, with ISRO for studying the use of satellite data for climate resilience, water management, and crop health.

Private companies, such as SES and Vikram Sarabhai Space Centre in India, are also involved in satellite communications and data analytics to address common challenges in both countries, such as improving connectivity in remote areas and using satellite-based technology for precision farming.

B. Viet Nam

Viet Nam has been incrementally working on its space and technology area successfully with collaborations of all relevant government agencies, academia, and private industry. These collaborative mechanisms will not only ensure innovative creation but also bring on crucial national challenges that could address disaster management, environmental surveillance, telecommunications, agriculture, and many more. And due to the effective mobilising of space technology potentials, Viet Nam is building a vibrant ecosystem which would be the resultant synergy product of these three inter-relevant sectors. Here are a few examples of many amongst such collaborative endeavors.

1. VNREDSat and space technology development

Launched in 2013, VNREDSat marked Viet Nam's first venture in having high-resolution satellites designed to view the earth. The joint effort took three partners: Viet Nam Academy of Science and Technology – VAST, the most central institution under MOST- and a set of private firms including one major Vietnamese telecommunication firm in satellite technologies known as Vinasat.

VAST's involvement as an academic body initiated the project, especially in the research and development phases. VAST contributed a major share to the project both as its expertise in satellite technology/space science and in furthering the development of a ground station for the satellites. The MOST-the state government body-provided its financial and regulatory support as both the design and launch had to be undertaken. Private sector involvement in the case of Vinasat has ensured the commercialisation of the satellite. It has operated the satellite and managed the distribution of the data received from the satellite and its applications in agriculture, disaster management, and environmental monitoring. This partnership has helped Viet Nam develop a satellite that integrates it into natural resource monitoring, helps in urban planning, and ensures environmental protection. This is a classic example of how academics, the government, and industries coming together can result in technology that benefits the country.

2. Viet Nam Space Center (Vinasat)

The other great example is the Viet Nam Space Center, locally known as Vinasat, that is the focal point of the country with regard to the development of satellite technology and space research. That center collaborates with all Vietnamese universities, research institutes, and private companies to initiate space research, satellite operation, and ground station management.

The Ministry of Information and Communications, as a government organisation, has given policy support and infrastructure for the center. For the research on satellite technology and space systems, institutions of higher learning like Hanoi University of Science and Technology (HUST) and VAST contributed to it. Vinasat, amongst other companies of the private sector has immensely contributed to the governance of space operations and provision of satellite-based commercial services, like communication, as well as broadband connections that are both urban as well as rural.

This has guaranteed the development of advanced satellite systems through academia, government, and industry collaboration. It has brought satellite communications closer to every place in Viet Nam. Such partnership not only helped in fortifying the country's space technology but also helped grow a national space industry capable enough to support commercial, research, and governmental needs.

3. Smart agriculture and remote sensing collaboration

Through remote sensing and satellite-based data, Viet Nam has, within recent years, been deploying space technology for agricultural use through smart agriculture. Developing the agricultural sector and food security have increasingly grown to be reliant on efforts interlinked amongst government departments, universities, and private bodies.

The MOST and the Ministry of Agriculture and Rural Development (MARD) have been integral in the integration of space technology into agricultural monitoring and resource management. Working in conjunction with academic institutions such as Viet Nam National University (VNU), research has focused on how to use satellite data in crop monitoring, pest detection, soil health analysis, and efficient water management.

The private sector, including Viettel and FPT companies, has played a pivotal role in applying space data in practical ways. The companies integrate satellite data with IoT technologies and deliver real-time insights on irrigation needs, crop health, and pest control to farmers. This collaboration has resulted in the development of platforms that help farmers make more informed decisions, improve crop productivity, and ensure sustainability. This partnership facilitated Viet Nam in using space technology to adopt high technology in transforming a primitive form of farming into creating more sustainable agriculture, which is at the heart of the food security and economic stability issues.

4. Vinasat-2 and space data for natural resource management

The Vinasat-2 satellite, launched in 2012, is another prime example of successful collaboration between industry, academia, and the government. This satellite project aimed at providing improved telecommunications, broadcasting, and satellite data services throughout Viet Nam.

The government, through MIC and MOST, played a significant role in planning and funding Vinasat-2. It was crucial in the regulation and establishment of the legal and operational framework for the satellite. VAST and other research institutions contributed their expertise in satellite systems, while the private sector, led by Vinasat, was responsible for satellite operations and the commercialisation of the satellite data for various sectors, including natural resource management.

Monitoring of natural resources, disaster preparedness, and environmental protection are also important in using the satellite. Vinasat-2 promotes prevention of deforestation and better land use management to safeguard marine and terrestrial biodiversity. Collaboration has significantly improved the country's ability to respond to environmental challenges, and it makes space technology an essential tool for sustainable development.

5. Technology incubation and startup ecosystem

Viet Nam is also nurturing a new tech incubation environment by initiating and developing startup companies in the space-related technologies as well as telecommunications. As an effort of the Vietnamese government, in addition to focusing on emerging technology innovation and entrepreneurship as motivators for collaboration.

MOST and MIC are government agencies that provide grants and regulatory support to space tech startups. A government-driven initiative, Viet Nam Innovative Startup Accelerator (VIISA), incubates early-stage companies through providing mentorship, funding, and business development support. Universities like VNU-Hanoi and IT Hanoi work with startups to provide needed technical expertise and research collaborations. Private companies like Viettel and VNPT help test and commercialise new technologies with them.

Such collaborations have led to the development of satellite communication systems, geospatial data applications, and AI-driven technologies that enrich the provision of space-based services. Such collaborations make sure Viet Nam has an increasing number of startups that support national and regional space industries.

C. Thailand

Thailand has, in the last few years, been progressing rapidly in its space sector, building up solid collaborations between the government, academia, and industry. While partnerships have indeed resulted in technological development in space, these also dealt with the country's most pressing national concerns – disaster management, agriculture, and environmental monitoring. The country thus created a thriving space ecosystem where innovation can thrive and help ensure sustainable development in the nation.

1. THEOS-2 satellite: synergy toward success

The THEOS-2 is one of the flagship space programmes of Thailand, and its success was based on the collaboration between the government, academia, and the private sector in achieving more complex space technologies. Launched in 2021, THEOS-2 was built for

Earth observation with high spatial resolution capabilities. This mission monitors the environment and use of natural resources and also supports disaster management activities.

The government played an active part in this collaborative initiative as the National Science and Technology Development Agency, alongside Geo-Informatics and Space Technology Development Agency, was steering this programme. MOST gave their support through policy level activities for alignment with the other country wide space development aims.

In this collaboration the educational establishments involved were Chulalongkorn University as well as King Mongkut's Institute of Technology. These institutions contributed their technical expertise in the design and development of the payloads and ground stations for the satellite. Researchers at these universities worked closely with the government and industry to ensure that the satellite would meet the country's needs for high-quality, reliable satellite data.

It is a testament that the private sector was instrumental in making this satellite come alive. Airbus Defence and Space collaborated with its Thai partners to design and manufacture the satellite. The partnership ensured the technical specifications of the satellite are fully in line with requirements of real-time applications such as disaster response, land-use monitoring, and agriculture.

The success of THEOS-2 satellite is an exemplary proof of the power of industry–academia–government collaboration towards developing space technologies that address national challenges and at the same time bring Thailand into a regional leadership space in innovation.

2. Space technology incubation and startup ecosystem

The government of Thailand has, therefore, taken a space capability development agenda to cultivate a space tech startup ecosystem in conjunction with academic institutions and private sector partners. The government will aim to position Thailand as the most significant hub for the development of space technology in Southeast Asia by encouraging innovation and supporting emerging entrepreneurs.

The National Innovation Agency (NIA) and NSTDA have established space technology incubators that provide funding, mentorship, and networking opportunities for startups working in the space sector. These incubators have become important in helping space tech companies bring new satellite systems, space applications, and telecommunications technologies to market.

This is supplemented further by Chulalongkorn University and Mahidol University, which researched small satellite technologies, remote sensing, and space communications. Research efforts focus on developing solutions that could be commercialised and rolled out in various sectors – from agriculture to disaster management, environmental monitoring, and so forth.

Joint effort private entities that are Siam Space, the companies, and Siam Technology have been collaborating along with universities and the government in supporting satellite communications, earth observation applications, through incubation and commercialising new technologies. It then translates research innovations into everyday practices and has thus spawned new entrepreneurs in space. Moreover, it has put the space industry of Thailand into an advantageous position to avail its economic activities by the growth of this space economy worldwide.

3. Smart agriculture: using space technology for food security

Thailand has, over the past two decades, taken up space technology to address problems in agriculture, mainly crop productivity, land management, and food security. The government has collaborated with universities and private companies in using satellite data and remote sensing technologies to optimise agricultural practices and support precision farming.

Ministry of Agriculture and Cooperatives and GISTDA jointly took national efforts toward incorporating space technology into agriculture. With this, the government was able to promote a sustainable means of farming that decreases resource usage and increases crop production through the application of satellite data in crop health monitoring, soil analysis, and detection of pests.

Kasetsart University, an academic institution, remains the center for the R&D of space-based solutions in agri. The work in precision farming using satellite data and IoT technologies conducted here has led to better management of farming practices, better water conservation, better ways of irrigation, and better knowledge of soil conditions in agriculture in real-time.

The private companies involved in this effort are Siam Space and ST Engineering, which collaborated with the universities and government agencies to commercialise these research innovations. These companies designed satellite-based platforms that provided real-time information about crop conditions, weather, and irrigation. Collaboration resulted in smart farming technologies with increased productivity and ensured food security across the country.

4. Disaster management and space-based solutions

Thailand is prone to serious natural disasters, such as floods, droughts, and landslides. This joint effort by the government, academia, and private organisations has been of utmost importance in building Thailand's capacity to apply space-based technologies for monitoring and responding to disasters.

The Geo-Informatics and Space Technology Development Agency assists in leading the integration of satellite data in the disaster management strategy of Thailand. These help in monitoring flood-prone areas through remote sensing technologies, assessing damage that may have occurred during the disaster events, and monitoring change in land use that will impact disaster preparedness.

Such as Chulalongkorn University, the universities in Thailand have also contributed to sophisticated algorithms in processing satellite imagery and analysis of data. These universities work with the government for perfecting geospatial data analysis for flood mapping, landslide detection, and more disaster-related services.

Private companies like ST Engineering and Siam Space provide the necessary satellite communication systems and data analytics for real-time disaster monitoring. Such technologies enable early warning systems and allow for more effective coordination during crisis situations, saving lives and reducing the damage caused by disasters.

5. Satellite communications for remote connectivity

Satellite communication has played an important role in ensuring connectivity, especially in far-flung regions of Thailand, which is involved in disaster management and agriculture. Expanding satellite-based communications between the government, academia, and industry has provided Thailand with internet access, phone services, and other telecommunications to some of its more underserved regions.

Support is made in Thailand toward improving the digital divide in the rural areas by the MDES in collaboration with NSTDA toward the development of satellite communications. Connectivity in areas where traditional telecommunications infrastructure is not available was able to be provided through satellite communication systems.

Kasetsart University and Chulalongkorn University, for instance, have collaborated with the government and industries to design solutions using satellites to connect rural internet. Their research is mainly in enhancing satellite networks, data transfer speed, and communication reliability in remote areas.

Private companies like Siam Technology and Siam Space have made contributions to develop and commercialise the satellite communication systems. Space-based solutions go to the most remote areas, connecting people to better education, access to healthcare, and economic empowerment.

6. Ignite programme: igniting entrepreneurial spirit in space technology

The Ignite Program is one of the many initiatives by Thailand in efforts to foster an entrepreneurial mindset amongst the country's university students, fresh graduates, faculty members, and researchers. The program challenges these individuals to think creatively and push forward innovative solutions that will possibly lead to the development of new space technologies.

Inspire creativity for potential innovation in satellite systems, remote sensing, and space communications: the core of the Ignite Program. It does this through a range of activities to engage participants with academic roadshows introducing students and researchers to the potential of space technology and innovation and making them aware of the possible benefits and applications of space in different sectors.

- Network Membership Recruitment enables participants to connect with industry professionals, researchers, and experts from other institutions to foster a collaborative supportive network.
- Technical Activities, such as UAV testing, give hands-on experience with the most recent space technologies.
- Internship programmes will enable students to get some experience in the space industry practically by working together with professionals and exposing them to the field.

The Ignite Program enables the creation of an innovation culture and entrepreneurship through these activities. It brings in skills, knowledge, and resources to help young talents pursue their careers in space technology and related fields. The programme supports the next generation of space entrepreneurs who play a crucial role in growing Thailand's space industry.

7. Lift-off programme: space startups

The objective of the Lift-Off Program is to empower the youngest entrepreneurs and new companies in Thailand by scaling them up, refining their operation, and making them nimbler and self-reliant. It brings together resources and mentorship meant to help overcome the main challenges startups face, but particularly those in the space sector. This programme is critical for supporting early-stage entrepreneurs in the process of taking innovative ideas to market as viable businesses. The key support offered by the Lift-Off Program is the following:

- Workspace, Tools, and Data Access: Startups can work in fully equipped spaces with access to essential tools and data for developing their technologies, especially space-based systems and satellite applications.
- Business Skills Training: The programme, in collaboration with University Business Incubation Centers, offers training in business management, marketing, and financial strategies to enable startups to refine their operations and scale their businesses properly.
- Professional Networking: This provides the entrepreneurs with a chance to interact with industry professionals, potential partners, and investors, who can help them grow their businesses and form important relationships.
- Product Development, Research, and Marketing Strategy Mentorship: Start-ups are mentored and walked through on how to advance their product and develop great marketing strategies in a move that ensures whatever they give the space will be in direct competition.
- Venture Capital Access: It brings entrepreneurs into contact with the potential investors who would invest in promising space technologies and innovative solutions.

The Lift-Off Program assists the startups to fine-tune their business models, test their products, and eventually succeed with a comprehensive suite of resources and support. This, in turn, ensures the promotion of the space sector in Thailand and effective commercialisation of new technologies.

8. ΔV (Delta V) programme: developing matured SMEs

The ΔV programme is specifically set to aim at the SMEs that occur in Thailand. They indeed have a stable business already but were yearning and looking forward to growing fast. This goal of such a programme called the Delta V Program aims at empowering them to grow the networks with an improved operation efficiency which induces innovation into space issues.

The ΔV Program assists small and medium enterprises (SMEs) build up their business by accelerating the growth process with such benefits:

- Consultations on Research and Development: The firm is exposed to advisory services to support it in developing its capability on R&D, satellite communications, remote sensing, and space systems engineering.
- Testing and Laboratory Service: SMEs are provided with the latest testing facilities and laboratories to fine-tune their products and ensure that they meet international standards.
- Training Programs: Companies are provided with specialised sessions on the latest trends in space applications.
- Strategic Partnerships and Joint Ventures: The programme allows for partnerships and joint ventures that allow SMEs to work on large-scale projects, thus opening new business opportunities and expanding their reach.
- Venture Capital Opportunities: Delta V connects SMEs with investors who are looking to fund innovative space technologies and commercial space solutions. The Delta V Program provides access to resources while it also gives SMEs the means of scaling up their business, joint projects, and partnerships so that they can engage in business in this highly competitive field of the space industry.

D. Indonesia

Indonesia is leading the way on collaboration between industry, academia, and government, most notably in its rapidly expanding space sector. These collaborations have enabled the country to advance technologies, improve infrastructure, and tackle national issues such as disaster management, agriculture, and telecommunications. With RIM Program, Pusat Kolaborasi Riset, and strategic alliances with international space agencies, there has been an environment conducive to innovation, making Indonesia a major player in the Southeast Asian space industry.

1. The RIM programme: fostering collaborative research and development

The RIM programme was known as Riset Insentif Indonesia Maju or, more clearly stated, Research Incentives in Indonesia. In promoting a collaborative research and development for universities, government units, and private sectors across the republic of Indonesia, RIM is part of that effort. Joint projects conducted should contribute towards strategic national priorities with which include space technology, disaster management, and green technologies. The programme shall achieve this through shared funding and incentives for impactful research projects.

This partnership is an important move toward the acceleration of technology advancement and the transfer of technology from academia to the private sector. For example, this programme has culminated in some major research findings on remote sensing technology, which plays a critical role in natural disaster monitoring, environmental protection, and city planning. Such bodies involved in this area include coordination between RISTEK the Ministry of Research and Technology and BRIN Badan Riset dan Inovasi Nasional, hence giving the sector a lot to focus on.

2. Pusat kolaborasi riset (research collaboration center)

The Pusat Kolaborasi Riset, which translates to Research Collaboration Center, has been established in collaboration with BRIN and other institutions of learning. It was formed to further boost the roles that universities can play in space technology development. In its work, it presents itself as an interdisciplinary research hub with good networking amongst the university centers and the private sectors. These partnerships focus on strategic areas that include space science, disaster management, and agricultural technologies. Academic institutions such as Universities Indonesia (UI) and Institute Technology Bandung (ITB) can take up the Pusat Kolaborasi Reset for research leading to innovation in satellite communications, remote sensing, and space exploration. This collaboration could lead to the design of small satellites for Earth observation and create space-based solutions to track natural resources and changes within the environment. The partners from the private sector, meanwhile, contribute to commercialising these technologies so that research would not go unrewarded by practical application.

3. BRIN and industry collaboration for technology transfer

BRIN plays a pivotal role in industry–academia collaboration in Indonesia's space sector. By facilitating private firms' partnerships, BRIN has expedited the pace of developing and applying space-based technologies to local as well as global issues. For instance, IndoSat is one of Indonesia's biggest satellite communication operators that engages BRIN, ITB, and other universities to design satellite systems and telecom infrastructure. Those collaborations brought the development of communication satellites that support improving internet connectivity in the most remote parts of the country. Meanwhile, technology transfer agreements also ensure that innovative ideas developed at the academic institutions are successfully commercialised and transferred into the market.

It can further cover collaborative efforts by BRIN in partnership with industry toward satellite imagery-based disaster management system development to monitor, forecast, and coordinate early action during a disaster by incorporating geospatial information and data. This aspect between the government, academy, and industries is more necessary for guaranteeing application through space technologies to contribute positively towards improving the disaster-resilience profile in Indonesia.

4. Space and satellite development programmes for disaster management

Indonesia has a significant vulnerability to natural disasters such as earthquakes, tsunamis, and floods. It has therefore made significant investments in space-based disaster monitoring. With government agencies, universities, and private companies working together, the country has developed sophisticated systems for using satellite data in disaster prediction and response.

GISTDA and BRIN have spearheaded several national projects that are fully integrated with satellite-based technology for real-time monitoring during disasters. Indonesian universities such as UGM and ITS have collaborated with the latter to develop geospatial data processing tools supporting the country's disaster preparedness and response.

Private companies, for example, Telkom Indonesia, partnered with such research institutions and collaborated to develop satellite communications with real-time data to deliver information during disasters that impact government agencies and disaster relief teams. Through such partnerships, Indonesia's ability to respond to a disaster has improved, and the impacts of such disasters on the country have been mitigated while augmenting the country's systems that deal with disasters.

5. Collaboration with international space agencies

Indonesia has established not only domestic partnerships but also international collaborations to support its space capabilities. These collaborations include partnerships with the global leading space agencies, namely NASA, the European Space Agency (ESA), and JAXA, Japan Aerospace Exploration Agency. Through these organisations, Indonesia gains satellite technology, expertise, and data-sharing initiatives that give the country a significant push in its space infrastructure. For example, NASA collaborates with BRIN and several Indonesian universities for data exchange on satellites and researches space. These collaboration projects have helped develop some remote sensing technologies that will help Indonesia monitor climate change, agriculture, and forests. In addition, being part of regional initiatives, such as the ASEAN Space Cooperation Program, has consolidated its relations with neighboring countries. This collaboration will emphasise disaster risk reduction, agricultural monitoring, and environmental protection, in order for Indonesia's space capabilities to be in alignment with the regional efforts on shared challenges.

E. Malaysia

Malaysia has made outstanding strides in space capability enhancement through collaboration that combines industry, academia, and government. Such partnerships have played a vital role in enabling the country to advance its space technology, satellite development, and telecommunications, where it can take on national issues such as disaster management, agriculture, and sustainable development. The strength of these sectors has, in turn, been utilised by Malaysia to create an ecosystem that fosters innovation, nurtures research and development, and encourages the commercialisation of space technologies. A few examples of such fruitful collaborations amongst industry, academia, and government in Malaysia include:

1. Angkasa-X initiative

The Public-Private Collaboration toward the Development of Satellite Malaysia embarks on the Angkasa-X Initiative, which is an industry–government–academia partnership geared toward developing, launching, and owning satellites. This effort is a collaboration between the private entity Angkasa-X Innovation Sdn Bhd with the National Tech Association of Malaysia (Pikom), the Malaysia Space Agency (MYSA), Malaysia Digital Economy Corporation (MDEC), and University Sains Malaysia (USM).

The Angkasa-X Initiative will be concentrated on the launch of small satellites and Earth observation satellites, positioning Malaysia at the forefront of the global space economy. The initiative will be leveraged by USM's strength in space technology through its Space Science and Technology Research Centre, which conducts research on satellite systems, space-based data analytics, and communications technologies. These universities play a very important role in providing the academic research and talent required to develop the next-generation satellite technologies.

The private sector, through Angkasa-X in partnership with Pikom, provides the operational and business development support necessary for commercialising space technologies. This partnership also helps MDEC in its bid as it provides funding and advisory services in support of the growth of the digital economy in Malaysia, including the space technology sector.

2. MySAT programme: nurture the next generation of satellite technologists

The MySAT Program is government-sponsored, intended to strengthen local capability in satellite technology. The MOSTI-USM-led MySAT will aid in creating a quality workforce to design, develop, and launch small Earth observation satellites for telecommunications as well as for scientific research.

It was reported that USM's Space Lab has been engaged in designing nanosatellites and picosatellites under the MySAT program. Apart from the above, the programme also collaborated with industry players, such as SpaceIn Sdn Bhd and ST Engineering. These entities back the programme with their manufacturing capabilities, satellite testing, and communications technologies. With this collaboration, MySAT-1 was produced, which happens to be Malaysia's very first student-built satellite that flew successfully under this programme to ensure the next generation of satellite technologists experiences it firsthand.

The MySAT Program also aims at commercialising satellite services and space data with the support of research activities in the universities to contribute to Malaysia's space industry and the country's digital economy growth. It's a synergistic mix of academic research, government funding, and private sector expertise that allows the MySAT Program to create a healthy ecosystem for fostering young talent while supporting the capability of the country in terms of developing its satellites.

3. Space innovation and knowledge park (SKP): a startup accelerator and SME hub

One of the key initiatives in Malaysia is to support startups and small and medium-sized enterprises, while also driving the growth of Malaysia's thriving space technology sector. As it sits on the campus of University Technology Malaysia (UTM), the SKP also serves as a platform for industry–academia collaboration and provides necessary resources to help entrepreneurs and startups in the space sector grow more quickly.

Through this programme, UTM teams with industry partners like Satellite Global, SSTL or Surrey Satellite Technology Limited and other companies in the local space technology industry. Such a connection provides startups and SMEs working with the satellite industry access to research and development consultations as well as laboratory services, which in turn help business developments. Through such a programme, the new business sharpens their satellite products, earth observation solutions, and their telecommunication systems that end up being ready for market.

The SKP also educates in the fields of space systems design, satellite communications, and remote sensing. Additionally, the government agency has partnership programmes that allow startups to get access to network opportunities and possible venture capital funding through partnerships with MDEC and other government agencies. Incubating innovation and providing hands-on assistance, the SKP plays a pivotal role in the growth of Malaysia's space industry and boosts its place in the global space economy.

4. Satellite-based disaster management

Malaysia has used space technology to reduce its vulnerability to natural disasters, especially floods and landslides. Government agencies, universities, and private sector companies have collaborated to develop satellite-based disaster management systems that improve early warning systems, disaster monitoring, and response coordination.

It engages them along with the Malaysia National Security Council (MKN) in cooperation with University Technology Malaysia (UTM) and University Kebangsaan Malaysia (UKM). Universities, such as UTM and UKM amongst the ones enlisted, are supportive because they are engaging in a cooperative role in processing geospatial data, analysing the images from satellites, and advancing technologies for disaster management.

Private sector companies, such as SSTL and ST Engineering, in association with these institutions, provide satellite communication systems, analytics platforms, and cloud computing solutions, which help in real-time monitoring of vulnerable disaster-prone areas. With satellite data and AI-predictive models, Malaysia has faced better disaster resilience and time taken in responding to the disasters and saved more lives and lower economic losses when natural disasters strike.

5. Space business incubators and collaborations for space startups

The Malaysian government has also put significant efforts into incubating the growth of space-related startups via a mix of space business incubators and collaborations between the universities and the private sector. One of the means by which the country is pushing for the intensification of commercialisation of space technologies and applications in space is through MDEC's Space Entrepreneurs Program.

University Technology Malaysia (UTM) and USM collaborate closely with MDEC and industry partners to create business incubators, where young entrepreneurs have the room to develop and scale space-related products. Such incubators provide important services including business mentoring, funding opportunities, and access to markets for start-ups focused on satellite communications, Earth observation, and space-based analytics.

Through the MYSA, the government is further actively pursuing linking startups with venture capitalists as well as other private investors who specialise in space ventures. With the support by both research and commercialisation, Malaysia will speed the development of a competitive space industry that is able to vie on a global scale space market.

F. Philippines

Some of the most significant examples of collaboration between industry, academia, and government in the Philippines are the following:

1. The Philippine Space Agency (PhilSA) and government collaboration for satellite data utilisation

The Philippine Space Agency (PhilSA) is one of the key initiatives. It was established in 2019 and is playing a central role in advancing the country's space development efforts. It collaborates with the government on the use of satellite data. As the national agency responsible for research, development, and commercialisation of space technology, PhilSA collaborates with various government agencies, universities, and private organisations to utilise satellite data for disaster monitoring, environmental management, and telecommunications, amongst others.

- Department of Agriculture: PhilSA engages the Department of Agriculture in the development of crop productivity and agriculture by using data provided through remote sensing and satellite imaging. It helps in judging the crop health, condition of the soil, and water supply, which informs better decision-making for the farmers.

- Department of Environment and Natural Resources (DENR): In cooperation with PhilSA, DENR uses satellite data in monitoring the forests, land use mapping, and environmental hazard detection, like illegal mining. Such collaboration ensures that the country's natural resources are preserved and the progress towards sustainable development is made.
- National Disaster Risk Reduction and Management Council (NDRRMC): PhilSA collaborates with NDRRMC to avail the satellite-based disaster management tools such as real-time flood monitoring and earthquake damage assessment.

2. Academic collaboration: research and development with Philippine universities

The academic institutions, through their universities, provide crucial players for the efforts of the Philippines in their R&D of space for future growth and development; it ensures that sustainable innovations occur. Some of the universities that join in the collaboration with PhilSA, industry partners, and international space agencies in furthering space technology as well as developing the satellite capability of the country include UP, DLSU, and Ateneo de Manila University.

- University of the Philippines (UP): The College of Engineering and UP Diliman College of Science are amongst the research and development groups for satellite technology and remote sensing applications in the country. These research collaborations aim to enhance the country's capabilities in Earth observation and geospatial data analysis. Furthermore, UP is involved in capacity-building programmes that train students and professionals in space technology and satellite communications.
- De La Salle University (DLSU): DLSU is the other important organisation that joins forces with PhilSA, together with the private sector, in its space-related research. At the same time, this university specialises in satellite engineering, data analytics, and the small satellite system in both communications and remote sensing missions.
- Philippine Commission on Higher Education (CHED): CHED collaborates with PhilSA and universities for space science education, such as scholarships and funding research programmes related to space. CHED also assists the universities in developing courses and research programmes in satellite engineering and space communications.

3. Collaboration with industry: satellite services and technology commercialisation

The private sector plays an important role in the Philippines' space ecosystem through the commercialisation of satellite data, the development of telecommunications infrastructure, and the creation of space-based applications. Globe Telecom, PLDT, and Philippine Long Distance Telephone Company (PLDT) have partnered with PhilSA and universities to implement satellite communication systems and remote sensing technologies for national development.

- Globe Telecom: Globe Telecom works with PhilSA to develop satellite-based broadband services in remote areas. Through this partnership, Globe helps provide telecommunication services to underserved regions, promoting digital inclusion and improving connectivity for education, healthcare, and businesses.
- PLDT: PLDT is working with PhilSA to develop satellite communications in terms of disaster resilience and urban planning. Through space technology, PLDT boosts the capacity for reliable internet connectivity in the countryside and during emergencies.
- Telesat: Telesat is teaming up with PhilSA and local universities to support research in satellite communications and space technology. These collaborations are aimed at telecommunications infrastructure, giving the commercial and government sectors the most advanced satellite solutions.

4. International collaborations for enhancing space capabilities.

A satellite programme by the name of Philippine has engaged in international collaboration with certain countries, for example, Japan, the United States, and the Republic of Korea, as some of its partners through which it acquires satellite-related technology, access to data for research, and technical man-hours that fortify the Philippine space capacity.

- Japan Aerospace Exploration Agency (JAXA): The Philippines has closely collaborated with JAXA in the areas of development and data sharing on satellite technology. Due to such cooperation, JAXA has provided technical support which has enabled the country to enhance its capabilities in disaster monitoring and protection of the environment through its Philippine Earth Observation Satellite (PhilSAT) programme.
- United States: The NASA–Philippines partnership focuses on satellite data sharing and climate research. The collaboration provides the Philippines with access to NASA's Earth science satellite data for climate change monitoring and disaster management. It also supports the development of space systems that enhance the country's capabilities in environmental monitoring and agriculture.
- Republic of Korea: The Philippines and the Republic of Korea have been partners in space research and technology transfer, especially on small satellite systems and utilisation of satellite data. Through this cooperation, the Philippines was able to develop its small satellite programmes and enhance its space data infrastructure.

5. Space technology for agricultural monitoring and smart farming

One of the most impactful applications of space technology in the Philippines would be through agriculture, particularly with monitoring through satellites and improvement of crop management to reduce losses as well as enhance food security. Remote sensing and geospatial data application for precision farming are supported by government agencies, universities, and private sectors. PhilSA works with the Department of Agriculture, and other universities such as UP and DLSU to integrate satellite data into crop monitoring, detection of pests, and assessment of soil moisture. This allows optimising irrigation systems and enhancing yields of crops through satellite solutions. DA partners with private sector companies on the development of satellite-based solutions to be able to provide actionability to farmers regarding crop health and even weather patterns. This ability allows farmers to have instant real-time data for their more informed decision-making purposes. The collaboration between government, academia, and industries brings this sector closer to gaining stronger resiliency and in bringing food security to this developing nation by tapping satellite-based data through which farming can be highly productive in resource utilisation.

G. Cambodia

Developments in the space-related area of Cambodia are getting new momentum, and might develop as a model example of future growth:

1. Cambodia's National Space Programme (CNSP): government-led initiative with industry and academia collaboration

The Cambodia National Space Programme is one of the main initiatives implemented by the Royal Government of Cambodia to develop space technology in the country. Under the programme, satellite systems and remote sensing technologies are being developed along with data applications derived from space. CNSP is a concerted effort by government agencies, academic institutions, and industry players aiming to advance Cambodia's position in space technology.

The Ministry of Post and Telecommunications (MPTC) and the Cambodian Space Committee (CSC), which oversees CNSP, are key contributors to keeping the country's space agenda on track and in line with national priorities. The government funds, guides on policy, and provides regulatory frames for the initiative. The Royal Government has been very enthusiastic about the use of space technology in disaster risk management, agriculture, environmental monitoring, and telecommunications.

Cambodian universities like the Royal University of Phnom Penh, RUPP, and Institute of Technology of Cambodia, ITC, were actively engaged in the country's effort to develop new generations of space scientists and engineers. Such institutions have joined hand with the government to come up with satellite technology programmes, curricula on space science and remote sensing research. Space technology and satellite communications can be found in the curriculum that RUPP offers; ITC, on the other hand, has on its engineering programmes, such as telecommunications and space systems.

Industry partners such as Telecom Cambodia and private sector firms in the telecommunications and satellite sectors are working with CNSP and academic institutions to help launch space technologies and telecommunications infrastructures. Such companies would be very crucial in developing satellite communication systems for broadband internet and boosting connectivity in rural and underserved regions. Their involvement ensures that space-based technologies have a more concrete impact on Cambodia's economic development.

2. Agricultural monitoring via remote sensing: private sector

Cambodian agriculture is highly significant for the economy of this nation. Crop monitoring and irrigation have been getting better because the remote sensing technology has been of considerable use to the country especially over soil health. The Cambodian government utilises satellite images partnered with the universities and the private firms to further advance precision agriculture.

MAFF works together with the CNSP in integrating satellite data into national agricultural strategies. Its collaboration with international organisations has led to improving agricultural productivity through the application of space technologies such as crop health monitoring, reporting of pest outbreaks, and optimising water usage.

RUPP and ITC collaborate with the government to conduct research in remote sensing for monitoring agriculture. The universities provide scientific expertise and data analysis as well as research on how to utilise satellite data in estimating crop yield, drought, and infestation conditions. They help develop the technical skills needed in analysing and interpreting satellite images for agricultural purposes.

Private companies, such as Telecom Cambodia, are integrated by satellite-based services into agricultural practice. It provides satellite communications infrastructures where farmers in rural areas will be able to obtain real-time data, which they can use as a basis for their management decisions on crops. Through this collaboration, it's hoped that food security can be improved, crop management enhanced, and the sustainable production of crops assured through the agricultural sector in the country.

3. Disaster management: space technology for crisis response

The country is very prone to natural calamities such as flooding, droughts, and typhoons. To make the country more disaster resilient, the government has adopted space technology in providing early warning systems, disaster monitoring, and crisis management. It encourages partnerships with academic institutions and industry partners in the integration of satellite data into disaster management systems.

This was collaborated by the Cambodian National Committee for Disaster Management with CNSP to effectively implement the use of satellite data in disaster risk reduction and early warning. The government acknowledged the significance of using space technology in coordinating disaster preparedness and response. For example, images taken from satellites monitor the flood-prone areas while following the storm system movements, which assess the area before the occurrence of any possible disaster.

RUPP and ITC conducted disaster risk management studies, using remote sensing together with GIS to observe and analyse the impacts caused by natural disasters. In this way, they could present their scientific expertise in the form of how satellite data may be incorporated into their disaster management systems to react more promptly and effectively towards natural hazards.

Telecom Cambodia companies are engaged in satellite communications with the government agencies and universities that provide a very crucial service during crises- the data analysis platforms. With such collaborations, the government will have the means to respond within no time, muster necessary resources, and provide timely aid to affected communities. Integration of satellite communication and data sharing is therefore critical for improving Cambodia's disaster resilience.

4. International collaboration in space science and technology

Beyond its domestic partnership, Cambodia also engaged with international collaboration to enhance the space capability. It reached an agreement with Japan Aerospace Exploration Agency (JAXA) and the United States. Through such collaboration, access to satellite data, space technology, and research capabilities were facilitated. All these collaborations can make a positive contribution toward the enhancement of the Cambodian space programme and its national infrastructure in space.

Through the CNSP, the Cambodian government signed agreements with Japan and other countries, including the United States, for technology transfer and sharing satellite data for purposes of disaster management, agriculture, and environmental protection. The agreements are critical for the country's continuation in the development of its space sector.

RUPP and ITC collaborate with JAXA and NASA on joint research projects on remote sensing and satellite applications. These collaborations have been of great benefit to the universities of Cambodia in accessing cutting-edge space technology and research resources to develop their capacity in space-related curricula and innovation.

Telecom Cambodia and other private companies benefit from these international collaborations by gaining access to advanced telecommunications systems and space data infrastructure, which are important for improving broadband services and connectivity across the country.

H. Lao PDR

Lao PDR is now striving to build its space capabilities through a collaboration of industry, academia, and government. Being a newcomer in the space sector, Lao PDR now focuses on how to use space technologies to develop its nation and some critical challenges that it needs to address such as disaster management, agriculture, and telecommunications. With all these resources from different sectors, Lao PDR has a huge potential for building a sustainable and innovative space ecosystem. Some of the successful initiatives of industry, academia, and government collaboration in Lao PDR are depicted below in terms of the influence on the country's space sector.

1. Lao PDR Space Research Program (LSRP): government-led collaboration for satellite development

The Lao PDR Space Research Program (LSRP) is one of the most crucial initiatives aimed at improving the country's space capabilities. This programme focuses on satellite technology, remote sensing, and exploitation of space-based data for national development purposes. It requires robust collaboration between the government, universities, and the private sector. The LSRP is overseen by the Ministry of Post and Telecommunications (MPT), ensuring that space initiatives are aligned with national development objectives.

The Lao government has also made investments in satellite communications and remote sensing systems in pursuit of better telecommunications in the countryside and disaster management. Universities can be mentioned, as such that involve research and development space technology. The examples include NUOL participating in research and development with the government while collaborating on educating the future generation of scientists and engineers who would be capable of assisting with developing satellite technology as well as its applications in space. Most of this programme is sponsored by the private sector for its provision of telecommunications infrastructure and satellite services. In particular, companies such as Lao Telecom and SkyNet cooperate with the authorities and institutions to assist with the launch of satellite technologies offering broadband Internet and telecommunication services for deprived regions, creating digital opportunities in remote and faraway parts.

2. Agricultural monitoring and precision farming using remote sensing

Lao PDR' agriculture accounts for much of the economic sector; therefore, applying satellite technologies has become part of an increasing trend and contributes toward crop monitoring efficiency, optimal irrigation management, and consequently higher agricultural yields. The collaboration between the Lao government, universities, and private companies is integrating remote sensing technologies into agricultural practices to address food security and climate change challenges. The Ministry of Agriculture and Forestry (MAF) works with the Lao National Agriculture and Forestry Research Institute (NAFRI) and the MPT to use satellite imagery and remote sensing data in monitoring crop health, soil conditions, and water resources. These initiatives help the government promote sustainable farming practices and improve food security across the country.

Universities such as the National University of Lao PDR (NUOL) work with the government and private sector to explore ways in which satellite technology can enhance agricultural practices. In fact, research projects are implemented to find out how the remote sensing data can be used to check the soil moisture, the existence of pest infestation, or growth of crops. This will enhance agriculture in Lao PDR to be more responsive to climate change and more efficiently use resources.

Other private companies like Lao Telecom and SkyNet play an important role in offering satellite-based services, which will help support precision farming. The companies assist in providing the satellite data to the farmers to be able to monitor weather patterns, assess crop health, and manage irrigation systems efficiently. Through the inclusion of satellite communications in the agricultural sector, Lao PDR is going great lengths in embracing the technology of adopting sustainable agricultural practices.

3. Disaster management programme: use of satellite data in the early warning and risk reduction

Different kinds of natural disasters, including floods, droughts, and storms, leave Lao PDR vulnerable. In dealing with this condition, the country employed satellite technologies that can support the reduction of risks posed by disaster conditions and early warning systems. Coordination between the government, academic institutions, and the private sector has really enhanced the capacity of Lao PDR for the monitoring and responses that need to be conducted following disasters.

The MoNRE of Lao PDR collaborated with MPT to monitor the areas that are prone to floods and monitor storm systems through satellite data. The Lao government integrated remote sensing data into its disaster management system, which has helped to predict and mitigate the effects of natural disasters. It gives early warnings on floods and droughts, thereby increasing the preparedness of the country against disasters.

NUOL and other universities in Lao PDR are conducting research into the use of satellite data for disaster resilience. In close collaboration with government agencies and international organisations, the universities contribute to developing geospatial systems that can be applied for disaster monitoring, early warning systems, and damage assessment after a disaster.

Lao Telecom and SkyNet, being private companies, provide the means for the speedy delivery of data that would otherwise have been sent with regards to a disaster. Lao Telecom and SkyNet partner with the government agencies and academicians so that in cases of a disaster, response teams have real-time information, hence giving them a window of action to react accordingly in a short period of time.

4. International collaboration in space technology and telecommunications

Other than domestic partnerships, Lao PDR also tries to develop and enhance its space capability in international cooperation. With the Japan Aerospace Exploration Agency (JAXA), China National Space Administration (CNSA), and the United States, the country gained high-tech satellite access, data-sharing agreements, and technical assistance.

The Lao PDR government has collaborated with JAXA, CNSA, and other space agencies on satellite systems for disaster management, environmental monitoring, and telecommunication. Such collaborations facilitate technology transfer, which helps Lao PDR build its own satellite systems and create the infrastructure needed to apply space-based technologies.

Universités Lao PDRiennes like NUOL are now engaging international actors to advance the frontiers of space education and research in the country. Students and researchers are therefore gaining easy access to the latest in space technologies and data that helps foster the development of the country's space sector.

International collaborations also support Lao PDR' private firms, through such means as utilisation of telecom infrastructure, satellite services, and space data, which assist in improving the connectivity throughout the country digitally. Examples include Lao Telecom trying to find ways to better communicate using the satellite and improve the Internet services in those not well-advanced areas with respect to digital inclusion and economic progress.

I. Timor-Leste

Timor-Leste, being a developing country, is now promoting collaboration amongst industry, academia, and government to build its science, technology, and innovation (STI) environment. Such partnerships are aimed at finding national solutions to issues that may contribute to sustainable development.

The National Institute of Science and Technology (INCT) is at the center of coordinating STI efforts in Timor-Leste. It collaborates with 18 higher education institutions and other stakeholders to encourage scientific research and innovation. For instance, INCT collaborated with the Pacific States Forum service of the Organisation of African, Caribbean and Pacific States, funded by the European Union, to implement feasibility studies on STI policies as well as establishing a national digital repository. The above projects, which were initiated in June 2021 and culminated in June 2022, point out the central role of STI policies in shaping this nation's future.

The higher education institutions are part of Timor-Leste's STI ecosystem. Some of them, like the National University of Timor-Leste, are actively involved in research and development activities; most of them, along with government agencies and international organisations, address problems at the local levels to achieve national goals. For instance, some of the projects undertaken by UNTL included those on sustainable agriculture, renewable energy, and environmental conservation, aligned with the development priorities of the nation.

More and more of the private sector of Timor-Leste is engaging with STI initiatives. Although this industry–academia–government partnership is still developing, new initiatives are emerging to fill the gap between academia and industry, with this collaboration aiming to turn scientific research into a practical application that fosters innovation and economic development. For instance, local companies have collaborated with academic institutions to develop environmentally friendly agriculture and ecotourism in the country to exploit its natural resources.

International cooperation also focuses on promoting the STI capacity of Timor-Leste. It has been interested in partnerships with countries like Indonesia and Australia to enhance economic and social development. These partners shall share resources and experience, which shall be used to address their challenges and spur regional growth. International organisations are also engaged in ensuring that the lives of Timor-Leste citizens have improved, especially educationally, health-wise, and in infrastructure development.

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Chapter 6

Developing a Scheme for Talent Development and Training by Japanese Universities and Research Institutions in ASEAN

6.1 Current Condition

A. Singapore

Japanese universities and research institutions have established a comprehensive scheme to foster talent development and strengthen research collaboration with Singapore. The initiative is aligned with Singapore's strategic focus on innovation, sustainability, and technological leadership in the region. Below are the key programmes under this scheme:

1. Joint Degree and Research Programmes

Japanese universities collaborate with Singaporean institutions to offer research-focused degree programmes and projects. These initiatives aim to enhance academic and professional capacities in cutting-edge fields such as space technology, sustainability, and artificial intelligence.

- Programme Structure: Students pursue joint degrees under the supervision of Japanese and Singaporean faculty members.
- Focus Areas: Advanced urban planning, satellite communications, environmental monitoring, and precision agriculture.
- Benefits: Participants receive funding for tuition, research activities, and short-term study opportunities in Japan, fostering international academic collaboration.

2. Visiting Scholar Programme (1–3 Months)

This short-term programme invites Singaporean researchers to Japan to engage in collaborative research at Japanese institutions.

- Eligibility: Researchers from universities and research institutions in Singapore with a strong research proposal.
- Support: Travel expenses, accommodation, and a stipend are provided.
- Goals: To enhance research skills, build international networks, and create opportunities for joint publications and projects.

3. Post-Doctoral Fellowship Programme

Designed for early-career researchers from Singapore, this programme allows participants to conduct advanced research in Japan.

- Key Features:

    - Competitive salary packages and research funding.
    - Opportunities to work alongside leading Japanese experts in fields like GNSS, satellite engineering, and quantum communication.
- Outcomes: Fellows contribute to impactful research publications, enhance technical expertise, and explore pathways to academic or industrial careers.

4. Internship and Industry Collaboration Programmes

These programmes bridge academia and industry, providing Singaporean students with hands-on training in Japanese industries and research facilities.

- Duration: Internships typically last 3–6 months.
- Areas of Focus: Satellite technology, environmental solutions, IoT, and advanced manufacturing.
- Support: Interns receive stipends to cover living expenses and travel costs.
- Impact: Participants gain practical industry experience, fostering employability and industry-academia linkages.

5. Scholarships for Advanced Studies

Japanese universities, in partnership with Singaporean organisations, offer scholarships for students and professionals to pursue advanced degrees in Japan.

- Scholarship Features:
    - Covers tuition fees, living expenses, and research costs.
    - Focuses on fields such as space technology, sustainability, and data science.
- Target Group: High-potential students and professionals looking to deepen their expertise through specialised programmes.

6. Collaborative Workshops and Training

Workshops and training programmes are co-organised by Japanese and Singaporean universities to develop skills in niche areas.

- Themes: Disaster risk management, satellite data analysis, and sustainable urban planning.
- Mode: Hybrid (in-person in Japan and virtual sessions for broader participation).
- Participants: Faculty, students, and professionals in Singapore.

7. Capacity Building for Advanced Research

Aimed at fostering innovation and leadership, this initiative supports Singaporean researchers in accessing Japanese labs and technology.

- Research Infrastructure Access: Use of Japan's advanced satellite technology labs and high-performance computing facilities.
- Technology Transfer: Collaboration on applying Japanese innovations to Singaporean contexts.

8. Quantum Satellite Research Collaboration

As part of a strategic focus on secure communications, this programme supports research into Quantum Key Distribution (QKD) technologies. Japanese research institutes and Singaporean universities collaborate to enhance QKD systems for financial and defense applications. Opportunities for joint experiments and publications to advance the field.

B. Viet Nam

Japanese universities and research institutions have initiated comprehensive programmes to foster talent development and enhance research collaboration with Viet Nam. These initiatives are designed to address Viet Nam's growing need for advanced skills in space technology, disaster management, and environmental monitoring while aligning with Japan's expertise in these areas. Below are the core programmes under this scheme:

1. Joint Research Degree Programmes

Japanese and Vietnamese universities collaborate to offer degree programmes emphasising research in space and environmental sciences.

- Programme Highlights:
    - Joint supervision by Japanese and Vietnamese faculty members.
    - Research conducted primarily in Viet Nam, with short-term study opportunities in Japan.
- Focus Areas: Disaster resilience, satellite technology, environmental monitoring, and precision agriculture.
- Scholarship Support: Covers tuition, research expenses, and travel grants for selected candidates.
- Outcomes: Enhances research capacity in Viet Nam while strengthening academic ties between the two nations.

2. Visiting Researcher Programmes

Short-term programmes (1–3 months) that allow Vietnamese researchers to collaborate with Japanese experts in their respective fields.

- Eligibility: Open to faculty and researchers from Vietnamese universities and research institutions.
- Support: Includes travel expenses, accommodation, and a stipend to ensure participants can focus on their work.
- Goals:
    - Knowledge exchange and skill enhancement.
    - Development of collaborative networks leading to joint publications and long-term partnerships.

3. Post-Doctoral Fellowship Opportunities

Japanese institutions offer post-doctoral positions for recent Ph.D. graduates from Viet Nam.

- Features:
    - Competitive salaries, research funding, and relocation support.
    - Access to Japan's advanced labs and technology for space research and disaster management.
- Focus: High-impact areas such as Synthetic Aperture Radar (SAR) technology, climate adaptation research, and advanced data analytics.
- Outcomes: Equips participants with cutting-edge expertise, enabling them to contribute significantly to Viet Nam's academic and industrial advancements.

4. Industry-Linked Internship Programmes

To strengthen academia–industry collaboration, Japanese institutions provide internship opportunities for Vietnamese students and young professionals.

- Duration: 3–6 months in Japanese industries and research centers.
- Focus Areas: Satellite development, environmental monitoring, GNSS, and renewable energy applications.
- Support: Stipends to cover living expenses and travel costs.
- Benefits: Hands–on training, exposure to advanced technologies, and improved employability in space-related industries.

5. Scholarship Programmes

Scholarships are available for Vietnamese students and professionals to pursue advanced studies in Japan.

- Key Features:
    - Tuition, living expenses, and research funding covered.
    - Focused on critical areas such as space technology, sustainability, and AI applications.
- Collaboration: Programmes aligned with Viet Nam's national development priorities and supported by Japanese institutions.
- Target Audience: Promising students and professionals with aspirations for academic and research excellence.

6. Technical Training Workshops

Japanese universities and research organisations conduct technical training workshops in collaboration with Vietnamese institutions.

- Workshop Themes: Satellite data analysis, disaster risk reduction, radar imaging technologies, and urban planning.
- Format: Hybrid delivery, combining in-person training in Japan with virtual sessions for wider participation.
- Participants: Students, researchers, and professionals from Viet Nam.

- Objectives:
    - Skill development in niche areas.
    - Practical application of satellite and remote sensing data in local challenges.

7. Collaborative Satellite Development Projects

Joint satellite development programmes between Japan and Viet Nam aim to build technical capacity and foster innovation.

- Projects:
    - Support for Viet Nam's radar satellites, such as LOTUSat-1 and LOTUSat-2.
    - Training Vietnamese engineers and scientists in satellite design, launch, and operations.
- Impact:
    - Strengthened Viet Nam's autonomy in satellite technology.
    - Enhanced capacity for climate monitoring and disaster management.

8. Technology Transfer and Infrastructure Development

Japan supports Viet Nam in establishing advanced infrastructure and transferring technology for space applications.

- Initiatives:
    a. Building ground stations and data processing centers.
    b. Equipping Vietnamese institutions with state-of-the-art tools for geospatial analysis.
- Impact: Enhanced self-reliance and operational efficiency in utilising satellite data.

C. Indonesia

Japanese universities and research institutions are set to launch a transformative initiative aimed at fostering talent development and enhancing research collaboration with Indonesia. This scheme encompasses several key programmes: Visiting Researcher opportunities, Post-Doctoral Research positions, Degree by Research programmes conducted in Indonesia, LPDP-targeted scholarships, and internship programmes.

1. Visiting Researcher Programme (1–3 Months)

This programme invites Indonesian researchers to immerse themselves in Japan's vibrant academic environment for a period of one to three months. The initiative is designed to provide these researchers with invaluable short-term opportunities to work alongside Japanese experts in their respective fields. Participants will benefit from travel expenses, accommodation, and a generous stipend, ensuring they can focus entirely on their research. Researchers from Indonesian universities and research institutions can apply by submitting a detailed research proposal, endorsed by their home institution. A panel of experts from Japanese institutions will evaluate the proposals, selecting those that promise the most impactful outcomes. Through this programme, participants will not only enhance their research skills but also build strong collaborative networks and potentially engage in joint publications with their Japanese counterparts.

2. Post-Doctoral Research Programme

Aiming to attract recent Ph.D. graduates from Indonesia, the Post-Doctoral Research Program offers a unique opportunity to conduct advanced research in Japan. This programme is tailored to provide post-doctoral researchers with a competitive salary, research funding, and relocation support, enabling them to focus on groundbreaking research projects. Applicants must present a detailed research proposal, supported by recommendation letters and undergo an interview process. Successful candidates will gain advanced research experience, contribute to high-impact publications, and potentially secure pathways to academic positions or further research opportunities.

3. Degree by Research Programmes in Indonesia

Japanese universities collaborate with Indonesian institutions to offer research-based degree programmes. These programmes will allow Indonesian students and researchers to pursue degrees under joint supervision by Japanese and Indonesian faculty. Research will primarily be conducted in Indonesia, with opportunities for short-term visits to Japan to further their studies. Scholarships will be provided to cover tuition, research expenses, and travel grants, ensuring that financial barriers do not impede academic pursuits. Prospective students will submit research proposals for evaluation by a joint selection committee, ensuring that the most promising candidates are chosen. This initiative aims to produce high-quality research outputs, strengthen academic ties between the two countries, and enhance the capacity of Indonesian institutions.

4. The Indonesian Endowment Fund (*Lembaga Pengelola Dana Pendidikan*/LPDP) for Education Targeted Scholarships

In collaboration with Indonesia's LPDP programme, this initiative will offer targeted scholarships for Indonesian students and researchers to study and conduct research in Japan. These scholarships will cover tuition, living expenses, and research costs, ensuring that financial constraints do not hinder academic ambitions. The application process will be aligned with LPDP priorities and selections will be made in collaboration with Japanese institutions. This targeted approach aims to increase the number of Indonesian scholars in Japan, fostering a robust bilateral academic and research collaboration.

5. Internship Programmes

To bridge the gap between academia and industry, the internship programme will offer practical training opportunities for Indonesian students and researchers within Japanese industries and research institutions. These internships, lasting between three to six months, will provide hands-on experience under the supervision of industry and academic mentors. Participants will receive stipends to cover living expenses and travel costs, ensuring a seamless experience. Joint selection by academic institutions and industry partners will ensure that participants are matched with relevant and impactful internship opportunities. This programme aims to enhance employability, provide practical industry experience, and strengthen industry–academia linkages.

D. Philippines

The Philippines has been constantly receiving talent development and training from Japanese Universities and Research Institutions through scholarships and collaboration projects. These Scholarships are either from local providers or from Japanese institutions such as the Japanese International Cooperation Agency (JICA).

1. Scholarships for Satellite Development Collaboration

The first satellites developed by the Philippines are in collaboration with some Japanese universities and JAXA. The two microsatellites of the Philippines, Diwata-1 and Diwata-2, were made in collaboration with Hokkaido University, and Tohoku University. The MAYA cube satellites were made in collaboration with Kyushu Institute of Technology. The launching of these satellites was made possible with the help of JAXA. Currently, JICA offers scholarships for satellite development courses in Japanese universities. Their first two scholars graduated from University of Tokyo and the Kyushu Institute of Technology both with a degree related to satellite development.

2. Scholarships on Local Space Technology Development

The Philippine government provides scholarships for Space Technology related courses in Japanese Universities for its experts through government agencies such as the Department of Science and Technology (DOST), and PhilSA.

3. Collaborations with JAXA

Aside from assisting with the satellite development and the launch of Philippine Satellites into space, JAXA also promotes its collaboration with the Philippines through space cooperation and space-related programmes.

E. Malaysia

1. Partnership Development:
   - Bilateral Agreements: Formalise partnerships with leading Japanese universities and research institutions that have established expertise in space technology and related fields.
   - Joint Curriculum Development: Collaborate on creating specialised curricula that are tailored to the needs of Malaysia's growing space industry, focusing on both theoretical and applied aspects of space technology.
2. Capacity Building Programmes:
   - Student Exchange Programmes: Establish student exchange programmes that allow Malaysian students to study and conduct research in Japan, gaining direct exposure to advanced space technology projects.

- Faculty Exchange and Joint Research: Facilitate faculty exchanges to foster research collaborations and share best practices in teaching methodologies and curriculum development.

3. Training and Certification:
    - Professional Development Workshops: Organise workshops and seminars led by Japanese experts to train Malaysian faculty and students in specialised space technology areas.
    - Certification Programmes: Develop certification programmes in collaboration with Japanese institutions that provide formal recognition of specialised skills in space technologies, enhancing employability and professional credibility.
4. Infrastructure and Resource Sharing:
    - Laboratory Access and Joint Ventures: Provide Malaysian students and researchers with access to advanced laboratories and facilities in Japan. Consider establishing joint research centers in Malaysia that focus on satellite technology, propulsion systems, and other critical areas.
    - Technology Transfer Initiatives: Facilitate technology transfer from Japanese institutions to Malaysian universities to update and enhance local research and educational facilities.
5. Industry Integration:
    - Internships and Job Placements: Create pathways for internships and job placements within Japanese aerospace companies and research institutions, offering practical experience and career opportunities for graduates.
    - Industry Advisory Panels: Establish panels consisting of industry leaders from both countries to ensure the relevancy of training programmes and align them with current and future industry needs.
6. Funding and Scholarships:
    - Scholarship Programmes: Secure funding for scholarships that support Malaysian students studying in Japan, particularly those pursuing advanced degrees in space-related fields.
    - Research Grants: Encourage joint applications for international research grants to support collaborative projects between Malaysian and Japanese institutions.

The Malaysia–Japan International Institute of Technology (MJIIT) is a faculty of Universiti Teknologi Malaysia (UTM) in Kuala Lumpur. Emerged from the Look East Policy implementations, MJIIT was established on 26 May 2010. MJIIT aims to provide advanced education and research in engineering and technology while upholding the cultural and educational values of Malaysia and Japan. Inspired by Japan's economic success, attributed to its perseverance and discipline, MJIIT is recognised as a global leader in

Malaysia–Japan oriented engineering education, supported by a consortium of 31 Japanese universities.

7. Malaysia–Japan Linkage (MJL) Office

On May 28, 2024, UTM launched the Malaysia–Japan Linkage (MJL) office, marking a significant milestone in enhancing academic, research, and industrial collaboration. The MJL office is the third phase of a project running from July 2023 to 2028, following the first phase (2010–2017) and the second phase (2018–April 2023). The MJL office aims to establish MJIIT as a prominent Japanese Industrial and Education Hub between ASEAN and Japan. It serves as a sustainable platform for collaboration with Japanese universities and industries, strengthening relationships with the Japanese University Consortium (JUC) and international institutes. The MJL office focuses on emerging areas such as Disaster Preparedness and Prevention, Food Security, Halal, and Green Technology.

8. Research at MJIIT

Research at MJIIT is organised into focus areas within 19 ikohzas and one research center, the Disaster Preparedness and Prevention Centre (DPPC). Ikohzas are formal structures for collaborative research, each led by a senior academic and consisting of members with similar interests, including academics, researchers, and students. The Senpai-Kohai mentoring concept is integral to this structure, where junior members receive guidance and support from their seniors and professors. Further details about each iKohza: https://mjiit.utm.my/wp-content/uploads/2022/12/iKohza-Eng-compressed.pdf

9. Disaster Preparedness and Prevention Centre (DPPC)

The DPPC aims to develop highly skilled human resources in disaster management for the government and societies of Malaysia and ASEAN. It seeks to improve the emergency management performance of NGOs, local and national governments, and international organisations through comprehensive research and development. The DPPC offers:

a. Master of Disaster Risk Management (MDRM) programme includes two semesters plus a short semester with a 2-week attachment in Japan. The MDRM programme balances education/training, research, and practice, developing Disaster Risk Management (DRM) professionals with a comprehensive set of skills. MDRM students join a network of DRM professionals from various countries and backgrounds.
b. Certified Professional Training (CPT) In Disaster Risk Management
c. Technical training in geophysics training.

The DRM programme in MJIIT is supported by the Japanese University Consortium (JUC) that consists of over 30 top Japanese Universities. The DRM Sub Committee of JUC includes Tsukuba University (Chair), Shibaura Institute of Technology (Co-chair), Kyoto University (Co-chair), Kyushu University (Co-chair), International Centre for Water Hazard and Risk Management (ICHARM), National Research Institute for Earth Science and

Disaster Prevention (NIED), Yamaguchi University, Kanazawa University and Japan International Cooperation Agency (JICA), with an additional of one new member which is Tokyo City University. The JUC members dispatch renowned Japanese educators, researchers and practitioners in the field of disaster risk management to MJIIT to teach and advise the MDRM students, and also support the research in DRM field. They also provide technical support to conduct MDRM projects and attachment programme in Japan. In addition, the DRM programme offers opportunities to collaborate with university and research institutes in Japan and other ASEAN countries through the Japan–ASEAN Science, Technology and Innovation Platform (JASTIP) (http://jastip.org/en/project/disaster_prevention/) and ASEAN University Network (AUN) administered under the JICA project, AUN/SEED-Net (http://www.seed-net.org/).

➢ Implementation Milestones

2024: Establish foundational partnerships and begin curriculum development.

2025–2027: Launch exchange programmes and start joint research projects.

2028–2029: Evaluate programme outcomes and expand successful initiatives.

2030: Achieve the target of 5,000 trained graduates in space technology.

F. Thailand

Japan and Thailand have fostered a robust collaboration to enhance talent development, technical skills, and innovation in space technology and related fields. The partnership includes a range of initiatives aimed at achieving economic impact, fostering innovation, and addressing critical challenges in agriculture, environmental monitoring, and disaster resilience. Below are the key programmes and initiatives under this scheme:

1. S-Booster Project with Japan

The S-Booster project is a space-based business idea competition that encourages Thai participants to generate innovative ideas for economic impact, focusing on critical sectors like agriculture and environmental sustainability.

- Objectives:
  - Foster creativity and innovation in space-based solutions.
  - Promote economic development by addressing challenges such as carbon emissions and resource optimisation.
- Key Features:
  - Participants work on real-world problems in agriculture and environmental monitoring.
  - Collaboration with the ASEAN Geospatial Challenge 2024, Singapore Land Authority (SLA), and SPACE CAMP.
- Impact: Cultivates entrepreneurial talent and innovative thinking, driving new business opportunities in space technology.

2. Training and Collaboration in GNSS Development

Japan collaborates with Thailand on Global Navigation Satellite Systems (GNSS) development and associated software.

- Key Partners:
  - Sony
  - The National Space Policy Secretariat (NSPS), Cabinet Office of Japan
  - Japan International Cooperation Agency (JICA)
- Focus Areas:
  - Development of GNSS applications for disaster management, transportation, and agriculture.
  - Hands-on training for Thai researchers and professionals in GNSS systems.
- Outcomes:
  - Enhanced technical expertise in satellite navigation systems.
  - Real-world applications in managing transportation and environmental challenges.

3. MADOCA/GNSS Training Programme

The Multi-GNSS Advanced Demonstration Tool for Orbit and Clock Analysis (MADOCA) training programme is designed to provide Thai professionals with cutting-edge skills in GNSS technology.

- Collaborating Institutions:
  - The University of Tokyo
  - CSSTESP (Center for Space Science and Technology Education in Asia and the Pacific)
  - ISRO (Indian Space Research Organization)
- Training Areas:
  - Advanced GNSS signal processing and data analysis.
  - Applications of GNSS in agriculture, urban planning, and disaster risk management.
- Outcomes:
  - Participants gain practical knowledge and technical skills in GNSS operations.
  - Collaboration with international experts strengthens Thailand's GNSS capabilities.

4. Joint Research and Development Programmes

Japan and Thailand collaborate on research projects targeting high-impact areas such as disaster resilience and carbon control.

- Focus Areas:
  - Remote sensing applications for flood and drought monitoring.

    - Carbon measurement technologies to support environmental conservation.
- Benefits:
    - Provides Thai researchers with access to Japanese satellite data and analytical tools.
    - Strengthens Thailand's ability to address climate and environmental challenges.

5. Space Technology Training Workshops

Workshops and seminars are organised to enhance the knowledge and skills of Thai researchers, students, and professionals.

- Themes:
    - Satellite data analysis for disaster management.
    - GNSS applications in smart cities and precision agriculture.
    - Software development for space systems.
- Format: In-person sessions in Japan, with hybrid options for wider accessibility.
- Outcomes:
    - Participants develop specialised skills for implementing space technology solutions.
    - Increased collaboration between Thai and Japanese experts.

6. Internship and Industry Engagement Programmes

Internship opportunities in Japanese research institutions and industries provide practical experience for Thai students and professionals.

- Key Features:
    - Internships focus on areas such as satellite engineering, GNSS applications, and software development.
    - Participants receive stipends to cover living and travel expenses.
- Impact:
    - Enhances employability and bridges the gap between academia and industry.
    - Strengthens industry–academia collaboration between Thailand and Japan.

7. Scholarships and Funding for Advanced Studies

Scholarships are offered to Thai students and researchers to pursue advanced degrees and training in Japanese universities.

- Fields of Study: Space technology, remote sensing, GNSS systems, and environmental sustainability.
- Support Includes: Tuition, research funding, and living expenses.
- Outcomes: Builds a pipeline of highly skilled professionals to support Thailand's space technology sector.

8. ASEAN Geospatial Challenge 2024

This regional initiative, in collaboration with Japan, provides Thai participants the opportunity to tackle real-world challenges using geospatial data.

- Focus Areas:
  - Sustainable urban development.
  - Advanced data analytics for resource management.
- Impact: Encourages innovation and regional collaboration in applying space technology.

G. Lao PDR

1. Scholarships for Advanced Studies

Japanese universities offer scholarships to Laotian students and professionals to pursue higher education in space-related fields.

- Fields of Study: Space technology, remote sensing, disaster management, and geospatial analysis.
- Support Includes:
  - Tuition fees, living expenses, and research costs.
  - Access to Japan's advanced research facilities and satellite data systems.
- Outcomes:
  - Develops a skilled workforce to address local challenges using satellite technology.
  - Provides opportunities for knowledge transfer and long-term collaboration.

2. Visiting Researcher Programmes

Short-term opportunities for Laotian researchers to conduct collaborative studies in Japanese institutions.

- Programme Features:
  - Duration: 1–3 months.
  - Research areas include environmental monitoring, agriculture, and disaster resilience.
  - Full support for travel, accommodation, and a stipend.
- Goals:
  - Enhance research capabilities through exposure to Japan's cutting-edge technology.
  - Build networks for future collaborative projects.

3. Technical Training Workshops

Workshops and training sessions are tailored to address Lao PDR's specific needs in space technology.

- Focus Areas:
  - Basics of satellite operations and maintenance.

    - Application of satellite data for flood monitoring, agriculture, and urban planning.
    - Capacity building in geospatial analysis and data interpretation.
- Delivery Format:
    - Hybrid approach combining in-person training in Japan and virtual sessions for wider reach.
- Impact:
    - Equips Laotian professionals with practical skills for applying space technology to national challenges.

4. Collaborative Research Programmes

Joint research initiatives between Japanese and Laotian universities aim to build local expertise and foster innovation.

- Research Themes:
    - Climate resilience using satellite data.
    - Precision agriculture applications for resource optimisation.
    - Environmental monitoring to combat deforestation and land degradation.
- Benefits:
    - Provides Laotian researchers access to advanced Japanese technologies and methodologies.
    - Creates opportunities for co-authored publications and long-term partnerships.

5. Infrastructure Development and Technology Transfer

Japan supports Lao PDR in developing essential infrastructure and transferring technology to establish local space capabilities.

- Initiatives:
    - Establishing ground stations for satellite communication and data processing.
    - Providing satellite imagery and tools for disaster management and agricultural planning.
    - Training local experts to maintain and operate space-related infrastructure.
- Outcomes:
    - Strengthened operational capabilities in Lao PDR.
    - Improved national resilience to climate-related and agricultural challenges.

6. Industry-Linked Internship Programmes

Internship opportunities provide Laotian students with hands-on training in Japanese industries and research centers.

- Duration: 3–6 months.

- Focus Areas: Satellite development, GNSS systems, and software for space applications.
- Support Includes: Stipends for living and travel expenses.
- Impact:
  - Bridges the gap between academia and industry.
  - Enhances employability and technical expertise amongst Laotian students.

7. Disaster Risk Management Training

Given Lao PDR's vulnerability to floods and natural disasters, this programme focuses on building capacity in disaster risk management.

- Key Features:
  - Use of satellite data for early warning systems and recovery planning.
  - Training in collaboration with Japanese disaster management experts.
- Outcomes:
  - Strengthens Lao PDR's disaster resilience through advanced planning and response capabilities.

H. Cambodia

Japanese universities and research institutions have developed tailored schemes to foster talent development and training in Cambodia. These programmes focus on building foundational capacity, addressing socio-economic challenges, and leveraging space technologies for sustainable development. Given the differing needs and stages of development, the initiatives for each country are aligned with their unique contexts and priorities.

1. Scholarships for Advanced Studies

Japanese institutions provide scholarships for Cambodian students to pursue higher education in space-related fields.

- Fields of Study: Remote sensing, disaster management, precision agriculture, and environmental monitoring.
- Support Includes:
  - Tuition fees, living expenses, and research costs.
  - Access to Japan's research infrastructure and satellite technology.
- Impact:
  - Develops a skilled workforce in Cambodia to tackle national challenges.
  - Encourages long-term academic and professional collaboration.

2. Collaborative Research Programmes

Joint research initiatives address Cambodia's pressing environmental and agricultural challenges.

- Focus Areas:

    - Flood and drought monitoring using satellite data.
    - Forest conservation and combatting deforestation.
    - Sustainable agricultural practices with precision monitoring.
- Outcomes:
    - Strengthened research capacities in Cambodian institutions.
    - Access to Japanese expertise and co-publication opportunities.

3. Technical Training Workshops

Workshops provide practical training in the application of space technologies.

- Themes:
    - Disaster risk reduction and early warning systems.
    - Geospatial data interpretation for urban and rural planning.
- Format: Conducted in Japan and Cambodia, with virtual options for broader participation.
- Impact: Equips Cambodian professionals with critical skills for using satellite data effectively.

4. Infrastructure Development Support

Japan aids Cambodia in developing local infrastructure for space technology.

- Initiatives:
    - Establishing ground stations for satellite communication and data processing.
    - Training local personnel to operate and maintain these facilities.
- Outcomes:
    - Increased self-reliance in space technology.
    - Improved capacity for national disaster and resource management.

5. Internship and Industry Collaboration

Internships in Japanese industries provide Cambodian students with hands-on experience.

- Focus Areas: Satellite systems, GNSS technology, and sustainable solutions.
- Support Includes: Stipends for travel and living expenses.
- Benefits:
    - Enhances employability and industry connections for Cambodian students.
    - Strengthens the link between academia and industry.

I. Timor-Leste

1. Scholarships for Capacity Building

Scholarships for Timor-Lesteese students aim to develop expertise in space technology applications.

- Fields of Study: Disaster management, agricultural monitoring, and environmental sustainability.
- Features:
    - Full funding for tuition and living expenses in Japanese universities.
    - Research opportunities in Japanese facilities with advanced technology.
- Impact:
    - Builds a skilled workforce in Timor-Leste to address local challenges.
    - Promotes long-term collaboration with Japanese institutions.

2. Visiting Researcher Programmes

Timor-Lestee researchers are invited to collaborate with Japanese institutions on short-term projects.

- Duration: 1–3 months.
- Focus Areas:
    - Developing early warning systems for disasters.
    - Using satellite data for resource optimisation.
- Support:
    - Travel, accommodation, and stipends provided.
- Outcome:
    - Knowledge exchange and capacity building for researchers.

3. Disaster Management Training

Given Timor-Leste's vulnerability to natural disasters, training programmes are tailored to enhance disaster resilience.

- Key Features:
    - Satellite-based early warning systems for cyclones and landslides.
    - Training local experts in recovery and disaster planning.
- Partners: Collaboration with Japanese experts and institutions specialising in disaster management.
- Outcomes:
    - Strengthens Timor-Leste's ability to respond to and recover from disasters.
    - Builds a network of disaster management professionals.

4. Joint Research and Technology Transfer

Collaborative projects focus on sustainable development and resource management in Timor-Leste.

- Initiatives:
    - Developing tools for precision agriculture using remote sensing data.
    - Research on climate resilience and land-use planning.
    - Technology transfer to support local data analysis capabilities.
- Benefits:

    - Enhances Timor-Leste's capacity for utilising space technologies independently.
    - Promotes sustainable economic development through innovative solutions.
5. Industry-Linked Training and Internships

Japanese industries offer internship opportunities for Timor-Lesteese students to gain real-world experience.

- Focus Areas: Satellite applications, renewable energy, and environmental technology.
- Features:
    - Stipends for travel and living costs.
    - Supervised training in Japan's leading research institutions and industries.
- Impact:
    - Prepares students for industry roles in Timor-Leste.
    - Bridges academic learning and practical application.

6.2 Scheme for Talent Development and Training by Japanese Universities and Research Institutions in ASEAN

The ASEAN region, with its diverse levels of remote sensing and space technology capabilities, provides a unique opportunity for Japanese universities and research institutions to design tailored schemes for talent development and training. By categorising ASEAN nations into Technological Innovators and Data Hubs, Established Space Capability Nations, Emerging Space Capability Nations, and Foundational Capacity-Building Nations, Japan can create customised programmes that address each group's distinct developmental needs.

6.2.1 Technological Innovators and Data Hubs

Focus Country: Singapore

Singapore stands out as a leader in satellite data processing, geospatial analytics, and smart city applications. Despite its lack of domestic satellite manufacturing and launch capabilities, Singapore has established itself as a global data hub, leveraging its expertise in AI, IoT, and big data to support national and regional needs. Japanese universities can help Singapore move further up the value chain by addressing its challenges related to data sovereignty and workforce specialisation.

To achieve this, Japanese institutions can focus on:

- Advanced Training in AI and Geospatial Analytics: Programmes that enhance Singapore's existing strengths in data processing while exploring advanced applications for urban planning, maritime security, and environmental monitoring.

- Building Satellite Development Capacity: Research partnerships and technical training on small satellite R&D and testing can reduce reliance on external data sources.
- Knowledge Exchange Programmes: Interaction between Japanese institutions such as JAXA and the research hubs in Singapore can allow talent to gain direct experience in the development and deployment of satellites.

By supporting Singapore's efforts to develop its satellite infrastructure and further refine its workforce's analytical skills, Japan can help the city-state maintain its position as a regional leader in smart data innovation.

6.2.2. Established Space Capability Nations

Focus Countries: Indonesia, Thailand, Viet Nam

Countries in the lead in space technology within ASEAN include Indonesia, Thailand, and Viet Nam, whose national agencies LAPAN of Indonesia, GISTDA of Thailand, and VNSC of Viet Nam propel satellite launches, development of ground stations, and disaster management. These countries employ remote sensing for such high priorities as disaster resilience, agriculture, and environmental monitoring. Challenges persist in extending the domestic satellite manufacturing, infrastructural development, and holding onto technical specialists with particular expertise.

Japanese universities can assist these countries with:

- Satellite Engineering and R&D Programs: Training on the design, production, and deployment technologies of the satellites, thus enhancing their capability and de-linking their use of foreign technology.
- Training for Real-Time Data Processing Capacity Building: Training with the objective of strengthening the systems for disaster response, environmental monitoring, and agriculture.
- Public Private Partnerships: Collaboration amongst Japanese space industries with relevant national agencies to accelerate transferring technology and innovation.
- HPC Training and Infrastructure Development: Deployment of high-performance computing resources to enable faster and more accurate analysis of remotely sensed data.

Through these initiatives, Japan can assist these nations in gaining greater autonomy, bolstering their infrastructure, and enhancing their capabilities to spearhead regional space initiatives.

6.2.3 Emerging Space Capability Nations

Focus Countries: Malaysia, Philippines

Malaysia and the Philippines are emerging contributors to the ASEAN space ecosystem through the successful launching of their own satellites and establishing local space agencies, namely, MYSA in Malaysia and PhilSA in the Philippines. They apply space technology for disaster management, environmental sustainability, and maritime monitoring but face challenges in building their local R&D capabilities, encouraging private sector involvement, and reinforcing policy frameworks.

Customised support offered by Japanese universities

- Satellite R&D Training: Programmes focused on building skills in designing, testing, and deploying small satellites to cultivate in-house expertise.Policy and Governance Workshops: Training government officials and researchers to formulate comprehensive space policies that attract investments and innovation.
- Maritime Security and Environmental Monitoring Programmes: Specialised training on coastal monitoring, fisheries management, and tracking deforestation using advanced remote sensing tools.
- Scholarship and Exchange Programmes: Train young scientists and engineers to get experience at Japanese institutions on satellite technology and data analytics.

By filling policy, workforce training, and indigenous R&D gaps, Japan will help Malaysia and the Philippines become key contributors in the ASEAN space ecosystem.

6.2.4 Foundational Capacity-Building Nations

Focus Countries: Cambodia, Lao PDR, Timor-Leste

Cambodia, Lao PDR, and Timor-Leste are at the initial level of adoption of remote sensing and space technologies. These nations focus more on the following areas: disaster management, agriculture optimisation, and resource mapping. The countries experience big infrastructure gaps, excessive dependency on foreign data and training, and lack of knowledge about the benefits that could be gained from using space technologies.

Japanese universities can work on the following aspects to overcome these difficulties.

- Basic Training Programmes: Introductory courses on remote sensing data interpretation, GIS mapping, and fundamental applications in agriculture and disaster preparedness.
- Technology Transfer and Support: Provision of Japanese tools, software, and infrastructure for processing of satellite data.
- Scholarship on Foundational Learning: Students and professionals are accorded opportunities to study in Japan and understand space technology and policies being developed.

- Workshops on Regulatory Frameworks: The workshops help governments prepare a basic framework for usage of data and collaborations that may align with international standards.

By building a foundational workforce and essential infrastructure, Japan will create opportunities for these countries to fully unlock the potential of remote sensing and better integrate into the burgeoning space economy of ASEAN.

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Chapter 7

Examining Collaborative Schemes and Developing a Framework for Industry – Academia – Government Cooperation for Implementing Space Technology Utilisation Solutions in ASEAN Countries and Regions

To foster industry–academia–government cooperation and develop a framework for space technology utilisation in ASEAN countries, a comprehensive scheme involving key stakeholders such as universities, government bodies, and industry partners across the region is proposed. This initiative aims to leverage the strengths of each sector to drive innovation, support startups, and promote technology transfer, thereby enhancing regional collaboration and capacity building in space technology.

The Collaborative Open Innovation Hub is envisioned as a transformative platform designed to unite government agencies, academic institutions, private industries, and international partners in advancing Geographic Information Systems (GIS) and Remote Sensing (RS) technologies across ASEAN. Rooted in inclusivity and collaboration, the hub aims to address shared regional challenges while fostering innovation, building capacity, and driving sustainable development. With its mission to advance shared GIS and RS capabilities and promote environmental sustainability, disaster resilience, and socioeconomic growth, the hub is guided by four foundational pillars: Collaborative Innovation Ecosystem, Capacity Building and Knowledge Transfer, Innovation and Incubation Programs, and Research and Development (R&D) Hubs.

7.1 ASEAN Member States (AMS) Collaboration Programme

7.1.1 Establishing an ASEAN Space Policy

Taking inspiration from the European Space Policy Coordination framework, ASEAN can develop a unified ASEAN Space Policy Coordination Framework to harmonise the diverse space programmes and priorities of its member states with broader regional objectives. This framework would act as a guiding document, aligning the space ambitions of AMS to address critical regional priorities such as sustainable development, disaster management, and climate resilience. By pooling resources, expertise, and funding, AMS can collectively develop and operate space initiatives that tackle shared challenges.

The ASEAN Space Policy would ensure that member states, regardless of their technological capabilities, actively participate in and benefit from these regional advancements. Such cooperation could include shared satellite missions, joint research projects, and a centralised platform for data sharing and analysis. Moreover, by aligning national initiatives with regional goals, AMS can present a unified voice in global space governance, enhancing their collective influence and competitiveness in the international space sector. This cohesive strategy would not only advance space and remote sensing capabilities within the region but also strengthen ASEAN's global standing in space technology and innovation, paving the way for a more resilient and interconnected Southeast Asia.

7.1.2 Developing an ASEAN Earth Observation Programme

Drawing inspiration from ESA's Earth Observation Envelope Programme (EOEP), ASEAN can develop its own ASEAN Earth Observation Program (AEOP) to address the region's unique environmental and developmental challenges. This programme would focus on launching shared satellite missions specifically designed to monitor critical issues such as deforestation in Borneo, agricultural dynamics in the Mekong Delta, urbanisation in cities like Jakarta, and climate-related vulnerabilities across the region.

A key component of the AEOP would be the establishment of a centralised data-sharing platform, enabling all ASEAN Member States (AMS) to access satellite data for decision-making and research purposes. Such a platform would facilitate the exchange of critical environmental and climate information, fostering collaboration amongst AMS in addressing transboundary issues such as haze, water management, and disaster risk reduction.

By leveraging collective resources and expertise, the AEOP would also promote joint research initiatives and capacity building, encouraging innovation in space applications across ASEAN. This collaborative approach ensures that even AMS with limited technological capabilities can benefit from and contribute to the region's advancements in Earth observation. Ultimately, the AEOP would strengthen ASEAN's ability to tackle environmental challenges while positioning the region as a leader in sustainable development through space technology.

7.1.3 ASEAN Regional Satellite Operations Centre

ASEAN could establish a centralised ASEAN Space Operations Centre (ASOC) to streamline the management of regional satellite operations. ASOC would serve as the command -and-control hub for ASEAN's shared satellite missions, overseeing tasks such as launch coordination, orbit control, data relay, and ground communication. This centralisation would significantly enhance efficiency, reduce duplication of efforts, and optimise resource utilisation amongst ASEAN Member States (AMS).

ASOC would also play a crucial role as a regional training hub, offering capacity-building programmes to develop technical expertise across AMS By providing hands-on training in satellite operations, data analysis, and ground station management, ASOC would ensure that all member states regardless of their current capabilities, can actively contribute to and benefit from ASEAN's space activities.

Moreover, the facility could support collaborative research and innovation by hosting joint projects and facilitating knowledge exchange. It could also serve as a coordination center during regional crises, leveraging satellite data to support disaster management and emergency response. By establishing ASOC, ASEAN would strengthen its collective capacity for space operations and reinforce its position as a cohesive and capable entity in the global space sector.

7.1.4 ASEAN Space Innovation Clusters

Inspired by ESA's regional innovation clusters and Business Incubation Centres (BICs), ASEAN could establish Space Innovation Clusters in strategic member states such as Singapore, Malaysia, and Thailand. These clusters would act as regional hubs for fostering collaboration amongst universities, industries, and governments, driving innovation in space technologies and applications tailored to ASEAN's unique priorities.

Each cluster could focus on addressing specific regional challenges. For example:

- *Fisheries Management Cluster (Philippines)*: Satellite-based solutions for fisheries management. Philippines, as an archipelagic nation, relies heavily on its marine resources for livelihoods and food security. Challenges such as overfishing, illegal fishing, and marine ecosystem degradation threaten this vital sector.
- *Forestry and Marine Conservation Cluster (Indonesia)*: Environmental conservation and marine resource management. Indonesia's vast forests and maritime zones are critical for regional and global environmental health, but they face significant challenges from deforestation, illegal logging, and marine pollution.
- *Disaster Resilience Cluster (Viet Nam):* Disaster resilience technologies leveraging Earth observation data. Viet Nam is highly vulnerable to natural disasters like floods and typhoons, necessitating advanced technologies for disaster preparedness and response.
- *Precision Agriculture and Climate Adaptation Cluster (Thailand)*: Enhancing agricultural productivity and resilience through space technologies. Thailand's economy is strongly tied to agriculture, and the country faces climate-related challenges such as droughts and floods. Space technology can play a transformative role in addressing these issues.
- *Urban Planning and Smart Cities Cluster* (*Singapore)*: As a global leader in urban innovation, Singapore is well-positioned to develop space-driven solutions for managing urban growth and sustainability.

The innovation clusters would provide access to shared resources such as research facilities, funding programmes, and mentorship opportunities. They would also support the growth of space-related startups by offering business incubation services and fostering public–private partnerships. By connecting stakeholders across AMS, these clusters would create an ecosystem that encourages the development and commercialisation of space applications.

Ultimately, the establishment of ASEAN Space Innovation Clusters would not only strengthen regional technological capabilities but also stimulate economic growth and create new opportunities for collaboration. These hubs would position ASEAN as a leader in space-driven solutions for sustainable development, resilience, and regional integration.

7.1.5 ASEAN-EUMETSAT Model for Meteorological Cooperation

ASEAN could replicate ESA's partnership with EUMETSAT by establishing an ASEAN Meteorological Satellite Network (AMSAT) to address the region's pressing weather and climate challenges. Given the frequent occurrence of typhoons, floods, droughts, and other extreme weather events in the region, AMSAT would play a vital role in improving disaster preparedness, enhancing agricultural planning, and supporting climate adaptation efforts. The network would involve the development and operation of shared meteorological satellites equipped with advanced sensors to monitor storm patterns, precipitation, temperature fluctuations, and atmospheric changes. These satellites would provide real-time and accurate data, accessible through a centralised platform, to all ASEAN Member States (AMS).

AMSAT's data would support enhanced early warning systems for natural disasters, enabling better regional disaster preparedness and coordinated response efforts. It would also provide valuable insights for precision agriculture, helping farmers optimise planting schedules, water management, and crop selection to adapt to changing climate conditions. Furthermore, the network would assist in developing long-term strategies for climate adaptation, such as drought-resilient farming practices and flood mitigation initiatives.

7.1.6 ASEAN Integrated Applications Programme

ASEAN could establish a Space Applications Development Program, inspired by ESA's Integrated Applications Promotion (IAP) Programme, to address regional challenges through the integration of space technologies. This programme would combine Earth observation (EO) data with other technologies, such as Global Navigation Satellite Systems (GNSS) and satellite communications, to create practical solutions tailored to the needs of ASEAN Member States (AMS). For instance, EO data paired with GNSS could support precision agriculture by optimising irrigation, monitoring crop health, and improving yield forecasts. Similarly, satellite communications could bridge the connectivity gap in remote and underserved areas, enhancing access to education, healthcare, and economic opportunities.

The programme would also focus on developing tools for disaster management, such as early warning systems that integrate EO data with telecommunications to disseminate critical information quickly. Public–private partnerships would be a key component, enabling the commercialisation of space-based applications and ensuring their financial sustainability. By involving startups, research institutions, and industries, ASEAN could foster an ecosystem of innovation that encourages the development of cutting-edge technologies and services.

Capacity building would be integral to the programme, with training initiatives designed to equip AMS with the technical skills needed to utilise and develop these integrated applications. By pooling resources, expertise, and funding, the programme would not only address pressing regional challenges but also drive economic growth and innovation. This collaborative effort would position ASEAN as a leader in space-enabled solutions, contributing to regional resilience, sustainability, and development.

7.1.7 ASEAN Climate Change Initiative (CCI)

ASEAN can establish a Regional Climate Monitoring and Adaptation Framework, to address the region's unique vulnerabilities to climate change. This initiative would focus on generating consistent, long-term climate data tailored to ASEAN's challenges, such as rising sea levels, increasing temperatures, and the intensification of extreme weather events. Using Earth observation satellites and advanced analytics, the framework would provide actionable insights for policymakers, researchers, and disaster management agencies across ASEAN Member States (AMS).

Collaborative research would be a cornerstone of this initiative, enabling AMS to analyse shared climate data and develop effective adaptation strategies. For example, satellite data could be used to monitor coastal erosion, predict flood risks, and track changes in agricultural productivity due to shifting weather patterns. These insights would support the development of region-specific solutions, such as improved water management systems, climate-resilient crops, and enhanced disaster response mechanisms.

Data sharing amongst AMS would not only foster regional collaboration but also strengthen ASEAN's collective resilience to climate challenges. By pooling resources and expertise, AMS could implement sustainable development practices that address both short-term vulnerabilities and long-term climate impacts. This initiative would also position ASEAN as a proactive player in global climate efforts, contributing valuable data and strategies to the international community. Through the Regional Climate Monitoring and Adaptation Framework, ASEAN would ensure the sustainable development and resilience of its member states in the face of growing climate risks.

7.1.8 ASEAN Space Charter for Emergency Response

Modeled after ESA's involvement in the International Charter on Space and Major Disasters, ASEAN could establish an **ASEAN Space Emergency Response Charter**. This charter would facilitate the use of space-based data for rapid disaster response, ensuring that AMS can quickly access satellite imagery and other resources during emergencies. For a region prone to natural disasters like typhoons, earthquakes, and floods, this charter would strengthen ASEAN's collective ability to manage crises and reduce disaster risks.

7.1.9 ASEAN Space Technology and Research Centre (ASTREC)

ASEAN could establish the ASEAN Space Technology and Research Centre (ASTREC) as a central hub for innovation, research, and capacity building in space technologies. Designed as an Open Innovation Hub, ASTREC would foster collaboration amongst ASEAN Member States (AMS), academic institutions, industries, and global partners. The facility would provide state-of-the-art infrastructure for satellite testing, assembly, and integration, enabling AMS to collectively design and develop space missions tailored to regional priorities, including disaster monitoring, environmental conservation, and resource management.

As an Open Innovation Hub, ASTREC would encourage the sharing of ideas, resources, and expertise across stakeholders, creating a dynamic ecosystem for developing cutting-edge space technologies. This model would also facilitate public–private partnerships, promoting the commercialisation of space-based solutions to address regional challenges. By hosting training programmes, workshops, and joint research initiatives, ASTREC would build technical expertise across AMS, ensuring that all member states, regardless of their current technological capabilities actively contribute to and benefit from ASEAN's space activities.

The collaborative environment of ASTREC would strengthen regional cohesion and position ASEAN as a leader in space technology innovation. Furthermore, partnerships with international space agencies, research organisations, and private sector players would enhance the region's access to global expertise and resources. By adopting an open innovation approach, ASTREC would not only advance ASEAN's technological capabilities but also drive economic growth, sustainability, and resilience across the region.

7.2 ASEAN Space Technology and Research Centre (ASTREC): The Collaborative Open Innovation Hub for GIS and Remote Sensing Technologies

The Collaborative Open Innovation Hub is envisioned as a transformative platform designed to unite government agencies, academic institutions, private industries, and international partners in advancing Geographic Information Systems (GIS) and Remote Sensing (RS) technologies across ASEAN. Rooted in inclusivity and collaboration, the hub aims to address shared regional challenges while fostering innovation, building capacity, and driving sustainable development. With its mission to advance shared GIS and RS capabilities and promote environmental sustainability, disaster resilience, and socioeconomic growth, the hub is guided by four foundational pillars: Collaborative Innovation Ecosystem, Capacity Building and Knowledge Transfer, Innovation and Incubation Programs, and Research and Development (R&D) Hubs.

Vision: 'To foster an inclusive and collaborative ecosystem for developing and applying GIS and RS technologies across ASEAN, enhancing data accessibility, innovation, and regional resilience.'

Mission: 'To advance shared GIS and RS capabilities, support environmental sustainability, promote disaster resilience, and enhance economic and social development across ASEAN nations.'

The Four Pillars of ASEAN Space Technology and Research Centre (ASTREC):

7.2.1 Collaborative Innovation Ecosystem

At the heart of the hub lies the Collaborative Innovation Ecosystem, which serves as the backbone for partnerships and cooperation amongst stakeholders across ASEAN and beyond. This ecosystem aims to break down silos between industry, academia, and government, creating a unified platform for collaboration and shared progress.

The ecosystem will prioritise:

- Multi-Stakeholder Partnerships: Establishing deep partnerships across ASEAN nations, leveraging the strengths of regional leaders like Singapore in data analytics and Viet Nam in environmental sustainability, while integrating expertise from global partners like Japan's.
- Regional Data Sharing Platforms: Developing a centralised, open-access database that ensures equitable access to satellite imagery and geospatial data. This will empower countries with limited resources, like Cambodia and Lao PDR, to utilise advanced GIS and RS technologies for their developmental needs.
- Policy Coordination: Facilitating policy alignment across ASEAN to establish unified data governance standards, ensuring seamless cross-border collaboration and ethical use of data.
- Global Integration: ASEAN nations will benefit from lessons learned and best practices from leading space ecosystems, such as NASA in the U.S. and ESA in Europe, enabling the region to scale its innovation capacity.

The Collaborative Innovation Ecosystem fosters a sense of shared purpose, driving innovation that addresses ASEAN's regional challenges while amplifying its role in the global geospatial community.

7.2.2 Capacity Building and Knowledge Transfer

To harness the full potential of GIS and RS technologies, the hub places a strong emphasis on Capacity Building and Knowledge Transfer, ensuring that ASEAN nations have access to the skills and expertise necessary to deploy these technologies effectively.

Key initiatives include:

- Specialised Training Programmes: Tailored to the unique needs of each ASEAN country, training programmes will span foundational skills in GIS and RS data analysis for nations like Timor-Leste and advanced topics such as AI-driven analytics and real-time data processing for Singapore, Thailand, and Indonesia.

- International Knowledge Exchange: Collaborations with global academic and research institutions, including Yamaguchi University, will facilitate hands-on learning and exposure to cutting-edge GIS and RS tools. These exchanges will focus on practical applications like disaster preparedness and smart urban planning.
- Public Sector Training: Building the capacity of government agencies to integrate GIS and RS into policymaking processes will enhance governance and improve decision-making on issues such as disaster response, infrastructure development, and environmental protection.
- Workforce Development: Scholarships, fellowships, and mentorship programmes will nurture a new generation of GIS and RS professionals, equipping them with the skills to drive innovation in their respective countries.

By bridging skill gaps and fostering a culture of continuous learning, the hub ensures that ASEAN nations are equipped to harness GIS and RS technologies for long-term growth and resilience.

7.2.3 Innovation and Incubation Programmes

The Innovation and Incubation Programs pillar drives entrepreneurial and technological advancement in GIS and RS by providing a robust platform for startups, small and medium enterprises (SMEs), and researchers to experiment, innovate, and commercialise their solutions.

Core activities include:

1. Startup Incubation and Mentorship: The hub will provide financial support, access to state-of-the-art facilities, and technical mentorship for startups focusing on GIS and RS applications. Areas of focus will include smart agriculture, flood risk mapping, and real-time urban planning solutions.
2. Open Innovation Challenges: ASEAN-wide competitions will encourage academic institutions, private firms, and individual innovators to propose novel solutions for challenges like coastal erosion management, renewable energy mapping, and disaster response systems.
3. Public–Private Partnerships (PPPs): Encouraging collaboration between industry leaders and governments will create opportunities for co-investment in scalable GIS and RS solutions, fostering regional economic growth.
4. Accelerators for Emerging Markets: Targeted programmes for emerging players like Malaysia and the Philippines will focus on reducing their dependency on imported technology by encouraging the development of indigenous GIS tools and technologies.

Through these initiatives, the hub will create a thriving ecosystem of entrepreneurs and innovators, driving localised solutions for ASEAN's unique challenges.

7.2.4 Research and Development (R&D) Hubs

The hub's R&D Hubs pillar is dedicated to fostering scientific research and technological development, with a focus on creating country-specific solutions that address regional challenges.

Key aspects include:

- Regional Centers of Excellence: Establishing specialised R&D hubs in strategic locations to focus on key areas of expertise:
- Fisheries Management Cluster (Philippines)
- Forestry and Marine Conservation Cluster (Indonesia)
- Disaster Resilience Cluster (Viet Nam)
- Precision Agriculture and Climate Adaptation Cluster (Thailand)
- Urban Planning and Smart Cities Cluster (Singapore)

Collaborative Research Projects: Joint R&D initiatives between ASEAN nations and global partners, including Japan, to develop and refine GIS and RS technologies for real-world applications.

- Data Analytics Infrastructure: Establishing high-performance computing (HPC) facilities to process large datasets, enabling ASEAN nations to make faster and more informed decisions in areas like disaster response and resource management.

Knowledge Dissemination: Publishing research findings and organising conferences to showcase ASEAN's contributions to the global GIS and RS community. These R&D hubs will serve as knowledge powerhouses, enabling ASEAN nations to develop innovative solutions while positioning themselves as leaders in geospatial technology.

7.3 Example of Open Innovation Hub: Advancing Collaborative Innovation in GIS and Remote Sensing

The Collaborative Research Center for Space Systems (YUCARS) at Yamaguchi University (http://yucars.eng.yamaguchi-u.ac.jp/) exemplifies the role of an Open Innovation Hub, fostering collaboration across academia, industry, and government to advance space systems, GIS, and remote sensing technologies. Positioned at the intersection of cutting-edge research and real-world application, YUCARS serves as a model for how innovation hubs can drive technological advancements, capacity building, and knowledge sharing on both regional and international scales.

YUCARS operates as a platform that connects diverse stakeholders to collaboratively address complex challenges in space and remote sensing technologies. Its approach to open innovation is built on the principles of:

- Multi-Stakeholder Collaboration: YUCARS brings together researchers, engineers, government agencies, and private sector players to co-create solutions. This interdisciplinary approach ensures that research outputs are both innovative and practically applicable.

- Shared Resources and Infrastructure: By providing access to cutting-edge facilities, data sets, and software tools, YUCARS enables collaborative research that might otherwise be inaccessible to individual entities.
- Knowledge Exchange and Dissemination: The center organises workshops, seminars, and conferences to share insights and foster continuous learning amongst its partners, promoting the exchange of expertise on a global scale.

This open innovation framework allows YUCARS to serve as both a research powerhouse and a collaborative hub, driving progress in GIS and remote sensing.

YUCARS is a leader in space systems research, with a strong focus on developing and applying GIS and remote sensing technologies for practical use. Key areas of expertise include:

1. Small Satellite Development: YUCARS has significant experience in designing, building, and testing small satellites, enabling nations and institutions to access cost-effective solutions for remote sensing and data collection.
2. Disaster Management Applications: The center specialises in using GIS and remote sensing technologies for disaster preparedness and response, a critical area for ASEAN nations prone to natural hazards.
3. Environmental Monitoring: With expertise in analysing land use, deforestation, and climate change, YUCARS supports sustainable development initiatives by providing actionable data and insights.

These capabilities make YUCARS a critical partner for ASEAN nations looking to enhance their technological capacities and address pressing challenges through GIS and RS solutions. YUCARS also plays a pivotal role in developing skilled professionals and advancing technical expertise through targeted capacity-building initiatives. The center's approach includes:

- International Training Programmes: YUCARS provides tailored training programmes for researchers, engineers, and students from ASEAN nations, focusing on areas such as satellite technology, GIS data processing, and environmental applications.
- Collaborative Research Opportunities: Partnering with universities and research institutions across ASEAN, YUCARS facilitates joint research projects that address regional challenges like disaster resilience, urban planning, and agriculture optimisation.
- Mentorship and Scholarships: The center offers mentorship programmes and scholarships for young professionals and academics, fostering a new generation of leaders in GIS and RS technologies.

By prioritising knowledge transfer and workforce development, YUCARS ensures that its expertise has a lasting impact on its collaborators and partners. As an Open Innovation Hub, YUCARS actively supports the incubation of new ideas and technologies, promoting entrepreneurship and innovation in the space sector. Its initiatives include:

1. Startup Support: Providing technical assistance, mentorship, and access to resources for startups working on GIS and RS applications, such as smart agriculture, flood risk mapping, and urban development.
2. Innovation Challenges: Hosting hackathons and competitions to encourage innovative solutions to real-world problems, fostering creativity and problem-solving amongst researchers and entrepreneurs.
3. Public–Private Partnerships (PPPs): Collaborating with industry leaders to co-develop scalable technologies, ensuring that research outputs are aligned with market needs and can be effectively commercialised.

Through these programmes, YUCARS promotes a culture of innovation that extends beyond academic research, empowering startups and SMEs to develop practical, impactful solutions. YUCARS can serves as a vital link between Japan and ASEAN, enabling knowledge exchange and technological collaboration that benefits both regions. The center's strategic position in Japan provides ASEAN nations with access to:

- Japanese Expertise in Space Systems: YUCARS leverages Japan's advanced capabilities in satellite technology, GIS analytics, and environmental monitoring to support ASEAN nations in building their capacities.
- Technology Transfer Programmes: By sharing tools, methodologies, and frameworks, YUCARS helps ASEAN countries adopt best practices in GIS and RS.
- Collaborative Projects for Regional Challenges: The center works with ASEAN nations to co-develop solutions for issues like disaster resilience, urban planning, and sustainable development, ensuring that its innovations are tailored to regional needs.

This partnership strengthens ASEAN's ability to address its unique challenges while fostering deeper ties with Japan in the fields of science, technology, and innovation. The operational model of YUCARS provides a blueprint for establishing similar Collaborative Open Innovation Hubs in ASEAN nations. Key lessons include:

- Fostering Regional Collaboration: YUCARS demonstrates the importance of uniting diverse stakeholders under a shared vision to drive innovation and address common challenges.
- Investing in Capacity Building: The center's focus on training and workforce development ensures long-term sustainability and impact.
- Balancing Collaboration and Competition: YUCARS successfully combines collaborative research with competitive innovation programmes, encouraging both teamwork and individual excellence.

By adopting YUCARS' principles, ASEAN nations can establish their own innovation hubs to advance GIS and RS technologies, tailored to their specific developmental contexts.

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Chapter 8

Conclusion

The potential of space technology to transform socio-economic landscapes in the ASEAN region has been clearly established in this study. With a focus on addressing environmental challenges, agricultural optimisation, disaster resilience, and regional connectivity, this research highlights the critical role of satellite remote sensing and related technologies in fostering sustainable development.

ASEAN nations face a complex array of challenges, ranging from natural disasters and environmental degradation to technological and regulatory limitations. These issues hinder socio-economic progress and underscore the need for innovative solutions. Space technology emerges as a transformative tool, offering capabilities such as remote sensing, synthetic aperture radar (SAR), and geospatial analytics to address these pressing issues effectively.

While advanced economies like Singapore lead in data processing and maritime monitoring, others, such as Cambodia and Timor-Leste, struggle with foundational gaps, including infrastructure deficits and skill shortages. This disparity necessitates a cohesive and collaborative regional approach to leverage the full potential of space technologies.

A significant outcome of this study has been the emphasis on collaborative frameworks involving industry, academia, and government. Partnerships with Japan and other international stakeholders have paved the way for knowledge transfer, capacity building, and the successful implementation of pilot projects tailored to regional needs. These projects have demonstrated the scalability of space technology solutions, with significant potential for broader application across ASEAN.

The following strategies offer a cohesive path forward for ASEAN's space technology initiatives:

- Establishing an ASEAN Space Policy: Inspired by the European Space Policy Coordination framework, ASEAN can develop a unified ASEAN Space Policy Coordination Framework. This framework would harmonise the diverse space programmes of its member states to address critical regional priorities such as sustainable development, disaster management, and climate resilience. By pooling resources, expertise, and funding, ASEAN Member States (AMS) can collectively tackle shared challenges through joint satellite missions, centralised data-sharing platforms, and unified governance structures.
- Developing an ASEAN Earth Observation Program (AEOP): Modeled after the ESA's Earth Observation Envelope Program, AEOP would focus on addressing the

region's unique environmental and developmental challenges. Shared satellite missions and a centralised data-sharing platform would enable AMS to collaboratively monitor critical issues such as deforestation, urbanisation, and climate vulnerabilities.

- ASEAN Regional Satellite Operations Centre (ASOC): A centralised hub for managing regional satellite operations would streamline tasks such as launch coordination, orbit control, and data relay. ASOC could also serve as a training hub, ensuring all AMS benefit from hands-on experience in satellite operations and data analysis.
- ASEAN Space Innovation Clusters: Regional clusters focused on specific challenges, such as fisheries management in the Philippines, forestry conservation in Indonesia, disaster resilience in Viet Nam, precision agriculture in Thailand, and urban planning in Singapore, would foster innovation and address local needs. These clusters would connect universities, industries, and governments, driving the development and commercialisation of space-based solutions.
- ASEAN Meteorological Satellite Network (AMSAT): Building a shared meteorological satellite network, similar to EUMETSAT, would enhance regional disaster preparedness and support climate adaptation efforts. AMSAT would provide real-time weather data, benefiting sectors like agriculture and disaster management.
- ASEAN Integrated Applications Program: This programme would integrate Earth observation data with technologies like GNSS and satellite communications to create practical solutions for ASEAN's challenges. Public–private partnerships and capacity-building initiatives would be key components of this effort.
- ASEAN Space Technology and Research Centre (ASTREC): As a collaborative Open Innovation Hub, ASTREC would unite government agencies, academic institutions, and private industries to advance GIS and remote sensing technologies. Its pillars: collaborative innovation, capacity building, innovation programmes, and R&D hubs, would ensure that AMS have access to shared resources and expertise.

The integration of space technology into ASEAN's socio-economic fabric represents a paradigm shift in the region's approach to development. By addressing critical challenges through innovative solutions and fostering collaboration across member states, ASEAN can build resilience, enhance equity, and drive sustainable growth. The strategies outlined in this study underscore the importance of unifying efforts, building capacity, and leveraging international partnerships to realise the transformative potential of space technology. As ASEAN advances on this journey, space technology will undoubtedly become a cornerstone of its developmental strategy, positioning the region as a global leader in innovation, resilience, and sustainability.

Appendix A: Patent Landscape Methodology

The patent landscape in this report was applied patent landscape methodology from World Intellectual Property Organization. Source as follows:

https://www.wipo.int/edocs/pubdocs/en/wipo-pub-1083-en-patent-landscape-report-graphite-and-its-applications.pdf

Dataset

The final dataset of remote sensing imagery-related inventions was retrieved on December 3, 2024. The dataset consists of patent applications published worldwide from 2004 to 2021, retrieved from the Derwent World Innovation (DII) database

Search string

To ensure the optimal recall and accuracy of the dataset retrieved, the search strings used in this report were formulated incorporating keywords, their synonyms and variants, relevant patent classification codes and indexing, for example, International Patent Classification (IPC) and Cooperative Patent Classification (CPC). Detailed lists of main keywords and the patent classification codes used are presented in Annex B.

Grouping by the Derwent World Patent Index family

Due to the territorial nature of the global patent system, applicants who seeking to protect the same invention in multiple countries must file separate patent applications in each jurisdiction. This often leads to the duplication of identical applications across jurisdictions. Therefore, in this report, the number of unique inventions is measured using the Derwent World Patent Index family counts.

Data inclusion

Automated data cleaning through the DII database was carried out to:

1. Remove non-patent specification, for example, utility models; and
2. Ensure the relevance of the dataset prior (earliest document) to carrying out the analyses.

Grouping of technology domain and areas

Grouping of patent families belonging to the retrieved dataset into the respective technology domains and areas was carried out based on patent classifications codes. To validate it, the taxonomy of the various categories and sub-categories was co-developed with input from subject-matter expert.

Regional specialisation index

The regional specialisation index (S_{is}) in this report is used to investigate the top countries of patent origin and their invention focus across different technology areas. It is calculated by the percentage of inventions related to a specific technology area over the total number of inventions filed by applicants in the countries.

Formula

$$S_{is} = \frac{W_{is}}{W_i}$$

Where:

W_{is} is the number of inventions related to a specific technology area originating from the country or region i,

W_i is the total number of remote sensing imagery-related inventions filed by applicants in the country i.

Recency

Recency in this report measures quantitatively how recently technologies were first filed for patent protection (developed). It is calculated by a weighted average of inventions, whereby a higher weighting is given to inventions filed in more recent years.

Formula

$$\underline{R} = \frac{\sum_{i=1}^{n} (w_i \times i)}{n \times \sum_{i=1}^{n} w_i}$$

Where:

i = 1 for the first year of the survey period, and i increases by 1 for every subsequent year in chronological order;

n is the total number of years of the survey period; and

w_i is the number of inventions filed in the year.

Relative recency

Refers to normalised recency by taking the recency of the entire remote sensing imagery-related technology dataset to be 1.

Appendix B: Patent Searches

Overall Dataset

A main query comprising two sub-queries was first established to retrieve an overall dataset for all remote sensing imagery-related patent applications in both developed countries (China, Japan, Singapore, United States) and developing countries (Indonesia, Malaysia, Viet Nam, Philippines, and Thailand). Selection of developing countries takes into account the availability of data during the analysis period. Considering the completeness of data in patent documents, we use different search techniques of the remote sensing technology patent between developed and developing countries, with search field combination as follows.

- Developed countries: Title, abstract, and IPC/CPC
- Developing countries: Title and abstract

Main IPC/CPC used

Based on the keywords of each technology category obtained from Expert, we use the patent classification recommendations from Espacenet (EPO database) to obtain the relevant IPC/CPC subclass (https://worldwide.espacenet.com/patent/cpc-browser). Here is the list of IPC/CPC subclass used.

IPC	Description
G06V	Image Or Video Recognition Or Understanding
G06T	Image Data Processing Or Generation, In General
Y02A	Technologies For Adaptation To Climate Change
G06F	Electric Digital Data Processing
G01B	Measuring Length, Thickness Or Similar Linear Dimensions; Measuring Angles; Measuring Areas; Measuring Irregularities Of Surfaces Or Contours
G06N	Investigating Or Analysing Materials By Determining Their Chemical Or Physical Properties
G01J	Measurement Of Intensity, Velocity, Spectral Content, Polarisation, Phase Or Pulse Characteristics Of Infrared, Visible Or Ultraviolet Light; Colorimetry; Radiation Pyrometry

G01S Radio Direction-Finding; Radio Navigation; Determining Distance Or Velocity By Use Of Radio Waves; Locating Or Presence-Detecting By Use Of The Reflection Or Reradiation Of Radio Waves; Analogous Arrangements Using Other Waves

H04N Pictorial Communication, E.G. Television

C01P Indexing Scheme Relating To Structural And Physical Aspects Of Solid Inorganic Compounds

A01B Soil Working In Agriculture Or Forestry; Parts, Details, Or Accessories Of Agricultural Machines Or Implements, In General

H04L Transmission Of Digital Information, E.G. Telegraphic Communication

H04W Wireless Communication Networks

Y02D Climate Change Mitigation Technologies In Information And Communication Technologies [Ict], I.E. Information And Communication Technologies Aiming At The Reduction Of Their Own Energy Use

G06Q Information And Communication Technology [Ict] Specially Adapted For Administrative, Commercial, Financial, Managerial Or Supervisory Purposes; Systems Or Methods Specially Adapted For Administrative, Commercial, Financial, Managerial Or Supervisory Purposes, Not Otherwise Provided For

E21C Mining Or Quarrying

G01N Investigating Or Analysing Materials By Determining Their Chemical Or Physical Properties

Y02E Reduction Of Greenhouse Gas [Ghg] Emissions, Related To Energy Generation, Transmission Or Distribution

Y02T Climate Change Mitigation Technologies Related To Transportation

Search queries

The search queries for remote sensing technology-related patent as follows:

Main category	Specific area (specific keywords)	Developing countries	Developed countries
Image pre-processing	Calibration	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(calibrat*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(calibrat*) AND AIC=(G06V OR G06T);
	Atmospheric	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(atmospher*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(atmospher*) AND AIC=(G06V OR G06T OR Y02A);
	Filtering	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(filter*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(filter*) AND IC=(G06V or G06T);
	Radiometric	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(radiometr*) AND TAB=(calibrat*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(radiometr*) AND TAB=(calibrat*) AND AIC=(G06T or G06V);
	Masking	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(mask*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(mask*) AND AIC=(G06T or G06V);
	Mosaicing	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(mosaic*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(mosaic*) AND AIC=(G06T or G06V);
	Harmonisation	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(harmon*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(harmon*) AND AIC=(G06T or G06V);
	Geometric rectification	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(geometric*) and tab=(correct* or calibrat*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(geometric*) and tab=(correct* or calibrat*) and aic=(G06V OR G06T);
image storage	Cloud storage	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote

Main category	Specific area (specific keywords)	Developing countries	Developed countries
		photogra* or 'remote sensing') AND TAB=(cloud*) and tab=(storag* or memor*);	sensing') AND TAB=(cloud*) and tab=(storag* or memor*) and aic=(G06V OR G06F);
	Big data	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('big data*');	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('big data*') and aic=(G06V OR G06F);
image processing	Artificial intelligence	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('artificial intelligence' or 'machine learning' or 'deep learning');	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('artificial intelligence' or 'machine learning' or 'deep learning') and aic=(G06V OR G06F OR G06N OR G06T);
	Clustering	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(cluster*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(cluster*) and aic=(G06V OR G06F OR G06N OR G06T);
	Classification	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(classif*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(classif*) and aic=(G06V OR G06F OR G06N OR G06T);
	Detection (or change detection)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('change detec*' or detec*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('change detec*' or detec*) and aic=(G06V OR G06F OR G06N OR G06T);
	Segmentation	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(segment*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(segment*) and aic=(G06V OR G06F OR G06N OR G06T);
	Feature Extraction	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('feature extract*');	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('feature extract*') and aic=(G06V OR G06F OR G06N OR G06T);
	Data Fusion	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('data fusion*');	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('data fusion*') and aic=(G06V OR G06F OR G06N OR G06T);

Main category	Specific area (specific keywords)	Developing countries	Developed countries
	Coherence	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(coherenc*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(coherenc*) and aic=(G01B OR G01T OR G06T OR G06N);
Image sensor	Multispectral	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(multispectr*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(multispectr*) and aic=(G01J OR G06T OR G06V);
	Hyperspectral	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(hyperspectr*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(hyperspectr*) and aic=(G01J OR G06T OR G06V);
	Synthetic Aperture Radar	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('synthetic aperture radar');	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('synthetic aperture radar') and aic=(G01S OR G06T OR G06V);
	Lidar	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('LIDAR');	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('LIDAR') and aic=(G01S OR G06T OR G06V);
	Thermal	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(thermal*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(thermal*) and aic=(H04N or G06V);
	Aerosol	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(aerosol*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(aerosol*) and aic=(C01P or G06T or G06F);
Image post-processing	Accuracy Assessment	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(accura*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(accura* OR PRECIS*) and aic=(G06T OR G06F OR G06V);
	Elevation Model	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(elevation*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('elevation') and aic=(G06T);
	Enhancement	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote

Main category	Specific area (specific keywords)	Developing countries	Developed countries
		photogra* or 'remote sensing') AND TAB=(enhanc*);	sensing') AND TAB=(enhanc*) and aic=(G06T);
	Land Use	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('land use');	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('land use') and aic=(G06T or GO6V);
	Land Cover	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('land cover');	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=('land cover') and aic=(G06T or GO6V or Y02A);
	Terrain Model	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(terrain*);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(terrain*) and aic=(G06T or GO6V);

The search queries for remote sensing application-related patent as follows:

Main Category	Specific area (specific keywords)	Developing countries	Developed countries
Remote sensing (image and GIS) applications	Agriculture (AGR)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(farm* or agri* or cultivat* or rice or crop or 'palm oil' or cattle* or livestock*) AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(farm* or agri* or cultivat* or rice or crop or 'palm oil' or cattle or livestock) and aic=(G06Q or Y02A0040 OR A01B) AND AIC=(G06V OR G06T);
	Telecommunication (TLC)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(telecommunic* or communicat*) AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(telecommunic* or communicat*) and aic=(G06V OR G06T) and aic=(H04W OR H04L OR Y02D OR G06Q OR G06C);
	Urban Planning (URP)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(urban* or housing or residen* or 'regional plan*' or 'real estate*' or 'city landscap*' or traffic*) AND AIC=(G06V	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(urban* or housing or residen* or 'regional plan*' or 'real estate*' or 'city landscap*' or

Main Category	Specific area (specific keywords)	Developing countries	Developed countries
		or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	traffic*) and aic=(G06V OR G06T) and aic=(H04W OR H04L OR G06Q);
	Marine (MRN)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(marine* or ocean* or nautic* OR BATHYMETR*) AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(marine* or ocean* or nautic* OR BATHYMETR*) and aic=(G06V OR G06T) and aic=(Y02A OR G06Q);
	Fisheries (FSH)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(fish* or aquacultur* or aquatic* or crustace* or shrimp* or crab* or lobster*) AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* or 'remote sensing') AND TAB=(fish* or aquacultur* or aquatic* or crustace* or shrimp* or crab* or lobster*) and aic=(G06V OR G06T) and aic=(Y02A OR G06Q);
	National Security (NSC)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(militar* or defen* or secur*) AND AIC=(G06V or G06T or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(militar* or defen*) and aic=(G06V OR G06T) AND AIC=(G06F OR G01B OR Y02A OR OT OR G06Q OR H04L OR G06B);
	Disaster (DST)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(disaster* or catastrop* or earthquake* or flood or hurricane* or tornado* or tsunami or eruption* or typhoon or landslid*) AND AIC=(G06V or G06T or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(disaster* or catastrop* or earthquake* or flood or hurricane* or tornado* or tsunami or eruption* or typhoon or landslid*) and aic=(G06V OR G06T) and aic=(G01B OR H04L OR G01V OR Y02A OR G01S);
	Mining (MNG)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(mine or mining* or petrol* or 'crude oil*' or fuel* or mineral* or fossil* or geolog* or metalurg* or coal* or 'natural gas*') not tab=('text mining' or 'data mining') AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(mine or mining* or petrol* or 'crude oil*' or fuel* or mineral* or fossil* or geolog* or metalurg* or coal* or 'natural gas*') not tab=('text mining' or 'data mining') and aic=(G06V OR G06T) and aic=(G01Q OR E21C OR G01V OR G01N);

Main Category	Specific area (specific keywords)	Developing countries	Developed countries
	Renewable Energy (RNE)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=('RENEWABLE ENERG*' OR WIND OR SOLAR OR GEOTHERMAL OR 'OCEAN ENERG*' OR HYDRO* OR BIOENERG* OR BIOMASS* OR TIDAL OR 'MARINE ENERG*') AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=('RENEWABLE ENERG*' OR WIND OR SOLAR OR GEOTHERMAL OR 'OCEAN ENERG*' OR HYDRO* OR BIOENERG* OR BIOMASS* OR TIDAL OR 'MARINE ENERG*') and aic=(G06V OR G06T) and aic=(G01Q OR Y02E OR Y02T);
	Public Health (PHT)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(health* or 'public healt*' or healthcare or hospital or disease* or 'air qualit*') AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(health* or 'public healt*' or healthcare or hospital or disease* or 'air qualit*') and aic=(g06v or g06t) and aic=(G06Q OR G16H or A16B OR H04W);
	Forestry (FRS)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(forest* or vegetat* or wood* or jungle or conservat* or timber) AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(forest* or vegetat* or wood* or jungle or conservat* or timber) and aic=(g06v or g06t) and aic=(G06Q OR Y02A or G06F);
	Climate (CLM)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(climate* or weather* or meteorolog* or geophysic*) AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(climate* or weather* or meteorolog* or geophysic*) and aic=(G01w OR Y02A or G06Q);
	Water Resources (WTR)	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(water* or 'water resource*' or 'water qualit*' or puddle* or lake or reservoir or lagoon OR river) NOT TAB=(WATERMARK*) AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=(water* or 'water resource*' or 'water qualit*' or puddle* or lake or reservoir or lagoon OR river) NOT TAB=(WATERMARK*) and aic=(G01Q OR Y02A) and aic=(g06t or g06v);
	Infrastructure And	CC=(ID OR MY OR PH OR TH OR VN) AND TAB=(imag* or photogra* OR 'remote sensing') AND TAB=('PLANT	CC=(JP OR CN OR SG OR US) AND TAB=(imag* or photogra* OR 'remote sensing') AND

Main Category	Specific area (specific keywords)	Developing countries	Developed countries
	Facilities (IFS)	area*' or 'plant facilit*' OR civil* or infrastructure* or building* or street* OR LAYOUT*) AND AIC=(G06V or G06T or Y02A or G06F or G01B or G01S or H04L or G06Q or G01J);	TAB=('PLANT area*' or 'plant facilit*' OR civil* or infrastructure* or building* or street* OR LAYOUT*) and aic=(g06t or g06v);