POLICY REPORT

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AI in Space Technologies: A Singapore Case Study

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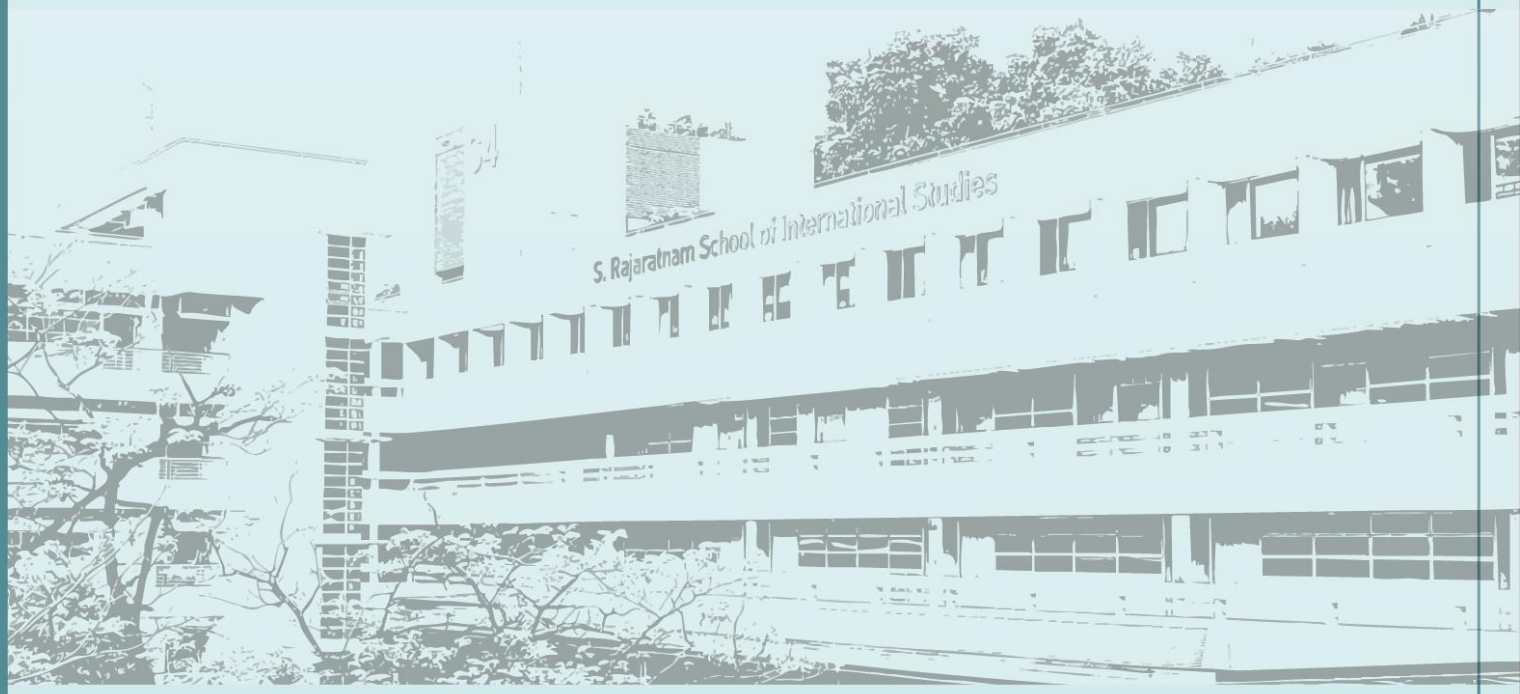

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Executive Summary

Singapore, Asia's smartest city in 2024, is treading towards integrating artificial intelligence (AI) with space technologies. This report examines the impact, potential, and challenges of this convergence, based on insights from five space experts across Singapore's public, private, and academic sectors. Key themes include: (i) AI's role in enhancing space and Earth sustainability; (ii) Singapore's focus on equatorial data collection with AI to bridge global data gaps; and (iii) fostering public-private-academic synergy in AI and space. Highlighted are AI applications for remote sensing, challenges like data quality and talent gaps, and the multi-stakeholder ecosystem in Singapore as a case for sustainable innovation. The report recommends that Singapore develop a National Space Strategy to ensure responsible and sustainable space and Earth activities, strive for sustained innovation momentum in AI applications for space technologies, establish stronger collaborative platforms across sectors that will aid in data sharing and address the talent gap, prioritise collection of climate and environmental data to improve forecasts, contribute to the global climate dataset, and expedite reactions to regional adverse events.

Introduction

Singapore has been acclaimed as Asia's smartest city in 2024[1] and a top technology innovation hub after Silicon Valley.[2] This achievement was made possible through various initiatives to maintain its status as a Smart Nation—a living laboratory and a hotbed for emerging technologies.[3] It is important to recognise that Singapore's technological landscape has opportunities for development, especially in the field of emerging technologies. The convergence of two such technologies, AI and space, presents a unique set of opportunities and challenges in the city-state.

In this report, we examine the impact of the integration of AI and space technologies and its applications by stakeholders in Singapore. We interviewed five space experts in Singapore in May 2024, spanning the public and private sectors and academia. The interviews were conducted in compliance with the Nanyang Technological University's (NTU) Institutional Review Board (IRB; reference number: IRB-2023-796) guidelines.

Aggregated responses highlighted three key themes. First, in Singapore, the integration of AI in space technologies is driven primarily by sustainability efforts for both space and the Earth. Second, Singapore is well-positioned to collaborate and specialise in gathering and analysing AI-enhanced equatorial data. And third, while there is some synergy among public sector groups, private companies, and universities in Singapore on AI research and development for space applications, there is still room for improvement.

We outline how Singapore applies AI in space for remote sensing and Earth observation, collecting data with higher quality specific to the region, from low Earth orbit (LEO) and very low Earth orbit (VLEO) satellites. Key opportunities and potential challenges illustrating how Singapore can serve as a case study for integrating AI into space technologies were also highlighted.

AI in Space for Sustainability

The use of AI in space applications focuses on both space sustainability and sustainability on Earth.

Prolonging Satellite Life

The proliferation of national and commercial satellites requires effective strategies to manage crowded orbits and navigate against space debris. Given the growing congestion of space orbits, a public sector expert opined that AI could enable the

[1] International Institute for Management Development, "IMD Smart City Index 2024," www.imd.org/wp-content/uploads/2024/04/20240412-SmartCityIndex-2024-Full-Report_4.pdf.
[2] KPMG, "Singapore Tops 2021 Ranking for Leading Technology Innovation Hubs", 16 July 2021.
[3] Smart Nation Singapore, "Transforming Singapore Through Technology," www.smartnation.gov.sg/about-smart-nation/transforming-singapore/.

implementation of anti-collision mechanisms,[4] which will autonomously maneuver satellites around debris, thereby preventing collisions and ensuring safer orbital paths. Since much of space debris originate from old satellites, extending the operational life of satellites can help reduce overcrowding. The same expert believes there is a growing effort to repair and upgrade existing satellites through in-space maintenance. This would help prolong satellite lifespans, reduce the frequency of new launches, and support a more sustainable and efficient space environment.[5]

The Issue of Space Radiation

Another prevalent issue, as shared by a private sector expert,[6] is high radiation in space. This can hinder the performance of CPUs and GPUs (central and graphics processing units), impacting AI models running on satellites. Thus, most satellites that carry sensitive AI systems operate in LEO and VLEO satellites, where radiation is lower.

While solutions like radiation hardening can help protect against radiation, performance of AI models is still affected, making it a real challenge for private companies working in space.[7] This presents an opportunity to install powerful AI systems onboard satellites that collect and process equatorial data. A private sector expert shared that Zero-Error Systems, a Singapore startup, has been developing radiation-hardened integrated circuits for such uses.[8]

Addressing Climate Change

According to interviewed experts,[9] AI plays a crucial role in Singapore's climate monitoring by predicting atmospheric changes, detecting climate variability patterns, and improving strategies to reduce its impact.

In academia, researchers are combining neural networks with physics-based models and ordinary differential equations to integrate human knowledge with machine learning.[10,11] They are exploring physics-informed AI to ensure models follow known physical laws, leading to more reliable predictions, especially when data is limited or noisy. These models are promising for simulating complex climate dynamics that traditional methods struggle to capture.

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[4] Interview with public sector experts, (2024).
[5] Interview with public sector experts, (2024).
[6] Interview with private sector expert 1, (2024).
[7] Interview with private sector expert 1, (2024).
[8] Interview with private sector expert 1, (2024); Debra Werner, "Zero-Error Systems raises $7.5 million," Space News, 12 June 2023, https://spacenews.com/zero-error-systems-raises-7-5-million/.
[9] Interview with public sector experts, (2024); Interview with private sector expert 1, (2024); Interview with private sector expert 2, (2024)
[10] Gu Kai, Xia Zhi, Qiao Jun, and Lin Wei, "Deep Dual-Channel Neural Network for Image-Based Smoke Detection," *IEEE Transactions on Multimedia* 22, no. 2 (2020): 311-323. 10.1109/TMM.2019.2929009.
[11] Gu Kai, Liu Hao, Xia Zhi, Qiao Jun, Lin Wei, and Daniel Thalmann, "$PM_{2.5}$ Monitoring: Use Information Abundance Measurement and Wide and Deep Learning," IEEE Transactions on Neural Networks and Learning Systems 32, no. 10 (2021): 4278-4290. 10.1109/TNNLS.2021.3105394.

A private sector expert[12] mentioned that AI-powered video satellites, which offer higher resolution and lower latency than traditional LEO satellites, can be enhanced by AI techniques. They also noted that AI-driven remote sensing can measure the urban heat index using thermal infrared data and monitor greenhouse gas emissions.[13]

Supporting Humanitarian Assistance and Disaster Relief

AI-driven remote sensing provides a powerful "eye in the sky" to aid in prediction, surveillance, and relief efforts in Singapore and neighbouring countries.[14] Remote sensing efforts in the region have proven to be instrumental in facilitating humanitarian assistance and disaster relief. The technology has been employed to assess volcanic impacts and improve flood mapping accuracy both by the academic and private sectors.[15]

Researchers are also developing deep learning techniques for synthetic-aperture radar (SAR) imagery to create innovative solutions for post-disaster damage mapping. These efforts demonstrate the importance of AI in space applications, such as monitoring biodiversity, assessing climate impacts, enhancing disaster resilience, and improving coastal adaptation management. The abovementioned research directions showcase both advanced research and practical applications in these critical areas.

AI in Space for Specialised Data

A Role in Equatorial Data Collection

As public and private sector experts have confirmed, Singapore leverages its satellites to gather vast amounts of data from the equator.[16] This is important because many satellites operate in higher inclination orbits that typically leave out the equatorial region. The shortage of local and regional data reduces the accuracy of climate models and hampers the development of climate scenarios. An academic expert pointed out that the lack of data from equatorial regions, where atmospheric interactions are complex, limits the ability to perform thorough data analysis.[17] Since AI depends heavily on data, incorporating it into space technologies could position Singapore as a key provider of regional data.

To avoid relying on estimates from non-equatorial data to create equatorial models, academics are combining physical models with big data.[18] A private company in Singapore is now able to provide significantly more accurate information than these

[12] Interview with private sector expert 1, (2024).
[13] Interview with private sector expert 1, (2024).
[14] Sentinel Asia, "Interview," https://sentinel-asia.org/interview/interview_EOS-RS.html.
[15] Sébastien Biass, Susanna Jenkins, David Lallemant, Tian Ning Lim, George Williams, and Sang-Ho Yun, "Chapter 12 - Remote sensing of volcanic impacts," in *Forecasting and Planning for Volcanic Hazards, Risks, and Disasters* edited by Papale, Paolo, 473–491. Elsevier, 2021.
[16] Interview with public sector experts, (2024).; Interview with private sector expert 1, (2024).
[17] Interview with an academic expert, (2024).
[18] Interview with an academic expert, (2024).

estimates, not only for understanding weather patterns but also for predicting the next major natural disaster in equatorial regions.[19] Combining Interferometric SAR (InSAR) with Global Navigation Satellite Systems Interferometric Reflectometry (GNSS-IR) allows for detailed measurements of vertical land movement. This provides both high spatial and temporal resolution, which is important for understanding one of the main factors contributing to regional sea level rise.[20,21]

The equatorial data problem has been highlighted across sectors. An academic and a public sector expert mentioned that in its current state, AI cannot address the data gap, nor is it meant to do so.[22] However, it is worth noting that geospatial foundation models, dubbed by one expert from the public sector as the "ChatGPT of space data," are being pre-trained with vast amounts of data and then fine-tuned with human-labelled data to understand data nuances.[23] This process is still in its early stages in Singapore, and significant development is needed to create stronger, general-purpose AI tools that can help reduce the time-consuming task of data labelling.[24]

It is also important to note that Singapore is not the only country in Southeast Asia collecting equatorial data. Indonesia, for example, has an equatorial satellite named LAPAN A2 that was launched into equatorial orbit with six-degree inclination in 2015.[25] The equatorial satellite, as compared to Sun-Synchronous Orbit (SSO) satellites, has been suggested to be more useful as it passes over Indonesia more frequently. LAPAN A2 has proven valuable during disasters in Indonesia, aiding in emergency communications and providing imagery of the affected area.[26]

Singapore can benefit from collaborating with Indonesia to address the current gap in equatorial data collection. A key approach could be to initiate joint projects that promote open information sharing between the two nations. This collaboration could expand the available data, potentially leading to the development of AI models capable of generating more accurate climate models. The partnership may also improve the understanding of natural disasters in the region. Such efforts are crucial, given the shared vulnerability of Southeast Asia to the impacts of climate change.

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[19] Interview with private sector expert 2, (2024).
[20] PDawei Peng, Lei Feng, Kristine M. Larson, and Emily M. Hill, "Measuring Coastal Absolute Sea-Level Changes Using GNSS Interferometric Reflectometry," *Remote Sensing* 13, no. 21 (2021): 4319.
[21] Ching-Heng Tay, Elizabeth O. Lindsey, Siu-Ting Chin, James W. McCaughey, Dirk Bekaert, Minh Nguyen, Heng Hua, Gregorio Manipon, Mohammad Karim, Brian P. Horton, Ting Li, and Emily M. Hill, "Sea-level rise from land subsidence in major coastal cities," *Nature Sustainability*, (2022): 1-9.
[22] Interview with public sector experts, (2024).; Interview with an academic expert, (2024).
[23] Interview with public sector experts, (2024).
[24] Interview with public sector experts, (2024).
[25] Wahyudi Hasbi, "LAPAN-A2 (IO-86) Satellite Roles in Natural Disaster in Indonesia," Paper presented at the 70th International Astronautical Congress (IAC), Washington D.C., United States, 21-25 October 2019, www.researchgate.net/publication/338804095_LAPAN-A2_IO-86_Satellite_Roles_in_Natural_Disaster_in_Indonesia
[26] Wahyudi Hasbi," LAPAN-A2 (IO-86) Satellite Roles in Natural Disaster in Indonesia"

AI and Satellite Communications

This explosion of data, however, is a double-edged sword. With massive amounts of data being transmitted from the satellite to the Earth and back, these activities contribute to congestion of a highly regulated radio frequency spectrum, impacting satellite communication services. Major Singaporean companies providing telecommunication services such as Singtel and ST Engineering iDirect have been working on solutions for handling the growing demand for mission-critical and satellite communications for more than 40 years. Space telecommunication providers now use AI algorithms to filter out noise and detect inconsistent data, helping to optimise data flow for their partners.[27]

While telecommunications are key to connecting in space, the experts interviewed did not point out any operational issues, suggesting that the current setup works and supports other space developments. However, to address the lack of equatorial data, experts from the public and private sectors, as well as academia, are discussing various solutions.[28]

A public sector expert shared that AI could provide super-resolution for satellites if properly trained.[29] This approach can save costs compared to using large payloads typically required for high-resolution imaging. Instead of transmitting terabytes of raw data for Earth observation, onboard AI can process the data in real time and send only the analysed information, reducing the need for large size, weight, and power payloads.[30] The private sector has also developed a platform that hosts data collected from more than 400 satellites, enabling automatic object detection, analysis of object movement, land use and changes over time, as well as land cover classification.[31]

AI in Space through Synergy among Stakeholders

Relationships across public and private sectors as well as the academe are outlined in this section. We further highlight the synergistic relationships that help drive innovation. However, this synergy is not perfect and there is room for improvement, as mentioned by one space expert from the academe[32] and another one from the private sector.[33]

Experts from both the public sector and academia note ongoing financial support for universities to sustain research and development.[34] However, academic partners, due to existing collaborations with international agencies, mostly focus on

[27] Office for Space Technology and Industry in Singapore, *Singapore's Space Ecosystem*, https://file.go.gov.sg/sgspaceecosystem.pdf.
[28] Interview with public sector experts, (2024).; Interview with private sector expert 1, (2024).; Interview with private sector expert 2, (2024).; Interview with an academic expert, (2024).
[29] Interview with public sector experts, (2024).
[30] Interview with public sector experts, (2024).
[31] Interview with private sector expert 1, (2024).
[32] Interview with an academic expert, (2024).
[33] Interview with private sector expert 1, (2024).
[34] Interview with public sector experts, (2024).; Interview with an academic expert, (2024).

climate and environmental monitoring, making extensive use of remote sensing and image processing. Meanwhile, private telecommunication companies in Singapore focus on communication services, working to develop solutions for rapid uplink and downlink data transmission. These companies support national defence, civil services, and regional humanitarian efforts.

Our findings indicate that Singapore can enhance synergies across sectors by strengthening cooperation and support between the public, private, and academic sectors, bolstered by international collaboration.

Public-Private Partnerships

Singapore's Office for Space Technology and Industry (OSTIn), established in 2013, plays a crucial role in enhancing small satellite capabilities and fostering public-private partnerships within the space sector. In 2022, OSTIn, in collaboration with the National Research Foundation, received S$150 million (over US$100 million) for the Space Technology Development Programme, which promotes collaboration among various stakeholders.[35,36]

OSTIn oversees and coordinates a range of initiatives that involve both public and private sectors, highlighting the importance of collaboration in Singapore's space ecosystem. According to the Singapore Space Ecosystem report[37] published by OSTIn in 2022, the country offers a diverse array of space-related services. While numerous entities are engaged in engineering and manufacturing space hardware—such as engines, cameras, sensors, and onboard computers—many private partners are also focused on developing AI-supported solutions. These solutions address persistent challenges in areas like navigation, inter-satellite communication, and space situational awareness, showcasing the impact of public-private partnerships in advancing Singapore's capabilities in the space industry.

A private sector expert shared that their company collaborates with the Singapore Civil Defence Force on disaster management technologies.[38] The programme promotes collaboration and AI innovation between Singapore, Indonesia, the Philippines, and Vietnam. A private sector expert who hosts a Software as a Service (SaaS) platform for satellite data is dedicated to breaking down data silos by providing access to public defence companies and private enterprises, both locally and globally.[39] Their company has an ongoing collaboration with defence agencies and enterprises across Southeast Asia. However, not every enterprise is eager to provide open access to the satellite data they collect.[40]

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[35] Office for Space Technology & Industry Singapore, *Singapore's Space Ecosystem*, https://file.go.gov.sg/sgspaceecosystem.pdf.
[36] Office for Space Technology & Industry Singapore, "OSTIn's Space Journey," www.space.gov.sg/about-our-history/.
[37] Office for Space Technology & Industry Singapore, *Singapore's Space Ecosystem*, https://file.go.gov.sg/sgspaceecosystem.pdf.
[38] Interview with private sector expert 2, (2024).
[39] Interview with private sector expert 1, (2024).
[40] Interview with private sector expert 1, (2024).

The public sector also supports the space industry by assisting startups focused on space-based weather and remote sensing, according to a private sector expert.[41] Space companies are experiencing a surge in interest in AI-driven solutions. One private sector expert mentioned that there are approximately 50 space technology firms in Singapore, while another private sector expert aims to strengthen collaboration with the government to further advance their company's objectives.[42]

Collaborative Efforts by/with Academia

Singapore's academic community benefits from the collaborative nature of international space initiatives. Such efforts ensure effective governance and focus on practical solutions for global challenges. Their participation in cross-border projects is advantageous, supported by a national commitment to AI development, local training, and effective solution implementation. Academics play a pivotal role by partnering with various agencies to create natural hazard forecasts, develop mitigation plans, and assess the impacts of climate change for global organisations.[43]

The Earth Observatory of Singapore Remote Sensing (EOS-RS) Lab and the Centre for Remote Imaging, Sensing and Processing (CRISP) at the National University of Singapore (NUS) play a crucial role in accessing and processing remote satellite data quickly. CRISP utilises its extensive expertise in operating high-performance antennas, while EOS-RS provides vital geospatial information to support disaster response efforts. For instance, after Super Typhoon Rai (Odette) struck the Philippines, EOS-RS produced flood and damage maps within a week for the UN World Food Programme and Manila Observatory. It also collaborates with the ASEAN Coordinating Centre for Humanitarian Assistance on Disaster Management (AHA Centre) and the Asian Disaster Preparedness Center to improve mapping products, making them lightweight and accessible for responders with limited internet access. For example, the AHA Centre used EOS flood maps during storms like Kajiki (2019), Goni (2020), Rai/Odette (2021), Nalgae (2022), and Noru (2022) to inform reports and estimate emergency needs.[44]

[41] Interview with private sector expert 2, (2024).
[42] Interview with private sector expert 1, (2024); Interview with private sector expert 2, (2024).
[43] Sentinel Asia, "Interview," https://sentinel-asia.org/interview/interview_EOS-RS.html.
[44] Sentinel Asia, "Interview," https://sentinel-asia.org/interview/interview_EOS-RS.html.

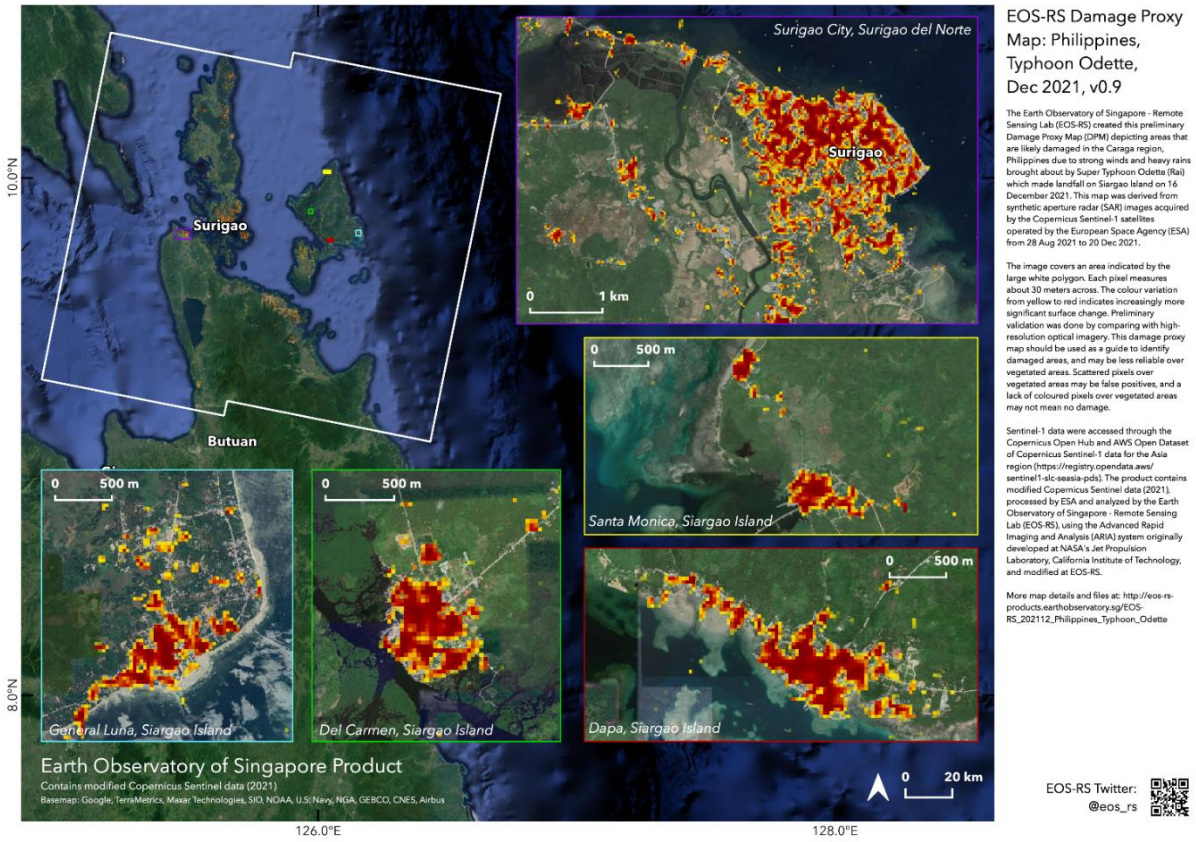

Image source: EOS - Remote Sensing Lab

EOS-RS also works with the Japan Aerospace Exploration Agency (JAXA) for satellite data.[45] CRISP works with the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and JAXA, among other agencies, to control environmentally sustainable practices, for instance, marine and air pollution.

Partnerships between the academe and the private sector also allow for combining deep learning with time series of InSAR coherence data to improve the quality of satellite-based damage mapping after disasters.[46] EOS-RS leverages modern satellite data and collaborates on upcoming missions to enhance Singapore's climate change efforts, contributing to the interdisciplinary Climate Transformation Programme by EOS.

AI Washing?

Despite concerns about "AI washing," the growing role of AI in space exploration is undeniable, largely driven by the need for automated satellite management as the number of launches increases. AI enhances data collection, improves onboard processing, and enables coordinated operations of satellite swarms. Furthermore, the challenging conditions of space drive AI innovation, with benefits extending to other strategic areas. As outlined in the National AI Strategy (NAIS), integrating AI into space

[45] Sentinel Asia, "Interview," https://sentinel-asia.org/interview/interview_EOS-RS.html.
[46] Oliver L. Stephenson, Tobias Köhne, Eric Zhan, et al., "Deep Learning-Based Damage Mapping With InSAR Coherence Time Series," *IEEE Transactions on Geoscience and Remote Sensing* 60: 1–17, https://doi.org/10.1109/TGRS.2021.3084209.

technologies can boost scientific advancement, operational efficiency, and climate change monitoring efforts.

In addition, the Singapore Space and Technology Ltd., a non-governmental space organisation, announced that the Global Space Technology Convention & Exhibition 2025 will tackle integrating AI into space technologies.[47] This aligns with Singapore's vision to leverage AI capabilities and accelerate the development of its space sector.

Opportunities and Challenges

The findings from this study highlight significant intersections of AI and space in Singapore and underscore opportunities and challenges to further innovative work among the two technologies.

Firstly, sustainability emerges as a strong driving force, with AI being leveraged for applications related to space sustainability by prolonging satellite life and maintaining inter-satellite communication and space navigation, as well as Earth sustainability by monitoring climate change impacts and supporting humanitarian assistance and disaster relief.

Secondly, our research underscores Singapore's specialisation in equatorial data collection and analysis. With its strategic location and advanced satellite capabilities, Singapore (alongside other actors such as Indonesia) is well-positioned to provide insights and predictions for the equatorial region.[48] However, challenges such as spectrum congestion, data gaps, and susceptibility to harsh environments complicate the effective utilisation of AI technologies. These can be mitigated by using AI techniques like super-resolution, onboard processing, and geospatial foundation models. To address this issue, public sector funding and support for experimental AI in space activities and academic applications can serve as a starting point. Extending the same support to the private sector would also enable them to scale AI in space technologies in ways that drive costs to a minimum.

Thirdly, the study highlights the importance of synergy among the public, private, and academic sectors. Collaborative efforts and strategic investments nurtured the space ecosystem in Singapore, with private, public, and academic stakeholders facilitating cross-sector collaborations.[49] One gap experts mentioned is lack of access to data across sectors (as not everyone is keen to share), which can impede progress in their endeavours. Platforms that host access to vast datasets collected from satellites can become gamechangers and international collaboration can facilitate transnational exchange of necessary information.[50] Supporting access to these platforms and

[47] Global Space Technology Convention & Exhibition, “Global Space Technology Convention & Exhibition 2025,” https://space.org.sg/gstce/.
[48] Interview with public sector experts, (2024).; Interview with private sector expert 1, (2024).; Interview with an academic expert, (2024).
[49] Interview with public sector experts, (2024).; Interview with private sector expert 1, (2024).; Interview with private sector expert 2, (2024).; Interview with an academic expert, (2024).
[50] Interview with private sector expert 1, (2024).

creating opportunities for information sharing among stakeholders across various sectors can further strengthen collaboration, prevent duplication of efforts, cut costs, and ensure that activities are more targeted and sustainable.

A major challenge highlighted by most experts is a significant talent gap,[51] with only 2,800 information and communications technology graduates annually for 60,000 job openings expected by 2024.[52] The aerospace sector also faces a challenge, that is, retaining talent within the industry, which different stakeholders have been trying to address.[53] A private sector expert confirmed that there is a talent shortage in most technology branches, exacerbated by integrating AI and space.[54] Steps are being taken across sectors to address the situation. With the NAIS launched in 2019 and enhanced in 2023, the Singapore government pioneered AI Singapore (AISG) which coordinates AI efforts across institutions. AISG also offers apprenticeship programmes to train local talent.[55] A public sector space expert is hopeful that the NAIS will benefit the space ecosystem, including talent recruitment and development.[56] The private sector seeks to nurture AI and space talents through educational initiatives[57] or outsourcing AI and space expertise offshore due to high hiring costs in Singapore.[58]

Universities in Singapore play a key role in developing AI and space talent through dedicated research centres and educational programmes. The Satellite Technology and Research Centre of NUS focuses on advanced satellite systems, while NTU's Satellite Research Centre integrates expertise from multiple fields. Both centres provide programmes for undergraduate and postgraduate students, which require consistent public funding. The private sector can further support this by offering apprenticeships to help students build workforce capacity.[59]

Policy Recommendations

The challenges mentioned underscore the critical need for a National Space Strategy in Singapore. This issue is particularly significant, especially since the country is well-positioned to work with other space agencies globally[60]—a strength that stems from its emphasis in partnering with both local and international stakeholders to drive talent development and innovation.

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[51] Interview with public sector experts, (2024).; Interview with private sector expert 1, (2024).; Interview with private sector expert 2, (2024).
[52] Joe Devanesan, “Is Singapore facing a tech talent crunch?” *Tech Wire Asia*, https://techwireasia.com/2020/09/is-singapore-facing-a-tech-talent-crunch/.
[53] Jeraldine Yap and Jalelah Abu Baker, “Singapore grooms talent, looks to scale up infrastructure to meet demand from aerospace industry”, *Channel NewsAsia*, 27 February 2024, www.channelnewsasia.com/singapore/aerospace-manpower-retention-st-engineering-edb-4152136.
[54] Interview with private sector expert 2, (2024).
[55] AI Singapore, ”AI Apprenticeship Programme (AIAP)®,” https://aisingapore.org/innovation/aiap/.
[56] Interview with public sector experts, (2024).
[57] Interview with private sector expert 2, (2024).
[58] Interview with private sector expert 1, (2024).
[59] Space Faculty, ”Internship Opportunities,” https://spacefaculty.co/internship-opportunities.
[60] Interview with public sector experts, (2024).

Based on the results of our report, this strategy needs to ensure that Singapore: (i) employs responsible and sustainable space activities through regulatory oversight; (ii) moves toward an innovative edge in space technologies, beginning with AI in space applications; (iii) establishes a collaborative, supportive, and shared platform between public, private, and academic sectors; (iv) facilitates and incentivises data sharing; and (v) nurtures space talents and builds capacity within the country.

Just as the NAIS benefits space, the upcoming National Space Strategy should ensure that advancements in space technologies positively influence Singapore's broader technological agenda. OSTIn would be a logical launching pad for this (as Singapore's national space office), but considering the findings of our report, insights and recommendations from the academe, the industry, other government institutions, and even international bodies are critical as well.

Additionally, including incentives to encourage students to pursue careers in the space industry should be explored in the strategy, given the growing opportunities for employment in the field. Scholarships and attachments to the space industry may be pull factors. Re-skilling of mid-career professionals, especially those working on AI, space, and adjacent technologies, can also be considered.

Recommendations from other well-established space agencies and lessons from national space strategies can likewise prove to be useful. Remarkably, national strategies focus mostly on the applications of space technology for security and military purposes. For instance, the US and EU holding massive manufacturing capabilities and benefitting from the long history of investments in space technologies, detailed the use of space for commercial activities,[61] defence, and security.[62,63] The UK's National Space Strategy[64] outlines the future directions for space development and highlights the actions for their achievement. On the contrary, public agencies such as ESA[65] and NASA[66] mention continuous collection of climate-related information as the primary strategic objective. With these in mind, Singapore's National Space Strategy can cover both traditional and non-traditional security aspects.

The upcoming strategy can additionally contribute to advancing space efforts in the Southeast Asian region, especially since Singapore has longstanding academic,

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[61] U.S. Space Force Commercial Space Strategy, "Accelerating the purposeful pursuit of hybrid space architectures," www.spaceforce.mil/Portals/2/Documents/Space%20Policy/USSF_Commercial_Space_Strategy.pdf.
[62] National Security Space Office, *National Security Space Strategy*, Washington, D.C.: National Security Space Office.
[63] European Commission, "EU Space Strategy for Security and Defence for a stronger and more resilient European Union," https://defence-industry-space.ec.europa.eu/eu-space/eu-space-strategy-security-and-defence_en.
[64] Great Britain, Government, *National Space Strategy*, https://assets.publishing.service.gov.uk/media/6196205ce90e07043d677cca/national-space-strategy.pdf
[65] European Space Agency, "Shared vision strengthens Europe's space strategy," www.esa.int/Applications/Observing_the_Earth/Shared_vision_strengthens_Europe_s_space_strategy.
[66] National Aeronautics and Space Administration, "NASA Strategic Plan 2022," www.nasa.gov/wp-content/uploads/2023/09/fy-22-strategic-plan-1.pdf?emrc=ff1a1e.

private, and public collaborations with suppliers of satellites and data (ESA, JAXA, Centre National d'Etudes Spatiales, United Arab Emirates Space Agency, regional observatories, etc.) and beneficiaries of space technologies (Japan International Cooperation Agency, AHA Centre, United Nations World Food Programme, Asian Disaster Preparedness Center, regional governments, etc.). Singapore has already deployed satellites that collect local climate- and weather-related data, monitored unsustainable practices, and identified disaster-stricken areas to quickly divert resources in the region, playing an important space role in the ASEAN region. With high connectivity with other regions, digital competitiveness, and easy access to investment and talent, Singapore lays the ground for a holistic space strategy.

Presently, there are varying levels of involvement among Southeast Asian countries in the space domain. Within ASEAN, countries such as Laos, Myanmar, Cambodia, and Brunei have limited space-related activities.[67] These countries do not seem to have their own national space strategy yet. On the other hand, Malaysia, the Philippines, and Thailand have since produced their own national space policy,[68] Philippine Space Development and Utilization Policy (PSDUP),[69] and masterplan,[70] respectively. Malaysia's national space policy, for example, outlined space goals and how it intends to strategically achieve them. As for the PSDUP, it will be the Philippines' main strategic space roadmap. It will be beneficial and timely for Singapore to have its own comprehensive National Space Strategy that can serve the needs of Singapore and contribute as well as collaborate with the wider ASEAN region.

Conclusion

The convergence of AI and space technologies positions Singapore as a potential key player in advancing sustainability, data specialisation, and synergy within the space sector. The nation's strategic focus on AI-powered sustainability initiatives underscores its commitment to both space and the Earth's environmental health. By leveraging its equatorial position, Singapore is poised to become a provider of specialised data, contributing to enhancing global understanding of equatorial climate phenomena. Furthermore, the collaborative efforts among public sector entities, private companies, and academic institutions foster a dynamic ecosystem driving innovation and addressing talent gaps. As Singapore continues to navigate the challenges and opportunities in this domain, its integrated approach serves as a case study of efforts, opportunities, and challenges for future advancements in AI and space technologies.

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[67] Quentin Verspieren, "CO23008 | ASEAN Space Programmes: Navigating Regional Rivalries," *RSIS Commentary*, www.rsis.edu.sg/rsis-publication/rsis/asean-space-programmes-navigating-regional-rivalries/.
[68] Malaysian Space Agency, "National Space Policy 2030," https://cms.spacesecurityportal.org/uploads/MLY_National_Space_Policy2030_English_501fa55c3e.pdf.
[69] Philippine Space Agency, "REPUBLIC ACT No. 11363 or Philippine Space Act," https://philsa.gov.ph/philippine-space-act/.
[70] Tita Sanglee, "Thailand's Space Age in the Making" *The Diplomat*, 18 January 2023, https://thediplomat.com/2023/01/thailands-space-age-in-the-making/.

Singapore, lacking opportunities for large manufacturing and testing facilities due to limited land availability, occupies a niche in developing LEO satellites for monitoring climate- and weather-related phenomena and unsustainable practices. While the private sector primarily focuses on developing satellites with more robust onboard AI systems, academics elaborate AI models for more efficient processing of data received from the satellites. The public sector provides funding to some projects and participates in efforts to build local manpower and facility capabilities. Multi-stakeholder approaches facilitated forecasting climate events and swifter reaction to adverse hazards, assessing the impacts, and monitoring unsustainable practices. But more can be done, especially if Singapore wants to become a key player in the international space ecosystem.

Given these, a National Space Strategy should be on the horizon to consolidate the main players and align Singapore's efforts in addressing global challenges such as climate change. As Earth and space sustainability are manifested in the country, the National Space Strategy should outline the steps to encourage interaction among local and regional stakeholders, provide the levers for open data sharing, and facilitate deployment and shared use of facilities.

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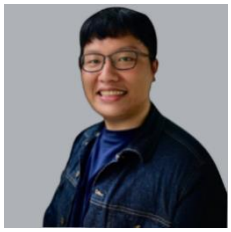

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