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Future Scenarios of the Space Industry in Thailand Using Foresight Methodology

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Abstract

The global space industry is witnessing rapid growth and the emergence of innovative service models that were previously unimaginable. This swift expansion brings uncertainties, presenting both opportunities and challenges. Foresight is a crucial tool for systematically exploring plausible scenarios in the space industry, helping to identify potential impacts and prepare for them. This study explores the future of Thailand's space industry over the next decade using the Foresight methodology, specifically the "Framework Foresight" approach, which includes Framing, Scanning, Forecasting, and Visioning. The research process involved online data collection, an internal workshop within the Office of the National Broadcasting and Telecommunications Commission (NBTC), interviews, a survey, and a workshop with stakeholders in the space industry. From these efforts, 28 trends and emerging issues were identified, leading to the development of four distinct future scenarios. Each scenario was analyzed for potential implications, with corresponding recommendations provided. The findings highlight the need for effective government support and policies, investment support, organizing human resources, and maximizing citizen benefits from the space sector in every scenario.

Keywords: Foresight, Scenario, Space Industry, Thailand

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1. Introduction

The space industry, a prominent and dynamic sector, has garnered substantial attention in business and policy discussions. Recent estimates place its global value at USD 200 to 350 billion, depending on the definition and measurement method, with projections anticipating growth to 1 trillion USD by 2040 (OECD, 2023). Playing a pivotal role in the economy, the space sector encompasses upstream activities (design, manufacturing, and launch) and downstream applications (broadband Internet, satellite television, and navigation, etc.). Additionally, space-derived activities impact various sectors such as telecommunications, transportation, and agriculture. Advancements in space technology, resulting in reduced costs of building and launching satellites, have made the space industry more accessible to the private sector and poised for substantial growth. For example, SpaceX's Starlink satellite network has enabled the provision of fast broadband internet service globally in just a few years. Despite the space industry's growth potential, its future is uncertain due to various challenges such as addressing environmental problems and disasters, geopolitical tensions, and emerging technologies. These challenges require stakeholders to prepare for an uncertain future.

Foresight is the systematic exploration, anticipation, and influence of the future to enhance preparedness for change. Some studies employ foresight methodologies to explore the future of the space industry, primarily in developed countries. For example, Black et al. (2022) analyze threats and opportunities for the UK National Space Strategy, mapping potential uses of space. Similarly, Copenhagen Institute for Future Studies (2023) formulates scenarios for European space exploration, while the University of Houston Foresight Program (2017) applies foresight to explores long-term strategic planning in NASA Langley Research Center (LaRC). However, the space industry in developing countries differs due to variations in several aspects, e.g. economic conditions, technological expertise, and the availability of a skilled workforce, etc.

Therefore, there exists a discernible gap in the literature concerning the future of the space industry in developing countries. This paper aims to address this gap by proposing a study on the future of the space industry in a developing country using foresight methodology. Thailand is chosen for this case study as it boasts a significant space industry, with over 35,600 businesses contributing approximately $1.5 billion annually to the nation's space-related market in 2021 (GISTDA, 2021). Thailand's government and regulators play a crucial role in shaping policies and regulations within the space industry to foster an environment conducive to business opportunities, while the private sector benefits from their support. For example, the Thai government has a national space master plan aimed at promoting Thailand's space economy and becoming a space hub in Southeast Asia (Akarakupt, 2019). Nevertheless, Thailand could also face an inevitably uncertain future in the space industry, which presents both opportunities and threats. To navigate uncertain futures, scenarios can be used as a foresight tool. This has led to the research question of this study: What do the future plausible scenarios of the space industry in Thailand in 2035 look like, and what are the implications for stakeholders and recommendations for the government and regulators?

This paper follows the widely accepted and referenced "Framework Foresight" (Hines and Bishop , 2013; Hines et al., 2015; Hines, 2020), as applied in communications regulation (Jaroonvanichkul, 2023) to explore future scenarios of the space industry in Thailand in 2035.

The outline of this paper is as follows: section 2 presents a literature review on space economy, foresight research and its practice in the space industry, and background of the space industry in Thailand. Section 3 discusses the methodology for conducting foresight based on the "Framework

Foresight," which includes Framing, Scanning, Forecasting, and Visioning. Section 4 provides results, and Section 5 concludes this paper.

2. Literature review

2.1 Space Economy/Industry

The Space Economy is defined by the OECD (OECD, 2022) as the full range of activities and the use of resources that create value and benefits for human beings in the course of exploring, researching, understanding, managing, and utilizing space. The space industry could be considered a subset of the space economy, as described by UK Space Industry (UK Space Agency, 2019), which includes all organizations engaged in any space-related activity to some degree. This includes both commercial organizations (i.e., businesses, companies) and institutions (e.g., universities, research institutes) that secure funding to contribute space-specific research and expertise throughout the industry's supply chain, often in partnership with commercial organizations.

The space industry can be considered as the collection of companies involved in space-related activities. The distinction between the space economy and the space industry is that the former refers to the range of activities, while the latter refers to the organizations engaged in those activities (Strada, 2018). The terms space economy and space industry are sometimes used interchangeably. Thus, for the purposes of this paper, "space industry" will be used to denote activities and organizations engaged in any space-related activity.

Value chain of space industry can be classified into 3 segments (OECD, 2022) as follows:

1. Upstream segment: includes scientific and technology foundations for space programs (e.g. Research and Development, Manufacturing and Launch).

2. Downstream segment: space operations and "down-to-earth" products and services directly rely on satellite capacity (e.g. Satellite TV, Satellite devices, Satellite Broadband Internet, etc.).

3. Space-derived/induced activities: Activities that are derived/induced from space activities but is not depended on it to function (e.g. technology transfers from the space sector to the automotive or medical sectors).

Table 1 shows examples of activities, products and services of the 3 segments.

Table 1. Value chain of space industry (OECD, 2022)

Segment	Activities	Example of products and services
1. Upstream	1.1 Research and development	Physical and Material research
	1.2 Ancillary services	Finance, Insurance Legal and Regulatory services
	1.3 Design and manufacturing of space equipment and subsystems	Build and assembly of spacecraft and satellites
	1.4 Space Infrastructure	Launch and landing site, Spaceport
	1.5 Launch and satellite operations	Rocket launching operation, Remote satellite control
2. Downstream	2.1 Space and Ground systems operations	Leasing and selling satellite capacity
	2.2 Data Distribution Services	Satellite Data Platforms
	2.3 Supple of devices and equipment supporting the consumer markets	Very small satellite terminals, Chipsets, GPS receivers
	2.4 Supply of services supporting the consumer market	Direct-to-Home, Broadcast TV, Broadband Internet, Location-based signal service

Segment	Activities	Example of products and services
	2.5 Supply of value-added data services	Satellite imagery, Telematics, Surveying, Meteorology
3. Space-derived activities	New activities in various economic sectors that derive from space technology transfers	Space derived/induced activities in Agriculture, Environment protection, Tourism, Energy, Health, Medicine, Pharmaceutical, Food, Logistic, and Transport

According to OECD (2023), recent estimates of the size of the global space economy, excluding government procurement, range from USD 200 to 350 billion, depending on the definition and measurement method. The upper-range estimates also include revenues from location-based services (e.g., mobility apps on mobile phones) enabled by global navigation satellite services (GNSS). Revenues from the upstream segment are dwarfed by those of downstream segments, typically satellite television and, increasingly, revenues generated by PNT (Positioning, Navigation and Timing) services and equipment. Overall space economy revenues are strongly affected by developments in the satellite television market, which is declining in the face of the rollout of fixed broadband and consumers' growing preference for streaming platforms over linear television.

Before 2019, the space industry saw steady growth in payload launches, increasing from around 1,000 to 2,000 between 2013 and 2019, averaging 285 per year (7% annual growth). From mid-2020 to 2022, launches surged from around 2,000 to nearly 7,000, averaging 2,500 per year (23% annual growth). This growth is due to lower satellite building costs for a race of mega-constellation Low Earth Orbit (LEO) and more frequent launches resulting from launch costs dropping from over $10,000 per kg in 2000 to nearly $2,500 per kg in 2010, mainly due to reusable launchers (OECD, 2023).

However, the exponential growth of the space industry raises several concerns, including competition for orbital slots and frequencies, inequitable resource distribution, and high costs for new entrants. First-mover advantages allow operators to occupy slots indefinitely by refiling and replacing old satellites, posing technological, economic, and regulatory challenges for newcomers. Spectrum assignment approval can take up to a year, and there are risks of radio frequency interference between satellites, ground stations, and terrestrial systems. Additionally, the increasing number of satellite payloads heightens concerns about space debris, necessitating urgent attention to these issues (OECD, 2023).

2.2 Review of Foresight

Foresight is defined by the European Commission (2020) as "the discipline of exploring, anticipating and shaping the future in a structured and systemic way to anticipate developments and better prepare for change." This concept encompasses various forward-looking activities from a long-term perspective (Miles, 2010). Other terms related to foresight include “futures studies, futures research, futurology, futuristics, futurics, forecasting, and prognostics” (Marien, 1984, p. 35).

Foresight can help shape policies to be "more appropriate, more flexible, and more robust in their implementation" in response to evolving times and circumstances (Coates, 1985, as cited in Cuhls, 2003, p. 96). The objectives of foresight in policymaking include expanding opportunities, setting priorities, evaluating impacts, assessing current policy impacts, identifying new demands and possibilities, defining preferred and unpreferred futures, and encouraging dialogue (Cuhls, 2003).

To conduct foresight practically, various foresight frameworks are available in the literature (Streit et al., 2021; Yuksel et al., 2017). These include Framework Foresight (Hines & Bishop, 2013; Hines et al., 2015; Hines, 2020), Six Pillars (Inayatullah, 2013), Generic Foresight Process (Voros, 2003), and Integrated Foresight (Schultz, 2006), as shown in Table 2.

Despite variations in steps and terminology, these frameworks encompass similar core elements: scanning for information, creating alternative future scenarios, and preparing for change.

Table 2. Various foresight frameworks in the literature

Framework	Steps
Framework Foresight Authors: Hines and Bishop (2013), Hines et al. (2015), Hines (2020)	**Framing**: Define the study's scope and focus areas. **Scanning**: Gather environmental information within the scope. **Forecasting**: Develop multiple future scenarios. **Visioning**: Assess implications of the future scenarios. **Planning**: Formulate strategic options. **Acting**: Communicate findings, monitor indicators, and integrate strategies.
Six Pillars Author: Inayatullah (2013)	**Mapping:** Analyze history and identify future-shaping forces, drivers, trends, and barriers. **Anticipation:** Consider possible future scenarios. **Timing:** Identify patterns, stages, and mechanisms of change. **Deepening:** Understand deeper forces, systemic causes, worldviews, and myths influencing the future. **Creating Alternatives:** Develop alternative future scenarios. **Transforming:** Define a preferred future and take actionable steps toward it.
Generic Foresight Process Author: Voros (2003)	**Inputs:** Scan for environmental changes. **Analysis:** Evaluate potential changes. **Interpretation:** Identify deeper influencing forces. **Prospection:** Create alternative futures. **Outputs:** Develop strategic options. **Strategy:** Make decisions and take actions.
Integrated Foresight Author: Schultz (2006)	**Identify** and track changes **Evaluate** and critique impacts **Imagine** alternative futures **Envision** ideal futures **Plan** and implement changes

2.3 Review of foresight in the space industry

Some of the previous foresight works in the space industry are as follows:

1) The Future of Work 2050 for NASA LaRC

The white paper "The Future of Work 2050 for NASA LaRC" (University of Houston Foresight Program, 2017) explores long-term scenarios on the future of work for NASA Langley Research Center (LaRC). The paper identifies key drivers of change, including digital transformation, workforce, work models, facilities, and lab & policy, and uses these drivers to develop four future scenarios for LaRC: "Good to Go," "Failure to Launch," "Breaking Orbit," and "New Frontier." The descriptions of the four future scenarios are as follows:

- **Good to Go (Continuation)** anticipates a highly automated, privatized world with unevenly distributed benefits.
- **Failure to Launch (Collapse)** depicts a collapse scenario where AI and automation fail to resolve social and economic challenges, leading to societal breakdown.

- **Breaking Orbit (New Equilibrium)** explores the consequences of AI gaining excessive control, necessitating a re-education of the human workforce.
- **New Frontier (Transformation)** envisions a symbiotic relationship between humans and AI, supported by Universal Basic Income, fostering a passion-driven workforce.

The four future scenarios lead to different implications. The study also develops strategic approaches to deal with these potential scenarios and their impacts. It outlines four options: "Bet the farm," where all resources are placed into preparing for only one scenario; "Robust," where there is a great deal of common ground across the scenarios, and the organization invests in resources aligning with that common ground; "Hedge," which treats all scenarios equally; and "Core-Satellite," which focuses on one primary scenario while also putting some investment into others.

Moreover, the study also provides strategic recommendations among four scenarios based on strategic approaches aimed to ensure NASA LaRC remains adaptive and forward-thinking in the face of future uncertainties.

2) Future uses of space out to 2050: Emerging threats and opportunities for the UK National Space agency

The document "Future Uses of Space Out to 2050: Emerging Threats and Opportunities for the UK National Space Strategy" (Black et al., 2022) provides a comprehensive analysis of the future landscape of space activities. Conducted by RAND Europe's Centre for Futures and Foresight Studies, the research examines the evolving space economy, highlighting both the opportunities and challenges anticipated by 2050.

The study emphasizes the increasing complexity and integration of space-based and terrestrial markets, driven by technological advancements and declining costs of space access. It leads to mapping future upstream and downstream markets as well as space-induced applications. Furthermore, this research identifies potential enablers such as incremental advances in space-based technology or commercialization, public-private sector partnerships, and fostering public discourse as well as public and political interest in space. While barriers could include limited access to funding, barriers to sector-wide innovation and adoption of Industry 4.0, or insufficient national and international legal and regulatory mechanisms for space up to 2050.

Moreover, the paper also includes policy implications of the identified landscape of future uses of space for the UK, as well as key insights for navigating and capitalizing on the transformative changes expected in the space domain by 2050.

3) Future of space exploration: Strategic Scenarios for European space exploration 2040 - 2060

The paper "Future of European Space Exploration 2040 - 2060," authored by the European Space Policy Institute in collaboration with the Copenhagen Institute for Future Studies, (Copenhagen Institute for Future Studies, 2023) presents a comprehensive foresight analysis for the European space sector. The report emphasizes the necessity of strategic anticipation in light of new geopolitical shifts, technological advancements, and demographic changes.

The study outlines the scenario planning process and methodologies used to develop four potential futures for European space exploration from 2040 to 2060. The report identifies key drivers, enablers, and barriers to space exploration based on different issues in six dimensions: politics (such

as European cohesion and stability, public government support, multipolarity, and international relations), economics (such as investment and yield, competition), social (such as social change, skills, and competencies), technology (such as automation and robotics, space infrastructure), environment (such as climate change, resources and energy, existential risks like space debris, solar flares), and legal (such as rights, obligations, disputes, property, and territory). These dimensions are used to formulate four future scenarios: United Orbits, Competitive Cosmos, Sovereign Spaceways, and Corporate Galaxy. The overview of each scenario is as follows:

- **United Orbits** envisions a cohesive, intergovernmental focus driving space initiatives, supported by the public sector as the backbone and strong social welfare programs.
- **Competitive Cosmos** foresees a fragmented Europe with national governments pursuing their agendas in collaboration with global powers, reflecting weaker intergovernmental institutions.
- **Sovereign Spaceways** imagines a Europe where space activities are dominated by national interests, emphasizing sovereignty and strategic autonomy.
- **Corporate Galaxy** focuses on the dominance of commercial players in space exploration, driven by technological innovations and market forces.

Moreover, the report also provides implications for each scenario for Europe’s space endeavors in key areas such as talent pool (human resources), regulatory environment, cost of access to space, and enabling technologies, and compares Europe's position to other space powers.

It is worth noting that previous work on foresight studies in the space industry often focuses on leading countries or regions, primarily developed nations, which have the resources to significantly contribute to the space sector. These countries typically play a crucial role across the entire value chain, encompassing upstream, downstream, and space-induced activities. They benefit from robust government support, a well-developed technological infrastructure, ample financial funding, and a highly skilled workforce. In contrast, developing countries, despite being involved in the space industry, face different challenges due to variations in several aspects, e.g. economic conditions, technological expertise, and the availability of a skilled workforce, etc.

2.4 Background of Thailand’s Space industry

Thailand's space industry has significantly developed over the past few decades. Initially, Thailand engaged in basic satellite communications and earth observation. The launch of its first communication satellite, "THAICOM-1," into geostationary orbit in 1993 marked a pivotal step in establishing its space presence. To date, Thailand has launched 15 satellites, including 7 communication geostationary satellites, 4 Earth observation satellites in non-geosynchronous orbits, 1 microsatellite, and 3 nanosatellites (Cubesats) (UNOOSA, 2024). All of those satellites have been launched from foreign spaceports.

In the communication satellite market, Thailand has played a crucial downstream role in the telecommunication and broadcasting sectors since the launch of THAICOM-1. Thailand has seven geostationary satellites, with three currently operational: THAICOM-4 (IPSTAR, the world's first broadband high-throughput satellite at 119.5° East), THAICOM-6 (a broadcast satellite at 78.5° East), and THAICOM-8 (another broadcast satellite at 78.5° East). The most prominent market segment is Direct-to-Home (DTH) satellite TV via C-band and Ku-band household receivers, covering approximately 70% of Thai households (Thaicom Public Company Limited, 2014). THAICOM-4

and THAICOM-6 are now operated by National Telecom Public Company Limited (NT), a government-state-owned telecom operator, while THAICOM-8 is operated by Thaicom PLC, a private satellite operator in Thailand.

Another prominent part of Thailand's space industry is its ownership of earth observation satellites. The first Thai earth observation satellite, "THEOS" (Thailand Earth Observation System), was launched into Sun-synchronous orbit from French Guiana in 2008. THEOS provides images with 2-meter resolution in Panchromatic mode and 15-meter resolution in Multispectral mode (GISTDA, 2009). In 2023, Thailand launched "THEOS-2" with improved capabilities: 0.5-meter resolution in Panchromatic mode and 2-meter resolution in Multispectral mode. Both satellites offer crucial data for environmental monitoring, urban planning, and natural resource management. The Thai government, through the Geo-Informatics and Space Technology Development Agency (GISTDA), has played a vital role in these projects (GISTDA, 2023).

In terms of policy and regulation, the Thai government has outlined a national space master plan 2023-2037 (Nation Thailand, 2022) with a vision "to develop and utilize space activities for prosperity, security, and sustainability." The mission of the master plan includes enhancing space security, promoting the space economy, and researching space innovation. The National Space Master Plan is driven by eight strategies: space for security, sustainable development, economic development, infrastructure management, innovation research, human capacity building, international cooperation, and implementation mechanisms. The goal is to leverage space activities for security, economic growth, public and commercial services, and international cooperation to enhance competitiveness.

Additionally, Thailand is introducing a new draft space law, known as the National Space Affairs Act. This act would aim to align national space legislation with international space law. The National Space Affairs Act would be based on three essential principles:

1. Establishing an organization to serve as the center for national space affairs administration.
2. Upholding and preparing for international space commitments.
3. Promoting and supporting the space industry, research and development in space technology, and the regulation of space affairs.

Moreover, there are two main policy approaches regulating communications satellite operators’ access to the Thai market. First, a Thai satellite operator can apply to the National Broadcasting and Telecommunications Commission (NBTC), an independent regulatory body overseeing the country's broadcasting and telecommunications industries, including the regulation of radio frequencies and satellite orbit management, for the right to use Thailand's orbit and satellite filing network. Second, a landing rights policy has been established to regulate the authorization for foreign satellite operators to access the Thai market and provide communication services (The Committee on Information Technology, Communication and Telecommunication, Senate of Thailand, 2021; NBTC, 2020). The state-level landing rights policy is adopted by the National Space Policy Committee, while the firm-level landing rights policy is managed by the NBTC.

3. Methodology

The methodology for studying future scenarios of the space industry in Thailand in this paper adopts the framework foresight (Hines and Bishop, 2013; Hines et al., 2015; Hines, 2020), as applied in communications regulation (Jaroonvanichkul, 2023). Four steps of the framework foresight were conducted: Framing, Scanning, Forecasting, and Visioning. Figure 1 shows an overview of 4-step framework foresight used as the methodology for this study.

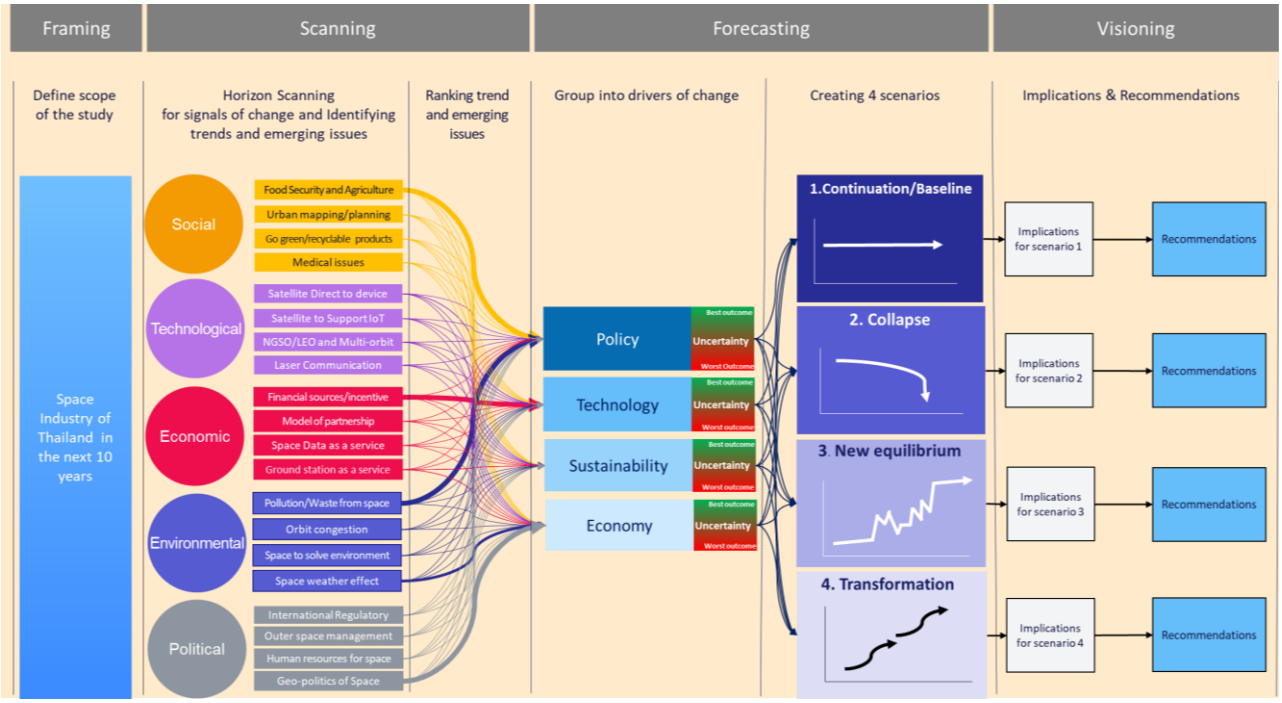

Figure 1. Overview of 4-step framework foresight adopted as the methodology for this study.

3.1 Framing

Framing involves defining the scope of the foresight exercise by taking into account various dimensions outlined in Table 3 (Porter, 2010; Jaroonvanichkul, 2023).

Table 3 Framing dimensions (Porter, 2010; Jaroonvanichkul, 2023)

Dimension	Description	Value used in this paper
Driver	The drivers dimension includes factors influencing future changes in the foresight exercise. It can encompass scientific research, technological developments, and broader contextual factors such as social, economic, and political elements.	Broader contextual factors (STEEP: Social, Technological, Economic, Environmental, and Political)
Scope	The scope dimension relates to the extent of the foresight exercise. It can concentrate on a single technology, multiple technologies, or take a comprehensive approach that includes various aspects of the space industry.	Various aspects of the space industry
Geography	The geography dimension defines the level at which the foresight exercise takes place.	Thailand, while also considering relevant international activities.
Time horizon	The time horizon dimension indicates the foresight exercise's timeframe.	10 years

Dimension	Description	Value used in this paper
Purpose	The purpose dimension defines the intended outcomes of the foresight exercise, provide general insights (informational) or address specific strategic issues (action-oriented).	Informational
Participation	The participation dimension involves the stakeholders in the foresight exercise, ranging from a narrow, closed process to a diverse, representative one.	Diverse mix, representative
Study duration	The timeframe used for conducting a foresight exercise.	7 months

3.2 Scanning

During the scanning phase, also known as Horizon Scanning, the goal is to identify, gather, and analyze various signals of change that could influence the future of a specific domain (Hines et al., 2019). The information gathered during scanning phase can be categorized as weak signals, emerging issues, and trends (Jaroonvanichkul, 2023). Weak signals are events and developments whose impacts and necessary responses are not yet fully understood (Hiltunen, 2008). Emerging issues occur when multiple weak signals converge, resulting in interconnected potential impacts (Amanatidou et al., 2012). Trends are gradual changes that occur over a long period and follow a specific direction (Hines & Bishop, 2013).

It is notable that scanning topics can be grouped into social, technological, economic, environmental, and political categories, commonly known as the "STEEP" acronym (Hines & Bishop, 2013). In this study, to identify trends and emerging issues that may be important for Thailand's space industry in the next 10 years, the process was conducted in three steps as follows:

1. Scanning information from various online sources.
2. Organizing an internal workshop within the Office of NBTC.
3. Interviewing stakeholders in the space industry.

The 17 stakeholders interviewed included 2 Thai startup groups, 1 defense representative, 2 governmental policymaker, 1 state space-related agency, 2 Thai satellite operators, 1 satellite component manufacturer, 2 foreign satellite operators, 3 educational institutions, 2 terrestrial operators, and 1 space-focused news agency. The interview followed a 7-question method (Government Office for Science, 2017) with the seven questions as follows:

Question 1) In your view, what issues will be important for Thailand's space industry or your organization over the next 10 years? You can raise issues in various areas such as social, technological, economic and business, environmental, political and policy, beyond the initial issues compiled by the Office of NBTC.

Question 2) If the future of Thailand's space industry in the next 10 years went in a good direction while still being realistic (optimistic but realistic), what would you see as a desirable future?

Question 3) On the other hand, if the future of Thailand's space industry in the next 10 years did not go as you expected (pessimistic), what would you see as a negative future?

Question 4) What factors in Thailand do you think should change in order to achieve the future of the space industry in the good direction you desire?

Question 5) Looking back at the past, what factors or events do you think have led the Thai space industry to its current situation?

Question 6) Looking ahead to the future, what do you see as priority actions which should be carried out in Thailand in order to achieve the future of the space industry in the good direction you desire?

Question 7) If there were no limitations and you could determine the direction to drive Thailand's space industry as you wish, what else would you want to happen?

3.3 Forecasting/ Futuring

In forecasting/Futuring, the goal is to explore possible scenarios by using information gathered from the scanning step (i.e. trends and emerging issues) to formulate different scenarios (Hines, 2020). Each scenario includes a title, a description/narrative, and key factors influencing the scenario.

Scenarios can be created using various methods. This study selects the scenario archetypes method (Hines, 2020). This method suggests that a domain or system typically follows one of four archetypal patterns of change: Continuation/Baseline, Collapse, New Equilibrium, and Transformation, as outlined in Table 4. To formulating scenarios, the outcomes of the previously identified important trends and emerging issues are clustered into drivers of change (Hines, 2020). The drivers of change are projected into different levels using the method of Morphological Analysis (Ritchey, 2015), divided into four levels, with level 1 being the most positive projection and level 4 the most negative projection. The different projections of drivers of change are mapped within each archetype, serving as the building blocks or plot elements for scenario development. This methodology ensures the creation of a comprehensive and diverse set of scenarios to work with (Jaroonvanichkul, 2023).

Table 4. The four scenario archetypes (Hines, 2020; Jaroonvanichkul, 2023).

Archetype	Description
Continuation/ Baseline	The current trends within the domain continue without major disruptions or unexpected events, maintaining its present trajectory without significant deviations.
Collapse	The system or topic encounters dysfunction or breakdown as traditional methods fail, leading to a deterioration in its condition.
New equilibrium	The system or topic confronts a major challenge to its current operations and must adapt, resulting in a new equilibrium among competing forces that differs significantly from the previous balance.
Transformation	The system or topic undergoes a fundamental transformation, where existing rules are abandoned, and new practices emerge.

3.4 Visioning

In the visioning step, all scenarios are analyzed to fully understand potential implications, leading to the formulation of recommendations and ultimately driving action (Jaroonvanichkul, 2023). The process of visioning can be divided into five steps as follows (Hines, 2020):

1. Choose a scenario.

2. Choose the categories: The categories to focus on for implications depend on the objective

of the foresight exercise. For this study, stakeholders participating in the space industry are chosen and divided into five categories: government, education and human resources, users, downstream players/operators, and the upstream segment.

3. Identify key changes in each category: For each category of stakeholders, brainstorm potential changes suggested by the scenario, assuming that the scenario occurs.

4. Identify additional implications using the Implications Wheel: The Implications Wheel® is a systematic approach to evaluating the effects of changes (Barker, 2011). Using "cascade thinking," it explores how a single event can lead to multiple impacts, each triggering further effects (Barker & Kenny, 2011). The process starts with first-order impact, then examines second-order impacts, and finally third-order impacts. These impacts, both positive and negative, stem directly from previous ones. Analyzing higher-order impacts with cascade thinking enables one to foresee the long-term, indirect effects of change (Jaroonvanichkul, 2023).

5. Select the most important implications and suggest recommendations: Identify the "most important" implications, preferably third-order ones, which can be either opportunities or challenges, as they hold significant importance and require stakeholders' attention. These implications are then converted into recommendations to provide ideas on how to deal with and prepare for them.

For this study, in the steps of Forecasting/Futuring and Visioning, a brainstorming workshop was held with a broad range of stakeholders participating in the space industry. The workshop included around 20 participants, such as Thai space startups, defense representatives, government officials, satellite component manufacturers, educational institutions, terrestrial operators, and the Office of NBTC. The workshop format featured group discussions with four groups, each consisting of mixed participants working on a scenario different from those of the other groups. The groups brainstormed ideas, refined and validated archetype scenarios and implications, and developed recommendations.

4. Results

4.1 Scanning

48 trends and emerging issues were identified, consisting of 6 social issues, 15 technological issues, 10 economic issues, 4 environmental issues, and 13 political issues, as shown in Table 5.

Table 5. Detailed information on trends and emerging issues that may be important for Thailand's space industry

Dimension	No.	Issue	Description
1. Social	1.1	Food Security and Agriculture	The use of space for food security and agricultural issues, both in the form of Space-to-Earth, such as using satellite data for crop planning, and Earth-to-Space, such as experimenting with seed cultivation in space.
	1.2	Medical Issues	The use of space for medical research, both in the form of Space-to-Earth, such as using satellite data for planning the prevention of epidemics resulting from climate change, and Earth-to-Space, such as researching drugs or cells in space under microgravity conditions.
	1.3	Urban Mapping/ Urban Planning	The use of space for urban development or urban planning, and population migration.
	1.4	Aging Society	The use of space to support an aging society

Dimension	No.	Issue	Description
	1.5	Go green and recyclable products	Environmental conservation and waste reduction for the planet, such as using electric vehicles and products made from recycled materials.
	1.6	Equitable Education	The utilization of space for promoting equal access to education
2. Technological	2.1	Satellite Direct-to-Device	Providing direct connectivity between regular mobile phones and satellite networks without the need for additional equipment.
	2.2	Satellite Industry to Support IoT	The satellite industry for enabling Internet of Things (IoT) connectivity.
	2.3	NGSO/LEO Satellites and multi-orbit models	Connectivity through non-geostationary satellite orbit (NGSO) and low Earth orbit (LEO) satellite networks, as well as the use of multi-orbit models.
	2.4	Extending lifespan of Satellites	- Reusing, recycling, and refueling satellites - Repairing satellites in orbit
	2.5	SmallSats and CubeSats	The utilization of small satellites (SmallSats) and cube satellites (CubeSats) in space.
	2.6	Onboard Wi-Fi supported by Satellites	Utilizing satellites to enable wireless internet (Wi-Fi) connectivity on aircraft and ships.
	2.7	In-Space Manufacturing and Additive Manufacturing	Manufacturing industry in space and spacecraft component production using 3D Printing technology.
	2.8	Data center and Cloud Computing in space	Building Data Centers and Cloud Computing via Satellite Networks in Space
	2.9	Laser Communication	The use of laser communication technology.
	2.10	5G/6G Non-Terrestrial Network (NTN) by Satellite	Connecting to 5G/6G networks using satellites instead of ground-based stations.
	2.11	Drone control by Satellite	Remote control of unmanned aircraft via satellite.
	2.12	AI in Space	Utilizing Artificial Intelligence (AI) technology in the space industry.
	2.13	Lunar Gateway	The development of a lunar-orbiting space station, known as the Lunar Gateway, for future lunar and Martian exploration missions. The station is expected to be operational by 2028.
	2.14	Very high throughput satellite (Geostationary orbit - GSO)	The use of Very high throughput satellite
	2.15	Inter-Satellite Communications	The use of communications between satellites
3. Economic	3.1	Commercial Space Industry players into the National Security Market	Commercial satellite and space service providers entering the national security market.
	3.2	New Space Economy	The growth of the space industry and the creation of value in the space economy, with participation from players ranging from small, medium, to large private companies entering the space industry market. This includes new types of companies such as Special Purpose Acquisition Companies (SPACs), which are gaining popularity in the United States market.
	3.3	Space Data as a service	Data services from space/satellite networks.
	3.4	Ground Station as a service (GSaaS)	Ground station connectivity services for satellite signal transmission with a global network infrastructure, eliminating the need for users to have their own gateways, and allowing control of these ground stations through cloud-based systems.

Dimension	No.	Issue	Description
	3.5	Space Tourism and Living in Space	Commercial space tourism and living in space.
	3.6	Concentration in Satellite market	The concentration of the satellite industry with few players, such as in the Low Earth Orbit (LEO) communication satellite market, where there are few companies, while there are increased mergers and acquisitions among players in the Geostationary Orbit (GSO) satellite market.
	3.7	Financial sources and incentive for Space activities	Funding sources for space activities, such as Venture capital (VC), government funding, and investment promotion measures, e.g. tax incentives.
	3.8	Model of partnership between stakeholders	Collaboration models between stakeholders in the space industry, such as: • Public-Private Partnerships (PPP) involving joint investment between the government and private sector. • Government-led initiatives. • Government procurement from the private sector to create demand. • Government funding for research and development in the initial stages. • Collaboration in the private sector between terrestrial operators and satellite operators.
	3.9	Vertical Integration	Vertical integration of major players in the space industry, which may affect market competition, such as a single player operating both as a satellite launch provider and a satellite service provider.
	3.10	Participation in global value chain	Thailand's involvement in the value chain of the space industry, which may leverage the capabilities of related existing industries, such as the electronics component industry.
4. Environmental	4.1	The use of space for solving environmental problems and disasters	Utilizing space for addressing environmental issues/disasters
	4.2	Pollution and waste from space activities	The pollution issues arising from space activities, such as light pollution from satellites orbiting the Earth affecting ecosystems and wildlife migration, as well as disrupting human life. Additionally, space debris generated from re-entry processes and space operations, including space junk and debris falling onto Earth.
	4.3	Orbit Congestion	Growth of satellites causing orbit congestion
	4.4	Space Weather Effect	The impact of space weather events such as solar storms, which may cause damage to satellites or satellite-based navigation systems.
5. Political	5.1	Digital Sovereignty	The concept of striving to reduce dependence on foreign technology by creating and utilizing one's own technology to minimize foreign intervention.
	5.2	Asserting Roles of States and International Collaboration in space affairs	The presence of each country's role by the state in space activities, as well as fostering cooperation in various forms on space issues, including at the inter-state, regional, and global levels. This may include Thailand's role as a leader in the ASEAN region.
	5.3	International Regulatory and Mechanism challenges	Challenges in international regulations and mechanisms, such as long-standing space laws that lack review or updating to modern standards. Additionally, there is a lack of effective enforcement mechanisms for international space laws.
	5.4	Geo-Politics of Space	The geopolitical competition between major powers at both regional and global levels in space (Space Race), safeguarding national security interests, defending against space threats, developing and using anti-satellite (ASAT) weapons, advancing space technology for potential space warfare, and conducting cyber-attacks via satellites.

Dimension	No.	Issue	Description
	5.5	Maintaining the right to access satellite orbits for Thailand	The effort to maintain the right to access satellite orbits, as mandated by the constitution of Thailand, which states that the state must maintain the right to access satellite orbits as a national asset. However, Act on Organization to Assign Radio Frequency and to Regulate the Broadcasting and Telecommunications Services B.E. 2553 (2010) as amended states that the right to access satellite orbits may be waived in cases where preserving this right imposes an undue burden on the state beyond the benefits it would receive.
	5.6	Regulatory Sandbox and Modernizing Regulations	Relaxing regulations during the development and testing of space innovations to accommodate new innovations not yet supported by current regulations. Additionally, revising regulations to support the space industry, including telecommunications and space-related activities.
	5.7	Local Gateway vs Virtual Gateway	Requiring satellite service providers to have satellite gateways in the service area, while current technology allows for the use of virtual gateways.
	5.8	Outer Space Governance	Awareness and cooperation of states in jointly taking responsibility in the space domain include Space Traffic Management (STM), Space Situation Awareness (SSA), and Space Debris Removal.
	5.9	Space Port in Thailand	The opportunity for Thailand to establish a space port, leveraging its geographical location and strong diplomatic relations with various countries, particularly those in the region and major powers.
	5.10	Sustainable and equitable use of spectrum and satellite-orbit resources	Providing sustainable and equal access to spectrum and satellite-orbit resources for all countries, in accordance with the ITU's principles.
	5.11	Level of foreign participation in Thailand’s Space industry	The level of involvement of foreign players in Thailand's space industry, such as granting landing rights to foreign satellites to provide services in the country and enabling foreign companies in the space industry to establish regional hubs in Thailand. This level of openness is related to concerns about national security.
	5.12	Thailand laws, policies and organizations for Space Industry	Ongoing legal and regulatory frameworks related to Thailand's space industry, including the draft Space Activities Act, policies and plans, a central agency regulating space activities, and potentially the establishment of a government space agency.
	5.13	Human Resources for Space Industry	Preparing and developing human resources for Thailand's space industry, promoting education, establishing specialized space academic programs, and providing additional training (reskilling) for individuals with knowledge or experience in other areas to work in the space industry.

4.2 Forecasting

From 48 trends and emerging issues, 28 were ranked as of high importance by survey responses from stakeholder for further consideration. These 28 trends and emerging issues were clustered into 6 drivers of changes as shown in Table 6.

Table 6. Drivers of change mapped from 28 trends and emerging issues ranked as of importance

Driver of change	Supporting trends & emerging issues (from Table 5.)	
Policy	5.6 Regulatory Sandbox and Modernizing Regulations 5.11 Level of foreign participation in Thailand's Space industry	5.12 Thailand laws, policies and organizations for Space Industry 5.13 Human Resources for Space Industry
Technology	2.1 Satellite Direct-to-Device 2.2 Satellite Industry to Support IoT 2.3 NGSO/LEO Satellites and multi-orbit models	2.9 Laser Communication 2.15 Inter-Satellite Communications
Application	1.1 Food Security and Agriculture 1.2 Medical Issues 1.3 Urban Mapping/Urban Planning 2.6 Onboard Wi-Fi supported by Satellites	3.3 Space Data as a service 3.4 Ground Station as a service (GSaaS) 4.1 The use of space for solving environmental problems and disasters
International affairs	5.2 Asserting Roles of States and International Collaboration in space affairs	5.3 International Regulatory and Mechanism challenges 5.4 Geo-Politics of Space
Sustainability	1.5 Go green and recyclable products 4.2 Pollution and waste from space activities 4.3 Orbit Congestion	5.8 Outer Space Governance 5.10 Sustainable and equitable use of spectrum and satellite-orbit resources
Economy	3.2 New Space Economy 3.7 Financial sources and incentive for Space activities	3.8 Model of partnership between stakeholders 3.10 Participation in global value chain

The six drivers of change were projected for scenario construction as shown in Table 7. Various possible outcomes of these six drivers were projected for scenario construction. Four scenarios were created by combining the interactions of the outcomes of each driver. Table 8 summarizes the four scenarios.

Table 7. Summary of projections from each driver of change

Driver of Change	Summary of projection (Level 1 – Most positive)	Summary of projection (Level 2)	Summary of projection (Level 3)	Summary of projection (Level 4 – Most negative)
Policy	Thailand has a clear strategic plan, with laws and organizations for space activities. Educational institutions meet domestic demands and also send personnel abroad.	Thailand has a strategic plan but lacks effective implementation. There are relevant agencies and laws in place. Educational institutions produce enough personnel to meet domestic market demands.	There is a strategic plan, but it lacks specific legal mechanisms and dedicated agencies. Adjacent agencies handle responsibilities. Educational institutions meet domestic market demands but cannot send personnel abroad.	There is no strategic plan or mechanisms for space activities. Space education programs have closed due to lack of demand from students and the labor market.
Technology	The development of technology on a global scale has led to groundbreaking discoveries like Satellite Direct-to-Device, which covers all areas and can match or replace terrestrial networks.	The development of technology on a global scale continues steadily, but it still does not match or replace terrestrial network services in capability or performance.	The development of technology on a global scale is slow, halted, or abandoned, as it fails to build a customer base sufficient to justify investment costs.	- *

Driver of Change	Summary of projection (Level 1 – Most positive)	Summary of projection (Level 2)	Summary of projection (Level 3)	Summary of projection (Level 4 – Most negative)
Application	Innovations and new applications are widely used in the space industry, other sectors, and by general users, including satellite communication and space data services.	Applications are mainly similar to existing services, widely used within the space industry and other sectors, with some innovations but mostly the same services.	Applications are limited to high-cost use, resulting in use only by select groups, with mostly the same services as before and few innovations.	- *
International Affairs	All countries globally cooperate to advance the space industry, sharing common values and working together for global progress.	Global divisions exist, but countries adhere to international laws, balancing national interests with maintaining cooperation and agreements between nations.	Intense competition in space activities arises, with powerful countries influencing international laws for national benefits, causing increased disparities and hindering less developed nations.	Countries engage in conflicts and space resource competition, using weapons and violence, disregarding international laws, leading to a state of space warfare.
Sustainability	There is strong awareness of sustainable and efficient space resource use, with effective management practices implemented to ensure long-term environmental benefits.	Awareness of sustainable and efficient space resource use exists, but implementation faces constraints that limit the effectiveness of management practices.	Some space industry groups support environmental sustainability, but poor management limits effectiveness, despite attempts to promote eco-friendly practices.	There is insufficient awareness of space industry sustainability, leading to practices that cause significant negative impacts on the global environment.
Economy	The space industry has many diverse players, both government and private, with high competition. Companies collaborate, share resources efficiently, and new international technologies drive cost reductions.	Thai companies are supported but face competition from foreign companies entering the market, resulting in a smaller market share for Thai companies.	Thai companies are supported without allowing foreign competition, leading to very slow technological development due to limited innovation and external collaboration.	The space industry is monopolized with no new businesses, hindering technological development. Small Thai companies cannot compete, causing high production costs and market shortages.

* Note: There are only 3 projections for technology and application.

Table 8. Summary of the four Scenarios

Scenario Name	The Slow Turtle	Relentless Fall	Light at the End of the Tunnel	The Golden Age of New Space
Scenario Type	Continuation	Collapse	New Equilibrium	Transformation
Projection Level	Policy: 3 Technology: 3 Application: 3 International Affairs: 2 Sustainability: 3 Economy: 3	Policy: 4 Technology: 3 Application: 3 International Affairs: 4 Sustainability: 4 Economy: 4	Policy: 2 Technology: 2 Application: 2 International Affairs: 2 Sustainability: 2 Economy: 2	Policy: 1 Technology: 1 Application: 1 International Affairs: 1 Sustainability: 1 Economy: 1
Summary	There is no national policy promoting space activities and no dedicated responsible agency, and most of the players and services remain the same.	Market dominance occurs, and the space resources are mismanaged. There is a lack of laws and agencies driving the space industry.	The opening of Thailand's space industry market to foreign players is a result of necessity.	A fully developed space industry has emerged in Thailand, with numerous and diverse players in the market, and widespread use of space technology.

Each scenario is described as follows:

1) The Slow Turtle

Narrative

Thailand has a strategic plan for space but lacks a national policy and a dedicated responsible agency, leading to adjacent agencies handling space missions. At the global level, technology continues to develop, but there are no new discoveries. In Thailand, there are a limited number of space industry players, mainly existing companies and few startups that are supported. This leads to few new services emerging and keeps prices high. Foreign participation in Thailand is limited, and Thailand's role in the global value chain is also limited. Space technology is partially utilized in Thailand across various sectors, primarily using existing technologies with limited new advancements.

Internationally, countries adhere to agreements and laws, with Thailand joining organizations like ITU but not incorporating space activities into domestic law.

In sustainability, some efforts like space debris management and Go Green policies are in place but are inefficient due to dependence on foreign policies. Educational institutions offer space-related courses but still do not adequately meet industry requirements. Curricula are being developed slowly, producing enough human resources for the domestic market but not internationally, with limited international support and knowledge exchange. Access to these courses is limited to only some people.

Key factors influencing this scenario

- Lack of a national policy promoting space activities.
- Agencies' lack of understanding and interest in new services.
- Lack of funding and incentives to support new players in the space industry.

2) Relentless Fall

Narrative

Thailand's space industry stagnates and is declining, unable to research new projects. With the public in Thailand lacking knowledge and understanding of the benefits of space technology, and no government support for the industry to advance technology, the number of players in the space sector is decreasing. Small businesses likely exit the market early on, leading to monopolies by large existing players, resulting in higher service prices and limited access to services for only few groups. Regarding national security, the government does not recognize the importance of leveraging space technology, continuing to allocate resources to traditional military means. In a war scenario, Thailand would struggle to compete with countries that incorporate space technology into their warfare strategies. As Thailand's space industry shows no signs of developing to international standards, it is unlikely any country would want to form alliances with Thailand, further impeding the growth of its space industry.

Key factors influencing this scenario

- The government lacks a clear strategic plan to support space education and the space industry. The public does not see the importance of space activities.
- Geopolitical conflicts arise, leading to space wars initiated by superpowers.

3) Light at the End of the Tunnel

Narrative

Thailand's space industry receives support from the government through a clear strategic plan, with relevant laws and a central agency. However, there is still a lack of effective law enforcement. Thailand is under pressure to maintain a balance with global power blocs, as multiple superpowers engage in space competition. Some superpowers conduct activities like lunar research, building lunar surface stations, and space resource exploration, which Thailand aims to participate in. Simultaneously, Thailand must maintain political equilibrium with other power blocs.

Additionally, Thailand faces technology disruption, changing consumer behavior leading to increased technology demands, and heightened awareness of space activities among the government and the public. Natural factors, such as floods caused by global warming in certain areas of the country, impact Thailand's communication networks, rendering them inoperable for extended periods. Meanwhile, Thailand's satellites cannot handle high usage simultaneously (or alternatively, Thai satellites were previously damaged by space debris collisions), potentially affecting national security and stability.

To address these issues, it has been proposed to open the market to foreign players, causing dissatisfaction among Thai operators. This led to measures supporting Thai businesses and conditions for foreign players entering the Thai market to transfer technology, conduct research, educate, and develop Thai human resources. This includes fostering domestic (government and private sector) and international (Thai and foreign operators) cooperation, benefiting Thai operators, especially in manufacturing space equipment both upstream and downstream. This knowledge transfer and expertise enhancement, combined with leveraging existing industries like electronics manufacturing, position Thailand as a major producer of space parts and ground equipment in the ASEAN region.

In terms of sustainability and the environment, space laws include environmental protection provisions, ensuring usual regulation and enforcement. Space industry operators are aware of and understand the importance of supporting environmental sustainability.

Key factors influencing this scenario

- The intense multi-polar space competition among superpowers
- The emergence of technology disruption.
- The demand for technology from users and increased awareness among the government and the public.
- Natural disaster problems impacting the country's communication systems

4) The Golden Age of New Space

Narrative

Thailand has developed clear strategic plans for space activities, reviewed every two years, with subordinate plans for operational implementation. The space industry is supported by clear laws aligned with international standards, a dedicated support fund, and government incentives such as tax benefits and eased regulations.

Private investment in the space industry has increased, creating a demand for skilled personnel. Specialized courses and institutions train professionals for both domestic and international markets, with reskilling/upskilling programs for workers from other industries. Thailand welcomes skilled foreign workers and facilitates knowledge exchange with other countries, supported by

government and private funding, and provides research infrastructure like hyper gravity testing and spaceports.

Global technology development continues rapidly, leading to groundbreaking discoveries advancing the space industry. Examples include satellite communication services like Satellite Direct-to-Device, competing with terrestrial networks, and progress in deep space exploration and interplanetary resource utilization. Thailand's space industry includes numerous diverse players from both public and private sectors, fostering high competition, collaboration, and efficient resource use, reducing space debris and lowering industry costs.

Space applications include space data as a service supporting sectors like agriculture (e.g., satellite imagery for yield prediction), medicine (e.g., thermal imagery for tropical disease prediction), and in-space research (e.g., pharmaceutical research under microgravity and plant growth research for space resources). Application of these technologies has led to significant investments from various sectors, effectively addressing problems and raising public awareness of the benefits of space technology in improving quality of life.

Globally, countries cooperate to promote the space industry, sharing values and recognizing the need for collaboration. A turning point event has emphasized the necessity of working together, efficient and environmentally friendly use of space resources, space traffic management, and supporting Go Green policies across the ecosystem.

Key factors influencing this scenario

- The Space Activities Act has been enacted, and a central organization has been established.
- The government prioritizes space activities and provides a dedicated fund, with continuous additional support such as budget allocations, involvement of the Board of Investment (BOI), tax benefits, and easing of measures and regulations like customs procedures.
- Globally, there is huge effort to invest in research and development in the space industry and to conduct space activities.
- A negative critical event, such as the collapse of terrestrial communication systems or global conditions severely impacting humanity, prompts an urgent shift towards the development and application of space technology.
- There are effective international laws and regulations governing space activities.

4.3 Visioning

In each scenario, first-order, second-order, and third-order impacts are analyzed. Table 9 provides an example of such implication analysis from “The Slow Turtle” scenario.

Table 9. Example of implications from “The Slow Turtle” scenario

Category	Key change	1st order impact	2nd order impact	3rd order impact
Government	There is no dedicated agency responsible for space policy, so neighboring agencies are assigned tasks, and there is no national policy.	Agencies lack coordination and work independently.	The space industry grows gradually.	The space industry has few players. *

Category	Key change	1st order impact	2nd order impact	3rd order impact
Education and HR	Space-related courses are offered in some educational institutions.	The space industry grows slowly.	The market is small with few players.	Thailand's space industry cannot compete internationally. *
	Space-related courses are available, but few are interested or cannot access them.	No new courses are being introduced, or the number of courses is reduced	Limited foreign investment.	Thailand's space industry grows slowly. *
Users	Service users (companies and consumers) have few new services and technologies and limited provider options.	Products and services are expensive and of lower quality.	Consumption decreases.	Only a select few can access essential services.
Downstream players/ Operators	New service providers are restricted.	Only existing providers remain, new entrants face barriers	Thailand lacks competitive advantage.	Thais cannot keep up with global trends. *
Upstream Segment	High production costs in the space industry.	Upstream producers try to reduce costs/increase profits.	Collaborate with foreign companies.	Small Thai companies not collaborating with foreign firms cannot operate. *

*Note: These are chosen as the most important implications for the scenarios for further recommendation suggestions.

The summary of the selected implications from each scenario, and their recommendations are shown in Table 10.

Table 10. Summary of implications and recommendation from the scenarios

Scenario	Implication	Recommendation
The Slow Turtle	The space industry has few players.	National policies need to be clear first for market access and open for doing business in space sector.
	Thailand's space industry cannot compete internationally.	The production of space personnel needs to be of high quality. It could also provide talent to other industries.
	Thailand's space industry grows slowly.	The government should focus on fostering the domestic space industry both directly and indirectly, such as supporting space tech startups and providing incentives.
	Only certain groups can access essential services.	The government must ensure that the public can access essential services from space technology.
	Thai people cannot keep up with global trends.	Both the public and private sectors need to be aware of global space industry trends.
Relentless Fall	There is no development or competition in Thailand's space industry.	Encourage public-private investment and allow conditional competition.
	The cost of using space technology services is increasing, but the quality of the technology is not improving.	Promote cost reduction and effective research.
	Barriers in using space technology are emerging.	Promote cost reduction and effective research.
	Investors are not investing more in the space industry.	Build investment confidence with public-private collaboration.
	“Brain drain” occurs as graduates move abroad for work.	Improve education and provide investment support.
	(For every implication)	Implement a strategic plan with clear actions, public hearings, and indicators.

Scenario	Implication	Recommendation
Light at the End of the Tunnel	Collaboration in space industry research within the country and with international partners.	Allocate a national budget for research and development of space technology. Develop strategic cooperation with international partners.
	Consumers benefit from competition in business, such as receiving good and fair prices.	Establish measures for competition and create a fair market environment.
	Thai operators cannot continue to run their businesses.	Operators benefit from technology transfers and government support in building and enhancing capabilities.
	Space activities are a part of daily life.	Raise awareness of the benefits of space technology to the public. Promote the development of high-quality public services using space technology.
	The national economy continues to grow.	Implement effective strategic plans and laws with government support. Enforce laws rigorously.
The Golden Age of New Space	There is an establishment of new Thailand's space law.	The government should emphasize the importance of space activities and recognize that space activities drive national growth and improve the quality of life.
	The government increases investment in space activities and co-invests with the private sector	The government should set up a national budget or fund, to provide subsidies that help businesses or offer benefits to the private sector, such as tax breaks and simplified registration procedures.
	Thai and foreign personnel are recruited to work in Thailand. Infrastructure such as spaceports or research facilities like hyper gravity/drop test are established.	Employers need to recognize the importance of skilled foreign personnel and their potential contribution to the industry. Continuous training should be provided to ensure a steady supply of skilled workers, anticipating the demand for space-related jobs. Collaboration between educational institutions and the government to create specialized curricula.
	International Space Law and Collaboration	Improve the country's readiness to participate in international agreements (G2G) and collaboration. Encourage participation in international standards and agreements where Thailand is not yet involved.
	The quality of life for citizens improves.	Improve education. Reduce the cost of space-related services. Increase welfare. Raise awareness about the benefits of space technology. Ensure that citizens benefit from space technology, such as in agriculture and health services.

The final implications and recommendations in Table 10 highlight that for every future scenario of Thailand's space industry over the next 10 years, several common aspects must be addressed: effective government support and policies, investment support, organizing human resources, and maximizing citizen benefits from the space sector. Both the public and private sectors should focus on these areas to prepare for any scenario.

5. Conclusion

The global space industry is undergoing rapid growth and the emergence of innovative service models that were unimaginable in previous decades. However, this swift expansion also introduces uncertainties, presenting both opportunities and threats for the future of the space sector. Foresight is a key tool for systematically exploring plausible scenarios in the space industry. It helps identify potential impacts and develop strategies to prepare for them.

This study has explored future scenarios of Thailand's space industry over the next 10 years using the Foresight methodology, based on the "Framework Foresight," including Framing, Scanning, Forecasting, and Visioning. The process involved online data collection, an internal workshop within the Office of NBTC, interviews, a survey, and a workshop with stakeholders in the space industry. This led to the identification of 28 trends and emerging issues ranked as important for Thailand's space industry, forming the basis for developing four distinct future scenarios. Each scenario was

analyzed for its potential implications, and recommendations were made accordingly.

In summary, the future scenarios and their implications highlight both opportunities and threats arising from various factors over the next decade. Thailand will still need to rely on international cooperation due to the global nature of the space industry. However, there are clear opportunities for Thailand to enhance its participation in the space industry value chain. This will require clear and effective government policies and regulations, support for investment to expand the space services market, and the development of human resources with industry-specific skills. Additionally, opening the market to space businesses and services with minimal barriers and maximizing the benefits of space technology for improving citizens' quality of life are crucial.

This paper contributes to the practice of foresight by exploring plausible scenarios for the space industry based on identified trends and emerging issues. It details the process of conducting foresight, offering a practical guide that policymakers and stakeholders can use for their own foresight exercises.

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