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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.

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	Build and assembly of spacecraft and satellites	
	space equipment and subsystems		
	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	Leasing and selling satellite capacity	
	operations		
	2.2 Data Distribution Services	Satellite Data Platforms	
	2.3 Supple of devices and	Very small satellite terminals, Chipsets, GPS receivers	
	equipment supporting the consumer		
	markets		
	2.4 Supply of services supporting	Direct-to-Home, Broadcast TV, Broadband Internet,	
	the consumer market	Location-based signal service	

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

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

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

Table 2. Various foresight frameworks in the literature

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).

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

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

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

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).

Archetype	Description
Continuation/	The current trends within the domain continue without major disruptions or unexpected events,
Baseline	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	The system or topic confronts a major challenge to its current operations and must adapt,
equilibrium	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.

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

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.

Dimension	No.	Issue	Description		
1. Social	1.1	Food Security and	The use of space for food security and agricultural issues, both in		
		Agriculture	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/	The use of space for urban development or urban planning, and		
		Urban Planning	population migration.		
	1.4	Aging Society	The use of space to support an aging society		

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

Dimension	No.	Issue	Description	
	1.5	Go green and	Environmental conservation and waste reduction for the planet,	
		recyclable products	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-	Providing direct connectivity between regular mobile phones and	
		Device	satellite networks without the need for additional equipment.	
	2.2	Satellite Industry to	The satellite industry for enabling Internet of Things (IoT)	
	2.2	Support IoT	connectivity.	
	2.3	NGSO/LEO Satellites	Connectivity inrough non-geostationary satellite orbit (NGSO) and	
		and multi-orbit models	multi-orbit models	
	2.4	Extending lifespan of	- Reusing, recycling, and refueling satellites	
		Satellites	- Repairing satellites in orbit	
	2.5	SmallSats and	The utilization of small satellites (SmallSats) and cube satellites	
		CubeSats	(CubeSats) in space.	
	2.6	Onboard Wi-Fi	Utilizing satellites to enable wireless internet (Wi-Fi) connectivity	
		supported by Satellites	on aircraft and ships.	
	2.7	In-Space	Manufacturing industry in space and spacecraft component	
		Manufacturing and	production using 3D Printing technology.	
		Additive		
	20	Manufacturing	Puilding Data Contars and Cloud Computing via Satallita	
	2.0	Computing in space	Networks in Space	
	2.9	Laser Communication	The use of laser communication technology	
	2.10	5G/6G Non-Terrestrial	Connecting to 5G/6G networks using satellites instead of ground-	
		Network (NTN) by	based stations.	
		Satellite		
	2.11	Drone control by	Remote control of unmanned aircraft via satellite.	
		Satellite		
	2.12	AI in Space	Utilizing Artificial Intelligence (AI) technology in the space	
	0.10		industry.	
	2.13	Lunar Gateway	The development of a lunar-orbiting space station, known as the	
	The statio		The station is expected to be operational by 2028	
	2.14	Very high throughout	The use of Very high throughput satellite	
	2.1 .	satellite		
		(Geostationary orbit -		
		GSO)		
	2.15	Inter-Satellite	The use of communications between satellites	
		Communications		
3. Economic	3.1	Commercial Space	Commercial satellite and space service providers entering the	
		Industry players into	national security market.	
		Market		
	32	New Space Economy	The growth of the space industry and the creation of value in the	
	5.2	New Space Leonomy	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	Ground station connectivity services for satellite signal	
		service (GSaaS)	transmission with a global network infrastructure, eliminating the	
			these ground stations through cloud based systems	
			uncoe ground stations unough croud-based systems.	

Dimension	No.	Issue	Description	
	3.5	Space Tourism and	Commercial space tourism and living in space.	
		Living in Space		
	3.6	Concentration in	The concentration of the satellite industry with few players, such as	
		Satellite market	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	Funding sources for space activities, such as Venture capital (VC),	
		incentive for Space	government funding, and investment promotion measures, e.g. tax	
	2.0	activities	Callaboration module between stable balders in the space in ductors	
	3.0	between stakeholders	conadoration models between stakeholders in the space industry,	
		between stakenoluers	• 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	
	2 1 0	D	both as a satellite launch provider and a satellite service provider.	
	3.10	Participation in global	Thailand's involvement in the value chain of the space industry,	
		value chain	which may leverage the capabilities of related existing industries,	
4 Environmental	4.1	The use of space for	Utilizing space for addressing environmental issues/disesters	
4. Environmentar	4.1	solving environmental	Offizing space for addressing environmental issues/disasters	
		problems and disasters		
	4.2	Pollution and waste	The pollution issues arising from space activities, such as light	
		from space activities	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	
5 Political	51	Digital Sovereignty	The concept of striving to reduce dependence on foreign	
5. I onticui	5.1	Digital Sovereighty	technology by creating and utilizing one's own technology to	
			minimize foreign intervention.	
	5.2	Asserting Roles of	The presence of each country's role by the state in space activities,	
		States and International	as well as fostering cooperation in various forms on space issues,	
		Collaboration in space	including at the inter-state, regional, and global levels. This may	
		affairs	include Thailand's role as a leader in the ASEAN region.	
	5.3	International	Challenges in international regulations and mechanisms, such as	
		Regulatory and	long-standing space laws that lack review or updating to modern	
		Mechanism challenges	standards. Additionally, there is a lack of effective enforcement	
	5 4		mechanisms for international space laws.	
	5.4	Geo-Politics of Space	The geopolitical competition between major powers at both	
			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	The effort to maintain the right to access satellite orbits, as
		to access	mandated by the constitution of Thailand, which states that the
		satellite orbits for	state must maintain the right to access satellite orbits as a national
		Thailand	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	Relaxing regulations during the development and testing of space
		and Modernizing	innovations to accommodate new innovations not yet supported by
		Regulations	current regulations. Additionally, revising regulations to support the
			space industry, including telecommunications and space-related
			activities.
	5.7	Local Gateway vs	Requiring satellite service providers to have satellite gateways in
		Virtual Gateway	the service area, while current technology allows for the use of
			virtual gateways.
	5.8	Outer Space	Awareness and cooperation of states in jointly taking responsibility
		Governance	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	Providing sustainable and equal access to spectrum and satellite-
		equitable use of	orbit resources for all countries, in accordance with the ITU's
		spectrum and satellite-	principles.
		orbit resources	
	5.11	Level of foreign	The level of involvement of foreign players in Thailand's space
		participation in	industry, such as granting landing rights to foreign satellites to
		Thailand's Space	provide services in the country and enabling foreign companies in
		industry	the space industry to establish regional hubs in Thailand. This level
			of openness is related to concerns about national security.
	5.12	Thailand laws,	Ongoing legal and regulatory frameworks related to Thailand's
		policies and	space industry, including the draft Space Activities Act, policies
		organizations for	and plans, a central agency regulating space activities, and
		Space Industry	potentially the establishment of a government space agency.
	5.13	Human Resources for	Preparing and developing human resources for Thailand's space
		Space Industry	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	manned from	n 28 trends a	nd emerging	issues ranke	d as of importa	nce
	DIIVEIS	of change	таррец поп	1 20 u enus a	ind emerging	15SUES Lank	a as or importa	nce

Driver of change	Supporting trends & e	merging issues (from Table 5.)
	5.6 Regulatory Sandbox and	5.12 Thailand laws, policies and organizations for
D 1'	Modernizing Regulations	Space Industry
Folicy	5.11 Level of foreign participation	5.13 Human Resources for Space Industry
	in Thailand's Space industry	
	2.1 Satellite Direct-to-Device	2.9 Laser Communication
Technology	2.2 Satellite Industry to Support IoT	2.15 Inter-Satellite Communications
reennoiogy	2.3 NGSO/LEO Satellites and multi-orbit	
	models	
	1.1 Food Security and Agriculture	3.3 Space Data as a service
	1.2 Medical Issues	3.4 Ground Station as a service (GSaaS)
Application	1.3 Urban Mapping/Urban Planning	4.1 The use of space for solving environmental
	2.6 Onboard Wi-Fi supported by	problems and disasters
	Satellites	
	5.2 Asserting Roles of States and	5.3 International Regulatory and Mechanism
International affairs	International Collaboration in space	challenges
	affairs	5.4 Geo-Politics of Space
	1.5 Go green and recyclable products	5.8 Outer Space Governance
Sustainability	4.2 Pollution and waste from space	5.10 Sustainable and equitable use of spectrum
Sustainability	activities	and satellite-orbit resources
	4.3 Orbit Congestion	
	3.2 New Space Economy	3.8 Model of partnership between stakeholders
Economy	3.7 Financial sources and incentive for	3.10 Participation in global value chain
	Space activities	

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.

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

Table 7. Summary of projections from each driver of change

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

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

Table 8. Summary of the four Scenarios

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

Each scenario is described as follows:

1) The Slow Turtle

<u>Narrative</u>

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

<u>Narrative</u>

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.

Category	Key change	1 st order impact	2 nd order impact	3 rd 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. *

Table 9. Example of implications from "The Slow Turtle" scenario

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

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

Table 10. Summary of implications and recommendation from the scenarios

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