Business and Politics (2024), 1–27
doi:10.1017/bap.2024.18

RESEARCH ARTICLE

Middle spacepowers' integration with the global supply chain for the space industry: Taiwan and Thailand

Kun-Chin Lin[1], William Matthews[2] and Sam Olsen[3]

[1]Professor of Military and Security Studies, Department of Spacepower (US Space Force), Johns Hopkins University School of Advanced International Studies (SAIS-JHU), Washington, DC, USA, [2]Director of Geopolitical Research, The Adarga Research Institute, London, UK and [3]VP, The Adarga Research Institute, London, UK
Corresponding author: Kun-Chin Lin; Email: klin54@jh.edu

Abstract

Space as a domain of economic and security competition between great powers has risen to become an arena of active statecraft for middle powers in the twenty-first century. It has set a high-stake stage for not only continuing struggles for catch-up industrialization of late developers but also offering opportunities to capture commercial gains of technological breakthroughs and globalization of markets. We examine these challenges for Taiwan and Thailand, surveying major trends in the emerging space industry and exploring four analytical perspectives on how government-business relations shape adaptive national industrial policies in high-technology sectors with proliferating end-users. We argue that the Asian developmental state model is evolving in response to specific challenges of a global supply chain for commercial space activities dominated by leading space firms and government regulatory actions in the United States. Significant differences in Taiwan's and Thailand's space and industrial policy approaches will likely create divergent technological trajectories and reinforce current constraints on improving national security. The longer-term prospect for middle spacepowers remains contingent on the space race between the United States and the People's Republic of China.

Keywords: Space industrial policy; US economic security; Global supply chains; Taiwan; Thailand

Introduction

Space as a domain of economic and security competition between great powers has risen to become an arena of active statecraft for middle powers in the twenty-first century. It has set a high-stake stage for not only continuing struggles for catch-up industrialization of late developers, but also offering opportunities to capture commercial gains of technological breakthroughs and globalization of markets—following the logistics revolution and trade explosion in the 1970s–1980s, and the digital economy in the 1990s–2000s. We examine these challenges for Taiwan and Thailand, surveying major trends in the emerging space industry and exploring four analytical perspectives on how government-business relations shape adaptive national industrial policies in high-technology sectors with proliferating end-users—including the government and military as the suppliers and consumers of economic statecraft. We argue that the Asian developmental state model is evolving in response to specific challenges of a global supply chain for commercial space activities dominated by leading space firms and government regulatory actions in the United States.

Motivated by the chip manufacturing success story and severely constrained by its isolated diplomatic status, Taiwanese economic planners have crafted a space manufacturing and commercialization strategy centered on a linear progression from parts manufacturing to assembly and testing of subsystems and finally to large system integration and fully domestically designed and manufactured small satellites for lower earth orbit (LEO) usages. In comparison, Thailand has enjoyed a greater leeway in exploring alternative international collaborations to develop domestic space capacity and deepen the role of the space sector in addressing wider national security challenges. We suspect that the differences in these developmental states' approaches will likely be less impactful on the success of their space and industrial policies than their relative abilities to convince the US government and leading firms such as SpaceX that their firms can reliably overcome the regulatory transaction costs and weather the political winds to produce components on a consistently lower cost basis to support the proliferating satellite constellations that will drive the industry. Nevertheless, Taiwan's and Thailand's different approaches will likely create divergent technological trajectories and reinforce current constraints on improving national security.

The global space industry

The size of the global space economy, which combines satellite services and ground equipment, government space budgets, and global navigation satellite services (GNSS) equipment, is estimated at $384 billion USD in 2022.[1] The bulk of that sum goes to satellite television and services enabled by communications satellites, and around one-quarter comprises of government space budgets. Satellite manufacturing and launch systems are projected to grow from $22.9 billion in 2022 to $28.6 billion by 2030 at a compound annual growth rate (CAGR) of 2.8 percent, dominated by North America as the largest market and Asia-Pacific as the fastest-growing region.[2] The satellite launch systems segment—currently a little below one-third of the market size—is projected to grow at the highest CAGR during the forecast period due to the rising demand for reusable launch systems to reduce overall satellite launch costs. The satellite payload market approximates $8.2 billion in 2020 and is projected to reach $17.6 billion in 2030 with a CAGR of 8.3 percent.[3] The small satellite market has taken off with CubeSats—satellites built in increments of 10 cm cubes, weighing around 1 kg instead of thousands of kgs of traditional ones, and having a three-year lifespan compared to fifteen for traditional ones.[4] CubeSats radically lowers the entry barrier to the space sector and shifts manufacturers and service providers toward a shorter-cycle business model based on newer and more technologically advanced fleets in orbit. The small satellites market was valued at $3.2 billion in 2020 and is projected to reach $13.7 billion by 2030, growing at a CAGR of 16.4 percent.[5] Global consulting firms have high expectations for space as a booming industry, with Morgan Stanley projecting it to reach $1.1 trillion in 2040.[6]

Investment in the space industry by public and private sectors has risen rapidly and with greater diversification of sources and types of capital, departing from the traditional government and military contractors-dominated capitalization model. The European Investment Bank documents the "NewSpace" phenomenon as marked by a 6.7 percent annual growth on average of the global space economy that grew between 2005 and 2017, with over 180 angel- and venture-backed space companies founded since 2000.[7] Venture capital firms represent the majority of investors in space companies, at around 46 percent of overall investments, and combined with angel investors make up around 66 percent of a total of around 400 worldwide investors in space ventures.[8] A comparable characteristic of the space industry to logistics and digital revolutions is its massive spillover effects on other sectors. See Figure 1 below. The experimental US Space Economy Satellite Account by US Bureau of Economic Analysis measures the cross-sectoral economic effects of the space economy using comparable indicators to traditional sectors. It registers the highest value-added to manufacturing, followed by

[1]Bryce Technology (2023). Also see FAA (2018). The following market subsector figures should be interpreted critically. Varying measures and estimations on space sub-sectors are often difficult to reconcile for an accurate and consistent over time market assessment. Allied Market Research (2021, 2022). PWC (2020) compares space industry projections by major sources; Military Satellites Global Market Report 2022 cited by GlobeNewswire (2022) states that the global military satellites market was predicted to grow from $52.28 billion in 2021 to $58.8 billion in 2026 at a compound annual growth rate of 1.2 percent. If true, this amount seems to dwarf the commercial figures cited above.

[2]PR Newswire (2024); see Fortune Business Insights (2021) for an alternative projection from $25.15 billion in 2019 to $54.17 billion in 2027 at a CAGR of 12.45 percent in the 2020–2027 period.

[3]See Deloitte (2022) on the rapid decline of launch and payload costs starting with the Falcon X breakthrough.

[4]Millan et al. (2019); Goldman Sachs (2017).

[5]Link Communications System UK (2021).

[6]Morgan Stanley (2020).

[7]European Investment Bank (2019).

[8]Ibid, p. 6. The report notes a need for more risk capital and finance for space for commercialization of products and reaching company maturity and emphasizes a continuing role for EU defense policy and public sector "pull" mechanisms for innovation and market development (p. 10).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

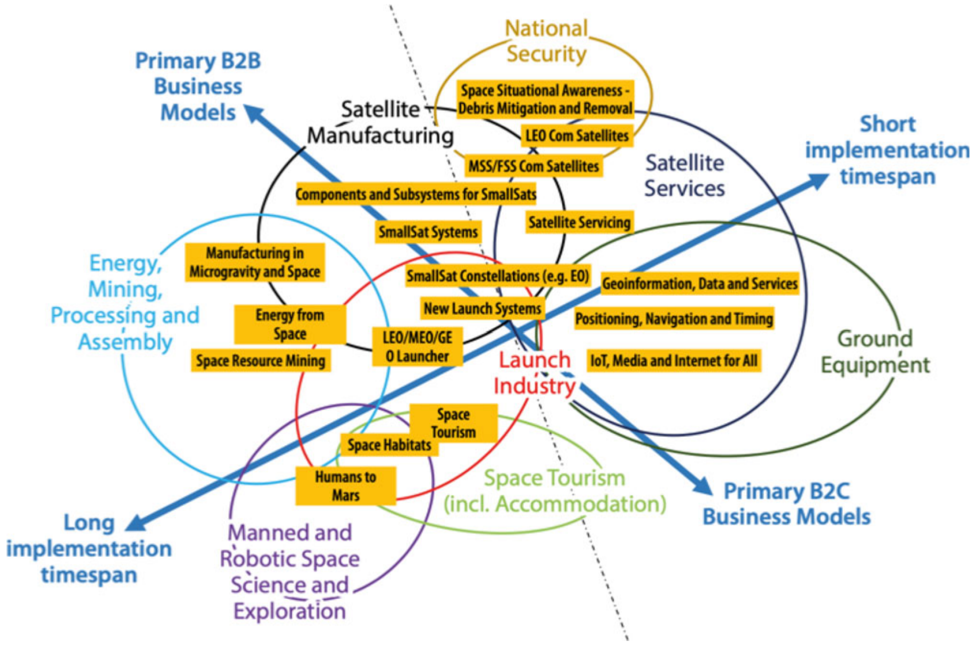

Figure 1. Composition of the space industry.
Source: Defense SA, "Space Industry 2016," p. 10.

information, wholesale, and government.[9] In recent years, investors and firms in these traditional sectors have become sensitized and interested in expanding into the space industry.

With the expansion of the space sector and diversification away from government and military applications, analysts have begun to study the global supply chain. Deloitte's 2022 Aerospace and Defense Industry Outlook's survey identifies supply chain disruptions (together with talent shortages) as the biggest risks or challenges for aerospace and defense (A&D) organizations in 2023, with "diversifying supplier base for critical supplies" emerging as the top priority for survey respondents of A&D companies.[10] Concrete strategies taken by these firms include moving toward local sourcing and nearshoring, building relationships with suppliers from countries with free trade agreements, and creating visibility deep into their complex and previously proliferating supply chains to better manage third-party risk.[11] Much of this corporate strategic development reflects recent government actions and anticipates further ones to come. The Biden Administration unveiled in June 2021 a sector-by-sector approach addressing critical supply chain vulnerabilities stemming from industrial policies adopted by allied and partner countries, such as Taiwan and South Korean in semiconductor manufacturing.[12] The 2022 CHIPS+ Act seeks to reduce reliance on foreign sources and increase chip research and development activities at home.[13]

US and other national policymakers and corporate decision-makers coping with the dual pressures of great power competition and an increasingly global market for space capabilities will continue to develop economic statecraft supportive of internal and external balancing. Predictably, geo-economic tensions will mount as the conflicting effects of the statecraft unfold. Boosting domestic manufacturing capability, leveraging government procurement, strengthening trade rules and regulatory powers, on the one hand, and external cooperation with non-PRC manufacturers of critical goods, on the other hand, do not always fit neatly politically or strategically. In essence, there will be trade-offs between approaches of economic nationalism and selective interdependence. Things get very complicated as

[9]OECD (2021), 8–9; SpaceTech Analytics (2021). Also see OECD's update statistical approach. OECD (2019, 2022).
[10]Deloitte (2022), p. 3.
[11]Ibid, p. 4.
[12]The White House (2021).
[13]CSIS (2022); CRS (2020), pp. 40–44.

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

soon as the analyst cross-tabulates any space-asset end-user's input needs and output markets—in other words, tracing the firm's interests across relevant value chains. For example, the abovementioned Deloitte report goes into detail on American A&D firms' demand for semiconductors, expansion into the back-end segment of chip production including assembling, testing, and packaging and reliance on critical minerals such as lithium for reliable and secure advanced battery technologies and nickel for aerospace superalloys.[14] Evident from this snapshot picture is a mismatch of the political discourse of the policymakers and the actual needs of firms.

Pathways to spacepower: analytical perspectives

Our exploratory case studies of the Taiwanese and Thai space industry development policies draw on the following four analytical perspectives that have applicable arguments on public-private partnership, government-business relations, and useful roles of the government in the global supply chains.

Geopolitical drivers of the space race

Conventional explanations for policy directions and capabilities of secondary spacepowers derive from the politically and technologically restrictive nature of the space sector during the Cold War—not unlike explanations for nuclear proliferation. Superpowers control allies' accession into the "space club" based on geopolitical calculus, locking them into technologically dependent trajectories with highly limited military applications.[15] Given the high cost of acquiring space capabilities, many developing countries enter the race for benefits other than materialist and military ones—specifically, they hope for short-term status gains and long-term economic development spillover effects of space technology transfers and commercial links to American firms.[16] The geopolitical and developmental logic for investing in space continued to resonate in most contemporary studies of Asian spacepowers.[17] Sarah Hisham describes "space as a national imperative," noting push and pull factors for Asian governments to invest, reorganize, and compete in space.[18] These factors center on a conceptual definition of the access and use of space as a matter of national security, the classification of space and supporting ground assets as critical infrastructure, and potential opportunities in the global commercial space market for domestic manufacturers and service providers.

This analytical approach focuses on the preferences and actions of the United States as the space hegemon and increasingly of its primary challenger in the PRC.[19] Broadly speaking, global opportunities for secondary powers to enter the space sector have largely derived from political, policy, and regulatory actions of the US government. In 1998, the US Congress passed a law reclassifying satellites and parts and equipment as weapons under International Traffic in Arms Regulations (ITAR). This national security measure resulted in a proliferation of foreign manufacturers, arguably at the expense of American firms.[20] The end of the space shuttle program in 2011 resulted in a decline in the commercial space industry workforce in the United States for several years.[21] Subsequent bills since 2012 have reassessed and relaxed the export control law, but the door to globalization of space manufacturing has been kicked wide open. Paradoxically, the US government has been one of a primary beneficiary of the rapid expanding space products and services industries, accounting for some 23 percent of global spending ten years ago.[22] Since then, the US government has actively promoted private sector entrepreneurial activities, apportioning military spending to support the rise of SpaceX and Orbital Sciences as well as the expansion of traditional

[14]Deloitte (2022), pp. 25, 42, 92, 99.
[15]Paikowsky (2017).
[16]Harding (2013).
[17]Moltz (2011).
[18]Hisham (2022).
[19]Goswami and Garretson (2020); Goswami (2022).
[20]US Department of Commerce (2014) estimated a loss of sales opportunities for US firms around estimated from 988 million to 2 billion in 2009–2012.
[21]CRS (2016), p. 12.
[22]CRS (2012), p. 1.

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

firms including Boeing, Northrop Grumman, and Lockheed Martin into the space business. By 2016, the US government's share of global spending on space has declined to 14 percent.[23] Technological advances and applications rapidly reduced the price of launch and orbit through reusable rockets and the use of CubeSats, creating constellations of commercial satellites that have established the new sensing high ground for military and government uses.[24] Relatedly, the National Aeronautics and Space Administration (NASA)'s and the Department of Defense (DoD)'s procurement processes have been revamped toward a contract-based, cost-controlling one, with closer interactions between the services/agency and contractor through the process and encouragement of greater private capital in space activities and competition of new space firms with traditional aerospace giants.

The commercialization momentum is concurrently restrained and spurred on in critical ways by the parallel securitization discourse and regulatory state impetus. In addition to the general trade and non-trade barrier restrictions, the US government maintains and could readily "weaponize" non-market leverages via the global reach of the Federal Aviation Agency (FAA) over aviation and launches, Federal Communications Commission (FCC) in spectrum setting and satellite licensing, National Oceanic and Atmospheric Administration (NOAA) for remote-sensing licensing, export controls, etc. NASA, DoD, and other US government scientific agencies also hold the upper hand with space situation awareness data used widely by other governments.[25] At the same time, the expanding procurement mandate and budget of the US Space Force under its commercial space strategy of leveraging private sector assets, data, and analytics have generated a boon.[26]

As with the internet, some analysts tend to see the "democratization" of power relations in the space domain following commercialization and globalization.[27] This view is premature and likely misleading.[28] The membership expansion of the "space club" does not lead to equality between states and public-private spheres.[29] Of the fifty or so spacefaring nations, only about nine nations have a national space budget over $1 billion as of 2016, with the rest divided evenly at the $100 million mark.[30] From a security perspective, moving away from a Cold War-era dominance of superpowers has created "a more complex, multi-stakeholder environment that has implications for deterrence and management of the risks associated with accidental escalation or purposeful conflict."[31] Most secondary spacefaring countries remain relatively helpless in face of the militarization and weaponization of space.[32] In a "space war," any space debris or incapacitated satellites will immediately affect all. In scenarios of a disastrous asteroid collision or massive climate change impact, secondary spacepowers could only rely on US and possibly Russian and Chinese capabilities. The increasing dependence of many systems on Earth—including finance, logistics, and manufacturing—on space services such as Earth observation (EO), satellite communications, and positioning, navigation, and timing creates differential "sensitivity" and "vulnerability" effects on countries.[33] It is not clear which countries are more at risk, and our case studies help to explore these effects.

The developmental state 2.0 in space

The developmental state concept in comparative politics and political economy literature continues to inform analysis of great and secondary power relations in twenty-first-century technological

[23]Other governments' budgets amounted to 10 percent. CRS (2016), p. 2.

[24]US Director of National Intelligence (2011), Harrison and Strohmeyer (2022), and Callahan (2010) makes a clear case for secure commercial access to space—specifically, launch services—as a national security imperative.

[25]Aerospace Corporation (2021); CRS (2018); DoC and FAA (2017).

[26]US Department of the Air Force (2023); Wong et al. (2023); FAA (2018).

[27]NASDAQ (2022); Welser IV (2016).

[28]For a sample of the liberal-institutionalist perspective, using the language of cooperation on "global commons," see Patton (2022). For a realist counterpoint, see Starling et al. (2021).

[29]Daniels (2020).

[30]Bryce Technology (2017).

[31]Black et al. (2022), p. 30.

[32]Yoo (2019); Dolman (2022).

[33]Ibid, p. 30.

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

competition.[34] Taking stock of the mixed record of government interventions and significant structural changes in the global economy since the 1990s, recent studies have developed conditional and nuanced arguments on state actions that could support domestic economic opportunities in a sector-specific setting. A 2022 Council for Foreign Relations report notes a return of the US industrial policy, prompted by economic and national security concerns, which could represent sector-specific (e.g., semiconductors) departures from a general decline in government funding for R&D and manufacturing's share of Gross Domestic Product (GDP) for advanced industrial countries since the 1970s.[35] Hauge (2020) critically assesses leading claims of global value chain (GVC) theories that the rapid expansion of GVC has rendered import-substitution industrialization and export-oriented industrialization policies obsolete, as it has become pointless to build a self-sufficient domestic supply chain and integrate an entire industry in order to produce a complete final product.[36] Instead, GVC theories claim that the role of the state should now focus on linking up with multinational corporations, identifying niche products for domestic production for GVC, aligning domestic politics and governance institutions to facilitate the technology transfer, etc.[37] Haugh offers a useful corrective in pointing out that Taiwan and South Korea in fact had "GVC-oriented industrial policies" in the 1960s–1980s. What remain constant for secondary powers in shaping effective industrial policies, in face of shifting global market and technological frontiers, are their relationship with great power patrons, state autonomy (broadly defined), policy-crafted leverages over foreign firms and investors, and influence over emerging global rules, standards. and practices.

For the space industry, Weinzierl (2019) argues that the role of government in the market economies framework has three components: (1) establishing the market through decentralization of decision-making and financing for human space activities, (2) refining the market through policies that address market failures and ensure a healthy market structure, and (3) tempering the market through regulation in pursuit of social objectives. Robinson and Mazzucato (2019) track the evolution of "mission-oriented policies" toward a "market creation policy" in the US and European space sector. The earlier missions of the NASA and European Space Agency (ESA) focused on clear challenges with identifiable concrete problems, directed by a strong centralized agency. In contrast, today these agencies address broadly defined grand challenges with decentralized innovation systems with mixed top-down and bottom-up problem definitions. The European Space Policy Institute (2021) analyzes "emerging space nations" by their "capacity" to achieve the full spectrum of space activities and integrate them into national infrastructure, policy, and strategies and by "autonomy" in policy and technology.[38] The milestones of these nations include

- Political commitments, mainly the adoption of a space policy/strategy, often in conjunction with a legal regime for space activities;
- Investment in governance institution and financial support, including the creation of a national institution specifically in charge of space activities (e.g., space agency), a dedicated budget for the national space program, and participation in international programs and/or space diplomacy;
- Provision of a space industrial policy and associated infrastructure, including the acquisition of space capabilities from third countries for national purposes, mobilization of domestic industrial means for the development and/or operation of space systems, and configuration of systems and/or facilities for access to space (e.g., spaceport, launch system).

We will examine these components in the context of Taiwan and Thailand in the following sections.

[34]Cheung and Fukushima (2023); Harvey et al. (2010).
[35]Siripurapu and Berman (2023).
[36]Hauge (2020), p. 2072.
[37]For a similar private sector perspective, see Chin et al. (2021).
[38]ESPI (2021), pp. 9–12.

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

American early-mover advantages in space markets

Schumpeterian creative destruction and oligopolistic market formation dominate narratives of structural challenges facing spacefaring nations.[39] "Space barons" (Davenport 2018) such as Elon Musk and Jeff Bezos bask in the limelight of public imagination and political commentaries, often masking much technological continuity from earlier military-industrial complex outputs and a more gradual movement toward a "normalized" balance of public-private investment in the space industry.[40] Barbaroux (2016) describes the decreasing "asymmetry between government [e.g., space agencies and military organizations] and non-government customers [e.g., universities, research laboratories and private companies]" before reaching a more stable balance.[41] Undoubtedly, this shift is not homogeneous among space nations. Barbaroux places the EU on one end of the "normal" and the PRC on the other end of a "centralized" model of the space industry.[42]

Asian space nations including Japan as the clear leader face the hard reality of the market dominance of Western firms. A general corporate strategy for addressing these concerns would include three elements: (1) securing contracts as a key supplier to SpaceX dominance, (2) expanding overseas business as individual Asian space markets and government contracts (aside from China) are too limited to sustain growth, and (3) developing core competence (and brand) from an original equipment manufacturing (OEM) or original design manufacturing (ODM) basis toward manufacturing and integration of subsystems and eventually the whole satellite. For example, Space BD Japan actively courts contracts from Taiwan, Australia, and Myanmar in placing their satellites in the International Space Station (ISS) for release.

Finding a niche in the global space industry supply chain is time-sensitive. With space businesses competing across borders, a winner-take-all dynamic is emerging in launch services and other segments—in 2023, SpaceX performed 98 launches—mostly for its Starlink satellites—out of a total of 223 globally, with no other company even coming close. As the industry is populated by specialized, young small and midsize enterprises (SMEs), and dependent on government procurement and venture or angel capital at the start, it has been particularly susceptible to coronavirus disease 2019 (COVID-19) disruptions to the supply chain. Industry concentration could be the most likely sectoral response to economic shocks, with debatable implications for the process of creative destruction over the long run. The flip side of the same coin of oligopolistic dominance is the oversized and prolonged role of the government in supporting domestic firms.[43] Similarly for interstate commercial relations, in EU-Japan space cooperation, "inter-agency [ESA-JAXA] relations feed almost 72% of the cooperation between Europe and Japan, 22% comes from inter-university activities, followed by 5.9% of industry-to-industry trade and the rest from hybrid relations."[44]

Global and regional supply chain analysis

As suggested by GVC and new industrial policy literature, governments could play a role in inserting domestic firms into supply chains dominated by non-national firms and governments.[45] The Asian Development Bank notes that the expansion of global supply chains slowed in 2010–2019 and may be shortening since 2020 due to geopolitical and pandemic factors. As a result, developing countries that had hoped to capture a niche in transnational supply chains—and thus engage in the benefits of indirect exports, as well as the non-trade, value transfer benefits of the intellectual properties of

[39]Berglof and Cable (2018) discussed the impact of intellectual properties for new globalization in a neo-Schumpeterian way; OECD (2019, 2021).

[40]Olson et al. (2022).

[41]Barbaroux (2016), p. 10.

[42]Ibid, p. 35.

[43]Dunphy (2016), p. 15.

[44]EU-Japan Centre for Industrial Cooperation (2015).

[45]For studies on high-tech sectors, see Autry (2018), Robinson and Mazzucato (2019), Lee and Tunzelmann (2005), Lee et al. (2022), Hauge (2020), and Kamakura (2022).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

contracting MNCs—would need to reassess their policies and approaches.[46] Intellectual property (IP) and trade in intangibles are particularly important for space industries, with many "factoryless" manufacturers organize their supply chains based on IP as their prime asset. This compounds the impact of geopolitical risk factors.[47] Smaller firms and nations are more vulnerable to multiple "chokepoints" and asymmetric impact of shock. This logic appears in Organisation for Economic Co-operation and Development's analysis of global value chains in the space sector.[48] While scientific activities and supply chains have been spread out more widely, and buyers of satellites seem to enjoy more choices in suppliers, it is far from a buyers' market. Subsystems are still dominated by American, European, and Japanese component, and electrical, electronic, and electromechanical parts come from very specialized firms, with existing niches reinforced by regulatory requirements for "space qualification."[49]

Compared with the developmental state approach above, GVC analysis shows that government support presents a dual-edged sword—it may create firms that cannot survive without "rent" or help start-ups get through hard times. The cross-border and ripple effects of government actions are unpredictable. Examining recent Japan-ROK disputes over critical materials, Haggard and Kim (2020) noted that "reputatively small administrative changes have highly disruptive effects on the industries in question"—in their case, the Japanese Ministry of Economy, Trade and Industry mandated review of imported South Korean fluorinated polyimide, photoresist, hydrogen fluoride, and related technologies. They conclude that both governments learned that protectionist policies could backfire.[50] Once manufacturing capabilities have largely exited, with the corresponding loss of a niche in the GVC, it is very difficult to bring them back. Kamakura (2022) reasons that "globalised semiconductor industry is unlikely to reshore to Japan even amid supply chain disruptions due to the coronavirus disease 2019 pandemic . . . [because it has become] embedded in Asian production networks and need to be optimised within a regionalised production system."[51] The main prohibitive factor seems to be the scale of public resources needed to subsidize a large-scale semiconductor production base in a limited domestic market, with atrophied firms and changing user companies, while facing other Asian government's subsidies for their producers with current comparative advantages along the regional production network.

Taiwan: a state-led pathway to system integration

In our fieldwork in Taiwan in July–August 2022, we were constantly reminded of the Hsinchu Industrial Park as the ecosystem and Taiwan Semiconductor Manufacturing Company (TSMC) as the corporate entity epitomizing the successful industrial policy of the last generation of Taiwanese economic planners.[52] In fact, one might imagine an ideal means to achieve national interest and space commercial success in one go would be a Taiwanese—owned and located in situ—space manufacturing firm that is as critical and irreplaceable to the national and economic security of all major powers as TSMC has been in recent years. But is it a pipedream or a useful reference point?

The story of formative semiconductor industry development in Taiwan in the 1980s–1990s need not be repeated here, except to underscore in the GVC literature the prerequisite of establishing a national innovation system that captures contributing actors and institutions—including corporate laboratories, public research institutes, R&D contract firms, and universities—in a relationship of "reciprocal causation," in which "the growing sophistication of the product itself causes process innovation. Process innovation in turn may enable or require further innovation in products, leading to an increasingly tighter

[46]ADB (2021), p. xxii.

[47]Ibid, p. 153.

[48]Undseth and Jolly (2015).

[49]Bryce Technology (2022).

[50]A similar reasoning led Chinese analyst Gui (2022) to predict that while the politics and policy of techno-nationalism in service of great power competition will likely persist, the implementation of "decoupling" will be pragmatic to mitigate the domestic costs of economic statecraft.

[51]Kamakura (2022), p. 261.

[52]Hwang and Chen (2022); Gillet (2021); Lee and Tunzelmann (2005).

linkage between product change and process change."[53] This dynamic feedback between products and manufacturing processes is arguably the Achille's heel of the Chinese "techno-security" (Cheung and Fukushima 2023) state's yet unrealized striving to become a leader in advanced chip manufacturing. Taiwan's national space strategy and industrial policy can be characterized as "developmental" (see above section) in both the primary *objective* of upgrading the national economy and the policy *approach* of leveraging a state-led corporatist approach to resource mobilization. However, the specific conditions of the global supply chains for the space industry demand different *means* of identifying Taiwanese firms for state support, engaging foreign contractors, and finding a defensible niche against competing secondary spacepowers and supporting industrial upgrading over time.[54]

Taiwan's space policy and agency development[55]

Taiwan is currently in phase 3 of a three-phase plan outlined in 1991 by the precursor of National Space Organization (NSPO).[56] The first phase, 1991–2006, relied almost exclusively on foreign technology and components for satellites assembled abroad and launched abroad but carrying Taiwanese payload with remote-sensing and atmospheric scientific experiments. The second phase, 2004–2018, was marked by significant technological transfers and absorption managed by the NSPO, with scientific inputs from several Taiwanese universities (discussed in the following section) and funding from dedicated central budgets for setting up core systems geared toward producing high-resolution remote-sensing satellites and ionosphere sounding rockets. The overall—and consistent to date—strategic approach derives from the National Applied Research Laboratories (NARLabs) mission statement and focuses on (1) human resource development, (2) continuing advancement toward the technological frontier, and (3) commercialization and promotion of the domestic space industry.[57]

The first two phases saw the completion of Formosat-1, Formosat-2, Formosat-3, and Formosat-5 projects that launched nine CubeSats, ten geosynchronous orbiting trials, and 4 rocket launch experiments.[58] Mostly carrying out missions of remote sensing and meteorological forecasting. Significant domestic content was introduced in Formosat-5, which received input from fifty Taiwanese firms and scientific institutes.[59] Predictably, numerous long-range plan objectives and timelines were revised due to political and technological constraints. For example, the Formosat-6 project—slated to be launched with Taiwan's self-made carrier rocket in 2008—quietly dropped off official documentation.[60] The official program focused on satellite R&D and sounding rocket projects, while launch vehicle activities went underground.[61] Heavily dependent on US university and agency collaboration in forms of technology transfers, satellite production and launch, and even finance, the Formosat-7 (named COSMIC-2 in the United States) constellation's launch was delayed by two years until 2019 due to US financial considerations.[62]

The current phase (2019–2028), formulated between 2015 and 2017 and approved by the Ministry of Science and Technology (MOST) and Executive Yuan in 2018, has received significant funding of over USD 900 million over ten years and staunch political support from President Tsai Ing-wen. In 2020, Tsai incorporated the space industry as one of the Six Core Strategic Industries in the national industrial policy

[53]Lee and Tunzelmann (2005).

[54]Borroz (2021).

[55]This section pulls together policy guidelines, evaluations, and case studies from official Taiwanese government sources, affiliated space institutes, and media interviews of space officials. The most authoritative and factually detailed account of Taiwan's space policy is the unclassified version of the Ministry of Science and Technology's report, "The Third Phase of the National Space Science & Technology Long-Range Development Plan (2019–2028)." NSPO-PLAN-0038 (Chinese version only), 16 January 2019. Henceforth referred to as NSPO (2019).

[56]NSPO (2019), pp. 20–31, 57.

[57]Ibid, pp. 38–39.

[58]Department of Information Services (2022). For NSPO's assessment of the first two phases, see NSPO (2019), pp. 41–42, 103–104.

[59]NSPO (2019), p. 32.

[60]One source suggests that the incoming President Ma Ying-jeou wished to decouple space science from the military—consistent with his reconciliatory stance before Beijing. Lin interview, 8–22.

[61]Global Security (2021).

[62]NSPO (2019), p. 31; Asia Times (2019).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

plan.[63] In January 2023, NSPO was upgraded administratively into a directly affiliated corporation under MOST and renamed the Taiwan Space Agency (TASA).[64] Prior to the upgrade, NSPO was nested under the NARLabs which constitutes an independent nonprofit institute under the guidance of MOST. Now TASA and NARLabs are administratively equals, although NARLabs is likely to continue to provide scientific and technical assistance to TASA.[65] The organizational mandate of NSPO has expanded from conducting fundamental research to "guiding business activity in the space sector in ways that align with national economic development plans.[66] As other ministries and agencies gained a stake in the use of space assets, along with NSPO, they became embedded in a "corporatist" framework of planning authority, consultation process, and patronage of university spin-off enterprises and private initiatives.[67]

In May 2021, the Legislative Yuan passed the Space Development Act, which declared a peaceful goal and global commercial orientation for Taiwan's space development.[68] A domestic launch center was put forward on the plan, taking advantage of Taiwan's proximity to the equator and surrounding by seas.[69] In July and November 2022, Taiwan conducted test flights of a two-stage hybrid-propellent rocket with guidance and control technology, launched from a site in Pingtung County. National Yang Ming Chiao Tung University and National Chen-Kung University were involved in building the "scientific research" rocket and payload including a domestic-made cosmic ray detector.[70]

The deliverable of the third phase is one satellite per year, building three satellite constellations and ten satellites.[71] The first flagship project of the third phase was the launch of "Triton," Taiwan's first locally built weather satellite, on 9 October 2023.[72] One of its functions is to cooperate with Formosat-7 to collect information about speed and other characteristics of winds near the ocean. NSPO officials have declared that 82 percent of the weather satellite's parts and components are locally designed and manufactured, 5 percent over the 78 percent of Formosat-5 and Formosat-7. The launch vehicle was a Vega-C rocket developed by France's Arianespace SA at the Guiana Space Centre in French Guiana.[73] The parallel Formosat-8 LEO constellation project would launch six remote-sensing satellites with Taiwanese components of image sensors, cameras, insulation materials, etc.[74] What remains less specific, and possibly in the works and involving repackaging of different initiatives, is the "Beyond 5G" plan to develop Taiwan's first LEO communications satellite—comparable in specifications to those of the Starlink satellites—scheduled for launch in 2025.[75] NSPO officials identify the lower earth orbit as the most attractive growth segment for which Taiwan already has more than thirty ground segment equipment and satellite manufacturers that have the potential to become important suppliers in the LEO satellite industry.[76] There will be a corresponding shift in the type and functions of satellites from scientific research and remote-sensing toward communications links space assets to IoT applications and space-enabled services.[77]

Domestic private sector players

The long-range development plan by NSPO provides an environmental assessment for the promotion of new space firms and global commercialization of existing space-related firms. Recognizing several

[63]Lin (2021b); Taiwan Today (2021).
[64]NSPO (2019), pp. 8, 62, 96–97. We will continue to use the term NSPO below, as the interviews and research were conducted before the agency's name change.
[65]Focus Taiwan (20–22b); Lin interviews, 8–22. For example, NARLabs has transferred remote-sensing expertise to NAPO.
[66]Borroz (2021), p. 3.
[67]NSPO (2019), p. 92. Lin interviews, 8–22.
[68]National Science and Technology Council (2022); Center for Global Affairs and Science Engagement (2022).
[69]MIRDC (2022).
[70]Wu et al. (2022); Huang (2022).
[71]Lin interview 7–22.
[72]TASA (2024); Focus Taiwan (2023).
[73]TASA (2022); Strong (2019).
[74]See NARLabs website: https://www.tasa.org.tw/inprogress.php?c = 20022501&ln = en
[75]Lin (2021a, 2021b).
[76]Center for Global Affairs and Science Engagement (2022).
[77]NSPO has offer projected revenue for the commercial value-added of phase 3. NSPO (2019), pp. 105–106.

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

bottlenecks for Taiwan's space manufacturing growth—including the small domestic consumer base, unspecialized workforce, and limited and unstable funding pool—NSPO has decided to bet on the rapid growth of SpaceX and similar type satellite constellations that depend on constantly renewing of small satellites and lowering costs of usable launch vehicles.[78] The key to compete in the constellation business is to mass produce components that are reliability and low cost, *not* necessarily requiring high or specialized specifications (e.g., there are very few uses for 2–3 nm chips in space applications). It follows that the market challenge of this sector is that the products substitution (e.g., from ROK and India) is expected to be fierce once these countries' industrial policies get rolling.[79]

According to this market developmental logic, NSPO would first help domestic firms to secure OEM contracts with tier-one or tier-two MNCs such as SpaceX and OneWeb for supplying satellite components and ground equipment and then support technology transfer and development to establish ODM companies and domestic subsystem manufacturing capabilities. The strong firms emerging from these early stages would then gain government support to become "system integrators" that are crucial partners to the big space firms like SpaceX, paving the way for their eventual maturity to be able to produce complete satellites![80] A critic would point out that inserting a few domestic firms into the global supply chain and helping them seek out potentially interested firms for their products would not likely produce a sum that is more than the parts. As a research unit in its DNA, NSPO has yet to demonstrate a confidence-inspiring record in marketing and selecting winners and losers for government support. The range of extant domestic firms contributing to the space supply chains include firms in ntegrated circuit, radio-frequency services, precision instruments, and ground equipment, including TSMC, Foxconn, Microelectronics Technology Inc., Microelectronics Technology Inc., Kinpo Electronics, Gongin Precision Ind. Co. Ltd., Chicony Power Technology Co., Elite Material Co. Ltd., Compeq Manufacturing Co. Ltd., Shenmao Technology Inc., Chung Yang, Lung Hwa Electronics, Hua Xiang, and Jonsa. Alongside these established firms are new, space-specific companies including TiSpace (launch services), Odysseus Space (launch and a range of space mission services, recently moved headquarters to Luxemburg for ESA contracts), LiscoTech (image sensing, onboard computing, artificial intelligence analysis), Jinduen (testing), WavePro (RF testing), Alpha Networks (network equipment supplier to D-Link), Tensor Tech (satellite Attitude Determination and Control System for CubeSats), Taurus (space heritage certification), and HelioX Cosmos (a niche role in linking Taiwanese payload needs to Japanese Space BD).[81] Space strategic consultancy firms such as Infinio Capital play an intermediating role between the government and private sectors, and domestic and US venture capital funds.[82]

NSPO is keen to support Taiwanese space firms by establishing their "flight heritage" via incorporation into the Formosat-8 project, which would enable them to sell components to the global market.[83] Director General Wu of NSPO made it clear that "Taiwan's space industry is centered around the ground segment of the GNSS, which makes use of components such as antennas, communication modules, power supplies, and wires. However, as satellite technology matures, upgrading original manufacturing specifications and ensuring passage through product testing and verification will be essential. Since 2019, the NSPO has been gathering resources to create the most comprehensive verification site in Taiwan."[84] The underlying logic of this function is that US regulators are not sufficiently accessible, the overlayered jurisdictions are daunting to Taiwanese firms, and the time and resources for certification in the United States would be prohibitive for any SME. Taiwanese OEM firms typically work on short cycles (3–5 years), preferring to leave certification to clients. However, this business model stunts sustained industrial and product development. Furthermore, Western firms would approach prospective Taiwanese suppliers under the assumption that volume is the magic word,

[78]Ibid, pp. 32, 53–55.

[79]Lin interviews, 8–22. In contrast, US and European firms are used to building larger, custom-designed and built satellites, without the Asian manufacturers' finely honed ability to scale up.

[80]NSPO (2019), pp. 76–80; Lin interviews, 8–22.

[81]Gillet (2021); Lin interviews, 8–22.

[82]Infinio Capital (2022).

[83]Lin (2021a); Lin interviews, 8–22.

[84]Center for Global Affairs and Science Engagement (2022).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

and thus one of their bargaining strategies is aggregating various clients' needs into one order with general specifications for the clients' needs.[85] The value-added of more customized designs would be lost in the process for the Taiwanese. Helping domestic SMEs clear the certification hurdle would enhance the firms' bargaining position and capture the market more effectively. Ultimately, without having at least a handful of leading firms with proprietary core technologies, it would be hard for the Taiwanese space industry to independently develop certification and standards. Furthermore, even as Taiwan starts to develop its certification, other states—most notably—Japan will be seeking to corner that market with major state investment and leveraging its close political relationship and regulatory familiarity with the United States. The Japanese vision is to establish a regional hub for certification, to which Asian and other regions' space firms would gravitate.

Lastly, NSPO attempts to overcome information asymmetry in the domestic space sector. In 2017—upon the launch of Taiwan's first self-made hi-res optical remote-sensing satellite—NSPO conducted an industry survey as part of the in-house analysis that proposed a space development model for the third phase.[86] NSPO also provides information and organizes Taiwanese firms in attending aerospace-related trade shows in the United States such as the annual Satellite Fair in Washington, DC. In the twenty-first century, Taiwanese planners appear unlikely to instate the kind of performance targets to discipline firms receiving state protection and support. Given the nature of the emergent space market and rapidly evolving technologies, the Taiwanese government has shown restraint in giving domestic firms "a runway to make mistakes and learn from them . . . [which would be] good for Taiwan's long-term position in the new space value chain."[87]

The Taiwanese sovereign wealth fund—the National Development Fund (NDF)—serves as a major platform for promoting industrial investment policies in Taiwan, selecting winners and losers through market intelligence and financial incentives.[88] Focusing on emerging and strategic industries, as well as the venture capital industry, NDF's portfolio included sixty-six companies for a total capital of NT $64.489 billion, and sixty venture capital investment companies for a total capital of NT$22.449 billion by the end of 2021.[89] This list included three aerospace, five optoelectronics, and five semiconductor companies (including TSMC), as well as venture capital companies with aerospace and space-enabled service portfolios. NDF's "Business Angel Investment Program" bets on several start-ups in information and communication application services—key end-users of space assets.[90]

Our interviews with NDF and NSPO officials uncovered a persistent theme—the government can reach out with business opportunities and foreign contacts, but individual firms may not respond. In fact, many established Taiwanese firms with existing core competence and businesses relevant to space manufacturing are skeptical of taking up the invitation. Interviewees offer two reasons: First, the OEM corporate culture—Taiwanese firms typically are persuaded by sizable order contracts, but producing components for foreign space firms often does not amount to significant profitability in the short run. Paradoxically, the larger the OEM supplier, the smaller the share of the space business would be for its overall revenue and the weaker interest in expanding the subcontracting relations.[91] Second, the Taiwanese government did not make a strong case for working with foreign firms including SpaceX seeking suppliers in Taiwan five years ago, as the planners themselves were unclear of the growth potential of the space industry and the publicly aired ambitions of SpaceX.[92] In recent couple of years, Taiwanese firms are beginning to come around—some twenty firms are currently supplying SpaceX—although it may be difficult to differentiate motivations of rent-seeking opportunities in the escalating government investment in space from a more mature and positive assessment of the global space

[85]Lin interviews, 8–22.

[86]Hwang and Chen (2022).

[87]Wang (2021).

[88]National Development Fund (2017–2022).

[89]National Development Fund (2017–2022).

[90]Idem.

[91]Examples of established electronics fabrication suppliers whose revenue from SpaceX orders constitute a small percentage of the corporate revenue include Chongqing Huatong Computer which fabricates printed circuit boards. Lin interviews, 8–22.

[92]Lin interviews, 8–22; Formosa News (2022).

industry.[93] The "social capital" between established and new firms in this emerging sector remains thin, slowing the government's attempts at coordinated and collective action and rapid dissemination of business opportunities and overseas contacts.[94]

The expanding knowledge-transfer ecosystem

Taiwan's R&D as % of GDP steadily rose from 2.96 percent in 2012 to 3.35 percent in 2018, on par with Sweden (3.32%) and Japan (3.28%), exceeding the US (2.83) and OECD (2.38) average but less than that of ROK (4.53%).[95] The MOST leads in receiving government S&T resources at around 47.7 billion in 2019, followed by the Ministry of Economic Affairs—all other departments/agencies trail far behind.[96] MOST actively supports the following government-affiliated universities and institutes:

- National Chung-Shan Institute of Science and Technology (NCSIST) has its origin as Taiwan's military R&D and systems integration center. NCSIST fulfills a function comparable to the American Defense Advanced Research Projects Agency (DARPA), but they also assume mixed roles in competing for and awarding research and development, integration, and manufacturing contracts. Along with the Aerospace Industrial Development Corporation, NCSIST it is considered to be one of the two Taiwanese prime defense contractors, ranking 60th in Stockholm International Peace Research Institute's list of 100 largest arms manufacturers in the world in 2022.[97]
- National Central University's Department of Atmospheric Sciences and the Institute of Space Sciences have been Taiwan's primary scientific knowledge base for ionospheric physics and space physics since the 1950s.[98] One of the department's faculty is Professor Loren Chang, who led the INSPIREsat-1 project, launched from India's Satish Dhawan Space Center on 24 February 2022. The satellite was engineered under the International Satellite Program in Research and Education (INSPIRE), whose membership includes a consortium of colleges and universities with space science programs. Taiwanese, Indian, US, and Singaporean universities were involved, with NCU designing the Compact Ionospheric Probe measuring ionosphere dynamics and the US Laboratory for Atmospheric and Space Physics (U of Colorado Boulder) designing the solar spectrometer measuring the sun's coronal heating process.[99]
- Other universities have departments with research capabilities, but not yet with proven project management records. For example, National Cheng Kung University (NCKU) is strong in electrical engineering and was an early designer of CubeSat, National Yang Ming Chiao Tung University has rocket specialization, Tamkang University has Taiwan's first aerospace engineering department, and Taiwan's top private university, Feng Chia University, houses a Geographic Information System (GIS) Research Center.[100] With the latest central government funding pull, National Taiwan University along with the other top university with strong physics and related departments has lined up to bid for space projects. Together with NCKU, the Institute of Astronomy and Astrophysics at the Academia Sinica had a five-year research Memorandum of Understanding (MoU) with JAXA from 2014—the first formal space research exploration agreement between Taiwan and another spacepower—to design and manufacture a high-resolution space observation instrument in Japan's Arase satellite.[101]

[93]Ibid.

[94]Chan et al. (2021), pp. 801–838, finds the importance of social capital accumulated at the industrial cluster—not just firm—level for sustainable growth, innovation, and strategic positioning of the sector.

[95]MOST (2021).

[96]NSPO (2019), p. 21.

[97]Strong (2022).

[98]Liu et al. (2016).

[99]Focus Taiwan (2022a).

[100]Ting (2021); GIS.FCU (2024).

[101]Taipei Times (2014); JAXA (2014); Institute of Astronomy and Astrophysics (2016). Financing needs might have been a motivation for JAXA to invite Taiwanese participation. Lin (2014).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

- There are several MOST-sponsored institutes providing satellite components and space payload, for example, the National Synchrotron Radiation Research Center, which in 2021 prepared a batch of virus-like particles for crystallization experiments on the ISS. This experiment was done in collaboration with Japanese company Space BD, appointed as the sole private partner by the Japan Aerospace Exploration Agency (JAXA) and coordinated by HelioX Cosmos—a Taiwanese space services start-up.[102] Industrial Technology Research Institute (ITRI) develops communications and ground terminals for launches and its R&D and international partnerships aim to bring down the cost for SMEs.[103]

Interestingly, and perhaps in contrast to the government's overture to private firms described above, research institutes—aside from the military-funded NCSIST—appeal for government support through traditional project funding mechanisms. NSPO also serves as a lobbying hub for the epistemic community. However, the government does not always recognize the merit and importance of the academic proposals. The multinational cooperation behind INSPIREsat-1 was not initiated by intergovernmental actors but by an international academic network used by Professor Loren Chang at NCU, who first contacted his fellow graduate student friends in Colorado and Singapore to talk shop on CubeSats.[104] No doubt the Taiwanese government had to clear international agreements for cooperation, and it showed a strong interest in the political benefits of such cooperation, but it is a story of transnational talent flows and social capital effects. Projecting these dynamics on a large scale would begin to approximate the critical linkages between Silicon Valley and the Hsinchu Industrial Park in propelling Taiwan's semiconductor industry. An industrial policy historian might recall that TSMC was created as Morris Chang's spin-off company while he was working for ITRI, which is a government-run technology R&D institute similar to NARLabs—both were under the National Science Council (NSC) that was reorganized into MOST in 2014.

Government priorities also constrain bottom-up university initiatives in tangible ways. Anecdotes point to NSPO relegating opportunities for cislunar payload opportunities proposed by NCU and negotiated by HelioX Cosmos with Japan's Space BD and SpaceX—possibly in consideration of NSPO's ongoing plans with NASA.[105] TiSpace's launch sites in Taitung County were deemed illegal by the county government, leading to fines and cutting off of electricity. It turned out that MOST had set its mind on a Pingtung site near a military base and NCSIST, which has been used to test missiles.[106] As NSPO pushes for indigenization of technology and production in Formosat-8 and other satellite projects, it has set quantitative targets for local content and capabilities (e.g., thrusters, inter-sat links) that may or may not be market rational for domestic firms to develop in the short run.[107]

Strong linkages with US government and firms

Throughout the progression of the three phases of Taiwan's space policy, Taiwanese planners have actively contracted foreign firms to secure technology and knowledge transfer in order to develop local expertise. For the Formosat projects up to Formosat-7, the Taiwanese depended on foreign firms including SpaceTech GmbH (Immenstaad, Germany), Ball Corporation (United Kingdom), Surrey Satellite Technology (United Kingdom), COM (Canada), RedEye (United States), etc. Above all, since 1994, Formosat programs have been "joint constellation meteorological satellite mission" by the Taiwanese and US government agencies including the NOAA as NSPO's primary partner, the US Space Force's Space Systems Command (SSC) and its Air Force Research Laboratory (AFRL), University Corporation for Atmospheric Research, and NASA's Jet Propulsion Laboratory and laboratories at Utah State University and University of Colorado Boulder.[108] In February 2022, American Institute in Taiwan signed an MoU

[102]Lin (2021c).
[103]Lin interviews, 7–22; Semiconductors Today (2022).
[104]Lin interviews, 7–22.
[105]Lin interviews, 8–22.
[106]Lin (2020).
[107]Lin interviews, 7–22.
[108]Asia Times (2019).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

for US-Taiwan cooperate in the Formosat-7 project (goes by the name of COSMIC-2 in the United States), again with NSPO-NOAA partnership as the basis of co-production governance.[109] Despite the much-heralded Taiwanese input, the outer casing of Formosat-7 was made by SSTL, and the internal payload had to meet US-NOAA and DoD requirements, as it was the COSMOS-2 project launched from the United States.[110]

What remains undocumented is the influence of American preferences on Taiwan's space development. There are signs of a strong influence. Gillet (2021) suggests:

> Taiwan has been reluctant to develop launch capabilities due to the dual use of the required technology, rocket technology being easily transformable into ballistic missiles or other military technology. It is suspected that the United States themselves, primary military ally of the island, have pushed Taiwan to refrain from developing such capability on the grounds that it could potentially give China a reason for intensifying military actions around the island.

Jaffe (2021) argues that Taiwan has benefitted from access to solid-state fuel for its rockets, which ROK did not until the past few years due to US concerns that it could be used to launch nuclear weapons. On the other hand, the United States has suppressed Taiwan's launch programs for fear that it could justify an aggressive, escalatory response from Beijing. Instead, Taiwan has largely relied on SpaceX and launch sites in California (including Vandenberg Air Force Base).[111] One could look closer at US trade restrictions and firms' timing and priorities in disclosing component specifications for OEM suppliers Taiwan to gauge US government's level of trust in Taiwan.

Publicly, Taiwanese officials concurrently offer an optimistic image of Taiwanese firms' prospects in supplying the dominant space firms and envision achieving self-sufficiency in satellite manufacturing. Tsai Tung-hung of NSPO stated in a 2021 panel discussion that "Taiwan is a key supplier for SpaceX, and it has the potential to make systems of its own, to cement its position in the global supply chain."[112] Another official boasted that "SpaceX's satellite project wouldn't be possible without Taiwan. Peek inside their satellites, and you'll find plenty of parts made by Taiwanese firms."[113] Aside from probable American reservations for a domestic launch site in Taiwan, National Cheng Kung University's participation in the Belgian government-sponsored QB50 mission of a CubeSat constellation exposed the cost and paperwork requirements of a foreign launch platform—unpredictable problems that exceeded the NCKU's resources.[114] Critics have pointed out that the government's plan to push firms to advance from OEM to self-sufficiency may turn out to be a failed strategy if the end goal is a finished satellite that can compete in the global market. Bill Chang of HelioX Cosmos offered a cautionary note to NSPO officials who seem gung-ho about Taiwan's economic opportunities in LEO—mainly riding on the back of SpaceX launches and proliferating telecommunications and remote-sensing applications. He argues that LEO is a saturated market and Taiwan should look elsewhere to establish a niche, including the cislunar orbits.[115] However, the process of striving for that goal could drive Taiwanese firms to acquire a supply chain presence, technological proficiency, and network capital to move the domestic space industry forward into new niches.

The silent partner: Taiwan's military

Our preliminary research to date has not identified a clear space policy position, expression of strategic interest and operational requirements in the space domain, or specific deployment of space assets by the

[109] Jacobs (2022).
[110] eoPortal (2013); Surrey Satellite Technology Ltd. (2019).
[111] Jaffe (2021).
[112] Formosa News (2022).
[113] Idem.
[114] Masutti et al. (2017).
[115] Formosa News (2022).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

Ministry of Defense.[116] On one hand, this sounds somewhat unbelievable given the escalating security threats from China and intensifying preparation for the cross-Taiwan Strait conflict with the People's Liberation Army. Nominally, no Formosat satellite has been used for military purposes such as surveillance. On the other hand, official statements often imply dual usage. The Triton, with its GNSS functions, is clearly capable of Intelligence, Surveillance, and Reconnaissance (ISR) functions with US military links.[117] For in discussing the Beyond 5G plan, NSPO officials have pointed out that Taiwan's external internet access runs through submarine cables. A LEO constellation will circumvent that obvious vulnerability. Knowledgeable analysts have begun to suggest the use of space assets for defense. Wang and Matossian (2021) propose that homegrown satellite optical, synthetic aperture radar capabilities can give Taiwan an edge in asymmetric warfare. The Taiwanese military forces' in-house think-tank, the Institute for National Defense and Security Research (INDSR), has held events and produced environmental analyses that advocate updating military strategy and procurement to make use of space resources.[118] As the Taiwanese military remains dependent on the US military, the use of space assets would become a salient issue area of inter-military dialogue and acquisition negotiations.[119]

Thailand: hedging strategies for space

Thailand launched its first satellite, Thaicom 1, in 1993, from the Kourou site in French Guiana.[120] Since then, the country has developed further satellite programs, the Thailand Earth Observation System (THEOS) and Napa, geared toward earth observation for purposes such as environmental monitoring and disaster relief, and in the past few years has developed an ambitious space program backed by dedicated legislation and institutions, and developing a greater focus on defense. Thailand's capacity to continue to develop its space ambitions hinge on international supply chains and collaboration with a range of external partners.

Developing countries increasingly tend to adopt strategies of collaboration that "go outside the traditional North-South arrangements" in order to avoid the dependencies associated with past cooperation with either the United States or the Soviet Union.[121] This is notably true of Thailand, whose space strategy should be understood in the context of the country's efforts to navigate a path between the United States and the growing influence of the People's Republic of China. However, these are not the only external actors involved, and Thailand's space program has traditionally involved collaboration with European firms as well.

Since the launch of Thaicom 1, Thailand's trajectory as a spacepower has shifted from a position of total reliance on foreign technology to an indigenous development program that continues to rely on contractors from abroad. As Thailand's domestic expertise and capabilities in space have increased, so have its ambitions for the role played by the space sector in wider questions of national security. Increasing capabilities and ambitions have also led to the development of international collaborative ties going beyond the development of satellites themselves. The growing importance of space to Thailand's national security priorities has geopolitical ramifications, the most significant of which is how the country balances its long-standing relationship with the United States as a treaty ally with the growing influence of the PRC.

The development of Thailand's satellite program: Thaicom and THEOS

The early stages of Thailand's satellite program were marked by a reliance on US, French, and German technology. Thailand's initial satellites, *Thaicom 1* and *Thaicom 2*, relied on collaboration with US and

[116]Lin interviews, July and August 2022. Understandably, the interest and role of the Taiwanese military are conspicuously absent in MOST-NSPO's 2019 report, which dutifully mentioned national security interests and the military as one among many government agencies whose interests are served by space, NSPO (2019), pp. 32–37.

[117]Lin interviews, 8–22.

[118]FRS Taiwan Program (2021).

[119]To complicate the picture, Taiwanese firms have supplied Israeli military satellites, and possibly others as well. Lin interviews, 8–22.

[120]Harding (2013), p. 9.

[121]Harding (2016).

European firms; both were launched from Kourou in French Guiana and used US firm Hughes Space and Communications Company's HS-376 satellite, French firm Arianespace's Ariane-44L H10+ rockets,[122] and further components from Aerospatiale (France), Contraves (Germany), and DASA (Germany) which then merged with Astrium (France).[123] Thaicom 4 (IPSTAR) was US-built and the world's first high-throughput satellite, providing broadband Internet across a large area of Asia-Pacific.

In 2004, Thailand launched its own satellite development program, marking an important milestone in the development of its space capabilities. The THEOS, an LEO satellite, was developed by Thailand's Geo-Informatics and Space Technology Development Agency (GISTDA), under the Ministry of Science and Technology, in collaboration with France-based EADS Astrium SAS as the primary contractor.[124] The primary purpose of THEOS has been environmental monitoring and natural resource management, but it has also been used to map territories disputed with neighboring Cambodia.[125] THEOS-2 was approved in 2017, to be manufactured by Airbus; meanwhile, Thailand has also developed CubeSats including KNACSAT, a university research satellite, and JAISAT-1, for amateur radio.[126] THEOS-2 was launched in October 2023,[127] following an initial delay due to a technical error caused by electrical overload, which also delayed the launch of Taiwan's Triton (Formosat-7R) weather satellite and ten European Space Agency satellites using the same rocket.[128]

Space strategy and national security: building an institutional and legal framework

Under the Prayut government, satellite development and space strategy more generally became increasingly linked to national security concerns and Thailand's long-term economic strategy. The government did not hold back in stating its ambitions and linking space directly to Thailand's continued development, economic prosperity, and international standing; in December 2020, Anek Laothamatas, Minister of Higher Education, Science, Research and Innovation, announced plans to launch a spacecraft into lunar orbit within seven years (which would make it only the fifth Asian nation to do so) and thus demonstrate to a domestic audience that Thailand is no longer a developing country but one with a bright future.[129]

This fits into a broader strategy for 2020–2037 laid out by Thailand's National Space Policy Committee in 2017, which called for GISTDA to draft a National Space Act that would establish a National Space Agency responsible for coordinating all Thailand's space activity other than that covered by the military or other agencies,[130] from the funding of research and manufacturing of satellites to areas as diverse as space tourism and space mining.[131] The Draft Act has yet to be passed into law but was approved by the Thai cabinet in July 2021; its core focus is the development of a space economy. According to a 2021 GISTDA report, over 35,600 enterprises operate space-related businesses in Thailand, generating around 56.122 billion baht.[132]

In addition to integrating space into its economic strategy, the Prayut government also emphasized the importance of space to national security, responsibility for which falls to the Royal Thai Air Force (RTAF).[133] The military importance of the space sector was concretized with the RTAF's establishment of a dedicated space operations center in 2019 as part of its 20-year strategic plan.[134] The purpose of the

[122] Gunter's Space Page (no date b).
[123] Gunter's Space Page (no date a).
[124] Kaewmanee et al. (no date).
[125] Sarma (2019).
[126] Sarma (2019).
[127] Bangkok Post (2023).
[128] Wipatayotin (2023).
[129] Lohatepanont (2020).
[130] Formichella et al. (2023).
[131] Lohatepanont (2020).
[132] Formichella et al. (2023).
[133] Royal Thai Air Force (2020).
[134] C. T. N. News (2020).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

center is to "enhance national security in space and protect the country against future threats."[135] The RTAF's 2020 White Paper is notable for its emphasis on space capabilities, predicting a "substantial increase" in application in future military operations.[136] It remains to be seen whether Thailand's broad trajectory as a spacepower will change under Prime Minister Srettha Thavisin.

The integration of space into defensive aspects of national security also marked a new stage in Thailand's satellite program with the launch of Napa-1, the country's first security-focused satellite, in August 2019.[137] A core mission of Napa-1 is space situational awareness (SSA)—the identification of potential foreign satellite-based espionage operations, and the monitoring of space objects falling over Thailand.[138] This represents a significant development in Thailand's satellite capabilities, but the country's space strategy remains reliant on international supply chains and the dominance of Western companies—the construction of Napa-1 was contracted to Dutch firm ISISpace. Napa-2, launched in July 2021, relied on a SpaceX Falcon 9 rocket and the launch facilities at Cape Canaveral Space Force Station, Florida, indicating the ongoing importance of the RTAF's cooperation with US Space Force.[139]

Bilateral and multilateral collaboration

Thailand's growing space presence has necessitated expanding bilateral and multilateral collaboration, including international treaties and inter-agency cooperation agreements. This includes being party to the 1967 UN Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space and the 1968 UN Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space. Bilaterally, Thailand has signed agreements with France (2000) and India (2002) on cooperation in space technology and its application and peaceful space exploration and use, respectively, as well as a MoU with Russia on cooperation in space technology and its application.[140]

The Theos program demonstrated to Thailand the need "to find global partners for inter-agency cooperation that would cut costs and increase resources"; a component failure led to collaboration between GISTDA and the Swedish Space Corporation to re-establish communication with Theos. Ultimately this initiated a push for inter-agency cooperation, including the 2010 Inter-Operability, Cooperation and Engineering (ICE) project with Taiwan's NSPO, covering cross-support in a range of areas concerning satellites.[141]

Such agreements also link Thailand to the PRC and the United States. Thailand is a member of the Asia-Pacific Space Cooperation Organization (APSCO), set up in 2008 and headquartered in Beijing, which shares resources in space science, technology, and application to promote multilateral cooperation and facilitate capacity building. This is a multilateral organization including Bangladesh, China, Iran, Mongolia, Pakistan, Peru, Thailand and Turkey. Member states gain access to Masters and PhD training sponsored by APSCO and the China Scholarship Council, through cooperation with three top Chinese universities, as well as short-term training programs for over 150 people each year.[142]

In 2018, the RTAF signed an agreement with United States Strategic Command (USSTRATCOM) on SSA services and data sharing, facilitating requests for specific data critical to satellite support from US Air Force Space Command; from 2019, these functions were taken over by the newly established United States Space Force Space Command. Similar agreements are maintained with sixteen other countries, two intergovernmental organizations (the European Space Agency and the European Organization for the Exploitation of Meteorological Satellites), and more than 70 commercial satellite owners, operators, and launchers.[143]

[135]Parameswaran (2019).
[136]Royal Thai Air Force (2020).
[137]Lohatepanont (2020).
[138]C. T. N. News (2020).
[139]Dominguez (2021).
[140]Formichella et al. (2023).
[141]Kaewmanee et al. (no date).
[142]Asia-Pacific Space Cooperation Organization (no date).
[143]United States Strategic Command Public Affairs (2018).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

As Thailand's space ambitions continue to develop, such multilateral and bilateral collaborations are likely to increase, as evinced most recently by Thailand's Excellence Center for Space Technology's MoU with the UK-based In-Space Missions Limited, with the aim of jointly manufacturing a satellite within two years and use it within three.[144] So far, Thailand has been fairly open to such collaborations; France, India, Russia, Sweden, Taiwan, the United States, and the members states of APSCO constitute a diverse range of countries which do not on necessarily commit Thailand to a particular geopolitical alignment on space. As a developing middle spacepower, this makes strategic sense as a means of avoiding dependencies. It is notable that Thailand engages in data sharing and support collaboration with both the United States (bilaterally) and the PRC (bilaterally, discussed below, and multilaterally through APSCO). Thailand's relationship with these two leading spacepowers and major geopolitical players in Southeast Asia will significantly influence the trajectory of its space program.

The key challenge: balancing the United States and China

Thailand is a long-standing treaty ally of the United States, but the size and proximity of the PRC necessitate careful navigation of bilateral relationships with both powers. This is becoming more difficult for Thailand in the context of China's rapidly increasing influence within the country, including elite capture at high levels of the Thai government, particularly since the United States began to distance itself from Bangkok following the 2014 coup.[145]

Thailand's traditional default foreign policy position has been to accommodate the United States, but a combination of domestic factors and the consideration of China have caused this to shift under certain circumstances. A case in point was NASA's request to use Thailand's U-Tapao airbase for scientific study as part of a 2012 proposal for a meteorological research project; such requests were routine, with U-Tapao often used by the US military.[146] However, in this case, the project met with considerable domestic opposition in Thailand on the grounds that the use of U-Tapao was part of a US strategy to militarily contain China in Southeast Asia, and allowing NASA to use the base might compromise Thailand's sovereignty and continued ability to balance its relationships with both China and the United States, potentially limiting future cooperation with Beijing. Ultimately, Thailand resolved to subject the issue to public scrutiny in parliament, delaying the plan, and NASA withdrew the request before the debate took place.[147]

A key area where the growing consideration of China is likely to continue to shape Thailand's space strategy is scientific investment and collaboration. China is involved in Thailand's overall scientific development via a range of collaborations. These include the Chinese Academy of Sciences (CAS) Innovation Cooperation Center (CASICCB), its first overseas organization, which opened in Bangkok in 2016. Its website lists a number of space-related research projects, including advanced microsatellite technology; the "Digital Belt and Road," building "a digital earth platform to achieve global big data sharing, crop monitoring, etc."; a "BeiDou-based vehicle intelligent control system" for BeiDou-based navigation and positioning; ultrahigh-resolution cameras for use with satellites and drones; and space automation technology including robots and high-end manufacturing equipment.[148]

Thailand's adoption of China's BeiDou GNSS is likely to be of crucial importance in determining Thailand's capacity to continue to balance its relationship with both China and the United States. A core reason why major spacepowers have developed alternatives to the US' GPS—such as the European Space Agency's Galileo, Russia's GLONASS, and China's BeiDou itself—is that such systems have significant potential to create technological dependency.[149] This has knock-on effects in terms of external influence

[144] Bangkok Post (2023).
[145] Evenstar Institute (2023).
[146] Busbarat (2016).
[147] Busbarat (2016), p. 249.
[148] CASICCB (no date).
[149] Petroni and Bianchi (2016).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

over any application of such technology, and as such has the potential to significantly shift international alignment,[150] not only over space strategy but also other policy areas dependent on GNSS.

Such effects of BeiDou's adoption are already apparent in Thailand. Wuhan Optics Valley BeiDou Holding Group Co. Ltd. holds two subsidiary companies in the country, focusing on the promotion and popularization of BeiDou technology and application in The Association of Southeast Asian Nations while also developing domestic market applications. It provides high-tech products, R&D and technology services, satellite navigation infrastructure construction, commercial satellite auxiliary product operation, commercial real estate investment and management, and industry and equity investment.[151] This includes collaboration with Thailand's National Science and Technology Development Agency, alongside Kunming Rongzhihuitu Business Consulting Co., to introduce smart transportation and a WeChat-based platform to develop local transport and tourism networks.[152] The company's involvement in the establishment of China-ASEAN BeiDou Technology City in Thailand will enable the expansion of BeiDou coverage further into Southeast Asia,[153] effectively making Thailand a hub from which China has the potential to extend technological dependency via any regional digital infrastructure reliant on BeiDou.

However, in other areas there are signs of pushback against China's influence over Thailand's space program. As discussed above, Thailand favors non-Chinese technology and launch providers for satellites themselves, primarily Western companies. The government's focus appears to be on building domestic technological capacity and sustainable economic development in a way that does not allow China, or domestic lobby groups, to gain a comprehensive edge; this extends to the RTAF itself, which collaborates with NASA on environmental monitoring projects and via scholarship programs for Thai astronauts.[154] Settapong Malisuwan of the Ministry for Digital Economy and Society has argued that "Thailand must strive to maintain balance in the space competition between great powers, and to develop our own domestic space industry . . . otherwise, we'll simply have to accept their policies and we'll have no bargaining power."[155] Nonetheless, worries regarding a shift toward China do exist. Col Setthapong Mali Suwan, Vice-Chairman of Telecommunications at the Ministry of the Digital Economy and Society, has voiced concern that GISTDA Executive Director Pakorn Apaphant favors Chinese technology and launch service providers.[156]

Most significantly, the avoidance of dependency on major spacepowers does not simply come down to providers of satellite components and launch facilities—an area where, despite these concerns, Thailand has so far successfully managed to ensure a diverse international supply chain and network of bilateral and multilateral collaborations. Rather, the space sector cannot be viewed in isolation from the broader requirements of national development. The key challenge Thailand faces in continuing to develop and maintain sovereignty over its domestic space industry is rather how the sector interacts with core foreign technologies such as China's BeiDou. If the country's digital infrastructure becomes locked into technological dependence on BeiDou-based platforms, then the development of satellite systems going forward is more likely to require integration with them. This has significant potential to realign Thailand's space strategy and related supply chains toward the PRC even if Thailand continues to maintain a diversified approach to satellite supply chains and inter-agency collaboration. Thailand's joining of Chinese-sponsored International Lunar Research Station (ILRS) program in April 2024 - only the ninth country to do so - indicates the pull of technological dependency.[157]

[150]Evenstar Institute (2023).
[151]General Office of Hubei Provincial People's Government (2016).
[152]Zhou (2020).
[153]Jory (2017).
[154]Saperstein (2020).
[155]Lohatepanont (2020).
[156]Saperstein (2020).
[157]Bosquillon (2024).

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

Conclusion: middle spacepowers and great power competition in Asia

Industrial policy is hard. It has been argued that many successful cases in Asian developmental state's glorious histories—including Taiwan's semiconductor story—occurred despite, not because, the government interventions. In the past decades, Taiwanese industrial policies aiming to gain an upper hand in the car parts and biomedical industries have largely under-delivered. Upstream automotive suppliers such as Bosch, Continental, and Delphi remain unchallenged, with Taiwanese producers competing at the lower end with Chinese, Mexican, and others. Taiwanese firms build 60–77 GHz RADAR modules with mmWave sensors with antenna elements for car onboard interfaces but depend on foreign IC design and German ceramic materials. In the biomedical field, the Taiwanese have been interested in genomic data, but there has been little to show aside from expensive sequencing machine purchases and a government-supported biobank. Critics would point out that Taiwan did not create an antiviral vaccine for COVID-19, despite its early achievements in preventive public health. In the end, analysts cannot rule out the possibility that space industrial policies by Taiwan and Thailand would have marginal effects. This paper has not discussed the regional competitive environment, but one only needs to look at South Korea with its chaebol resources and India with highly developed (and loosely regulated!) launch capabilities to anticipate that Taiwan and Thailand will face an uphill climb.

As developmental states, Taiwan and Thailand remain conservative in strategic choices: betting on mature technologies, leveraging existing core competence in the private sector, relying on market intelligence and funding networks in the United States and Europe, investing in human resources and domestic R&D, and quietly or openly integrating space further into its broader national security strategy in terms of military support, counter-espionage, and environmental surveillance and monitoring. Critics may say their space agencies lack vision or market savviness. One could counter that they make responsible uses of government resources, taking cautious first steps as newly mandated agencies with significant capacity gaps to fill and bureaucratic turf wars to win.

Fundamentally, geoeconomics constraints have changed for these countries since the 1990s. During the Cold War, these countries' defense-security and developmental-globalization imperatives had overlapped to a large extent given their bilateral relations with the United States. While both countries remain highly exposed to political and regulatory demands from the US and European governments, given these leading spacepowers' market impact, at least in the case of Thailand the options in technological, capital, and new market development partnerships are wide today given recent Chinese economic expansionism and a general lowering of barriers to entry into the global supply chain for the space industry. With the continuing momentum toward techno-nationalism for both the United States and the PRC and China's turn toward a more insular economy, these diversification or hedging options may turn out to be strategic dilemmas for the national planners. Thailand's reliance on Western countries for components, facilities, and expertise, coupled with China's growing provision of key elements of the country's digital infrastructure is likely to be unsustainable. This is because ultimately it will mean integrating Western technology into Chinese digital and GNSS frameworks, which would become unacceptable for Western providers operating under increasingly restrictive rules at home. As Thailand's space program leads to requirements for increasingly advanced equipment and deeper international collaborations, it is possible that such "securization" considerations will necessitate a fundamental rethink of its space supply chain strategy.

In this sense, Taiwanese space agency officials have a relatively simpler task at hand of working within the Western supply chains. NSPO and other space policy insiders have directed their primary concerns to market competitors including South Korea, India, and even Australia.[158] China is shutting its doors to the global space industry supply chains, and there is no way to plan around it aside from reinforcing Taiwan's interdependence with American firms. The national security dimension and implications of space assets will remain highly repressed in Taiwanese policy debates and public discourse, although it would seem inevitable that for the United States to help the Taiwanese military

[158]Lin interviews, 8–22.

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

the space capabilities would have to be integrated into the hardware upgrades and wargaming preparations. Yet the Taiwanese military has been very quiet as a stakeholder in President Tsai's championship of the space development policy.[159] In the third phase and beyond, the use of space will likely remain purely scientific or commercial for Taiwan to avoid the obvious reality of Taiwan's dependence on US protection.

References

Aerospace Corporation. 2021. "A Space Policy Primer: Key Concepts, Issues and Actors." 19 January 2019. Accessed on 3 March 2024, https://csps.aerospace.org/papers/space-policy-primer-key-concepts-issues-and-actors.

Allied Market Research. 2021. "Small Satellite Market . . . Global Opportunity Analysis and Industry Forecast, 2021–2030." Accessed on 3 March 2024. https://www.alliedmarketresearch.com/small-satellite-market.

Allied Market Research. 2022. "Commercial Satellite Imaging Market . . . Global Opportunity Analysis and Industry Forecast, 2021–2031." Accessed on 3 March 2024. https://www.alliedmarketresearch.com/commercial-satellite-imaging-market.

Asia-Pacific Space Cooperation Organization. No date. "About APSCO." Accessed on 21 December 2022. http://www.apsco.int/html/comp1/content/WhatisAPSCO/2018-06-06/33-144-1.shtml.

Asia Times. 2019. "Taiwanese Satellites Head for Space via USA." 14 April 2019. Accessed on 3 March 2024. https://asiatimes.com/2019/04/taiwanese-satellites-head-for-space-via-usa/.

Asian Development Bank (ADB). 2021. "Global Value Chain Development Report 2021: Beyond Production." November 2021. Accessed on 3 March 2024. https://www.adb.org/publications/global-value-chain-development-report-2021.

Autry, Greg. 2018. "Commercial Orbital Transportation Services: A Case Study for National Industrial Policy." *New Space* 6 (3): 191–200.

Barbaroux, Pierre. 2016. "The Metamorphosis of the World Space Economy: Investigating Global Trends and National Differences among Major Space Nations' Market Structure." *Journal of Innovation Economics & Management* 2 (20): 9–35.

Bangkok Post. 2023. "Thai-UK Deal Seeks to Boost Space Capabilities." *Bangkok Post*, 12 November 2023. Accessed on 15 December 2023. https://www.bangkokpost.com/thailand/general/2683589.

Berglof, Erik, and Vince Cable. 2018. "Back in Business: Industrial Policy for Emerging Economies in the New Globalization." Asian Development Bank, February 2018. Accessed on 3 March 2024. https://www.adb.org/publications/industrial-policy-emerging-economies.

Black, James, Linda Slapakova, and Kevin Martin. 2022. "Future use of Space 2050: Emerging threats and opportunities for the UK National Space Strategy." RAND Corporation, 2 March 2022. Accessed on 3 March 2024. https://www.rand.org/pubs/research_reports/RRA609-1.html.

Borroz, Nicholas. 2021. "Comparing Space Agency Intervention in Taiwan and South Korea." *Journal of Indo-Pacific Affairs*, Spring 2021. Accessed on 3 March 2024. https://www.airuniversity.af.edu/JIPA/Display/Article/2462258/comparing-space-agency-intervention-in-taiwan-and-south-korea/.

Bosquillon, Christophe. 2024. "#SpaceWatchGL Geopolitics – Thailand Joined the ILRS – Now What?" SpaceWatch Asia Pacific, Accessed on 6 June 2024. https://spacewatch.global/2024/04/spacewatchgl-geopolitics-thailand-joined-the-ilrs-now-what/#:~:text=Next%2C%20in%20April%202024%2C%20Thailand,and%20China%20is%20two%2Dfold.

Bryce Technology. 2017. "Global Space Industry Dynamics." Accessed on 3 March 2024. https://brycetech.com/reports/report-documents/Global_Space_Industry_Dynamics_2017.pdf.

Bryce Technology. 2022. "2022 State of the Satellite Industry Report." 13 July 2022. Accessed on 3 March 2024. https://brycetech.com/reports.

Bryce Technology. 2023. "2022 Global Space Economy at a Glance." 29 September 2023. Accessed on 3 March 2024. https://brycetech.com/reports.

Busbarat, Pongphisoot. 2016. "'Bamboo Swirling in the Wind': Thailand's Foreign Policy Imbalance between China and the United States." *Contemporary Southeast Asia* 38 (2): 233–257.

Callahan, Tara et al. 2010. "National Security and the Commercial Space Sector." A Report of the CSIS Defense-Industrial Initiatives Group, July 2010. Accessed on 3 March 2024. https://www.csis.org/analysis/national-security-and-commercial-space-sector.

CASICCB. No date. "Project." Accessed on 21 December 2022. https://www.casiccb.com/Project.php?page = 5&Category = &search = .

Center for Global Affairs and Science Engagement, Ministry of Science and Technology, Taiwan. 2022. "Taiwan Launches Its Vision for the Space Industry." 7 June 2022. Accessed on 3 March 2024. https://trh.gase.most.ntnu.edu.tw/en/newsletter/latest.

Center for Strategic and International Studies (CSIS). 2022. "A Look at the CHIPS-Related Portions of CHIPS+." 9 August 2022. Accessed on 3 March 2024. https://www.csis.org/analysis/look-chips-related-portions-chips.

Chan, Shu-Ting, Hsi-Mei Chung, Li-Hsuan Cheng. 2021. "The Dark Side of the Advantages on Industrial Clusters in Taiwan." In *Succession and Innovation in Asia's Small- and Medium-Sized Enterprises*, edited by Hsi-Mei Chung and Kevin Au. London: Palgrave MacMillan.

Cheung, Tai Ming and Yasuhito Fukushima. 2023. "Techno-Security Space Innovation." In *The Oxford Handbook of Space Security*, edited by Saadia M. Pekkanen and P.J. Blount. Oxford: Oxford University Press.

[159]Idem.

https://doi.org/10.1017/bap.2024.18 Published online by Cambridge University Press

Chin, Vincent, et al. 2021. "As Supply Chains Localize, Industrial Policy Springs Back." BCG.com, 21 November 2021. Accessed on 3 March 2024. https://www.bcg.com/publications/2021/the-importance-of-global-value-chains-as-industrial-policy-springs-back.

Congressional Research Service (CRS). 2012. "Commercial Space Industry and Launch Market." 20 April 2012. Accessed on 3 March 2024. https://www.everycrsreport.com/files/20120420_R42492_63f6f0770a711eb5094b9871844ae5fe28e34a4e.pdf.

Congressional Research Service (CRS). 2016. "Commercial Space Industry Launches a New Phase." 12 December 2016. Accessed on 3 March 2024. https://crsreports.congress.gov/product/pdf/R/R44708/3.

Congressional Research Service (CRS). 2018. "Commercial Space: Federal Regulation, Oversight, and Utilization." 29 November 2018. Accessed on 3 March 2024. https://crsreports.congress.gov/product/details?prodcode = R45416.

Congressional Research Service (CRS). 2020. "Semiconductors: U.S. Industry, Global Competition, and Federal Policy." 26 October 2020. Accessed on 3 March 2024. https://www.everycrsreport.com/reports/R46581.html.

C. T. N. News. 2020. "Thailand's Air Force Set to Launch a Napa-1 Security Satellite." Chiang Rai Times—CTN News, 17 June 2020. Accessed on 21 December 2022. https://www.chiangraitimes.com/news/thailands-air-force-set-to-launch-a-napa-1-security-satellite/.

Daniels, Matthew. 2020. The History and Future of US-China Competition and Cooperation in Space." Johns Hopkins Applied Physics Laboratory. Accessed on 3 March 2024. https://www.jhuapl.edu/sites/default/files/2022-12/Daniels-Space.pdf.

Davenport, Christian. 2018. *The Space Barons: Elon Musk, Jeff Bezos, and the Quest to Colonize the Cosmos*. New York: Public Affairs.

Department of Information Services, Executive Yuan, Taiwan. 2022. "Pushing the Development of Space Technology." 22 August 2022. Accessed on 3 March 2024. https://english.ey.gov.tw/News3/9E5540D592A5FECD/46f4d4cc-ccea-4d22-874e-ecb93e5cf1b8.

Deloitte. 2022. "The Economics of Space." Accessed on 3 March 2024. https://www2.deloitte.com/uk/en/pages/consulting/articles/economics-of-space.html.

Dolman, Everett C. 2022. "Space is a Warfighting Domain." *Æther: A Journal of Strategic Airpower and Spacepower* 1 (1): 82–90.

Dominguez, Gabriel. 2021. "SpaceX Launches Royal Thai Air Force's Second Earth Observation Satellite." *Janes*, 8 July 2021. Accessed on 15 December 2023. https://www.janes.com/defence-news/news-detail/spacex-launches-royal-thai-air-forces-second-earth-observation-satellite.

Dunphy, Ryuichi. 2016. "Space Industry Business Opportunities in Japan: Analysis on the Market Potential for EU SMEs Involved in the Earth-Observation Products & Services." EU-Japan Centre for Industrial Cooperation, October 2016. Accessed on 3 March 2024. https://www.eu-japan.eu/sites/default/files/publications/docs/2016-10-space-industry-business-opportunities-japan-ryuichi-dunphy-min.pdf.

eoPortal. 2013. "FormoSat-7/COSMIC-2 (Constellation Observing System for Meteorology, Ionosphere and Climate)." 29 April 2013. Accessed on 3 March 2024. https://www.eoportal.org/satellite-missions/stp2-formosat-7.

EU-Japan Centre for Industrial Cooperation. 2015. "EU-Japan Industrial Cooperation 30 Years Together." Accessed on 3 March 2024. https://www.eu-japan.eu/sites/default/files/publications/docs/booklet_web.pdf.

European Investment Bank. 2019. "The Future of the European Space Sector." 22 January 2019. Accessed on 3 March 2024. https://www.eib.org/en/publications/the-future-of-the-european-space-sector-report.

European Space Policy Institute (ESPI). 2021. "Emerging Spacefaring Nations." Accessed on 3 March 2024. https://www.espi.or.at/wp-content/uploads/2022/06/ESPI-Report-79-Emerging-Spacefaring-Nations-Full-Report.pdf.

Evenstar Institute. 2023. "Southeast Asia's Emerging Geopolitical Order: China's Structural Influence and the Evolving Regional Balance of Power".

Federal Aviation Administration (FAA). 2018. "The Annual Compendium of Commercial Space Transportation: 2018." January 2018. Accessed on 3 March 2024. https://www.faa.gov/about/office_org/headquarters_offices/ast/media/2018_ast_compendium.pdf For updates see: FAA Commercial Space Data site: https://www.faa.gov/data_research/commercial_space_data.

Focus Taiwan. 2022a. "Satellite of Love: Taiwan-developed INSPIREsat-1 enters orbit." 14 February 2022. Accessed on 3 March 2024. https://focustaiwan.tw/sci-tech/202202140022.

Focus Taiwan. 2022b. "Taiwan's Legislature clears bill to upgrade national space agency." 19 April 2022. Accessed on 3 March 2024. https://focustaiwan.tw/sci-tech/202204190022.

Focus Taiwan. 2023. "Taiwan's first domestic Triton weather satellite launches." 9 October 2023. Accessed on 3 March 2024. https://focustaiwan.tw/sci-tech/202310090002.

Formichella, John P., Naytiwut Jamallsawat, and Onnicha Khongthon. 2023. "The Space Law Review: Thailand." *The Law Reviews*, 5 January 2023.

Formosa News. 2022. "Taiwan space industry ready for takeoff." 1 May 2022. Accessed on 3 March 2024. https://english.ftvnews.com.tw/news/D164D1ED70029AA177464A38B2A5D5E6.

Fortune Business Insights. 2021. "Space Technologies Market Research Report." Accessed on 3 March 2024. https://www.fortunebusinessinsights.com/satellite-manufacturing-and-launch-systems-market-103549.

FRS Taiwan Program. 2021. "A Conversation with Chen-wei Lin, April 2021." Accessed on 3 March 2024. https://www.frstrategie.org/sites/default/files/documents/programmes/Programme-Taiwan/2021/taiwan-itw1.pdf.

General Office of Hubei Provincial People's Government. 2016. "Wuhan Optics Valley Beidou Holding Group Co., Ltd.—The People's Government of Hubei Province". 7 May 2016. Accessed on 22 December 2022. http://en.hubei.gov.cn/business/enterprises/201607/t20160705_1437767.shtml.

Gillet, Aurélie. 2021. "Taiwan: A Serious Up-and-Coming Player in the Space Industry." *Satellite Executive Briefing*, December 2021 Year in Review. Accessed on 3 March 2024. https://satellitemarkets.com/news-analysis/taiwan-serious-and-coming-player-space-industry.

GIS.FCU. 2024. “GIS-FCU Overview—The Largest Professional Research Organization of GIS in Taiwan.” Feng Chia University. Accessed on 3 March 2024. https://www.gis.tw/en-US/group-profile/.

GlobeNewswire. 2022. “Military Satellites Global Market Report 2022.” 28 February 2022. Accessed on 3 March 2024. https://link.gale.com/apps/doc/A695179564/HRCA?u = anon~763068f4&sid = sitemap&xid = 341eae6d.

GlobalSecurity.org. 2021. “TSLV Taiwan Small Launch Vehicle.” 9 June 2021. Accessed on 3 March 2024, https://www.globalsecurity.org/space/world/taiwan/tslv.htm.

Goldman Sachs. 2017. “Episode 64: Space—The Next Investment Frontier.” Exchanges at Goldman Sachs podcast, 3 May 2017. Accessed on 3 March 2024. https://www.goldmansachs.com/intelligence/podcasts/episodes/05-22-2017-noah-poponak.html#:~:text = Episode%2064%3A%20Space%20%2D%20The%20Next%20Investment%20Frontier&text = 22%20MAY%202017%20%2D%20Long%20dominated,like%20launch%2C%20communications%20and%20exploration.

Goswami, Namrata, and Peter Garretson. 2020. *Scramble for the Skies*. Lanham, MD: Lexington Books.

Goswami, Namrata. 2022. “The Second Space Race: Democratic Outcomes for the Future of Space.” *SFS*, 25 Jan 2022. Accessed on 3 March 2024. https://gjia.georgetown.edu/2022/01/25/the-second-space-race-democratic-outcomes-for-the-future-of-space/.

Gui, Yongtao. 2022. “Moving Toward Decoupling and Collective Resilience? Assessing US and Japan’s economic statecraft against China.” *China International Strategy Review*. 4: 55–73.

Gunter’s Space Page. No date a. “Ariane-44L H10+.” Accessed on 22 December 2022. https://space.skyrocket.de/doc_lau_det/ariane-44l_h10plus.htm.

Gunter’s Space Page. No date b. “Thaicom 1, 2.” Accessed on 21 December 2022. https://space.skyrocket.de/doc_sdat/thaicom-1.htm.

Haggard, Stephan, and Jeongsoo Kim. 2020. “Disrupting Supply Chains: Evidence on the Japan-Korea Conflict.” KEI. 13 April 2020. Accessed on 3 March 2024, https://keia.org/the-peninsula/disrupting-supply-chains-evidence-on-the-japan-korea-conflict/.

Harding, Robert C. 2013. *Space Policy in Developing Countries: The Search for Security and Development in the Final Frontier*. Oxon: Routledge.

Harding, Robert C. 2016. “Introduction: Space Policy in Developing Countries.” *Space Policy* 37 (2), 1–5.

Harrison, Todd, and Matthew Strohmeyer. 2022. “Commercial Space Remote Sensing and Its Role in National Security.” CSIS Brief, 2 February 2022. https://www.csis.org/analysis/commercial-space-remote-sensing-and-its-role-national-security.

Harvey, Brian, Henk H. F. Smid, and Theo Pirard. 2010. *Emerging Space Powers: The New Space Programs of Asia, the Middle East and South America*. New York: Praxis.

Hisham, Sarah. 2022. “The Race is On: Emerging Space Economies in Asia-Pacific.” GWPrime, 22 September 2022. Accessed on 3 March 2024. https://www.geospatialworld.net/prime/emerging-space-economies-apac/.

Hauge, Jostein. 2020. “Industrial Policy in the Era of Global Value Chains: Towards a developmentalist framework drawing on the industrialisation experiences of South Korea and Taiwan.” *The World Economy* 43 (8): 2070–2092.

Huang, Tzu-ti. 2022. “Launch of NCKU’s hybrid rocket hailed as breakthrough in Taiwan.” Taiwan News, 8 November 2022. Accessed on 3 March 2024. https://www.taiwannews.com.tw/en/news/4711132.

Hwang, Feng-Tai, and Shih Ning Chen. 2022. “A Proposed Approach for NewSpace Industry Development in Taiwan.” *New Space* 10 (4): 307–314.

Infinio Capital. 2022. “Infinio Capital Launches Venture Studio.” 31 August 2022. Accessed on 3 March 2024. https://www.infiniocapital.com/infinio-capital-launches-venture-studio/.

Institute of Astronomy and Astrophysics, Academia Sinica. 2016. “ERG satellite mission in which ASIAA has collaborated with JAXA was launched successfully on December 20th, 2016.” Accessed on 3 March 2024. https://www.asiaa.sinica.edu.tw/news/sciencehighlight.php.

Jacobs, Erik M. 2022. “Taiwan-US Science and Technology Cooperation Continues with Satellite Program.” Global Taiwan Institute, 20 April 2022. Accessed on 3 March 2024. https://globaltaiwan.org/2022/04/taiwan-us-science-and-technology-cooperation-continues-with-satellite-program/.

Jaffe, David Michael. 2021. “Is it Taiwan’s turn to invest in space?” *Taiwan Insight*, 18 March 2021. Accessed on 3 March 2024. https://taiwaninsight.org/2021/03/18/is-it-taiwans-turn-to-invest-in-space/.

Japan Aerospace Exploration Agency (JAXA). 2014. “Exploration of energization and Radiation in Geospace (ERG)—Message for the ERG by Chang, Tzu-Fang. Accessed on 3 March 2024. https://global.jaxa.jp/projects/sas/erg/column.html.

Jory, Patrick. 2017. “Enter the Dragon: Thailand Gets Closer to China”. *The Interpreter*, 7 July 2017. Accessed on 22 December 2022. https://www.lowyinstitute.org/the-interpreter/enter-dragon-thailand-gets-closer-china.

Kamakura, Natsuki. 2022. “From Globalising to Regionalising to Reshoring Value Chains? The case of Japan’s semiconductor industry.” *Cambridge Journal of Regions, Economy and Society* 15 (22): 261–277.

Kaewmanee, M., T. Choomnoommanee, and R. Fraisse. No date. “Thailand Earth Observation System: Mission and Products.” Accessed on 22 December 2022. http://isprs.free.fr/documents/Papers/T04-16.pdf.

Lee, John, Meia Nouwens, and Kai Lin Tay. 2022. “Strategic Settings for 6G: Pathways for China and the US.” The International Institute for Strategic Studies (IISS) Research Papers, 12 August 2022: 17–18. Accessed on 3 March 2024. https://www.iiss.org/en/research-paper/2022/08/strategic-settings-for-6g-pathways-for-china-and-the-us/.

Lee, Ting-Lin, and Nick Von Tunzelmann. 2005. “A Dynamic Analytic Approach to National Innovation Systems: The IC industry in Taiwan.” *Research Policy* 34 (4): 425–440.

Lin, Chia-nan. 2014. “Study Upending Theories on Auroral Formation.” *Taipei Times*, 22 January 2014. Accessed on 3 March 2024. https://www.taipeitimes.com/News/taiwan/archives/2021/01/22/2003751023.

Lin, Chia-nan. 2020. "Ministry Plans Site for Sounding Rocket Launch." *Taipei Times*, 13 June 2020. Accessed on 3 March 2020. https://www.taipeitimes.com/News/taiwan/archives/2020/06/13/2003738141.

Lin, Chia-nan 2021a. "Interview: NSPO eyes industry partnership." *Taipei Times*, 26 May 2021. Accessed on 3 March 2024. https://www.taipeitimes.com/News/taiwan/archives/2021/05/26/2003758072.

Lin, Chia-nan. 2021b. "Taiwan must secure spot in 'new space age.': Tsai." *Taipei Times*, 15 September 2021. Accessed on 3 March 2024. https://www.taipeitimes.com/News/front/archives/2021/09/15/2003764394.

Lin, Chia-nan. 2021c. "'Viruses' heading to space in local study." *Taipei Times*, 19 November 2021. Accessed on 3 March 2024. https://www.taipeitimes.com/News/taiwan/archives/2021/11/19/2003768128.

Link Communications System UK. 2021. "The small satellite market 2022." 29 April 2022. Accessed on 3 March, 2024. https://www.linksystems-uk.com.

Liu, J-Y., Chang, Loren C-W., Chao, C-K. et al. 2016. "The Fast Development of Solar Terrestrial Sciences in Taiwan." *Geoscience Letters* 3 (18). Accessed on 3 March 2024. https://doi.org/10.1186/s40562-016-0049-0.

Lohatepanont, Ken Mathis. 2020. "Is the Thai Government Serious about Space?" *Thai Enquirer* (blog), 29 December 2020. Accessed on 22 December 2022. https://www.thaienquirer.com/22045/is-the-thai-government-serious-about-space/.

Masutti, D., et al. 2017. "The QB50 Mission for the Investigation of the Mid-Lower Thermosphere: Preliminary Results and Lessons Learned." 68th International Astronautical Congress (IAC), Adelaide, Australia, 25–29 September 2017. Accessed on 3 March 2024. https://researchportal.northumbria.ac.uk/en/publications/the-qb50-mission-for-the-investigation-of-the-mid-lower-thermosph.

Metal Industries Research & Development Centre (MIRDC). 2022. "Taiwan Re-enhances core technologies to take industries to space." 22 July 2022. Accessed on 3 March 2024. https://www.mirdc.org.tw/English/NewsView.aspx?Cond = 3402.

Millan, Robyn M. et al. 2019. "Small Satellites for Space Science: A COSPAR scientific roadmap." *Advances in Space Research* 64 (8): 1466–1517.

Ministry of Science and Technology (MOST), Taiwan. 2021. "National S&T Development Plan, 2021–2024." September 2021. Accessed on 3 March 2024. https://www.nstc.gov.tw/nstc/attachments/fd10ecfa-f319-44fe-8058-f379d3de22c2.

Morgan Stanley. 2020. "Space Industry Investing in the Final Frontier." 24 July 2020. Accessed on 3 March 2024. https://www.morganstanley.com/ideas/investing-in-space.

Moltz, James Clay. 2011. *Asia's Space Race*. New York: Columbia University Press.

NASDAQ. 2022. "The Democratization of Space: A Welcoming New Frontier." 27 October 2022. Accessed on 3 March, 2024. https://www.nasdaq.com/articles/the-democratization-of-space.

National Development Fund, Taiwan. 2017–2022. "Annual Report." Accessed on 3 March 2024 https://www.df.gov.tw/eng/News11.aspx?n = 16841C88DAE4CCCE&sms = 24D4F1B081C7825E.

National Science and Technology Council, Taiwan. 2023. "Space Development Act." Accessed on 3 March 2024. https://law.moj.gov.tw/ENG/LawClass/LawAll.aspx?pcode = H0160078.

National Space Organization (NSPO), Taiwan. 2019. "The Third Phase of the National Space Science & Technology Long-Range Development Plan (2019–2028). NSPO-PLAN-0038 (Chinese version)." 16 January 2019. Henceforth referred to as NSPO 2019.

Olson, J., S. Butow, E. Felt, and T. Cooley. 2022. "State of the Space Industrial Base 2022." Defense Technical Information Center Report, August 2022. Accessed on 3 March 2024. https://apps.dtic.mil/sti/trecms/pdf/AD1190754.pdf.

Organisation for Economic Co-operation and Development (OECD). 2019. "The Space Economy in Figures: How Space Contributes to the Global Economy." OECD Publishing, Paris. https://doi.org/10.1787/c5996201-en.

Organisation for Economic Co-operation and Development (OECD). 2021. "Space Economy for People, Planet and Prosperity." OECD background paper for the G20 Space Economy Leaders' Meeting, Rome, 20–21 September 2021.

Organisation for Economic Co-operation and Development (OECD). 2022. "OECD Handbook on Measuring the Space Economy, 2nd Edition." 12 July 2022. Accessed on 3 March 2024. https://www.oecd-ilibrary.org/science-and-technology/oecd-handbook-on-measuring-the-space-economy-2nd-edition_8bfef437-en.

Organisation for Economic Co-operation and Development (OECD). 2023. "The Space Economy in Figures: Responding to Global Challenges." 15 December 2023. Accessed on 3 March 2024. https://www.oecd-ilibrary.org/science-and-technology/the-space-economy-in-figures_fa5494aa-en.

Paikowsky, Deganit. 2017. *The Power of the Space Club*. Cambridge: Cambridge University Press.

Parameswaran, Prashanth. 2019. "What's in Thailand's New Military Space Center Launch?" *The Diplomat*, 23 August 2019. Accessed 22 December 2022. https://thediplomat.com/2019/08/whats-in-thailands-new-military-space-center-launch/.

Patton, Daniel. 2022. "Is Space a Global Commons?" Security World Foundation, Space Sustainability Briefs 2022/1. Accessed on 3 March 2024. https://swfound.org/media/207517/swf_brief_is_space_a_global_commons_pp2301_final.pdf.

Petroni, Giorgio, and Davide Gianluca Bianchi. 2016. "New Patterns of Space Policy in the Post-Cold War World." *Space Policy*, Special Issue: Developing Countries, 37: 12–19. https://doi.org/10.1016/j.spacepol.2016.10.002.

PR Newswire. 2024. "Satellite Manufacturing and Launch—Global Strategic Business Report." 27 February 2024. Accessed on 3 March 2024. https://www.prnewswire.com/news-releases/global-satellite-manufacturing-and-launch-business-report-2022-2024-and-2030-earth-lunar-planetary-stellar–interstellar-discoveries-drive-the-focus-on-small-spacecraft-smallsats-launches-302073088.html.

PWC. 2020. "Main Trends & Challenges in the Space Sector, 2nd Edition." December 2020. Accessed on 3 March 2024. https://www.pwc.fr/fr/assets/files/pdf/2020/12/en-france-pwc-main-trends-and-challenges-in-the-space-sector.pdf.

Robinson, Douglas KR, and Mariana Mazzucato. 2019. "The Evolution of Mission-Oriented Policies: Exploring changing market creating policies in the US and European space sector." *Research Policy* 48 (4): 936–948.

Royal Thai Air Force. 2020. "Royal Thai Air Force White Paper." Accessed on 22 December 2022. https://www.mzv.cz/file/3896487/Thailand_RTAF_White_Paper_2020_ENG_complete_text.pdf.
Saperstein, Hadrien T. 2020. "Thailand's Space Program Drifts out of China's Orbit." *East Asia Forum*, 12 December 2020. Accessed on 22 December 2022. https://www.eastasiaforum.org/2020/12/12/thailands-space-program-drifts-out-of-chinas-orbit/.
Sarma, Nandini. 2019. "Southeast Asian Space Programmes: Capabilities, Challenges and Collaborations." *ORF*, 7 March 2019. Accessed on 22 December 2022. https://www.orfonline.org/research/southeast-asian-space-programmes-capabilities-challenges-collaborations-48799/.
Semiconductors Today. 2022. "Altrum RF announces new grant and collaboration with ITRI and TMYTEK." 28 September 2022. Accessed on 3 March 2024. https://www.semiconductor-today.com/news_items/2022/sep/altumrf-280922.shtml.
Siripurapu, Anshu and Noah Berman. 2023. "Is Industrial Policy Making a Comeback?" Council on Foreign Relations Backgrounder, last updated 18 September 2023. Last Accessed on 3 March 2024. https://www.cfr.org/backgrounder/industrial-policy-making-comeback.
SpaceTech Analytics. 2021. "SpaceTech Industry Year 2021 Overview." Accessed on 3 March 2024. https://analytics.dkv.global/spacetech/spacetech_industry_year_2021_overview_onepager.pdf.
Starling, Clementine G., Mark J. Massa, Lt Col Christopher P. Mulder, and Julia T. Siegel. 2021. "The Future of Security in Space: A Thirty-Year US Strategy." Atlantic Council Strategy Paper Series, 11 April 2021. Accessed on 3 March 2024. https://www.atlanticcouncil.org/content-series/atlantic-council-strategy-paper-series/the-future-of-security-in-space/.
Strong, Matthew. 2019. "France's Arianespace wins bid to launch Taiwan satellite in 2021." *Taiwan News*, 15 November 2019. Accessed on 3 March 2024. https://www.taiwannews.com.tw/en/news/3817999.
Strong, Matthew. 2022. "Taiwan missile producer joins global top-100 arms makers." *Taiwan News*, 6 December 2022. Accessed on 3 March 2024. https://www.taiwannews.com.tw/en/news/4742118.
Surrey Satellite Technology Ltd. 2019. "Press Release: SSTL expertise enables new space mission for the FORMOSAT-7 weather constellation." 25 June 2019. Accessed on 3 March 2024. https://www.sstl.co.uk/media-hub/latest-news/2019/sstl-expertise-enables-new-space-mission-for-the-formosat-7-weather-constellation.
Taipei Times, "Taiwan, Japan sign space research mission." 19 January 2014. Accessed on 3 March 2024. https://www.taipeitimes.com/News/taiwan/archives/2014/01/19/2003581636.
Taiwan Space Agency (TASA). 2022. "Taiwan-Made TRITON Satellite Fully Assembled, Expected to Be Ready for Use by End of 2022." TAXA Latest News 20 July 2022. Accessed on 3 March 2024. https://www.tasa.org.tw/news_view.php?c = 221202001&ln = en.
Taiwan Space Agency (TASA). 2024. "Active Programs, Triton." Accessed on 4 March 2024. https://www.tasa.org.tw/inprogress.php?c = 20030305&ln = en.
Taiwan Today. 2021. "President Tsai vows to make Taiwan integral part of space technology supply chains." 15 September 2021. Accessed on 3 March 2024. https://taiwanreview.nat.gov.tw/news.php?unit = 2&post = 207758&unitname = Politics-Top-News&postname = President-Tsai-vows-to-make-Taiwan-integral-part-of-space-technology-supply-chains.
The White House. 2021. "Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-Based Growth. 100-Day Reviews Under Executive Order 14017." June 2021. Accessed on 3 March 2024. https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf.
Ting, Will. 2021. "Overview of Space Developments in Taiwan." Netherlands Innovation Network at the Netherlands Office Taipei, August 2021. Accessed on 3 March 2024. https://www.rvo.nl/sites/default/files/2022-06/Space%20Developments%20Report%20Taiwan.pdf.
U.S. Department of Commerce (DoC). 2014. "U.S. Space Industry 'Deep Dive' Assessment: Impact of U.S. Export Controls on the Space Industrial Base." February 2014. Accessed on 3 March 2024. https://www.bis.doc.gov/index.php/documents/technology-evaluation/898-space-export-control-report/file.
U.S. Department of Commerce (DoC) and Federal Aviation Administration (FAA). 2017. "US Export Controls for Commercial Space Industry, 2nd Edition." November 2017. https://www.space.commerce.gov/wp-content/uploads/2017-export-controls-guidebook.pdf.
U.S. Department of the Air Force. 2023. "Comprehensive Strategy for the Space Force." August 2023. Accessed on 3 March 2024. https://www.spaceforce.mil/Portals/2/Documents/Space%20Policy/CRR-FY23-Comprehensive-Strategy-Space%20Force-15-Aug-23.pdf.
U.S. Director of National Intelligence. 2011. "National Security Space Strategy." https://www.dni.gov/index.php/newsroom/reports-publications/reports-publications-2011/item/620-national-security-space-strategy.
United States Strategic Command Public Affairs. 2018. "USSTRATCOM, Thailand Sign Agreement to Share Space Services, Data." Air Force Space Command (Archived), 16 October 2018. Accessed on 22 December 2022. https://www.afspc.af.mil/News/Article-Display/Article/1663941/usstratcom-thailand-sign-agreement-to-share-space-services-data/https%3A%2F%2Fwww.afspc.af.mil%2FNews%2FArticle-Display%2FArticle%2F1663941%2Fusstratcom-thailand-sign-agreement-to-share-space-services-data%2F.
Undseth, Marit and Claire Jolly. 2015. "Globalization of Space Manufacturing." Paper for the 31st Space Symposium, Technical Track, Colorado Springs, Colorado, USA, 13–14 April 2015. Accessed on 3 March 2024. https://www.spacesymposium.org/wp-content/uploads/2017/10/C.Jolly_31st_Space_Symposium_Tech_Track_paper.pdf.
Wang, Jason. 2021. "Strategic Focus Areas for Taiwan's Burgeoning Domestic Space Industry." *Taiwan Insight*, 25 October 2021. Accessed on 3 March 2024. https://taiwaninsight.org/2021/10/25/strategic-focus-areas-for-taiwans-burgeoning-domestic-space-industry/.
Wang, Jason and Mark Matossian. 2021. "David vs Goliath: How Space-Based Assets Can Give Taiwan an Edge." *The Diplomat*, 27 March 2021. Accessed on 3 March 2024. https://thediplomat.com/2021/03/david-vs-goliath-how-space-based-assets-can-give-taiwan-an-edge/.
Weinzierl, Matthew. 2019. "Space, the Final Economic Frontier." *Journal of Economic Perspectives* 32 (2): 173–92.
Welser IV, William. 2016. "The Democratization of Space." The RAND Blog, 28 March 2016. Accessed on 3 March 2024. https://www.rand.org/pubs/commentary/2016/03/the-democratization-of-space.html.

Wipatayotin, Apinya. 2023. "Thai Earth Satellite Launch Delayed." *Bangkok Post*, 7 October 2023. Accessed on 15 December 2023. https://www.bangkokpost.com/thailand/general/2659508.

Wong, Jonathan P. et al. 2023. "Leveraging Commercial Space Services: Opportunities and Risks for the Department of the Air Force." RAND Corporation, 6 September 2023. Accessed on 3 March 2024. https://www.rand.org/pubs/research_reports/RRA1724-1.html.

Wu, Po-hsuan, Tsai Chang-sheng and William Hetherington. 2022. "Team successfully tests domestically made rocket." *Taipei Times*, 11 July 2022. Accessed on 3 March 2024. https://www.taipeitimes.com/News/front/archives/2022/07/11/2003781532.

Yoo, John. 2019. "Rules for the Heavens: The Coming Revolution in Space and the Laws of War." *University of Illinois Law Review*, 2020 (1), 4 February 2020. Accessed on 3 March 2024, https://illinoislawreview.org/print/vol-2020-no-1/rules-for-the-heavens/#:~:text=The%20Coming%20Revolution%20In%20Space%20and%20the%20Laws%20of%20War&text=This%20Article%20addresses%20whether%20the,international%20agreements%20to%20ban%20them.

Zhou, Xiaolin. 2020. "Case Study from China on CATTC—China-ASEAN Technology Transfer Center. Contribution to the OECD TIP Co-Creation Project." OECD, 2020. Accessed on 22 December 2022. https://stip.oecd.org/assets/TKKT/CaseStudies/38.pdf.

Cite this article: Lin K-C, Matthews W, and Olsen S (2024). Middle spacepowers' integration with the global supply chain for the space industry: Taiwan and Thailand. *Business and Politics* 1–27. https://doi.org/10.1017/bap.2024.18