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SMALL STATES IN SPACE: CRAFTING A STRATEGY FOR SINGAPORE

Quah, Yi Han Edwin

Monterey, CA; Naval Postgraduate School

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SMALL STATES IN SPACE: CRAFTING A STRATEGY FOR SINGAPORE

by

Yi Han Edwin Quah

September 2022

Thesis Advisor: James C. Moltz
Second Reader: Stephen H. Tackett

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Many nascent space powers have initiated strategic assessments and announced policy objectives to integrate space activities to serve their national interests. This thesis seeks to study: How should Singapore, a small state with limited capacities (e.g., geographical size, population, and resources), develop near-term policy objectives that best draw on its competitive advantages? This provides clarity to Singapore's progress as an emerging spacefaring nation, in response to emerging global trends in space and in leveraging space in meeting its national interests. To draw meaningful comparisons and lessons, this thesis examines the key policies, strategies, and programs as well as the objectives and priorities driving the sectoral developments of two trailblazing small states (the United Arab Emirates and Luxembourg). This thesis presents policy recommendations for Singapore to best capitalize on its competitive strengths as it progresses as an emerging spacefaring nation. Recommendations include institutionalizing national authority and space act, increased participation in bilateral and multilateral space cooperation and diplomacy, dedicating budget to the application of space security, and nurturing space ecosystem and talent pipeline.

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SMALL STATES IN SPACE: CRAFTING A STRATEGY FOR SINGAPORE

Yi Han Edwin Quah
Military Expert 5, Republic of Singapore Air Force
BSMSE, Nanyang Technological University, 2010

Submitted in partial fulfillment of the
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Approved by: James C. Moltz
Advisor

Stephen H. Tackett
Second Reader

James H. Newman
Chair, Space Systems Academic Group

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ABSTRACT

Many nascent space powers have initiated strategic assessments and announced policy objectives to integrate space activities to serve their national interests. This thesis seeks to study: How should Singapore, a small state with limited capacities (e.g., geographical size, population, and resources), develop near-term policy objectives that best draw on its competitive advantages? This provides clarity to Singapore's progress as an emerging spacefaring nation, in response to emerging global trends in space and in leveraging space in meeting its national interests. To draw meaningful comparisons and lessons, this thesis examines the key policies, strategies, and programs as well as the objectives and priorities driving the sectoral developments of two trailblazing small states (the United Arab Emirates and Luxembourg). This thesis presents policy recommendations for Singapore to best capitalize on its competitive strengths as it progresses as an emerging spacefaring nation. Recommendations include institutionalizing national authority and space act, increased participation in bilateral and multilateral space cooperation and diplomacy, dedicating budget to the application of space security, and nurturing space ecosystem and talent pipeline.

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LIST OF ACRONYMS AND ABBREVIATIONS

3D	Diplomacy, Development cooperation, Defense
3SAS	Strategic Space Situation Awareness System (NATO)
APRSAF	Asia-Pacific Regional Space Agency Forum
APSCO	Asia-Pacific Space Cooperation Organization
ARTES	Advanced Research in TElecommunications Systems
ASEAN	Association of Southeast Asian Nations
CNES	Centre National D'Etudes Spatiales (French Space Agency)
COPUOS	Committee on the Peaceful Uses of Outer Space (United Nations)
COTS	Commercial-off-the-shelf
CSA	Cyber Security Agency (Singapore)
DSS	Defense Space Strategy (Luxembourg)
DSTA	Defence Science and Technology Agency (Singapore)
E3P	European Exploration Envelope
EIAST	Emirates Institute for Advanced Science and Technology (UAE)
ELM	Emirates Lunar Mission
EMM	Emirates Mars Mission
ESA	European Space Agency
ESPI	European Space Policy Institute
ESRIC	European Space Resources Innovation Center
GNSS	Global Navigation Satellite System
GSTC	Global Space Technology Convention
IAF	International Astronautical Federation
ISR	Intelligence, Surveillance and Reconnaissance
LEO	Low Earth Orbit
LFF	Luxembourg Future Fund
LIST	Luxembourg Institute of Science and Technology
LSA	Luxembourg Space Agency
MBRSC	Mohammed Bin Rashid Space Centre (UAE)
NAP	National Action Plan (Luxembourg)
NASA	National Aeronautics and Space Administration

NATO	North Atlantic Treaty Organization
NRF	National Research Foundation (Singapore)
NSP	National Space Policy (UAE)
NSS	National Space Strategy (UAE)
NUS-CRISP	National University of Singapore Centre for Remote Imaging, Sensing, and Processing
NZSA	New Zealand Space Agency
OSTIn	Office for Space Technology and Industry (Singapore)
PAROS	Prevention of an Arms Race in Outer Space
PNT	Positioning, Navigation and Timing
R&D	Research and Development
S&T	Science and Technology
SAR	Synthetic-Aperture Radar
SATCOM	Satellite Communications
SCNI	Société Nationale de Crédit et d'Investissement (Luxembourg)
SDGs	Sustainable Development Goals (United Nations)
SES	Société Européenne des Satellites (Luxembourg)
SpaceX	Space Exploration Technologies Cooperation
SRC	Space Reconnaissance Center (UAE)
SSA	Space Situational Awareness
SSL	Space Sector Law (UAE)
SSN	Space Surveillance Network (United States)
SSP	Start-up Support Program (Luxembourg)
SSTL	Singapore Space & Technology Limited
ST Geo-Insights	Singapore Technologies Geo-Insights
STL	Space Technology Ladder
STM	Space Traffic Management
STSC	Scientific and Technical Subcommittee (United Nations)
UAESA	United Arab Emirates Space Agency
UNOOSA	United Nations Office for Outer Space Affairs
VLEO	Very Low Earth Orbit
X-SAT	eXperimental SATellite

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I. INTRODUCTION

A. MAJOR RESEARCH QUESTION

As the benefits of space technology permeate our everyday lives, many nascent space powers have initiated strategic assessments and announced policy objectives to integrate space activities to serve their national interests. This thesis seeks to study: How should Singapore, a small state with limited capacities (e.g., geographical size, population, and resources) develop a long-term strategy and orientate near-term policy objectives that best draw on its competitive advantages? This will provide clarity to Singapore's future trajectory in addressing global challenges in space.

In order to draw a comparison and possible lessons, this thesis examines the case studies of the United Arab Emirates (UAE) and Luxembourg in regard to space strategy. It focuses on the connection between the motivations, challenges, constraints, and opportunities pertinent to small states in seeking to develop competitive strategies. Drawing on the insights gleaned, the thesis discusses the strategic choices facing Singapore in the areas of economics, technology, national defense, education, and international cooperation to make the most of its unique competitive advantages. Finally, the thesis recommends a course for Singapore's long-term space strategy and then specific near-term policy objectives towards getting there.

B. SIGNIFICANCE OF THE RESEARCH QUESTION

Singapore made its first foray into space in 2003 with a program to indigenously design and build a satellite named X-SAT (eXperimental SATellite). The program that involved the national laboratory and academia was completed in 2009 and launched by the Indian Space Research Organization (ISRO) in 2011.[1] Its success led to the formation of a new industry venture—ST Electronics (Satellite Systems), which built Singapore's first

[1] "X-SAT," Gunter's Space Page, accessed April 11, 2022, https://space.skyrocket.de/doc_sdat/meznsat.htm.

commercial satellite TeLEOS-1[2] in 2015.[3] To date, there have been more than 50 local and international companies with over 1,800 professionals within Singapore's budding space industry.[4] The establishment of satellite programs by academia[5] has also encouraged space technology research and development (R&D) with the successful launch of 13 indigenously built satellites for science and technology (S&T) applications.[6]

As a small and trade-dependent economy, Singapore has recognized the need to always stay ahead of emerging trends and has continuously strived to seek new growth opportunities. To this end, a national space office—Office for Space Technology and Industry (OSTIn) with a $90 million Satellite Industry Development Fund was established in 2013.[7] This was intended to foster a tripartite partnership between the commercial, governmental, and academic sectors and nurture local space-tech companies in "developing internationally competitive capabilities in space." [8]

At the 14th Global Space Technology Convention (GSTC) 2022, the Singapore government further announced initiatives to spur growth in its domestic space sector: (1)

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[2] TeLEOS-1 is a commercial earth observation satellite in the low Earth orbit. It was launched on a PSLV-C29 vehicle of the Indian Space Research Organization from the Satish Dhawan Space Centre at Srihari Kota, India.

[3] Derrick A Paulo et al., "Singapore's foray into space: Boldly going where no little red dot has gone before," *CNA Insider*, last modified October 12, 2020, https://www.channelnewsasia.com/cnainsider/singapore-foray-space-race-budding-industry-satellite-boldly-go-759796.

[4] Begum Shabana, "Singapore on Track to Building a Thriving Space Sector," The Straits Times, last modified March 7, 2022, https://www.straitstimes.com/singapore/environment/singapore-on-track-to-building-a-thriving-space-sector.

[5] Singapore's universities have established satellite organizations such as the Centre for Remote Imaging, Sensing and Processing (CRISP), the Satellite Technology and Research Centre (STAR), the Satellite Research Centre (SaRC), and the Centre for Quantum Technologies (CQT).

[6] "Introducing Office for Space Technology & Industry (OSTIn)," Economic Development Board (Singapore), accessed January 28, 2022, https://www.edb.gov.sg/content/dam/edb-en/our-industries/aerospace/OSTIn-brochure.pdf.

[7] "Speech by Mister S. Iswaran at the Global Space and Technology Convention 2014," Ministry of Trade and Industry (Singapore), last modified February 6, 2014, https://www.mti.gov.sg/Newsroom/Speeches/2014/02/Mr-S-Iswaran-at-the-Global-Space-and-Technology-Convention-2014.

[8] ANI. "Is Singapore's USD 110 Million Space-Tech Investment an Opportunity for Indian Firms?" The Print, last modified February 14, 2022. https://theprint.in/world/is-singapores-usd-110-million-space-tech-investment-an-opportunity-for-indian-firms/830587/.

committing $110 million to encourage local space startups in driving technological innovation that supports nationally important sectors, such as aviation and maritime purposes; and (2) building international partnerships with like-minded space-faring nations such as the United Kingdom, to build a pipeline for its domestic space sector "to expand into more mature space industries abroad and tap into more robust international experience."[9]

Despite the commendable growth in its space ecosystem in the past decade, there appears to be a lack of concerted effort by the government to orchestrate and coordinate space activities at the national level. This was most evident in the absence of a national agency capable of bringing all space activities under one single management and taking on the responsibility of setting vision and long-term goals that is aligned with its strategic interests. Consequently, Singapore's progress to become a credible space actor has been less effective than it could be. In this regard, research into the competitive advantage, policy objective and the space strategy of small states is significant for three reasons:

1. The thesis examines the motivations, challenges, constraints, and opportunities pertinent to small states. This offers useful insights into the orientation and contours of space policies of emerging space powers that are constrained by both geographical size and population sizes (e.g., Luxembourg, the UAE). These emerging space powers have published or refreshed their national space policies within the past decade and provide temporal relevance and lessons for space-keen states such as Singapore.

2. In a similar light, the number of small states with interests to utilize space for commercial, civil, and security purposes have increased exponentially. While much has been discussed for established space powers, little effort has been made to provide an account of the motivation, challenges,

[9] "Speech by Minister Gan Kim Yong at the 14th Global Space and Technology Convention," Ministry of Trade and Industry (Singapore), February 9, 2022, https://www.mti.gov.sg/Newsroom/Speeches/2022/02/Speech-by-Minister-Gan-Kim-Yong-at-the-14th-Global-Space-and-Technology-Convention; Soh Gena, "Singapore Government to Invest $150 Million in Space-Tech R&D," The Straits Times, last modified February 9, 2022, https://www.straitstimes.com/singapore/environment/singapore-government-to-invest-150-million-in-space-tech-rd.

constraints, and opportunities pertinent to small states, comparatively and systematically.

3. A holistic analysis of Singapore's space ecosystem and activities against its national objectives can provide timely feedback on its progress, as well as give clarity about its future trajectory. The proposed national space policy and strategy can guide the allocation of finite resources (e.g., budget, people, infrastructure) and encourage collaborative space activities to promote access and diffusion of technology and information. This can guide political decision-making into integrating space activities to serve Singapore's strategic interests.

C. LITERATURE REVIEW

1. Global Trends in Space

Exponential growth in the number of commercial space actors has seen a shift from a strategic, government-led sector into a commercially driven one. Historically, the public sector has played a pivotal role in driving space technology R&D and delivering space-based services for geopolitical,[10] national security and socio-economic purposes.[11] The last decade has seen widespread changes that can be attributed to a combination of emerging technologies and new operating models, and that is largely driven by the innovation of the private space sector for commercial gain.[12] This shift is encouraged by falling costs of accessing space[13] and dramatic improvements with satellite manufacturing

[10] Ram S Jakhu, Kuan-Wei Chen, and Bayar Goswami, "Threats to Peaceful Purposes of Outer Space: Politics and Law," *Astropolitcs—The International Journal of Space Politics & Policy* 18 (April 6, 2020), https://doi.org/10.1080/14777622.2020.1729061.

[11] Matt Weinzierl and Mehak Sarang, "The Commercial Space Age Is Here," *Harvard Business Review*, last modified February 12, 2021, https://hbr.org/2021/02/the-commercial-space-age-is-here.

[12] "A Space Perspective: Tech Trends 2019," *Deloitte Insights*,accessed January 28, 2022, https://www2.deloitte.com/us/en/pages/public-sector/articles/government-space-tech-trends.html.

[13] Jeff Greason and James C Bennett, "The Economics of Space: An Industry Ready to Launch," *Reason Foundation*, last modified June 1, 2019, https://reason.org/wp-content/uploads/economics-of-space.pdf.

techniques[14] and commercial-off-the-shelf (COTS) or commoditized technologies,[15] such as miniaturized satellites and reusable launch systems. The emergence of bottom-up, net-centric, commercially led space innovation represents a significant shift with deep implications for national space policy and strategy.[16]

According to Surrey Satellite Technology, the world's leading developer of small satellite technologies and applications, there has been a *10-fold reduction* in the cost including launch and insurance, of a constellation of three small satellites delivering sub-meter imagery, allowing access to high-quality Earth observation imagery at a fraction of the price of previous systems.[17] Space Exploration Technologies Corporation (SpaceX)'s "fully rapidly reusable orbital rocket" is capable of launching cargo and people into orbit at a 100-fold reduction in cost when compared to what the National Aeronautics and Space Administration (NASA) currently pays for the same task.[18]

The lower costs and fewer barriers to entry have, in turn, brought opportunities for commercial space actors to launch large satellite constellations. Globally, governments have facilitated or encouraged an increase in the funding for commercial space activities. In a report by the Space Foundation, a nonprofit advocacy organization, the global space ecosystem exhibited a five-year trend of uninterrupted growth and is 55% higher than a decade ago. In 2020, commercial space activity expanded 6.6% and accounted for nearly 80% of the global space economy. In contrast, the collective space spending by global governments has contracted 1.2% in 2020, with nearly 58% attributed to space activity by

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[14] Tim Ellis, "Additive Manufacturing Will (and Should) Change Everything," Via Satellite, accessed January 28, 2022, https://interactive.satellitetoday.com/additive-manufacturing-will-and-should-change-everything/.

[15] Adrienne Harebottle, "Satellite Manufacturing in the Era of Mass Production," Via Satellite, accessed January 28, 2022, http://interactive.satellitetoday.com/via/september-2021/ground-segment-aims-to-fly-high-in-the-new-space-environment/.

[16] James Clay Moltz, "The Changing Dynamics of Twenty-First-Century Space Power," *Strategic Studies Quarterly*, March 2019, 66.

[17] Anita Bernie, "Small Satellites: In-Orbit Operational Solutions Are At Hand," *MilsatMagazine*, last modified January 2013, http://www.milsatmagazine.com/story.php?number=1517707651.

[18] Vidya Sagar Reddy, "The SpaceX Effect," *New Space* 6, no. 2 (June 1, 2018), https://doi.org/10.1089/space.2017.0032.

the U.S. Notably, the collective space spending by military has fallen to constitute the "smallest share of government space spending" in a decade.[19]

The expansion in the scope and scale of space activities is not without its challenges. As satellite constellations grow larger, orbits are projected to become significantly congested in the coming decade. Given the growing number and diversity of objects and actors, there have been growing concerns about the increased risk of collisions in space. While few catastrophic collisions have been reported in space thus far, the likelihood of one is assessed to be imminent. With the addition of announced large commercial constellations from SpaceX and OneWeb, simulation models have shown that current space surveillance processes can produce millions of conjunction warnings per year, and half a dozen actual collisions if no action were taken.[20] With evolving space activities and satellite architectures, the complexity of space operations will inevitably increase. This has called for closer partnership between government operators and commercial entities for enhanced data sharing, as well as a global investment to improve capabilities (e.g., space situational awareness (SSA) and space traffic management (STM)) and processes (e.g., data architecture approaches, data and conjunction sharing).[21]

To this end, many space powers have begun reshaping their space policies to consider these emerging global trends. In December 2021, the United States released its space priorities framework, acknowledging the historic changes in access to and use of space and highlighting its policy priorities and plans to: (1) leverage worldwide interest in space activities as opportunities to collaborate with allies and partners; (2) bolster space situational awareness sharing by working with industry and international partners; and (3)

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[19] Space Foundation, "Global Space Economy Rose to $447B in 2020, Continuing Five-Year Growth," SpaceRef, last modified July 15, 2021, http://www.spaceref.com/news/viewpr.html?pid=57786.

[20] Theodore J. Muelhaupt et al., "Space Traffic Management in the New Space Era," *Journal of Space Safety Engineering* 6, no. 2 (June 2019): 80–87, https://doi.org/doi.org/10.1016/j.jsse.2019.05.007.

[21] National Space Council Users' Advisory Group, "Recommendations on Trust and Interoperability in Space Situational Awareness Data," NASA, last modified September 2, 2020, https://www.nasa.gov/sites/default/files/atoms/files/white_paper_on_saa_data_findings_and_recommendations_rev2020-10-22b.pdf.

foster a policy and regulatory environment to enable a competitive and burgeoning commercial space sector.[22]

While recent enactment or updates to national space policies have centered on commercial interests and international cooperation, there has been significant policy divergence among states that are operating "at different scales and with different levels of ambition" concerning space security.[23] Growing militarization and weaponization of the space environment has manifested gaps in global space governance and can undermine the required development of shared norms and understanding across states needed to facilitate civil and commercial applications.[24] Beyond a closer partnership on collision and conjunction avoidance, progress in international cooperation and mechanisms on conflict prevention will need to gain traction to ensure the sustainable use and development of space activities.[25]

2. Small States in Space

While the activities of major space agencies (i.e., NASA, ESA) and private space companies and products (i.e., SpaceX, Starlink, Virgin Galactic), have dominated the headlines, the activities of emerging and space-keen states vying for the fast-growing space economy must not be neglected.[26] According to Euroconsult Group, the space spending of

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[22] "United States Space Priorities Framework, "White House, December 2021, https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf.

[23] "ESPI Report 79 - Emerging Spacefaring Nations - Full Report," European Space Policy Institute, last modified June 1, 2021, https://www.espi.or.at/wp-content/uploads/2022/06/ESPI-Report-79-Emerging-Spacefaring-Nations-Full-Report.pdf.

[24] Mike Stone, "U.S. in Hypersonic Weapon 'Arms Race' with China—Air Force Secretary," Reuters, last modified November 30, 2021, https://www.reuters.com/business/aerospace-defense/us-hypersonic-weapon-arms-race-with-china-air-force-secretary-2021-11-30/; and "Russia Conducts Test Launch of Hypersonic Missile—Interfax," Reuters, last modified December 24, 2021, https://www.reuters.com/world/europe/russia-conducts-test-launch-hypersonic-missile-interfax-2021-12-24/.

[25] James Clay Moltz, *Crowded Orbits: Conflict and Cooperation in Space* (New York: Columbia University Press, 2014), 7, 170–193.

[26] Teck Boon, Tan. "Small States in the New Space Age: Policy Lessons from UAE and Luxembourg." RSIS Commentary, last modified October 28, 2021. https://www.rsis.edu.sg/rsis-publication/rsis/small-states-in-the-new-space-age-policy-lessons-from-uae-and-luxembourg/.

emerging or nascent powers does not appear to be commensurate with the contraction in global government space spending. Several notable small states include Luxembourg ($193M); Israel ($164M); the UAE ($148M); Singapore ($35M); and New Zealand ($13M) in 2020.[27] Beyond space spending, frontrunners such as Luxembourg and UAE have differentiated themselves from competing states by introducing policies that leverage education and international cooperation with both the private and public space sectors. Unique to small states, these trends have been observed:

a. Small states have become intrinsically motivated

Retired Canadian Space Agency official Graham Gibbs offers three motivations for investing in a national space program as being "an essential part of a nation's infrastructure, as an engine for innovation and economic prosperity," and a dual-use (military and civil) application.[28] Danielle Wood and Annalisa Weigel identify five dimensions of space activity that have high relevance to meeting the national needs of a developing country: (1) applying satellite services to bring values for civil applications; (2) leveraging space technology to enhance the national level of technical sophistication while reducing dependence on foreign technical expertise; (3) enabling new economic activity by transforming domestic satellite programs into new space companies; (4) inspiring new technology applications in other sectors; and (5) building scientific knowledge with access to space science data.[29] The International Space University further expands these dimensions to include cooperation and partnership, cultural, and opportunity loss as rationales for space activities. States failing to engage in space activities can result in a loss of opportunity such as to profit from a growing space economy, ability to forecast natural

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[27] Simon Seminari, "Government Space Budgets Surge Despite Global Pandemic," Via Satellite, last modified March 2021, http://interactive.satellitetoday.com/via/march-2021/government-space-budgets-surge-despite-global-pandemic/.

[28] Graham Gibbs, "An Analysis of the Space Policies of the Major Space Faring Nations and Selected Emerging Space Faring Nations," *Annals of Air and Space Law* 37 (2012): 279–332.

[29] Danielle Wood and Annalisa Weigel, "A Framework for Evaluating National Space Activity," *Acta Astronautica* 73 (2012): 222, https://doi.org/10.1016/j.actaastro.2011.11.013.

disasters, grow adjacent technology markets, and compete internationally in technological fields.[30]

Traditionally, small states are extrinsically motivated by a long-standing perception of prestige and technological prowess associated with space activities. In the NewSpace age, however, national space programs are driven by pragmatism and are intrinsically motivated for socio-economic purposes. Back in 1981, Israel established its space program to satisfy its national security needs. In recent years, however, the state has shifted its objectives to leverage its defense industrial infrastructure for commercial spin-offs aimed at capturing the booming space economy and to prevent a brain drain for young Israeli professionals.[31] Worthy of its status as a space startup nation, Luxembourg's space sector has consistently generated approximately 2% of its GDP since 2017.[32] Luxembourg's space strategy has portrayed the country as "a catalyst for collaboration, technological innovation, and the commercial development of space" to transform its economy.[33] Both states have capitalized on a boom in the global space ecosystem to drive innovation and education, and to bring an enduring benefit to their economies.

b. The programs of nascent powers will no longer follow established evolutionary patterns of developed space powers

Wood and Weigel introduced the Space Technology Ladder (STL) to map the development of a country's space programs along four major technology categories. The framework posits:

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30 "A Roadmap for Emerging Space States," (International Space University, 2017), https://isulibrary.isunet.edu/doc_num.php?explnum_id=1350.

31 Issac Ben Israel and Zvi Kaplan, "Israel at 60—Out of This World: Israel's Space Program," (Israel Space Agency 2008), 99–102, https://mfa.gov.il/mfa/aboutheministry/publications/pages/israel_60_beginnings_to_vibrant_state_1948-2008.aspx; and Dhrubajyoti Bhattacharjee, "Israeli Space Program—The Challenges Ahead," *Indian Council of World Affairs*, last modified October 17, 2016, https://www.icwa.in/show_content.php?lang=1&level=3&ls_id=5068&lid=776.

32 Michael Sheetz, "The Space Industry Is Now 2% of Luxembourg's GDP, Deputy Prime Minister Etienne Schneider Says," CNBC, last modified November 11, 2017, https://www.cnbc.com/2017/11/11/etienne-schneider-the-space-industry-is-now-2-percent-of-luxembourgs-gdp.html.

33 Hwan Doo, Kim *Global Issues Surrounding Outer Space Law and Policy* (Pennsylvania: IGI Global, 2021, 96–98.

1. establishing a national space agency,
2. owning and operating a satellite in low Earth orbit,
3. owning and operating a satellite in geostationary orbit, and
4. launching satellites.[34]

Paikowsky introduced the space club pyramid that also encompasses aspects of purchasing satellite services, leveraging collective space capability, and human flight.[35] In defining and mapping a country's transition into a spacefaring nation, the Euporean Space Policy Institute (ESPI) classified emerging space actors according to two key dimensions of space power: (1) Capacity—the "ability of a country to implement space strategies to achieve its economic, political or social goals"; and (2) Autonomy—the "ability to formulate space-related interests on its own, independent from or against the will of divergent political interests."[36]

As space technology becomes more commoditized, capable, and cheaper, a small state's ascension up the STL or into the space club, is no longer linear and solely dependent on its national space ecosystems (e.g., infrastructure, expertise, experience). Instead, a state's advancement in space technology is contingent on the size and commitment of its space spending, as well as its ability to attract the private or public sectors for foreign direct investment and international collaboration.

A small state is no longer enticed to own and operate an indigenously built satellite to receive data. Instead, it can leverage a range of mechanisms such as coalitions, strategic alliances, strategic co-funding, and public-private partnerships to gain access to space capability. This trend has further shifted from technology and knowledge transfers to

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[34] Danielle Wood and Annalisa Weigel, "Charting the Evolution of Satellite Programs in Developing Countries," *Space Policy* 28, no. 1 (2012): 15–24, https://doi.org/10.1016/j.spacepol.2011.11.001.

[35] Deganit Paikowsky, *The Power of the Space Club* (Cambridge: Cambridge University Press, 2017), 23–24.

[36] "ESPI Report 79 - Emerging Spacefaring Nations - Full Report," *European Space Policy Institute*, last modified June 1, 2021, https://www.espi.or.at/wp-content/uploads/2022/06/ESPI-Report-79-Emerging-Spacefaring-Nations-Full-Report.pdf.

buying technology and products[37] and, most recently, to buying space access-as-a-service, such as terrestrial-based networks, launch windows and terrestrial data.[38] Resultantly, a small state can now concentrate its finite resource on building applications of strategic importance.

In 2016, New Zealand set up its space agency to regulate its expanding space sector, with a focus to regulate commercial space launches by American aerospace company—Rocket Lab.[39] Hitherto, it did not own nor operate any satellite and relied on foreign direct investment to establish a commercial spaceport that provides launch services for small satellites.[40] In recent times, the UAE Space Agency (UAESA) has been actively pursuing cooperation with numerous foreign space agencies as well as commercial spaceflight companies, such as Virgin Galactic.[41] Despite being a relative newcomer to the space scene, the UAESA has set in plan wildly ambitious plans to reach the zenith of space technology (i.e., human flight and space exploration).[42]

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

[38] "Maintaining Momentum in National Security Space," *Center for the Study of the Presidency & Congress*, last modified May 2021, https://static1.squarespace.com/static/5cb0a1b1d86cc932778ab82b/t/6091590346925079280 6e545/1620138253623/CSPC+Report-Maintaining+Momentum+in+National+Security+Space-+May+2021.pdf.

[39] Rocket Lab is a public American aerospace manufacturer and small satellite launch service provider with a wholly owned New Zealand subsidiary.

[40] Marcel Sanmarti, "Is the New Zealand Commercial Space Success Story a Model for Other Countries?" *The Space Review*, last modified October 19, 2020, https://www.thespacereview.com/article/4048/1.

[41] "UAE Space Agency Signs MoU With Virgin Galactic For Al Ain Operations," spacewatch.global, accessed January 28, 2022, https://spacewatch.global/2019/03/uae-space-agency-signs-mou-with-virgin-galactic-for-al-ain-operations/.

[42] Jonathan Porter, "UAE's Giant Leap into Space," *National Geographic*, last modified October 25, 2021, https://www.nationalgeographic.com/science/article/paid-content-uaes-giant-leap-into-space; and "NASA, UAE Space Agency Sign Historic Implementing Arrangement for Cooperation in Human Spaceflight," NASA, last modified October 4, 2018, https://www.nasa.gov/press-release/nasa-uae-space-agency-sign-historic-implementing-arrangement-for-cooperation-in-human.

c. Burden-sharing on SSA and STM as a basis for collaboration

SSA and STM are key elements to mitigate against risks threatening space systems and to ensure global freedom of action in space. Today, only a small set of actors can develop persistent SSA information, with an even smaller set capable of generating precise conjunction analysis required for collision avoidance.[43] Due to technical challenges[44] and lack of geographic diversity for ground-based sensors, operators worldwide, especially small states with finite resources have relied extensively on the U.S. DOD's data processing and analysis capabilities for basic SSA data and free conjunction alert. This has made the U.S. DOD the indisputable supplier of global SSA information.

However, given its legacy architecture against a fast-growing number and diversity of objects and actors in space, DOD's SSA system and Space Surveillance Network (SSN) is no longer adequate to meet the expanded global needs across civil, national security and commercial applications.[45] This has called for newer capability with higher precision sensor data, more frequent tracking of debris objects, sharing of owner-operator data and flight plans. Beyond building new capability and data sharing architecture, a review of the "Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space" is required. This includes revising the current operational debris mitigation practices and considering future mitigation methods concerning cost-efficiency. Scientific cooperation on space debris can "maximize the benefits of space debris mitigation

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[43] Brian Weeden and Victoria Samson, "Global Counterspace Capabilities," (Secure World Foundation, April 2021), https://swfound.org/media/207162/swf_global_counterspace_capabilities_2021.pdf.

[44] Daniel L. Oltrogge, "The Technical Challenges of Better Space Situational Awareness and Space Traffic Management," *Journal of Space Safety Engineering* 6, no. 2 (2019): 72–79, https://doi.org/10.1016/j.jsse.2019.05.004.

[45] "Global Trends in Space Situation Awareness and Space Traffic Management," *IDA Science & Technology Policy Institute*, last modified April 2018, https://www.ida.org/-/media/feature/publications/g/gl/global-trends-in-space-situational-awareness-ssa-and-space-traffic-management-stm/d-9074.ashx.

initiatives" proposed by the United Nations Office for Outer Space Affairs (UNOOSA).[46] In line with its priority to increase efforts to mitigate, track and remediate space debris,[47] U.S. DOD announced in 2020 that it has awarded LeoLabs, a supplier of commercial radar tracking services for objects in Low Earth Orbit (LEO), a $15M contract to provide commercial SSA to augment the SSN.[48] LeoLabs with its ground-based phased array radars deployed across the globe can detect objects as small as 2-centimeter, as opposed to the much coarser 10-centimeter objects tracked by the legacy detection systems.[49] LeoLabs data can also be purchased commercially by companies and U.S.-allied and partner countries.

During 2017's Scientific and Technical Subcommittee (STSC) convened by UNOOSA, the Russia Federation put up a proposal calling for the concept of data pooling and an open architecture between countries, intergovernmental organizations, private operators, and national and international NGOs to contribute and provide access to globally integrated SSA data.[50] The world's leading space power, the United States, echoed this notion by articulating plans to lead in cooperation with commercial industry, international allies, and partners to strengthen a rules-based international order for space and bolster space SSA sharing and space traffic coordination. To date the U.S. DOD has signed SSA

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[46] Ashley Vanderley and Therese Jones, "Perspectives from the United States on Coexistence and Sustainability of Large Satellite Constellations & Terrestrial Astronomy," UN Committee on the Peaceful Uses of Outer Space, last modified August 30, 2021, https://www.unoosa.org/documents/pdf/copuos/2021/COPUOS-DQS-SATAST-USA-2021Aug30.pdf; and "Compendium of Space Debris Mitigation Standards Adopted by States and International Organizations," United Nations - Office for Outer Space Affairs, accessed January 28, 2022, https://www.unoosa.org/oosa/en/ourwork/topics/space-debris/compendium.html.

[47] "United States Space Priorities Framework, "White House, December 2021, https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf.

[48] Sandra Erwin, "DOD Awards $15 Million Defense Production Act Contract to LeoLabs," SpaceNews, last modified July 10, 2020, https://spacenews.com/dod-awards-15-million-defense-production-act-contract-to-leolabs/.

[49] Debra Werner, "LeoLabs Raises $65 Million in Series B Funding Round," SpaceNews, last modified June 3, 2021, https://spacenews.com/leolabs-series-b/.

[50] Russian Federation, "Further Ideas on a Set of Goals for Achieving the Vienna Consensus on Space Security," United Nations - Office for Outer Space Affairs, last modified January 17, 2017, https://www.unoosa.org/oosa/oosadoc/data/documents/2017/aac.105c.1l/aac.105c.1l.361_0.html.

data-sharing agreements with 26 foreign nations, two intergovernmental organizations, and over 70 commercial satellite operators.[51] The advantages of defense space partnerships were articulated by the Aerospace Corporation's Center for Space Policy and Strategy—a diverse set of geographically distributed sensors are required to provide complete orbital coverage and to increase the frequency with which objects are tracked.[52]

With space powers keen on broadening and deepening their network of alliances and partnerships through space activities, small states are encouraged to play an active role to foster a safe and secure space environment. Therefore, it is assessed that the development of SSA capabilities and participation in global/regional STM operations will become a centerpiece for international collaboration between the public and private sectors. New Zealand, a member of Five Eyes[53] participated for the first time in a U.S. DOD.–led multinational space operation that deliver foundational SSA to assure global freedom of action in space.[54] Through a multi-year agreement, the New Zealand Space Agency (NZSA) alongside Californian-based SSA experts—LeoLabs, have developed the "Space Regulatory and Sustainability Platform" to track objects launched from New Zealand and alert operators in real-time.[55] Luxembourg announced in 2021 that it will partner with

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[51] Sandra Erwin, "U.S. Space Command signs data-sharing agreement with Libre Space Foundation," SpaceNews, last modified July 3, 2021, https://spacenews.com/u-s-space-command-signs-data-sharing-agreement-with-libre-space-foundation/.

[52] Robert S. Wilson, Colleen Stover, and Steven R. Tomaszewski, "Defense Space Partnerships: A Strategic Priority," *Space Agenda* 2021 (Center for Space Policy and Strategy, September 2020), https://aerospace.org/sites/default/files/2020-09/Wilson_DefensePartnerships_20200916.pdf.

[53] Five Eyes is an Anglosphere intelligence sharing and collaboration between Australia, Canada, New Zealand, the United Kingdom, and the United States.

[54] Max Blenkin, "US and Five Eyes Continue to Expand Space Domain Co-Operation," Defence Connect, last modified January 8, 2020, https://www.defenceconnect.com.au/key-enablers/5377-us-and-five-eyes-continue-to-expand-space-domain-cooperation; and "U.S. Strategic Command Fact Sheet," Combined Space Operations Center, accessed January 28, 2022, https://www.stratcom.mil/Portals/8/Documents/CSpOC_Factsheet_2018.pdf.

[55] "New Zealand Space Agency launches new tool to track satellites, combat space debris," 1News, last modified June 26, 2019, https://www.1news.co.nz/2019/06/25/nz-space-agency-launches-new-tool-to-track-satellites-combat-space-debris/; and "MBIE and LeoLabs Sign Multi-Year Agreement for World-Leading Regulatory and Space Sustainability Platform," Ministry of Business, Innovation & Employment (New Zealand), last modified August 6, 2021, https://www.mbie.govt.nz/about/news/mbie-and-leolabs-sign-multi-year-agreement-for-world-leading-regulatory-and-space-sustainability-platform.

Quebec-based space information provider—NorthStar Earth & Space Inc—to provide "precise space traffic data, collision avoidance, and navigation services" through the deployment of satellite constellations with "dedicated optical sensors."[56] This allows Luxembourg to overcome its lack of geographical size for ground-based sensor deployment and contribute to ESA's SSA program.[57]

D. POTENTIAL EXPLANATIONS AND HYPOTHESIS

The major research question examines how Singapore, a small state with limited capacities (i.e., small geographical size, population size, and economy) can orientate its space policy to best draw on its competitive advantages. The thesis investigates three alternative orientations that best exemplifies its comparative advantages. These orientations draw on the explanations offered in the case studies, adapted in the context of Singapore.

The first orientation focuses on improving a nation's soft power through space cooperation. Singapore could collaborate with public and private entities in civil applications (e.g., space safety & security) that are generating interest and financial commitment among the space powers and companies, such as SSA, space debris removal, and space-based observation of carbon emissions and detection of oil-spills. Singapore could form coalitions or strategic alliances with established space actors to facilitate knowledge transfer. This improves its credibility as a space actor as well as its national expertise in the space domain. As a credible space actor, it could then leverage technology transfer and partnerships to gain access to or shorten the time needed to develop or acquire the capability of interest.

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[56] "Luxembourg Future Fund Invests in Northstar Earth & Space that Establishes Its European Headquarters in the Grand Duchy to Support Sustainable Space Activities," NorthStar Earth & Space Inc, last modified December 22, 2021, https://www.prnewswire.com/news-releases/luxembourg-future-fund-invests-in-northstar-earth--space-that-establishes-its-european-headquarters-in-the-grand-duchy-to-support-sustainable-space-activities-301449618.html.

[57] "SSA Programme Overview," European Space Agency, accessed January 28, 2022, https://www.esa.int/Safety_Security/SSA_Programme_overview.

In line with it being an advocate of international space and stability, and the rule of international law, Singapore could be active in diplomatic efforts to promote the "peaceful uses of outer space and long-term sustainability of outer space activities".[58] Regionally, Singapore could lobby for the establishment of a regional space organization dedicated to collective civil objectives to bring benefits to the citizens of the Association of Southeast Asian Nations (ASEAN) and the world. By coordinating the financial resources and consolidating the intellectual expertise of its members, the region could cooperate to undertake programs far beyond the capacity of any single ASEAN member. Domestically, the investment into civil applications could bring a variety of positive socio-economic impacts such as increased industrial activity, technological and scientific excellence, and productivity gains in other economic sectors. The proliferation of dual-use space technologies might also facilitate positive spillover effects that improve national security.

Against a backdrop of rising security threats at sea and transnational terrorism threats, the second orientation focuses on pursuing national security objectives and building space applications to strengthen domain awareness, security, and defense. Singapore could rely on indigenous development or strategic co-funding with like-minded partners, to build applications in maritime domain awareness, early warning, and cyber protections for space-based systems. In this trajectory, international cooperation might be confined to smaller close groups or bilaterally, on security and defense space missions and exercises to ensure the freedom of access to and operations in space.

As a concerned and responsible member of the United Nations (UN), Singapore could promote the prevention of an arms race in outer space (PAROS) resolution that would prevent any space actor from placing objects carrying any type of weapon into orbit or promote the "reducing space threats through norms, rules, and principles of responsible behaviors" resolution that would reduce the "potential threats and security risk to space

[58] United Nations - Office for Outer Space Affairs. "Long-Term Sustainability of Outer Space Activities." Accessed July 28, 2022. https://www.unoosa.org/oosa/en/ourwork/topics/long-term-sustainability-of-outer-space-activities.html.

systems." [59] Regionally, it could advocate for better transparency to the usage of satellite capability and capacity to keep pace with the proliferation of dual-use space technologies. This would provide clearer distinction between peaceful and potential hostile applications thereby mitigating political sensitivity. Active regional cooperation to meet national security objectives could also help ASEAN[60] reap greater effectiveness in planning and managing resources and lower costs to governments. Domestically, this could enhance the resilience and security of its national infrastructure to allow continuity of government and critical operations in times of crisis. This, coupled with Singapore's legal and political stability, would attract foreign investment, and bring positive socio-economic impacts.

The final orientation is a derivative of the experiences of Luxembourg and New Zealand. It centered on taking advantage of the global boom in the commercial space sector to diversify Singapore's economy. On the regulatory front, Singapore could leverage its investment-friendly policy and support for a competitive market to attract capital investment and international start-ups. On the developmental front, Singapore could nurture niche viable products and services by commercializing R&D outcomes that could generate economic value. When harnessed together, this approach allows Singapore to capture future market opportunities, such as in space exploration and utilization of space resources and commercial spaceport. Singapore could form public-private partnerships with established space companies that could accelerate the growth of its space ecosystem, as in the case of New Zealand.

A stable and secure space environment underpins a robust and competitive commercial space sector. To this end, Singapore must ratify a wide range of international space laws, treaties, and agreements. The collective growth of the ASEAN space ecosystem could complement Singapore's status as a regional hub for commercial space activities, as seen in the case of Luxembourg with the ESA. With the life cycle of space projects being

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[59] United Nations. "Report of the Secretary-General on Reducing Space Threats through Norms, Rules and Principles of Responsible Behaviors (2021)." Accessed July 28, 2022. https://www.un.org/disarmament/topics/outerspace-sg-report-outer-space-2021/.

[60] Sub-committee on Space Technology and Applications, ASEAN Committee on Science, Technology, and Innovation

streamlined, it is improbable for a single state's ecosystem to cover the entire spectrum of technology, products, and services. Interaction between the upstream and downstream industries within ASEAN nations can result in collaborative development. Domestically, the legislation of new regulatory law would be required to enhance authorization and supervision of space activities and to provide a safe and attractive environment for operators, investors, and start-ups. The ability to capture the opportunities of a thriving global space economy could bring obvious socio-economic impacts, such as GDP through employment and revenue gains, boosting economic growth, and improving the competitiveness of other related sectors.

Common to all scenarios, Singapore's government is expected to play a central role to (1) formulate and implement a national space policy that guides political decision-making and integrates space into the national objective; and (2) encourage some forms of international/regional collaboration (e.g., coalitions, strategic alliances, strategic co-funding, public-private partnership) among diverse stakeholders to stimulate innovation and promote access and diffusion of technology and information.

E. RESEARCH DESIGN

1. Case Selection

Traditional studies of small states have looked at measurable characteristics of smallness such as (1) geographical size; (2) population size; (3) size of the economy (e.g., GDP); or the lack of "weight" such as (1) international relations; (2) strength of the military.[61] In this thesis, the former—measurable indices, will be adopted, as data are readily available to serve as quantitative indicators for other small but space-keen states.

To provide meaningful lessons, the thesis reviews the space strategies, policies, programs, and sectoral developments of case studies with contrasting orientations. Specifically, the case studies must meet the following criteria: (1) an emerging space state that has established an official space agency or office within the past decade; (2) have

[61] Matthias Maass, "Small States as 'Small Countries' and 'Little States,'" *International Studies Annual Convention*, March 2008, https://www.researchgate.net/publication/295907113_Small_States_as_'Small_Countries_and_'Little_States.

publicly demonstrated or released evidence of spending into national space programs; (3) have contrasting focuses for their space agencies; and (4) be in different geographical regions.

2. Comparative Case Comparison

The case studies are summarized and compared with both the qualitative and quantitative approaches. The metrics introduced by Shabbir, Sarosh and Nasir are adopted to provide a qualitative representation of the orientation of space policy in the application domains of civil, commercial, and national security space.[62] Qualitative research data gathered from the case studies is used to determine the reality of a scenario.

The thesis examines and explains the orientation against the influence of extrinsic/ intrinsic motivation and space trends facing each small state. The challenges, opportunities, and comparative advantages of the respective space strategies are also discussed. Whenever possible, data of key indicators are collated to measure and represent the differences between the small states. This methodology may provide lessons for Singapore, that is, how best to orientate its national space policy and strategies to maximize its competitive advantages and capitalize on global trends in space.

The research materials comprise open-source, scholarly works, including conference proceedings, and reports and white papers from relevant government departments and agencies, as well as journal articles and books from academic publishers. Reputable new sources specific to the case studies will also be used to address information gaps on the most recent developments.

[62] Zaeem Shabbir, Ali Sarosh, and Imran Nasir, "Policy Considerations for Nascent Space Powers," *Space Policy* 56 (May 2021): 1–10, https://doi.org/10.1016/j.spacepol.2021.101414.

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II. CASE STUDY: UNITED ARAB EMIRATES

The past decade has seen an expansion in the scope of space activities by traditional space-faring states, along with the emergence of many space-keen states that have established national space agencies or administrations to place dedicated emphasis on space. Significantly, small states, such as Paraguay, the UAE, Bahrain, New Zealand, Greece, Luxembourg, Portugal, have accounted for half of these new entrants.

The emergence of small state space programs and activities has far-reaching effects to the growing global space sector. An awareness of these developments offers valuable insights for decisionmakers about the opportunities and challenges for the global space community regarding international cooperation and diplomacy. Specific to other small but space-keen countries, such as Singapore, an appreciation of key policies, frameworks, and programs, as well as the objectives and priorities driving strategies, provides meaningful lessons to the development of their own national strategies.

In this context, the thesis seeks to review the space strategies, policies, programs, and sectoral developments of case studies with contrasting orientations. The selected case studies of the UAE and Luxembourg provide an overview of small state space programs and draws the connection between strategies with the associated motivations, opportunities, and challenges as lessons for Singapore. The following chapter focuses on the UAE.

A. SPACE ACTIVITIES OVERVIEW

The UAE is a small Gulf state with a population size shy of 10 million and is a relatively new entrant into the space sector. It started its space journey in 1997, when the UAE government founded the Thuraya Communications Company to resolve its lack of communication coverage in the Middle East. To this end, Thuraya partnered with Boeing to develop and operate Middle East's first mobile communication satellite, Thuraya 1, in

2000.[63] Notably, the launch of the Khalifa-Sat Earth Observation satellite by Japan's H-IIA rocket in 2018 marked the first satellite to be indigenously designed and manufactured by an Emirati team from the ground up.[64] To date, the UAE has commissioned 10 spacecraft in the applications of telecommunications, Earth observation, and space science and technology, and is supported by a space sector that provides more than 3,200 jobs. Over 57 space companies and entities are currently operating in the UAE, including international and start-ups, and five space science research centers.[65]

Major institutional milestones were achieved when the UAE Space Agency (UAESA) was created in 2014, as a dedicated body to orchestrate the national space activities on behalf of the UAE government; and the Mohammed Bin Rashid Space Centre (MBRSC) that was created in 2015 as the sole scientific and technological hub of the UAE. The establishment of dedicated bodies to manage the functions of national security, safety, and stability; science and exploration; commerce; and international cooperation, brought renewed focus and momentum to the country's space activities. Through Federal Law No. 12 of 2019—Regulation of the Space Sector—these bodies have been entrusted by the UAE government to make financial and administrative decisions independently and to represent and advance the UAE's interests in space during bilateral and multilateral exchanges. The issuance of the National Space Policy (NSP) in 2016 and National Space Strategy (NSS) in 2019 by the UAESA complemented Federal Law No. 12 and constitute the major instruments that make up the legal and regulatory framework to guide and support the national space activities.

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[63] Nasir Sarwat, "Staying Connected: UAE Marks 20 Years since It Launched Middle East's First Mobile Telecoms Satellite, "*national news (UAE)*, last modified October 22, 2020, https://www.thenationalnews.com/uae/staying-connected-uae-marks-20-years-since-it-launched-middle-east-s-first-mobile-telecoms-satellite-1.1097678.

[64] Mohammed Bin Rashid Space Centre, "KhalifaSat: The First Emirati Satellite Built up Ground Up," *National Geographic*, accessed March 28, 2022, https://www.nationalgeographic.com/science/article/partner-content-KhalifaSat-first-Emirati-built-satellite.

[65] Nasir Sarwat, "UAE Enters into Space Tourism Partnership with Jeff Bezos's Blue Origin, "*national news (UAE)*, last modified October 28, 2021. https://www.thenationalnews.com/uae/2021/10/28/uae-confirms-space-tourism-partnership-with-jeff-bezos-blue-origin/.

B. SPACE POLICY, STRATEGY, AND LAW

Launched in 2010, the UAE Vision 2021 initiative articulated that the UAE has foreseen significant economic changes in the coming decade and has initiated its preparation to transit into a "knowledge-based economy" through innovation and R&D, and encouraging high value-adding sectors.[66] Driven primarily by motives to diversify its economy away from hydrocarbon exports, tourism, and logistics, and to engrain the culture of innovation through technology, the UAE has invested its accumulated wealth into growth areas regarded as opportunity pathways,[67] among them outer space.

A quote by Sheikh Mohammed bin Rashid Al Maktoum, vice president, prime minister, and ruler of the Emirates of Dubai, summarized the core strategy of the UAE by stating: "the establishment of an integrated space industry in the UAE that is fully supported by the required human resources, infrastructure, and scientific research is a matter of high national interest."[68] The UAE has differentiated itself from competing states through its dedication to developing an integrated space industry that is well supported by its national space ecosystem. UAE's interests in space have consistently been highlighted as part of its vision and priorities within a series of national long-term plans and strategies—i.e., the UAE Vision 2021, the UAE Centennial 2071, and articulated as goals and guidelines within the NSS and NSP. To this end, the UAE has committed public investment sustainably to grow its national capacity and leverage mechanisms such as public-public and public-private partnerships to develop its national capability and competency.

Underpinning the growth of the national capacity has been sustained public investment by domestic economic development entities, such as the Mubadala Investment Company, the Dubai Future Foundation, and the Abu Dhabi Holding Company. This has

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66 "Competitive Knowledge Economy," UAE Vision 2021, accessed May 24, 2022, https://www.vision2021.ae/en/national-agenda-2021/list/economy-circle.

67 Opportunity pathways identified are renewable energy, civilian nuclear power, defense industry, cyber space, and outer space.

68 "National Space Strategy (UAE) 2030," UAE Space Agency, last modified October 23, 2021, https://space.gov.ae/Documents/PublicationPDFFiles/2030-National-Strategy-Summary-EN.pdf.

seeded the growth of human resources, infrastructure, and scientific research, and has helped establish partnerships and built workstreams with industry leaders that facilitated the import of space technologies and specialist skills. To date, over $5 billion of public investment has been committed to develop the national space ecosystem, with over $2.5 billion expended during the past four years.[69]

1. National Space Policy

The UAESA issued the NSP in 2016, to translate the vision, priorities, and goals articulated within the UAE Vision 2021 initiative, the Higher Policy for Science, Technology and Development, and the National Innovation Strategy, into motivations, goals, and guidelines to provide the main directions for the national space sector.[70] Importantly, the NSP communicates motivations including:

- Enhance the lives of UAE citizens through enhancement of education, job creation, provision of better services, and instilling national pride and happiness,
- Support UAE national interests that include safety, security, and stability,
- Support growth and diversification of UAE economy by continuously develop and grow national space capabilities and capacities,
- Promote collaboration and support UAE status by strengthening cooperation, coordination, and partnerships in the space domain between the government sector, private sectors, academia, and R&D centers in the UAE, as well as with the international space community, and
- Respect international laws and treaties by recognizing the right of all nations to explore and use space for peaceful proposes and for benefit of humanity—a safe, sustainable, and stable space environment, free from impediments to access and utilization.[71]

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[69] Hussein Hazem, "Investments in Space Industries Witness Renewed Momentum with Announcement of the UAE's New Space Project," Emirates News Agency - WAM, last modified October 14, 2021, https://wam.ae/en/details/1395302980835; and "United Arab Emirates Investing Heavily in Space and STEM," ASME.org, last modified April 19, 2021, https://www.asme.org/government-relations/capitol-update/united-arab-emirates-investing-heavily-in-space-and-stem.

[70] "UAE National Space Policy," UAE Space Agency, accessed April 4, 2022, https://space.gov.ae/Documents/PublicationPDFFiles/UAE_National_Space_Policy_English.pdf.

[71] UAE Space Agency, "UAE National Space Policy," 19–21.

The NSP also specifies goals including:

- Expand the utilization of space to protect and support vital domestic sectors,
- Develop a sustainable, competitive, and innovative commercial space industry,
- Conduct scientific space missions,
- Promote a safe and stable space environment that supports sustainable space activities, and
- Establish and expand the UAE's leadership in space regionally and internationally.[72]

Finally, the NSP articulated guidelines that fall into three key interdependent areas that support space activities in the function of: national security, safety and stability; science and exploration; and commerce.[73] These guide the respective stakeholders in achieving the NSS goals, thereby supporting the growth of the national space sector. Significant is the manifestation of its national security objectives, which brought focus to utilizing space systems in the service of border and ports security and protection, and in incorporating space systems for early-warning missions against various threats.

2. National Space Strategy

In 2019, the UAESA issued the NSS to guide the national space industry across the respective areas of science, technology, applications, and services, in achieving the envisaged national vision of the space domain. The centerpiece of the NSS is its view of "space as an engine" to drive development in national social, economic, political, and security policy in a sustainable manner.[74] It translates the goals of the NSP into national programs and initiatives that the respective civil, commercial, and national security sectors would work on executing until 2030, while also aligning with the national ambitions drawn by the NSP. To ensure continuing relevance, the UAESA oversees the execution and the periodic review of the NSS.

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[72] UAE Space Agency, "UAE National Space Policy," 23–26.

[73] UAE Space Agency, "UAE National Space Policy," 36–49.

[74] "National Space Strategy (UAE) 2030," UAE Space Agency, last modified October 23, 2021, https://space.gov.ae/Documents/PublicationPDFFiles/2030-National-Strategy-Summary-EN.pdf.

Beyond serving its domestic interests, the NSS also reviewed and took alignment with relevant international space policies and treaties—i.e., the UN Sustainable Development Goals (SDGs) 2030, the UN Committee on the Peaceful Uses of Outer Space (COPUOS) Long Term Sustainability Guidelines, the International Space Exploration Coordination Group's Global Exploration Roadmap, and binding treaties and principles, such as the Treaty on the Peaceful Uses of Outer Space (signed 2000), the Liability Convention (signed 2000), the Space Objects Registration Convention (signed 2020), the Rescue and Return Agreement (signed 2017), and the Artemis Accords (signed 2020) etc.[75]

Significantly, the NSS reviewed the stakeholder groups to become: (1) relevant UAE government entities; (2) relevant international government entities; (3) UAE space industry; (4) UAE non-space industry; (5) international companies in the UAE; (6) research centers and academia; and (7) relevant civil society organizations. This serves to better inform the engagements required within each key sector, and to provide clarity in the lines of effort and interaction between national, regional, and international governmental, commercial, and research entities.[76]

3. Federal Law No. 12 (Space Sector Law) and UAE Space Court

The UAE's Ministry of Justice issued Federal Law No. (12) in 2019, also known as the Space Sector Law (SSL), which was designed to reflect and support the goals of the 2016 NSP, as well as the UAE's commitment to its international obligations.[77] It strives to create a regulatory and legal framework capable of supporting the UAE's ambitions to become a major space-faring nation. In addition to the implementation of obligations prescribed by the series of treaties—all UN space treaties, except for the Moon Agreement—the SSL also established a system for regulating space activities to be carried

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[75] Ibid., p. 25-26.

[76] Ibid., p. 53-56.

[77] "On the Regulation of the Space Sector," Federal Law No. (12) of 2019, *Ministry of Justice (UAE)*, December 19, 2019, https://www.moj.gov.ae/assets/2020/Federal%20Law%20No%2012%20of%202019%20on%20THE%20REGULATION%20OF%20THE%20SPACE%20SECTOR.pdf.aspx.

out either from UAE territory or by UAE nationals outside the UAE. This aims to attract and encourage foreign companies to establish space activities in the UAE. To this end, the SSL provided an appropriate legal and regulatory framework through comprehensive licensing and liability regimes, which are complemented by a flexible insurance requirement. This provides clarity on the operator's legal rights and obligations and empowered the UAESA with responsibility for the overall conduct and safety of space activities.

With the issuance of Article 18 of the SSL, the UAE became the third country in the world, after the United States (U.S. Space Act of 2015) and Luxembourg (Luxembourg Space Law of 2017) to have established specific provisions within its national legal framework on the exploitation and utilization of space resources.[78] Unlike most space powers, which have not yet taken a stance on this issue, the UAE anticipates the advance and proliferation of space exploration and mining technology and has portrayed itself as a business-friendly environment for the onset of such activities.

In January 2021, it established the UAE Space Court aimed at settling commercial disputes. Complementing the SSL, arbitration at the UAE Space Court was open to both Emirati and foreign space companies. In tandem, the Courts of Space initiative was launched "to build [and support] a new judicial network to serve the stringent commercial demands of international space exploration."[79] Supporting the initiative was the assembling of an Integrated Working Group that comprises experts and stakeholders from the public and private sectors, as well as observers from the UNOOSA. Significantly, this group strives "to explore space-related legal innovations" and "provide an outlook on potential outcomes of scenarios revolving around space-related disputes and disagreements," and eventually to create the Space Dispute Guide, which encompasses a

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[78] Blount P.J. and Mohamed Amara, "SPARC Brief - United Arab Emirates," *SPARC (blog)*, last modified August 1, 2020, https://www.sparc.uw.edu/uae/.

[79] France-Presse Agence, "Dubai Creates 'Space Court' for Out-of-This-World Disputes," Courthouse News Service, last modified February 1, 2021, https://www.courthousenews.com/dubai-creates-space-court-for-out-of-this-world-disputes/#:~:text=Dubai%20announced%20Monday%20the%20creation, presence%20in%20the%20space%20sector.

set of proposals to resolve space-related disagreement, as well as building capacity in the arbitration of space-related disputes.[80]

C. ANALYSIS OF SPACE STRATEGY

The UAESA was able to comprehensively capture and articulate the respective lines of effort within the NSS 2030 to set the general framework and has provided a roadmap for the key sectors (e.g., academia, R&D centers) and activities (e.g., government-initiated, commercial, and scientific) in the years leading up to 2030. The agency also outlined a core strategy that was anchored in developing its own space capabilities in the technology areas regarded as opportunity pathways, while actively seeking collaboration with governmental, industrial, and academic partners to perform a range of space missions, especially in the areas of space exploration, information exchange, and open data policy to enhance the role of space in sustainable development.

Despite the proliferation of commercial space technology and global industry, the UAE has remained consistent and committed in its approach to leverage partnerships with both private and public space actors to build its national capacity and competency and advance its national capability. The analysis of the space strategy also highlighted the strength of UAE's integrated space sector and the success of its approach to leverage knowledge transfer program and international cooperation to accelerate the building of national capacity and capability.

1. Civil Sector

MBRSC leads the space activities in the civil function and is responsible with the goals of conducting scientific space missions and to execute space activities in the application of space science and exploration. To achieve this policy goal, the MBRSC has

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[80] Space dispute issues such as equipment failures, space cargo disputes, failure to deliver components on time, sub-standard materials, or design faults. Disagreement over satellite purchases, rocket launches, and disputes regarding collisions between devices in space.

"Dubai's Courts of Space Launches International Working Group to Explore Space-Related Legal Innovations," Dubai International Financial Centre Courts, accessed April 8, 2022, https://www.difccourts.ae/media-centre/newsroom/dubais-courts-space-launches-international-working-group-explore-space-related-legal-innovations.

been entrusted with the legal capacity required to develop the national space sector by building the national capacity and competency and advancing capability through civil applications.

As a new entrant to the space sector, the UAE government issued the Federal Law No. 17 of 2015, to consolidate the Emirates Institute for Advanced Science and Technology (EIAST) that was founded in 2006 with the MBRSC to provide critical mass and expertise to function as the sole scientific and technological hub of the UAE. To sustain this effort, the center also serves as an incubation chamber for building national manufacturing and development capacity as well as national capability in space technology. To grow national capacity, the MBRSC builds and upgrades scientific facilities and infrastructure, launches scientific projects and missions, supports the development of policies and laws that facilitate research and adoption of advanced space technology, and designs, manufactures, and operates satellites indigenously. Importantly, it has also supported the growth of the commercial sector by facilitating knowledge transfer and incubation programs that supported the establishment of space startup and companies.

To promote science, technology, and education in space applications, the UAESA has translated the goals into concrete R&D projects through partnerships with national universities. Nayif-1, UAE's first nanosatellite, was developed through a knowledge transfer program with the University of Sharjah[81]; the MYSAT1 CubeSat was developed locally at the Yahsat Space Lab, Khalifa University with Masdar Institute of Science and Technology[82]; and the MeznSat CubeSat was co-developed by Khalifa University and the University of Ras Al Khaimah.[83]

The UAE's venture into space exploration programs represented its long-term ambitions that encompasses all the stipulated goals within the NSP and comprises three

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81 "NAYIF-1," Mohammed Bin Rashid Space Center, accessed April 11, 2021, https://www.mbrsc.ae/satellite-programme/nayif-1.

82 "MYSAT 1," Gunter's Space Page, accessed April 11, 2022, https://space.skyrocket.de/doc_sdat/mysat-1.htm.

83 "MeznSat," Gunter's Space Page, accessed April 11, 2022, https://space.skyrocket.de/doc_sdat/meznsat.htm.

main projects: the Emirates Mars Mission (EMM), the Emirates Lunar Mission (ELM), and Mars 2117. In 2017, the UAE announced a highly ambitious national space program—Mars 2117, with the intention to build a human settlement on Mars with a 100-year plan for its implementation.[84] To this end, the leading agency, MBRSC, put in place strategies that included, preparing a specialized national cadre of experts, developing national capabilities in the fields of space science and technologies; directing, investing in, and promoting several initiatives via the UAESA that include setting up research and manufacturing infrastructures,[85] and nurturing scientific competencies of Arab youth[86] and assembling of its first astronaut corps,[87] the launch of the EMM—Hope Probe, the ELM, and the Emirati Interplanetary Mission, as building blocks to develop intellectual capacity in space science and related technologies. Significantly, the successful launch of the first Emirati astronaut in September 2019 aboard Russian Space Agency's Soyuz MS-15 spacecraft, the first space science satellite[88] ("Hope" Mars probe), and the first nanosat—Nayif-1 for scientific research[89] have shown that the UAE has made

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84 "Mohammed Bin Rashid, Abu Dhabi Crown Prince Launch National Space Program," Emirates News Agency - WAM, last modified April 12, 2017, http://wam.ae/en/details/1395302608363.

85 Nasir Sarwat, "Inside Al Ain's New Hi-Tech Space Satellite Facility, "national news (UAE), last modified September 15, 2020, https://www.thenationalnews.com/uae/science/inside-al-ain-s-new-hi-tech-space-satellite-facility-1.1078084; and "Mohammed Bin Rashid Opens 2nd Phase of UAE Satellite Manufacturing Complex," Emirates News Agency - WAM, last modified March 11, 2016, http://wam.ae/en/details/1395302496371.

86 UAE Space Agency, "Arab Space Pioneers Programme by The UAE Space Agency Attracts 27,000 Applications from Africa," Space in Africa, last modified July 18, 2020, https://africanews.space/arab-space-pioneers-programme-by-the-uae-space-agency-attracts-27000-applications-from-africa/.

87 The MBRSC oversees the UAE Astronaut Program that aims to develop skilled and capable Emirati astronauts to embark on scientific space exploration missions. It also serves to create a culture of scientific endeavor and to inspire Emirati youth to pursue a career in space science and technology. "The UAE Astronaut Programme, "Official Portal of UAE Government, accessed March 29, 2022, https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/the-uae-astronaut-programme.

88 Bartels Meghan, "Welcome to Mars! UAE's Hope Probe Enters Orbit around Red Planet," Space.com, last modified February 9, 2022, https://www.space.com/uae-hope-mars-mission-orbit-insertion-success.

89 Nasir Sarwat, "We Have Lift-off: UAE's DMSat-1 Satellite Launches into Space, "national news (UAE), last modified March 22, 2021, https://www.thenationalnews.com/uae/science/we-have-lift-off-uae-s-dmsat-1-satellite-launches-into-space-1.1188844.

considerable progress on its long-term roadmap to develop an integrated national space ecosystem.

The successful launch of the Hope Probe—a state-of-the-art weather satellite marks the highlight of its short history in space. Launched in 2020, the Hope Probe has since reached its desired orbit around Mars in February 2021 to gather and transmit space science data of Mars' climate and atmosphere. This achievement made UAE the sixth country to have successfully launched a Mars mission. Built in collaboration with the University of Colorado at Boulder, University of California at Berkeley, and Arizona State University, the UAESA funded and oversaw the project's administration and implementation while MBRSC took charge of the project's technical conception and program management.

A thriving civil sector functions as a strategic domain for Emirati citizens to work in. To prepare the future generation of Emirati engineers, experts, and researchers in the UAE space industry, the center has raised awareness of the importance of science, innovation and space exploration through an outreach and ambassador program that has provided internship and research opportunities to all levels of academia. Specifically, the center has implemented training and education programs (conducted by the Yahsat Space Laboratory), scientific research programs (conducted by the Sharjah Academy of Astronomy & Space Sciences and Technology, National Space Science and Technology Center, and Center for Space Science), and has facilitated partnerships between industries and universities, investment vehicles. Through the Space Investment Promotion Plan,[90] UAE seeks continued investment into its space industry by supporting start-ups and entrepreneurship.

To accelerate the advancement of its national capability, the MBRSC has been actively entering into public-private partnerships on space technology. Facilitated by the UAESA, it was able to strengthen its Earth observation capability by partnering with EPI to design and develop the MBZ-Sat, which would become the "most powerful Earth observation satellite" among Arab states. Beyond satellite and launch programs, the center

90 "Space Investment Promotion Plan" (UAE Space Agency), accessed May 24, 2022, https://space.gov.ae/Documents/PublicationPDFFiles/Space_Invest_Plan_EN_Summary_042020.pdf.

is responsible for all announced national space programs, as well as the planned construction of the Mars Science City to replicate conditions on Mars to prepare astronauts. Significantly, it has also partnered with foreign universities in a series of space exploration programs to accelerate the growth of its technical expertise and program management for space exploration missions.

Backed by a credible and vibrant civil sector, the center has been able to enter into agreements through MoUs with leading international space organizations and prestigious space programs to establish official work streams for knowledge transfer and resource sharing. Most recently, it has signed agreements with NASA to collaborate in space exploration, with U.S. Strategic Command to share data and services related to SSA, and with UNOOSA to increase cooperation in the peaceful uses of outer space and to commence joint research projects on the use of space technology for economic and social benefits.[91] This has also helped the UAE to become the first Arab state to have gained membership to leading international space organization such as the International Astronautical Federation (IAF), IAF's International Space Exploration Committee and Coordination Group, as well as the first to host the International Astronautical Congress in 2021 since its establishment in 1950.[92]

2. Commercial Sector

The UAESA oversees space activities in the commercial sector and is responsible for the goals of "developing a sustainable, competitive, and innovative commercial space industry," as well as "promoting a safe and stable space environment that supports

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[91] "UNOOSA Signs MoU with Mohammed Bin Rashid Space Centre to Promote the Peaceful Exploration and Use of Outer Space," United Nations - Office for Outer Space Affairs, last modified November 20, 2019, https://www.unoosa.org/oosa/en/informationfor/media/2019-unis-os-524.html; and "UNOOSA and MBRSC Sign a Memorandum of Understanding for Satellite Payload Hosting," United Nations - Office for Outer Space Affairs, last modified October 28, 2021, https://www.unoosa.org/oosa/en/informationfor/media/2021-unis-os-561.html.

[92] "IAF Received 3,356 Abstracts from 86 Countries for the First International Astronautical Congress in Dubai," Space in Africa, last modified March 8, 2021, https://africanews.space/iaf-received-3356-abstracts-from-86-countries/.

sustainable space activities".[93] To achieve these policy goals, the UAESA has been entrusted to make financial and administrative decisions independently. Consequently, the agency has the mandate to authorize national space activities, and to represent and advance the UAE's interest in space during bilateral or international cooperation and exchanges. This has allowed the agency to encourage private sector participation in national space activities and to autonomously simulate investment in the areas in the technology areas regarded as opportunity pathways that were captured within the 2020 white paper—Towards a Roadmap for Future UAE Deep Space Missions and Sustainable Settlement of Humans on Mars.[94]

The development of the UAE's commercial sector has represented a conventional and structured approach along the space technology ladder that was driven by a motivation to diversify its economy. This has seen the technological focus shifted from providing mobile telecommunications, television broadcasting, and satellite broadband coverage to the Arab region; to building Earth-observation satellite technologies to provide satellite imagery services and analysis to government and commercial entities globally; to exploiting opportunities such as launch capability and space exploration, that could capture the NewSpace economy.

In the earlier days of its space journey, the UAE had relied on partnerships between government-funded ventures (Thuraya and Yahsat) with foreign commercial aerospace companies to manufacture satellites for telecommunication purposes (Boeing for Thuraya 2 & 3; Airbus, Thales for Al Yah 1 & 2; and Orbital ATK and Northrop Grumman for Al Yah 3). Over a 10-year knowledge and technology transfer program, the UAE partnered with South Korea's Satrec Initiative to gain expertise on satellite design, manufacture, and operations (DubaiSat-1, DubaiSat-2, and Nayif-1), before integrating this knowledge to develop an indigenous Emirati satellite capabilities for Earth observation—Khalifa-Sat. This has allowed the small state to import commercially viable mobile telecommunications

[93] UAE Space Agency, "UAE National Space Policy," 23–26.

[94] Rafael Popper et al., "Towards a Roadmap for Future UAE Deep Space Missions and the Sustainable Settlement of Human on Mars," UAE Space Agency / VTT Technical Research Centre of Finland, (2020), doi.org/10.32040/2020.978-951-38-8826-8.

technologies, partner with industrial leaders to gain expertise and in-house development capacity and capability over Earth observation satellites. The proliferation of space technology and the rapid growth of the global space industry has, however, compelled the UAE to keep pace by expanding on its current mechanisms through strategic co-funding and partnership.

Through Aabar Investments, the UAE government had taken a stake of over 39% (or $300 million) in the private spaceflight company Virgin Galactic.[95] In 2019, the level of partnership deepened with the signing of MoU between UAESA and Virgin Galactic, that provided official workstreams to bring knowledge, expertise, jobs to the UAE in the aspect of space vehicle manufacturing and commence spaceport operations. The lack of tangible progress then saw the UAE partner with another private spaceflight company, Blue Origin, which has announced its interest in setting up a spaceport in the UAE desert for suborbital flights, and thereby superseding the extant agreement with Virgin Galactic.[96] While the use of space launch vehicle is subjected to the Missile Technology Control Regime and pending negotiation between the U.S. and the UAE, such agreements have precedents in arrangements worked out previously at Brazil's Alcântara spaceport and New Zealand's Mahia spaceport.

Through this collaboration, the UAE aims to leverage Blue Origin's "leading expertise in space manufacturing and low Earth orbit flight services" to support its goal of "developing a sustainable, competitive, and innovative commercial space industry."[97] The

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[95] "United Arab Emirates - Country Commercial Guide (Space)," International Trade Administration, last modified January 8, 2022, https://www.trade.gov/country-commercial-guides/united-arab-emirates-space; and Abi-Habib Maria, "Virgin Galactic Sells Stake to Abu Dhabi," WSJ, July 30, 2009, https://www.wsj.com/articles/SB124877138837886345.

[96] Nasir Sarwat, "Jeff Bezos's Blue Origin Has Its Eye on UAE Desert for Spaceport, "national news (UAE), last modified October 26, 2021, https://www.thenationalnews.com/uae/2021/10/26/jeff-bezos-blue-origin-has-its-eye-on-uae-desert-for-spaceport-to-launch-tourism-flights/; and Nasir Sarwat, "UAE Enters into Space Tourism Partnership with Jeff Bezos's Blue Origin, "national news (UAE), last modified October 28, 2021, https://www.thenationalnews.com/uae/2021/10/28/uae-confirms-space-tourism-partnership-with-jeff-bezos-blue-origin/.

[97] Ismail Esraa, "Ministry of Economy Explores Mechanisms to Develop Space Economy, Investment, Tourism Opportunities," Emirates News Agency - WAM, last modified October 28, 2021, https://wam.ae/en/details/1395302986067.

establishment of a spaceport would drive economic development through space tourism—a market valued at $3 billion by 2030.[98] This partnership would also seed the knowledge transfer of space manufacturing and suborbital flights expertise into building its national capacity and capability. Continuing the success with Khalifa-Sat, the MBRSC announced in 2020 that it had partnered with EPI—an engineering solution company based in Abu Dhabi, to design and develop the MBZ-Sat. Projected to launch on a SpaceX Falcon 9 rocket in 2023, MBZ-Sat would be the second satellite to be entirely designed and manufactured by Emirati engineers and is expected to be the region's most powerful Earth observation satellite.[99]

This was again evident when it partnered with industry leader—Airbus to establish the Satellite Assembly, Integration and Testing Center in Al Ain (AIT Satellite Centre), where development work has begun for two Global Navigation Satellite System—augmentation System (GNSSaS[100]) satellites. Funded by the UAESA, Emirati engineers will receive training at Airbus facilities and will be supported in the procurement, installation, and operational qualification of the equipment by Airbus. The GNSSaS would be the first project to be executed at the newly established AIT Satellite Center and aims to develop local capabilities in the design and development of positioning, navigation, and timing payloads.[101]

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[98] Berrisford Carl, "Longer Term Investments - Space" (UBS, last modified November 30, 2018), https://www.ubs.com/content/dam/WealthManagementAmericas/documents/space-p.pdf; and Sheetz Michael, "Super-Fast Travel Using Outer Space Could Be $20 Billion Market, Disrupting Airlines, UBS Predicts," CNBC, last modified March 18, 2019, https://www.cnbc.com/2019/03/18/ubs-space-travel-and-space-tourism-a-23-billion-business-in-a-decade.html.

[99] Nasir Sarwat, "MBZ-Sat: UAE to Launch Region's Most Powerful Earth-Imaging Satellite in 2023, "national news (UAE), last modified October 27, 2021, https://www.thenationalnews.com/uae/2021/10/27/mbz-sat-uae-to-launch-regions-most-powerful-earth-imaging-satellite-in-2023/.

[100] The technology demonstrator will include a GNSS augmentation RF signaling demonstrator payload, GNSS reflectometry payload for remote sensing, and a UHF/VHF experiment for measuring the effects of the ionosphere on these RF frequencies.

"GNSSaS Satellite," National Space Science and Technology Center, accessed May 24, 2022, https://www.nsstc.ae/satellites/gnssas-satellite-1030.

[101] Nasir Sarwat, "UAE to Develop and Launch Navigation Satellite Next Year, "national news (UAE), last modified August 9, 2020, https://www.thenationalnews.com/uae/science/uae-to-develop-and-launch-navigation-satellite-next-year-1.1061317.

Beyond traditional areas of space technology, the UAE has taken a stance in anticipation of potential growth of niche and emerging ventures. The promulgation of the SSL has provided a comprehensive and well-defined legal framework that was fundamental in shaping how the national space sector would prepare to capture the proliferation of space exploration and mining technology, while meeting its policy goal of promoting the safety and sustainability of the space domain. Spearheading its long-term vision and ambitions, the issuance of Federal Law No. 12, Article 18, allowed the UAE to go beyond traditional legal measures to capture potentially lucrative venture in conducting space exploration missions and exploiting space resources.

According to Chairwoman of the UAESA Sarah Al Almiri, the UAE has made sustained public investment into building national space expertise and experience in the public space sector before "taking a big bet in transferring a lot of the experience gained over the course of last 15 years onto the private sector," and "this was fundamental to enable the new space economy that other space faring nations are also capitalizing on."[102] The reinvestment of its national capacity from civil to commercial functions has been key to seizing first-mover advantage and capturing breakthrough opportunities in lucrative components of the commercial space sector.

Overall, the UAESA, which represented the government's priorities, has played a significant role in positioning the commercial sector to capitalize on the NewSpace movement. Articulated within the National Plan for the Promotion of Space Investment,[103] the UAESA aimed to proactively design a conducive environment to welcome local start-ups and to attract foreign investors with access to businesses in the UAE that could drive their growth potential. The role of the UAE government in absorbing the financial risk of high-risk ventures has provided a fail-safe environment, while the enactment of the Law

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[102] Brunswick Shelli, "Op-Ed | More than Hope, UAE Is Transforming Its Future in Space," *SpaceNews*, last modified March 31, 2021, https://spacenews.com/op-ed-more-than-hope-uae-is-transforming-its-future-in-space/.

[103] The Space Investment Plan relies on four pillars: (1) sustaining the growth of the UAE Space Industry; (2) increasing the UAE space sector's contribution to the diversification of the national economy and towards a knowledge-based economy; (3) supporting other national strategic interests; and (4) promoting partnerships at national and international levels.

no.19 (the Foreign Direct Investment Law) in 2018 has permitted up to 100% foreign investment and ownership in the space sector.[104] Favorable fiscal policies coupled with a thriving space industry have positioned UAE well to attract foreign investors and start-ups.[105] This has facilitated the transition from government-directed and funded, to one that is collaborative and commercially-driven.

The creation of a legal infrastructure, a framework, and specific space-related communities further demonstrate the UAE's intent and dedication to playing a leading role in advancing the global judicial systems on commercial space-related disputes. The directing of national capacity and capability into building a judicial system has strengthened its portrayal as a business-friendly environment for the onset of space activities in a novel environment.

3. National Security Sector

The NSP articulated the UAE's goal in expanding the utilization of space to protect vital domestic sectors and, more specifically, in improving "safety and security of space activities and the space environment, including cyber and terrestrial infrastructure security." To this end, it sought to "mitigate space debris, increase space situational awareness operations and capabilities, and assure assess to, in, and from space."[106]

The Space Reconnaissance Center (SRC), established in 2000, has the responsibility of protecting the UAE's national security objectives. Supported by the Universal Ground Station, the center is capable of receiving imagery data directly from three satellite groups—IKONOS (commercial-owned, U.S.), IRS (government-owned, India), and KOMPSAT (government-owned, South Korea), as well as aerial data sources

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[104] Jansen Rita, "Attracting Investment into the UAE," International Bar Association, accessed April 13, 2022, https://www.ibanet.org/article/00A0C5A0-020E-4672-8E10-0A0B541CC639.

[105] Holmes Mark, "SpaceChain Opens Abu Dhabi Office to Expand to the Middle East," Via Satellite, last modified March 16, 2022, https://www.satellitetoday.com/business/2022/03/16/spacechain-opens-abu-dhabi-office-to-expand-to-the-middle-east/; and Nasir Sarwat, "How the UAE Plans to Become a Leading Space Power in the RegionS, "national news (UAE), last modified April 3, 2022, https://www.thenationalnews.com/uae/uae-in-space/2022/04/04/how-the-uae-plans-to-become-a-big-space-power-in-the-region/.

[106] UAE Space Agency, "UAE National Space Policy," 26.

from F-16, Mirage 2000/9, and UAV platforms.[107] The ability to centrally task satellite systems and to process and exploit collected imagery data has allowed the center to provide direct and independent high-resolution satellite imagery to support a wide range of end users from the military and national security organizations—e.g., Military Intelligence Directorate, the Intelligence, Surveillance and Reconnaissance (ISR) Sections of the Army, Air Force, and Navy, coastal and border guard forces, the police and civil defense; civil service, mapping, and planning organizations for environmental monitoring and urban planning; as well as organizations responsible for crisis response, management, and monitoring.[108] With the successful launch of the Airbus-built Falcon Eye 2 satellite by a Soyuz ST Fregat rocket in 2020, it is assessed that the center now owns and operates high-resolution optical reconnaissance capability with a sub-meter resolution.[109]

The UAE places high priority on national security, with an estimated defense spending between 12 to 14 percent of its total federal budget or approximately $2.3 billion in 2019.[110] Specific to the space domain, the UAE has not publicly announced plans to establish a space force and nor defense policy or doctrine akin to a defense space strategy. Due to sensitivity, it has not disclosed the portion of defense spending that has been allocated to acquire space capabilities.[111]

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[107] "Sensors," United Arab Emirates Space Reconnaissance Center, accessed April 2, 2022, http://src.gov.ae/Sensors.html.

[108] "End Users," United Arab Emirates Space Reconnaissance Center, accessed April 2, 2022, http://src.gov.ae/EndUsers.html.

[109] Foust Jeff, "Soyuz Launches Falcon Eye 2 Satellite for UAE," *SpaceNews*, last modified December 1, 2020, https://spacenews.com/soyuz-launches-falcon-eye-2-satellite-for-uae/.

[110] In 2019, the UAE federal budget spending was reported to be $16.4 billion.

Saleh Yasmine, "UAE Raises Defence Spending by around 41% in 2019 Federal Budget," ZAWYA, last modified January 10, 2018, https://www.zawya.com/en/economy/uae-raises-defence-spending-by-around-41-in-2019-federal-budget-ccarw2sd.

[111] Melissa Dalton and Hijab Shah, "Evolving UAE Military and Foreign Security Cooperation: Path Toward Military Professionalism," *Malcolm H. Kerr Carnegie Middle East Center*, January 12, 2021. https://carnegie-mec.org/2021/01/12/evolving-uae-military-and-foreign-security-cooperation-path-toward-military-professionalism-pub-83549.

A special report by General (Ret.) Khalid Abdullah Al Bu-Ai, former commander of the UAE Air Force & Air Defence proposed a network-centric UAE Armed Forces that would make use of space as the ultimate high ground for military intelligence, around the clock surveillance, 3D mapping, and resilient communications.[112] This corroborates with the acquisition of the Airbus-built Falcon Eye 2 satellite and provision for strategic and secure satellite communications through the Thuraya and Al Yah-satellites. While the UAE has emphasized the development of the space program for civil applications, the dual-use nature of space technologies, coupled with an intention to utilize space for national security objectives, has unequivocally suggested that national assets could serve military operations as well.

During the International Astronautical Congress 2021 held in Dubai, Shlomi Sudri, general manager of Israel Aerospace Industries, opined that between Israel and UAE, the Abraham Accords Peace Agreements have opened the door to potential military partnership and cooperation in space due to the relatively similar threat environment both countries face. These small states share common vulnerabilities against the backdrop of Iran's growing hostility in the region and might pursue potential military cooperation through the sharing of imagery data and analysis.[113]

4. Space Cooperation and Diplomacy

The UAESA represents and advances the UAE's interest in space cooperation and exchanges to meet its policy goal of "establish[ing] and expand[ing] the UAE's leadership in space regionally and internationally."[114] A member to many regional and international institutions, the UAE has signed MoUs with numerous space agencies. Notably, it is

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[112] Khalid Abdullah Al Bu-Ainnain, "A Vision for Transforming UAE Armed Forces into Network Centric Operations," *Institute of Near East and Gulf Military Anal*ysis, February 2010, http://www.inegma.com/uaenco.pdf.

[113] Ahronheim Anna, "Potential for Middle East Space Force Collaboration with Israel and UAE, "Jerusalem Post, November 9, 2021, https://www.jpost.com/middle-east/potential-for-middle-east-space-force-cooperation-with-israel-and-uae-684473.

[114] UAE Space Agency, "UAE National Space Policy," 26.

cooperating with all major space actors, namely the United States,[115] Europe,[116] China,[117] Japan,[118] and Russia[119] over a wide range of activities, but especially on the sharing of space service and data, space exploration, and human spaceflight. Reflecting its motivations and principles, the UAE has pursued collaboration with a diverse range of space powers, despite geopolitical tensions and rivalry between them.

Beyond major space actors, it has entered into agreements with small states, such as Israel and Luxembourg. In 2017, Luxembourg and the UAE signed an agreement to cooperate bilaterally, that was built on a shared motivation and interest in space exploration, and in the use of space resources for peaceful purposes.[120] To foster closer collaboration, the UAE/Luxembourg Space Investment Forum was convened in 2020,

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115 "USSTRATCOM, UAE Sign Agreement to Share Space Services, Data," U.S. Strategic Command, last modified April 11, 2016, https://www.stratcom.mil/Media/News/News-Article-View/Article/983694/usstratcom-uae-sign-agreement-to-share-space-services-data/; "NASA, UAE Space Agency Sign Historic Implementing Arrangement for Cooperation in Human Spaceflight," NASA, last modified April 10, 2018, https://www.nasa.gov/press-release/nasa-uae-space-agency-sign-historic-implementing-arrangement-for-cooperation-in-human; and Nasir Sarwat, "UAE Joins Nasa Space Treaty as Global Plans to Explore the Moon and Mars Take Shape, "national news (UAE), last modified October 13, 2020, https://www.thenationalnews.com/uae/science/uae-joins-nasa-space-treaty-as-global-plans-to-explore-the-moon-and-mars-take-shape-1.1093146.

116 "ESA Expertise Aids UAE Spaceflight," ESA, last modified September 18, 2019, https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/ESA_expertise_aids_UAE_spaceflight.

117 "UAE and China Sign Space Cooperation Agreement, "national news (UAE), last modified December 27, 2015, https://www.thenationalnews.com/uae/uae-and-china-sign-space-cooperation-agreement-1.106644.

118 "JAXA and UAESA Sign a Cooperation Arrangement," Japan Aerospace Exploration Agency, last modified March 26, 2016, https://global.jaxa.jp/press/2016/03/20160322_uaesa.html; "MBRSC Teams Up with Japan's Ispace on Emirates Lunar Mission," ispace inc, last assessed April 14, 2021, https://ispace-inc.com/news/?p=1874; and "UAE, Japan Discuss Closer Cooperation in Space Industry," ZAWYA, last modified October 28, 2021, https://www.zawya.com/en/press-release/uae-japan-discuss-closer-cooperation-in-space-industry-hw5glpvd.

119 "UAE, Russia Sign Agreement to Cooperate in Space Exploration," Emirates News Agency - WAM, last modified October 26, 2021, http://wam.ae/en/details/1395302985408; and "UAE Signs Space Cooperation Agreement With Russia and Kazakhstan," spacewatch.global, last modified April 1, 2018, https://spacewatch.global/2018/04/uae-signs-space-cooperation-agreement-russia-kazakhstan/.

120 "Luxembourg and the United Arab Emirates to Cooperate on Space Activities with Particular Focus on the Exploration and Utilization of Space Resources, "Government of the Grand Duchy of Luxembourg, last modified October 10, 2017, https://space-agency.public.lu/dam-assets/press-release/2017/2017-10-10-press-release-mou-space.pdf.

which gathered senior leadership, space officials, and industrial leaders from the private and public sectors of both countries, to discuss and promote economic and political cooperation.[121]

Building on the historic peace treaty, the Abraham Accords Peace Agreement,[122] Israel and the UAE signed an agreement to enhance space cooperation in scientific research, space exploration, and knowledge transfer to stimulate economic growth and accelerate the progress of science and technology. The agreement laid the framework for a mutually beneficial strategic partnership with a focus on issues common to both Israel and UAE: e.g., exchanging research and developing scientific instruments for lunar missions and sharing of earth observation data to examine phenomena related to agriculture, desertification, water monitoring, and climate change. An educational program was also initiated to encourage Arab and Jewish students to study satellite engineering and astronomy at the Nazareth Space Center, with an eventual goal of "developing a space program that would be a combination of Israel and the Arab world."[123]

As a member state of UNOOSA, the UAESA signed an agreement with the UN office in 2017 aimed at building capability in the technical and legal aspects of the peaceful uses of outer space and the use of space tools to achieve the UAE's USS 2030, as well as to raise awareness of the "Space as Driver for Socio-Economic Sustainable Development" initiative that was captured within UNOOSA's SDGs.[124] The level of partnerships deepened in 2020 with a second agreement, which led to the establishment of a UNOOSA project office in the UAE's capital, Abu Dhabi, which acts as a "new global hub to foster

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121 "UAE Hosts Luxembourg At Abu Dhabi Global Market For Space Investment Forum," spacewatch.global, last modified February 1, 2020, https://spacewatch.global/2020/02/uae-hosts-luxembourg-at-abu-dhabi-global-market-for-space-investment-forum/.

122 Israel and the UAE agreed to full normalization of diplomatic relations in August 2020, marking the first peace treaty between Israel and an Arab country in 25 years.

123 "Israel, UAE Sign Historic Space Agreement, "*Jerusalem Post*, last modified October 21, 2021, https://www.jpost.com/israel-news/israel-uae-sign-historic-space-agreement-682672.

124 "Agreement Boosts Cooperation between UN Space Affairs Office and UAE," United Nations News, last modified November 8, 2017, https://news.un.org/en/story/2017/11/570212-agreement-boosts-cooperation-between-un-space-affairs-office-and-uae.

international progress on space sustainability and space for development issues." This collaboration aims to strengthen global dialogue, research, and trend analysis on space sustainability issues, reinforce efforts to catalog best practices in responsible and sustainable space activities.[125] To this end, the UAESA organized and funded several international events and high-level forums, including the 2016 "Space as Driver for Socio-economic Sustainable Development" forum, which conceived the Dubai Declaration,[126] and the 2020 World Space Forum—a platform for space experts and political leaders to "exchange views on the four pillars of space economy, space society, space accessibility, and space diplomacy." [127]

The UAE has also been an active lobbyist on the topic of peaceful uses of outer space by leading several initiatives. In 2019, it submitted a resolution on Space Resource Utilization that proposed and communicated the rationale of establishing a working group to analyze the current state of space UAE resource utilization by space-faring nations and define recommendations and principles on the matter.[128] In 2020, it submitted proposals on a "Voluntary Implementation Reporting Survey for the Guidelines related to Long-Term Sustainability of Outer Space Activities," as well as for "The Establishment of a Working

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125 "UNOOSA and UAE Space Agency Announce Agreement to Advance Space Sustainability," United Nations - Office for Outer Space Affairs, last modified June 10, 2020, https://www.unoosa.org/oosa/en/informationfor/media/2020-unis-os-532.html.

126 The Dubai Declaration was used to guide the ongoing work of the UNCOPUOS, especially in the lead-up to the planned UNISPACE+50 activities in 2018. "Dubai Declaration," United Nations - Office for Outer Space Affairs, last modified November 24, 2016, https://www.unoosa.org/documents/pdf/hlf/1st_hlf_Dubai/Dubai_Declaration.pdf.

127 "The World Space Forum Series," United Nations - Office for Outer Space Affairs, accessed July 28, 2022. https://www.unoosa.org/oosa/en/ourwork/world-space-forum/WSF-main-page.html.

128 "Proposal by the United Arab Emirates on the Work Related to Space Resources Utilization of the Committee on the Peaceful Uses of Outer Space," vol. 62, A/AC.105/2019/CRP (Committee on the Peaceful Uses of Outer Space, UNOOSA, 2019), https://www.unoosa.org/oosa/oosadoc/data/documents/2019/aac.1052019crp/aac.1052019crp.17_0.html.

Group under the agenda item on the Long-Term Sustainability of Outer Space Activities."[129]

Regionally, space has become a field of competition between Middle Eastern and North African states vying for regional and international leadership, as well as seeking economic diversification and military capabilities. The past decade has seen several Arab states establish space agencies, develop a space program, and operate satellites. Resembling those in the UAE, the space activities in the competing states have revolved around interests in human spaceflight (e.g., Egypt, Iran) and space exploration (e.g., Saudi Arabia, Turkey). Many competing states have also announced the use of satellites in orbit to support military operations (e.g., Saudi Arabia, Qatar, Egypt, Iran, Turkey, and Israel). Despite this contestation, the UAE has demonstrated leadership regionally in space and maturity by remaining consistent over its diplomatic and foreign policies. In 2008, the UAE initiated the creation of a "Pan-Arab Space Agency as a civilian space agency, to provide Arab states with access to space," while reducing the collective costs of satellite operations.[130] Despite the lack of progress since its proposal, the UAE has maintained its interest to bring together Arab states to work on common objectives and goals. In 2019, a derivation of a regional space agency was founded in the form of the Arab Group for Space Collaboration. Chaired by the UAESA, the group is responsible for coordinating regional space efforts through joint projects and the sharing of knowledge.[131] In tandem, the UAE-led group revealed the development of an advanced Earth observation satellite—813, that

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[129] "Proposal by the United Arab Emirates - Long-Term Sustainability of Outer Space Activities," vol. 57, A/AC.105/C.1/2020/CRP (Committee on the Peaceful Uses of Outer Space - Scientific and Technical Subcommittee, UNOOSA, 2020), http://www.unoosa.org/res/oosadoc/data/documents/2020/aac_105c_12020crp/aac_105c_12020crp_10_0_html/AC105_C1_2020_CRP10E.pdf; and "Proposal on Voluntary Implementation Reporting Survey for the Guidelines Related to Long-Term Sustainability of Outer Space Activities," A/AC.105/C.1/2020/CRP (Committee on the Peaceful Uses of Outer Space - Scientific and Technical Subcommittee, UNOOSA, 2020), https://www.unoosa.org/res/oosadoc/data/documents/2020/aac_105c_12020crp/aac_105c_12020crp_12_0_html/AC105_C1_2020_CRP12E.pdf.

[130] Shaykhoun, Sonya. "Pan-Arab Space Agency: Pipe Dream or Real Possibility?" Via Satellite, last modified August 26, 2014. https://www.satellitetoday.com/uncategorized/2014/08/26/pan-arab-space-agency-pipe-dream-or-real-possibility/.

[131] Nasir Sarwat, "UAE Launches Arab Space Collaboration Group," *Khaleej Times*, last modified March 19, 2019, https://www.khaleejtimes.com/uae/uae-launches-arab-space-collaboration-group.

was funded by the UAESA. Projected to launch in 2024, it marks the first pan-Arab satellite to be designed and manufactured by Arab engineers from the founding countries, and where collected data would be shared with universities and institutions in the Arab world.[132] To date, the group has gathered 14 member states.[133] Underlying its intent to become the regional leader in space, the UAESA organizes the Global Space Congress annually, as a platform for industrial leaders to discuss initiatives relating to the development of the Middle Eastern space sector.[134]

Diplomatically, the UAE has been able to leverage space activities and collaboration to exert soft power at the international level, particularly regarding space exploration. The UAE has signed numerous bilateral cooperation agreements and partnerships with major space-faring nations, showing its broad diplomatic and commercial relations and keenness to consolidate ties with strategic partners and to promote international cooperation in the field of space to drive sustainability. The signing of a peace deal and cooperation agreement with Israel showed that it was willing to look beyond political tension, military conflicts, and other disputes, and displayed an ability to exert soft power using cooperation on common interests and concerns.

Domestically, the UAE has established itself as a credible space actor by developing indigenous space program and mounting space exploration missions. These successes reinforce its legitimacy as a rising space power and have distinguished itself from other competing space states.

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[132] Langton James, "New Pan-Arab Satellite '813' Named after the Arab World's Golden Era, "national news (UAE), accessed April 26, 2022, https://www.thenationalnews.com/uae/science/new-pan-arab-satellite-813-named-after-the-arab-world-s-golden-era-1.840802; and "813 Arab Satellite," Global Security Organization, accessed April 26, 2022, https://www.globalsecurity.org/space/world/uae/813.htm.

[133] The member states include Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Mauritania, Morocco, Oman, Saudi Arabia, Sudan, Tunisia, and the UAE. Iderawumi Mustapha, "Egypt Signs Arab Space Cooperation Group's Basic Charter," Space in Africa, last modified October 29, 2021, https://africanews.space/egypt-signs-arab-space-cooperation-groups-basic-charter/#:~:text=The%20Arab%20Space%20Cooperation%20Group%20is%20a%20regional%20space%2Dfocused,among%20the%2014%20member%20states.

[134] "Welcome to Global Space Congress," Global Space Congress, accessed April 13, 2022, https://www.globalspacecongress.com/.

III. CASE STUDY: LUXEMBOURG

A. SPACE ACTIVITIES OVERVIEW

Luxembourg is one of the smallest European countries with a population size of around 650,000. Despite being heavily constrained in its population and land area, and being landlocked, the small state was able to grow a strong financial sector and has recorded the "highest GDP per capita in the world" since 2015.[135] With fiscal support from the state government, Luxembourg started its space journey in 1985 by establishing Europe's first commercial satellite operator, Société Européenne des Satellites (SES). The successful launch of the SES's Astra 1A by French Ariane 4 in 1988 pioneered the distribution of commercial television and radio programs from geostationary satellites.[136]

The growth of SES's satellite fleet from a pan-European to global footprint spurred the growth of the national space sector—with many space startups and companies being created to support or provide satellite and terrestrial telecommunications products and services. To date, SES has commissioned 18 Luxembourg communications satellites in geostationary orbit; owns and operates over 70 satellites in the geostationary and medium Earth orbits,[137] and has become one of the leading geostationary telecommunication satellites operators by revenue, while the Luxembourg government remains a major shareholder.

Encouraged by this success, Luxembourg made a strategic decision to further develop its space sector aimed at diversifying its monolithic financial-sector-dependent economy, which accounted for approximately one-third of its GDP. Today, Luxembourg has a thriving space industry that contributes 2% to the nation's GDP and comprises over 50 companies and two public research organization that build solutions for the commercial exploration and

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[135] O'Neill Aaron, "Gross Domestic Product (GDP) per Capita in Luxembourg 2027," Statista, accessed May 24, 2022, https://www.statista.com/statistics/381064/gross-domestic-product-gdp-per-capita-in-luxembourg/.

[136] "SES - Our History Highlights," SES, accessed May 3, 2022, https://www.ses.com/about-us/our-history-highlights.

[137] "SES - Discover Our Global Coverage." SES. Accessed May 24, 2022. https://www.ses.com/our-coverage#/.

utilization of space resources, with approximately 800 personnel working in the roles of R&D, manufacturing, and operation.[138]

In parallel to the growth of its commercial sector, Luxembourg has taken steps in enhancing its credibility as a space-faring nation, while seeding growth opportunities for its space economy. Since 2000, Luxembourg has participated in the Advanced Research in TElecommunications Systems (ARTES) program of the ESA, which supported R&D in telecommunications and transferred technologies to commercial applications. In 2005, Luxembourg became the 17th member state of ESA, which provided R&D opportunities, access to the European space sector, and participation in a wider range of ESA space programs.

In 2008, Luxembourg issued the first iteration of its National Action Plan (NAP) for Space Science and Technology which outlined a roadmap around the space activities proposed to be undertaken by the civil and commercial sectors in the near term. A major institutional milestone was achieved when the Ministry of the Economy created the Luxembourg Space Agency (LSA) in 2018, with objectives including:

- Promote Luxembourg's commercial space sector by providing support to the space industry,
- Foster new and existing businesses,
- Develop human resources,
- Offer access to financial solutions, and
- Support academic learning and research.[139]

With the existence of LSA, the national space activities were further categorized into those undertaken and implemented as part of ESA, and other activities that fall under the responsibility of the LSA.

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138 "Business Sector - Space," Luxembourg Trade & Invest, accessed May 19, 2022, https://www.tradeandinvest.lu/business-sector/space/.

139 "Luxembourg Space Agency - A New Era for Space Development," Luxembourg Space Agency, accessed May 24, 2022, https://space-agency.public.lu/en/agency/lsa.html.

Amid major geopolitical shifts, complex and evolving security environment, Luxembourg has also released its first Spatial Defense Strategy in February 2022, which defines the long-term objectives and plans of the national security and defense sectors.

B. SPACE POLICY, STRATEGY, AND LAW

A quote by Etienne Scheider, Deputy Prime Minister, Minister of the Economy summarized the motivation and strategy of his country's activities in space: "For Luxembourg, the diversification of its economy is an everyday challenge. The space sector is one of the priority sectors that Luxembourg has constantly promoted since its entry into the space business more than 25 years ago. The efforts to put in place the necessary measures to support the continued strengthening of Luxembourg's space sector clearly demonstrate the long-lasting commitment of the government."[140]

For three decades, the growth of the national space sector is underpinned by expertise satellite communications, along with the supporting infrastructure, and has consistently generated almost 2% of the state's GDP since 2017.[141] While Luxembourg remains a leader in satellite communications, it has acknowledged growing competition by shifting its technology focus to pursuit of potential risky but lucrative new ventures. Driven by a continual need for economic diversification, the small state has in the past decade, combined the strength of its financial sector and its experience with satellite communications operations, to establish a global hub for space exploration activities, with an aim to commercialize space resources.

1. National Action Plan for Space Science and Technology

The fourth iteration of the NAP was issued in 2020 and serves as Luxembourg's national space strategy. While the NAP has expanded its scope to encompass a broader range

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[140] "Luxembourg Space Capabilities - Update 2016," Luxembourg Space Cluster, accessed May 3, 2022, http://www.innovation.public.lu/en/brochures-rapports/s/space-capabilities-2016/catalogue-space-2016.pdf.

[141] Sheetz Michael, "The Space Industry Is Now 2% of Luxembourg's GDP, Deputy Prime Minister Etienne Schneider Says," CNBC, last modified November 11, 2017, https://www.cnbc.com/2017/11/11/etienne-schneider-the-space-industry-is-now-2-percent-of-luxembourgs-gdp.html.

of space activities, the strategic objectives remain unchanged since its inception in 2008. The objectives include:

- Contribute to the diversification and sustainability of economic activities in Luxembourg,
- Consolidate and enhance existing skills and expertise in media and satellite communications services,
- Strengthen the competitiveness of companies and public research organizations in the space sector, and
- Develop skills and expertise in the space sector by enhancing the integration of Luxembourg players in international networks.[142]

To achieve these objectives, the NAP has committed funding and capacity to participate in the space programs at both ESA- and national-levels, in education and skills development, legal framework, and international cooperation to promote its standing as a "European hub for the development of [its] commercial industry." To this end, the NAP has announced a budget of $223 million over the period of 2020 to 2024, aimed at supporting the list of ESA mandatory and optional programs for civil applications, as well as national initiatives and bilateral and multilateral partnerships in space cooperation for defense and commercial applications.[143] Significantly, the allocated budget has remained consistent since the first iteration of NAP in 2008. To ensure continuing relevance, the NAP is revised every four years within the framework of ESA Ministerial Councils—a review of the budget and proposed activities is performed and communicated.

2. Space Resources Initiative of 2016

Building on its successful venture with SES, Luxembourg has been encouraged to invest into other emerging space activities that could strengthen its space economy. In 2016, the Ministry of Luxembourg launched the Space Resources Initiative or SpaceResources.lu,

[142] "National Action Plan (2020-2024)" (Ministry of the Economy, Luxembourg), accessed May 18, 2022, https://space-agency.public.lu/dam-assets/publications/2020/Luxembourg-space-action-plan-ENG-final-kw.pdf.

[143] Ibid., p. 50.

which presented the national space policy goals of: (1) generating new economic value; (2) increasing international collaboration; and (3) continuing SATCOM leadership.[144]

Significantly, the initiative highlighted exploring and utilizing space resources as Luxembourg's next big bet in space that could generate new economic value. To this end, Space Resources Initiative communicates:

> - Ensure national political support of the initiatives and promote international cooperation, including international agreements and participation in international forums,
> - Build an attractive legal and regulatory framework to encourage sector growth and responsible behavior,
> - Promote long-term workforce development by creating a pipeline of talent and expertise through public research and education,
> - Offer dedicated support for commercial R&D activities to remain competitive, and
> - Develop long-term financial instruments tailored to the needs of the commercial space sector.[145]

Through the Ministry of the Economy, Luxembourg has rolled out a range of national programs or financial resources to complement SpaceResources.lu: (1) LuxIMPULSE—budget to promote R&D and innovation, and help startups bring innovative ideas to market[146]; (2) Lux Young Graduate Trainees (LuxYGT)—budget to help graduates enter the training program of ESA[147]; and (3) budget to develop bi- or multi-lateral cooperation with space actors outside Luxembourg. Beyond these space-specific funds, the commercial sector can also tap the venture capital fund—Luxembourg Future Fund (LFF), which was launched

144 "SpaceResources.Lu - Vision, Goals, Challenges, Actions," United Nations - Office for Outer Space Affairs, accessed May 24, 2022, https://www.unoosa.org/documents/pdf/hlf/HLF2017/presentations/Day1/Session_1/Presentation3.pdf.

145 "SpaceResources.Lu Initiative - Pioneers in Space," Luxembourg Space Agency, accessed May 24, 2022, https://space-agency.public.lu/en/space-resources/the-initiative.html.

146 "National Programme - LuxIMPULSE and R&D Support," Luxembourg Space Agency, accessed May 21, 2022, https://space-agency.public.lu/en/funding/funding-space.html.

147 "Training - Luxembourg Young Graduate Trainee Programme," Luxembourg Space Agency, accessed May 21, 2022, https://space-agency.public.lu/en/talent/training.html.

and sponsored by the government in 2015 to simulate the "diversification and sustainable development" of its economy.[148]

Executed by the LSA and funded by Société Nationale de Crédit et d'Investissement (SNCI)—a public-law banking institution wholly state-owned, SpaceResources.lu has been supported well by flexible and wide-ranging funding mechanisms and has been the centerpiece driving numerous activities undertaken at the political, legal, and regulatory levels. Through these initiatives, Luxembourg has provided a conducive business environment that encourages the space sector to explore and use space resources for commercial purpose.[149]

3. National Space Law

As a founding member of the EU and UN, Luxembourg has aligned itself with the international legal framework issued by the UN's COPUOS. This includes binding instruments, such as international treaties, as well as non-binding instruments, such as the UN General Assembly Resolution. Except for the Moon Agreement, Luxembourg has been a long-standing signatory to the Treaty on the Peaceful Use of Outer Space (signed 1967), the Rescue and Return Agreement (signed 1968), and the Liability Convention (signed 1972); and most recently, the Space Objects Registration Convention (signed 2020), as well as the Artemis Accords (signed 2020).[150]

Governmental impetus to institutionalize forward-looking policy standards has allowed the Luxembourg's space sector to keep pace with changing technologies and business models, as well as with evolving space activities around the globe. To support and regulate the national space sector, the government has issued numerous national space laws that

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148 "Luxembourg Future Fund (LFF)," European Investment Fund, accessed May 21, 2022, https://www.eif.org/what_we_do/resources/lff/index.htm.

149 "SpaceResources.Lu Initiative - Pioneers in Space," Luxembourg Space Agency, accessed May 24, 2022, https://space-agency.public.lu/en/space-resources/the-initiative.html.

150 "Legal Framework - International Space Law," Luxembourg Space Agency, accessed May 21, 2022, https://space-agency.public.lu/en/agency/legal-framework.html; and "Luxembourg, NASA and Several Other Partner Countries Are among the First Signatories of the Artemis Accords," governement.lu, last modified October 14, 2020, https://gouvernement.lu/en/actualites/toutes_actualites/communiques/2020/10-octobre/14-luxembourg-nasa-artemis.html.

constitute the national legal framework: (1) Electronic Media Law of 1991 to facilitate the distribution of content through electronic communications networks; (2) Frequency Bands Law of 2005 to organize and manage frequency bands; (3) Space Resources Law of 2017 following the launch of the SpaceResource.lu initiative stating that "space resources are capable of being appropriated" and that resembles the model established in 2015 by the U.S. Space Act; and (4) Space Activities Law of 2020 to authorize and supervise all national space activities not yet covered by existing space laws.[151] The Ministry of the Economy and LSA has been tasked with authorizing, supervising, and supporting national space activities and has assumed responsibility for the authorization procedure set forth within the national legal framework.

Significantly, the enactment of the Space Resources Law offered a legal and regulatory framework and clarified its position in appropriating space resources for commercial purposes.[152] Contrary to the U.S. Space Act, the Space Resources Law and the Space Activities Law do not impose restriction on the nationality of the shareholders or associates provided that sound and prudent operations can be guaranteed.[153] As a non-signatory to the Moon Agreement, Luxembourg is not subjected to restriction such as "an equitable sharing by all States Parties in the benefits derived from [natural resources of the moon]."[154]

Significantly, a focus on authorizing, supporting, and monitoring space exploration activities has helped conceive a safe and business-friendly environment. This has been an

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[151] Calmes, Bob, Laurent Schummer, and Gladysz-Lehmann. "The Space Law Review: Luxembourg." The Space Law Review, last modified December 9, 2021. https://www.lexology.com/library/detail.aspx?g=0f7921ae-9ebf-41c7-8221-17cf0cac707a.

[152] Graas, Jacques. "Luxembourg Space Resources Act: Paving the Legal Road to Space." Allen & Overy, last modified September 28, 2017. https://www.allenovery.com/en-gb/global/news-and-insights/publications/luxembourg-space-resources-act-paving-the-legal-road-to-space.

[153] legilux.public.lu. "Law of July 20, 2017, on the Exploration and Use of Space Resources.," last modified July 14, 2017. https://legilux.public.lu/eli/etat/leg/loi/2017/07/20/a674/jo; and "Legal Framework - Law on Space Resources," Luxembourg Space Agency, accessed May 21, 2022, https://space-agency.public.lu/en/agency/legal-framework.html.

[154] "Agreement Governing the Activities of States on the Moon and Other Celestial Bodies," United Nations - Office for Outer Space Affairs, accessed July 29, 2022. https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/moon-agreement.html.

invaluable tool to foster the growth of a dynamic and competitive national space sector and has reinforced its position as the "commercial space hub for Europe."[155]

4. Defense Space Strategy of 2022

Against a security environment that is radically changing, the Deputy Prime Minister and Minister of Defense François Bausch presented Luxembourg's first Spatial Defense Strategy on 28 Feb 2022 by stating, "space has become an increasingly contested, competitive and congested environment, and along with cyber defense, has become a real national security issue." He added, "in the space field, Luxembourg can have an impact and make its fair contribution to the overall effort in terms of security and defense."[156]

Also known as the Defense Space Strategy (DSS) of 2022, it defines Luxembourg's long-term objectives and action plans that the national security and defense sectors would work on executing until 2030. Central to the strategy is the aim to boost Luxembourg's role as a reliable reference partner in the field of space at both the national and international levels. To this end, the DSS specifies strategic objectives that include: (1) consolidating current space capabilities, increasing their resilience, and developing new systems; (2) supporting freedom of action in and from space; (3) fostering national and international cooperation; and (4) attracting and securing a skilled and motivated workforce in the defense sector.[157] Beyond serving its domestic interests—e.g., to safeguard economic development opportunities in space, the DSS also reviews and aligns itself with relevant strategies and approaches of NATO and EU—i.e., NATO's Approach to Space[158] and the EU's Strategic Compass for Security

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155 Trade&Invest.lu. "Commercial Space Hub for Europe," last modified June 24, 2021. https://www.tradeandinvest.lu/news/commercial-space-hub-for-europe/.

156 "Luxembourg Presents First Spatial Defence Strategy," Chronicle.lu, last modified March 1, 2022, https://chronicle.lu/category/at-home/39844-luxembourg-presents-first-spatial-defence-strategy.

157 "Defence Space Strategy 2022," Directorate of Defense - Luxembourg, last modified February 1, 2022, https://gouvernement.lu/dam-assets/documents/actualites/2022/02-fevrier/28-bausch-strategie-spatiale-defense/32022-0012-Strategie-spatiale-EN-24p-WEB.pdf.

158 "NATO's Approach to Space," NATO, last modified December 2, 2021, https://www.nato.int/cps/en/natohq/topics_175419.htm.

and Defense.[159] Common to these strategies is the acknowledgement of "space as a new operational domain" and the increased importance attached to the field of space as a new frontier for defense and crisis response.

C. ANALYSIS OF SPACE STRATEGY

While government-directed and controlled space activities are the norm, the space sector development of Luxembourg has exhibited a non-traditional approach that is driven by the resource constraints inherent to a small state. Luxembourg has focused on encouraging commercial space activities through favorable fiscal and legal policies, with national initiatives typically undertaken to attract and support private space companies, while civil and defense space activities have typically been undertaken and implemented as part of ESA.

1. Civil Sector

Luxembourg's civil sector is driven by motivations of guarding its national interests and being a responsible and respected regional (EU/ESA) and international (NATO) space actor. Consequently, its civil space activities have predominantly been undertaken at the regional level and through ESA's initiatives in ensuring the "long-term availability of worldwide uninterrupted access to secure and cost-effective satellite services" for its member states and national public agencies.[160]

Through a range of funding mechanisms, Luxembourg has made sustained contributions to European space programs, by supporting technology development and developing space-based products, services, and infrastructures. Between the period of 2016 to 2020, Luxembourg has contributed $130 million through the NAP; $120 million through LuxIMPULSE; and an undisclosed amount through SpaceResources.lu, which has undertaken activities at the political, legal, and regulatory levels to advance the maturity of

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159 "A Strategic Compass for a Stronger EU Security and Defence in the next Decade," Council of the European Union, last modified March 21, 2022, https://www.consilium.europa.eu/en/press/press-releases/2022/03/21/a-strategic-compass-for-a-stronger-eu-security-and-defence-in-the-next-decade/.

160 European Commission. "Space: EU Initiates a Satellite-Based Connectivity System and Boosts Action on Management of Space Traffic for a More Digital and Resilient Europe," last modified February 15, 2022. https://ec.europa.eu/commission/presscorner/detail/en/IP_22_921.

space exploration and in utilizing space resources.[161] Moving forward, Luxembourg has made new financial commitments in the NAP for 2020 to 2024, which would see an increase in contributions to ESA to $210 million.[162]

In the past decade, Luxembourg has participated in a series of ESA space programs, such as the GALILEO Global Navigation Satellite System (GNSS) for Positioning, Navigation and Timing (PNT), Copernicus for Earth observation using the Sentinel satellites, the EU Space Surveillance and Tracking for SSA, GOVSATCOM for satellite communication services, and European Exploration Envelope (E3P) program to launch human and robotic exploration missions. The allocation of finances towards at the European level has allowed Luxembourg to gain access to technology that is beyond its national capabilities: specifically, capabilities with high specificities and entrance barriers. Access to the regional market has benefited the growth of its commercial sector—Luxembourg companies were awarded an aggregated $530 million by ESA, over the period of 2014–2018.[163] Significantly, the dual-use nature of these capabilities has also benefited Luxembourg's defense sector in the applications of PNT, SATCOM, Earth observation, and SSA.

Domestically, the LSA has initiated national programs, such as the EarthLab Luxembourg and LSA Data Center, to facilitate fast and reliable access and the use of artificial intelligence on space data. Significantly, the launch of LSA Data Center in 2019 has created a central repository, allowing downstream sectors, such as agriculture, to search, discover, and access imagery data products from the Sentinel constellation of ESA's Copernicus program.

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[161] National Action Plan (2020-2024), 7–8

[162] "Luxembourg to Contribute €198.5m to ESA in New Space Science, Technology National Action Plan," Chronicle.lu, last modified January 17, 2020, https://chronicle.lu/category/space/31534-luxembourg-to-contribute-eur198-5m-to-esa-as-part-of-new-space-science-technology-national-action-plan.

[163] National Action Plan (2020-2024), 30.

2. Commercial Sector

The launch of SpaceResource.lu in 2016 provided a framework that has guided the commercial space activities of Luxembourg. Having identified space resources as a key growth area, Luxembourg has leveraged mechanisms such as public-private cooperation and strategic co-funding to unlock the vast potential of the space resources market. To this end, it has also regarded the EU as an integral part of its space sector, where its involvement in regional initiatives would provide new opportunities for Luxembourg's commercial space sector.

In mid-2016, Luxembourg entered into private-public joint ventures with U.S.-based asteroid mining startups, Deep Space Industries[164] and Planetary Resources, Inc,[165] aimed at commercializing "return to Earth"[166] applications such as asteroids. Through MoUs, Luxembourg has co-funded relevant R&D projects in this field. In return, the industry leaders have brought key activities, such as space hardware development, space services, applied R&D, into Luxembourg, thereby accelerating the growth of its commercial sector. Through the SNCI, Luxembourg leveraged strategic co-funding by taking a major stake (at $26 million) and becoming a shareholder of Planetary Resources, Inc.[167] Despite the eventual decline of both companies, the Luxembourg government persisted in this high-risk venture by shifting its focus from "return to Earth" applications into building "use in space" applications. Mechanism-wise, it has also expanded beyond private-public ventures to pursue space cooperation with major and emerging space actors that have shown an interest in exploring and utilizing space resources. This coincided with the creation of the LSA in 2018.

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164 "Luxembourg Government and Deep Space Industries Sign Memorandum of Understanding for the Exploration and Use of Space Resources," SpaceResource.lu, last modified May 5, 2016, https://space-agency.public.lu/dam-assets/press-release/2016/2016_05_05PressReleaseMoUDSIand.pdf.

165 "Luxembourg Government and Planetary Resources Sign MoU to Develop Activities Related to Space Resource Utilization," SpaceResource.lu, last modified June 13, 2016, https://space-agency.public.lu/dam-assets/press-release/2016/2016_05_13PressReleaseMoUPR-LuxGvt.pdf.

166 Application focused on mining metals from asteroids with the goal of selling them back on Earth.

167 "SpaceResources.Lu: The Luxembourg Government Becomes a Key Shareholder of Planetary Resources, Inc., the U.S.-Based Asteroid Mining Company," SpaceResource.lu, last modified November 3, 2016, https://space-agency.public.lu/dam-assets/press-release/2016/2016_11_03PlanetaryResourcesAgreement.pdf.

Unlike traditional space agencies, the LSA was founded on the principle of promoting the growth of the Luxembourg's commercial space sector and not orchestrating the entirety of Luxembourg's space activities. To this end, the LSA acts as a one-stop-shop "in all matters related to the development of the space sector," by providing fiscal support for business-keen space ventures and guidance in navigating the national legal and regulatory framework, and in accessing R&D grants and funding.[168]

The agency was able to perform its role without distractions from non-commercial space activities, such as conducting space science research, building indigenous spacecraft, and launching human spaceflight missions. To this end, the LSA engages in activities such as seeking new partnerships with foreign space companies, fostering deeper partnerships between Luxembourg-based space companies, with academia and research center, and with international financial organizations. These activities are often regarded as secondary to a traditional space agency.

Facilitated by LSA, Luxembourg has taken a stake as well as funded the R&D activities of numerous foreign space companies. Since 2018, it has committed $126 million into U.S.-based Spire Global,[169] $40 million into Canadian-based NorthStar Earth & Space, and substantially into Finland-based ICEYE,[170] and have become a major stakeholder in these companies. It has also provided R&D opportunities to Denmark-based GomSpace,

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[168] "Luxembourg Space Agency - A New Era for Space Development," Luxembourg Space Agency accessed May 24, 2022. https://space-agency.public.lu/en/agency/lsa.html.

[169] "Luxembourg Government and Spire Global Signed Cooperation Agreement to Open a European HQ in the Grand Duchy," SpaceResource.lu, last modified November 15, 2017, https://space-agency.public.lu/dam-assets/press-release/2017/2017-11-15-press-releas-spire.pdf; and "Luxembourg Future Fund Held Its Annual General Meeting on 29 September 2020," Luxembourg Future Fund, last modified September 29, 2020, https://www.snci.lu/files/99229.pdf.

[170] Werner Debra, "Iceye Raises $87 Million in Series C Investment Round," SpaceNews, last modified September 22, 2020, https://spacenews.com/iceye-series-c-round/.

Japan-based ispace.inc,[171] and U.S.-based Made In Space, Inc, Hydrosat, and CubeRover.[172] It is expected to continue seeking new partnerships with both private and public space actors through MoUs and fundings from LFF and LuxIMPULSE. Consistent in its approach, these agreements have led to companies registering their businesses in Luxembourg, the opening of Luxembourg-based European HQs, and bringing the associated key activities—e.g., space platform engineering, space data analytics, space infrastructure engineering into Luxembourg. This have benefited the commercial sector with contracts and job opportunities that, ultimately, have accelerated the growth of its space economy.

Significantly, NorthStar Earth & Space has established a Luxembourg-based "center of excellence for SSA" that will focus on developing a high-performance and unique space-based commercial object-tracking services.[173] ICEYE, the largest commercial synthetic-aperture radar (SAR) microsatellite operator has announced the opening of a "Machine Learning Center of Excellence" in Luxembourg that will focus on proliferating the use of "machine learning and artificial intelligence for SAR and Earth observation technologies."[174] Thales Alenia Space has opened a "Digital Center of Excellence" in Luxembourg, that will focus on developing "highly innovative digital solutions for the company's space

171 "Luxembourg and Ispace, a Tokyo-Based Lunar Robotic Exploration Company, Sign MoU to Co-Operate within the SpaceResources.Lu Initiative," SpaceResource.lu, last modified March 2, 2017, https://space-agency.public.lu/dam-assets/press-release/2017/2017_03_02Pressrelease-MoU-iSpace-Lux-Gvt.pdf.

172 "Three U.S. Space Companies Choose Luxembourg to Implement Activities in Europe," Luxembourg Space Agency, last modified September 27, 2018, https://space-agency.public.lu/dam-assets/press-release/2018/2018-09-27-Three-US-space-companies-choose-Luxembourg-to-implement-activities-in-Europe.pdf.

173 Rainbow Jason, "NorthStar Expanding to Luxembourg after $45 Million Funding Round," SpaceNews, last modified December 23, 2021, https://spacenews.com/northstar-expanding-to-luxembourg-after-45-million-funding-round/; and "Luxembourg Invests in NorthStar Earth & Space That Establishes Its European Headquarters in the Grand Duchy to Support Sustainable Space Activities," Luxembourg Space Agency, last modified December 17, 2021, https://space-agency.public.lu/en/news-media/news/2021/NorthStar.html.

174 "ICEYE Opens New Office and Machine Learning Center of Excellence in Luxembourg," ICEYE, last modified December 2, 2021, https://www.iceye.com/press/press-releases/iceye-opens-new-office-and-machine-learning-center-of-excellence-in-luxembourg.

communications, observation, and navigation products."[175] The LuxIMPULSE program has been effective in facilitating partnerships between the domestic space industry with major space contractors in the region. In particular, the projects carried out with Thales Alenia Space have helped seed the growth of local supplier companies, such as Euro-Composites, GRADEL, and HITEC Luxembourg.[176]

The LSA has been equally successful in pursuing cooperation with the public space actor. In November 2020, the LSA entered into a strategic partnership with ESA and the Luxembourg Institute of Science and Technology (LIST) to create the European Space Resources Innovation Center (ESRIC), marking an important milestone in its bid to become a "hub of excellence for space resources in Europe." Based within the LIST, the center aims at becoming an "internationally recognized centre of expertise for scientific, technical, business, and economic aspects related to the use of space resources for human and robotic exploration, as well as for the future space economy."[177] To this end, it will partner with "public and private international players" to amalgamate the excellence of public research and its facilities, with the efficiency of the private sector.[178]

In 2021, the ESRIC launched the Start-up Support Program (SSP) as the first global program dedicated to space resources that facilitates collaboration with space ventures and start-ups to develop "business models targeting space resources utilization."[179] Such partnership has supported national initiatives and Luxembourg-based startups by offering

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175 "Thales Alenia Space Creates Digital Center of Excellence in Luxembourg and Expands Its European Footprint," Thales Group, last modified September 1, 2022, https://www.thalesgroup.com/en/worldwide/space/press-release/thales-alenia-space-creates-digital-center-excellence-luxembourg-and.

176 National Action Plan (2020-2024), 13.

177 "Welcome to the European Space Resources Innovation Centre," esric.lu, accessed July 29, 2022. https://www.esric.lu/.

178 "Luxembourg Teams up with ESA to Create a Unique 'European Space Resources Innovation Centre' to Be Established in the Grand Duchy," governement.lu, last modified November 18, 2020, https://gouvernement.lu/en/actualites/toutes_actualites/communiques/2020/11-novembre/18-luxembourg-spaceresources.html.

179 "European Space Resources Innovation Centre (ESRIC) Launches the World's First Start-up Support Programme Dedicated to Space Resources.," esric.lu, last modified October 26, 2021, https://space-agency.public.lu/dam-assets/press-release/2021/EN-ESRIC-SSP-final.pdf.

mechanisms for business incubation and technology transfer. Complemented by SpaceResource.lu, the launch of the SSP has reinforced Luxembourg's commercial sector as a pioneer in the field as it seeks needed technological breakthroughs.

3. National Security Sector

Due to its "smallness" and limited military capacity, Luxembourg has considered cooperation with partners and the maintenance of a stable national and international security environment as strategic priorities.[180] To this end, it has adopted a foreign policy that combines diplomacy, development cooperation, defense (3D), and has portrayed itself as a country of peace and multilateralism that respects a rule-based system of international affairs. Being a member state of EU and NATO, Luxembourg's government has accepted that its territorial integrity depends on the security of its neighbors, of the EU and NATO, and global stability. Consequently, Luxembourg has not pursued a traditional build-up of a military forces; instead, it seeks to contribute to the collective defense capabilities of its allies through cooperative development and the provision of aid.

In practical terms, the 3D approach suggests that Luxembourg will spend more of its resources providing development aid over building its national defense capability and will forge diplomatic partnership as leverage to prevent conflicts. Hence, defense has not been a priority for Luxembourg, whose defense spending stands at 0.65 percent of its GDP or approximately $460 million and was the lowest in NATO in 2021.[181] Specific to NATO's defense, Luxembourg contributed $16 million, which was equivalent to 3 percent of its defense budget. Considering renewed challenges to the security of NATO and the EU, Luxembourg announced plans to increase its defense budget to become 0.72 percent of its

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[180] "Luxembourg Defence Guidelines for 2025 and Beyond," Directorate of Defense - Luxembourg, last modified July 12, 2017, https://chronicle.lu/category/at-home/22632-luxembourg-defence-guidelines-for-2025-and-beyond-revealed.

[181] "Defence Expenditure of NATO Countries (2014-2021)" NATO, last modified March 31, 2022, https://www.nato.int/nato_static_fl2014/assets/pdf/2022/3/pdf/220331-def-exp-2021-en.pdf; and Hoffmann Diana, "Luxembourg to Increase Defence Budget by €100 Million," RTL Today, last modified March 29, 2022, https://today.rtl.lu/news/luxembourg/a/1889326.html#:~:text=At%20the%20moment%2C%20the%20defence,rate%20will%20increase%20to%200.72%25.

GDP or approximately $590 million by 2024, but it is set to fall significantly short of NATO's guidelines to work towards spending 2 percent of GDP on defense by 2024.[182]

Despite criticisms from NATO members and especially the United States to "up its game" on defense spending, Luxembourg has remained resolute against excessive spending to build up a traditional defense force. In response, Minister of Defense François Bausch made clear that while Luxembourg would "significantly increase" its defense budget, there was no intention to comply with NATO's guideline of committing 2 percent of the country's GDP to defense spending, saying "we have to keep our feet on the ground and invest in projects that make sense for our country." He explained that "2 percent of GDP on defense is neither realistic nor doable" for Luxembourg, given its huge economy compared to a small army of around 1,000 active soldiers. Instead, Luxembourg would look to develop activities it has the capacity to manage in existing areas, such as intelligence and reconnaissance, space, and cybersecurity.[183] This intent has been ingrained in the DSS of 2022, which articulated a strategy that is centered on: (1) leveraging Luxembourg's niche in space as an opportunity to make a global impact; (2) investing in capabilities that have global effect; and (3) developing new capabilities through participating in international programs aimed at cooperative development and system sharing.

Specifically, the DSS has articulated goals to develop space capabilities and capacities in the main categories of SATCOM, Earth observation, SSA, and PNT, through national-level programs or in cooperation with NATO/EU partners, and by strengthening the resilience of these capabilities. These capabilities will serve not just its domestic needs, but also contribute to international organizations and allied countries, thereby consolidating its role as a reliable reference partner in the field of space by 2030. Under the authority of the Minister of Defense, the Directorate of Defense and the Luxembourg Armed Forces are responsible for coordinating and implementing the DSS at both the national and international levels.

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[182] Yannick Lambert, "Luxembourg to Double Defence Spending by 2028," Luxembourg Times, last modified June 24, 2022. https://www.luxtimes.lu/en/luxembourg/luxembourg-to-increase-defence-spending-by-2028-62b5739cde135b9236c55bc6.

[183] Schnuer Cordula, "US Asks Luxembourg to 'up the Game' on Defence Spending," DELANO, last modified March 31, 2022, https://delano.lu/article/us-asks-luxembourg-to-up-the-g.

For SATCOM capability, defense has leveraged its long history and expertise in providing SATCOM services to also include secure and resilient communications for national security applications. Since February 2015, the Luxembourg government has partnered with Luxembourg-based, SES, in a private-public venture, LUXGOVSAT, to own and operate satellites dedicated to national security and defense applications. LUXGOVSAT has since launched the SES-16/GovSat-1 in January 2018, to provide X-band and military Ka-band coverage over Europe, the Middle East, and Africa. In support of its NATO obligations, defense has also pre-committed a significant amount of the satellite capacity, while providing the remaining capacity to governmental and institutional users.[184] As a joint participant, it has partially funded the U.S.-operated Wideband Global SATCOM (WGS-9) program in exchange for military broadband communications since 2017.[185] In March 2022, the existing WGS partners (including Luxembourg) entered into discussions with U.S. officials to explore cost-sharing of the proposed WGS-11+. The WGS satellite is currently being developed by Boeing and would be procured through the National Security Space Launch program by U.S. Space Force and projected for launch in 2024.[186]

For Earth observation capability, the government legislated the creation of the Luxembourg Earth Observation System (LUXEOSys) program in August 2018, which authorized defense to acquire, own, and operate an Earth observation satellite and its ground segment for national security and defense applications. Initially budgeted for $180 million, the program received additional funding of $325 million in October 2021, constituting a significant portion of Luxembourg's defense spending.[187] Also known as the National

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184 "SES Orders New Satellites in Joint Venture with Luxembourg," SES, last modified February 16, 2015, https://www.ses.com/press-release/ses-orders-new-satellite-joint-venture-luxembourg.

185 "Air Force Ready to Launch Ninth WGS Satellite," United States Space Force, last modified March 17, 2017, https://www.losangeles.spaceforce.mil/News/Article-Display/Article/1122557/air-force-ready-to-launch-ninth-wgs-satellite/; and "Selected Acquisition Report - Wideband Global SATCOM," last modified December 1, 2018, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2018_SARS/19-F-1098_DOC_86_WGS_SAR_Dec_2018.pdf.

186 Erwin Sandra, "U.S. and International Partners to Share Launch Cost of New Communications Satellite," SpaceNews, February 22, 2022, https://spacenews.com/u-s-and-international-partners-to-share-launch-cost-of-new-communications-satellite/.

187 Schnuer Cordula, "Military Satellite on Track after Budget Snafu," DELANO, last modified October 12, 2022, https://delano.lu/article/military-satellite-on-track-af.

Advanced Optical System, the satellite is being built by defense and space manufacturer OHB Italia and scheduled for launch in 2023. The sun-synchronous satellite is designed to carry a panchromatic and multispectral payload that could provide more than 100 images at a ground resolution of 0.5 m daily.[188] In tandem, an operational center would be established to pilot the satellite and to manage image requests and production. Defense is also studying the development of an imagery analysis center to process and produce imagery data products from LUXEOSys, as well as airborne systems, such as UAVs.[189] Through these capabilities and infrastructure, defense intends to participate more actively in the efforts of NATO and the EU. Like the GovSat-1, Luxembourg has pre-committed a significant amount of capacity to NATO, the UN, as well as other allies.[190]

For PNT capability, defense has articulated the use of and access to satellite based PNT services as essential for most of its activities. As a member state of the EU and ESA, it has participated in and funded the GALILEO GNSS program that turned operational in 2016. Driven by the dependency risk on U.S.'s and Russia's GNSS, need for better coverage at high latitudes over northern Europe, and economic incentives, GALILEO was primarily designed and intended for civilian and commercial usage. It was subsequently approved by the European parliament in July 2008 for defense application. Due to its dual-use nature, the European parliament "aims to create a space surveillance system to watch out for space debris and other [security] threats, for example, monitoring the proliferation of weapons of mass destruction," thereby allowing member states secure, independent, and sustainable access to space.[191]

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[188] Pultarova Tereza, "Luxembourg Eyes Earth-Observation Satellite for Military and Government," SpaceNews, last modified November 7, 2017, https://spacenews.com/luxembourg-eyes-earth-observation-satellite-for-military-and-government/.

[189] Directorate of Defense—Luxembourg, "Defence Space Strategy 2022," 14

[190] "LUXEOSys Satellite Project on 'Right Track,'" Chronicle.lu, last modified October 12, 2021, https://chronicle.lu/category/satellite/37993-luxeosys-satellite-project-on-right-track.

[191] "European Parliament Approves Military Use of Galileo Satellite," DW, last modified July 10, 2008, https://www.dw.com/en/european-parliament-approves-military-use-of-galileo-satellite/a-3474226.

For SSA capability, defense has acknowledged space as an operational domain that has become more congested, contested, and competitive. Hence, there is a need to develop new capability to detect, characterize, and determine the trajectory of orbital objects for collision avoidance, as well as to prevent the potential threats of anti-satellite capabilities. Defense aims to strengthen the resiliency of its strategic space capabilities as well as contribute to the collective security of its allies and partners. To end this, defense has signed a joint statement with NATO to fund and develop a $7 million Strategic Space Situation Awareness System that supports NATO's Space Situation Center.[192] Domestically, defense has announced plans to put in place ground- and space-based sensors to detect a wide range of threats and ensure the detection of all objects down to 10 cm in size and is poised to benefit from the commercial sector's investment into developing space-based SSA capabilities.[193]

4. Space Cooperation and Diplomacy

Since 2016, Luxembourg has entered into numerous bilateral agreements with major space actors, namely Japan,[194] China,[195] Russia,[196] the United States, ESA,[197] and European states, such as France and Italy. Reflecting its policy goals, Luxembourg has

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[192] "NATO and Luxembourg Boost Alliance Space Situational Awareness," NATO, last modified June 15, 2021, https://www.nato.int/cps/en/natohq/news_185365.htm; and Schnuer Cordula, "Bausch Signs €6.7m Deal on Nato Space Project," DELANO, last modified June 16, 2021, https://delano.lu/article/delano_bausch-signs-eu67m-deal-nato-space-project.

[193] Directorate of Defense - Luxembourg, "Defence Space Strategy 2022," 14

[194] "Luxembourg and Japan Agree to Cooperate on Exploration and Commercial Utilization of Space Resources," SpaceResource.lu, last modified November 29, 2017, https://space-agency.public.lu/dam-assets/press-release/2017/2017-11-29-press-release-mou-japan-space.pdf.

[195] "Luxembourg Cooperates with China in the Exploration and Use of Outer Space for Peaceful Purpose, Including in the Utilization of Space Resources," SpaceResource.lu, last modified January 17, 2018, https://space-agency.public.lu/dam-assets/press-release/2018/2018-01-17-press-release-cooperation-china-luxembourg.pdf.

[196] "Luxembourg Agreed to Cooperate with Russia on Space Resources," Trade&Invest.lu, last modified February 15, 2018, https://www.tradeandinvest.lu/news/luxembourg-agreed-cooperate-russia-space-resources/.

[197] "Luxembourg Teams up with ESA to Create a Unique 'European Space Resources Innovation Centre' to Be Established in the Grand Duchy," gouvernement.lu, last modified November 18, 2020, https://gouvernement.lu/en/actualites/toutes_actualites/communiques/2020/11-novembre/18-luxembourg-spaceresources.html.

pursued space development cooperation with a diverse range of space powers, without being constrained as a member state of the EU and NATO. Beyond major space actors, it has entered into agreements with small or emerging space states, such as Portugal, the UAE, Poland,[198] the Czech Republic,[199] and Belgium.[200] Central to each agreement is a commitment to strengthen cooperative development on scientific and technological projects and the global rules over exploring and utilizing of space resources. Such agreements have conceived Luxembourg-based R&D centers, such as China's Research Laboratory of Deep Space Exploration and ESA's ESRIC. Significantly, the establishment of ESRIC has since attracted French Space Agency, Centre National D'Etudes Spatiales (CNES), and French-based and world leader in oil and gas industry, Air Liquide, Airbus Defense and Space, as research partners to develop R&D activities encompassing "space exploration and in-situ space resource utilization."[201]

As a member state of UNOOSA, Luxembourg has participated actively in COPUOS, and especially with "the 'Space2030' Agenda: space as a driver of sustainable development." In 2019, Luxembourg signed an agreement to fund UNOOSA's "Space Law for New Space Actors" project, with objectives to increase national adherence to the standing UN legal framework and international space law governing outer space activities, while promoting the sustainability of outer space activities. This underlines the importance of space-based activities to UNOOSA's SDGs and provides Luxembourg opportunities to

198 "Luxembourg and Poland Sign Cooperation Agreement for Space Activities," Trade&Invest.lu, last modified October 29, 2018, https://www.tradeandinvest.lu/news/luxembourg-and-poland-sign-cooperation-agreement-for-space-activities/.

199 "Luxembourg and the Czech Republic Cooperate in the Frame of Space Resources Exploration and Utilization," Luxembourg Space Agency, last modified October 10, 2018, https://space-agency.public.lu/dam-assets/press-release/2018/2018-10-10-Press-release-MoU-Czech-Lux-FINAL.pdf.

200 "The Grand Duchy of Luxembourg and Belgium Join Forces to Develop the Exploration and Utilisation of Space Resources," gouvernement.lu, last modified January 23, 2019, https://gouvernement.lu/en/actualites/toutes_actualites/communiques/2019/01-janvier/23-schneider-ressources-espace.html.

201 "France-Luxembourg Space Cooperation Quadripartitie Agreement to Focus on Exploration and Space Resources," esric.lu, last modified July 13, 2021, https://www.esric.lu/news/france-luxembourg-space-cooperation-quadripartite-agreement-to-focus-on-exploration-and-space-resources; and "European Space Resources Innovation Centre (ESRIC) and Airbus Defence and Space to Collaborate on Lunar Resources Extraction Technologies.," esric.lu, last modified October 26, 2021, https://space-agency.public.lu/dam-assets/press-release/2021/EN-ESRIC-AIRBUS-MoU-final.pdf.

build tailored capacity and capability that supports new and emerging space-faring states in conforming with international space law.[202] Collectively, this has helped the United Nations to intervenes and governs the conduct of national space activities from the onset.

Convened by the Hague Institute for Global Justice, Luxembourg has been an active participant in the "Hague International Space Resources Governance Working Group," since 2016. The working group leads an international effort in addressing legal issues related to space mining, and has been attended by industrial leaders, scientists, diplomats, as well as political and legal expertise from across the globe to identify and formulate "building blocks as the basis for a future international framework for the peaceful exploration and use of space resources."[203] Significantly, Luxembourg funded and hosted the second phase of the meetings that conceived a list a "20 legal building blocks" for consideration as the international community draws up a new international legal model capable of governing the exploitation of space resources.[204] Luxembourg has since been an active lobbyist on the topic of governance of space resource activities by facilitating the exchange of information and expertise. In 2022, it submitted in quick succession to COPUOS a working paper seeking endorsement of the "Work Plan for the Working Group on the Long-term Sustainability of Outer Space Activities on Potential Legal Models for Activities in the Exploration, Exploitation, and Utilization of space resources"; a proposal to establish a "Dedicated International Conference on Space Resources under the Auspices of the UN," as a platform to involve all relevant stakeholder in both public and private sectors to exchange achievements, future plans, opportunities and challenges to the

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202 "United Nations Office for Outer Space Affairs Signed an Agreement with the Government of Luxembourg to Launch New 'Space Law for New Space Actors' Project," United Nations - Office for Outer Space Affairs, last modified November 13, 2019, https://www.unoosa.org/oosa/en/informationfor/media/2019-unis-os-523.html.

203 "The Hague Space Resources Governance Working Group," vol. 18, A/AC.105/C.2/2018/CRP.18 (Committee on the Peaceful Uses of Outer Space - Legal Subcommittee, UNOOSA, 2018), https://www.unoosa.org/res/oosadoc/data/documents/2018/aac_105c_22018crp/aac_105c_22018crp_18_0_html/AC105_C2_2018_CRP18E.pdf.

204 "Final Building Blocks Released by Hague International Space Resources Governance Working Group," Secure World Foundation, last modified November 13, 2019, https://swfound.org/news/all-news/2019/11/final-building-blocks-released-by-hague-international-space-resources-governance-working-group.

envisaged space resource activities[205]; and a commentary for the "Building Blocks for the Development of an International Framework for the Governance of Space Resource Activities," designed to clarify the content of each building block and to reflect on agreed provisions and suggestions.[206]

Since the establishment of LSA in 2018, Luxembourg has aggressively pursued space cooperation with major as well as emerging space actors. The LSA has effectively made use of events held in Luxembourg (e.g., NewSpace Europe conference, Space Resources Week, and the Space Forum) to invite partnering countries and has facilitated the sharing of their respective policies and fostered the future development of their space sectors. However, unlike many national space actors, the LSA does not function as an overarching national space authority. Instead, Luxembourg has adopted a decentralized approach to foster and pursue international cooperation, where the ministry-in-charge represents and advances the interests of the respective space sectors. This was evident in its cooperation with the United States, where the Ministry of the Economy signed a space cooperation agreement in May 2019 to collaborate across a wide range of applications, from space exploration and scientific research, to SSA and space resources[207]; while the Ministry of Defense has recently announced potential cooperation with the U.S. Space Force to boost the resilience of space infrastructure and to access new innovative

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205 "Working Paper on the Endorsement of the Work Plan for the Working Group Established under the Legal Subcommittee Agenda Entitled 'General Exchange of Views on Potential Legal Models for Activities in the Exploration, Exploitation, and Utilization of Space Resources' and Proposals for a Dedicated International Conference on Space Resources under the Auspices of the United Nations," vol. 22, A/AC.105/C.2/2022/CRP.21 (Committee on the Peaceful Uses of Outer Space - Legal Subcommittee, UNOOSA, 2022), https://www.unoosa.org/res/oosadoc/data/documents/2022/aac_105c_22022crp/aac_105c_22022crp_21_0_html/AAC105_C2_2022_CRP21E.pdf.

206 "Building Blocks for the Development of an International Framework for the Governance of Space Resource Activities: A Commentary," vol. 22, A/AC.105/C.2/2022/CRP.23 (Committee on the Peaceful Uses of Outer Space - Legal Subcommittee, UNOOSA, 2022), https://www.unoosa.org/res/oosadoc/data/documents/2022/aac_105c_22022crp/aac_105c_22022crp_23_0_html/AAC105_C2_2022_CRP23E.pdf.

207 Foust Jeff, "United States and Luxembourg Sign Space Cooperation Agreement," SpaceNews, last modified May 10, 2019, https://spacenews.com/united-states-and-luxembourg-sign-space-cooperation-agreement/.

capabilities, such as the Boeing-built O3b mPower,[208] as well as to participate in international space exercises and training.[209] Luxembourg has demonstrated that cooperation at both the bilateral- and multilateral-level can advance and safeguard its interests in space.

[208] The O3b mPower is a communications satellite system in the medium Earth orbit, that is owned and operated by SES.

[209] Bauldry Jess, "Defence: Luxembourg Eyes Space Force Cooperation," Silicon Luxembourg, last modified February 24, 2022, https://www.siliconluxembourg.lu/defence-luxembourg-eyes-space-force-cooperation/; and Schnuer Cordula, "'Stronger Together': Space Force General on US-Lux Cooperation," DELANO, last modified July 22, 2021, https://delano.lu/article/stronger-together-space-force-.

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IV. CONCLUSION

This thesis has examined the space strategies of two trailblazing small states, as a response to emerging global trends in space and in leveraging space to meet their national interests. The ensuing chapter aims to translate relevant insights into recommendation for Singapore space policy. To this end, the chapter provides a summary of key findings regarding the space activities and space strategies of the UAE and Luxembourg and possible their lessons for Singapore. In formulating policy recommendations, the chapter has examined the present state of Singapore space ecosystem against its space strategy and has drawn relevant lessons from the UAE and Luxembourg, as well as relevant domestic sectors of Singapore. Table 1 summarizes the comparative analysis between the UAE and Luxembourg.

A. SUMMARY OF KEY FINDINGS

Table 1. Comparative Analysis between the UAE and Luxembourg

	UAE	**Luxembourg**
Space Activities		
Operational Capacity (e.g., ability to develop and conduct full spectrum of space activities)	Building towards full spectrum of space activities	Building capabilities to support commercial activities; rely on ESA and NATO for civil and security applications
Institutional Capacity (e.g., ability to integrate space domain into national infrastructure, policies, and strategies)	Integrated into civil and commercial sectors, integrating into national security sector	Integrated into commercial sector; integrating for defense sector; civil application undertaken at ESA
Technical Autonomy (e.g., ability to access and operate in space without relying on others)	Emerging as a spacefaring nation; pursuing national space launch facility and capability	Support technology development of ESA to access regional space capabilities and infrastructure
Political Autonomy (e.g., ability to define space policies independently from others)	Space policies largely adopted from major spacefaring nations and UNCOPUOS	Space policies largely adopted from major spacefaring nations and UNCOPUOS

	UAE	Luxembourg
Space Strategies		
Main Motivation	Socio-economic, Geopolitical, Centralization, Regulatory	Socio-economic, Coordination, Regulatory
Comparative Advantage	Wealth to invest into building capacity and infrastructure; History and expertise in space; Strategically located as a gateway to enter the Middle East and African markets; Business-friendly policies and infrastructure	History and expertise in space; Agile with setting new policy standards; Strategically located at the heart of Western Europe; Well-established financial ecosystem
Challenges	Brain drain; Lack of foreign investment	Landlocked; Extremely limited in geographical and population size
Orientation of National Space Sector	Centered on civil and commercial sectors	Centered on commercial sector
Purpose of National Space Agency	Overarching authority over civil, commercial, and security activities	Business-oriented to support commercial activities
Ownership and Operations	Own and operate own programs;	Co-own and co-operate ESA programs;
Purpose of National Programs	For space diplomacy, economy, accessibility, security	For space economy and accessibility; Support the space endeavors of private companies
Approach	Public-Public and Public-private cooperation; Strategic co-funding	Public-private cooperation, Strategic co-funding for commercial; Support technology development for ESA programs
International Cooperation	Centralized through national space agency; With like-minded major and emerging space-faring nations over the sharing of space service and data, the exploration and utilization of space resources, human spaceflight	Decentralized through ministry-in-charge representing each sector; With like-minded major and emerging space-faring nations over technology development and the exploration and utilization of space resources

B. RECENT DEVELOPMENTS IN SPACE IN SINGAPORE

During the 58th session of the Science and Technical Subcommittee of UNCOPUOS, Singapore articulated the utility of space in supporting many important civil and government functions, such as "urban planning, weather monitoring, telecommunications, peace support, and disaster relief operations," as well as its interest in growing its domestic space ecosystem, to capture emerging economic opportunities in the application of space-based technologies and to support nationally important sectors, such as aviation and the maritime industry.[210]

Singapore's foray into the space sector has largely focused on space science and technology through the academic frontier coming from national universities and institutions, aimed at supporting key pillars of its extant economy, as well as generating new economic value and strengthening its space economy. To this end, the Singapore government created the Office for Space Technology & Industry in 2013, (OSTIn) under Singapore's Ministry of Trade & Industry (MTI), with objectives strongly resembling those of Luxembourg's space agency. The objective includes:

- Nurture the development of space technologies to serve national imperatives,
- Grow a globally competitive national space industry,
- Foster an enabling regulatory environment for national space activities,
- Establish international partnerships and contribute to the development of multilateral norms on space, and
- Support the development of a future workforce through space-based STEM outreach.[211]

In April 2020, the mandate of OSTIn was expanded by the Singapore government to encompass the responsibility of a "full-fledged national space office," aimed at

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[210] "Office for Space Technology & Industry, Singapore (OSTIn)," Linkedin, accessed June 27, 2022, https://www.linkedin.com/company/ostinsingapore/?originalSubdomain=sg.

[211] National Statement by Singapore - 58th Session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space - Vienna, Austria - 19 to 30 April 2021," United Nations - Office for Outer Space Affairs, accessed July 8, 2022, https://www.unoosa.org/documents/pdf/copuos/stsc/2021/statements/2021-04-23-AM-Item03-03-SingaporeE.pdf.

supporting the growth of its domestic space ecosystem.[212] Funded by the National Research Foundation[213] (NRF), OSTIn is expected to play an aggregator role in bringing domestic space companies together "to nurture space technology development through investing in R&D, and to support industry development and innovation in the [domestic] space sector."[214]

Complementing the government's efforts is the Singapore Space & Technology Ltd (SSTL)—a non-government organization with the focus "to accelerate the adoption and commercialization of space-related innovations and to cultivate space talent ahead of the curve."[215] Funded by Enterprise Singapore[216] (ESG), SSTL is committed to fostering partnerships between the global space industry, with the domestic space sector, and with government agencies to build space-based products and services, thereby growing Singapore's space ecosystem.[217]

Most recently, Minister for Trade and Industry of Singapore, Gan Kim Yong (Minister Gan) presented the space strategy of Singapore at the Global Space and

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212 Tang See Kit, "Singapore Signs US-Led Pact on Space Exploration," Channel News Asia, last modified March 28, 2022, https://www.channelnewsasia.com/singapore/singapore-signs-artemis-accords-space-exploration-2591746.

213 The National Research Foundation, Singapore is a department within the Prime Minister's Office which sets the national direction for research and development by developing policies, plans, and strategies for research, innovation, and enterprise. It aims to transform Singapore into a vibrant R&D hub that contributes towards a knowledge-intensive, innovative, and entrepreneurial economy.

214 "National Statement by Singapore - 58th Session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space - Vienna, Austria - 19 to 30 April 2021," 1.

215 "About Singapore Space & Technology Ltd," Space.org.sg, last accessed June 27, 2022, https://www.space.org.sg/singapore-space/.

216 Enterprise Singapore is a statutory board under the Ministry of Trade and Industry of the Government of Singapore. It was formed to support startups and small and medium enterprises in financing, capability and management development, technology, and innovation, and support the growth of Singapore as a hub for global trading and startups.

217 "About Singapore Space & Technology Ltd," Space.org.sg, accessed June 27, 2022, https://www.space.org.sg/singapore-space/.

Technology Convention 2022[218] (GSTC 2022) held in Singapore: (1) to increase R&D in space-based capabilities that support key pillars of its economy such as aviation and the maritime industry; (2) to invest in R&D in emerging and potentially disruptive space technologies to seek breakthroughs in sustainability; (3) to grow the local space ecosystem and to nurture internationally competitive companies; (4) to enhance partnerships with like-minded space-faring nations; and (5) to build a "talent pipeline for the space sector."[219]

C. ANALYSIS OF SINGAPORE SPACE STRATEGY

Despite the expansion in its mandate, OSTIn's efforts have so far met with mixed success, lagging in the objectives of "fostering an enabling regulatory environment for national space activities" and "nurturing the development of space technologies to serve national imperatives."[220]

1. Grow a Globally Competitive National Space Industry

OSTIn has succeeded in bringing together domestic entities to translate space science and technology research into commercially viable products and services. To date, it has supported numerous space tech startups (e.g., Equatorial Space Industries,[221]

[218] The Global Space and Technology Convention is led by Singapore Space and Technology Limited and serves as a platform to provide insight into industry trends and technologies update, while allowing space and satellite companies to connect with the burgeoning space industry in Asia. Held annually in Singapore since 2008, GSTC draws close to 1,000 delegates from 350 companies from over 50 countries.

[219] "Speech by Minister Gan Kim Yong at the 14th Global Space and Technology Convention," Ministry of Trade and Industry Singapore, last modified February 9, 2022, https://www.mti.gov.sg/Newsroom/Speeches/2022/02/Speech-by-Minister-Gan-Kim-Yong-at-the-14th-Global-Space-and-Technology-Convention.

[220] "Office for Space Technology & Industry, Singapore (OSTIn)," Linkedin, accessed June 27, 2022, https://www.linkedin.com/company/ostinsingapore/?originalSubdomain=sg.

[221] Equatorial Space Systems develops low-cost hybrid-engine rockets and provides affordable space launch services.

Transcelesetial Technologies,[222] Addvalue Technologies Ltd[223]), including spin-offs from universities and labs (-e.g., Aliena,[224] SpeQtral[225]), to develop capabilities in "emerging and potentially disruptive technologies [such as] small satellites, satellite data exploration and AI, in-space manufacturing, and on-orbit servicing and assembly."[226]

In the immediate term, OSTIn has also facilitated the launch of several R&D grant calls where space-based technologies are critical enablers to support Singapore's national priorities. This research includes space-based VHF communications to achieve better range and reliability compared to current means, and disruptive small satellite technologies to improve the performance of satellite buses and payloads, while reducing size and cost. Funded by its flagship Space Technology Development Program (STDP), OSTIn has supported a consortium involving local universities (e.g., Nanyang Technological University and National University of Singapore) and Singapore-based space-tech companies (e.g., ST Engineering, Aliena and Lighthaus Photonics[227]), to develop Very Low Earth Orbit (VLEO) small satellite remote-sensing solutions as an emerging and potentially disruptive technology. To this end, the consortium will build an experimental 100-kg remote-sensing micro-satellite to gather empirical data that informs the architecture

222 Transcelestial develops space data network for terrestrial and satellite applications which will use lasers to transfer data at up to 1000x faster than currently available and does not require pre-allocation and regulation of spectrum management.

223 Addvalue operates the Inter-satellite Data Relay System (IDRS) and provides economical low latency, on-demand data communication services to enable real-time tasking of satellites.

224 Aliena produces proprietary electric propulsion engines that enables the operating of remote-sensing satellites closer to the Earth and reap the benefit of differentiated capabilities.

225 SpeQtral offers commercial space-based Quantum Key Distribution to overcome the weakness of public key encryption in satellite operations.

226 Gagua Frances, "How Spacetech Is Soaring in Singapore," Singapore Business Review, accessed June 30, 2022, https://sbr.com.sg/information-technology/in-focus/how-spacetech-soaring-in-singapore.

227 LightHaus Photonis produces the Singapore's first locally designed space camera that can take high-resolution images of objects as small as 0.5m.

and design of a commercial VLEO satellites with remote-sensing and communication applications for climate and weather monitoring.[228]

As an aggregator, OSTIn has encouraged local space actors to collaborate on space R&D and developing capabilities. An MoU between Singapore Technologies Geo-Insights (ST Geo-Insights) and the National University of Singapore Centre for Remote Imaging, Sensing, and Processing (NUS CRISP) to collaborate on the development of satellite-based AI applications in areas such as infrastructure and agricultural monitoring, and climate change (e.g., monitoring of greenhouse gas emissions and the quality of coastal waters). Significantly, ST Geo-Insights partnered with Defence Science and Technology Agency (DSTA) to acquire an Electro-Optic satellite for launch in 2022. Named the DS-EO, the satellite is envisaged to provide "higher resolution and multispectral imaging" to better address the demand of Singapore's governmental and civil agencies, in applications such as maritime security and oil spill detection. In tandem, this has allowed the local industry to grow and deepen its capabilities and capacity in commercial imagery services.[229]

In tandem with the initiatives by OSTIn, SSTL runs the Space Accelerator Program that deploys state investment from ESG into early-stage space and deep-tech startups, with a vision to nurture globally competitive Singapore enterprises. To date, the program supports 37 companies from 17 countries, across the applications of 5G connectivity, remote-sensing technologies, cybersecurity for critical infrastructure, and semi-autonomous space robots.[230]

These initiatives have helped grow Singapore's space sector to over 50 companies and 1,800 professionals being engaged at the various steps of satellite manufacturing and

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228 "Singapore Consortium to Launch an Advanced Small Satellite at Very Low Earth Orbit to Trial New Technologies," ST Engineering, last modified February 9, 2021, https://www.stengg.com/en/newsroom/news-releases/singapore-consortium-to-launch-an-advanced-small-satellite-at-very-low-earth-orbit-to-trial-new-technologies/.

229 "SM Teo Chee Hean at the Global Space and Technology Convention," Prime Minister's Office (Singapore), last modified June 7, 2021, https://www.pmo.gov.sg/Newsroom/SM-Teo-Chee-Hean-Global-Space-Technology-Convention.

230 "Press Release GSTC 2022," Singapore Space & Technology Limited, last modified February 9, 2022, https://www.space.org.sg/press-release-gstc-2022/.

satellite-based services. In addition, it has helped nurture local SMEs in becoming globally competitive enterprise.

2. Establish International Partnerships and Contribute to the Dialogue and Development of Multilateral Norms on Space

In its national statement at the 58th session of the Science and Technical Subcommittee of UNCOPUOS 2021, Singapore opined "that small states and emerging space players too can play a constructive role in promoting the peaceful uses of outer space." It further reiterated its commitment to the objectives and purpose of UNCOPUOS, that is to "promote an open, inclusive, and rules-based approach to the responsible use of space by all."[231]

Driven by resource constraints inherent to a small state, Singapore "has always advocated an open, inclusive, and collaborative" foreign policy.[232] In the context of the space domain, Singapore has strived to forge "stronger cooperation with partners in [the SEA] region and beyond, and to develop novel solutions for the benefit of humanity."[233] Partnering with SSTL, OSTIn participates actively in multilateral platforms such as the UNCOPUOS, the Asia-Pacific Regional Space Agency Forum (APRSAF), the Association of South Asian Nations (ASEAN) Committee on Science, Technology, and Innovation, the Space for Climate Observatory initiative, as well as organize the annual GSTC.

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231 "National Statement by Singapore - 58th Session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space - Vienna, Austria - 19 to 30 April 2021," 2.

232 "SM Teo Chee Hean at the Global Space and Technology Convention," Prime Minister's Office (Singapore), last modified June 7, 2021, https://www.pmo.gov.sg/Newsroom/SM-Teo-Chee-Hean-Global-Space-Technology-Convention.

233 "National Statement by Singapore - 57th Session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space - Vienna, Austria - 3 to 14 February 2020," United Nations - Office for Outer Space Affairs, accessed July 8, 2022. https://www.unoosa.org/documents/pdf/copuos/stsc/2020/statements/2020-02-05-PM-Item04-02-SingaporeE.pdf.

Bilaterally, OSTIn have entered into numerous agreements with major space actors such as the United States,[234] the United Kingdom,[235] France,[236] and India[237] to collaborate in the areas of space R&D and space law and policies, while SSTL has led the collaboration on investment and trade, as well as human capital development with non-government organizations, such as the Space and Aeronautics Association of Indonesia,[238] BHE Boon Hungary Electronics Limited,[239] and the UK Science and Technology Facilities Council.[240] Significantly, the engagement by OSTIn and SSTL, with both government and non-government space actors, has embodied the multi-pronged strategy of Singapore in fostering international cooperation.

Significantly, during U.S. Vice President Kamala Harris's trip to Singapore in August 2021, the United States and Singapore agreed on expanding bilateral cooperation in the field of space and the importance of creating a safe and transparent environment that facilitates

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234 "Fact Sheet: Strengthening the U.S.-Singapore Strategic Partnership, "White House, last modified August 23, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/08/23/fact-sheet-strengthening-the-u-s-singapore-strategic-partnership/.

235 "Singapore and the UK Strengthen Collaboration in Enterprise Co-Innovation and Joint R&D," Enterprise Singapore, last modified December 9, 2021, https://www.enterprisesg.gov.sg/-/media/esg/files/media-centre/media-releases/2021/november/mr10321_singapore-and-the-uk-strengthen-collaboration-in-enterprise-co-innovation-and-joint-rnd.pdf; "UK Singapore Space Sector Grand Challenge Workshop February 2020," RAL Space (United Kingdom), last modified March 1, 2020, https://www.ralspace.stfc.ac.uk/SiteAssets/Pages/Mission-to-Singapore-2020/UK%20Singapore%20Grand%20Challenge%20Workshop%20Feb2020%20Final%20Report.pdf.

236 "France-Singapore Space Cooperation: Successful 'Innovate Together in Space' Seminar Organized by CNES and EDB on the Eve of Singapore Airshow," Centre national d'études spatiales (French Space Agency), last modified February 5, 2018, https://presse.cnes.fr/en/france-singapore-space-cooperation-successful-innovate-together-space-seminar-rganized-cnes-and-edb.

237 "Update on ISRO's International Cooperation - Presentation to 62nd Session of COPUOS," United Nations - Office for Outer Space Affairs, accessed June 30, 2022, https://www.unoosa.org/documents/pdf/copuos/2019/copuos2019tech44E.pdf.

238 "Singapore, Indonesia Associations Sign MoU on Aerospace and Astronautics Development," Space.org.sg, last modified February 14, 2019, https://www.space.org.sg/singapore-indonesia-associations-sign-mou-on-aerospace-and-astronautics-development/.

239 Goh Deyana, "Hungary Signs Space MoU with Singapore's SSTA," Space.org.sg, last modified February 7, 2020, https://www.space.org.sg/hungary-signs-space-mou-with-singapores-ssta/.

240 "Press Release GSTC 2022," Singapore Space & Technology Limited, last modified February 9, 2022, https://www.space.org.sg/press-release-gstc-2022/.

space exploration, science, and commercial activities.[241] In the ensuing month, Minister Gan proceeded to sign the Artemis Accords, making Singapore the eighth nation and first country in the SEA region to join the United States-led pact on space exploration.[242]

3. Support the Development of Future Workforce through Space-based STEM Outreach

OSTIn, together with SSTL, has partnered with local universities to provide Singaporean youth with exposure opportunities to cutting-edge space technologies. OSTIn launched the "Space Explorers' Network" outreach program in 2021 as a ground-up initiative by educators and students to explore topics of interest related to space and collaborates with ST Geo-Insights and NUS-CRISP to organize workshops on remote sensing and communication with satellites. In 2022, OSTIn initiated a "Spacelab" program that allows Singapore students to design microgravity experiments that will be performed on the International Space Station.

Since 2007, SSTL has partnered closely with the domestic space industry to organize the "Singapore Space Challenge" to challenge and motivate Singapore youth to participate in space-related activities. With an aim to increase the diversity and encourage participation globally, the landmark platform was rebranded in 2021, as the "International Space Challenge".[243] To date, it has drawn participation from over 2000 youths from over 20 countries and served as a platform for interaction on creative space engineering concepts.

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241 "Fact Sheet: Strengthening the U.S.-Singapore Strategic Partnership, "White House, last modified August 23, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/08/23/fact-sheet-strengthening-the-u-s-singapore-strategic-partnership/.

242 "Republic of Singapore Signs the Artemis Accords," U.S. Department of State last modified March 28, 2022, https://www.state.gov/republic-of-singapore-signs-the-artemis-accords/.

243 "International Space Challenge (ISC) 2022," Singapore Space & Technology Limited, accessed July 1, 2022, https://www.space.org.sg/isc/.

4. Foster an Enabling Regulatory Environment for National Space Activities

To date, Singapore has 16 satellites in orbit, most of them built by local academia for R&D and demonstration of new technology.[244] To meet the satellite imagery requirements of Singapore government agencies and to provide commercial imagery services, ST Geo-Insights operates the TeLEOS-1,[245] which was co-developed with South Korea's Satrec Initiative, as well as provides access to imagery data from satellite groups such as ICEYE (commercial-owned, Finland), COSMO-SkyMed (government-owned, Italy), Terrasar-X (commercial-owned, Germany), SPOT (commercial-owned, France), Pleiades (government-owned, France) and KOMPSAT (government-owned, South Korea). Most recently, in June 2022, the ISRO launched two more Singapore LEO Earth-observation satellites—DS-EO and NeuSAR built by South Korea's Satrec Initiative. DS-EO carries an "electro-optic, multi-spectral payload with 0.5 m resolution imaging capability," while NeuSAR is "Singapore's first [small] commercial satellite carrying a SAR payload" to provide all-weather Earth observation.[246]

The footprint of the space industry is expected to grow significantly as Singapore ventures into developing disruptive technologies for small satellites and VLEO constellation and commercial imagery services, thereby shifting from government-directed and controlled space activities into commercially driven ones. Despite having a thriving space sector, Singapore has neither an overarching space agency, national space program, nor a national space law to coordinate the efforts of the public and private sectors and guide national space activities.

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[244] Begum Shabana, "Singapore on Track to Building a Thriving Space Sector, "Straits Times, last modified March 7, 2022, https://www.straitstimes.com/singapore/environment/singapore-on-track-to-building-a-thriving-space-sector.

[245] TeLEOS-1 was launched in December 2015 on an Indian PSLV-CA vehicle and offers 1-meter resolution satellite imagery in the electro-optical spectrum.

[246] "PSLV-C53/DS-EO Mission," Indian Space Research Organisation, accessed June 29, 2022. https://www.isro.gov.in/launcher/pslv-c53-ds-eo-mission.

5. Nurture the Development of Space Technologies to Serve National Imperatives

Globally, space actors have begun acknowledging space as an operational domain that has become more congested, contested, and competitive, as well as the interdependency of space activities between the functions of national security, safety and stability, science and exploration and commerce.

To this end, emerging space actors with business-oriented objectives too have expressed interests in building capabilities in civil applications to ensure space safety and security. Specifically, Luxembourg has partnered with NATO/EU members into building capabilities such as SSA and PNT at the regional and international levels, while strengthening the resiliency of its national space capabilities. Meanwhile, the UAE has invested heavily into developing a full spectrum of space activities and has leveraged space cooperation with the U.S. Strategic Command to access data and services related to SSA. While these approaches differ, both small states have primary interests in developing or acquiring capabilities in the complementary civil applications to safeguard economic development opportunities in space.

As Singapore's dependence on space grows, it needs to do more to protect and defend its national interests in and through space. With this context in mind, Singapore has been negligent and lacks tangible space capabilities and capacities to keep pace with evolving threats.

D. POLICY RECOMMENDATIONS

Drawing lessons from earlier chapters, Singapore's progress as an emerging spacefaring nation should be marked by several important milestones in the coming decade. The milestones include:

- Institutionalize dedicated authority in charge of national space activities,
- Establish national space programs with dedicated budget,
- Adopt a space policy/strategy, and a legal and regulatory framework to guide space activities,
- Acquire space capabilities for national purposes,
- Develop domestic space industry for the development and/or operation of space systems,

- Develop domestic space infrastructure and facilities for access to space, and
- Participate in international programs and/or space diplomacy.[247]

The development of the space sector should capitalize on its comparative strengths in: (1) the relative ease of setting up businesses with conducive initiatives and polices; (2) a balanced foreign policy and expansive diplomatic relations built on the basis of mutual interest; (3) the availability of a skilled labor force; and (4) the availability of a cutting-edge technology infrastructure.[248] Domestically, Singapore has prior experience in building up the cybersecurity sector, which has also experienced and endured key shifts in its operating environment.

The past decade has seen Singapore establish an overarching cybersecurity national agency and release a national strategy to tackle new and emerging cross-border/transnational threats. The Singapore Cybersecurity Strategy was published in 2016, and subsequently reviewed in 2021 to outline the nation's goals and approach "to adapt to a rapidly evolving strategic and technological environment [where] threat actors are becoming more sophisticated and taking advantage of increasingly ubiquitous connectivity to launch more cyberattacks." The 2021 strategy seeks "to actively defend [the national] cyberspace, simplify cybersecurity for end-users, and promote the development of international cyber norms and standards." To this end, it articulates three strategic pillars: (1) build resilience infrastructure, (2) enable a safer cyberspace, and (3) enhance international cyber cooperation; via two foundational enablers: (a) developing a vibrant cybersecurity ecosystem, and (b) growing a robust cyber talent pipeline.[249]

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[247] "ESPI Report - Emerging Spacefaring Nations - Review of Selected Countries and Considerations for Europe," European Space Policy Institute, last modified June 1, 2021, https://espi.or.at/publications/espi-public-reports/send/2-public-espi-reports/577-emerging-spacefaring-nations-full-report.

[248] Subhani Ovais, "Singapore Retains Top Spot as World's Most Competitive Economy, "Straits Times, last modified June 16, 2020, https://www.straitstimes.com/business/economy/singapore-retains-top-spot-as-worlds-most-competitive-economy.

[249] "The Singapore Cybersecurity Strategy 2021," Cyber Security Agency (Singapore), last modified October 5, 2021, https://www.csa.gov.sg/News/Publications/singapore-cybersecurity-strategy-2021.

Significantly, the cross-border nature of cyber threats has compelled Singapore's Cyber Security Agency (CSA) to collaborate internationally with stakeholders from the public (including local and overseas academia) and private sectors to conceive the 2021 strategy. Centered to the 2021 strategy are goals that include: (1) coordinating the efforts of the public and private sectors; (2) developing a vibrant ecosystem underpinned by research and innovation; (3) growing a robust talent pipeline and workforce to meet the nation's security and economic needs, and (4) enhancing international cooperation for capacity building and the development and promotion of norms and standards. These goals highly resemble those set out by Singapore's space office—OSTIn and could serve as the backbone for policy formulation in the space sector.

1. Institutionalizing National Authority and Enacting National Space Act

Like Luxembourg's space agency, OSTIn was created under a ministry-in-charge (i.e., the Ministry of Trade and Industry), tasked with business-focused objectives and activities that support the growth of the domestic space industry. While the creation of a space office is a step forward, there remains much to be done by the Singapore government to strengthen and support OSTIn in executing its strategic objectives.

To this end, the thesis proposes the expansion of OSTIn into a full-fledged space agency akin to Singapore's CSA. As an overarching authority in charge of national space activities, the agency could be entrusted with the resources and responsibilities to work towards critical milestones, such as establishing national space programs into building or acquiring relevant capability, such as SSA, to serve its national imperative; and enact national space legislation to foster an enabling regulatory environment to guide the fast-expanding national space scene. To allow greater organizational agility, the national space agency could be granted independent legal status from the government, such as the SSTL, and be entrusted with a degree of freedom and flexibility to make decisions, sign contracts and agreements, and grant R&D investments. This would allow the domestic space industry to remain agile and nurture emerging new space technologies and startups.

While dedicated legislation is not a pre-requisite to having a space industry, Singapore should move toward implementing a comprehensive legal and regulatory regime as it strives

to become spacefaring. Drawing lessons from Luxembourg and the UAE, the enactment of a national space law enables a state to readily fulfil its obligations under the relevant international laws and treaties governing outer space activities and to help to clarify the state's position on its approach in ensuring safe, sustainable, and responsible space activities. In this regard, Singapore has ratified the Treaty on the Peaceful Use of Outer Space (in September 1976[250]), the Rescue and Return Agreement (in September 1976[251]), and the Liability Convention (in August 1975[252]) and has signed but not ratified the Space Objects Registration Convention (in Aug 1976[253]). Implementing a legal and regulatory regime with licensing, inspection, and liability provisions would allow Singapore to meet the obligations imposed under these binding instruments.

In the context of growing the domestic space industry, the enactment of a national space law would provide a focal point and would allow Singapore to achieve consistency and predictability concerning its space activities. This would serve to better inform engagement, integration, and coordination within and across the key sectors and provide clarity to the lines of effort interaction between public (e.g., national, regional, and international governmental, research, and academia) and private entities. The creation of an effective and attractive regulatory environment could serve to attract foreign investors and ease the setting up of businesses in Singapore.

Finally, the enactment of a national space act would build greater knowledge and competence in space among policymakers and raise awareness and interest across and among

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250 "Singapore," United Nations - Office for Disarmament Affairs, accessed June 6, 2022, https://treaties.unoda.org/s/singapore.

251 "Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space," United Nations - Treaty Collection, accessed June 6, 2022, https://treaties.un.org/pages/showDetails.aspx?objid=080000028012504f.

252 "Convention on the International Liability for Damage Caused by Space Objects," United Nations - Treaty Collection, accessed June 6, 2022, https://treaties.un.org/pages/showdetails.aspx?objid=08000002801098c7.

253 "Convention on Registration of Objects Launched into Outer Space," United Nations - Treaty Collection, accessed June 6, 2022, https://treaties.un.org/Pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXIV-1&chapter=24&Temp=mtdsg3&clang=_en.

the public of the importance of space science, technology, and innovation, thereby reinforcing Singapore's goals of developing a vibrant space ecosystem and a robust talent pipeline.

2. Participating in Bilateral and Multilateral Space Cooperation and/or Space Diplomacy

Singapore must enhance bilateral and multilateral partnerships, with burden-sharing on SSA; promote the development of international norms and standards to support safe, sustainable, and responsible space activities; exchange knowledge and expertise on space science and technology; and co-own and co-operate regional space infrastructure, as viable bases for collaboration.

Unlike Luxembourg's strategic partnership with ESA, there has yet to be a regional civil space agency or security alliance in SEA that could coordinate the financial and intellectual resources of regional members and shape the development of space capabilities to deliver benefits to the citizens of SEA and its partners. This is not helped by the existence of two contrasting space cooperation organizations in the wider Asia-Pacific region, namely APRSAF (led by Japan and India) and the Asia-Pacific Space Cooperation Organization (led by China).[254] Given the contentious nature and the "unspoken space race" between Asian space powers, it remains unlikely that regional space cooperation would find a way forward in the Asia-Pacific.[255]

Consequently, Singapore would undertake such efforts alone, or could leverage space cooperation in bilateral and/or multilateral forms. The latter would reap immeasurable efficiencies and allow Singapore to undertake space programs and activities far beyond the scope of its capacity and capability, in an accelerated manner.

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[254] Rajagopalan Rajeswari, "Asia in Space: Cooperation or Conflict?" Asia & the Pacific Policy Society, last modified October 10, 2018, https://www.policyforum.net/asia-space-cooperation-conflict/.

[255] James Clay Moltz. "Asia's Space Race," *Nature* (December 2011): 171–173, https://doi.org/10.1038/480171a.

At the bilateral level, space cooperation could take shape with: (1) like-minded emerging states, such as Luxembourg[256] and the UAE[257]; (2) ASEAN states that have exhibited strong operational and institutional capacities in the space domain, such as Indonesia,[258] Vietnam,[259] and the Philippines[260]; and (3) expanded extant cooperation on cybersecurity and defense with major space powers such as the United States,[261] the United

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256 "Luxembourg and Singapore Establish Bilateral Research Collaborations," Luxembourg National Research Fund, last modified November 15, 2016, https://www.fnr.lu/luxembourg-singapore-establish-bilateral-research-collaborations/.

257 Baharudin Hariz, "Singapore and UAE Reaffirm Bilateral Ties, Seek Greater Tech Collaboration, "Straits Times, last modified March 22, 2021, https://www.straitstimes.com/singapore/singapore-and-uae-reaffirm-bilateral-relations-seek-greater-collaboration-in-technology.

258 Indonesia has the most advanced space program and the longest standing space agency (i.e., LAPAN) within ASEAN. Founded in 1964 and it has performed research on rocket, remote sensing, satellites, and space science. It has articulated a Space Development Plan with strategic objectives including mastery of rocket technology, building national observatory and launch site, and growing its national remote sensing data bank and national earth monitoring system. In 2013, it enacted the Indonesia Space Act/Law of the Republic of Indonesia on Space Activities. It reported s space spending of $303M in 2020.

259 Vietnam sent the first Southeast Asian into space through the Soyuz 37 mission in 1980. It has established a national space center (i.e., VNSC) in 2011 to develop capacity in the fields of space science and technology, and to focus on international cooperation with agencies such as NASA, Japan Aerospace Exploration Agency, CNES, and ESA. It has articulated the Vietnam's Space Strategy to 2030 with strategic objectives including developing and operating "Made in Vietnam" satellite, exploiting satellite imagery for socio-economic development and national security, developing a center of excellence for space science, and promoting awareness on space, especially among the youth generation.

260 The Philippines launched the National Space Promotion, Awareness, and Capabilities Enhancement (SPACE) development Program in 2015 to provide the national space R&D agenda, satellite development roadmap, satellite data sharing and management policy and space industry development roadmap. In 2019, it established a national space agency (i.e., PhilSA) to centralize the management and operation of all space programs of the Philippine government. In tandem, the enactment of the Republic Act No. 11363 (including the Philippine Space Act and the Philippine Space Development and Utilization Policy) provided the agency with the mandate as the central government agency. It reported s space spending of $57M in 2020.

261 "United States and Singapore Expand Cooperation on Cybersecurity," Cybersecurity & Infrastructure Security Agency (United States), last modified August 23, 2021, https://www.cisa.gov/news/2021/08/23/united-states-and-singapore-expand-cooperation-cybersecurity; "Readout of Secretary of Defense Lloyd Austin III Meeting with Singapore Minister for Defence Dr. Ng," U.S. Department of Defense, last modified November 3, 2021, https://www.defense.gov/News/Releases/Release/Article/2832471/readout-of-secretary-of-defense-lloyd-austin-iii-meeting-with-singapore-ministe/; and "Singapore, U.S. Enhance Defence Cooperation in Cyberspace," MINDEF (Singapore), last modified August 23, 2021, https://www.mindef.gov.sg/web/portal/mindef/news-and-events/latest-releases/article-detail/2021/August/23aug21_nr.

Kingdom,[262] France,[263] Japan,[264] and India.[265] Multilaterally, it could also build on the agenda of international platforms, such as the Artemis Accords, as well as regional platforms, such as the ASEAN Committee on Science, Technology, and Innovation[266] and the ASEAN Defence Ministers' Meeting,[267] to foster space cooperation.

An inability to establish constructive space cooperation imposes significant costs and capacity on small states to build or acquire dedicated capabilities to assure a safe and attractive environment for operators and investors. Failure to do so could undermine its ability to attract foreign investment and trade partnership with industry leaders, thereby compromising its national interests. The UAE, with its accumulated wealth, has also regarded space cooperation with regional and global partners as a key thrust to accelerate the building of national capacity

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262 "Singapore and the UK Strengthen Collaboration in Enterprise Co-Innovation and Joint R&D," Enterprise Singapore, last modified December 9, 2021, https://www.enterprisesg.gov.sg/-/media/esg/files/media-centre/media-releases/2021/november/mr10321_singapore-and-the-uk-strengthen-collaboration-in-enterprise-co-innovation-and-joint-rnd.pdf.

263 "CSA Signs First International MOU with France to Strengthen Cyber Security Collaboration," Cyber Security Agency (Singapore), last modified May 18, 2015, https://www.csa.gov.sg/news/press-releases/csa-signs-first-international-mou-with-france-to-strengthen-cyber-security-collaboration; and "Singapore and France Reaffirm Strong and Broad-Based Defence Ties," MINDEF (Singapore), last modified June 11, 2022, https://www.mindef.gov.sg/web/portal/mindef/news-and-events/latest-releases/article-detail/2022/June/11jun22_nr5.

264 "The First Japan-Singapore Joint Committee Meeting on Cooperation in Science and Technology," Ministry of Foreign Affairs of Japan, last modified April 19, 2018, https://www.mofa.go.jp/dns/isc/page25e_000193.html; and "Singapore Signs Memorandum of Cooperation on Cybersecurity with Japan at the Sidelines of SICW 2017," Cyber Security Agency (Singapore), last modified September 18, 2017, https://www.csa.gov.sg/news/press-releases/singapore-signs-memorandum-of-cooperation-on-cybersecurity-with-japan-at-the-sidelines-of-sicw-2017.

265 "CSA Signs MOU with India to Strengthen Cooperation on Cyber Security," Cyber Security Agency (Singapore), last modified November 24, 2015, https://www.csa.gov.sg/news/press-releases/csa-signs-mou-with-india-to-strengthen-cooperation-on-cyber-security; and "Singapore and India Reaffirm Strong and Long-Standing Defence Relations at Defence Ministers' Dialogue," MINDEF (Singapore), last modified January 20, 2021, https://www.mindef.gov.sg/web/portal/mindef/news-and-events/latest-releases/article-detail/2021/January/20jan21_nr.

266 "ASEAN Committee on Science, Technology, and Innovation - Sub-Committee on Space Technology and Applications," ASEAN Science & Technology Network, last modified accessed June 4, 2022, https://astnet.asean.org/sub-committee-on-space-technology-and-applications-scosa/.

267 "ADMM Convenes in Person, Reaffirms Commitment to Strengthen Regional Cooperation," MINDEF (Singapore), accessed July 1, 2022, https://www.mindef.gov.sg/web/portal/mindef/news-and-events/latest-releases/article-detail/2022/June/22jun22_nr.

and capability and to establish official work streams to access space while reducing the collective costs of satellite operations.

During the signing of the Artemis Accords in March 2022, Minister Gan articulated Singapore's interest by stating: "I hope Singapore will be able to cooperate more closely with like-minded partners like the United States to progress international conversation on space norms and spur the development of the global space sector," and "I look forward to seeing more exchanges and collaborations among companies, officials, [and] researchers between Singapore and the United States, as well as other Artemis Accords signatories, leading to a robust space sector in Singapore."[268]

In the context of leveraging cooperation to promote the development of international norms and standards to support safe, sustainable, and responsible space activities, the space sector could also take reference from the cybersecurity sector. The cross-border nature of space threats and security should compel Singapore to develop its national security space strategy in consultation with public and private stakeholders, including from government actors and non-government, industry, and academic entities, as well as experts and policymakers from the regional and global space ecosystem. Specific to enhancing international collaboration in securing the cybersecurity environment, Singapore's CSA has partnered with like-minded nations, such as the United States, the United Kingdom, France, and India, in areas such as "regular exchange of information on cyber threats, coordination of response to cybersecurity incidents, and joint cybersecurity training and exercises."[269] Specific to the space domain, Singapore could engage in exchanges of best practices on legal and regulatory matters related to space activities and establish agreements with like-minded nations to have a larger voice in promoting standards and norms of behavior favorable to its

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[268] Tang See Kit, "Singapore Signs US-Led Pact on Space Exploration," Channel News Asia, last modified March 28, 2022, https://www.channelnewsasia.com/singapore/singapore-signs-artemis-accords-space-exploration-2591746.

[269] "Singapore's Approach to Cyber Security," FTI Consulting, Inc, accessed June 4, 2022, https://www.fticonsulting.com/~/media/Files/apac-files/insights/white-papers/singapore-cybersecurity.pdf; and Mahmud Aqil Haziq, "More Cybersecurity Cooperation between Singapore, U.S. in Public, Defence and Financial Sectors," Channel News Asia, last modified August 23, 2021, https://www.channelnewsasia.com/singapore/singapore-us-mou-cybersecurity-cooperation-public-defence-finance-2130121.

national interests. This could shape norms of behavior that enhance the national security of itself, the region, and strategic partners, while also reducing the likelihood for competing states or potential adversaries to misinterpret intent as a result of national space activities. The adoption of an open data policy and architecture could facilitate the sharing of data and services related to SSA and create a platform to exchange information and expertise on mutually beneficial matters, such as space science and technology.

Like the UAE, Singapore could leverage space activities to cooperate on common interests and concerns, and to exert soft power in the SEA region. Most recently in February 2022, Singapore and Indonesia signed a set of agreements to reduce misunderstandings by addressing longstanding bilateral issues, such as the Flight Information Region (FIR) alignment, military training in the South China Sea Danger Area, and extradition of fugitives between both countries.

The ministerial statement of Singapore's Coordinating Minister for National Security Senior Minister Teo Chee Hean's (SM Teo) explains: "Both countries have agreed that the best way to resolve these three outstanding issues is actually to discuss them together, come to agreements on them at the same time, and then to bring them into force concurrently," "and I think that will bring many benefits to both countries, so that it would reduce any chances of misunderstandings and provide a very strong basis for future cooperation."[270]

The conclusion of these agreements demonstrated the strength and maturity of Singapore-Indonesia relations and laid a solid foundation for future cooperation. In the context of space cooperation, the two states could collectively explore the use of space technologies for addressing common interests and concerns, such as satellite communications to manage

270 "Singapore and Indonesia Reaffirm Close and Long-Standing Defence Relations," MINDEF (Singapore), last modified January 25, 2022, https://www.mindef.gov.sg/web/portal/mindef/news-and-events/latest-releases/article-detail/2022/January/25jan22_nr; and Mahmud Aqil Haziq, "Singapore-Indonesia Agreements Will Apply Simultaneously to Reduce Misunderstandings, Allow Future Cooperation: SM Teo," Channel News Asia, last modified February 14, 2022, https://www.channelnewsasia.com/singapore/singapore-indonesia-agreement-fir-defence-extradition-2496971.

air traffic[271] and satellite imagery to study and monitor Indonesia's seasonal forest fires and carbon emissions.[272] Against a backdrop of the growing assertiveness of China's territorial claims over and an increased threat of piracy activity in the South China Sea, the freedom of navigation and overflights of the international waterway have been compromised.[273] This could encourage security cooperation between Singapore and Indonesia and materialize with the sharing of satellite imagery data for maritime domain awareness and security.

Regionally, space cooperation could take shape in the form of co-funding, co-owning, and co-operating regional space infrastructure, such as a commercial space port. In this regard, Singapore possesses advantages both geographically (e.g., equatorial location—latitude of 1.35° N or 85 miles north of the equator, open water to the east, and low occurrence of natural disasters, such as earthquakes and hurricane) and institutionally (e.g., rule of law, strong financial and technical infrastructure, experience in managing infrastructure assets, and human capacity focused on innovation and technology). A strategic partnership between ASEAN members and launch companies such as SpaceX and Blue Origin could conceive a gateway to space in the SEA region and provide socio-economic opportunities for ASEAN member states to partake in the global space economy by contributing at the various steps of the value chain of a commercial launch service provider. Such a value proposition would

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271 "CAAS, OSTIn, SITA and Startical to Trial Satellite Communication Between Pilots and Air Traffic Controllers," Civil Aviation Authority of Singapore, accessed June 28, 2022, https://www.caas.gov.sg/who-we-are/newsroom/Detail/caas-ostin-sita-and-startical-to-trial-satellite-communication-between-pilots-and-air-traffic-controllers.

272 "Indonesia Forest Fires Have 'major Impact' on Climate, 360m Tonnes of CO2 Released since August: Masagos," Channel News Asia, last modified September 26, 2019, https://www.channelnewsasia.com/singapore/indonesia-forest-fires-haze-climate-impact-carbon-masagos-1327221; and Yeung Jessie, "Indonesian Forests Are Burning, and Malaysia and Singapore Are Choking on the Fumes," CNN, last modified September 11, 2019, https://www.cnn.com/2019/09/11/asia/malaysia-singapore-pollution-intl-hnk/index.html.

273 Shiying Wong, "Piracy and Armed Robbery Cases in Singapore Strait Hit 6-Year High in 2021, "Straits Times, last modified January 18, 2022, https://www.straitstimes.com/singapore/piracy-and-armed-robbery-cases-in-singapore-strait-hit-6-year-high-in-2021; and "Number of Actual and Attempted Piracy Attacks in Indonesia 2008–2021," Statista, last modified March 2, 2022, https://www.statista.com/statistics/250866/number-of-actual-and-attempted-piracy-attacks-in-indonesia/#:~:text=In%202021%2C%20there%20were%20nine,by%20Peru%20and%20Singapore%20Straits.&text=Piracy%20attacks%20in%20Indonesian%20waters,when%20108%20incidents%20were%20reported.

ensure regional access to space and is aligned with the aims and purposes of ASEAN—i.e., "accelerate the economic growth, social progress, and cultural development in the region."[274]

3. Dedicating Budget to Develop or Acquire Capability, Infrastructure, Facilities in the Applications of Space Safety and Security

As a member state of UNOOSA and UNCOPUOS, Singapore has made clear its intent to cooperate more closely with like-minded partners so that the outer space remains a peaceful global common. To this end, it has been participating in global initiatives such as the resolution on Prevention of an Arms Race in Outer Space (PAROS),[275] the voluntary guidelines for the Long-term Sustainability of Outer Space Activities,[276] and the Artemis Accords. While it has been an active advocate in promoting the relevance of the global space governance framework in support of safe, sustainable, and responsible space activities, it lacks tangible capability in space to safeguard its economic interests and to protect its territory.

Luxembourg has provided a good model on how a small state, while limited in its geographical size, can leverage a range of mechanisms to serve its domestic interest while also contribute to the collective security of its allies and partners. Domestically, Luxembourg will put in place space-based sensors to detect a wide range of threats by partnering with commercial space information provider—NorthStar Earth & Space Inc thereby overcoming its lack of geographic diversity for ground-based sensors and its inability to burden-share on SSA. Regionally, Luxembourg has participated in and funded ESA's optional SSA program

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274 "Association of Southeast Asian Nations (ASEAN)," asean.org, accessed June 29, 2022, https://asean.org/what-we-do#asean-aims.

275 "Singapore's Explanation of Vote for the First Committee Resolution 'Further Practical Measures for the Prevention of an Arms Race in Outer Space', 72nd UNGA," Ministry of Foreign Affairs (Singapore), last modified October 30, 2017, https://www.mfa.gov.sg/Overseas-Mission/New-York/Mission-Updates/First_committee/2017/10/press-20171030.

276 "National Statement by Singapore - 57th Session of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space - Vienna, Austria - 3 to 14 February 2020," United Nations - Office for Outer Space Affairs, accessed July 8, 2022, https://www.unoosa.org/documents/pdf/copuos/stsc/2020/statements/2020-02-05-PM-Item04-02-SingaporeE.pdf; and "National Statement by Singapore - 64th Session of the Committee on the Peaceful Uses of Outer Space - Vienna, Austria - 25 August to 3 September 2021," United Nations - Office for Outer Space Affairs, accessed July 8, 2022, http://www.unoosa.org/documents/pdf/copuos/2021/statements/item_4_Singapore_ver.1_1_September_AM.pdf.

since 2017 and has access to early-warning services such as space-weather, near-Earth objects, and space surveillance and tracking. Internationally, Luxembourg has funded the development of the Strategic Space Situation Awareness System (3SAS) that supports NATO's Space Situation Center. This has allowed Luxembourg to build capacity and develop skills and expertise, while reinforcing its role as a reliable reference partner in the field of space. Correspondingly, these activities have brought strong benefits to the Luxembourg space sector by attracting companies and foreign investment and fostering space cooperation both bilaterally and multilaterally. Central to its approach has been its commitment to bring something to the table by dedicating budget to develop or acquire SSA capabilities, infrastructure, and facilities, and to participate in international/regional space security operations.

In the context of Singapore, it must "up its game" in the applications of space safety and security by developing or acquiring SSA capability, infrastructure, and facilities. The lack of such expertise and experience should compel the small state to explore partnership with industry leaders such as NorthStar Earth & Space Inc (partnering with Canadian Space Agency, U.S. DoC, and Luxembourg's Space Agency and SES, Japan Space Imaging Cooperation),[277] LeoLabs (partnering with U.S. DOD and DoC, New Zealand Space Agency, and Japan's MoD[278]), and ExoAnalytic Solutions (partnering with Australian Defence Force, U.S. DOD and DoC, and Luxembourg's SES[279]) to accelerate the building of national capacity and capability. These are viable in providing solutions to overcome Singapore's lack of geographical size for ground-based sensor deployment and to allow Singapore to acquire data services and technology required to participate in space security operations—e.g., tracking and monitoring, collision avoidance and space domain awareness.

Significantly, a partnership with NorthStar on space-based SSA capability would allow a land-scarce Singapore to avoid deploying ground-based infrastructure. Starting in

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277 "NorthStar Earth & Space - Media," NorthStar Earth & Science, accessed July 2, 2022, https://northstar-data.com/media/.

278 "LeoLabs - Newsroom," LeoLabs, accessed July 2, 2022, https://leolabs.space/newsroom/.

279 "Exo In the News," ExoAnalytic Solution, accessed July 8, 2022, https://exoanalytic.com/news/.

2023, NorthStar is scheduled to begin operation of the Skylark constellation to deliver "near real-time high-fidelity tracking services." The provision of SSA services in the near-earth orbits are well-suited and complement Singapore's interest in developing VLEO small satellite remote-sensing solutions as an emerging and potentially disruptive technology. Beyond SSA, Singapore could also explore complementing applications, such as space debris removal[280] and on-orbit serving.[281] These initiatives would strengthen Singapore's credibility and maintain its relevance and usefulness to the international community.

4. Nurturing Space Ecosystem and Talent Pipeline

As in the cybersecurity sector, the development of a vibrant space ecosystem and a robust talent pipeline are foundational enablers in growing a global competitive national space industry. Backed by its first-rate educational system and economic-centric immigration policy, Singapore has been successful in attracting foreign talent that has helped build a skilled and diverse workforce, which has helped Singapore become one of the world's most competitive economies.[282]

The current approach, however, does not serve the growth of the space sector well. Unique to the space sector, which requires its workforce to upskill and retrain overtime as innovation and technology progresses swiftly, Singapore would need to reform its educational system and immigration policy so that it would continue to meet the evolving needs of space businesses and economy. Today, there exists little to no opportunities for Singapore's youth to acquire space-specific knowledge and skills from its education system.

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[280] Astroscale, a Singapore-headquartered space debris removal startup has launched a demonstrator in 2021 and is on track to start space debris removal operation by 2024. Pultarova Tereza, "Commercial Space Clean-up Service Could Be Ready in 2024," Space.com, last modified May 26, 2021, https://www.space.com/commercial-space-debris-removal-2024-astroscale.

[281] OSTIn will launch an open grant call in 2022 in emerging areas such as on-orbit servicing and assembly.

[282] Ang, Shermaine, "Singapore Rebounds to Third Spot in Global Competitiveness Ranking, "Straits Times, last modified June 15, 2022. https://www.straitstimes.com/singapore/singapore-rebounds-to-worlds-3rd-most-competitive-economy; and Klaus Schwab, and Saadia Zahidi, "The Global Competitiveness Report Special Edition 2020: How Countries Are Performing on the Road to Recovery, "Global Competitive Report. World Economic Forum, last modified December 16, 2020. https://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2020.pdf.

The UAE has provided a good model on how a small state, while limited in its population size, can leverage a range of mechanisms to accelerate the building of national capacity and expertise. Sustained public investment in industry leaders has facilitated the import of space technologies and specialist skills, which have seeded the growth of human resources, infrastructure, and scientific research domestically. Partnerships with foreign government entities, such as NASA and U.S. Strategic Command, have established official work streams for knowledge transfer and resource sharing. Significantly, this has created opportunities for UAE talent to gain operational experience and expertise in the areas of collaboration.

In the context of Singapore, beyond collaborative efforts with foreign partners on investment and trade, Singapore should explore opportunities to participate in flagship multilateral science and technology missions that would facilitate education and knowledge transfer. Specific to space security, Singapore could also explore opportunities to participate or observe multi-national space operations and exercises, such as the U.S. DOD-led Combined Space Operations Center and the French-led ASTERX. This would provide exposure for Singapore talent to gain operational experience and expertise in SSA.

To build a robust talent pipeline, Singapore should build practical partnerships between industrial, educational, and research institutions to develop space-related or space-specific curricula that are accessible to general education. To this end, it could leverage established satellite programs and facilities at local universities as a springboard to provide tailored local education programs and curricula for university students on space technologies. The development of a complementary information program would raise awareness through space education and activities and encourage youth—Singaporean and foreign—to join the space sector. These initiatives would strengthen its ability to attract more meritorious immigrants and transform Singapore into a value-creating economy through space science and technology.

E. SUMMATION

The recommended policy reforms and changes focus on leveraging space cooperation in bilateral and multilateral forms to improve Singapore's soft power. In the immediate term,

growing OSTIn into a full-fledged space agency with an overarching authority, responsibilities, and dedicated resources, would position it well for executing key initiatives such as formulating and enacting a national space act and establishing national space programs in SSA.

Globally, Singapore could build on its strong foundation in space science and technology and reap many benefits by participating in flagship multilateral science and technology missions. In the context of space safety and security, it could foster greater public-public and public-private cooperation in applications (e.g., SSA, STM, and space debris removal) that are generating interest and financial investments among the space powers, industry leaders, and regional neighbors. As an advocate of international space and stability, the possession of SSA capability would ensure national space activities proceed safely, sustainably, and responsibly. Furthermore, it would provide Singapore with the tools to participate in multi-national space operations and exercises such as U.S. Space Command "pathway to partnerships" program and its annual Global Sentinel event,[283] thereby building official work streams for its workforce to gain operational experience and expertise in SSA.

Regionally, Singapore could seed multilateral cooperation in space to address common interests and concerns. The proposed establishment of a regional spaceport on a co-fund, co-own and co-operating basis would ensure regional access to space and support the aims and purposes of ASEAN. In the context of national security, the growing assertiveness of China's territorial claims over and an increased threat of piracy activity in the South China Sea could catalyze unprecedented cooperation in the SEA region through the sharing of satellite imagery data to enhance maritime domain awareness.

Domestically, the investment into such activities would bring a variety of positive socio-economic impacts, such as increased foreign investment, start-ups, and industrial activity, technological and scientific excellence, cost efficiencies, and productivity gains in other economic sectors. In tandem with developing a vibrant space ecosystem, Singapore

[283] U.S. Space Command, "25 Nations Participate in Global Sentinel 22," last modified August 3, 2022. https://www.spacecom.mil/Newsroom/News/Article-Display/Article/3115832/25-nations-participate-in-global-sentinel-22/.

would need to reform its educational system and immigration policy to build a sustainable and robust talent pipeline that would continue to meet the evolving needs of a fast-evolving space economy. In anticipation of a growing space footprint that is driven by commercial players, Singapore must implement a legal and regulatory regime with licensing, inspection, and liability provisions to allow national space activities to meet international obligations. Together with its strong financial and technical infrastructure, this would help Singapore realize a development strategy that focuses on nurturing niche variable products and services by commercializing R&D outcomes. These initiatives would accelerate Singapore's transformation into a value-creating economy that is driven by space science and technology. Table 2 summarizes the policy recommendations for Singapore.

Table 2. Policy Recommendations for Singapore

Space Strategies	**Current**	**Recommended**
Main Motivation	Socio-economic	+ Geopolitical, Regulatory
Orientation of National Space Sector	Space science and technology development for commercial applications	Commercial emphasis, supported by space safety and security applications to ensure safe, responsible, and sustainable space activities
Purpose of National Space Agency	N.A.	Overarching authority in charge of national space activities across commercial, civil, security sectors and space cooperation Formulate and enact space policy (e.g., National Space Act) to provide the legal and regulatory framework that support the growth of domestic space industry Responsible for national space programs to develop or acquire space safety & security applications
Purpose of National Programs	N.A.	For space economy and accessibility by supporting space endeavors of private companies For space security to protect and defend its national interests in and through space

Space Strategies	**Current**	**Recommended**
Ownership and Operations	Government-directed and academia-driven space activities	Commercially driven supported by government-directed on security operations
Approach	Support domestic R&D development with funding Exchanges and collaborations among companies, officials, researchers Leverage skilled and diverse workforce	Participate in multilateral science and technology missions and program Develop tools to participate in multi-national space operations and exercise Strengthen STEM education and outreach through space-related or space-specific curricula for general education
International Cooperation	Decentralized through agency-in-charge representing each sector Bilaterally over R&D, trade and investment, development of human capital, space norms and standards	Centralized with national space agency; Exchanges of best practices on legal and regulatory matters related Strengthen credibility and usefulness to international space community through technical (e.g., burden share on SSA) and political (e.g., promote space norms and standards) Seed multilateral cooperation with co-funding, co-owning, and cooperative regional space infrastructure

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