NATO PARLIAMENTARY ASSEMBLY

SCIENCE AND TECHNOLOGY COMMITTEE (STC)

ENHANCING NATO S&T COOPERATION WITH ASIAN PARTNERS

General Report

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NATO has continuously fostered its cooperation with countries that lie outside the geographical scope of the Alliance. Through a series of programmes and initiatives, NATO engages multi- and bilaterally with partner nations that share the Alliance’s values and interests. Cooperation in the area of Science and Technology (S&T) is part and parcel of that engagement. In recognition of the changing regional security environment in the Asia-Pacific, which is driven by both the rise of China and the increasing strategic role of Emerging and Disruptive Technologies (EDT), the Alliance is actively focused on deepening ties with its partner nations in Asia-Pacific.

While S&T cooperation forms an important part of NATO’s partnership system in general, your rapporteur concludes that the Science and Technology dimension of cooperation with NATO’s Asian partners in particular is an underexplored pillar of this mutually beneficial relationship. Japan and ROK are world leaders in, inter alia, several technology areas and are science and technology powerhouses more broadly. This report identifies the comparative S&T advantages these NATO partners enjoy in key dual-use technologies and suggests that cooperation can be improved in a variety of ways. Your rapporteur recognises that deepening and expanding cooperation in the S&T realm will depend on the degree to which partner nations make use of NATO’s vast network of scientific and technological expertise. To that end, your rapporteur welcomes the recent decision of the NATO Science and Technology Board to include Japan as an STO Enhanced Opportunities Partner (EOP) nation and suggests that the STB might consider inviting other Asian partners to become STO-EOP nations, if they so desire.

I. INTRODUCTION

1. ***"As we look to 2030, we need to work even more closely with like-minded countries. Like Australia, Japan, New Zealand, South Korea. To defend the global rules and institutions that have kept us safe for decades. To set norms and standards. In space and in cyberspace. On new technologies and global arms control. And ultimately, to stand up for a world built on freedom and democracy."*** (NATO Secretary General Jens Stoltenberg, "NATO 2030", June 8, 2020). ***"We are enhancing political dialogue and practical cooperation with our long-standing Asia-Pacific partners – Australia, Japan, New Zealand, and the Republic of Korea – to promote cooperative security and support the rules-based international order."*** (NATO, Brussels Summit Communiqué, 14 June 2021)

2. In the 21st century, the Asia-Pacific region has emerged as the strategic centre of gravity in the international system. Asia-Pacific nations have long acted as an engine of the global economy, and their economic prowess naturally drives a further strategic trend: the region's emergence as a global hub for S&T innovation. Asia-Pacific nations such as China, Japan, and the Republic of Korea (ROK) increasingly lead in the development of Emerging and Disruptive Technologies (EDT), many of which are dual-use and expected to revolutionise military capabilities.

3. As part of its economic and technological growth, the Asia-Pacific region is also emerging as a potential security concern to the NATO Alliance. The rise of China is a central driver of these concerns. Fuelled by China's growing economic and technological clout, Chinese military capabilities have grown dramatically in the past decade, as has its willingness to employ those capabilities towards an aggressive foreign policy. Today, China simultaneously subverts the rules-based international order and undermines the local Asian security order – especially the maritime security order in the East and South China Seas. While Allies enjoy important economic ties with China, then, the NATO Alliance has concerns regarding its regional and global ambitions. Meanwhile, North Korea's aggressive stance against ROK and Japan, and the continued expansion of its illegal nuclear weapons programme further underline the strategic importance of the Asia-Pacific region to NATO.

4. In response to these challenges, NATO has sought to deepen ties with its partners in the region – especially with Japan and ROK. As Japan and ROK are global technological leaders in their own right, each possessing comparative technological advantages in the development of EDTs, the Alliance has been especially eager to invite these partners to join a variety of bilateral and multilateral programmes, each of which offer structured exchanges of defence-related knowledge, expertise, and standards.

5. This short report therefore provides an overview of NATO's developing S&T cooperation with its Asian partner nations Japan and the ROK. The report sheds light on the mutual benefits of that cooperation, identifies the defence-related comparative S&T advantages which might make this cooperation even more robust, and concludes that all parties should deepen their cooperation to tap into these potential benefits.

II. SECURITY IN A CHANGING TECHNOLOGICAL ENVIRONMENT

6. Throughout history, armed forces equipped with the more advanced technologies (and the deeper understanding of their application in military operations) usually enjoyed victory on the battlefield. Those that failed to keep pace were often defeated. During World War II, for example, British innovations in radar technology – amongst other Allied innovations – played a decisive role in the Allies' victory (Harford, 2017).

7. For over seventy years now, NATO has relied on its member states' technological superiority to deter and defend against adversaries. During the Cold War, NATO first deterred the Warsaw

Pact by relying on its advantages in nuclear weapons technology. When the Warsaw Pact achieved nuclear parity in the 1970s, the Allies responded by developing advanced conventional military technologies like stealth, precision-guided munitions, and space-based ISR capabilities to enhance their defence and deterrence (Breedlove and Kosal, 2019).

8. In the 21st century, new EDTs will have far-reaching implications for NATO's technological edge and Allied security more broadly. In an attempt to keep pace with today's rapid technological change and ensure that all member states enjoy the most sophisticated technology, NATO's innovation activities currently focus on seven key areas, which were identified as priorities in the Coherent Implementation Strategy: Artificial Intelligence (AI), Data and Computing, Autonomy, Quantum-enabled Technologies, Biotechnology and Human Enhancements, Hypersonic Technologies, and Space. NATO's Science and Technology Organization (STO) produced a major report last year on the likely impact of these EDTs, together with novel materials. Technologies such as Big Data and Advanced Analytics (BDAA), Artificial Intelligence (AI), Autonomy, Hypersonic Weapons, and Space Technology are primarily disruptive in nature, in that they are projected to have a widespread impact in the next decade or earlier (indeed, hypersonic weaponry, AI, and even autonomous systems are already in use by some militaries). By contrast, technologies such as Quantum Computing, Biotechnology, Additive Manufacturing (3D Printing) and Novel Materials Use are still emerging in character, meaning that their impact remains unclear. These technologies are all highly interrelated and highly interconnected. When combined, they are likely to produce complex interactions and interdependencies whose effects will shape future military capabilities and, by association, NATO's technological edge (NATO STO, 2020). In February 2021, NATO Defence Ministers endorsed an Implementation Strategy on EDTs which will guide NATO's adoption of and adaptation to these technologies. The Strategy focuses on fostering the development of dual-use technologies and on the exchange of best practices that help protect against threats (NATO, 2021c).

EMERGING AND DISRUPTIVE TECHNOLOGIES	
Big Data and Advanced Analytics (BDAA)	*Big Data* describes data that presents significant volume, velocity, variety, veracity and visualisation challenges. *Advanced (Data) Analytics* describes advanced analytical methods for making sense of and visualising large volumes of information. They span methods, such as artificial intelligence, optimisation, modelling & simulation (M&S), human factors engineering and operational research.
Artificial Intelligence (AI)	*Artificial Intelligence* (AI) refers to the ability of machines to perform tasks that normally require human intelligence – for example, recognising patterns, learning from experience, drawing conclusions, making predictions, or taking action – whether digitally or as the smart software behind autonomous physical systems. AI in Russia; Japan; ROK
Autonomy	*Autonomy* is the ability of a system to respond to uncertain situations by independently composing and selecting among different courses of action in order to accomplish goals based on knowledge and a contextual understanding of the world, itself, and the situation. The 2020 STCTTS Report sheds light on the possible use of autonomous systems in future urban combat. Autonomy in Japan; ROK
Hypersonic Weapons System (HWS)	*(Advanced) Hypersonic Weapons Systems* (missiles, vehicles, etc.) operate at speeds greater than Mach 5 (6125 kph). In such a regime, dissociation of air becomes significant, and rising heat loads pose an extreme threat to the vehicle. This class of weapon system includes air-launched strike missiles (HCM), manoeuvring re-entry glide vehicles (HGV), ground-sea ship killers, and post-stealth strike aircraft. See also the 2020 STC General Report on these weapon systems. HWS in Russia; Japan
Space Technologies	*Space Technologies* exploit or must contend with the unique operational environment of space (beginning 90 - 100 km above sea level), which includes: freedom of action, global field of view, speed, freedom of access, a near-vacuum, micro-gravity, isolation,

	and extreme environments (temperature, vibration, sound and pressure). See also the STC Special Report on "Space and Security". Space in Japan
Quantum Technologies (QT)	Next-generation *quantum technologies* exploit quantum physics and associated phenomena at the atomic and sub-atomic scale. These effects support significant technological advancements primarily in cryptography, computation, precision navigation and timing, sensing and imaging, communications, and materials.
Biotechnologies	*Biotechnologies* use organisms, tissues, cells or molecular components derived from living things, to act on living things; or act by intervening in the workings of cells or the molecular components of cells, including their genetic material. The 2021 STCTTS Report on Biological Threats sheds light on some of the promises and perils of biotechnology.
Novel Materials and Manufacturing (NMM)	*Advanced (novel) materials* are artificial materials with unique and novel properties. Advanced materials may be manufactured using techniques drawn from nanotechnology or synthetic biology. Development may include coatings with extreme heat resistance, high-strength body or platform armour, stealth coatings, energy harvesting & storage, superconductivity, advanced sensors & decontamination, bulk production of food, fuel and building materials. Novel Materials in Japan *Additive Manufacturing*, which is often used as a synonym for 3D printing, is the process of creating an almost arbitrary 3D solid object from a digital model through layered addition of materials. Additive Manufacturing can be used for: rapid prototyping, in situ production & repair of deployed military equipment, and production of precision, custom or unique parts. Additive Manufacturing in ROK

(Source: NATO Science & Technology Organization, 2020)

9. The Alliance's concerted technological efforts are timely and significant; indeed, today NATO's technological edge stands at risk of being eroded, due primarily to ongoing shifts in the global technological environment and the changing nature of technology's development and diffusion. During the Cold War, a great deal of advanced military Research and Development (R&D) was driven by government-funded projects. Organisations like the Defense Advanced Research Project Agency (DARPA) led the development of military technologies which gave the Alliance an advantage on the battlefield. Moreover, the development and diffusion of these advanced military technologies could be tightly controlled through government regulations and protected information networks. Some of these technologies found widespread applications in commercial settings. These so-called "dual-use" technologies include the precursor to the Internet, GPS, and synthetic rubber (Frohlich et al., 2019). Since the end of the Cold War, however, this relationship has been reversed. Today, private sector efforts surpass government-funded projects, and private sector technologies are increasingly adapted to military use. Private firms now spend more on R&D than national governments and integrate new technologies into public use more quickly. As a result, today EDTs are developed more rapidly and proliferated through commercial markets more widely than before.

10. This evolving technological environment offers advantages to less sophisticated and economically advanced state and non-state actors by enabling their access to previously unattainable capabilities (DARPA, 2019). North Korea, for example, has utilised advanced offensive cyber capabilities to engage in activities ranging from international financial theft to offsets for its conventional military weaknesses – all capabilities that were previously available to only the most advanced states (DuBois, 2020). Another example is the ongoing revolution in the use of drone technology by state and non-state actors, another capability formerly available to only the international great powers. This phenomenon ranges from Daesh's use of drones in Iraq and

Syria for ISR purposes to Iran's use of drones in a kinetic attack on Saudi oil production facilities (Soufan Center, 2018).

11. More importantly, this new environment offers advantages to NATO's chief strategic competitors Russia and China. As new technologies emerge, both competitors are looking to grasp potential opportunities to "leapfrog" NATO's technological edge and render current NATO advantages obsolescent. Both nations are developing national overarching strategies to tap into their innovation systems and exploit their scientific and technological investments. They have also deepened cooperation with one another on S&T matters in recent years. This includes the establishment of bilateral dialogues and exchanges, the development of industrial S&T "parks" and innovation hubs, and the expansion of cooperation between the two nations' respective academic communities (Bendett and Kania, 2019).

12. China is racing to develop key EDTs via a national technology strategy of Military-Civil Fusion (MCF). MCF actively blurs the line between the civilian and military technology sectors, making Chinese private sector innovations and resources available to the Chinese military establishment at the latter's request. This takes place via a set of legal frameworks, funding mechanisms, and public-private partnerships. Through MCF, China hopes to emerge as an economic superpower and a military superpower simultaneously. China is particularly interested in the development of AI, which it sees as key to its quest to become a "world-class military by 2049." Other interests include 5G, quantum computing, autonomy, robotics, hypersonic systems, and biotechnology, amongst others.

13. Meanwhile, Russia lacks the economic capacity to match Allied and Chinese R&D investments, so it is instead keeping pace by developing asymmetric uses for EDTs. For example, experts believe Russia is implementing a national AI strategy in the hopes of being a "niche" but nonetheless world-class AI power by 2030; one that excels at particular military applications of AI like autonomous weapon systems and offensive cyber warfare (Markotkin and Chernenko, 2020). Beyond AI, Russia is arguably the global leader in the development and deployment of hypersonic weapon systems. Russia is the first country to deploy a hypersonic "boost-glide" vehicle – the *Avangard* – and is currently developing several other hypersonic systems for deployment in the coming decade (Davis, 2020).

14. In response to this changing technological environment, NATO itself is taking steps to further improve its S&T capabilities. Allies have bolstered their national innovation pipelines internally, while NATO is actively leveraging the combined S&T efforts of member and partner nations (Alleslev, 2020). The centrepiece of Allied S&T cooperation is the NATO Science and Technology Organization (STO) and its collaborative network. The network, which is actively managed by the STO's Collaboration Support Office (CSO), brings together over 6,000 scientists and their respective organisations to jointly address S&T and EDTs towards national and NATO defence and security purposes. The strength of the STO network lies in its multidomain approach, bringing together private sector, academic, and government scientists to work on security-related projects in the STO's collaborative research programme of work. The network not only researches new technologies, but also identifies the technologies that will be key to NATO's future security needs, to support national and NATO military commanders to integrate these technologies into their forces (NATO, 2020a). Other relevant NATO entities include the Defence Investment division (including Command Control Communication), the NATO Communications and Information Agency (NCIA), the Emerging Security Challenges Division (ESCD), the International Military Staff including Allied Command Transformation (ACT), Centres of Excellence such as the NATO Cooperative Cyber Defence Centre of Excellence (CCDCOE), and NATO "start-ups," which exist within the Alliance structure as a kind of "in-house" private sector (Brasseur et al., 2020).

III. SCIENCE AND TECHNOLOGY IN ASIA

15. In recognition of this changing strategic environment and the growing threat posed by Chinese militarisation, NATO is deepening ties with its partner nations in the Asia-Pacific. Japan and ROK are world leaders in, inter alia, several EDT sectors, and are widely recognised as S&T powerhouses. This section, then, highlights the comparative S&T advantages these partners possess, identifying key dual-use technologies that both nations are pursuing while highlighting explicit military-technological areas these countries lead in. This section also examines Singapore; although not a NATO partner, Singapore is a global innovation leader, holds excellent relations with NATO, and has welcomed official visits by the NATO PA and NATO bodies in recent years.

A. JAPAN

JAPAN – QUICK FACTS

2021 World Intellectual Property Organization (WIPO Ranking: 16th
2021 International Federation for Robotics (IFRIFR Ranking: 3rd (364 robots per 10,000 employees)
2021 Bloomberg Innovation Index Ranking: 12th
2019 OECD R&D expenditure total: USD 172.6 billion
2019 OECD R&D expenditure as % of GDP: 3.24%
2019 OECD R&D expenditure ranking (% of GDP): 5th

16. Japan's reputation as a technologically advanced nation is well-established. The island nation enjoys world-class technological and innovation capabilities and ranks highly in key innovation metrics like global R&D expenditure, patent applications, and numbers of researchers per capita. As a result, Japan is either a leader or emerging player in many of the EDTs identified by the NATO STO as critical to future security. These include robotics, autonomy, space technologies, AI, hypersonic systems, and advanced materials. As these technologies are generally dual-use in character, Japan has necessarily made advances in both their civilian and military development and deployment.

17. First and foremost, Japan is the undisputed global leader in robotics. Japan has long been at the forefront of robotic design, is far and away the predominant robot manufacturing country, and enjoys one of the highest densities of "robots per worker" in the world. In 2020 alone, Japan produced about half of the world's robots, and exported more than a third of total robots on the international market (IFR, 2021). Indeed, the implementation of robotics-based solutions is widespread in Japanese industry and society, with robots utilised everywhere from sophisticated factories to restaurants, and the sight of automated assembly lines mass-producing automobiles is almost synonymous with Japan itself (Rich, 2020).

18. Japanese leadership in robotics has naturally lent the country an advantage in autonomy. Japanese firms are at the forefront of research and implementation of autonomous systems in existing technologies, but they are also world leaders in the most experimental uses of autonomous systems – especially in the realm of transportation. For example, Japanese automobile companies like Honda are setting the pace for the development of so-called "self-driving" cars, taking major steps in the deployment of autonomous vehicles on public roads (Till, 2020). As an island nation, Japan's significant maritime needs have also led domestic firms to explore truly innovative autonomous solutions in the shipping industry, including the use of so-called "robo-ship" technology and fully autonomous cargo ships and ferries. Some Japanese experts forecast that half of all Japanese coastal ships could be autonomous by 2040 (Yoshida, 2020; The Economist, 2020).

19. Parallel to its capacity in robotics and autonomy, Japan is a global leader in the design and adoption of AI. In a comprehensive 2020 national AI ranking compiled by a group of industry experts, Japan ranked well into the top echelon of nations in overall AI capabilities, with the index recognising Japan as a "rising star" with specific comparative advantages in AI R&D and infrastructure implementation (Tortoise, 2020). With regards to implementation in particular, Tokyo

has established a USD 4 billion fund sponsoring AI innovation in private companies, allowing Japanese firms to implement more experimental AI solutions in their corporate networks compared to other domestic economies (Tsuji, 2018). Similarly, Japanese government agencies are amongst the most advanced in the world in terms of installing AI programmes for public use (Oxford Insights, 2021).

20. Japan has also emerged as a leader in space technology. This past year, Japan budgeted a record USD 4.14 billion for space-related activities (one of the largest space budgets in the world), with funds appropriated for both civilian and military purposes (Si-Soo, 2021). Japan's space agency, the Japanese Aerospace Exploration Agency (JAXA), is considered to be the partner of choice for NASA and its Artemis programme, which plans to send manned spacecraft to the Moon in the near future, and Japanese firms like Toyota and Mitsubishi are being tapped to play an important role in providing equipment and support for joint NASA-JAXA missions (Patel, 2020). Moreover, Japan is one of the few nations to possess its own indigenous space-based navigation satellite system, having recently expanded its Quasi-Zenith Satellite System (GZSS) – essentially a complementary system to US GPS. Perhaps most impressive, Japan was the first space power to successfully land a spacecraft on an asteroid, which then successfully extracted a material sample from the asteroid's exterior before returning that sample to Earth, a major step forward for the space mining industry (Ryan, 2021).

21. Finally, it is worth shining a light on Japan's capabilities in novel materials research. Japan's geographic location and geological history give it access to key raw materials and composites, which it then processes for use in several technology areas. Japan's materials industry gives it an undeniable edge in developing key civilian and military technologies. For instance, Japan is a critical player in the production of silicon ingots, the key raw material on which the global semiconductor industry is based. Indeed, two Japanese companies, Shin-Etsu and Sumco, account for more than 60 percent of the world's silicon wafer production (Platzer et al., 2020). Novel materials are also critical to the development of advanced military capabilities including stealth platforms and hypersonic weapons capabilities.

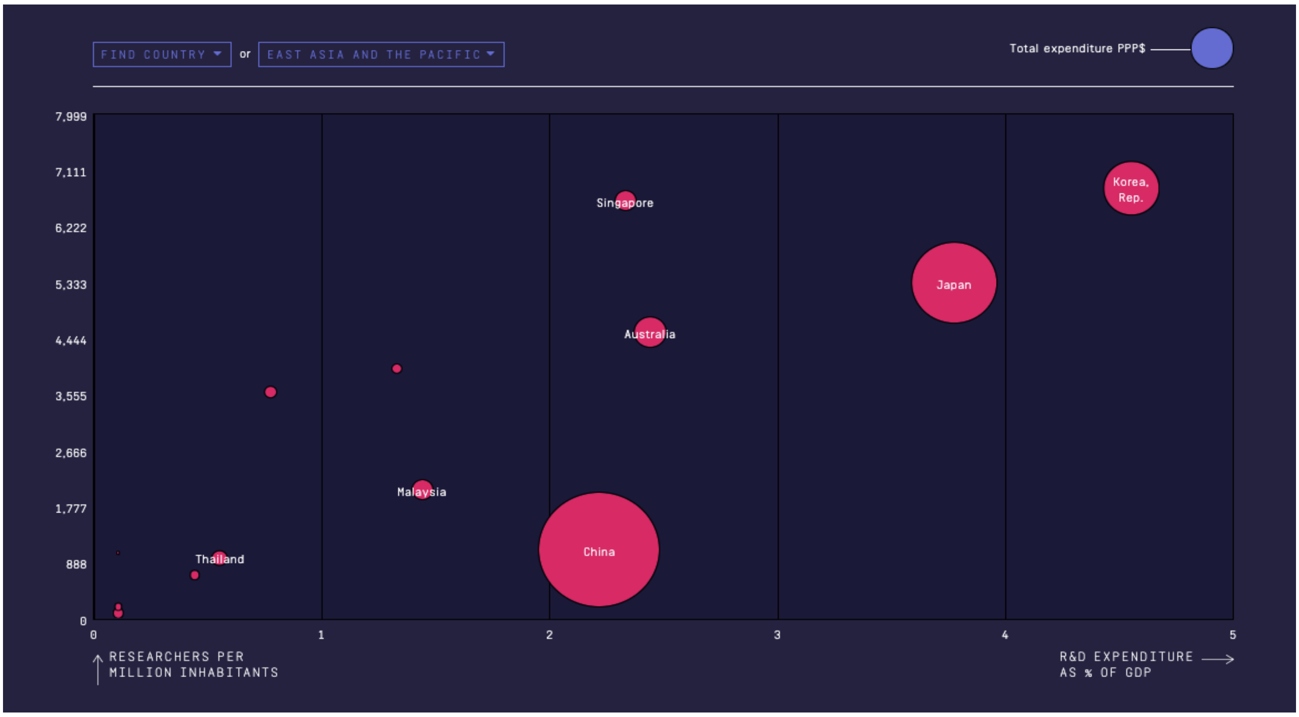
22. With these clear advantages in EDTs, Japan is naturally expanding its indigenous defence technology base in parallel. To promote the development and integration of high-end technology into the national armed forces, the Japanese Ministry of Defence (MoD) established the Acquisition, Technology & Logistics Agency (ATLA) in October 2015. ATLA is heavily involved in the development and testing of new Japanese military platforms, with ATLA's budget increasing from approximately USD 1.6 billion in fiscal year 2020 to about USD 2.1 billion in 2021. ATLA and the Japanese MoD are actively pursuing innovative military capabilities that utilise the EDTs highlighted above in concert with one another, working to first identify and then synergise key technologies together to create powerful new systems.

23. As part of its 2019 R&D Vision, the MoD and ATLA have placed a major emphasis on the design of fully autonomous systems by combining the technological competencies Japan possesses in robotics, AI, and space technology. Japanese researchers hope to design unmanned aerial vehicles (UAVs) as well as unmanned underwater vehicles (UUVs) that can one day soon form a key pillar of Japanese air and maritime security. Moreover, owing to the intense information requirements for truly autonomous systems (which require enormous amounts of data on their surroundings to function effectively), these systems will likely spur innovations in navigation satellite technology and other space-based ISR systems as well (Japan Ministry of Defense, 2019).

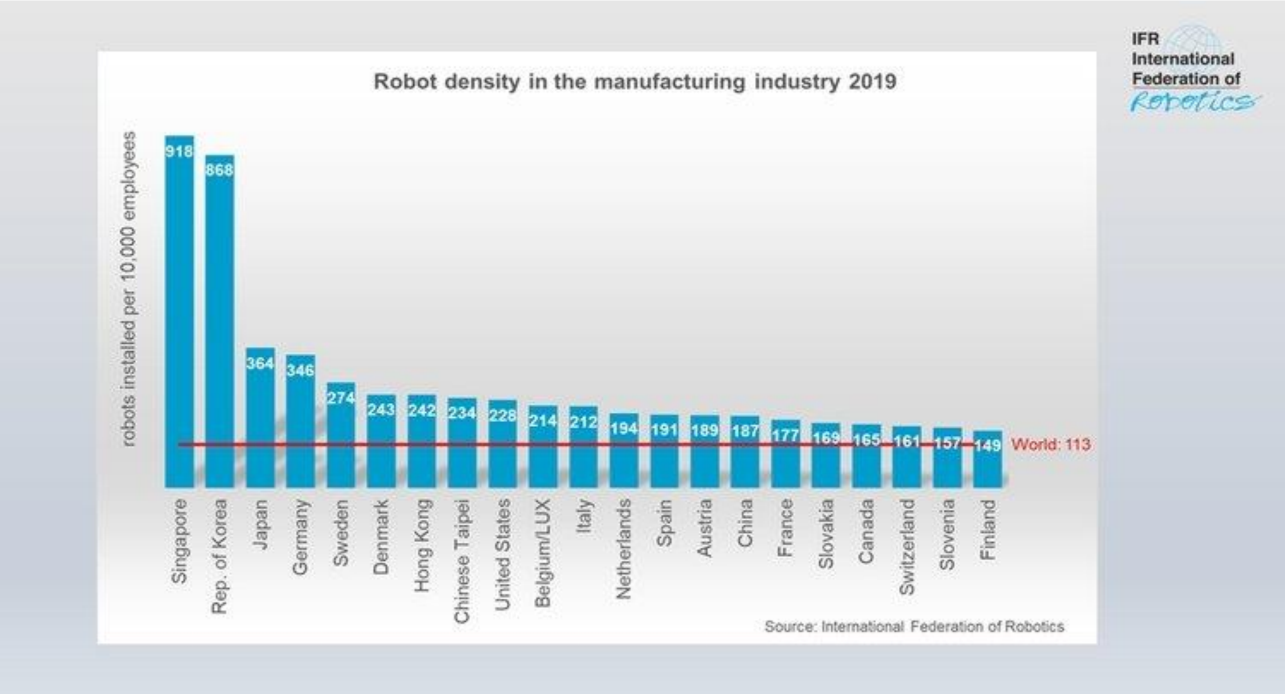
24. Meanwhile, Japan is also developing its own indigenous, cutting-edge sixth generation stealth fighter jet (the F-X, often referred to as the F-3). The project is managed by Mitsubishi Heavy Industries, the prime developing integrator, who is cooperating with domestic and international industry partners. Like other sixth generation stealth fighters under development such as the Franco-German-Spanish Future Combat Aircraft System (FCAS), the F-X will likely be

equipped with so-called autonomous “wingman” drones that together form a “system of systems” around the fighter jet itself (Yeo, 2021). Indeed, the F-X is seen as a “technological testbed” that encourages innovations in key aviation technologies like radars, engines, and advanced materials like novel composites and radar-absorbent coating (Yeo, 2018; Yeo, 2020a; Uesaka, 2016).

25. Similarly, ATLA is actively pursuing a hypersonic weapon capability, with Japanese scientists aiming to test and deploy both a hypersonic cruise missile and a hypersonic “glide vehicle” in the next decade. Research into these systems will simultaneously advance Japanese knowledge in advanced heat-resistant materials – required due to the enormous friction generated around the body of a missile during hypersonic flight – as well as in space navigation technologies, which will be necessary to guide hypersonic missiles as they travel at speeds that surpass traditional satellite-borne navigation capabilities. Similar to the F-X, then, research on hypersonic systems will likely benefit a suite of related technologies that go well beyond the hypersonic systems themselves (Yeo, 2020b).



(Source: UNESCO Institute for Statistics, 2021)



Source: International Federation of Robotics

B. THE REPUBLIC OF KOREA

26. Over the past five decades, the Republic of Korea (ROK) has made remarkable technological strides. Led by large business conglomerates called *chaebol*, ROK has emerged as a global leader in several dual-use technologies that currently define the S&T landscape. Indeed, *chaebol* like Samsung, LG, and Hyundai lead the way in the development of EDTs themselves as well as the adjacent technologies that form the basis of those EDTs, including semiconductors and cutting-edge information and communication technology (ICT) like 5G.

THE REPUBLIC OF KOREA – QUICK FACTS

WIPO Rankings: 10th (2021)
IFR Ranking: 2nd (868 robots per 10,000 employees)
Bloomberg Innovation Index Ranking: 1st in 2021
OECD R&D expenditure total: USD 100 billion
OECD R&D expenditure as % of GDP: 4.64% (2019)
OECD R&D expenditure global ranking (% of GDP): 2nd

27. Due to the Korean government's long-term emphasis on technological development, ROK has emerged as one of the most research-intensive states globally. The country is second only to Israel in terms of R&D expenditure as a percent of its GDP and it enjoys the highest density of researchers per capita in the world (OECD, 2019). Moreover, the government recently announced that it would further expand its relative expenditure on R&D as a percent of GDP for the 2022 fiscal year, primarily to target key EDTs like AI and quantum computing. (Yonhap, 2021a). Beyond their R&D capacities, Korean firms are reputed for the skilful implementation and commercialisation of new technologies. In 2021, Korea topped the Bloomberg Innovation Index, a comprehensive ranking system that considers both R&D and the ability of firms and governments to scale new innovations for widespread use. It is the seventh time in the past nine years that Korea tops the index, outranking several countries that spend far more in absolute terms (Jamrisko et al., 2021).

28. Korea and Taiwan are the leading nations in the reliable design and mass production of semiconductors. Semiconductors, or "chips," are the central component to all advanced electronics manufacturing and form the core foundation for technologies like AI, Big Data, robotics, and autonomy. The structure of the semiconductor industry is also highly diversified, with the design and manufacturing stages of semiconductor production segmented and geographically distributed

in a highly complex global supply chain. Due to the limited number of advanced semiconductor fabrication centres, then, semiconductor fabrication is widely considered to be the critical technological “chokepoint” in the global economy (FP Analytics, 2021).

29. Whereas most nations specialise in just one segment of the semiconductor supply chain, Korea stands as one of the few nations that possesses world-class expertise in multiple segments. *Chaebol* like Samsung and SK Hynix excel at the design of semiconductor chips, with nearly 50% market share, but they and other Korean firms are also at the cutting edge of semiconductor fabrication (Deloitte Insights, 2020). Besides its Taiwanese rival Taiwan Semiconductor Manufacturing Company (TSMC), Korea-based Samsung is the only manufacturer in the world capable of fabricating the most cutting-edge chips measuring under 10 nanometres (Lee and Kleinhans, 2020). These smaller chips, which are more efficient and consume less energy relative to their processing power, are considered critical to technologies like Big Data and AI. Beyond the *chaebol*, moreover, Korea can boast of over 20,000 semiconductor-related SMEs, rounding out the most advanced and comprehensive domestic chip-making economy in the world (Deloitte Insights, 2020). Recognising its comparative advantage, the Korean government has committed USD 450 billion in spending to ensure its status as a chip “powerhouse” for the next decade (Yonhap, 2021a).

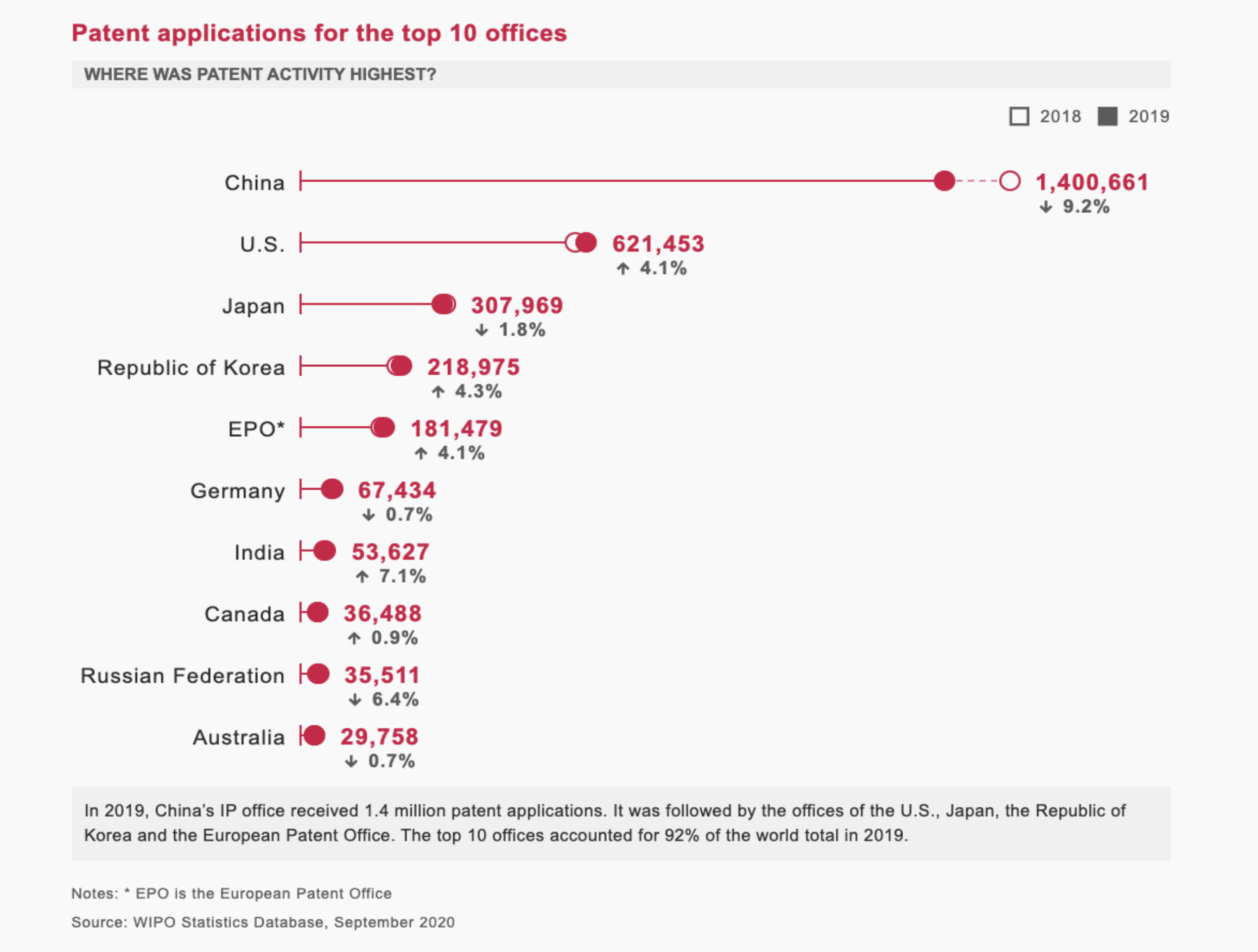
30. An edge in chip manufacturing provides Korea with natural comparative advantage in AI. AI relies on large quantities of data to be effective; storing and processing this data requires advanced “memory” chips – in other words, chips that are specifically designed to hold large quantities of data as efficiently as possible (Khan and Mann, 2020). Already, Samsung and fellow Korean rival SK Hynix are the first and third largest memory chipmakers in the world respectively and together own half of the global memory chip market share (Liao, 2020). The Korean government has encouraged their progress by launching a National Strategy for Artificial Intelligence, employing thousands of Korean researchers to develop up to 50 AI-focused semiconductor models in the next decade alongside AI programmes themselves (Yonhap, 2020).

31. Beyond chips and AI, ROK is perhaps most-known for being one of the world’s leaders in ICT and 5G technology, giving it a boost in the emerging technology sector of autonomy. Indeed, Samsung is already the largest smartphone producer in the world, is second only to Chinese telecommunications giant Huawei in terms of 5G patent ownership and became the first company to roll out a national 5G service, with 85 cities scheduled for coverage by the end of 2021 (White, 2020; Kim, 2019; Woo-Hyun, 2021). Domination in 5G will enable greater amounts of data to be passed between machines and greater reliability and lower latency than in the past. As a result, 5G systems will allow autonomous systems to better receive and relay information on their surroundings, rendering them more intelligent, rapid, and decisive. As a result, Korea could emerge as a key player in autonomy in the very near future.

32. Owing to its civilian technological capabilities, ROK has also steadily emerged as a leading developer of defence technologies. Over the past decade, the government in Seoul has reformed the Korean defence industry, rendering it a global export player on par with NATO defence manufacturers. Seoul is finding eager buyers for its conventional military technology abroad, and several Korean defence systems like the Hanwha K9 Thunder self-propelled howitzer and the T-50 light combat aircraft have been selected for service by NATO nations, including Norway, Estonia, Turkey, and Poland (Yeo, 2020c).

33. To further enhance the competitiveness of Korea’s defence technology base, Korea’s main procurement agency, the Defense Acquisition Program Administration (DAPA), has rapidly expanded its R&D budget in recent years, with almost USD 4 billion earmarked for military technology projects in 2021 and steady increases planned for the next half decade. It has also pushed for and successfully passed legislation that will revamp and streamline Korean research to better exchange dual-use technologies between the civilian and defence sectors (Grevatt, 2021).

34. A key component of ROK’s drive for indigenous capabilities is its ongoing development of a fighter jet capability through the KF-X multirole fighter programme. As fighter jets are highly complex military platforms that require expertise in multiple research areas, the development of an indigenous military aviation industry encourages significant innovation and technological growth. The KF-X will likely see 65 percent of its components produced locally, and Korean scientists believe that the programme will lead to breakthroughs in ISR technologies in particular (Kim, 2021; Newdick, 2020).


Patent applications for the top 10 offices

WHERE WAS PATENT ACTIVITY HIGHEST?

In 2019, China’s IP office received 1.4 million patent applications. It was followed by the offices of the U.S., Japan, the Republic of Korea and the European Patent Office. The top 10 offices accounted for 92% of the world total in 2019.

Notes: * EPO is the European Patent Office

Source: WIPO Statistics Database, September 2020

C. SINGAPORE

35. Singapore is not currently a NATO partner and does not maintain official bilateral cooperation with NATO. That said, Singaporean officials are in frequent, informal contact with NATO officials and work closely with NATO and NATO member states on issues such as counterpiracy, maritime security, and counternarcotic operations in Afghanistan (NATO, 2017). The NATO PA Science and Technology Committee also led a delegation of NATO Parliamentarians on an official visit to Singapore in 2019, where there was a highly productive exchange of ideas with Singaporean officials. Members were impressed by Singapore’s S&T vision and its broader achievements, and both sides were hopeful for future cooperation with the city state (NATO Parliamentary Assembly, 2019).

SINGAPORE – QUICK FACTS

WIPO Ranking: 8th
IFR Ranking: 1st (918 units per 10,000 employees)
Bloomberg Innovation Index Ranking: 2nd
OECD R&D expenditure total: USD 9.89 billion
OECD R&D expenditure as % of GDP: 1.84%
OECD R&D expenditure global ranking (% of GDP): 19th

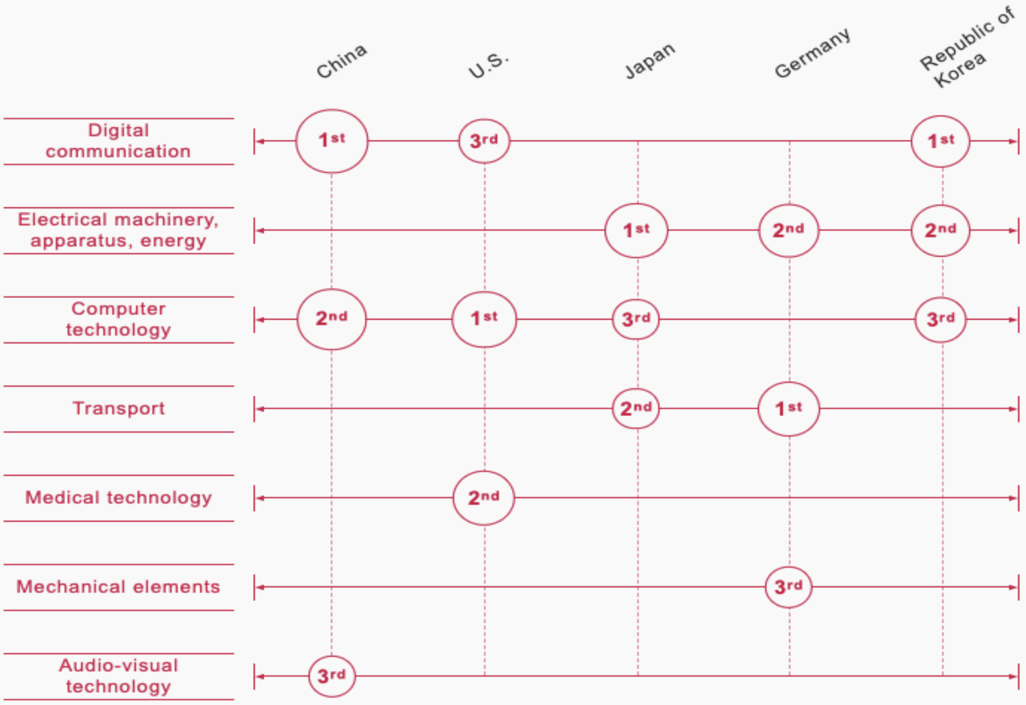
36. As a small city-state with no natural resources, Singapore punches well above its weight in the S&T landscape. Singaporean leaders are aware that human capital is their chief comparative advantage and have promoted education and individual well-being to maximise this asset. The clearest demonstration of Singapore's S&T prowess is the means through which it promotes innovation itself. Since the 1990s, Singapore has launched successive Research Innovation and Enterprise (RIE) plans, which provide R&D funds and guidance to Singaporean universities and private firms. The most recent RIE2025 will dedicate a record USD 25 billion over the next five years to invest in key technology sectors like AI (Tan, 2020).

37. The RIE2025 is a key mechanism through which Singapore is pushing its broader Smart Nation Initiative begun in 2017, wherein the city government looks to promote a digitalised and technologically advanced Singapore. Today, as a result of these efforts, Singapore has a vibrant start-up culture and an international attractive pull as a S&T hub. Key investment areas in Singapore's Smart Nation Initiative are AI and cybersecurity defences. When the STC Members conducted a mission trip to Singapore in 2019, NATO PA parliamentarians and officers were impressed with Singapore's efforts to foster a pool of high-quality AI researchers and cybersecurity experts. Members were also informed of Singapore's two-phase AI Roadmap, wherein the government is investing heavily in digital infrastructure development, the construction of dedicated AI and cyber institutions, and the organisation of urban start-up clusters (NATO Parliamentary Assembly, 2019).

38. Finally, the Singaporean Ministry of Defence and the Defence Science and Technology Agency (DSTA) have also been eager to utilise technological solutions to security problems, especially as they relate to manpower shortages, lack of strategic depth, and urban warfare challenges (Budden and Murray, 2019). To that end, Singaporean defence leaders are fully committed to obtaining technological solutions to their security needs, which includes research on weapons automation, the reduction of ISR operators' workloads, and general technology to improve individual soldier performance (NATO Parliamentary Assembly, 2019).

Top technical fields in PCT applications

WHICH COUNTRIES SPECIALIZE IN WHICH TECHNOLOGIES?



	China	U.S.	Japan	Germany	Republic of Korea
Digital communication	1st	3rd			1st
Electrical machinery, apparatus, energy			1st	2nd	2nd
Computer technology	2nd	1st	3rd		3rd
Transport			2nd	1st	
Medical technology		2nd			
Mechanical elements				3rd	
Audio-visual technology	3rd				

Applicants from China and the Republic of Korea filed intensively for patents related to digital communication, while those from the U.S. filed most in the field of computer technology. For Japan, the top technology field was electrical machinery, and for Germany it was transport.

Source: WIPO Statistics Database, September 2020

IV. NATO S&T COOPERATION WITH PARTNER NATIONS

39. NATO partnerships are guided by two principles: the principle of inclusiveness, which relates to non-discrimination and an assurance that all partners are offered the same basis for cooperation, and the principle of self-differentiation, or the right of partner nations to decide for themselves the extent and intensity of cooperation with NATO. In other words, all partners have equal access to NATO's partnership activities, and each partnership is tailored so as to respect the partner's sovereignty, interests, and requirements.

40. The Individual Partnership and Cooperation Programme (IPCP) and its successor, the ITPP (Individual Tailored Partnership Programme)[1] provide a strategic framework through which many partner nations participate in NATO activities – including workshops, joint trainings and exercises, capability development, and political consultations (Wiklund, 2019). The IPCP system is supported by bilateral documents like the Individual Partnership Action Plan (IPAP), which focuses more on domestic reforms, and the Annual National Programme (ANP), which engages the partner on comprehensive internal security and political reforms (NATO, 2016).

41. NATO S&T cooperation with partner nations also occurs through broader, multilateral frameworks. These include NATO's Science for Peace and Security (SPS) programme, which

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[1] The ITPP is the new format for partnership documents that has just been approved by Allies.

promotes research, innovation, and knowledge exchanges, as well as the Partnership Interoperability Initiative (PII), an Initiative launched at the 2014 Wales Summit that improves NATO partner nations' technological and procedural cohesion and familiarity (NATO, 2021a; NATO, 2020b). Within the PII, NATO has also established the Enhanced Opportunities Partners (EOP) programme for select partner nations, which offers closer and more tailored access to NATO structures and processes.

42. NATO's STO has impressive S&T capabilities, based, among other things, on its vast network. Mutual exchanges with these nations benefit both sides and allow all parties to better orchestrate and accelerate the innovation process moving into the future. More importantly, partnership status with NATO grants partner nations access to the NATO STO's activities and structures. This includes access to STO Sessions held by the organisation's main policy body, the Science and Technology Board (STB), as well as access to researchers in the STO's collaborative network and the STO's various internal research programmes.

43. Inclusion in the STO network, particularly as an EOP partner, offers critical benefits to partner nations. Since both NATO member states and NATO partner nations each possess comparative S&T advantages, the STO offers a network through which these actors can securely exchange their expertise. Cooperation in the STO network promotes standardisation of methods and processes between the Alliance and selected partner nations, thus improving interoperability and integration between each side's military platforms. The whole of the network, then, is greater than the sum of its individual parts, as the overall proficiency of the network allows each participant to overcome S&T deficiencies by relying on the particular expertise of their fellow participants. This is especially important for smaller countries which lack the economic capacity to engage in multiple technology sectors, but nonetheless possess niche technological specialisations (Author Interview with Representatives of the Swedish Ministry of Defence, 2021).

44. Cooperation in the STO network deepens relations with NATO member nations and partner nations. This is also the case for NATO's relations with its global partners, even though their individual level of cooperation is not as comprehensive as that of selected partners in the Euro-Atlantic region. As cutting-edge technologies are rapidly evolving, it is difficult to acquire all necessary technologies through national R&D activities. Partner nations therefore recognise the need to strengthen technological cooperation with other countries and with international organisations including the STO. Finally, and perhaps most elementary, network access reduces simple human barriers to cooperation, including travel schedules and time management (Swedish MoD, 2021; Dr Mishima; 2021; Dr Hokazono; 2021).

45. More broadly, cooperation within the STO network allows both NATO member states and partner nations to establish which EDTs will be crucial for future defence and security needs. This, of course, is important for all parties in terms of keeping pace in key technology sectors, but it also plays an important role in the planning and future direction of NATO's partner nations (Author Interview with Swedish MoD, 2021). Science and technology cooperation with NATO will contribute to the early acquisition of important technologies and to ensuring technological superiority as well as the strengthening of the partnership between partner nations and NATO, as partners sharing fundamental values and responsibilities for global security challenges. (Dr Mishima, 2021; Dr Hokazono, 2021).

46. Finally, the NATO STO network and SPS programme can and should provide an opportunity to promote young experts in the fields of science, technology, engineering and mathematics. In this context your rapporteur needs to stress that the science, technology, engineering, and mathematics (STEM) field still suffers from an underrepresentation of women who account for less than 30 percent of researchers worldwide (NATO, 2021d). The gender gap is particularly concerning in the ICT sector where women represent only three percent of all students in higher education (UNESCO, 2020). It is important to note that the issue of persistent gender inequality in the scientific workforce deprives STEM-related R&D of diverse perspectives, creativity, and

innovation and thus prevents these fields from reaching their full potential (UNESCO, 2020). For example, closing the gender gap in STEM was found to further boost productivity, help increase employment and create economic growth (EIGE, 2020). While some progress is being made, more is necessary. In this context it is noteworthy that in 2020, NATO's SPS programme awarded 88 stipends across 40 multi-year projects to young scientists, 37 of whom were women. In 2019, SPS also hosted an Advanced Research Workshop at Qatar University to discuss how to encourage female participation in the cyber workforce. The participants underlined the importance of expanding professional networks for women in science across NATO and partner nations, highlighting one of many ways how S&T cooperation can contribute to a more diverse workforce (NATO, 2019a).

47. Finally, participation in the NATO STO network is an essential mechanism through which NATO and partner scientists and researchers can build personal relationships with one another. Since organisations and institutions are built on individuals, and the world of S&T research is relatively small and insular, the development of shared personal bonds between scientists benefits not only the individual projects on which these scientists are working together, but also the broader interorganisational ties and familiarity which are crucial to effective cooperation at the macro-level (Swedish MoD, 2021; Dr Mishima, 2021; Dr Hokazono, 2021).

A. NATO'S PARTNERSHIP WITH JAPAN

48. Japan is NATO's longest-standing partner nation outside of the Euro-Atlantic region. Cooperation between the two sides began in the early 1990s, when Japan offered important assistance to NATO in the latter's efforts to stabilise the Balkan region. Collaboration then evolved further during NATO's missions in Afghanistan, wherein Japan provided strong financial support to the International Security Assistance Force (ISAF). Cooperation between Japan and NATO has since accelerated in the past decade. In 2013, Japan signed a joint political declaration with NATO, which was then bolstered with the signing of an IPCP in 2014 (most recently renewed in 2020). Likewise, Japan is an active participant in both the SPS Programme and the PII and was approved as an EOP member by the STB in February 2021. Finally, Japan has also established a Mission to NATO in 2018, operating through Japan's Embassy to Belgium.

49. Despite this strong political relationship, however, Japan's cooperation with NATO, particularly in the area of military S&T, has been relatively limited. This is largely due to historical reasons and Japan's domestic political preferences regarding external military cooperation in general. With the exception of its special bilateral relationship with the United States, Japan banned the transfer of military equipment and technology until 2014, in accordance with the "Three Principles on Arms Exports." In 2014, however, Japan adopted a new export control policy which enables Japan to identify and develop cooperative S&T opportunities with NATO (Author Interview with Dr Hokazono, 2021).

50. In this context, the Japanese Ministry of Defence established official dialogue channels with NATO and NATO member states to explore S&T cooperation opportunities on defence-related programmes. Japanese scientists actively participate in the Science for Peace and Security (SPS) Programme, wherein they engage in several areas of joint activities. These include developing technologies to enhance border and port security as well as infrared detection. In addition to SPS programmes, Japan pursues bilateral projects with individual NATO Allies. Cooperation has been especially close with scientists from the United Kingdom and France. For example, Japan does research together with the United Kingdom on resilience to chemical and biological agents, a new air-to-air missile and a next-generation radiofrequency sensor. Another joint programme is with France on autonomous mine detection systems. (Dr Hokazono, 2021). \

51. Furthermore, NATO-Japan S&T cooperation has also been fruitful in the realm of cyber defences. Both sides have worked together to enhance resiliency to cyberattacks, and in October 2019, NATO was invited to Japan for cyber defence staff talks. During these talks, NATO officials

first assessed current cyberthreats and policy developments with their Japanese counterparts, before engaging with academia and industry. A key focus was the need to jointly foster a norms-based, predictable, and secure cyberspace (NATO, 2019). In December 2019, Japan also actively participated in NATO's cybersecurity war games, progressing from its previous status of observer country (Miki, 2019). Japan has also sent an expert to work at NATO's Cooperative Cyber Defence Centre of Excellence (CCDCOE). Finally, in 2019, Japan participated in a STO Symposium on the Integration of Women into Ground Combat Units. This work is recorded in the recent NATO Chief Scientist report on the science the STO has undertaken on "Women in the Armed Forces".

52. One area of future collaboration with Japan could be maritime security and maritime-related technologies. China has engaged in aggressive behaviour in the South and East China Seas, with Beijing utilising ever more sophisticated means to destabilise the region (including the use of undersea autonomous drones to probe other countries' sovereign waters) (Sutton, 2021).

53. At the beginning of 2021, the NATO Science and Technology Board has included Japan as a STO-EOP nation, a move which will provide for further interactions. The Board now has all G7 members participating.

B. NATO'S PARTNERSHIP WITH THE REPUBLIC OF KOREA

54. NATO's relationship with the Republic of Korea is less evolved than its relationship with Japan but has nonetheless been very fruitful and productive. ROK began its relationship with NATO in 2005 and has been an important partner to NATO in Afghanistan, working closely with ISAF in the region from 2010 to 2013. The partnership reached a new level with the signing of an IPCP in 2012, which was most recently renewed in November 2017. Likewise, Korea is a participant in both the SPS Programme and the PII. Although not a member of the EOP programme, ROK has expressed a desire to work more closely with NATO on questions of military interoperability – especially regarding exchanges of civilian and military personnel, joint trainings and exercises, and cooperation in standardisation and logistics (NATO, 2021b).

55. Practical security cooperation between NATO and the Republic of Korea has concentrated on a variety of areas but has likewise remained limited. The SPS Programme is a central vehicle for cooperation between ROKand NATO. ROKparticipates in several Multi-Year Projects (MYP) within the SPS framework, which are longer-term cooperative ventures on key EDTs that Korean scientists engage in with scientists from NATO member states. These MYPs have tackled complex questions on EDTs like robotics, nanotechnology, and automation more broadly. Other areas of cooperation also include cyber defence, counterterrorism, civil preparedness, and disaster relief (NATO, 2021e).

56. One important area of collaboration is the non-proliferation of WMD and WMD delivery systems. North Korea's aggressive testing of nuclear systems as well as its wanton assassination of a North Korea citizen using a nerve agent at an airport in Malaysia has raised concerns in the region of CBRN threats. To that end, scientists from the Republic of Korea and NATO have cooperated to develop cutting-edge sensor systems which can detect CBRN residues and emissions (NATO, 2021e). Within the STO, ROK has been active in the Modelling and Simulation Group.

57. Overall, however, cooperation with the Republic of Korea can be significantly deepened in areas of mutual interest. One clear area that ROK may be interested in would be the inclusion of more interoperability programmes – if such a move were amenable to both sides. Since NATO member countries purchase conventional military technology from ROK's defence industry, any effort to improve standardisation between ROK technologies and NATO would be of benefit to ROK's defence industry and would also improve NATO's own internal cohesion and integration.

V. CONCLUSIONS

58. S&T cooperation is a relevant yet underexplored pillar of NATO’s relationships with its Asian partner nations. This pillar is naturally useful for the collective defence and security of both NATO and the partner nations themselves – especially as it relates to capability development and interoperability. Indeed, S&T cooperation also generates synergies in military and dual-use technology development and reduces duplication and other inefficiencies. As, on the one hand, NATO’s Asian partner nations are second to none in key EDTs, and, on the other hand, the NATO STO maintains the world’s largest collaborative research forum in the field of defence and security, cooperation between these two sides would necessarily be of the highest quality.

59. NATO’s Asian partner nations, as well as Singapore, are already involved in STO events on the strategic and planning level, as well as in STO’s Collaborative Programme of Work (CPoW) and the Programme of Work of the STO’s CMRE. Their participation has been on a focussed scale – due, among other reasons, to geographical distance and related logistical issues. As online videoconferences and teleworking become more widespread in the aftermath of the COVID-19 crisis, however, prospects for deeper and more comprehensive cooperation in the STO framework appear promising.

60. The fact that the NATO Science and Technology Board included Japan as a STO-EOP nation at the beginning of 2021 is therefore a welcome and – in the view of your rapporteur – logical development. Deepening and expanding cooperation in the S&T realm obviously depends also on the degree to which partner nations make use of NATO’s vast network of scientific and technological expertise. The inclusion of Japan as a STO-EOP nation will deepen and expand cooperation between Japan and NATO. In view of maintaining the technological edge in a stepwise approach, the STB might consider inviting other nations to consider becoming a STO-EOP nation. Expanding the number of participating STO-EOP partner nations would allow the latter to better identify technological trends and build human networks by utilising NATO S&T networks. For STO, it would enlarge the pool of scientists and draw upon their expertise, particularly in the area of EDTs.

61. S&T cooperation with partner nations currently appears to be particularly pertinent in the cyber domain. Cyber has become crucially important for national security, but also for increasing resilience. As both NATO Allies and their Asian partner nations heavily depend on the freedom of the seas, closer cooperation in maritime technology seems equally compelling. More generally, closer cooperation between NATO and Asian partner nations can, over time, lead to the development of a comprehensive technological policy dialogue concerning EDTs, both from a military and economic security perspective. For example, cooperation in these areas can help to advance global standards in the cyber and space domains. Other areas of interest could include operational concepts, training, technological standards, and ethics and safety of technology use.

62. Furthermore, NATO and Asian partner nations can share best practices regarding new ways to leverage the creativity of their national S&T institutions and to expand the limited pool of expertise in disruptive technologies. Encouraging women to engage in defence-related S&T should receive higher priority to increase the diversity of ideas and perspectives of R&D efforts. This will bring the benefit of expanding the intellectual base in S&T, and foster innovation more broadly. NATO and Asian partner nations could share best practices on how to promote the participation of women in defence-related research of EDTs. Encouraging the participation of women is likely to bring new ideas and perspectives to research, development and implementation. Possible actions could include an evaluation of the NATO SPS programme with a view to encourage particularly young female scientists. Another option could be the establishment of a mentorship programme for women within the STO as well as the expansion of thematically focused networks for women experts across NATO and partner nations.

63. In addition, NATO could engage in structured political consultations with Asian partner nations on topics which reflect shared areas of interest, such as intellectual property protection, enhanced export controls of sensitive technologies, screenings of investments, and restrictions against S&T/innovation collaboration with problematic institutions associated with adversarial nations.

64. The NATO PA can also help promote S&T cooperation with Asian partner nations on the parliamentary level by raising awareness of the opportunities and challenges of S&T. This could be achieved by exploring efforts of NATO partner nations on resilience during future visits, and more generally by putting S&T issues more prominently on the agenda of NATO PA visits to the region.

BIBLIOGRAPHY

Alleslev, Leona, "Defence Innovation," *NATO Parliamentary Assembly,* 20 November 2020. https://www.nato-pa.int/download-file?filename=/sites/default/files/2020-12/041%20STC%2020%20E%20rev.%202%20fin%20%20-%20REPORT%20-%20DEFENCE%20INNOVATION_0.pdf

Bendett, Samuel, and Elsa B. Kania, "China, Russia Deepen Technological Ties," *Defense One,* 4 October 2019. https://www.defenseone.com/threats/2019/10/china-russia-are-turning-each-other-tech-help-west-limits-access/160364/

Brasseur, Michael D., Rob Murray, Sean Trevethan, "NATO's Startup Charts a Bold Future in Maritime Unmanned Systems," *Defense News,* 20 April 2020. https://www.defensenews.com/opinion/commentary/2020/04/20/natos-start-up-charts-a-bold-future-in-maritime-unmanned-systems/

Breedlove, Philip, and Margaret E. Kosal, "Emerging Technologies and National Security: Russia, NATO, & the European Theater," *Hoover Institution,* 25 February 2019. https://www.hoover.org/research/emerging-technologies-and-national-security-russia-nato-european-theater

Budden, Dr. Phil, and Prof. Fiona Murray, "Defense Innovation Report," *MIT Lab for Innovation Science and Policy,* May 2019. https://innovation.mit.edu/assets/Defense-Innovation- Report.pdf

DARPA, "Creating Technology Breakthroughs and New Capabilities for National Security," *Defense Advanced Research Projects Agency,* August 2019. https://www.darpa.mil/attachments/DARPA-2019-framework.pdf

Davis, Susan, "Hypersonic Weapons – A Technological Challenge for Allied Nations and NATO?" *NATO Parliamentary Assembly,* 20 November 2020. https://www.nato-pa.int/download-file?filename=/sites/default/files/2020- 11/039%20STC%2020%20rev.%202%20fin%20-%20HYPERSONIC%20WEAPONS.pdf

Deloitte Insights, "Rise of the 'Big 4': The Semiconductor Industry in Asia Pacific," *Deloitte,* 28 August 2020. https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/technology-media-telecommunications/cn-tmt-rise-of-the-big-4-en-082820.pdf

Dubois, Eun, "Building Resilience to the North Korean Cyber Threat: Experts Discuss," *Brookings Institute,* 23 December 2020. https://www.brookings.edu/blog/order-from-chaos/2020/12/23/building-resilience-to-the-north-korean-cyber-threat-experts-discuss/

Economist (The), "As Crews Grow Old, Japanese Shipping Firms Try to Do Without Them," 25 July, 2020. https://www.economist.com/asia/2020/07/23/as-crews-grow-old-japanese-shipping-firms-try-to- do-without-them

European Institute for Gender Equality, "How gender equality in STEM education leads to economic growth," 2020. https://eige.europa.eu/gender-mainstreaming/policy-areas/economic-and-financial-affairs/economic-benefits-gender-equality/stem

FP (Foreign Policy) Analytics, "Semiconductors and the U.S.-China Innovation Race," *Foreign Policy,* 16 February 2021. https://foreignpolicy.com/2021/02/16/semiconductors-us-china-taiwan-technology-innovation-competition/

Frohlich, Thomas C., Evan Comen, and Grant Suneson, "These 15 Commericial Products are the Direct Result of Military Research," *USA Today,* 16 May 2019. https://eu.usatoday.com/story/money/2019/05/16/15-commercial-products-invented-by-the-military/39465501/

"The Global AI Index." n.d. Tortoise. https://www.tortoisemedia.com/intelligence/global-ai/

Grevatt, Jon, "South Korea Enacts Law to Transform Defence R&D Culture," *Janes Defence Weekly*, 01 April 2021. https://www.janes.com/defence-news/news-detail/south-korea-enacts-law-to- transform-defence-rd-culture_16639

Harford, Tim, "How the Search for a 'Death Ray' Led to Radar," *BBC*, 9 October 2017. https://www.bbc.com/news/business-41188464

Hokazono, Dr Hirokazu (Senior Advisor for the Institute of Future Engineering, former Deputy Commissioner & Chief Defense Scientist, ATLA), Author Interview, 2021.

IFR, "Robot Race: The World's Top 10 Automated Countries," *International Federation of Robotics,* 27 January 2021. https://ifr.org/ifr-press-releases/news/robot-race-the-worlds-top-10-automated-countries

Jamrisko, Michelle, Wei Lu, and Alexandre Tanzi, "South Korea Leads World in Innovation as U.S. Exits Top Ten," *Bloomberg,* 3 February 2021. https://www.bloomberg.com/news/articles/2021-02-03/south-korea-leads-world-in-innovation-u-s-drops-out-of-top-10

Japan Ministry of Defense, "R&D Vision: Toward Realization of Multi-Domain Defense Force and Beyond," 2019. https://www.mod.go.jp/atla/en/policy/pdf/rd_vision_full.pdf

Kania, Elsa B., and Lorand Laskai, "Myths and Realities of China's Military-Civil Fusion Strategy," *Center for a New American Security,* 28 January 2021. https://www.cnas.org/publications/reports/myths-and-realities-of-chinas-military-civil-fusion-strategy

Khan, Saif M., and Alexander Mann, "AI Chips: What They Are and Why They Matter," *Center for Security and Emerging Technology (Georgetown University),* April 2020. https://cset.georgetown.edu/publication/ai-chips-what-they-are-and-why-they-matter/

Kim, Brian, "South Korea Unveils Prototype of Homegrown KF-X Flighter Jet," *Defense News,* April 9, 2021. https://www.defensenews.com/industry/techwatch/2021/04/09/south-korea-unveils-prototype-of-homegrown-kf-x-fighter-jet/

Kim, Sam, "South Korea is Getting a Head Start in 5G as U.S. and China Spar Over Huawei," *Bloomberg,* 4 April 2019. https://www.bloomberg.com/news/articles/2019-04-04/south-korea-gets-5g-head-start-as-u-s-china-spar-over-huawei

Lee, John, and Jan-Peter Kleinhans, "Taiwan, Chips, and Geopolitics: Part 1," *The Diplomat,* 10 December 2020. https://thediplomat.com/2020/12/taiwan-chips-and-geopolitics-part-1/

Liao, Rita, "South Korea Pushes for AI Semiconductors as Global Demand Grows," *Tech Crunch,* 13 October 2020. https://techcrunch.com/2020/10/13/south-korea-pushes-for-ai-semiconductors-as-global-demand-grows/

Lufkin, Bryan, "What the World Can Learn From Japan's Robots," *BBC,* 6 February 2020. https://www.bbc.com/worklife/article/20200205-what-the-world-can-learn-from-japans-robots

Markotkin, Nikolai, and Elena Chernenko, "Developing Artificial Intelligence in Russia: Objectives and Reality," *Carnegie Endowment for International Peace,* 8 May 2020. https://carnegie.ru/commentary/82422

Miki, Rieko, "Japan Joins NATO Cybersecurity Drills to Counter Chinese Hackers," *Nikkei Asia,* 3 December 2019. https://asia.nikkei.com/Politics/International-relations/Japan-joins-NATO-cybersecurity-drills-to-counter-Chinese-hackers

Mishima, Dr Shigenori, (Deputy Commissioner and Chief Defense Scientist, ATLA), Author Interview, 2021.

NATO,

- (2016): "Partnership Tools," June 24, 2016. https://www.nato.int/cps/en/natohq/topics_80925.htm#:~:text=The%20Individual%20Partnership%20and%20Cooperation,(NAC)%20and%20the%20partner.
- (2017): "Relations with Partners Across the Globe," 19 May 2017. https://www.nato.int/cps/en/natohq/topics_49188.htm
- (2019a): "NATO encourages women's participation in cyber security," 31 October, 2019. https://www.nato.int/cps/en/natohq/news_171188.htm?selectedLocale=en
-
- (2019b): "NATO and Japan Intensify Dialogue on Cyber Defence," 9 October 2019. https://www.nato.int/cps/en/natohq/news_169493.htm?selectedLocale=en
- (2020a): "NATO Science and Technology Organization," 8 January 2021. https://www.nato.int/cps/en/natohq/topics_88745.htm
- (2020b): "Partnership Interoperability Initiative," 3 November 2020. https://www.nato.int/cps/en/natohq/topics_132726.htm
- (2021a): "Science for Peace and Security," 19 January 2021. https://www.nato.int/cps/en/natolive/78209.htm
- (2021b): "Relations with the Republic of Korea," 22 March, 2021. https://www.nato.int/cps/en/natohq/topics_50098.htm (2021c): "Emerging and disruptive technologies" 18 June, 2021, https://www.nato.int/cps/en/natohq/topics_184303.htm

- (2021d) "NATO supports women and girls in science," February 2021. https://www.nato.int/cps/en/natohq/news_181323.htm
  -
  -
  - (2021e): "NATO SPS Programme Country Flyer – Republic of Korea," January 2021. http://www.nato.int/science/country-fliers/Republic-of-Korea.pdf

NATO Parliamentary Assembly, "STC Mission Report – Singapore, 6-9 May, 2019." 21 November 2019. https://www.nato-pa.int/download-file?filename=/sites/default/files/2019-11/202%20STC%2019%20E%20-%20Mission%20Report%20Singapore.pdf

NATO STO, "Science and Technology Trends 2020-2040: Exploring the S&T Edge," *NATO Science & Technology Organization,* March 2020. https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf

Newdick, Thomas, "Photos Show South Korean Next-Generation Fighter Jet Rapidly Taking Shape," *The Drive,* 3 September 2020. https://www.thedrive.com/the-war-zone/36177/photos-show-south-koreas-next-generation-fighter-jet-rapidly-taking-shape

OECD, "Gross Domestic Spending on R&D," 2021. https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm

Oxford Insights, "AI Readiness Index 2020," *Oxford Insights,* 2021. https://www.oxfordinsights.com/government-ai-readiness-index-2020

Patel, Neev V., "Why Japan is Emerging As NASA's Most Important Space Partner," *MIT Technology Review,* 22 July, 2020. https://www.technologyreview.com/2020/07/22/1005546/why-japan-jaxa-nasas-most-important-space-partner-artemis-moon-gateway/

Platzer, Michaela D., John F. Sargent Jr., and Karen M. Sutter, "Semiconductors: U.S. Industry, Global Competition, and Federal Policy," *Congressional Research Service,* 26 October, 2020. https://www.everycrsreport.com/files/2020-10-26_R46581_ee55af430d9ef4cf749766bbe749625b5c759b1a.pdf

Rich, Motoko, "Japan Loves Robots, but Getting Them to Do Human Work Isn't Easy," *The New York Times,* 4 January 2020. https://www.nytimes.com/2019/12/31/world/asia/japan-robots-automation.html

Ryan, Jackson, "Inside the daring Mission to Bring Pieces of Ancient Asteroid Ryugu Back To Earth," *CNET,* 30 June, 2021. https://www.cnet.com/features/inside-the-daring-mission-to-bring-pieces-of-ancient-asteroid-ryugu-back-to-earth/

Schneider, Todd, Gee Hee Hong, and Anh Van Le, "Land of the Rising Robots," *Finance and Development* Vol. 55, No. 2 (June, 2018). https://www.imf.org/external/pubs/ft/fandd/2018/06/japan-labor-force-artificial-intelligence-and-robots/schneider.htm

Si-Soo, Park, "Japan Budgets a Record $4.14 Billion for Space Activities," *Space News,* 9 March, 2021. https://spacenews.com/japan-budgets-a-record-4-14-billion-for-space-activities/

Soufan Center (The), "IntelBrief: Terrorist' Use of Drones and Other Emerging Technologies," *The Soufan Center,* 3 October 2018. https://thesoufancenter.org/intelbrief-terrorists-use-of-drones-and-other-emerging-technologies/

Sutton, H. I, "Underwater Drone Incidents Point to China's Expanding Intelligence Gathering," *Royal United Services Institute (RUSI),* 15 January 2021. https://rusi.org/commentary/underwater-drone-incidents-point-china-expanding-intelligence-gathering

Swedish Ministry of Defence, Representatives, Author Interview, 2021.

Tan, Audrey, "Record $25 Billion For Research and Innovation Over the Next 5 Years to Secure Singapore's Future," *The Strait Times,* 11 December 2020. https://www.straitstimes.com/singapore/record-25-billion-for-research-and-innovation-over-next-five-years-to-secure-singapores

Till, Andrew, "Honda Autonomous Vehicle: How Japan Has Raised the Bar For Autonomy and Cybersecurity," *Trustonic,* 30 November 2020. https://www.trustonic.com/opinion/honda-autonomous-vehicle-how-japan-has-raised-the-bar-for-autonomy-and-cybersecurity/

Tortoise. "The Global AI Index." n.d. https://www.tortoisemedia.com/intelligence/global-ai/

Tsuji, Takashi, "Japan To Expand Innovation Fund to $4bn in AI Push," *Nikkei Asia,* 29 August 2018. https://asia.nikkei.com/Economy/Japan-to-expand-innovation-fund-to-4bn-in-AI-push

Uesaka, Yoshifumi, "Japan's Stealth Fighter Promises More Than Military Defense," *Nikkei Asia,* 25 February 2016. https://asia.nikkei.com/Business/Biotechnology/Japan-s-stealth-fighter-promises-more-than-military-defense

UNESCO, "Boosting gender equality in science and technology. A challenge for TVET programmes and careers," 2020. https://unevoc.unesco.org/pub/boosting_gender_equality_in_science_and_technology.pdf

UNESCO Institute for Statistics, "How Much Does Your Country Invest in R&D?" 2021. http://uis.unesco.org/apps/visualisations/research-and-development-spending/

White, Edward, "Samsung Mounts 5G Offensive as Countries Review Huawei Networks," *The Financial Times, 4* October 2020. https://www.ft.com/content/4ef1d31f-ebfe-475e-97fb-3c7993b11202

Wiklund, Marlene, "NATO's Partnerships are Diverse, Valuable, and Flexible to the Circumstances at Hand," *Atlantic Council,* July 2, 2019. https://www.atlanticcouncil.org/blogs/new-atlanticist/nato-s-partnerships-are-diverse-valuable-and-flexible-to-the-circumstances-at-hand/

WIPO, "Global Innovation Index 2020," *World Intellectual Property Organization,* 2020. https://www.wipo.int/global_innovation_index/en/2020/

Woo-Hyun, Shim, "S. Korea to Further Expand 5G Infrastructure," *The Korea Herald,* 26 January 2021. http://www.koreaherald.com/view.php?ud=20210126000927

Yeo, Mike,

- (2018): "Japan and South Korea Face Headwinds on Homegrown Jets," *Defense News,* 5 February 2018. https://www.defensenews.com/digital-show-dailies/singapore-airshow/2018/02/05/japan-and-south-korea-face-headwinds-on-homegrown-jets/
- (2020a): "Japan Unveils Timeline For Indigenous Fighter Jet Program," *Defense News,* 9 July 2020. https://www.defensenews.com/air/2020/07/09/japan-unveils-timeline-for-indigenous-fighter-jet-program/
- (2020b): "Japan Unveils its Hypersonic Weapons Plans," *Defense News,* 13 March 2020. https://www.defensenews.com/industry/techwatch/2020/03/13/japan-unveils-its-hypersonic-weapons-plans/
- (2020c): "Reform Efforts in South Korea Create Ecosystem for Defense Industry Growth," *Defense News,* 17 August 2020. https://www.defensenews.com/top-100/2020/08/17/reform-efforts-in-south-korea-create-ecosystem-for-defense-industry-growth/
- (2021): "Japanese Defense Firms Prosper Amid Futuristic Tech Orders, Export Drives," *Defense News,* 12 July 2021. https://www.defensenews.com/top-100/2021/07/12/japanese-defense-firms-prosper-amid-futuristic-tech-orders-export-drives/

Yonhap,

- (2020): "S. Korea Aims to Develop 50 AI Chips by 2030," *Yonhap,* 12 October 2020. https://en.yna.co.kr/view/AEN20201012007500320
- (2021a): "S. Korea to Invest 23.5 Tln Won In Core R&D Projects Next Year," *Yonhap,* 24 June 2021. https://en.yna.co.kr/view/AEN20210624006100320?section=search

Yoshida, Keigo, "'Robo-Ships' Offer Lifeline for Japan's Shorthanded Industry," *Nikkei Asia,* 23 September 2020. https://asia.nikkei.com/Business/Transportation/Robo-ships-offer-lifeline-for-Japan-s-shorthanded-industry