Warwick Think Tank Report

The Technology & Innovation report

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Political, Economic and Social Implications of Races to Produce Technologies of the Future

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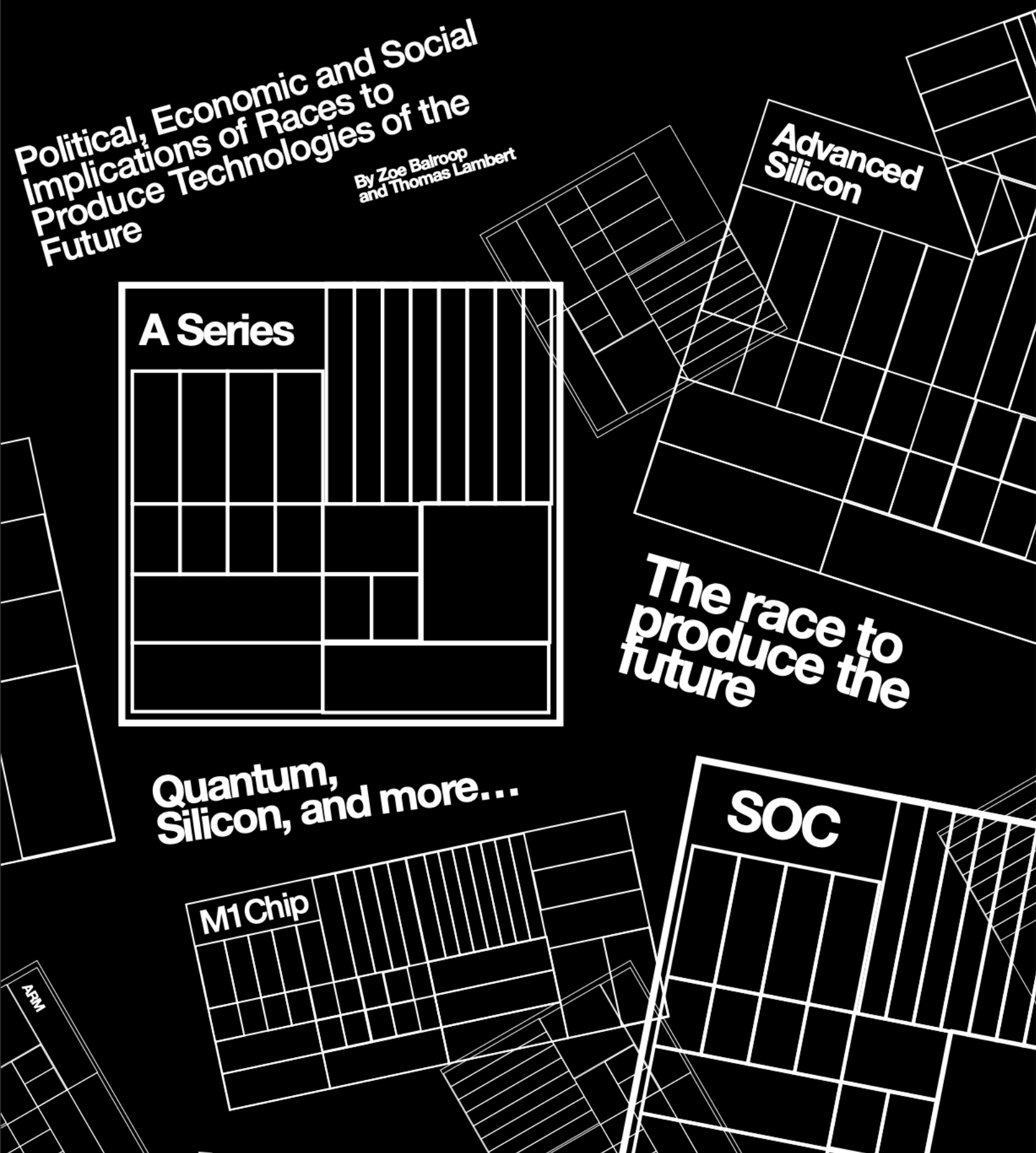


Briefing Note

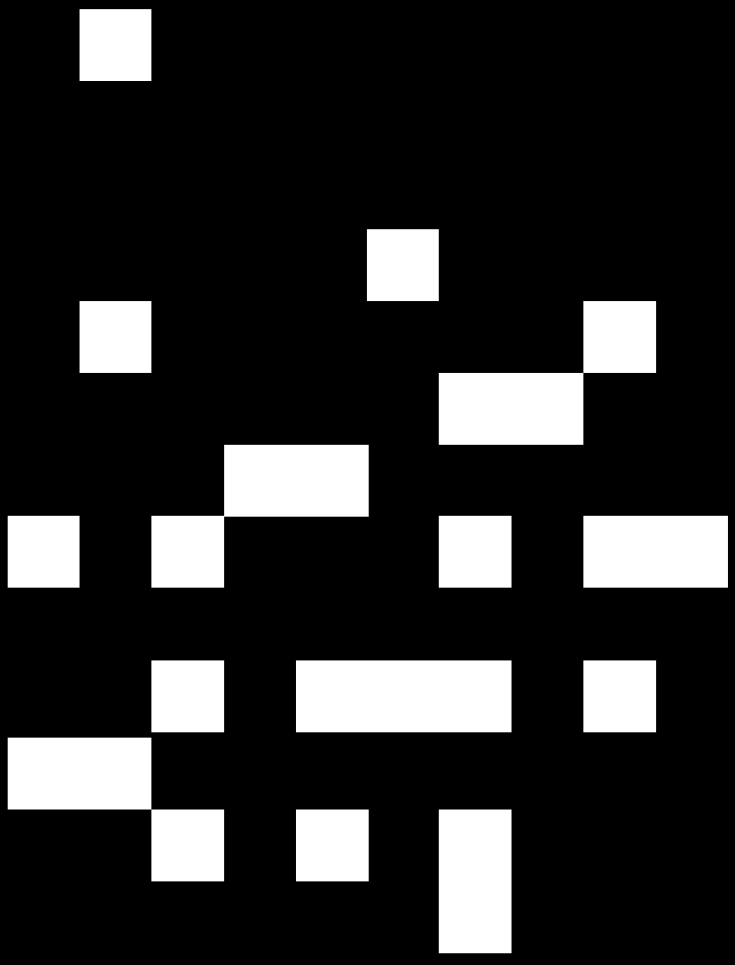
With the advent of AI and the continued growth of technology, combined with the COVID-19 pandemic which has effectively catalysed our such reliances, governments are funnelling increasing proportions of GDP into Research and Development (R&D) funding. With China taking a phenomenal lead, undoubtedly spending the most on technological development, it will become of utmost importance to consider how this will impact other societies as international power relations shift. China has already made it clear that their incomparably high R&D expenditure reflects their goal to dominate fields related to technology and innovation. As trade and wider political relations between the USA and China continue to gradually break down, China achieving supremacy in the various technology races could certainly change societies worldwide as we know them. Hence, by analysing the Semiconductor Manufacturing Race in Taiwan; the race for AI weaponry development; and the race for quantum supremacy; we will explore the potential powers Asia may soon have to shape and influence the rest of the world.

Overview

- Quantum computing promises us the potential to compute complex data problems within seconds, compared to the years traditional computers would take. The time required to process vast quantities of variables will be unimaginably reduced to a mere fraction of what we can achieve now, and with demonstrably widespread future applications, it is a profitable area of focus for many companies and countries. In a race to achieve what is currently impossible, Europe and America seem unable to match China's spending on related R&D, creating uncertainty as to what the world will look like if Asia continues to lead this charge.
- Rising political tensions in Asia, between China and Taiwan, are not only an issue of territorial independence and ownership. As relationships deteriorate further, the supply and trade of semiconductors - the computer chips the whole world has become so incredibly dependent upon - risks getting caught in the midst of the turmoil. With very few options for alternative sourcing methods of these chips, the rest of the world stands to be severely impacted by affected and diminished supply, highlighting the power Taiwan has in this way, with its monopolistic manufacturing model.
- By now it's becoming clear that Asia tends to be a superpower in all matters pertaining to technological dominance and being at the forefront of cutting-edge technology development. AI is no different, and China is already an established leader in this sphere. With regards to warfare and weaponry, their increasing military spending budget, rising significantly year on year, could prove to be a threat to competitors in the West, as a combination of their AI technologies and military funding would likely prove a challenge for our current defences. Examples of their increasing power are already playing out in South East Asia, and Europe/ USA need to ensure they don't fall too behind in the AI warfare race.

Qubit?

The basic blocks of information used in quantum computing



THE INTERNATIONAL QUANTUM SUPREMACY RACE

The race to establish quantum supremacy is clearly underway and for good reason; expansive applications have already been forecasted for those who can provide winning technologies

- In 2019, Google's Sycamore 53-qubit quantum processor became the first to surpass the performance of conventional computers today.
    - In 2021, IBM then announced a huge advancement, breaking the 100-qubit barrier for the first time, with their 127-qubit processor called Eagle[1].
    - With IBM now announcing they plan to create a 1000-qubit processor by the end of 2023[2], the race is well and truly on in the West.
- BCG studies suggest that the quantum computing market could be worth approximately $50billion by 2030. Furthermore, with new markets predicted to emerge, the spillover effects will be widespread.
    - IBM and Google are looking to switch to quantum computing for search-optimisation and machine learning worth potentially more than $20billion;
    - pharmaceutical applications could create another $20billion new market by 2030;
    - and material science-intensive industries are expected to represent an additional $7billion[3].
- McKinsey predicts that additional applications to other technology-intensive fields could see a $2-3billion injection of cash by 2030 to the automotive industry[4].

On an international scale, huge amounts of public funding are being channelled into quantum Research and Development, owing to expected political advantages for countries who lead the race.

- According to McKinsey's Quantum Technology Monitor, as of 2021, China is leading the field in quantum technology patents, holding 27.4% of all those in the market, and India houses the most relevant quantum talent, contributing to 29.6% of top researchers[5].
- With COVID19 accelerating the adoption and developments of newer technologies, Europe is stimulating its own investment to put towards the race, with Germany alone committing to €2billion of quantum computing R&D funding, and the European Union investing €1billion[6]. Over in America, to compete with China's current supremacy, the

[1] BBC News, 2021, IBM claims advance in quantum computing - BBC News
[2] IBM, 2020, IBM's roadmap for scaling quantum technology | IBM Research Blog
[3] BCG, 2018, The Coming Quantum Leap in Computing
[4] AIMultiple, 2022, Quantum Computing Statistics: Forecasts & Facts 2022
[5] McKinsey & Company, 2021, The Rise of Quantum Computing | McKinsey & Company
[6] McKinsey & Company, 2021 A quantum wake-up call for European CEOs | McKinsey

US Senate passed an act, June 2021, agreeing to invest a total of $110billion over five years into technologies such as AI and quantum computing[7].

- By January 2022, political tensions in America meant that other funding intended for quantum research, from the Quantum User Expansion for Science and Technology (QUEST) Act, has now been dropped, costing America $340million of necessary investment to keep their quantum technology development on par with China.
- Many believe that America's reluctance to even attempt to match China's expenditure - 2.44trillion yuan, or $378billion in 2020[8] - on R&D, in general, will cost them supremacy in coming years. This could easily leave them vulnerable in fields such as ethics and policy-making, military defences, pharmaceutical developments, as well as the obvious: technological dominance[9].

While quantum computing often embodies the quantum goal, quantum processing/ simulations will have significant impacts on other industries such as pharmaceuticals, finance, and military defences.

- It is estimated that quantum simulation could increase drug formula discoveries, both more efficient and with fewer unintended side effects, by 5-10%, and accelerate their development by 15-20%, thus showing high hopes for quantum technologies in all aspects of the pharma industry[10].
- Finance was one of the first to embrace the benefits of Big Data, and they too plan to take full advantage of quantum technologies when they become a reality. With 28% of quantum technologies expected to impact the finance sector[11], Goldman Sachs and JP Morgan are already working to create quantum algorithms for use within 5 years[12].
- At its current trajectory, China seems set to confidently dominate the quantum race, which will in turn give them the ability to upgrade military systems to levels the UK/US won't be able to reach. Although Trump pledged a $3.6billion budget for the Defence Advanced Research Projects Agency (DARPA) in 2020, failure to maintain a respectable place in the quantum race will leave the US vulnerable to compromised communication and surveillance attempts, and a complete inability to shield from quantum powered radars[13].

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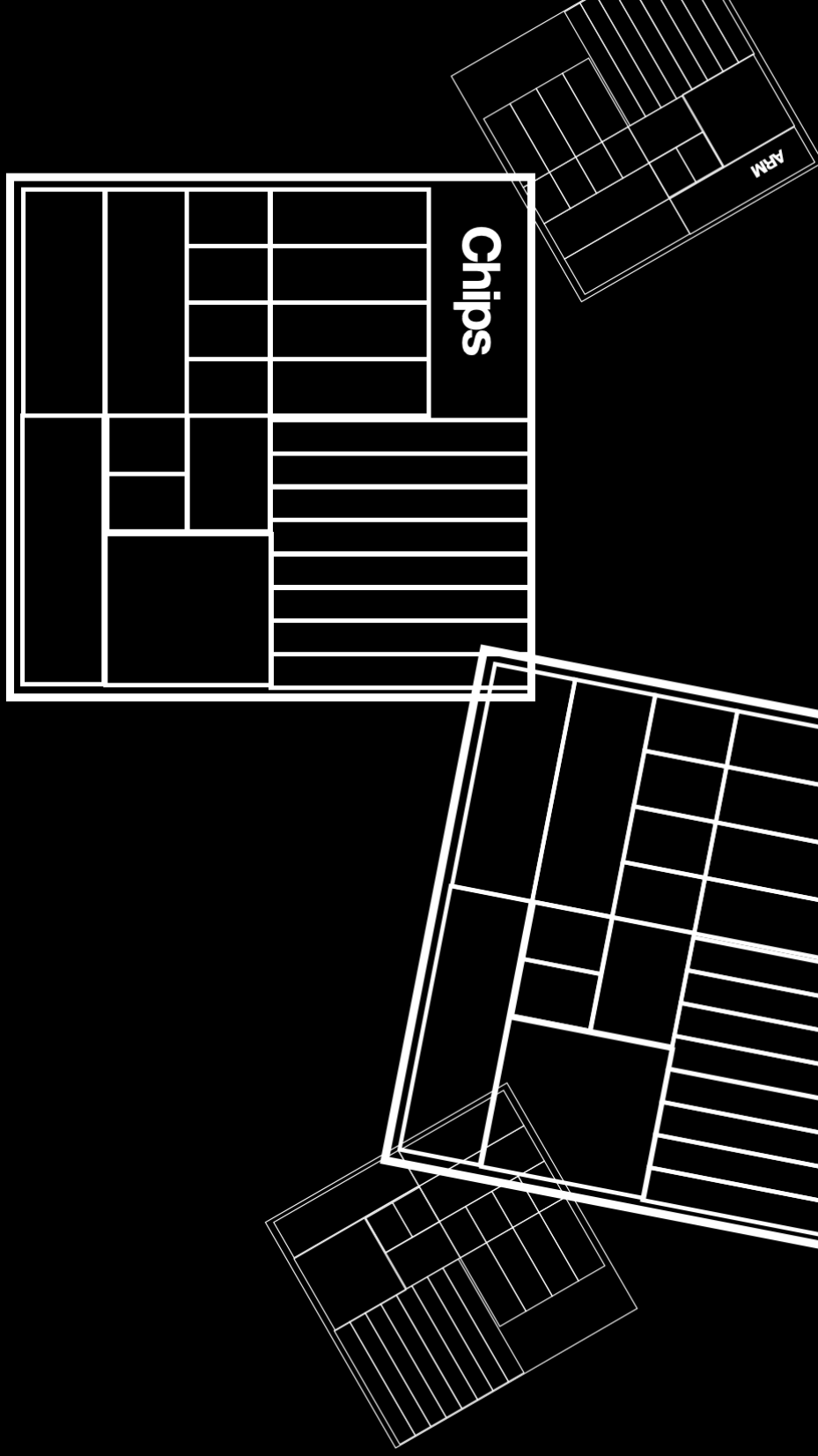
[7] Inside Quantum Technology, 2021, Governments Spending Billions to Outpace Chinese Quantum Spending - Inside Quantum Technology
[8] CNBC, 2021, China to boost R&D spending in push for tech breakthroughs
[9] Fortune, 2022, A quantum failure - US-China tech race
[10] BCG, 2018, The Coming Quantum Leap in Computing
[11] AIMulitple, 2022, Quantum Computing Statistics: Forecasts & Facts 2022
[12] Goldman Sachs, 2022, Investing at Quantum Speed
[13] Forbes, 2019, Quantum USA Vs. Quantum China: The World's Most Important Technology Race



10 nanometer chips

South East Asia dominates
the manufacture of and supply
of 10 nanometer and below chips

COMPUTER CHIPS AND GEOPOLITICS IN ASIA

TMSC's dominance is a vital aspect of Taiwan's survival (importance to China and vitally America, military tech, technology leadership of US).

- The risk of conflict with China over Taiwan seems at a record high as China has raised levels of aggression, sending a record number of warplanes into Taiwanese territory.[14]
- However, TSMC, the world leader in advanced chip manufacturing accounts for 90%[15] of the production of the most advanced chips and plans to spend $100bn over the next 3 years[16]. with clients ranging from gaming card designers like Nvidia to the automotive industry and the military.
- The strength of TSMC's market position means that it is vital for Chinese, and most importantly, American technology companies. More than 90% of semiconductors used in China come from abroad[17], and a recently released report by the National Security Commission on Artificial Intelligence warned of the vulnerability of the US's reliance on TSMC as 62% of its revenue comes from North American firms.[18]

Owing to globalisation, the world is dangerously dependent on South-East Asia for semiconductors, with no real means of alternative sourcing methods.

- Southeast Asian companies dominate microchip manufacturing, especially in advanced chips, where TSMC and Samsung of Korea produce 92, and 8% of the world's supplies of 10 nanometres and below chips.[19]
- This dependence is set to increase, or at least remain the same as TSMC invests $100 billion over the next three years[20] and Samsung seeks to increase its competitiveness in advanced manufacturing, planning to introduce 2nm production by 2025.[21]
- Across the entire market, Taiwan accounted for more than 60% of total global foundry revenue in 2020, where chips are actually produced, and TSMC singly accounted for 54% of total foundry revenue.[22]
- These companies are necessary for the world's $433 billion semiconductor industry[23], and a loss of Taiwan alone would cost the worldwide electronics industry $490 billion.[24]

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[14] CNN, 2021, 5 things to know about China's record surge of warplanes near Taiwan
[15] BCG & SIA, 2021, Strengthening the Global Semiconductor Supply Chain in an Uncertain Era
[16] The Economist, 2021, How TSMC has mastered the geopolitics of chipmaking
[17] Reuters, 2021, Taiwan chip industry emerges as battlefront in U.S-China showdown
[18] The Economist, 2021, How TSMC has mastered the geopolitics of chipmaking
[19] BCG & SIA, 2021, Strengthening the Global Semiconductor Supply Chain in an Uncertain Era
[20] Fortune, 2021, How will chipmaker TSMC spend $100 billion in 3 years? Easy
[21] The Economist, 2021, Samsung Electronics wants to dominate cutting edge chip making
[22] CNBC, 2021, 2 Charts show how much the world depends on Taiwan for semiconductors
[23] SIA, 2020, Worldwide Semiconductor Revenues
[24] NIKKEI ASIA, 2021, The $490bn question: Can the world afford its Taiwan chip dependence?

The dependence can also been seen in a study by the St Louis Fed, whereby industries reliant on semiconductors raised their prices 40% more than those that aren't.[25]

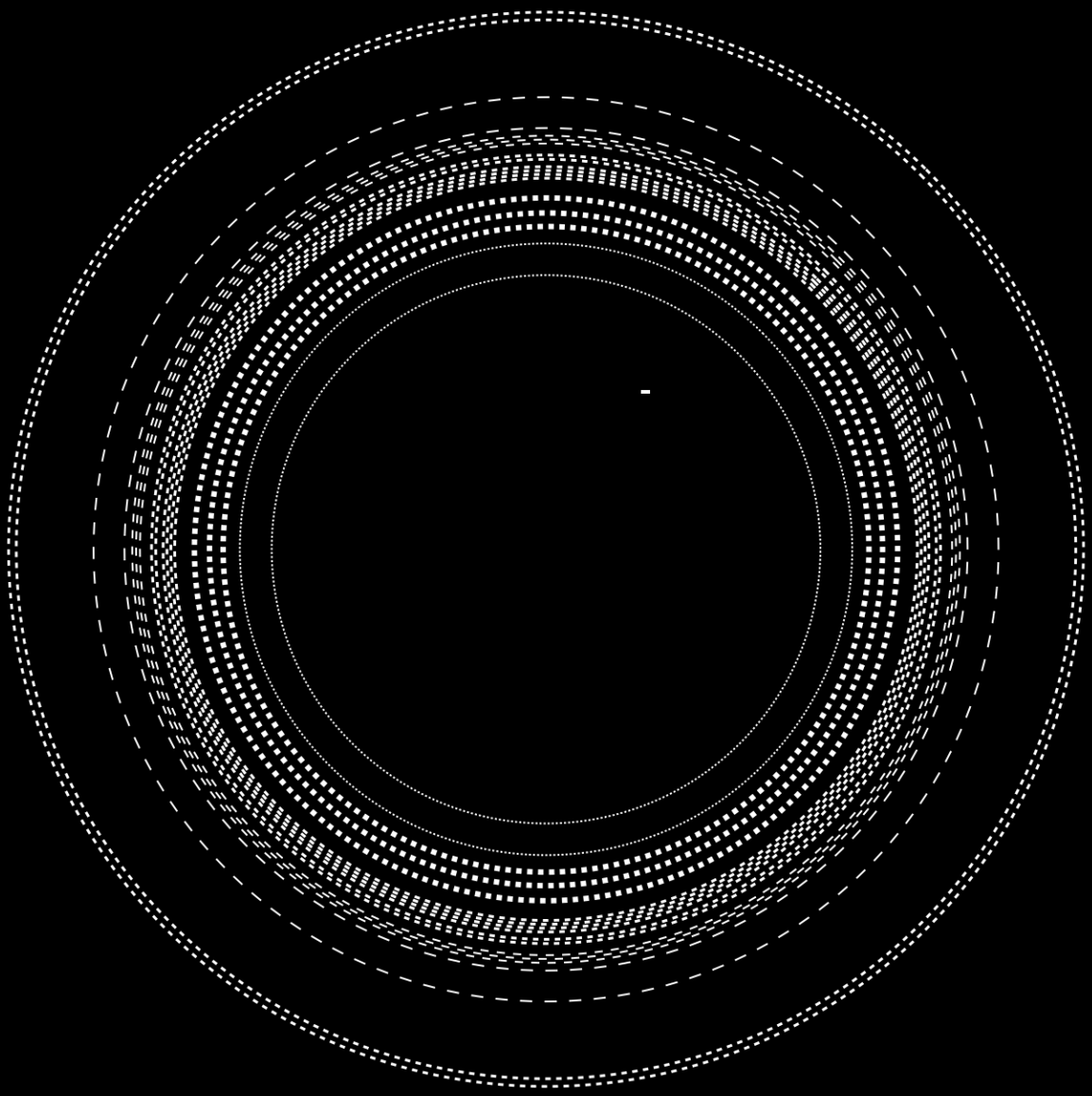
- The reach of the industry and impact can be seen sharply in the automotive world with modern cars reliant on chips, where the chip shortage is set to cost the industry $210 billion in 2021.[26]

Semiconductors are major areas of importance to more South-East Asian economies than just Taiwan

- South Korea is the world leader in total production, capturing 19% of the global semiconductor revenue, [27]and is home to over 20,000 businesses in the semiconductor industry, and employs almost 150,000 people[28]. It's importance to the Korean government can be seen in the 510 trillion won ($450billion) investment plan supported by the Korean government with tax breaks and subsidies of up to 50% for semiconductor R&D.[29]
- Electrical and electronics make up for 39.4% of all Malaysian exports and account for 7% of the global semiconductor trade. [30]
- China sees the semiconductor industry as an area of national importance and security. It saw sales of $40 billion in 2020 and accounts for 9% of global sales. [31]China is incredibly ambitious in its aims, with its recent national strategy setting out to achieve 70% self-sufficiency by 2025. [32]

[25] St Louis Fed, 2021, Supply Chain Bottlenecks and Inflation: The Role of Semiconductors
[26] AlixPartners, 2021,Shortages related to semiconductors to cost the auto industry $210 billion in revenues this year

[27] Deloitte, 2020, Rise of the "Big 4" The semiconductor industry in Asia Pacific
[28] Statista, 2022, • South Korea: semiconductor industry employment by division 2014 | Statista
[29] KBS World, 2021, "K-Semiconductor Belt Strategy" to establish the world's largest supply network by 2030 I KBS WORLD
[30] Malaysian Investment Development Authority, 2021, Malaysia Remains an Attractive Location For Semiconductor And E&E Companies - MIDA | Malaysian Investment Development Authority
[31] Semiconductor Industry Association, 2022, China's Share of Global Chip Sales Now Surpasses Taiwan's, Closing in on Europe's and Japan's - Semiconductor Industry Association
[32] Semiconductor Industry Association, 2021, Taking Stock of China's Semiconductor Industry



The race to develop AI-powered weaponry.

THE RACE TO DEVELOP AI-POWERED WEAPONRY

With the second-highest military expenditure budget, China is well on its way to match US grade military defences, posing an increasingly significant threat to its potential enemies

- China is currently the second-largest military spender in the world, spending $209 billion in 2021[33], and having increased its spending by a factor of 7 in the last 20 years, as well as rising to 5.4% share of total government spending.[34]
- For example, the People's liberation army navy (PLAN) has numerically the largest navy in the world numbering 355 ships and submarines. China also has the world's third-largest aviation force with over 2,250 combat aircraft, and more importantly, by far the largest in the region, with almost 3 times that of its closest competitor South Korea.[35]
- The threat the Chinese military poses is also clearly seen in its nuclear arsenal, with 290 as of 2021[36] and a plan to possess at least 1,000 deliverable warheads by 2030.[37]

In terms of AI warfare, China is actually ahead of, or at the very least on par with, American progress and development

- According to the Harvard Business Review, China is already a world leader in AI. It is first in the research field, producing 27.68% of the world's research papers in the field.[38]
- Furthermore, while dominance in research is important, two other critical areas: data computer science and engineering talent are similarly vital, and are both areas where China is very strong, with its weaker data privacy laws and a much greater sample set with its 1.4 billion domestic market
- The Chinese government sees AI as a major area of competition and a 'strategic technology that will lead in the future.' And according to a study by the Centre for Security and Emerging Technology, the Chinese state is spending at least $1.6 billion a year on AI-enabled systems, on par with the pentagon, and likely much higher.[39]
- Many aspects of AI progress are likely to have a dual-use application to both civilian and military uses, for example in autonomous drones and robots.[40]

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[33] CSIS, 2021, Understanding China's 2021 defense budget
[34] CFR, 2020, China's Modernizing Military
[35] World Population Review, 2022, Largest Air Forces in the World 2022
[36] Arms Control Association, 2022, Nuclear Weapons, Who Has What at a Glance
[37] Office of the Secretary of Defense, 2021, Military and Security Developments Involving the People's Republic of China 2021
[38] Harvard Business Review, 2021, Is China Emerging as the Global Leader in AI?
[39] Centre for Security and Emerging Technology, 2021, Harnessed Lightning, How the Chinese Military is Adopting Artificial Intelligence
[40] Conference on Artificial Intelligence, Ethics and Society, 2018, An AI Race for Strategic Advantage: Rhetoric and Risks

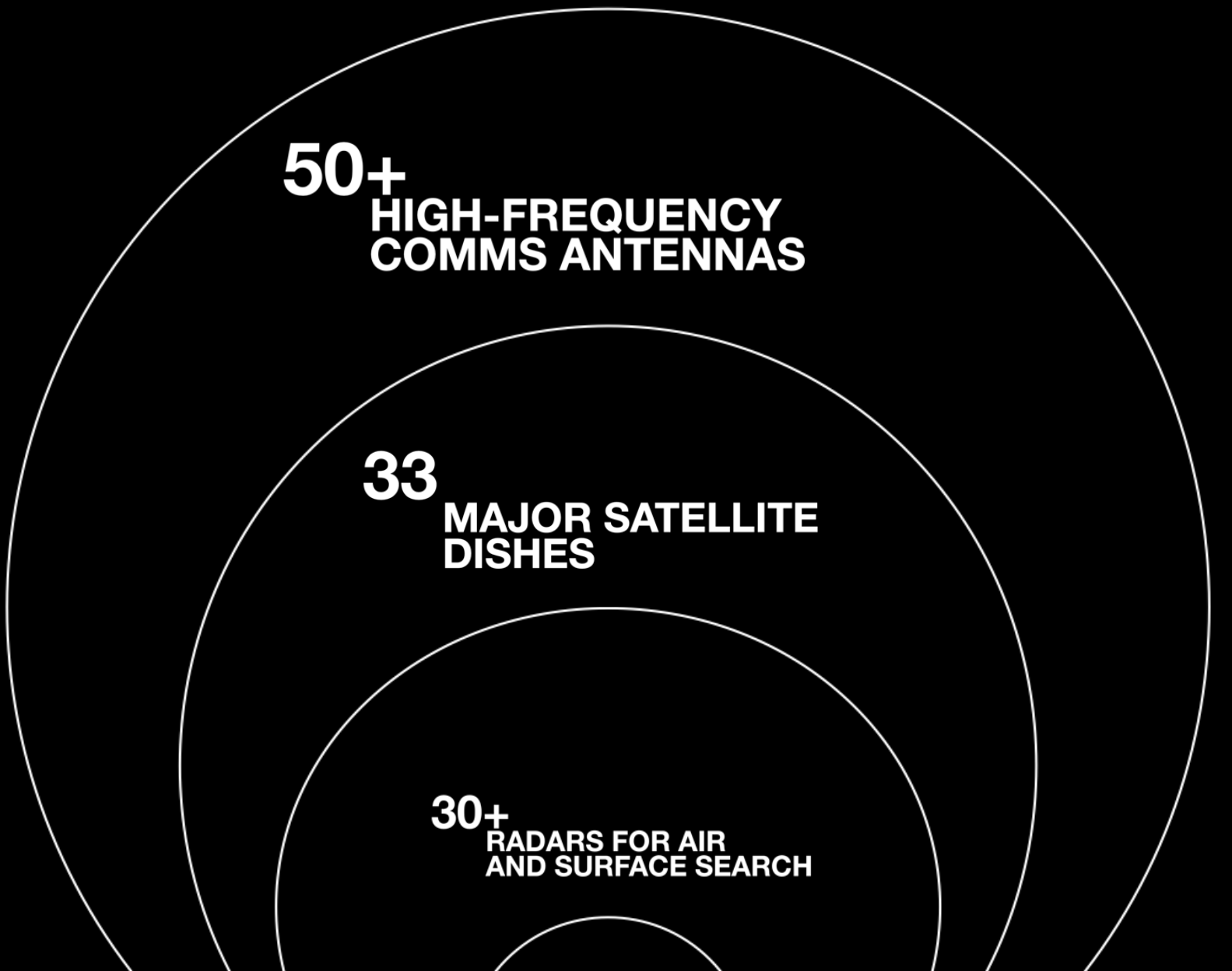
- China aims to fully incorporate AI and similar technologies into its military strategy through 'intelligentized' warfare. From areas such as tactical and strategic decision support, autonomous air and weapons systems as well as social media analysis and propaganda.[41]

China is utilising advanced military technology to assert dominance in the South China Sea, in what is only the start of their potential military supremacy

- China has attempted to assert its claims to the 9 dotted line in the South China Sea which stretches almost 1,500km from the Chinese coast on Hainan Island to 50km off Malaysian Borneo. However, its claims to the island defy international law and the United Nations Convention on the Law of the Sea, and a claim brought against China by the Philippines saw China lose on 14/15 points at the International Arbitral Tribunal.[42]
- Chinese government procurement contracts reveal that the city responsible for the administration of the South China Sea, Sansha City, has acquired, or plans to acquire equipment from at least 25 different companies in the US and elsewhere.[43]
- China has recently significantly boosted its Intelligence, Surveillance, and Reconnaissance capability in the South China Sea; expanding its radar, UAV, and satellite technology.[44] Across the seven Chinese island reefs, there are 33 major satellite dishes, over 50 high-frequency communications antennas, and over 30 radars for air and surface search.[45]

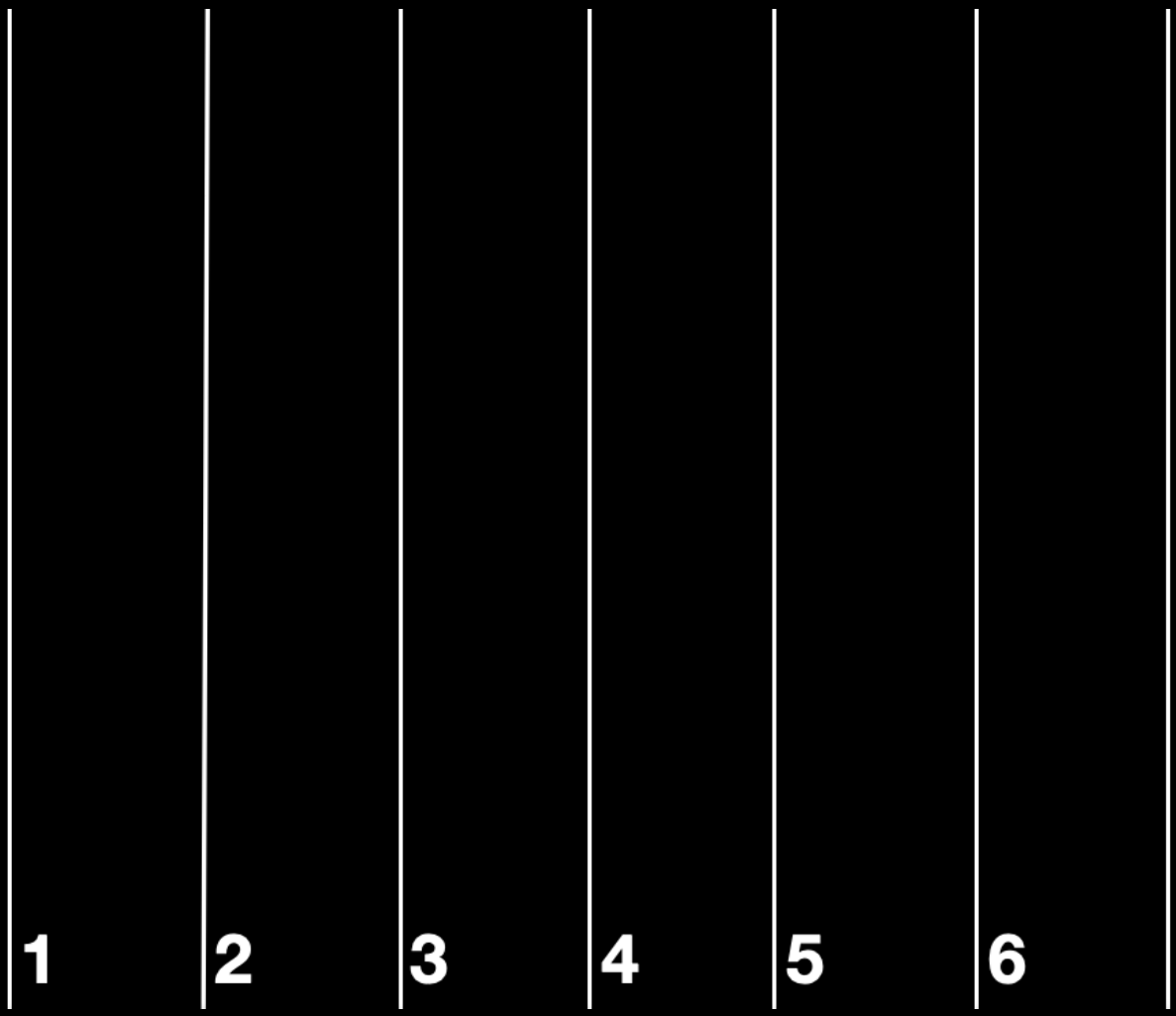
[41] CFR, 2021,DoD's 2021 China Military Power Report: How Advances in AI and Emerging Technologies Will Shape China's Military
[42] The New York Times, 2016, Tribunal Rejects Beijing's Claims in South China Sea
[43] Radio Free Asia, 2021, How China is Leveraging Foreign Technology to Dominate the South China Sea
[44] Foreign Policy Research Institute, 2021, China's Maritime Intelligence, Surveillance, and Reconnaissance Capability in the South China Sea
[45] War on the Rocks, 2020, Beyond "Conventional Wisdom": Evaluating the PLA's south China Sea Bases in Operational Context

China has recently significantly boosted its Intelligence, Surveillance, and Reconnaissance capability in the South China Sea; expanding its radar



INSIGHT

International races in innovation



INSIGHT

Overview

International technology races have for a long time been areas of intense focus for governments of developed nations, the recent space race being a prime example. Aspiring to be leaders in innovation, nations at the forefront of these races have typically been the West, China, and Russia, and each has its own strengths.

In this next section, we will focus on the significance of three particular international races: quantum supremacy, semiconductor manufacturing, and cutting-edge warfare. By exploring current situations and forecasted results, we will discuss the potential international implications with regard to politics, social issues, and economic outcomes. All of these races will inevitably produce one winner, the question is who will it be and what does that mean for the rest of us? No one country in the race has any incentive to slow down in the name of helping international relations, so each must prepare to continue to fight for victory or face the consequences.

The race to achieve quantum supremacy is a race for global dominance, rewarded with unimaginable technological powers, impacting high-risk sectors like national security

Quantum technologies, especially quantum computers, have recently become buzzwords in the technology and innovation space. Much like the space race, it's a field with significant forecasted results where profits, global leadership, and international dominance are concerned. Those who achieve quantum success first will reap many benefits in the directly relevant technological sphere, but also other industries expected to be revolutionised by such advancements. This includes, but is not limited to, the pharmaceutical industry, automotive industry, finance, and defence/ security, as outlined in our briefing. This section will explore the vast changes one could expect to see as the international quantum race for supremacy develops, with fierce competition between China, the USA, and the EU, as well as battles within the private sector, to emerge victorious.[46] With the race already well underway, understanding why quantum mechanics lies at the foundation of such game-changing technologies will be essential to anticipate potential outcomes at the international level.

At a basic level, quantum computers are hugely advantageous, and thus highly aspired to, because of their unrivaled information-processing powers. Using principles of quantum mechanics, they make use of photons' abilities to take on multiple states at once, a phenomenon known as a superposition. For example, in quantum mechanics waves can behave like particles, and particles like waves - something completely incompatible with the principles of classical physics, upon which today's computers are built. In this way, quantum computers use these photons, known as qubits, to transmit significantly more information than is possible - 1 million or more times [47] as much - with conventional computer bits, while also using less energy. The ability of qubits to carry so much information simultaneously also makes quantum technologies highly sought after in encryption innovation. Quantum key encryption is unbreakable because of the aforementioned superposition phenomenon.[48] As said, this is similar to the logic behind wave-particle duality, and essentially information-carrying photons used in encryption will hold all possible data until they reach their assigned destination, whereupon the true data is revealed. However, premature observation of these photons forces their superposition to collapse into a randomly decided state, meaning you can never know the true value of the data if you observe it without being the intended recipient. With clear potential to be used for sensitive military-grade encryptions, quantum key encryption would be an unimaginable advantage for countries who implement it first, upgrading their national security to levels currently impossible. In scenarios of war and hostility therefore, we can expect quantum technologies to be very impactful, especially with regards to international power dynamics.[49]

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[46] Forbes, 2019, Quantum USA Vs. Quantum China: The World's Most Important Technology Race
[47] Forbes, 2017, What Is Quantum Computing? A Super-Easy Explanation For Anyone
[48] Arqit, Quantum Encryption Technologies
[49] Forbes, 2019, Quantum USA Vs. Quantum China: The World's Most Important Technology Race

But who seems most likely to be that quantum-technology-leading nation, and what could that mean in the context of today's global political scene? At the time of publication, China appears to be a clear future winner in the quantum race. They have, and continue to, actively outspend all other countries where R&D and technological development is concerned.[50] In this way, they are positioning themselves to achieve quantum supremacy first, making leaps and bounds in the right direction to create these technologies. There are obvious political implications that follow from this; being first to market with successful quantum tech will reinforce their status and power within trade, supply, and international negotiations. Considering the ongoing trade war between superpowers China and USA, continued political tensions have led successive governmental bodies to up the stakes, and not back down from their stances. With these issues since 2018,[51] quantum technologies certainly could prove to be the next major point of competition between these powers. While there is huge potential for spillover impacts in other industries besides technology,[52] this race could also have drastic political implications for countries directly involved, and those who rely on them for import and export relations. If China and the USA are willing to enter an almost-5-year-long trade war over solar panels and washing machines in the name of 'national security', imagine the lengths they may go to for the world's most powerful computers, and unbreakable encryption software - both of which could be genuine threats to national security.[53]

To say that the USA or EU should increase their R&D budgets for quantum technology development in order to avoid a less-than-ideal political outcome would perhaps be naive though. Any winner of the quantum development race could use and abuse their newfound power - it's not just China. Ultimately one nation, or body thereof, will emerge the winner; or, maybe it will be the private sector giants, like IBM and Google, who have also entered the race rearing to go.[54] 2021 has already seen the birth of new tech start-ups focused on quantum computing technologies merging with larger tech corporations for sums as high as $2 billion[55] in recognition of their future worth, and we can only expect this trend to continue. The financial prospects for quantum technologies, centred around the goal to create the first working quantum computer, are clearly viewed as limitless by experts in the field. The international dynamic implications could go in many directions, depending solely on who cracks it first, making it arguably as high profile as the space race. While China owns the most quantum patents[56] to date, whoever wins this international race will receive a level of global power never seen before. But since it is China that edges towards the finish line in the first place, for now, there is probably a reasonable concern for the rest of the world as to what this truly means for us.

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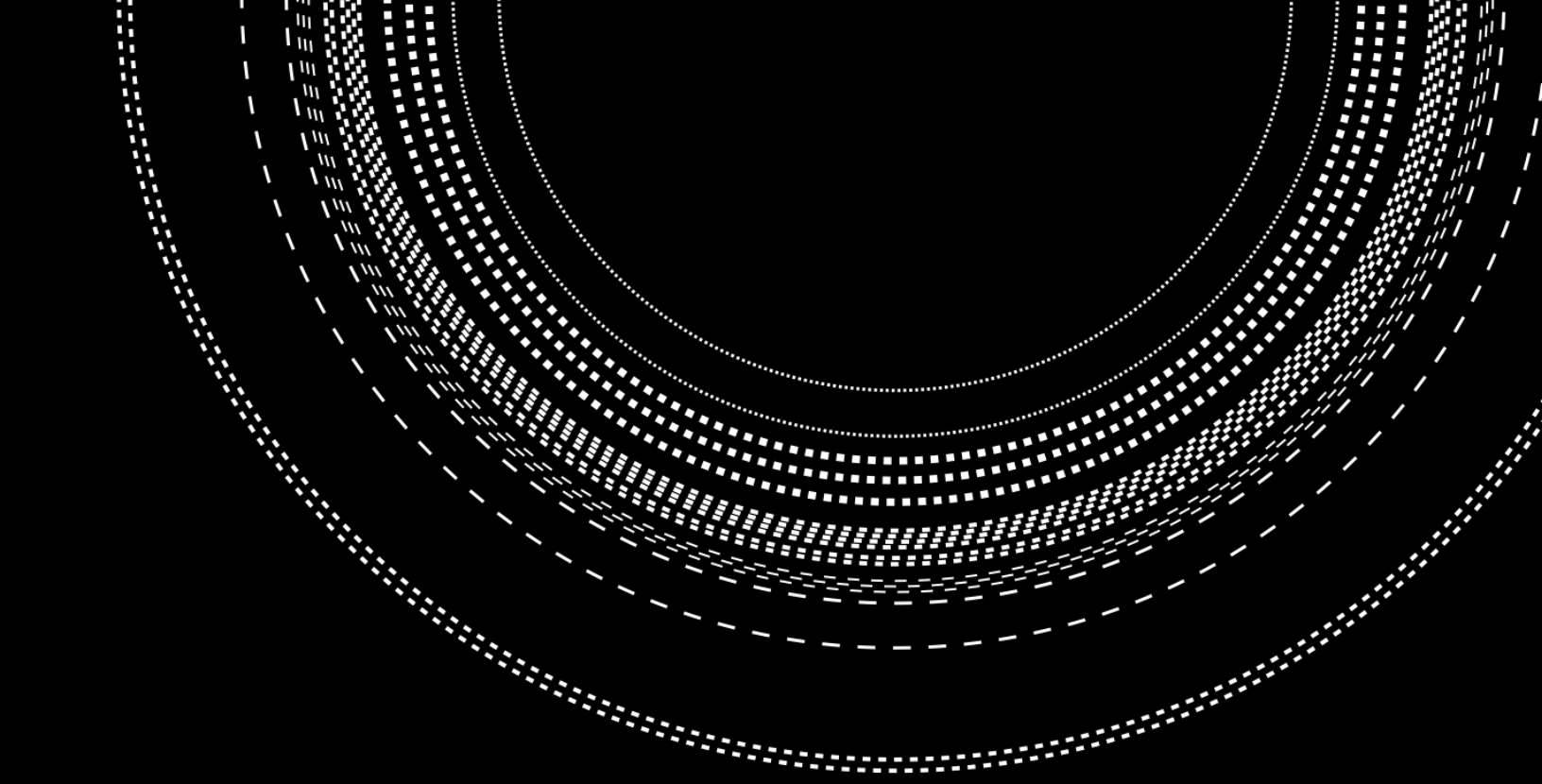
[50] CNBC, 2021, China to boost R&D spending in push for tech breakthroughs
[51] PIIE, 2022, Trump's Trade War Timeline: An Up-to-Date Guide
[52] AIMultiple, 2022, Quantum Computing Stats: Forecasts & Facts for 2022 & Beyond
[53] AIMultiple, 2022, Quantum Computing Stats: Forecasts & Facts for 2022 & Beyond
[54] BCG, 2018, The Coming Quantum Leap in Computing
[55] DCD, 2021, Quantum encryption startup Arqit to go through SPAC merger, plans to launch satellites
[56] McKinsey & Company, 2021, The Rise of Quantum Computing | McKinsey & Company



“Unimaginable Technologic powers

Semiconductors play a vital role in South East Asian economies, and Taiwan's dominant position in the global semiconductor industry makes it strategically important both to China and the US.

One of the most pressing geopolitical issues in Southeast Asia is that of China and its territorial claims. A major issue is its 9 dotted line claim to much of the South-China Sea, far beyond its 200 mile sovereign borders. However, more worryingly, and with a greater cause for concern is China's claim to an entire country, Taiwan. The CCP has never acknowledged the existence of Taiwan as anything more than a Chinese province and has repeatedly stated its aim of bringing Taiwan back under its fold. Furthermore, Xi Jinping has made the return of Taiwan an explicit aim under his administration, something that 'must be fulfilled'.[57] Recent years have brought with them a seemingly even greater urge for reunification, and tensions have reached historic highs, and the chance of war at its '*highest in 25 years'*.[58]

Yet there are several factors an aggressive China must consider before launching an invasion. First and foremost is the historic promise of protection the United States has extended to Taiwan. Ever since the establishment of formal relations with the People's Republic of China in 1978, the Taiwan Relations Act a year later has defined the U.S's official relations with Taiwan. It does not explicitly promise military intervention upon chinese invasion, but does promise that the US will provide all necessary help to '*enable Taiwan to maintain a sufficient self-defence capabilities',* and a recent announcement by President Joe Biden of the US's commitment to defending Taiwan,[59] and a similar announcement by the Japanese Foreign minister in 2021,[60] provides more security to Taiwan, and greater threat of retaliation to China.

Perhaps even more striking is the strength provided by Taiwan's de facto monopoly on the fabrication of the world's most advanced semiconductors. This position provides a further layer of protection against Chinese invasion. The likely consequence of an invasion stopping, at least temporarily, the production of firms like TSMC, and the $500 billion price tag involved would greatly antagonise the world's advanced economies, many of who's advanced industries rely heavily on semiconductors to operate; illustrated by the European Commission's recent European Chips Act which sets to increase Europe's microchip resilience. [61]

Yet Taiwan's semiconductor lead could almost act like a lure to the Chinese government. It acts as an unacceptable showcase of the progress this part of 'China' has made under a capitalist system compared with mainland China's own struggling semiconductor sector. Indeed, the

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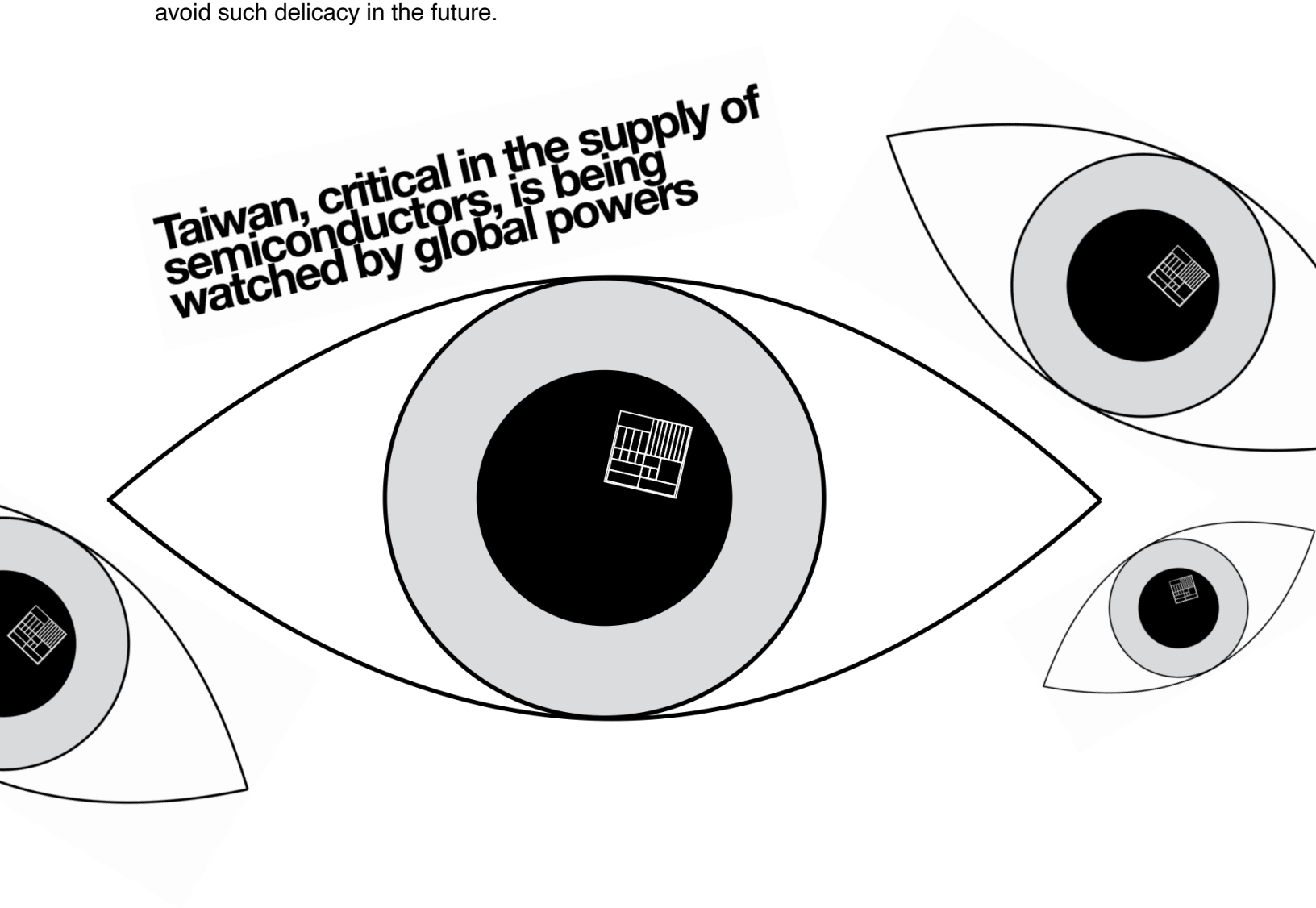
[57] BBC, 2021, China-Taiwan tensions: Xi Jinping says 'reunification' must be fulfilled - BBC News
[58] South China Morning Post, 2022, Taiwan war risk highest in past 25 years as US tensions rise, mainland expert warns | South China Morning Post
[59] BBC, 2021, Biden says US will defend Taiwan if China attacks - BBC News
[60] The Times, 2021, Japan pledges to defend Taiwan if China attacks, says deputy prime minister Taro Aso | World | The Times
[61] European Commission, 2022, Digital sovereignty: Commission proposes Chips Act

Taiwanese coastline is only 80 miles away, and TSMC's headquarters and surrounding cluster of fabs are only 12km from the coast, underlining just how exposed this critical piece of Taiwan's, and the world's, infrastructure is.

The focus on Taiwan, and the geopolitical problems it raises just act to highlight further the importance of South East Asia as a region to the semiconductor supply chain. Together, South Korea and Taiwan account for 92% of the production of the most advanced chips, with East Asia as a whole home to three-quarters of global chip capacity.[62] This global reliance on the region and the commercial, and military implications this raises, has caused other regions to reconsider their reliance. Covid, and the supply chain issues this has brought, has acted as a catalyst for other advanced regions, namely the EU and US, to want to revitalise their own semiconductor industries. And as semiconductor inventory falls to just 5 days' worth, many countries face urgent questions about how to protect their own supplies, and what it will take to avoid such delicacy in the future.



[62] Financial Times, 2021, In charts: Asia's manufacturing dominance | Financial Times

The modern war will be won by future technologies. Chinese dominance in these technologies will have major impacts on the global balance of power, and vitally on hot spot areas such as Taiwan and the South China Sea

America is seen as the preeminent military power in the world, and has been since the Cold War. This has given security to many of the US's allies, from Germany to South Korea, and has allowed for their safe development without having to field large militaries of their own. Previously the USSR, and then Russia was seen as the second place power, yet in the last 20 years, as China has grown to become the world's second largest economy, its military has grown with it as it aims to become a world power capable of exporting its worldview and supporting its allies, much as the US has done for the past 50 years.

China is already the second largest military spender in the world, with expenses of $209 billion in 2021, and as the possibility of China becoming the world's largest economy increases, with some forecasting China overtaking the US already in 2028[63], comes also the spectre of China becoming the world's largest military spender, and power. China is already the most powerful in the region by far, thus the possibility of China as the world leading military raises serious questions about the willingness and capability of the US and its allies to maintain their dominant presence in the Pacific and more specifically the highly contested South China Sea.

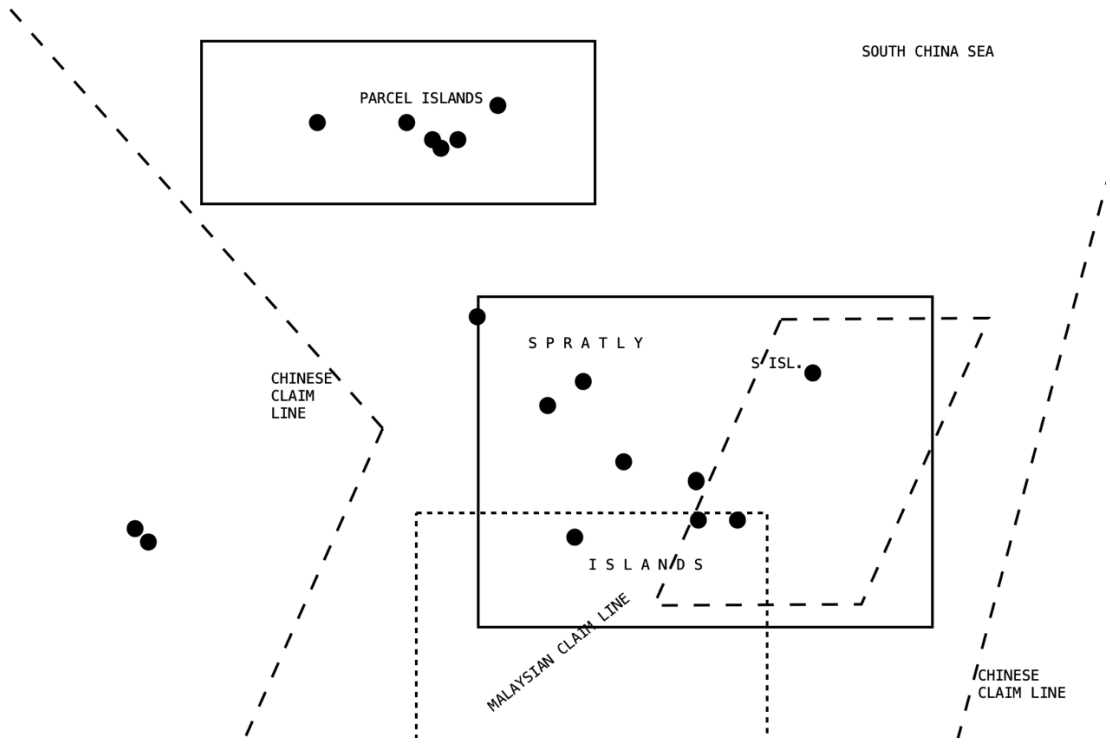
Crucially, China sees 'intelligentized' warfare, the operationalization of artificial intelligence and its enabling technologies, e.g. cloud computing, unmanned systems and big data analytics, as the future of warfare and is focussing a lot of resources on this area.[64]This focus is seen in China's publicly released 'Next Generation AI plan' which outlines the aim to establish China as the world leader on AI by 2030, pursuing a 'whole of society effort' to become the global leader through military-commercial cooperation and the designation of private sector 'AI champions' to pursue and develop the most advanced technologies.

In pursuit of this, China has already established a world-class, and in some aspects, world leading AI sector. In the research field, according to the Harvard Business Review, China is already a world leader, producing 27.68% of the world's leading research papers in the field. [65]China's massive domestic population and relaxed privacy laws allow its researchers access to vast datasets for them to train AI on, the crucial part of AI's development[66]. What's more, China's military spending on AI is already on par with the US[67] and could realistically be much higher. This challenges the West, and China's adversaries on how to remain ahead, or keep up with China's increasing military technology development. And a rising China, as well as recent

[63] World Economic Forum, 2021, China to leapfrog US as world's biggest economy by 2028 - think tank
[64] CSIS, 2021, Chinese Strategy and Military Forces in 2021
[65] Harvard Business Review, 2021, Is China Emerging as the Global Leader in AI?
[66] Nature, 2020, The race to the top among the world's leaders in artificial intelligence
[67] Centre for Security and Emerging Technology, 2021, Harnessed Lightning, How the Chinese Military is Adopting Artificial Intelligence

embarrassments for the West, such as their defeat in Afghanistan, raises the question as to what extent the US and its allies can maintain their global military hegemony which has lasted so far throughout the 21st century.

The implications of a militarily dominant China can already be seen in the South China Sea. It currently claims as sovereign territory-everything within its 9 dotted lines, stretching almost 1500 km from the Chinese coast on Hainan Island to almost 50 km off Malaysian Borneo. Although it has lost almost all claims at the International Arbitral Tribunal and is contested by all neighbouring countries, it continues to exert pressure in the area, building up artificial island chains to extend both its territorial claim, and military pressure such that, if not in law, it has de facto control over much of the area it claims. In pursuit of this, it has relied heavily on technology, significantly expanding its Intelligence, Surveillance, and Reconnaissance capability across the Sea.[68] Although this area relies more on conventional military technology, the fact that China has been so capable of exerting its influence challenges the West, and the rest of East Asia on how to combat China's rising belligerence, and military prowess. Its AI expertise simply creates new areas of warfare for China to deploy such as AI drone technology, and unmanned underwater vessels could be a key technology in challenging China's long-standing acknowledged weakness in undersea warfare.[69]Although Chinese 'dominance' may still be a few years away, its growing power, and expertise, in important areas of military technology mean China is a continuing and only increasing threat to the current international order.



[68] Foreign Policy Research Institute, 2021, China's Maritime Intelligence, Surveillance, and Reconnaissance Capability in the South China Sea
[69] The National Interest, 2021, UUVs are Giving China New Means of Naval Attack | The National Interest

Although Chinese ‘dominance’ may still be a few years away, its growing power, and expertise, in important areas of military technology mean China is a continuing and only increasing threat to the current international order.

Conclusion

- Winning the international race for quantum supremacy will bestow not only national pride but a multitude of benefits with regard to international power. With the ability to revolutionise hugely profitable industries in the private sector, but also wreak havoc on current standards of military software, countries in the running will want to ensure they are maximising their input and efforts with regards to R&D specifically, or consider the outcomes of a non-NATO winner. While these technologies will continue to be developed and will advance our current computing abilities in unimaginable ways, they do also have the power to do great damage, and thus this needs to be anticipated too.
- The semiconductor supply chain is an inherently global one, and fiendishly complex. Yet it also contains several key concentration points, specifically in South East Asia: South Korea and Taiwan. For both of these countries, semiconductors are areas of national importance and pride, yet for Taiwan it takes existential importance, acting as an important ‘silicon shield’ deterrence against any possible Chinese invasion.
- The future of war is tech, and especially areas of artificial intelligence and massive processing power. China wishes to gain dominance of the South China Sea as its own for which it relies on military and technological superiority over nearby nations. US presence in the area is crucial, and if China were to achieve military technology dominance over the US in important areas like AI it could have negative consequences for freedom of the sea in the South China Sea and the legitimate territorial claims of nearby states.

POLICY RECOMMENDATIONS

POLICY RECOMMENDATIONS

Overview

The following policy recommendations have been made with the aim of addressing potential political, social, and economic impacts of different outcomes to the discussed international technological races.

- **Action 1 -** China winning the race for quantum supremacy would change global power dynamics significantly. While there would undoubtedly be impacts on the private sector - such as the finance and pharma industries - international security will arguably be endangered the most, and so the West needs to find a sense of urgency in increasing their R&D spending
- **Action 2 -** Global Semiconductor supply chains must be diversified to increase the resilience of supply and to ensure that global supply issues such as those we experienced these past years do not repeat
- **Action 3 -** Technology transfer controls must be strengthened in Europe to address the issue of military use of technology in China. A European consensus must be built and screening processes to ensure the most sensitive technology cannot be used for Chinese military development
- **Action 4 -** International parties interested in protecting freedom of navigation in the South China Sea and stymieing Chinese expansion must take more coordinated action and local players must also increase their military capabilities to independently ensure their safety against China

Action 1 - China winning the race for quantum supremacy could change global power dynamics significantly, arguably impacting international security the most, and so the West need to find a sense of urgency in increasing their R&D spending

As we discussed in the Insights section of this report, China is currently dominating the race to be the first to achieve quantum supremacy on many levels; they own the most quantum-related patents and spend significantly more than other large economies on R&D. We have also established that no matter which nation wins this international race, with great power comes great responsibility, and this is no exception. The quantum winner(s) will have such technological superiority compared to their competitors, that there is a hugely worrying opportunity for it to be used maliciously.

The first and foremost cause for concern pertains to military and defence. Should China continue towards its projected victory, there must be serious changes to how the West operates their national security measures. Firstly, current methods of surveillance would be inadequate when up against quantum computing decryption methods, and similarly standard computing power won't be sufficient to crack quantum encrypted messages. This means that we wouldn't be able to spy on China's covert messages, but they would be able to decrypt ours quite easily. Secondly, quantum radars are another target technology, with unparalleled supremacy compared to what's on the market today. With the potential to identify stealth operatives, the US, in particular, could see their aircrafts such as the B-2 Spirit, F-22 Raptor, F-35 Lightning II[70], all significantly threatened and essentially neutralised. Finally, the Chinese are also working towards developing quantum interference technologies that reduce the effectiveness and scope of their opponents' (NATO especially) submarine warfare.

With the risks outlined, the EU, UK, and US cannot afford to let China win without putting up a respectable fight. Similarly, the quantum race is no secret to anyone, and so failure to act to prevent China from winning would be almost akin to inviting attacks on their military defences. This is why we propose two policy recommendations. The most obvious solution is for the West/ NATO to come together as allies, recognise the risks of falling behind in this race, and invest significantly more in R&D than they currently do. Without matching/ coming close to China's level of expenditure, we cannot expect to gain and maintain any lead on China.

Our second proposition stems from a recognition that while seeing an increase in R&D spending would help, many countries in the West have generally seen R&D as a percentage of GDP falling in recent years, with more focus on commercial product development than government research-intensive developments. Therefore, individual government subsidies/ incentives for large corporate companies, such as Google and IBM, who have taken an active role in the international quantum race, could help ease pressure on governments while still encouraging

[70] Forbes, 2019, Quantum USA Vs. Quantum China: The World's Most Important Technology Race

higher levels of R&D (even if it's a private not public sector initiative) than we are currently seeing outside of China.

In these ways, we can hope that the EU, UK, and the US, are able to at least match China's progress towards quantum victory, and at the very least are not sufficiently far behind that we have a genuine cause for concern in terms of international security. Failure to at least keep up to some extent really is not a situation we should consider, as a mere contingency plan for losing is likely not enough of a policy response to properly safeguard international relations. When it comes to potential warfare, we are already seeing that those strongly opposed to NATO in 21st century international conflict will use everything in their arsenal to dominate those they desire.

This said, quantum technologies absolutely will be revolutionary, allowing for computing capabilities that we could never envisage today and transforming many technologies, processes, and sectors for the better. Therefore, aside from the acknowledged potential for harm, there is also an incentive to win simply to be the first to market and a global supplier for cutting-edge quantum technology; in other words, the quantum race isn't a story of pure political malice.

Action 2 - Global Semiconductor supply chains must be diversified to increase resilience of supply

From a Southeast Asian, and especially Taiwanese and Korean perspective the semiconductor industry represents more than simply commercial interests but also, in the case of South Korea, an area of national interest and importance given the proportion of the economy which it and related industries constitute. And for Taiwan as well as providing an engine of growth, the advanced semiconductor manufacturing industry and specifically the quasi-monopoly that TSMC holds on the production of the most advanced chips is more than an area of economic importance, it acts to anchor the rest of the world on Taiwan in terms of their reliance for its chips and acts as a 'silicon shield' to defend against the existential threat that is an invasion from China.

However, the world economy, and those of the west do not benefit from this shaky status-quo. With 90% of DRAM and NAND produced in Japan, South Korea, Taiwan or Singapore and all advanced chips above 100 million transistors per millimetre produced in South Korea or Taiwan[71] the West faces serious issues with the physical concentration of production capacity and a severe lack of supply chain resilience. As was seen and continues to be an issue Covid disruptions in factories in China and the rest of South Asia have exacerbated the existing supply chain issues in the semiconductor field and mean that shipments of these crucial chips are frustratingly out of the hands of European and American policy makers and industrial leaders. A greater selection of suppliers to choose from and a more diverse supply chain would result in more options for firms and reduced risk from regional issues. The supply chain is also incredibly complex, with semiconductors crossing 70 international borders and travelling three times around the globe during their production process. This illustrates well the fragility of the ecosystem, and the potential value there is in focussing production closer to home.

There are potential costs to this approach, not just those inefficiencies that inevitably arise when an efficient global supply chain is onshored, potentially duplicating production already available and suffering from lack of native technology, as highlighted by a report from the *Stiftung Neue Verantwortung*, which makes the case against massive investment in European fab technology as an unnecessary and unproductive waste of resources.[72] Furthermore Taiwan may lose an essential part of its silicon shield if TSMC and associated manufacturers lose their dominance in global microchip manufacturing and thus Chinese dependence. However, this seems unlikely given the US's and Europe's hostile stances towards Chinese access to future technology. Many Chinese semiconductor manufacturers already face import bans from the U.S including one of the most advanced chip designers HiSilicon[73], which used to be TSMC's second largest customer, and SMIC, China's largest contract chip maker. This means future advanced Chinese chips won't

[71] Semianalysis, 2022, I, Semiconductor. The regionalization of semiconductors due to global supply chain instability
[72] Stiftung Neue Verantwortung, 2021, The lack of semiconductor manufacturing in Europe
[73] Reuters,2020, U.S. Strikes at a Huawei Prize: chip juggernaut HiSilicon

be able to use any new US based foundries and will have to continue to rely on Taiwanese and South Korean manufacturers where possible, and would thus face the same, if not stronger effects from an invasion of Taiwan, if the recommended diversification of the supply chain with more of it located in Europe and the US takes effect. Thus, even with less of a monopoly on the production of the most advanced chips, or anywhere else along the value chain, Taiwan would inevitably remain a dominant player in the global semiconductor industry and thus would remain both an important ally of the US and the West as well as maintain its deterrence against China.

Action 3 - Strengthen technology transfer controls to address the issue of military use in China and hence build European consensus and screening process to ensure the most sensitive technology doesn't go to China

China has made massive technological progress in the past 20 years and is well on its way to becoming competitive in many advanced technological sectors. However, in the area of semiconductor manufacturing it still lags behind, with its semiconductor import bill totalling over $300 billion a year, more even than imports of oil, and it was able only to produce 15% of domestic demand.[74] This may not seem immediately connected to concerns relating to the South China Sea, and cutting edge microchips are not currently used in military technology. However, as laid out in China's own military development plan, the future of warfare is digitalization and the integration of ever smarter AI into systems which in the future will require more advanced technology. Thus if the goal is to stymie Chinese military development, it is vital that their domestic chip manufacturing sector remains behind, that a 'technology gap' between China and the West remains as the US is struggling enough already to contain Chinese expansionism without having to fight them on equal footing. This is in the interests of all those who oppose Chinese interests, especially those nations surrounding the South China Sea, the hottest point of contention behind Taiwan in Chinese foreign policy.

China already faces several problems when it comes to the development of world leading technology: that of the wasteful nature of its top down investment, a severe human resources problem as well as the affect of continued American sanctions. Our recommendation is that European countries put in more of an effort to prevent their technology being used to further Chinese military interests through the implementation of strict investment screening processes to prevent intangible technology transfers. This will require the building of a European consensus on the issue of what technology needs to be restricted. At the same time more coordination must be held on a transatlantic level between the US and Europe governments as well as industrial partners to coordinate their policies and build a positive agenda.

[74] Institut Montaigne, 2021, The Weak Links in China's Drive for Semiconductors

Action 4 - The parties interested in protecting freedom of navigation in the South China Sea and stymieing Chinese expansion must take more coordinated action and local players must also increase their military capabilities to independently ensure their safety against China

Current US and local strategies are not working in preventing continued Chinese belligerence and expansion in the SCS. The current activities of freedom of navigation operations, overnight operations and security assistance are not enough. There is currently a collective action issue regarding the security of the four main local states: Malaysia, Vietnam, Philippines and Thailand. They all to varying degrees rely on US security hegemony to make up for and excuse their own naval weaknesses and thus lack the resources required to effectively cooperate with the US and allies in operations as well as embark on their own operations against China. Furthermore, given the vast distances and varying interests involved there has been limited military cooperation between the states. They have although recently come together diplomatically at the 2020 ASEAN summit taking the initiative to make the United Nations Convention on the Laws of the Seas the basis for resolving disputes in the SCS.

However, this will not be enough to threaten China's advance and firmer action is required. The first step that must be undertaken is the strengthening of the individual nations' navies so that they can respond independently to Chinese threats. Secondly, as put forward by Dr Stephen Burgess of the US Air War College[75] is greater US action with a new strategy of 'targeted denial'. This would see the US Navy backed by the Air Force shadowing Chinese forces to block attacks on Philippine targets such as fishing boats or oil exploration vessels, especially around hotspots such as the Pag-asa islands and the Spratleys. So as to avoid direct confrontation and the issues this could represent between US and Chinese forces, the idea would be for allied troops to lead the way behind which would follow US ships. The strategy would result either in Chinese accession to Philippine claims or could be escalated further so as to force the Chinese to the negotiation table. This approach would also require greater cooperation in training as well as more joint exercises and training.

A complimentary approach to increase US engagement in the area and to show the world and local states that the US and West are serious about defending rights of the sea in the area. As James Holmes of the Naval War College comments. Without continued efforts to defend these rights, akin to the idea of right of way in English common law which disappears without continued use, these extra legal claims such as the one China is making have a way of calcifying to become part of the existing legal international order. Instead of simple freedom of navigation manoeuvres by the US, multinational efforts which combine with other forces to pass through and remain in

[75] Air University, 2020, Confronting China's Maritime Expansion in the South China Sea: A Collective Action Problem

contested areas are required to challenge the Chinese narrative of their control, and right to control, these areas.

Whatever specific policy is enacted, the only country which can singly prevent continued Chinese expansion is the United States, and currently what they are doing is not enough to prevent further Chinese aggression and infringement of other nations' territorial rights.

Conclusion

It is of course inevitable that these races will continue with full steam ahead, and as they do, political tensions and the possibility for certain nations to dominate certain fields will become of growing concern. In terms of power dynamics, global powers need to think about what they foresee as being potential threats in the future, especially in the case of failure to develop respective technologies first, such as quantum. Similarly, from a trade and economics perspective, alliances and lack thereof will increasingly determine who loses and benefits from sanctions imposed by countries who have a monopoly on production and manufacturing, as we see with semiconductors and chips.