Department for
Science, Innovation
& Technology

National Semiconductor Strategy

May 2023

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National Semiconductor Strategy

Presented to Parliament
by the Secretary of State for Science, Innovation and Technology
by Command of His Majesty

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Contents

1. Ministerial foreword

I am proud to be the Secretary of State for Science, Innovation and Technology. The creation of this new department is a demonstration of our commitment to becoming a science and technology superpower, driving toward stronger growth, better jobs and bold discoveries.

This Strategy from our new department demonstrates how fundamental technology is to the UK and the exciting opportunities it presents. We will build on the UK's deep foundations and core strengths in semiconductor technology, as part of our commitment to become one of the most innovative economies in the world.

Semiconductors are one of the five technologies of tomorrow, along with quantum, AI, engineering biology and future telecoms. They are critical to the UK's economic and national security and to the strategic advantage we will secure on the global stage.

We are also clear-eyed about the risks given that semiconductors are fundamental to so many technologies - from ventilators to fighter jets - and their supply chains are vulnerable. Meanwhile, hostile states can seek to acquire technical advantage to the detriment of our national security. And a compromise to the cyber security of the hardware behind every device powering modern life is not acceptable.

The UK Strategy is rightly differentiated from the approaches other countries are taking to expand large-scale silicon manufacturing, instead focusing on what is best for the UK. Close work with industry has identified that the UK is better positioned to pursue alternative opportunities within the sector that build on our proud history of innovation and strong foundations in this vital technology.

The UK has enormous strengths in compound semiconductors, in R&D, and in IP and chip design. Our approach, informed by and delivered hand in hand with industry, is to double down on those strengths and to take them even further. Building on our strengths will help us achieve our ambitions elsewhere: to lead the way on artificial intelligence, to enable advances in quantum computing and telecommunications, to power high performance computing, and to facilitate progress towards net zero and in life sciences. Advances in all of these areas will bring tangible benefits to the lives of the British people, whether that is using quantum computers to discover new lifesaving drugs, or high performance computing to more accurately predict the weather. All of this will rely on semiconductors.

Our vision is that over the next 20 years, the UK will secure world leading positions in the new semiconductor technologies of the future by focusing on these fundamental strengths. We will foster new discoveries and technological innovation. We will bolster our international position to improve supply chain resilience, and protect our security. And we will grow the UK's sector, tapping a market of huge potential.

This is why we are launching the UK Semiconductor Infrastructure Initiative and investing up to £200 million into our semiconductor sector over the years 2023-25 and up to £1 billion in the next decade. This is also why we are launching a new UK Semiconductor Advisory Panel, to ensure that government, academia and industry are all working together to deliver on the priorities set out in this Strategy.

Our Strategy represents the culmination of what government, industry and academia have already done in this sector. And it sets our vision for its future. A wealth of exciting opportunities lie ahead: to grow the economy, to create highly skilled jobs, and to be at the cutting-edge of technology that underpins every aspect of modern life.

Rt Hon Chloe Smith MP
Secretary of State for Science, Innovation and Technology
Department for Science, Innovation and Technology

2. Overview of the UK's vision

VISION	The UK will secure areas of world leading strength in the semiconductor technologies of the future by focusing on our strengths in <u>**R&D, design and IP, and compound semiconductors**</u>. This will facilitate technological innovation, boost growth and job creation, bolster our international position in order to improve supply chain resilience, and protect our security.		
APPROACH	Our approach is targeted and value for money, securing UK advantage in future technologies such as AI, high performance compute, quantum and cyber, driving economic growth and future discoveries. We will increase our international influence and work with partners to improve supply chain resilience.		
OBJECTIVES	**Grow the domestic sector**	**Mitigate the risk of supply chain disruptions**	**Protect our national security**
EXECUTION	<u>We are taking action to support the sector through the technology cycle, fostering a new culture of enterprise.</u> The Government is committing up to £200 million over the years 2023-25, and up to £1 billion in the next decade: ***Semiconductor Advisory Panel:*** Bring together figures from industry, government and academia to cohere the industry. Take forward implementation and hold each other to account for how we deliver this vision. ***Research and development:*** Generate breakthroughs and innovations that will drive next-gen semiconductors. Applied	<u>We are building greater resilience in semiconductor-dependent critical sectors through domestic and international action, maximising UK influence in the global market to mitigate extreme disruption scenarios:</u> ***Preparing economic sectors:*** We will support industry to better understand the risks it faces from future shortages and encourage appropriate mitigations. ***Protecting critical sectors - domestic action:*** We will work with industry to improve resilience in the supply chains of critical sector product manufacturers.	<u>We are mitigating national security risks by strengthening protection for the UK's most sensitive semiconductor assets, appropriately balancing security with sector growth; and addressing cyber security risks through the UK's expertise in hardware security:</u> ***Protecting UK assets:*** We will protect our strengths, using appropriate levers, including investment screening and the use of export controls, to prevent hostile actors building tech capability that causes national security harm. ***Building on our hardware strengths to improve cyber security:*** We will use

	research should be oriented towards the needs of industry and end-markets. ***Infrastructure***: We are currently carrying out a comprehensive scoping exercise with industry, and will launch a UK Semiconductor Infrastructure Initiative to improve access to infrastructure to boost UK commercial innovation for start-ups/SMEs: this could include design tools & IP, silicon prototyping, compound manufacturing and advanced packaging, including making start-ups more attractive to investors. ***Skills and talent:*** Work with industry and academia to improve the ability of the UK ecosystem to attract the skilled talent it needs, and train tomorrow's semiconductor innovators, including through Centres for Doctoral Training.	***Protecting critical sectors - international co-operation:*** With international partners, we will prioritise access to chips for particularly critical sectors of our economies and take action to ensure that supply is diversified and more resilient.	existing expertise to ensure that the importance of hardware for cyber security is considered, and more widely prioritised, at the design stage of chips across the world. This includes investing in the Digital Security by Design programme.

3. Executive Summary

Semiconductors (commonly referred to as "chips") are the core component of all electronic devices, and underpin our economy, national security and modern way of life. They are one of the five technologies of tomorrow. As set out in the Integrated Review and the UK Science and Technology Framework[1], they are vital to the UK securing our position as a science and technology superpower.

Global revenue in the semiconductor sector was $601.7 billion in 2022[2], representing a 100.6% increase from 2012[3]. While the industry is characteristically cyclical, market analysis suggests that the industry's aggregate annual growth could average from 6% to 8% a year up to 2030[4]. This growth is set to be driven by a wide range of applications, including automotive applications as the market for electric vehicles grows.

The sector is also growing in terms of volume. Over a trillion semiconductors - of many different types - are manufactured globally each year. The most advanced are incredibly technically complex: chips the size of a postage stamp can have 60 billion transistors. Meanwhile, technological advances in new types of semiconductors are vital to making progress in other technologies such as AI, quantum, and 6G.

Semiconductors are produced through an extremely disaggregated global supply chain, with thousands of production stages spread across the world. This has generated a high degree of interdependence, complexity and geographical concentration across different production stages. For example, most manufacturing takes place in East Asia, particularly in Taiwan. This leads to a high degree of vulnerability in the event of potential disruption, as we saw with the negative impact on automotive production during the coronavirus (COVID-19) pandemic.

Alongside taking action to improve domestic supply in response to these supply chain dynamics, countries are also increasingly seeking to protect their supply of semiconductors, or to uplift their defence or technological capabilities, through the acquisition of semiconductor companies and technologies. This can present national security risks. In addition, there are other avenues through which semiconductor technologies can present risks to our security. As the underlying hardware within every electronic product, if semiconductors are not secure, our cyber security can be compromised.

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[1] UK Science and Technology Framework - 2023

[2] Gartner Says Worldwide Semiconductor Revenue Grew 1.1% in 2022 - 2023

[3] Gartner Market Share Analysis: Semiconductor Revenue, Worldwide, 2012 - 2013

[4] McKinsey The semiconductor decade: A trillion-dollar industry - 2022

Given these opportunities for growth, complicated supply chain dynamics and relevance to national security, there is a clear need for a focussed vision to address these challenges and seize the opportunities. Our vision for the sector is that over the next 20 years, the UK will secure areas of world-leading strength in the semiconductor technologies of the future by focusing on our strengths in R&D, design and IP, and compound semiconductors. This will facilitate technological innovation, boost growth and job creation, bolster our international position in order to improve supply chain resilience, and protect our security. This approach is targeted and aligned with what the sector has told us will make the most difference.

We will do three things:

- ***Grow the domestic sector*** - We will build on our strengths - in IP and design, compound semiconductors and R&D - to retain and expand our vital place in this sector.
- **Mitigate the risk of supply chain disruptions** - We will increase the resilience of semiconductor-dependent critical sectors through domestic and international action, and do what we can to reduce the impact of maximum disruption scenarios.
- **Protect our national security** - We will use the levers we have available to us to protect the technology we need secured, while recognising the international nature of markets and the need for the sector to grow.

How we achieve this: growing the UK sector - *Chapter 7*

We have strongly supported our R&D system to date and we will continue to do so. The Department for Science, Innovation and Technology now brings together the policy and wider R&D ecosystem in one place. Our engagement has highlighted skills, financing and the cost of accessing critical equipment and infrastructure as the most significant barriers to growth. This is particularly acute for our design sector and in commercialising research. We recognise that young companies & research organisations can struggle to access the tools, manufacturing equipment and infrastructure they need to either develop their designs or manufacture prototypes to use as proof of concept to attract investment.

Government action is not the whole solution and we believe that an entire sector response is needed. We will only deliver on our vision for the sector if we act in lockstep with industry and academia.

To achieve this:

- We will launch a UK Semiconductor Advisory Panel that will combine industry, government and academia to drive progress toward our vision for the sector, and ensure we are implementing the right actions. Our UK Semiconductor

Advisory Panel, jointly chaired by the Minister for Tech and the Digital Economy and by industry, will ensure that government, academia and industry are all working together to deliver this Strategy. It will speak on behalf of the sector to give us advice and feedback. We will formally launch the Advisory Panel at London Tech Week in June 2023 as part of our drive to promote the sector as a cornerstone of the digital economy.

- We are investing up to £200 million into the sector over the years 2023-25, and up to £1 billion in the next decade.
- This funding will allow us to launch the UK Semiconductor Infrastructure Initiative. We have commenced detailed scoping with industry partners for plans for this initiative. This research is led by the Institute for Manufacturing at Cambridge in collaboration with the Compound Semiconductor Applications Catapult, the Photonics Leadership Group, Silicon Catalyst UK and Techworks. This delivery plan will be developed during the remainder of this year.
- This initiative will consider options to support commercial R&D and SME growth through the development of the UK's enabling infrastructure, this may include expansion of the UK's compound 'open foundry' ecosystem, greater access to chip design tools/IP and prototyping facilities for silicon.
- We will pilot a new UK incubator programme to support new semiconductor start-ups in the UK and to encourage a more dynamic, commercial ecosystem. The incubator will lower the barriers to growth for new companies in the sector, providing access to design tools and prototyping, business coaching and networking opportunities.
- The funding will also allow Innovate UK and the Engineering, and Physical Sciences Research Council (EPSRC) to continue investing in the sector. This includes investing in a call to develop emerging semiconductor technology innovation capability.
- We will provide further support for Centres for Doctoral Training in semiconductor related fields, through EPSRC.
- We will ensure that occupational standards for apprenticeships, higher technical qualifications and T-Levels meet the specific requirements of employers in the semiconductor sector to increase the flow of talented people into the industry.
- We are supporting the Department for Education's Institute of Technology programme which has been backed by £300 million of government capital investment. We are encouraging more employers who serve the semiconductor industry to engage with Institute of Technology programmes to ensure that the sector's specialisms are better served through this novel education delivery mechanism.

- We will announce plans by the autumn to further support the competitiveness of the semiconductor manufacturing sector that is critical to the UK tech ecosystem or the UK's national security.

How we achieve this: supply chain resilience - *Chapter 8*

As we saw in the pandemic, unexpected pressure on the semiconductor supply chain can lead to widespread supply shortages. The semiconductor supply chain is highly concentrated and the current pattern of supply chain concentration has developed over a long period of time. Different countries hold specific specialties within the supply chain. The complexity of the supply chain means we will need to work domestically and internationally to improve resilience of supply.

Countries have responded differently to the shocks to supply. For example, the approach taken by the US and EU has been to strengthen their manufacturing capabilities. The UK does not have a significant share of global silicon semiconductor manufacturing and industry tells us that the UK is better positioned to pursue alternative opportunities within the sector as opposed to building advanced silicon manufacturing capabilities to rival those in East Asia.

No country will be able to achieve supply chain autonomy. Instead, we want to help UK sectors mitigate the impact of supply shortages in the future. This includes action to help our high-tech manufacturing and infrastructure industries better prepare themselves for future shocks. We also want to protect our critical sectors (essential services, healthcare, critical national infrastructure and defence) from disruptions that could cause risks to life, or national security. Our plan for improving the UK's supply chain resilience therefore has three parts: preparing economic sectors; protecting critical sectors through domestic action and protecting critical sectors through international co-operation.

To achieve this:

- We will publish semiconductor resilience guidance to improve sectors' understanding of the potential risks to semiconductor supply chains and the steps they can take to better prepare for future disruption and minimise their exposure to risks.
- We will establish a cross-government and industry forum which helps to better identify and mitigate supply chain disruptions. We will improve our collective understanding of specific sectors more likely to be vulnerable to shortages.
- We will bring together government, critical sectors and the manufacturers that support them in a broad crisis and contingency planning exercise to consider the impacts of future major disruptions, alongside possible mitigations.

- We will engage with external suppliers to critical industries on risks to chip supply, encouraging co-operation and transparency to improve resilience.
- We will pursue plurilateral co-operation to develop and implement a coordinated approach to supply chain resilience across like-minded nations, including at the G7 in 2023, as a central part of the UK's broader ambition on issues related to mutually-beneficial trade, shared security and values.
- We will identify the supply chains for critical sectors around the world that are most at risk of being impacted by a semiconductor related supply chain shock.

How we achieve this: Protecting national security - *Chapter 9*

Semiconductors can be associated with a range of national security risks. In particular, the acquisition of sensitive UK semiconductor companies and technologies by hostile states can then be used to build up the military capabilities of our adversaries. In addition, there can be increased exposure to cyber-attacks caused by vulnerabilities in semiconductor technologies, whether introduced deliberately or otherwise. In this context, we are seeking to:

- ***Protect UK assets:*** Being clearer about how the UK uses its protective levers - such as the National Security and Investment Act and export controls - to protect the most sensitive UK semiconductor companies and technologies. We have already made a series of decisions under the National Security and Investment Act, and we will continue to do so to protect the most sensitive areas of our sector.
- ***Build on our hardware strengths to improve cyber security:*** Using our expertise in hardware security to more widely improve the security credentials of semiconductor devices which are used in both consumer and sensitive systems. We are already running successful programmes - such as Digital Security by Design - seeking to raise international standards in the use of better hardware design for the benefit of cyber security. The Ministry of Defence and other sensitive parts of government also have existing programmes to protect their supply chains.

To achieve greater protection against these risks:

- We will review the scope of Computing Hardware and Advanced Materials definition under The National Security and Investment Act 2021 (Notifiable Acquisition) (Specification of Qualifying Entities) Regulations 2021.
- We will provide updated guidance regarding the elements of the sector we consider to be more sensitive for investment security.
- We will work with business to assess the export control regime and how it could be expanded for sensitive emerging technologies, including semiconductors.

- The world leading Product Security and Telecommunications Infrastructure (Product Security) Regime will come into effect in April 2024.
- We will convene security experts across government, academia and business to identify areas of further government support into improving security through hardware.
- We will continue to support the future growth of the Digital Security by Design programme. This includes expanding international outreach on the global challenge in delivering semiconductor chips that embed digital security. This will include both working with other governments, as well as international business, to promote the rapid and widest possible uptake of the technology that has been realised through Digital Security by Design.

By taking action across all three pillars of our Strategy, we will see the sector grow, become more resilient, and be better protected against national security risks. Achieving our vision is a shared responsibility between government, industry and academia. We will work collaboratively to: deliver the activity we have set out here; identify any action we might need to take in the future; and drive better jobs, new discoveries and economic growth.

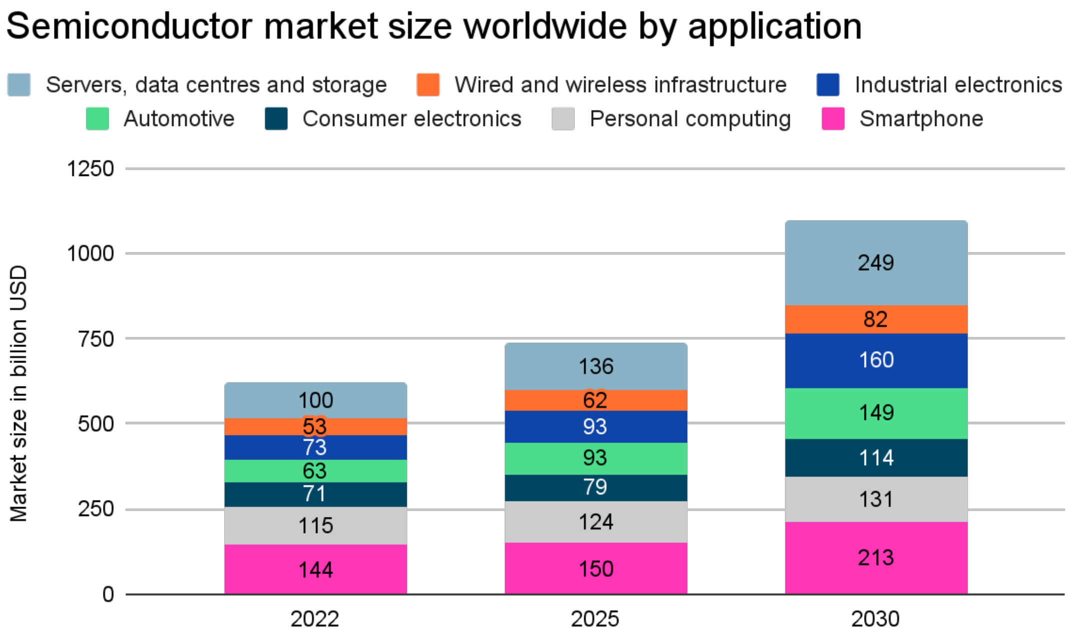
Part one: The current landscape

4. Semiconductors today

4.1 What are semiconductors?

Semiconductors are a class of materials which are used to create the hardware that underpin electronic devices. The digital economy would be unable to function without them. Technically, they are the basis upon which integrated circuits, or computer chips, are built. They are also used in discrete devices, such as those involved in power management, radio frequency, lasers and sensors.

Global revenue in the semiconductor sector was $601.7 billion in 2022[5], representing a 100.6% increase from 2012[6]. While the industry is characteristically cyclical, market analysis suggests that growth in the industry's aggregate annual growth could average from 6% to 8% a year up to 2030[7]. Industry forecasts suggest that this growth is set to be driven across a wide range of applications, as the graph below[8] shows, including automotive applications as the market for electric vehicles grows.



[5] [Gartner Says Worldwide Semiconductor Revenue Grew 1.1% in 2022](#) - 2023
[6] [Gartner Market Share Analysis: Semiconductor Revenue, Worldwide, 2012](#) - 2013
[7] [McKinsey The semiconductor decade: A trillion-dollar industry](#) - 2022
[8] [ASML, Megatrends, wafer demand and capacity plans to support future growth](#) - 2022

[Data Source: ASML, Megatrends, wafer demand and capacity plans to support future growth]

The term ‘semiconductor’ describes a range of elements and compounds whose electrical conductivity is between that of an insulator (for example, glass) and a conductor (for example, copper) and whose characteristics can be specifically altered through the addition of impurities[9]. Through these additions, semiconductors can have their properties altered to direct the flow of, and amplify, electrical current when switched on or off.

These ‘switches’ are known as transistors and are a fundamental building block of modern electronics. Some of the most advanced semiconductor ‘chips’ can comprise billions of transistors. Semiconductors are usually - but by no means exclusively - made of silicon. Some semiconductor devices can be made of materials such as graphene or diamond. Devices composed of two or more chemical elements (such as those made from gallium and nitrogen to make gallium nitride) are known as compound semiconductors.

While not exhaustive, there are four main types of semiconductor device (often made up of an array of tens to billions of components and from different semiconducting materials):

- **Logic:** process information to complete tasks such as a Central Processing Unit or Graphics Processing Unit
- **Memory:** hold programs and data either permanently or temporarily. Include volatile memory such as dynamic random-access memory used for primary storage, or non-volatile memory including NAND flash memory and read-only memory

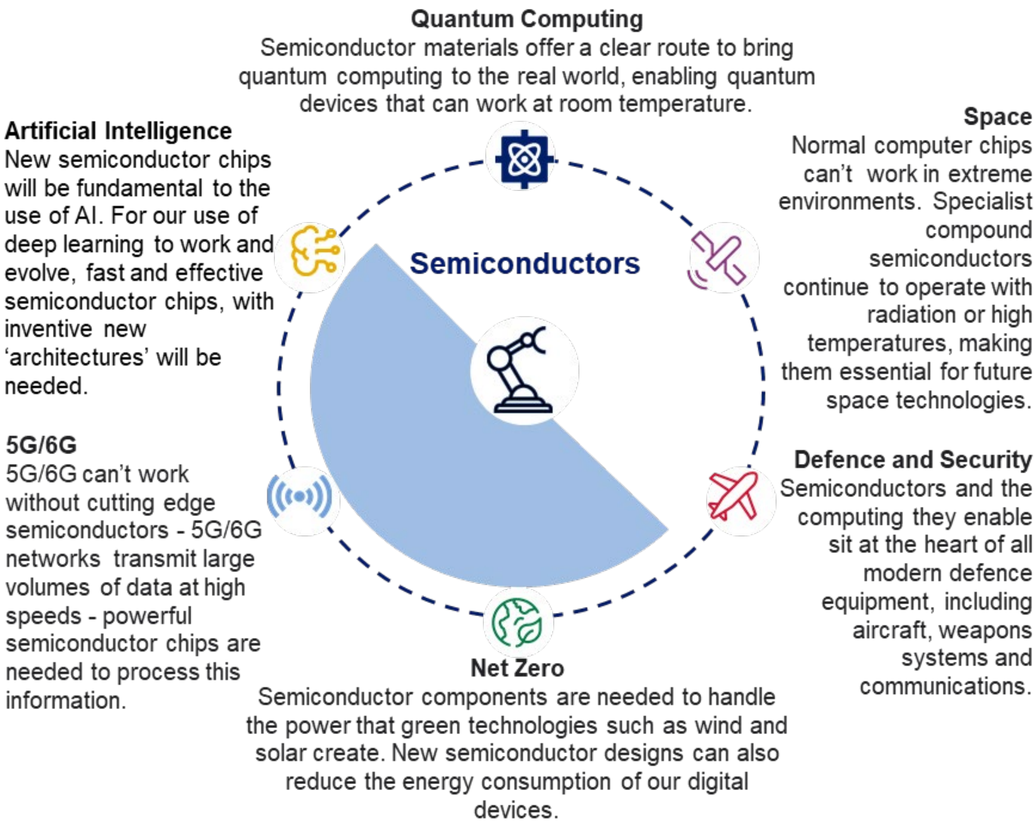
[9] Semiconductor Industry Association, Semiconductors are the Brains of Modern Electronics - 2014

- **Analogue:** generate a signal, or change signal characteristics. Especially prevalent in power management, automotive, sensors and audio applications
- **Discrete:** designed to perform specific electronic functions[10] and can only perform one function, for instance, an individual transistor

Technological progress at the semiconductor level is essential to unlock future innovation in the broad range of technologies which they enable. This includes the technologies and outcomes this government has committed to supporting, including, but not limited to:

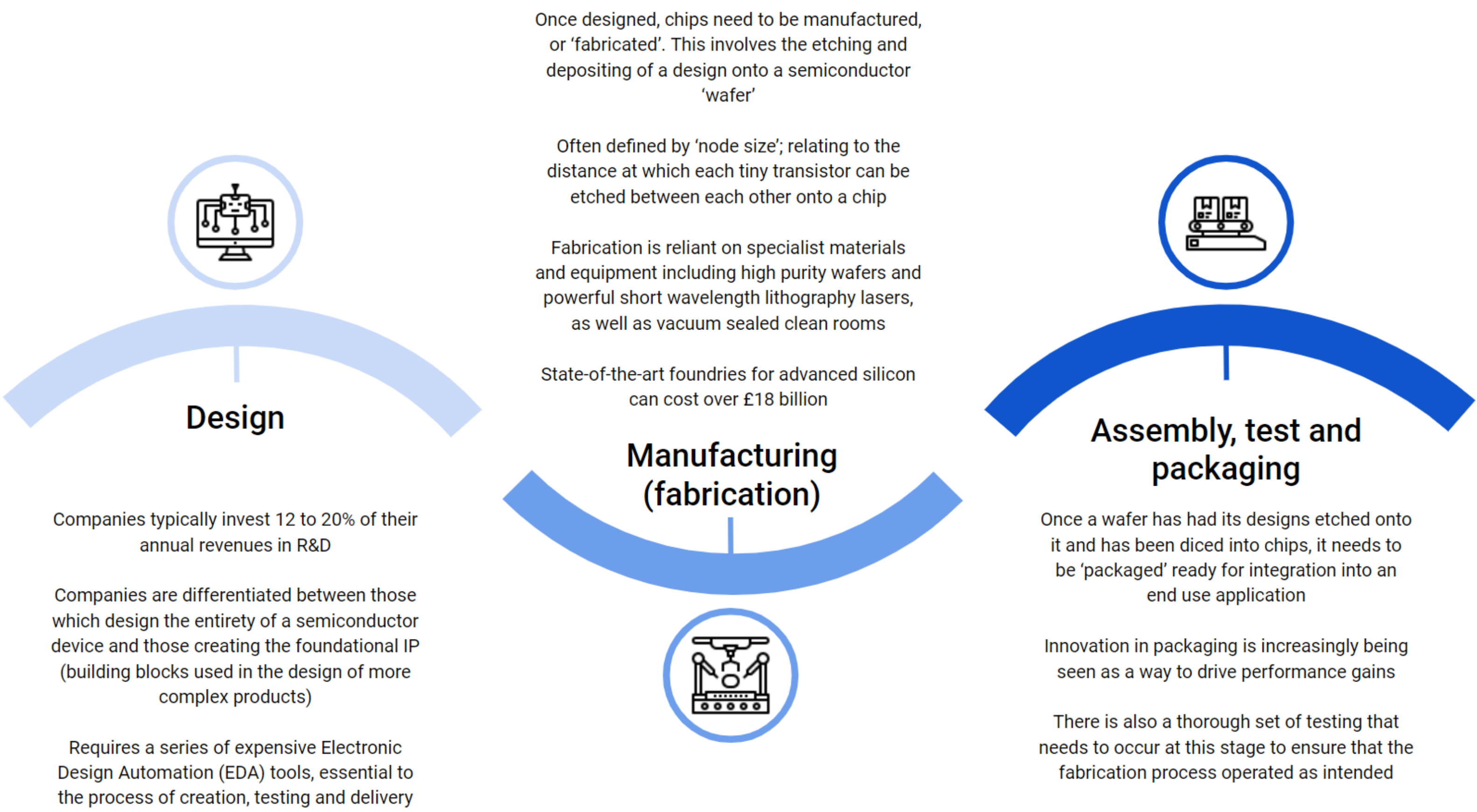
- The UK securing our status as a science and technology superpower;
- Achieving net zero by 2050;
- Making breakthroughs in quantum computing and delivering on the vision set out in the National Quantum Strategy;
- Achieving the vision in the National Space Strategy;
- Helping to ensure strong UK cyber security as set out in the National Cyber Strategy and;
- Ensuring the development of leading strengths in Artificial Intelligence as set out in the National AI Strategy

SIGNIFICANCE OF SEMICONDUCTORS ACROSS SECTORS



10 Information Technology & Innovation Foundation, Moore's Law Under Attack: The Impact of China's Policies on Global Semiconductor Innovation - 2021

THE STAGES OF MAKING A SEMICONDUCTOR DEVICE



4.2 Current market dynamics - complex supply chains

Specialisation, concentration and vulnerability

The semiconductor supply chain is highly specialised and globally dispersed. Thousands of production stages are spread across the globe. The nature of the supply chain has developed over many years and represents the culmination of years of foresight, innovation and vision by industry, academia and governments. Within this global picture, the UK holds a unique position, with marked strengths in design, compound and R&D (full details on the UK position provided below).

The US (which has world-leading universities and a large pool of engineering talent) leads in areas of the supply chain which are most reliant on R&D, including design and electronic design automation[11]. East Asian countries lead in fabrication, which is hugely capital-intensive. This has been supported by the decisions of respective governments in that region to provide incentives and subsidies, in addition to a highly skilled workforce and private sector innovation.

The globalisation of the industry - with interdependence across different production stages - has brought tangible benefits. Boston Consulting Group has found that "a

[11] Center for Security and Emerging Technology, The Semiconductor Supply Chain Assessing National Competitiveness - 2021

hypothetical alternative with parallel, fully "self-sufficient" local supply chains in each region to meet its current levels of semiconductor consumption would have required at least $1 trillion in incremental upfront investment, resulting in a 35% to 65% overall increase in semiconductor prices and ultimately higher costs of electronic devices for end users."[12]

However, specialisation and concentration in specific geographical areas means that supply chains are vulnerable. Significantly diversifying or changing the geographical spread is unlikely. This is because there are significant financial and technical barriers to entering the semiconductor market. This includes high expenses, both in manufacturing infrastructure and R&D. For example, cutting edge commercial-scale semiconductor plants can cost upwards of £10 billion. Demand for some key semiconductor manufacturing equipment is also greater than supply, which creates a bottleneck in growing chip supplies. Additionally, semiconductor manufacturing and R&D require skilled staff who command high wages and are in demand globally.

Specific geographic concentrations pose their own challenges. Manufacturing is heavily concentrated in Taiwan. Over 90% of advanced manufacturing and 20% of global manufacturing capacity is located on the island[13]. This supply could be disrupted by natural disasters, infrastructure shutdowns, or international conflicts, and may cause severe interruptions in the supply of semiconductors. As such, the risks of any prolonged disruption to supply from Taiwan would have serious

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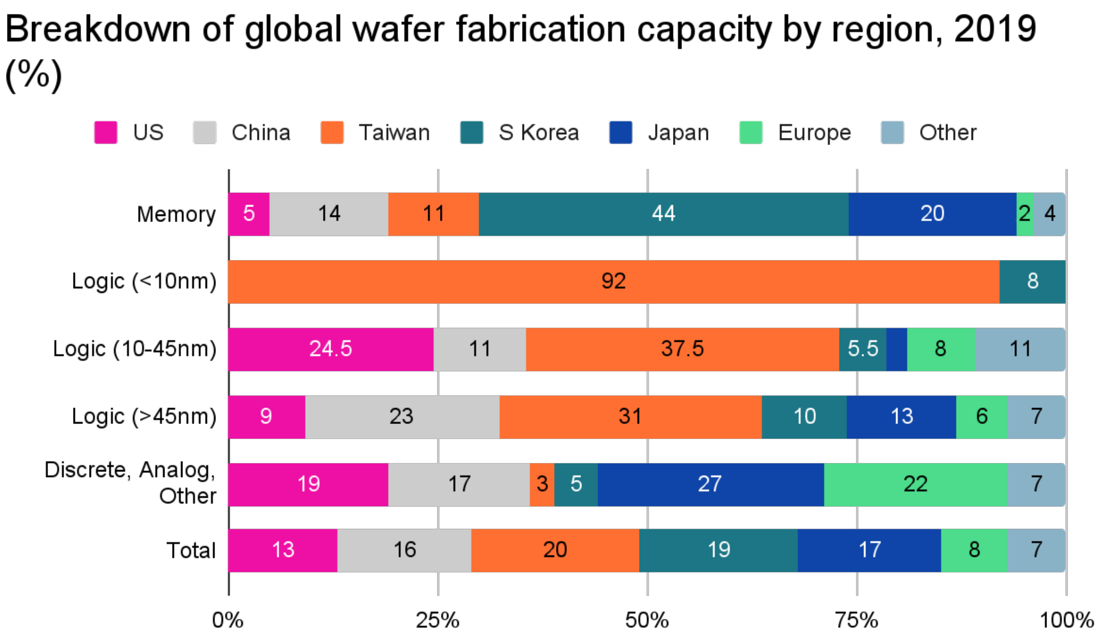
[12] BCG x Semiconductor Industry Association, Strengthening the Global Semiconductor Supply Chain in an Uncertain Era - 2021

[13] https://web-assets.bcg.com/9d/64/367c63094411b6e9e1407bec0dcc/bcgxsia-strengthening-the-global-semiconductor-value-chain-april-2021.pdf - 2021

implications for the global economy, including for critical sectors such as healthcare and defence.



[Data source: BCGxSIA report: Strengthening the global semiconductor supply chain in an uncertain era -2021]

The production of semiconductors also requires critical minerals, including silicon and gallium, as defined in the UK's Critical Minerals Strategy[14]. 91% of the world's gallium is produced in China, while Russia produces 4%[15]. Gallium is a by-product of

[14] BEIS, Critical Minerals Strategy - 2022

[15] British Geological Survey - UK Criticality Assessment of Technology Critical Materials and Metals - 2022

bulk metal mining, meaning that supply and demand dynamics are complex, and markets are vulnerable to supply shocks.

Transparency

The majority of semiconductors arrive in the UK as part of an integrated end-use application. This means they are already installed in cars, phones and fridges and in critical products such as MRI machines and ventilators, as well as telecom relays and data centres in communication networks.

Multiple semiconductors are required for these different products and systems. For example, in one type of advanced modern car, there are approximately 3800 distinct semiconductor components. A ventilator will contain different semiconductors to determine the rate, volume, and amount of oxygen per breath; accurately adjust oxygen levels; and control the speed of the mechanised breathing for a patient. Most semiconductors used in these products will come from different factories, each with their own unique and complex supply chain.

This complexity means it is difficult for any market actor to have full visibility of the market as there are too many stages in the supply chain. International efforts to increase transparency have revealed that those who buy intermediate products (for example manufacturers of medical equipment or automotive manufacturing companies) can often not know about the dependencies within their own supply chains. Consequently, users and manufacturers of end products find it difficult to anticipate shortages. They also find it difficult to signal demand back to earlier stages of the supply chain, making it harder for semiconductor manufacturers to correctly anticipate future capacity needs. Given the length of time required to add additional manufacturing capacity this leads to boom and bust cycles in the market.

This squeeze on supply has played out over the last three years. The added demand for consumer electronics generated by the pandemic, a higher than expected sustained demand for items such as cars, and a number of unexpected supply shocks such as fires and storms at major manufacturing centres, put unexpected pressure on a highly concentrated supply chain, leading to widespread shortages. This has been particularly acute for the automotive sector, with many companies having to reduce production output in the UK. Analysts now suggest that some areas of the industry are entering a period of over-supply as manufacturers responded to shortages and higher demand by ramping up production where possible.

4.3 Current market dynamics - technological innovation

Performance gains in semiconductor technology and sectoral innovation have largely relied on miniaturisation over the last forty years. Gains have been driven by Moore's Law (see below). The prediction made by Moore's Law has generally held true for decades. But our ability to continue relying on Moore's Law to drive performance gains is reaching its physical limits.

What is Moore's Law?

Moore's Law is a term used within computing which refers to the observation made by Gordon Moore - who later went on to found Intel - in 1965 that the number of transistors in a dense IC doubles about every 2 years. While never claimed as a 'law' in the strictest sense of the term, it described the intense performance gains that he thought were possible within the industry thanks to the work and dedication of researchers and engineers.

The fundamental premise of predictable improvement and steady growth has held strong. The exponential nature of Moore's Law consistently drove growth, opportunities and performance improvements within the industry. However, there are some within the industry who believe that Moore's Law is now slowing to the point that some ask if it is 'dead'.

As innovation within the industry has continued, transistors have become more and more complex and difficult to design. Fundamentally the evolution of semiconductor process technology is reaching its molecular limits as the industry moves towards transistors at the 3 nanometer scale and beyond, thereby slowing the exponential nature of Moore's Law.

This phenomenon has led the semiconductor industry to consider how it can move to 'More than Moore' and drive performance gains through new and novel technologies.

The next generation of semiconductors will rely on new materials and processes, inviting a wave of renewed global competition. Advancements are expected in technologies such as compound semiconductors, which have specific properties (explained below) making them suited to facilitate dependent technologies such as 5/6G, net zero and quantum technologies.

Advantages and applications of compound semiconductors

Compound semiconductors currently account for around 20% of chips used globally[16], but the compound semiconductor market is growing quickly. This is driven by trends like electrification and net zero technologies, telecommunications, self-driving vehicles and the Internet of Things. Market analysis suggests that the global compound market is forecast to grow from $67 billion currently to $350 billion by 2030[17].

[16] The UK Semiconductor Industry: Current Landscape and Future Opportunities - 2022

[17] CSA Catapult - About Us - no date

Compound chips are not a single market, but rather a series of similar materials with linked supply chains, each able to perform different functions to silicon chips in certain ways.

- Indium Phosphide, Silicon Germanium, Gallium Nitride and Gallium Arsenide can be used to create components able to transmit and detect light, or other radio frequencies, making them particularly useful for photonics. These materials will play an increasingly vital role in devices with lasers, LIDAR, and sensors, to help connectivity and for use in satellite applications. Gallium Arsenide chips are predominantly used for radio frequency communication and defence applications. Indium Phosphide chips are used for facial recognition and high-speed optical communications, especially in demanding sub-sea environments.

- Silicon Carbide excels in power electronics applications, and Silicon Carbide chips play an important role in electric vehicles, helping control the flow of energy around the vehicles, and into/out of batteries. Silicon Carbide chips are also used for electric vehicle propulsion systems.

Advancements in 2.5D and 3D packaging and heterogeneous integration - which is when separately manufactured components are brought together in a single chip/assembly that provides enhanced functionality and performance - are also expected. This will allow for multiple manufacturing process flows to be combined on a single device.

The benefits of advanced packaging techniques are relevant to a wide range of end-use applications. In the case of consumer electronics, such as mobile phones and Internet of Things devices, advanced packaging can help make products smaller by reducing the surface area of the chips that they contain. The enhanced speed of 2.5D or 3D packages can help increase the performance of processors used in demanding computing applications such as gaming, while chips used in high-temperature industrial environments can benefit from clever ways to dissipate heat.

4.4 Current market dynamics - geopolitical relevance

The 2021 Integrated Review made clear that advances in science and technology science and technology are of increasing importance to the UK's position in the world. It states that "over the coming decade, the ability to advance and exploit science and technology will be an increasingly important metric of global power, conferring economic, political and military advantages. The tech 'superpowers' are investing to maintain their lead."[18] We have re-endorsed this in the refreshed Integrated Review[19].

This dynamic has been borne out in the semiconductor sector as several countries invest in their industries. The US CHIPS Act represents an ambitious effort to maintain technological advantage and build domestic capabilities - largely in silicon manufacturing - backed by $52 billion in support over five years. Taiwan is aiming to maintain and expand its silicon fabrication dominance in the coming years. Japan and South Korea are also investing heavily in manufacturing. The EU is aiming to increase its Member States' share of manufacturing backed by €43 billion (a combination of Commission and member state funding).

China has a sustained and public focus on gaining a greater market share across the supply chain and technological autonomy. It has a highly integrated system that consists of long-term strategies, financial incentives, foreign acquisitions and research partnerships. Market estimates indicate that China has committed over $150 billion of state-backed investment into the semiconductor industry since 2014[20]. While this drive has been met with mixed results, China has increased its expertise in certain areas including design. It now accounts for around 5% of the overall design sector[21], as well as increasing its manufacturing capacity at less advanced node sizes. This augments China's existing strengths in assembly, test and packaging.

4.5 Current market dynamics - importance to security

The supply chain vulnerabilities and dependencies associated with semiconductors can represent a security risk. The implications of an interruption to the supply of semiconductors from East Asia would be considerable for the global economy and would affect sectors relevant to security, including defence and critical national infrastructure.

In addition, semiconductors' position at the bottom of the tech-stack, their facilitatory nature for other technologies, and their presence in defence and other sensitive systems, mean that they represent a vector for a range of security threats.

Innovation in semiconductors can be 'dual use'. This means that innovation in semiconductor technology which facilitates wider progress in areas such as AI may also have future military applications. This dynamic has catalysed governments

[18] UK Integrated Review: Global Britain in a Competitive Age - 2021

[19] UK Integrated Review Refresh: Responding to a more contested and volatile world - 2023

[20] SIA Whitepaper: Taking Stock of China's Semiconductor Industry -2021

[21] Center for Security and Emerging Technology, The Semiconductor Supply Chain: Assessing National Competitiveness -2021

across the world to protect their most sensitive semiconductor related assets from hostile states. Protective security levers have been applied such as investment screening regimes, and export controls.

We have seen this dynamic play out in recent months. For instance, the German government blocked Chinese investment into two German semiconductor companies on national security grounds in November 2022[22]. The US introduced new export controls in October 2022 which seek to limit China's "ability to both purchase and manufacture certain high-end chips used in military applications."[23] The Netherlands introduced similar controls in March 2023[24].

The secure design and manufacture of semiconductors has always been important for defence and other sensitive supply chains. But the growth in importance of the Internet of Things, the advent of self-driving vehicles, and greater automation across our everyday lives, mean that these cyber security considerations are increasingly important for consumer goods[25]. There is therefore a growing necessity for the design and manufacture of semiconductors to take security into account.

5. The UK's position

The UK has a proud history of innovation across science and technology. Science and technology industries are vital to the UK's economic growth and to creating higher paying jobs. Novel discoveries will create new opportunities for growth and employment. From the World Wide Web, to advances in AI through companies such as DeepMind, huge amounts of the world's technological innovations have relied on UK expertise. This is also true of semiconductors. The UK has been instrumental in developing many of the underpinning technologies of today's ecosystem.

The UK has strengths across the semiconductor value chain, but possesses three particular areas of strategic advantage - semiconductor design and IP, compound

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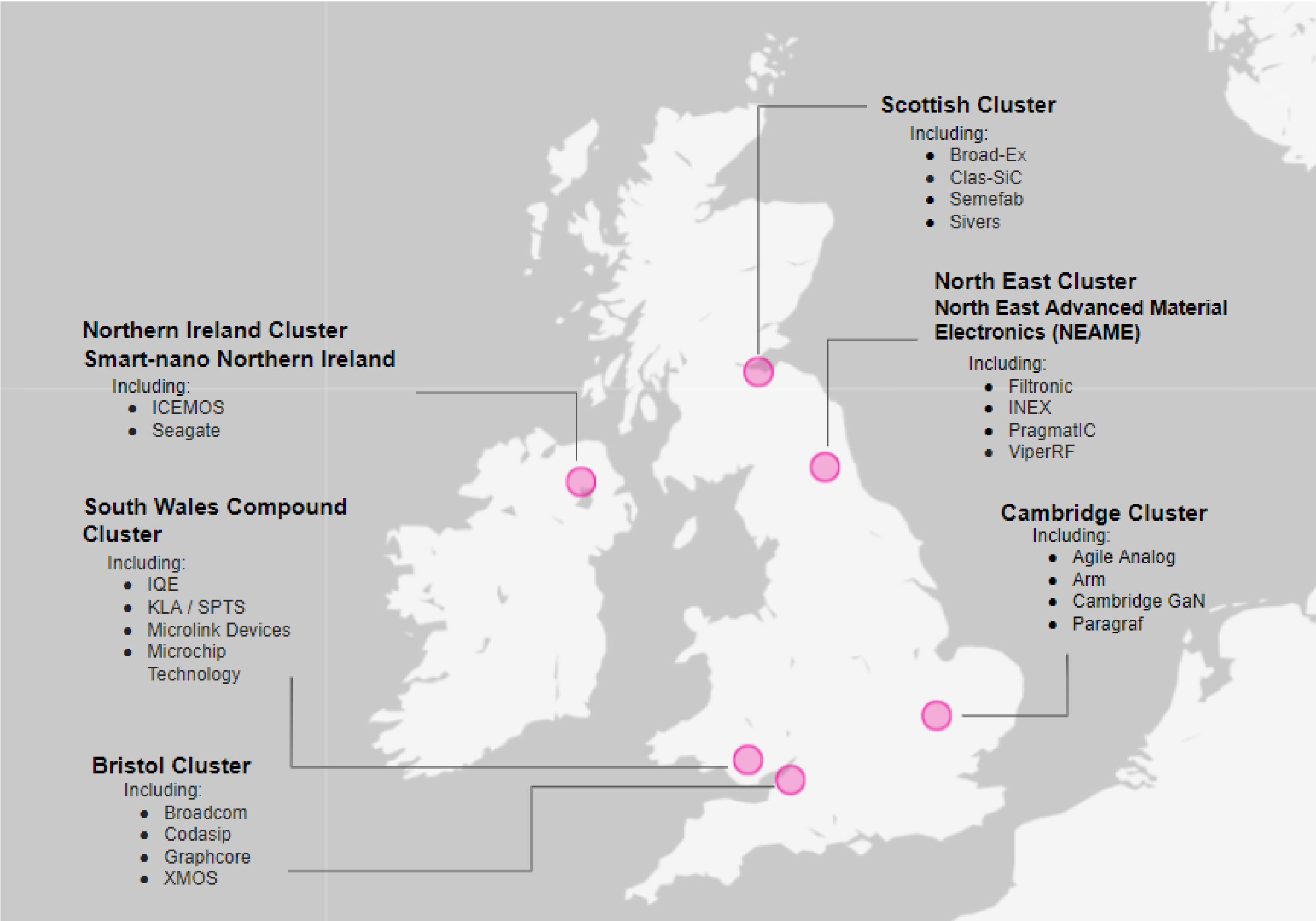
[22] Reuters, Germany blocks Chinese stake in two chipmakers over security concerns - 2022

[23] US Bureau of Industry and Security, Commerce Implements New Export Controls on Advanced Computing and Semiconductor Manufacturing Items to the People's Republic of China (PRC) - 2022

[24] BBC News, US-China chip war: Netherlands moves to restrict some tech exports - 2023

[25] House of Commons Briefing - The Product Security and Telecommunications Infrastructure Bill - 2022

semiconductors, and our world-leading research and innovation system, supported by our fantastic universities.



These strengths are spread across all regions of the UK, with particularly notable clusters of activity in Cambridge, Bristol, South Wales, Scotland (Glasgow and Edinburgh and the corridor between them, once known as 'Silicon Glen'), and the North East. The UK is home to Arm, which is based in Cambridge and designs the Instruction Set Architecture and Central Processing Unit IP which have driven the smartphone revolution. Arm technology is now so ubiquitous that 29.2 billion Arm-based chips shipped in 2021 alone[26].

The UK is also home to significant companies across other sub-sectors, including in key parts of the supply chain such as wafer production and manufacturing tools. There are currently around 25 semiconductor manufacturing sites in the UK. These capabilities vary in output and complexity. Facilities process anywhere from a few hundred wafers to several thousand wafers per month, covering both legacy silicon

[26] Arm, Arm delivers record revenues and record profits in FY21 - 2022

manufacturing to world-leading thin film fabrication (helping to produce flexible semiconductor devices) and compound epitaxy (the process of growing or depositing crystals on a wafer).

Most UK fabs produce components or devices for a variety of end markets including battery technology, sensors, communications, photonics and power electronics. In addition to fabrication, the UK also possesses some packaging capability with around 20 companies engaged in this segment of the production process.

5.1 Research and Innovation

The UK has world leading semiconductor research capabilities. For instance, the UK is 8th globally and 3rd in Europe for the number of semiconductor International Patent Families, behind Germany and France. The UK's volume is comparable to India[27]. Our strength in semiconductor research gives us the potential to build novel semiconductor technologies from a world-leading base. The UK has particular areas of research expertise in design, advanced materials, compound semiconductors, power electronics, photonics, quantum technologies and heterogeneous integration. All of these could lead to UK strategic advantage in the next stage of technology evolution, especially as we seek to develop the hardware which will be required for breakthroughs in AI, quantum computing, large-scale compute and the pursuit of net zero.

UK research proficiency has already created many innovative, forward-looking companies. The UK is home to disruptive companies like Pragmatic, which has recently secured $125 million to scale up its business, including more than doubling headcount and building a second fabrication facility in the UK to manufacture thin-film flexible integrated circuits that are quicker and cheaper to produce than conventional silicon chips. These flexible chips are thinner than a human hair and can be invisibly embedded in a wide variety of things. This enables innovators to create novel solutions to everyday problems that are not practical with conventional electronics, including for sectors such as healthcare, consumer goods, retail and security[28].

The quality of semiconductor research in the UK has also led to improvements to cyber security. The Digital Security by Design programme - which brings together £70 million of government funding matched by £117 million from industry - builds on academic research from the University of Cambridge.

[27] UKIPO analysis of PatentSight

[28] Pragmatic - Our Company - no date

5.2 Design and IP

The UK is strong across semiconductor design and IP and has a number of dedicated design houses, with over 110 companies[29]. IP providers who are headquartered in the UK, such as Arm and Imagination Technologies, hold a strategic global position. This helps the UK to drive the proliferation of UK standards and values to meet wider objectives, such as cyber security.

We see high international interest and investment into the UK. Our talent is sought-after and we have exceptional R&D clusters in Cambridge and Bristol. The UK is also an attractive place to list. Canadian IP company Alphawave has relocated to London and completed an IPO on the London Stock Exchange in 2021. In October 2022, Sondrel Holdings, a fabless semiconductor company focused on the design of application specific integrated circuits chose to list on London's AIM market.

Internationally leading companies also have a UK presence in semiconductor design. Apple has an office in St Albans focused on semiconductor design, Intel has a team in Swindon focusing on Graphics Processing Unit development and Infineon, a large German semiconductor company, has an R&D office in Bristol. Meanwhile, we have home-grown unicorns such as Graphcore, who are based in Bristol and are at the cutting edge of AI-enabling hardware. The UK has leadership in wider emerging technologies critical to prosperity and economic growth, as well as security needs.

Design is estimated to have a 29.8% share of total value add within the semiconductor value chain[30]. It is second only to the manufacturing of semiconductors at 38.4%[31]. The presence of world-leading companies in the UK within this high-value aspect of the industry is a real area of opportunity for future UK economic growth.

5.3 Compound semiconductors

Built on our physical sciences and engineering research base, the UK has developed a strength across the compound semiconductor supply chain. We have world-leading research, development, innovation, and commercialisation of the technology. The UK has a significant share of the global compound semiconductor market - driven by companies like IQE which is a key player in supplying compound semiconductor wafer products and advanced material solutions to the semiconductor industry. The UK also has expertise in compound semiconductor fabrication. For example: Sivers in Glasgow produces large volumes of Indium

[29] Global Counsel/Imagination. The future of the UK's semiconductor strategy - 2022

[30] Manufacturing Technology Centre, The UK Semiconductor Industry: Current Landscape and Future Opportunities - 2022

[31] Manufacturing Technology Centre, The UK Semiconductor Industry: Current Landscape and Future Opportunities - 2022

Phosphide chips, ClasSiC in Lochgelly has expertise in producing Silicon Carbide chips and Lumentum in Towcester has produced large volumes of Indium Phosphide chips for over 10 years.

The UK government has invested extensively through the EPSRC in compound semiconductors and their wider applications since 2006, facilitating this strength in compound semiconductors and generating UK academic excellence across the UK. This has been seen particularly in central Scotland, Sheffield, Oxford, Cambridge, London and Southampton. We now have hotspots of expertise like the Fraunhofer Centre for Applied Photonics and Cambridge Centre for Gallium Nitride. We have leading tool manufacturers such as Oxford Instruments, and, backed by strong UK and Welsh government support, the world's first compound semiconductor cluster in South Wales - CSconnected.

Compound semiconductor strengths in South Wales[32]

South Wales is pioneering the design, development, and commercialisation of the compound semiconductors needed for a net zero economy.

The CSconnected cluster in South Wales is a unique collective of organisations including academic institutions, semiconductor firms, and prototyping and manufacturing facilities. The cluster is already generating considerable economic benefit. In 2021, it directly supported £194 million of Gross Value Added and 1,600 Full Time Equivalent employees, alongside a further £83 million of Gross Value Added and 790 Full Time Equivalent jobs elsewhere in the Welsh economy[33]. CSconnected expects these annual figures to double by 2025 due to investment received and high demand for compound semiconductors[34].

The CSconnected cluster in South Wales offers internationally recognised expertise and capabilities to service the growing demand for compound semiconductor enabled technologies. Companies can exploit the region's assets and expertise across technology development. This includes research, innovation and design through to full-scale compound semiconductor manufacturing, providing solutions across a range of high-growth applications.

The region's assets, such as the Institute for Compound Semiconductors and the Centre for Integrative Semiconductor Materials, are driving innovation. The Compound Semiconductor Centre and the Compound Semiconductor Applications Catapult are accelerating integration and commercialisation of this technology.

Further collaborative opportunities exist with compound semiconductor

[32] DIT, Compound semiconductors and applications in South Wales - no date

[33] CSconnected, Annual Report - 2022

[34] CSconnected, Response to BEIS Committee Call for Evidence - 2022

companies in the region including IQE and SPTS Technologies (a KLA company).

The region is also home to four leading universities that create 13,260 industry-ready graduates a year, specialising in engineering and technology, physical science and computer science.

Cardiff University is home to a Centre for Doctoral Training in Compound Semiconductor Manufacturing, which brings together expertise to train engineers and scientists with the skills, knowledge and confidence to tackle today's evolving issues and future challenges. The Centre also creates new working cultures, builds relationships between teams and forges lasting links with industry.

The Institute for Compound Semiconductors undertakes fundamental research on compound semiconductor materials.

The Centre for Integrative Semiconductor Materials brings together advanced materials platforms and processes to deliver new technologies and products.

Global demand for compound semiconductors is high, as compound semiconductors are essential to electrification, including the growth - and reduction in costs - of electric cars as the UK makes the transition to net zero. We expect commercial opportunities to be considerable and sector growth to be quick; market analysis suggests that the global compound market is forecast to grow from $67 billion currently to $350 billion by 2030[35].

The UK is home to the Compound Semiconductor Applications Catapult (CSA Catapult). The Catapult is a very strong example of government, industry and academia working together. It was established by Innovate UK in 2016 following a two-year consultation with industry and academia. It has now initiated over £160 million of projects, working with over 100 companies across the UK developing advanced electronic products. The CSA Catapult has built an enviable record of generating industrial collaborations to commercialise its research, including through compound semiconductor manufacturing.

The Catapult's priority areas include electric vehicles, future 5G telecom networks, defence and quantum technologies. The CSA Catapult will expand its operations in 2023, opening UK facilities to support regional clusters developing satellite communications and future telecom networks. In 2020, the CSA Catapult signed a memorandum of understanding with the Industrial Technology Research Institute of Taiwan, paving the way for a long-lasting collaborative partnership.

[35] CSA Catapult - About Us - no date

Part two: Delivering our vision

6. Our vision for the sector

Now is the time for the UK to capitalise on our strengths. The industry is continually innovating and finding new ways to achieve performance gains, relying on novel research and development. The UK's foothold in R&D, IP and design and compound semiconductors provides an opportunity to gain a competitive advantage. Maintaining, and building on, where we are most innovative will drive growth, bolster supply chain resilience, and improve our national security.

The government - in collaboration with industry and academic experts - recognise the opportunities these strengths provide the UK, particularly in driving innovations in future areas of semiconductor technology, and has therefore worked to identify the most compelling 'leapfrog' areas to secure the greatest impact from our interventions. These interventions will not be entirely government owned, but will need to be executed in partnership with industry and academia. Success will see the UK develop a set of capabilities that build our strategic advantage. The UK will grow as an important actor globally, deepening our strategic position, which will improve our ability to collaborate with partners and enhance our international influence. The government's vision for the sector is:

> Over the next 20 years, the UK will secure areas of world leading strength in the semiconductor technologies of the future by focusing on our strengths in R&D, design and IP, and compound semiconductors. This will facilitate technological innovation, boost growth and job creation, bolster our international position in order to improve supply chain resilience, and protect our security.

To deliver this vision, the Strategy is guided by three clear objectives:

1. ***To grow the domestic sector*** - We will build on our strengths - in design, compound semiconductors and R&D - to retain and expand our vital place in this sector. This will ensure our domestic semiconductor sector improves the UK's prosperity. It will drive growth and support our ambitions in quantum, net zero and AI. Bolstering our domestic sector will also have beneficial impacts for our ability to engage internationally on a range of issues. This is explored further in Chapter 7.

2. ***To safeguard the UK against supply chain disruption and build supply chain resilience*** - We need to ensure - as best we can - that we safeguard a reliable supply of semiconductors to the UK, including individual components and within finished goods. This is essential to the UK's economy and is

increasingly acute in the wake of potential global supply disruption. Given the complexity of the global supply chain, there are no easy solutions here and we are proposing to work collaboratively with industry and international partners. This is explored further in Chapter 8.

3. ***To protect the UK against the security risks arising from semiconductor technologies*** - We also need to ensure that our response is proportionate to growing national security threats in the sector, including preventing hostile actors building defence or technological capabilities which present a national security threat, and addressing the cyber security of increasingly connected devices. This is explored further in Chapter 9.

7. Our plan to grow the domestic sector

7.1 Supporting our domestic sector through the technology cycle

The semiconductor sector is vital to securing our status as a science and technology superpower by 2030. The global semiconductor market, which was valued at $601.7 billion in 2022, is expected to grow by 6% to 8% a year up to 2030[36] and is forecast to reach a total market size of $1 trillion by 2030[37]. We will seize the opportunities offered through this growth by realising three objectives:

- We will maintain and build on the UK's leading edge in chip design and IP, furthering UK ambitions in wider digital technologies.

- We will make the UK one of the top global centres for compound semiconductor innovation, building on our existing foundations. This will enable our goals in automotive, aerospace, defence, net zero, telecoms and quantum technologies and will complement and interface with the UK's expertise in photonics.

- We will build on our existing research base, enabling the UK to gain a foothold in the next generation of semiconductor technologies. This could include post-Moore's Law technologies such as hybrid and heterogeneous integration, advanced material semiconductors, and novel production processes. This will make the UK a key player in the next evolution of hardware across end use applications.

The most effective route to achieve our objectives is to double down on where the UK has expertise and establish a foothold in the areas of technological advancement and innovation that can secure our position in the global market and supply chain. This means we are focused on compound semiconductors, R&D and design. The government supports the industry across the full spectrum of the semiconductor sector's value chain and will celebrate our sector's successes. But we will seek to accelerate the next generation of new companies and novel innovation, in those areas of greatest focus, going forward.

The UK has a proud history of supporting our innovative companies to grow, from research to spin-outs, early stage commercialisation to international expansion. We have great start-ups in the UK and world-class late-stage companies based here. The government will build on this by focusing on the conditions for companies to start and grow, and addressing key barriers at different stages of the journey from lab to

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[36] McKinsey The semiconductor decade: A trillion-dollar industry - 2022

[37] Imperial College London, Response to BEIS Select Committee Call for Evidence - 2022

market. To unlock the full potential of the semiconductor sector, catalysing future investment, this chapter of the Strategy is focused on activity in three key areas which government has heard from industry contain barriers to progress:

1. ***Research and development:*** We will build on our research excellence by enhancing support for academic and commercial R&D. This will focus on building an ecosystem to enable a strong pull-though from innovative ideas to commercial development that will boost the UK economy, creating the start-ups and spin-outs that will be the industry leaders of tomorrow.

2. ***Infrastructure:*** We will improve access to infrastructure that will reduce barriers and catalyse growth for UK firms, particularly for start-ups and SMEs. This could include improved access to prototyping and piloting facilities and chip design tools and IP, facilitating the journey from lab to fab.

3. ***Skills and talent:*** We are addressing the fundamental challenge that not enough people possess the right technical skills and qualifications to meet the needs of industry. Taking a holistic approach across the whole skills pipeline from STEM education, apprenticeships, industry-led learning and attracting talent is vital to meet the growing needs of the sector.

We are taking action to resolve the specific challenges which semiconductor companies are facing across these areas. But there are broader factors which the wider technology sector faces which also impact semiconductors. For example, semiconductor companies, like other forms of ‘deep technology’, can be seen as a risky investment as they require significant upfront capital to go from concept to proven product. Long returns on investment, due to the time it takes to establish and solidify a product base, mean that it can be challenging to attract the requisite capital to ensure that innovative UK companies commercialise successfully.

The government is looking to holistically address these issues - across sectors. To attract more investment into the UK, we need to create a strong pipeline of start-ups and spin-outs through support for R&D and commercialisation, and providing the conditions to enable more established firms to scale-up. As part of this the Department for Science, Innovation and Technology will review the pre-seed/seed funding opportunities available through UK Research and Innovation (UKRI) and public or private business incubators to support start-ups to launch and grow.

There are also several incentives and schemes that exist for companies with high research and development outlay. These include the Enterprise Investment Scheme and Venture Capital Trust scheme which provide incentives to Knowledge Intensive Companies. Knowledge Intensive Companies are often characterised by high capital requirements and long R&D timescales. For Knowledge Intensive Companies, the incentives include an overall investment limit of £20 million and a limit by which the initial relevant investment must be made (within 10 years of first commercial sale or turnover exceeding £200,000). While the Knowledge Intensive Companies process remains case-by-case, many semiconductor companies may be in scope and therefore benefit from this categorisation.

Like all technology sectors, the semiconductor sector relies on investment from overseas in order to thrive. To further raise awareness of the investment potential in the UK semiconductor sector among international investors, the government will support the work of the Venture Capital Unit and the Office for Investment.

Through the Department for Business and Trade the government supports businesses in attracting the right kind of investment and entering new markets. The Department for Business and Trade has recently expanded its High Potential Opportunities tech programme, to drive foreign direct investment into emerging sub sectors including compound semiconductors. The Department for Business and Trade also has a dedicated Science and Technology Directorate focused on supporting the international expansion of UK companies in the National Science and Technology Council priority technology sectors, including semiconductors. The Department for Business and Trade is also focusing the Digital Trade Network in Taiwan to increase our capability to support semiconductor trade and investment. We will also promote the sector, and put it at the heart of London Tech Week 2023 to bring the sector, government and investors together.

Collaboration is essential to seize the opportunities for the sector. Our UK Semiconductor Advisory Panel will work to ensure that government, academia and industry are all working together to deliver on the priorities set out in the Strategy. Jointly chaired by the Minister for Tech and the Digital Economy and by industry, the Panel will support the implementation of the Strategy by ensuring that government, academia and industry are all working together to deliver on the priorities set out in this Strategy. It will involve the sector in the delivery of our vision and will speak on behalf of the sector to give us advice and feedback.

Over the coming weeks we will work to identify representation across the ecosystem to join the Advisory Panel. We will formally launch the Advisory Panel at London Tech Week in June 2023 as part of our drive to promote the sector as a cornerstone of the digital economy.

7.2 Research and development

The problem

Over the last decade the government has spent hundreds of millions of pounds on academic and industrial R&D, securing the UK's position as an innovation leader in semiconductor design, compound semiconductors and advanced materials. We have identified the areas where the UK has genuinely cutting-edge research to add to the global development of semiconductor technologies. The government has invested, via UKRI and its funding bodies, EPSRC and Innovate UK, into the research base that underpins our world-class innovation in semiconductors, and will continue to do so. This includes both fundamental and applied research and innovation in semiconductor technology, as well as closely related and dependent technologies such as quantum, AI and electric vehicles.

However, most of this work is delivered through open calls where semiconductors compete with other physical science sectors, or through programmes targeted at application verticals such as Driving the Electric Revolution or Commercialising Quantum Technologies.

In order that the UK can continue to hold our strategic position in the semiconductor sector, there is a need for further strategic funding to boost research and innovation in the key horizontal areas identified in this Strategy - chip design, compound semiconductors and next generation technologies such as advanced packaging.

Government Support for Research and Innovation to date

Over the past 10 years through its ICT theme, EPSRC has supported semiconductor research through 498 grants, totalling £539 million. Major EPSRC investments include the National Epitaxy Facility, a collaboration between UK universities to provide advanced production facilities for compound semiconductors for academic researchers and industry. The facility has been operating since 1979, and as of June 2022 has supported £150 million of research across 25 universities[38]. Since 2017, funding from EPSRC and the Science and Technology Facilities Council has also supported over 450 PhD students to begin semiconductor related research. Over the years EPSRC has supported a number of Centres for Doctoral Training. There are currently seven active Centres for Doctoral Training funded that support semiconductor related doctoral research.

The commercialisation of research out of universities and into burgeoning start-ups is supported by the government via Innovate UK. Over the last 10 years, Innovate UK has distributed £214 million of grants directly to SMEs in the semiconductor space alone.

[38] The National Epitaxy Facility, Response to BEIS Committee Call for Evidence - 2022

Direct and indirect support for the semiconductor sector has been provided through Industrial Strategy Challenge Fund challenges, such as: the Driving the Electric Revolution Challenge, investing £80 million in electrification technologies including power electronics, electric machines and drives (PEMD); the Digital Security by Design Challenge and; the £153 million Commercialising Quantum Technologies Challenge which is driving innovation across a range of sectors including automotive, healthcare, infrastructure, telecommunications, cyber security and defence. All these activities have leveraged further industrial investment in excess of the original grant values.

Our solution

The creation of the new Department for Science, Innovation and Technology represents a huge opportunity. The bringing together of a new department that is focused on positioning the UK at the forefront of global scientific and technological advancement will enable us to better build on our strong foundations of world-class research, and more effectively optimise current R&D activity to meet the needs of the semiconductor sector and the aims of this Strategy. As we look ahead, this new department will give the government greater visibility over how R&D investment and activities support the full range of the technology ecosystem, including semiconductors, while contributing to building greater UK expertise in our areas of strategic priority. The UK Semiconductor Advisory Panel will help us to achieve this goal.

Meanwhile, the government will expand targeted support for research and innovation. This will feed the start of the technology cycle and help to provide the training and skills to move the industry forward. Through Innovate UK, who have designated semiconductors as one of several 'Transformative Technologies', and EPSRC, government has committed to activities through to 2025 to support four main categories of research activity:

- ***Design and IP*** - work around the design of processors and other chips, as well as electronic design automation tools.
- ***Front-end manufacturing and fabrication*** - for both silicon and compound semiconductors, and for the use of quantum and photonics.
- ***Back-end manufacturing*** - larger scale fabrication, advanced packaging/heterogeneous integration research, innovation around moving from die/wafer towards 2D/3D structures, creating physical interfaces, building chiplets, and carrying out integration.
- ***System architecture*** - how to build systems with the above technologies.

To do this, we will:

- Invest up to £200 million over the years 2023-25 specifically on interventions to support the UK semiconductor ecosystem.

- As part of this, we will invest in innovation projects to address semiconductor skills shortages. This will enable the creation and subsequent delivery of course content and materials that will support skills, talent and training across semiconductor manufacturing and supply chains. This will build awareness of the opportunities in the semiconductor industry and fill key gaps in the UK's workforce talent and training capabilities. Options span the full suite of the skills lifecycle from engagement in schools, to vocational training and further professional development.

- Encourage the scale-up of businesses in the semiconductor industry with innovative manufacturing capabilities. This will be via collaborative innovation-led research and development projects. All projects are required to identify and deliver a clear, game-changing intervention and address an identified industrial requirement or improvement. This investment provides a long-term commitment to supporting the UK semiconductor industry.

- Invest in emerging semiconductor technology innovation capability, through an open call funded through EPSRC and Innovate UK. This will follow the successful Innovation and Knowledge Centre model and will run over a five year period, being university-based and focused on transferring research in emerging semiconductor technologies into a commercial offering that is accessible to investors. This would support emerging technologies in areas such as:
    - Hybrid and heterogeneous integration
    - Integrated Circuit Design
    - Photonic Integrated Circuits, including photonic logic/switching, on-chip and inter-chip communications
    - Neuromorphic hardware/semiconductors for AI
    - New materials, fabrication techniques and sustainability

- Continue and enhance support for Centres for Doctoral Training in semiconductor related fields, through EPSRC. These Centres for Doctoral Training will produce the next generation of internationally recognised doctoral researchers - researchers who will address key interdisciplinary engineering and physical sciences needs aligned to regional, national and global priorities across academia, industry and other sectors.

- Provide additional tax relief for R&D intensive SMEs. Through the Spring Budget, the Government announced a higher rate of relief for loss-making R&D intensive SMEs will be introduced. SME companies for which qualifying R&D expenditure constitutes at least 40% of total expenditure will be able to claim a higher payable credit rate of 14.5% for qualifying R&D expenditure. A technical note setting out more detail was published alongside the Spring Budget.

7.3 Infrastructure for R&D translation and scale up

The problem

Developing semiconductor technology is highly capital intensive. Difficulty accessing the software tools and manufacturing equipment to design, prototype, pilot and produce innovations is a major barrier to the sector's growth. The government has engaged extensively with industry and sector experts, who have told us that there are four key areas where a lack of UK capability creates barriers to the growth of the sector:

1. **Chip Design Tools & IP**

The structure of the design market can make it difficult for innovative design companies to access the fundamental set of software, tools and IP required to stand a chance of taking their product past the prototyping phase without giving up significant levels of equity, let alone beginning to consider commercialisation.

There is limited choice in who young companies can approach to access these services. The high upfront costs and long negotiations can make it difficult for semiconductor design startups in the UK to launch and thrive, as they may be unable to meet the high capital requirements, or negotiate prices down. This makes the cost of equipment, tools and licences prohibitively high for academia and smaller companies. Helping to reduce this burden will be critical to stimulate greater early-stage innovation and growth in the sector.

2. **Silicon manufacturing for prototyping and piloting**

Many semiconductor startups struggle to access manufacturing facilities to create prototypes of designs to use as proof of concept to attract further investment, or to use for further R&D. There is currently limited fabrication capacity in the UK. And what does exist is largely for older legacy nodes and is often not available for relevant UK chip design firms to use for prototyping. UK startups have to go abroad for prototyping, which can be costly, time consuming and limited in availability. While this will always be required in some instances, greater access to key capabilities within the UK ecosystem could help accelerate innovation and increase discretion in business practices.

3. **Compound open-access manufacturing**

The UK currently has a strong ecosystem developing 'early stage' compound semiconductor technologies, which the government has supported through interventions such as the CSA Catapult. However, a key barrier to the sector's growth is the ability to translate the critical mass of UK industrial and academic innovations into reliable, scalable solutions to meet industry demand. Open-access foundry capability may accelerate commercialisation of compound semiconductor R&D by providing manufacturing capability for companies looking to increase production.

4. **Advanced Packaging**

Packaging is an essential part of the semiconductor supply chain that is usually outsourced internationally. However, as technology develops, greater packaging capability is needed to support the production of new and more advanced chips and to enable small firms to get to market. Innovation in packaging has become a source of improved semiconductor performance and functionality. The UK could, by developing capability in this area, gain a specialism in the next generation of technologies and capture market share.

Heterogeneous integration offers real opportunities and is often referred to as a 'more than Moore' approach as it means performance gains outside of increasing the density of transistors on a wafer.

Developing advanced packaging capability in the UK would allow researchers to experiment with novel techniques and materials for industry, and help SMEs with prototyping designs, including those that integrate die from multiple vendors. This would help the UK to build on its strengths in compound semiconductors, photonics and chip design.

Our solution

Delivering accessible infrastructure to support commercial R&D and SME growth will be an important part of improving the UK's semiconductor ecosystem. This will enable startups to access design software and manufacturing capability in a streamlined, cost effective and agile way to increase the pace of innovation and time to market. That is why to address the sector's industry needs:

- As part of the investment of up to £200 million over the years 2023-25, and up to £1 billion in the next decade we will support R&D in the sector.

- We will launch a UK Semiconductor Infrastructure Initiative to support commercial R&D and SME growth. This is for the creation of a new national institution to bring the sector together and the development of enabling infrastructure for UK start-ups and SMEs. This may include an expansion of the UK's compound 'open foundry' ecosystem, and greater access to chip design tools/IP and prototyping facilities for silicon.

- Without industry involvement, data and evidence we cannot design a potential delivery roadmap toward achieving this. We have therefore commenced detailed scoping with industry partners for the development of a roadmap for the UK Semiconductor Infrastructure Initiative, to determine the longer-term infrastructure requirements for the UK sector. This research is led by the Institute for Manufacturing at Cambridge in collaboration with the Compound Semiconductor Applications Catapult, the Photonics Leadership Group, Silicon Catalyst UK and Techworks. This consortium will look at the model a national initiative could take to have the most positive impact on the industry. This delivery plan will be developed during the remainder of this year.

- We are launching a new UK incubator programme to pilot support for new semiconductor start-ups in the UK over the next two years, and to encourage a more dynamic, commercial ecosystem. The incubator will lower the barriers to growth for new companies in the sector, providing access to design tools and prototyping, business coaching and networking opportunities.

- As highlighted in the Spring Budget, we are launching the Long Term Investment for Technology and Science programme, to support Defined Contribution scheme investment into innovative UK companies. The scheme will provide a key stimulus for industry to create the structures needed to mobilise Defined Contribution scheme investment into our most cutting-edge companies.

- As also detailed in the Spring Budget, we are creating a series of Investment Zones to catalyse knowledge-intensive growth clusters across the UK focused on driving growth. English Investment Zones will have access to interventions worth £80 million over five years and local government and research institutions will be able to tailor their Investment Zone plan to their local circumstances. The Department for Levelling Up, Housing and Communities is working closely with the devolved administrations to establish how Investment Zones in Scotland, Wales and Northern Ireland will be delivered.

- We will announce plans by the autumn to further support the competitiveness of the semiconductor manufacturing sector that is critical to the UK tech ecosystem or the UK's national security.

7.4 Skills and talent

The problem

Skills are a fundamental building block underpinning the semiconductor sector at every stage from research, development, and innovation, through to commercialisation and industrial scale up. However, from our engagement with industry it is clear that the UK needs to do more to sustain and grow the pipeline of talent available to industry so that the sector has the people it needs to scale up.

There is clear demand for skilled people to work in the sector. In a survey carried out by the UK Electronic Skills Foundation, 63% of surveyed employers in the compound semiconductor market have experienced skills shortages[39]. Additionally, over 80% of UK companies with any semiconductor design capability are seeking new engineers, with over 1,000 current vacancies[40].

The government's engagement with industry has highlighted specific problems with skills which are holding back the growth of the UK's domestic sector. First, not enough people are studying STEM subjects related to semiconductor development. UCAS acceptances for UK domiciled students for electrical and electronic engineering courses have seen little change between 2007 and 2020 (2,765 to 3,105; UK domiciled students[41]).

Second, there is a gap between theoretical teaching and practical skills - for some roles, people take more than two years before being able to work unsupervised. An Institute of Physics survey of 91 semiconductor companies with a UK presence, found that 54% said that applicants lacking the required specialist skills or qualifications was among the biggest factors explaining recruitment difficulties[42]. Meanwhile, business and commercial skills can also be in short-supply for researchers and start-ups, with many engineers struggling to navigate complex legal, licensing, and investor environments.

Third, there are shortages at different levels. The semiconductor industry relies on a supply of strong intellectual talent, who tend to be at a postgraduate (doctoral or masters-qualified) level. This is alongside operator and technician level-positions, which can be forgotten[43]. The demand for skills, and addressing potential shortages, is complex and requires vocational studies alongside graduate and post-graduate qualifications.

Fourth, we need to inspire the next generation of semiconductor experts that will drive the growth of tomorrow by promoting physics, engineering and electronics

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39 UKESF - Compound Semiconductor Skills Survey - 2018

40 Joint report from UKESF, TechNES, Silicon Catalyst, TechWorks and IC Resources

41 Higher Education Statistics Agency

42 Institute of Physics skills survey - 2022

43 BEIS Select Committee, The semiconductor industry in the UK - 2022

through STEM programmes. UKRI's STEM Ambassadors delivered half a million volunteering hours last year, encouraging young people from a diverse range of backgrounds to consider a STEM career and reflecting the diversity of local populations. The CREST Awards has recognised project work in STEM subjects for over 30 years, and achievement of CREST Silver has been shown to raise attainment in a young person's best Science GCSE by half a grade.

Finally, in the short term, and to fill this gap in the talent pipeline, UK companies are finding that they are increasingly dependent on foreign talent, which presents a number of challenges in a market with high demand globally. As the sector grows globally, this issue is likely to be exacerbated as competition increases.

Our solution

The government has already recognised the digital skills challenge for the future economy. Having the right skills and talent available to technology sectors can be just as important as the right levels of investment. The government published the Digital Strategy[44] last year, and committed to raise the base level of skills of the next generations to enter the workforce. Consequently, we will maximise the use of existing, acknowledged routes to increase the number of people ready to get well-paid jobs in the semiconductor sector.

As set out in the recently published UK Science and Technology Framework[45], the government is committed to building a pipeline into STEM subjects that are core to future careers in the semiconductor sector - physics, mathematics, engineering and electronics. The Department for Education is developing a Skills Dashboard in 2023 to understand the supply and demand of science and technology skills for the technologies that we plan to prioritise, including semiconductors. Meanwhile, the government is also taking forward the Prime Minister's ambition for all young people to study Maths to 18.

Our approach to skills within this Strategy comes broadly in two parts: first, our investment in schools and teachers, as well as career advice and outreach programmes to inspire the next generation, and to nurture the higher education sector. Second, we will promote industry-led learning to ensure a robust pipeline of talent that meets their needs.

As we increase our pipeline of home-grown talent, we will also ensure the UK is an attractive destination for international talent. The UK Semiconductor Advisory Panel

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44 DCMS, UK's Digital Strategy - 2022

45 DSIT, UK Science and Technology Framework - 2023

will ensure government, academia and industry work together across the sector to achieve this.

These actions will make the UK talent pool stronger and more dynamic, supplying industry across all regions of the UK with the right people to do the job. This will include:

- We are offering a Levelling Up Premium to teachers worth up to £3,000 tax-free each academic year from 2022/23 to 2024/25 in subjects including mathematics and physics that are vital foundations for the semiconductor sector. The funding supports teachers in the first five years of their careers who choose to work in disadvantaged schools, supporting recruitment and retention of specialist teachers in these subjects and in the schools and areas that need them most.

- We are supporting teachers to access training and resources in physics, engineering, electronics and mathematics, subjects critical to the education needed for the future semiconductor workforce. We are expanding the 'Engineers teach Physics' Initial Teacher Training course nationally to 17 providers for the 2022/23 recruitment cycle, enabling more engineers to be trained to teach physics. We will continue to fund the network of Science Learning Partnerships to ensure teachers can access high quality Continuing Professional Development to raise the standard of science teaching.

- We support STEM outreach activities in the semiconductor sector, including connecting industry and local schools to provide a deeper understanding of the opportunities and inspire children to pursue a semiconductor career[46]. UKRI's STEM Ambassador Programme and the CREST Awards are opening up knowledge of careers within the semiconductor sector and wider STEM, as well as ensuring that their achievements in STEM project work are recognised and awarded.

- We are supporting the Apprenticeships Diversity Champions Network, which champions apprenticeships and diversity amongst employers. The Network provides practical suggestions to increase diversity in the workforce, as well as encouraging people from underrepresented groups to consider apprenticeships within STEM.

- We have set up the Unit for Future Skills to improve the quality of data relating to jobs and skills, which will support the government, including the National

[46] STEM Learning, The Impact of STEM Ambassadors - 2021

Science and Technology Council to ensure the skills system responds effectively to the needs of the semiconductor sector as one of the top five priorities. The Unit for Future Skills will improve our understanding of current skill mismatches and future demand throughout the country in the semiconductor sector. And it will also make that data accessible to users including learners, providers, local areas, businesses and researchers.

- We are putting forward the largest increase in government funding for the higher education sector in over a decade to support students and teaching. In 2022, we provided an additional £750 million over the next three financial years (2022-23 to 2024-25) to support high quality teaching and facilities in higher education. This includes engineering, physics, and electronics, boosting the pipeline of talent available to the semiconductor sector. £300 million of this is recurrent Strategic Priorities Grant funding, the majority of which goes to supporting the provision of courses in these and more high-cost subjects.

We are supporting industry-led learning:

- The Department for Science, Innovation and Technology and The Department for Education are working to ensure that occupational standards for apprenticeships, higher technical qualifications and T-Levels meet the specific requirements of employers in the semiconductor sector.

- We are supporting the Institute of Technology programme which has been backed by £300 million of government capital investment. This is an initiative which brings further education providers, universities and employers together to offer higher level technical skills (mainly at levels 4 and 5) in STEM sectors where employer demand is greatest. We are encouraging more employers to engage with Institute of Technology programmes, including those who serve the semiconductor industry, to ensure that the sector's specialisms are better served through this novel education delivery mechanism, which can be a more accessible route into higher technical careers.

- We will support the Digital Skills Council, launched as part of the Digital Strategy that brings together government and industry to drive forward industry led action, addressing industry's current and future demand for digital skills, including semiconductor specific skills.

We are welcoming international talent:

- The GREAT Talent Campaign provides resources to encourage highly-skilled international talent to live and work in the UK on tech. We will continue to promote the UK semiconductor sector through a dedicated campaign web-page.

- We will support the recruitment of talented engineers from across the world, as employers based in the UK can make use of visa schemes such as the High Potential Individual Visa, Scale-Up Visa, and Global Talent Visa, amongst others.

- We will work with international allies - such as Japan, as agreed in the UK-Japan Digital Partnership - to facilitate the mutual exchange of our skilled researchers, academics, students and engineers with international institutions and companies. This will encourage skilled talent from overseas to experience the unique strengths of the UK ecosystem, while also bolstering UK engineer's strengths in new areas of the sector.

8. Our plan to safeguard the UK against supply chain disruption and build supply chain resilience

8.1 The problem

The semiconductor supply chain is complex, concentrated and at risk of disruption. The majority of semiconductors arrive in the UK already integrated in their end-use application, installed in cars, phones and fridges, or as components in pre-prepared modules for manufacturing. This makes it incredibly difficult for UK businesses to understand where issues in their supply chains actually emerge, or take action to prevent them.

These are long-standing challenges. But the sector is currently emerging from a particularly acute period of disruption, which resulted from an unexpected surge in demand for consumer electronics through the early stages of the COVID-19 pandemic, meaning that supplies for other sectors were reduced. The automotive sector felt these challenges particularly acutely. KPMG analysis suggested that it accounted for 80%[47] of the $125 billion estimated lost sales as a result of the shortage (despite only representing 10% of global semiconductor sales). Due to long-lead times and fully allocated capacity for new chip production, this disruption is predicted to last for some industries through 2023.

While the market is historically cyclical and demand is likely to wax and wane at certain points, pressures on the semiconductor sector are not likely to ease in the long-term. Generally, the trend will see demand continue to rise through continued digital innovation. In 2021, the industry experienced a bumper 26.2% increase in sales, reaching a record $556 billion, with the vast majority of this demand coming from consumer products, such as computers and laptops (31.5%) and phones (30.7%)[48].

Over the next decade, a further rise in demand is predicted to be driven by newer applications, including in the automotive industry, data storage and wireless technologies. Market analysis suggests that the industry's aggregate annual growth could average from 6% to 8% a year up to 2030[49], and despite large investments to increase supply, global chip demand is likely to outstrip capacity over the next 10 years[50].

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47 KPMG, Surviving the Silicon Storm - 2021

48 SIA 2022 Factbook

49 McKinsey The semiconductor decade: A trillion-dollar industry - 2022

50 New York Times,Commerce Dept. Survey Uncovers 'Alarming' Chip Shortages - 2022

Alongside these challenges, the manufacture of semiconductors is highly concentrated in East Asia, amid global uncertainty surrounding the area. A key step in the supply chain, this has profound implications for the global economy.

Semiconductor manufacturing is also dependent on the supply of critical minerals. Work ongoing under the UK Critical Minerals Strategy will support end-users of critical minerals, including UK semiconductor manufacturers, to further understand the dependency on critical minerals and promote the resilience of their critical mineral supply chains.

Addressing these issues and building resilience is challenging. The UK does not have a significant share of global silicon semiconductor manufacturing, with a comparatively small number of facilities focused on legacy technologies; although legacy semiconductor technologies do still remain a vitally important part of the global picture, and an integral part of many electronic devices and systems. However, industry and sector experts have made it clear that the UK should pursue alternative opportunities within the sector as opposed to building advanced silicon manufacturing capabilities to rival those in East Asia. They have also made it clear that building such capabilities would not materially build supply chain resilience. The UK will build on our strengths - in design, compound semiconductors and R&D - to retain and expand our vital place in this sector which will help to bolster our position in the global market.

The complexity and variety of semiconductors make it impossible for any country to achieve supply chain autonomy, while also very difficult for any market actor to fully gain sight of the market as there are too many stages in the supply chain. We believe that the best way to build better resilience in supply chains will be through international action. Building international resilience will require a greater geographical spread of manufacturing across the range of semiconductor technologies, as well as improved levels of transparency to allow more flexible market adjustments. This is particularly important as many critical systems depend on older chip technologies, which receive less market and government support. This level of additional resilience can not be achieved quickly. But the international structures necessary to achieve this objective (outlined below) could serve as a mechanism to coordinate mitigations in the event of a future disruption. This would enable the UK to show leadership in next-generation technologies, alongside existing bilateral conversations.

8.2 Our solution

We want to help economic sectors mitigate the impact of supply shortages in the future, including our high-tech manufacturing and infrastructure industries. We also want to take action to protect our critical services (essential services, healthcare, critical national infrastructure and defence) from disruptions that could cause risks to life or national security.

Our plan for improving the UK's supply chain resilience consists of:
- Preparing economic sectors
- Protecting critical sectors: domestic action
- Protecting critical sectors: international co-operation

8.3 Preparing economic sectors

As the shortage during the COVID-19 pandemic demonstrated, there are significant economic impacts from the disruption of chip supply for components used across high-tech sectors, such as automotive and consumer electronics.

It is primarily the responsibility of the companies themselves to take action to improve the resilience of their chip procurement practices and ensure that they have adequate forecasts for their future needs. Industries are already starting to take action and reconsider fragile supply chain practices. These steps are welcome.

However, there are steps that government will take, working in collaboration with industry, to help these important sectors in ensuring that they have access to the chips they need and are better prepared for future shocks. The government will support industry to better understand the risks it faces from future shortages and encourage appropriate mitigations:

- We will publish semiconductor resilience guidance to improve UK SMEs' understanding of the potential risks to semiconductor supply chains, and the steps they can take to better prepare for future disruption and minimise their exposure to risks (including through stockpiling, improving supply chain transparency, and consolidating components to reduce exposure).

- We will establish a government-industry forum and bring together a group to better identify and mitigate supply chain disruptions, to build our collective understanding of what specific sectors are likely to be more vulnerable to shortages.

8.4 Protecting critical sectors: domestic action

There are a range of sectors reliant on products involving semiconductors for running essential services, protecting life and critical functions. This includes healthcare, defence, telecoms, and the rest of our critical national infrastructure.

The semiconductors used across these sectors vary, and measures to shore-up supply chain resilience already exist. But the impact of a severe and prolonged future supply chain shock could be significant. As a result, there is a rationale for the government to take more proactive action to ensure that these sectors are more comprehensively protected against prolonged shocks. As such:

- We will undertake a crisis and contingency planning exercise - drawing in cross-government stakeholders and representatives from critical sectors and the manufacturers that support them - to consider the impacts of future major disruptions, alongside possible mitigations.

- We will work with external suppliers to critical industries, including to the UK's critical national infrastructure, to understand and address risks to their chip supply, encouraging co-operation and transparency to improve resilience.

- We will evaluate the UK's future domestic semiconductor manufacturing needs as part of our commissioned research project reporting in the autumn, to see where a baseline level of manufacturing could provide a low volume of chips for critical infrastructure, recognising that volume manufacturing would be impossible.

- We will work to develop, build and secure a sustainable and assured supply chain of semiconductor components for defence purposes, working closely with the UK's defence industry.

8.5 Protecting critical sectors: international co-operation

Due to the global nature of the supply chain, and the sheer variation of semiconductors needed across every sector, protecting the UK's critical functions and increasing supply chain resilience will require international co-operation. Although the market and some governments are already responding, governments can play a greater role together to address the market failures that leave our critical sectors vulnerable.

We recognise the centrality of manufacturing that is concentrated in East Asia to the UK's interests at a time when, as the Integrated Review sets out, the geopolitical and economic centre of gravity is moving eastward towards the Indo-Pacific. We have tilted with it, as demonstrated through our recent accession to the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP). As part of that tilt, we set out our intention to preserve freedom of navigation through the Indo-Pacific region to ensure continued trade, including for sectors such as semiconductors, and to deepen our co-operation on science and technology with partners in the region.

The Integrated Review also affirmed our deep commitment to multilateralism. As such, the UK will work with partners to lead on developing a new, plurilateral approach to tackle semiconductor resilience that brings together like-minded governments and the semiconductor industry.

We will use our collective influence to improve supply chain resilience for critical sectors. In addition to initiatives that increase capacity, increased resilience will also require measures that look to address the structural issues within the supply chain. Measures to be considered include improving supply chain transparency across the sector, and ensuring government investments provide some protection against significant supply shocks. This is alongside encouraging, and where relevant, requiring, companies across the world (alongside those in the UK) to ensure greater resilience in their supply chains as well as re-prioritising and assuring supply in the event of a severe shocks. As such:

- We will pursue plurilateral co-operation to develop and implement a coordinated approach to supply chain resilience across like-minded nations, including at the G7 in 2023, as a central part of the UK’s broader ambition on issues related to mutually-beneficial trade, shared security and values.

- We will identify the supply chains for critical sectors around the world that are most at risk of being impacted by a semiconductor related supply chain shock.

- We will focus the UK’s Asia Pacific Digital Trade Network – a joint Department for Science, Innovation and Technology and Department for Business and Trade initiative – in Taiwan, to bolster UK capability and expertise in this critical region, raising the profile of the UK’s semiconductor industry and driving trade and investment.

Alongside this, the UK will strengthen our existing bilateral relationships with allies and like-minded governments, including the UK-US Technology Partnership, UK-South Korea agreement on supply chain resilience, and UK-Japan Digital Partnership, embedding core principles of freedom, responsibility, security and resilience in the way we work.

As well as collaborating on tackling supply chain resilience, these partnerships will increase skills co-operation, enhance industry and academia links, and develop joint approaches to research and development. Consequently, we will spend some of the up to £1 billion we have identified for the next decade to support international semiconductor collaboration projects, bolstering our position in the global market.

9. Our plan to protect the UK against security risks arising from semiconductor technologies

9.1 A changing threat landscape

Semiconductors can be associated with a range of national security issues. This Strategy is focused on taking action to protect the country against two particular areas of risk which can be caused by semiconductor technologies:

- The acquisition of sensitive UK semiconductor companies and technologies by hostile states which can then be used to build up the military capabilities of our adversaries.

- An increased vector for cyber attacks if caused by vulnerabilities in semiconductor technologies, whether introduced deliberately or otherwise.

The importance of semiconductors to wider technological progress and military applications means that hostile states are looking to acquire semiconductor technologies to achieve their goals for defence and military advancement. As a critical building block to further technological advances, semiconductor technology can allow other militaries and state actors to fill the gaps to support their future needs. As the UK seeks to secure what it needs to support our military's capabilities, so too do other nations.

The government - particularly through the Ministry of Defence and the National Cyber Security Centre - has long taken action to mitigate the potential vulnerabilities which semiconductors can pose, particularly for use in sensitive systems. The Ministry of Defence, in particular, has a complex network of semiconductor related requirements across a wide range of different types of technology, particularly non-silicon analogue chips.

Semiconductor security is becoming ever more important as the whole economy is becoming increasingly connected. The number of Internet of Things connections worldwide is forecast to increase from 12.2 billion in 2021 to 27 billion in 2025[51]. This means that the security of a larger number of semiconductor devices - increasingly in consumer as well as sensitive applications - are now inextricably linked with protecting the UK's wider national security. This includes mass-market consumer electronics, or business infrastructure beyond critical national infrastructure, security and defence.

[51] IOT Analytics 2022

But the potential for severe disruption through the exploitation of vulnerabilities - accidentally or deliberately introduced into the design and manufacture of semiconductors, particularly processors - has increased. And cyber threats are growing, with cyber attacks increasing by 62% worldwide between 2019 and 2020[52].

In this context, the government is doing the following:

- ***Protecting UK assets:*** Being clearer about how the UK uses its protective levers - such as the National Security and Investment Act and export controls - to protect the most sensitive UK semiconductor companies and technologies.

- ***Building on our hardware strengths to improve cyber security:*** Supporting our expertise in hardware security - by championing UK design standards and innovations across a range of semiconductor technologies - to more widely improve the security credentials of semiconductor devices which are used in both consumer and sensitive systems.

9.2 Protecting UK assets

The UK has a number of levers to protect our most sensitive semiconductor companies and technologies from potential threats which may jeopardise our national security:

- The National Security and Investment Act 2021
- Export Controls
- Research Collaboration Advice Team

National Security and Investment Act 2021

The National Security and Investment Act came into force in January 2022 and grants the government greater powers to intervene in acquisitions and investments into entities and assets where those transactions may pose a national security risk. The Act is actor agnostic and interventions are made on a case-by-case basis. There are 17 sensitive areas of the economy[53], which are considered more likely to give rise to national security risks. Subject to certain criteria, acquisitions in these areas must be notified to the government.

This includes some acquisitions and investments into companies working in the semiconductor sector (those carrying on activities under the ‘computing hardware’ and ‘advanced materials’ definitions specified in The National Security and

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[52] SonicWall Cyber Threat Report

[53] Advanced Materials; Advanced Robotics; Artificial Intelligence; Civil Nuclear; Communications; Computing Hardware; Critical Suppliers to Government; Cryptographic Authentication; Data Infrastructure; Defence; Energy; Military and Dual-Use; Quantum Technologies; Satellite and Space Technologies; Suppliers to the Emergency Services; Synthetic Biology; Transport

Investment Act 2021 (Notifiable Acquisition) (Specification of Qualifying Entities) Regulations 2021). These acquisitions must be notified to - and cleared by - the government before they can take place.

The UK's strength in early-stage R&D means that the potential applications for semiconductor technology can be numerous and hard to predict accurately from inception. So, the government has to use its national security investment screening judiciously at multiple stages of the supply chain, from acquisition of novel research or a university spin-out, to long-established companies.

In the Act's first year, the government made a number of decisions to block or impose conditions on investments into the semiconductor sector and will continue to do so where necessary and proportionate. We have also reviewed a larger number of acquisitions that were subsequently cleared to proceed without conditions.

The government has learned lessons from the Act's first year of operation. We know from industry feedback in relation to the semiconductor sector, that there are changes we can make to be clearer and more transparent about which elements of the sector the government will be most interested in scrutinising. So, where possible, the government will seek to provide greater transparency on our approach, being clear on what we are seeking to protect. The areas of the sector where government has seen particular concerns potentially arising are:

- UK-developed research and technology which is a building block for future applications that could be deployed in ways contrary to UK security interests and values.

- Activity in the compound semiconductor sector; which has use cases both commercially and for defence and security. The UK's relative strength in the sector also means that investments within the sector may be more likely to provide a capability uplift to adversaries.

- We are also, across the supply chain, particularly interested in protecting semiconductor assets which are used explicitly for UK defence purposes.

But we will continue to make decisions on a case by case basis, on the facts and circumstances of the time with national security at the heart of those decisions. Our security toolkit is one that works agnostically across all areas of strategically important sectors. This is right for the UK. National security evolves, and our response evolves with it.

We are also improving the transparency of the Act's operation in relation to semiconductors:

- We will review the scope of Computing Hardware and Advanced Materials definition under The National Security and Investment Act 2021 (Notifiable Acquisition) (Specification of Qualifying Entities) Regulations 2021.

- We will provide updated guidance regarding which elements of the sector we consider to be more sensitive.

Export controls

The UK semiconductor sector is highly reliant on exports, particularly companies working on design and IP. However, exports can present national security risks. Adversaries gaining access to semiconductor technology or its underlying software, IP, employees or related know-how via exports could gain an uplift to their military or security capabilities, now or in the future.

The UK has a robust export control regime in place which provides a framework for addressing exports that pose a security concern. This includes the enhanced Military End-Use Control provisions, introduced in 2022. These allow the government to prevent exports which may be intended for a military end-use in an embargoed destination, even where the item does not currently fall on the list of controlled items. It is essential that firms undertake thorough due diligence into their customers, and manage their communications with customers carefully.

However, while our export control regime provides a robust framework for addressing exports that pose a security concern, there may be a small number of applications where the pace of technological change has outstripped that of the export control regime. The government keeps export controls under continual review and, where the need for change is identified, will carry out assessments to ensure any changes strike an appropriate balance between protecting security and promoting the economic prosperity of the sector. As such:

- Government will work with businesses to assess the export control regime and how it could be expanded for sensitive emerging technologies, including semiconductors.

Research Collaboration Advice Team (RCAT)

The UK has invested into our research base in semiconductor technology and we want to protect that. We recognise that the research stage offers huge potential for new discoveries and innovation that moves us rapidly forward. We recognise also the challenge in understanding national security risks and how they might present themselves in this context.

RCAT is a collaboration between the government and academia which provides research institutions with a first point of contact for official advice about national security risks linked to international research.

RCAT works to make national security advice accessible and digestible for the academic community. RCAT team-members are based in offices around the country and maintain close advisory relationships with the UK's leading research institutions.

- We will continue to support RCAT to provide advice to UK academics working on sensitive areas of semiconductor research.

9.3 Building on our hardware strengths to improve cyber security

Cyber security vulnerabilities that are built into hardware are very hard to fix. This includes vulnerabilities added as a result of imperfect design, and those introduced deliberately by hostile actors. These design vulnerabilities may ultimately be exploited by malicious software to undermine the cyber security of a chip and, therefore, the many critical applications it may enable.

Once a chip design has been sent to be manufactured, it is possible for a hostile actor to tamper with it before it is fabricated into a wafer, opening a security 'backdoor' or causing a deliberate failure in the device. Chips can be compromised when they are being 'packaged', as any functionality added in can change the workings of a chip.

A significant example of these types of vulnerabilities include the Meltdown/Spectre vulnerabilities that impacted microprocessors in January 2018, allowing unprivileged attackers to access data that they should not have been able to access. These vulnerabilities were inadvertently built into processor hardware. While firmware patching and updates did help, ultimately hardware fixes needed to be built into future hardware to fully mitigate the risks. This is difficult, both in terms of time and money, and underlines how important it is to get hardware designed correctly from the beginning.

Although the likelihood of such an attack may be low, the potential impact is significant: if flaws are introduced into enough computers, these 'backdoors' can represent a threat to critical national infrastructure, opening an opportunity to compromise whole networks in a single attack.

Meanwhile, there are limited market factors to push chip designers and manufacturers to improve the security of the chips they create, beyond government mandated regulations and external standards. Discribe reported in 2021 that semiconductor business leaders conclude that hardware security tends to only be prioritised as a result of compliance or regulatory needs, rather than pursued as an independent end-goal[54].

As set out in the National Cyber Strategy[55], the government is committed to working with the stakeholder community to shape the development of global digital technical standards in the priority areas that matter most for upholding our democratic values, ensuring our cyber security, and advancing UK strategic interests through science and technology.

The UK possesses world-leading expertise in hardware security and is already running programmes seeking to raise international standards in hardware design for the benefit of cyber security. The government wants the UK to capitalise on this expertise to ensure that the importance of hardware for cyber security is considered and more widely prioritised at the design stage of chips across the world, as recognised in the National Cyber Strategy[56].

The Product Security and Telecommunications Infrastructure Act 2022 addresses some of these issues. This landmark Act provides Ministers with the ability to specify and amend minimum security requirements in relation to consumer connectable products, ensuring that the mass-market products that we use every day are built and made available to UK consumers with secure design principles in mind. The Act also sets out a series of enforcement measures for when a breach of compliance occurs.

To reduce the risks at the chip-level, the government has invested in the ongoing Digital Security by Design programme led by UKRI, the National Cyber Security Centre and The Department for Science, Innovation and Technology. This programme is collaborating with Arm and others to ensure the memory safety of software without needing to rewrite trillions of lines of existing code, along with the secured compartmentalisation of applications - which together would block cyber-attacks from at least 70% of today's ongoing vulnerabilities. This technology is applicable to all microprocessors and microcontrollers.

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[54] Discribe, Economic and Consumer Chain Analysis of Secure Hardware Adoption - 2021

[55] HMG, National Cyber Strategy - 2022

[56] HMG, National Cyber Strategy - 2022

The programme has achieved strong results to date - including demonstration of the techniques realised in a high-performance Arm-based chip, provided on development boards for companies to test and validate. Although Digital Security by Design has focused on the Arm architecture, we are also supporting the industry with implementations on Intel's x86 architecture and RISC-V and the essential intellectual property to adopt the Digital Security by Design approach is freely available, making it possible to ultimately become a standard feature in all chips worldwide.

Working to fix security issues at the hardware level can also help to mitigate risks associated with software and firmware - a specific kind of software embedded within a device's hardware. For instance, the technology behind Digital Security by Design is hardware-based, but also mitigates software vulnerabilities, either by making them unexploitable or mitigating the impact of any exploitation.

Case study: Digital Security by Design

Digital Security by Design is an initiative supported by the government to transform digital technology and create a more resilient, and secure foundation for a safer future. Through collaboration between academia, industry and government, these new capabilities will pave the way for business and people to better use and trust technology.

The programme stems from the government's Industrial Strategy Challenge Fund. It is a wave 3 programme from the Industrial Strategy Challenge Fund (run by UKRI) bringing £70 million of government funding matched by over £200 million of industry co-investment, including from companies such as Microsoft, Arm, HP and Google. The programme has also received a further £15 million from other government funding sources.

The programme aims to radically update the foundation of the insecure digital computing infrastructure by creating a new, more secure hardware and software ecosystem. Built on new security capabilities, the technologies developed through this programme will underpin future digital products and services. The scope of the challenge includes implementing updated hardware architecture, developing the software and system development tools that will run on it, and demonstrating its application and value in different industry sectors.

The Digital Security by Design programme has already delivered the first hardware implementation of Digital Security by Design technology as a prototype System on Chip and development board, Morello. Developed by UK-based Arm, the Morello board is a real-world test platform for the Morello prototype architecture developed by Arm, based on the University of Cambridge Computer Lab's CHERI protection model. CHERI extends conventional hardware Instruction-Set Architectures with new architectural features to enable fine-grained memory protection and highly scalable software compartmentalisation.

The UK's historic thought leadership in hardware security will stand us in good stead to apply our expertise to future technological advances where cyber security is a concern. Recent advances in the open-standard Instruction-Set Architecture RISC-V, is an area where concern with cyber security must be balanced with the opportunities for emerging semiconductor technologies.

RISC-V offers a great opportunity for users to design chips at low cost and also offers opportunities for wider innovation in microprocessors, given it represents a different way for companies and researchers to access an Instruction Set Architecture to test their designs. Our leadership in R&D allows us to build on this standard. However, because RISC-V is an open standard, there is a risk that it may develop in a way which is not in line with the UK's security values, and that proprietary designs based on the standard may not meet the UK's desired security characteristics.

Case study: RISC-V

RISC-V is an open standard Instruction Set Architecture. An Instruction Set Architecture is the specification that defines the set of instructions that can be used by software running on a computer processor. The design of an Instruction Set Architecture is fundamental to the security of systems built on processors that implement it.

RISC-V is managed by the non-profit, RISC-V International, who manage the definition of the minimal base instruction set and a series of Instruction Set Extensions. As the Instruction Set Architecture and Instruction Set Extensions are publicly available, anyone can produce a processor design that implements the instruction set, royalty free, meaning that RISC-V can be used by academics, hobbyists, and industry.

RISC-V is the world's most successful open-standard Instruction Set Architecture. The two other big closed standards Instruction Set Architectures are ARM and Intel's x86. There are other Instruction Set Architectures available, both closed and open standard, but they tend to be used in a small number of use cases, whereas these 'big three' are used in a wide range of devices.

Although RISC-V is open standard, there is no requirement for its implementations to be open. While there are a range of open-source implementations, there are also a growing range of companies who are creating proprietary RISC-V products and licensing them to the wider market, including in the UK.

To protect against cyber security risks, we will leverage our world-leading status in hardware security for the benefit of the entire technology ecosystem:

- The world leading Product Security and Telecommunications Infrastructure (Product Security) Regime will come into effect in April 2024.

- We will continue to support the future growth of the Digital Security by Design programme. This includes expanding international outreach on the global challenge in delivering semiconductor chips that embed digital security. This will include both working with other governments, as well as international business, to promote the rapid and widest possible uptake of the technology that has been realised through Digital Security by Design, in all chips from Arm as well as other architectures. This support will include encouraging companies to design and use future technology in keeping with Digital Security by Design principles and deliver digital security by design across our entire digital world.

- We will convene security experts across government, academia and business, in 2023, to identify areas of further government support into improving security through hardware.

- We will ensure international conversations related to semiconductors concentrate on issues of hardware supporting security. We will focus on assuring the security of mass-market manufacturing and ensure that chips manufactured for sensitive use-cases can also be trusted. The UK will continue to advocate for security 'by design' principles in these discussions, given the difficulty with assuring all products manufactured across the disparate semiconductor supply chain.

- We will support the UK's strengths in RISC-V, in a manner which also ensures the technology grows with security in mind. This support will include engagement with experts across government, industry, and academia and could include:
    - Targeted academic research programmes
    - Forming a UK community of interest for industry and academia involved in RISC-V development.

Part three: Next steps

This Strategy sets out a clear vision for the next 20 years, which will be delivered by a focus from the government on three guiding priorities: growing the UK sector, improving supply chain resilience, and assuring the UK's security.

Strategies will always evolve with time and changing circumstances. This is why achieving our vision will require an ongoing, committed, coordinated and holistic partnership between government, industry and academia to develop the UK's capabilities within the semiconductor sector for the first time in decades.

The government can only realise these goals through close collaboration and co-operation with industry, and a range of other relevant stakeholders. This is why our approach is rooted in working together with the sector, academia and international partners to achieve our vision. Our delivery of the game-changing UK Infrastructure Initiative will rely on continued collaboration and the government will provide further updates in due course as we take forward the results of the initial research study once it is completed in autumn 2023.

The UK Semiconductor Advisory Panel grants us a clear mechanism to ensure delivery against our objectives. We will officially convene and launch the Advisory Panel in June 2023, coinciding with London Tech Week where semiconductor technology will feature as part of government's commitment to promote and support the sector.

Meanwhile, we will continue to prioritise the domestic and international action required to improve our supply chain resilience in respect of semiconductors. And the government will provide further updates on the increased market guidance and transparency we wish to give the sector on our use of protective security levers such as the National Security and Investment Act in due course.

The table below provides a summary of all the actions which we are taking through this Strategy. But we remain open for feedback, consultation and challenge. If any interested parties wish to provide views, we encourage you to contact: semiconductorstrategy@dsit.gov.uk

10. Summary of actions the government is taking

Our vision: Over the next 20 years, the UK will secure areas of world leading strength in the semiconductor technologies of the future by focusing on our strengths in R&D, design and IP, and compound semiconductors. This will facilitate technological innovation, boost growth and job creation, bolster our international position in order to improve supply chain resilience, and protect our security.		
Area of focus	**Action**	**Short (6-month), medium (6-12 month) or long-term (12 months +)**
Grow the UK sector		
R&D	Support innovation projects to address semiconductor skills shortages.	Short-medium
	Encourage the scale-up of businesses in the semiconductor industry with innovative manufacturing capability. This will be via collaborative innovation-led research and development projects.	Short-medium
	Continue and enhance support for Centres for Doctoral Training in semiconductor related fields, through EPSRC. These Centres for Doctoral Training will produce the next generation of internationally recognised doctoral researchers.	Short-medium
Infrastructure for R&D translation and scale up	Launch the UK Semiconductor Infrastructure Initiative. The initiative will consider options to support commercial R&D and SME growth through the development of enabling infrastructure, such as expansion of the UK's compound 'open foundry' ecosystem, and greater access to chip design tools/IP and prototyping facilities for silicon. We have commenced detailed scoping with industry partners for this initiative. This research is led by the Institute for Manufacturing at Cambridge in collaboration with the Compound Semiconductor Applications Catapult, the Photonics Leadership Group, Silicon Catalyst UK and Techworks. This delivery plan will be developed during the remainder	Long

	of this year.	
	Launch a pilot of a new UK incubator programme to support new semiconductor start-ups in the UK and to encourage a more dynamic, commercial ecosystem. The incubator will lower the barriers to growth for new companies in the sector, providing access to design tools and prototyping, business coaching and networking.	Short
	We will announce plans by the autumn to further support the competitiveness of the semiconductor manufacturing sector that is critical to the UK tech ecosystem or the UK's national security.	Medium
Skills and talent	Offer a Levelling Up Premium to teachers worth up to £3,000 tax-free each academic year from 2022/23 to 2024/25 in subjects including mathematics and physics that are vital foundations for the semiconductor sector.	Short-medium
	Expanding the 'Engineers teach Physics' Initial Teacher Training course nationally to 17 providers for the 2022/23 recruitment cycle.	Short
	Continue to fund the network of Science Learning Partnerships to ensure teachers can access high quality Continuing Professional Development to raise the standard of science teaching.	Short
	Support STEM outreach activities in the semiconductor sector, including connecting industry and local schools to provide a deeper understanding of the opportunities and inspire children to pursue a semiconductor career.	Short-medium
	Support the Apprenticeships Diversity Champions Network, which champions apprenticeships and diversity amongst employers.	Ongoing

	We have set up the Unit for Future Skills to improve the quality of data relating to jobs and skills, which will support the government, including the National Science and Technology Council to ensure the skills system responds effectively to the needs of the semiconductor sector as one of the top five priorities.	Ongoing
	Investing an additional £750 million over the next three financial years (22/23-24/25) to support high quality teaching and facilities in higher education, including engineering, physics and electronics.	Long
	Ensure that occupational standards for apprenticeships, higher technical qualifications and T-Levels meet the specific requirements of employers in the semiconductor sector.	Medium-long
	Continue to support the Institute of Technology programme and encourage more semiconductor employers to engage with the programme.	Medium
	Support the Digital Skills Council in considering more semiconductor specific skills.	Short-medium
	Launch a semiconductor campaign page as part of the Great Talent Campaign.	Short
	Support the recruitment of engineers across the world through use of the High Potential Individual Visa, Scale-Up Visa and Global Talent Visa.	Ongoing
	Facilitate the mutual exchange of our skilled researchers, academics, students and engineers with our international allies such as Japan, as per the UK-Japan Digital Partnership.	Medium-long
Safeguarding the UK against supply chain disruption		

Preparing economic sectors	Publish semiconductor resilience guidance to improve sectors' existing understanding of the potential risks to semiconductor supply chains and the steps they can take to better prepare for future disruption and minimise their exposure to risks	Short-medium
	Establish a government-industry forum to better identify and mitigate supply chain disruptions. We will improve our collective understanding of specific sectors more likely to be more vulnerable to shortages.	Short-medium
Protecting critical sectors: domestic action	Undertake a crisis and contingency planning exercise - drawing in cross-government stakeholders and representatives from critical sectors and the manufacturers that support them - to consider the impacts of future major disruptions, alongside possible mitigations	Short-medium
	We will work with external suppliers to critical industries, including to the UK's Critical National Infrastructure, to understand and address risks to their chip supply, encouraging co-operation and transparency to improve resilience.	Medium
	Evaluate the UK's future domestic semiconductor manufacturing needs as part of our commissioned research project reporting in the Autumn, to see where a baseline level of manufacturing could provide a low volume of chips for critical infrastructure, recognising that volume manufacturing would be impossible.	Medium
	Work to develop, build and secure a sustainable and assured supply chain of semiconductor components for defence purposes, working closely with the UK's defence industry.	Medium
Protecting critical sectors:	Pursue plurilateral co-operation to develop and implement a coordinated approach to supply chain resilience across like-minded nations, including at G7 in 2023.	Short-medium

international action	Identify the supply chains for critical sectors around the world that are most at risk of being impacted by a semiconductor related supply chain shock.	Medium-long
	Focus the UK's Asia Pacific Digital Trade Network – a joint Department for Science, Innovation and Technology and Department for Business and Trade initiative – in Taiwan, to bolster UK capability and expertise in this critical region, raising the profile of the UK's semiconductor industry and driving trade and investment.	Medium-long
	Strengthen our existing bilateral relationships with allies and like-minded governments, including the UK-US Technology Partnership, UK-South Korea agreement on supply chain resilience, and UK-Japan Digital Partnership.	Ongoing
Protecting the UK against security risks arising from semiconductor technologies		
Protecting UK assets	Review the scope of Computing Hardware and Advanced Materials definition under The National Security and Investment Act 2021 (Notifiable Acquisition) (Specification of Qualifying Entities) Regulations 2021.	Medium
	Provide updated guidance regarding which elements of the sector we consider to be more sensitive.	Medium
	Work with business to assess the export control regime and how it could be expanded for sensitive emerging technologies, including semiconductors.	Medium
	Continue to support RCAT to provide advice to UK academics working on sensitive areas of semiconductor research.	Medium
Building on our hardware	The world leading Product Security and Telecommunications Infrastructure (Product Security) Regime will come into effect in April 2024.	Short

strengths to improve cyber security	Continue to support the future growth of the Digital Security by Design programme. This will include expanding international outreach and support for Digital Security by Design internationally.	Ongoing
	Convene security experts across government, academia and business in 2023, to identify areas of further government support into improving security through hardware.	Short
	Ensure international conversations related to semiconductors concentrate on issues of hardware supporting security.	Ongoing
	Support the UK's strengths in RISC-V, in a manner which also ensures the technology grows with security in mind. This will include engagement with experts across government, industry, and academia and could include targeted academic research programmes and forming a UK community of interest for industry and academia involved in RISC-V development.	Medium

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