Royal Academy of Engineering

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

Critical technologies: past and future

Introduction

Governments can play a pivotal role in supporting the advancement of critical technologies. Government interventions increasingly need to be agile and responsive to keep pace with a rapidly evolving global technology landscape. The effective identification and prioritisation of critical technologies can be an important tool in promoting economic growth, societal well-being, national security and achieving long-term sustainability goals. This paper examines the UK government's previous approaches to technology prioritisation over the last decade and explores potential avenues for future prioritisation efforts.

A factual overview of previous technology prioritisation initiatives made by the UK government since 2013 is provided. These initiatives encompass various industrial and innovation strategies, missions, and challenge-driven approaches in which the support of technologies and sectors has been carried out. Each major phase of technology strategy in the UK over the last decade is summarised with details of the criteria employed for technology selection and the mechanisms of support implemented. This analysis identifies key trends and observations in the changing support for these technologies and provides a retrospective lay of the land for future strategies.

The paper also provides insights for what the future of technology prioritisation could look like in the UK, drawn from a roundtable on critical technologies, hosted by the Royal Academy of Engineering in collaboration with the Foundation for Science and Technology (FST). The key themes from the roundtable discussions are summarised along with a set of guiding principles for effective technology prioritisation.

By examining both past efforts and future opportunities, this paper aims to contribute to an informed and strategic approach to technology policy in the UK.

Technology prioritisation – a decade in review

The history of prioritisation in technologies and sectors by the UK Government since 2013 is outlined in this section.

Key strategies and subsequent changes in priorities over the last decade are summarised along with the processes by which these technologies and sectors have been identified. A visual representation of trends in choices is presented in Figure 1. The rationale behind these choices and examples of interventions for each technology/sector are outlined in Table 1.

The analysis interrogates technology prioritisation rather than sector prioritisation, although the distinction can sometimes be unclear. Similarly, the types of interventions a government may choose to make can have conceptual challenges. Missions and challenges are relatively well defined, but not all government interventions are neatly categorised, as they may seek to 'create an environment for a technology to flourish' or wish to secure 'strategic capabilities'. Box 1 sets out the most common definitions.

Over the last decade various industrial and innovation strategies have identified priority technologies, sectors, challenges, and missions to deliver prosperity and security to the UK, as well as wider benefits to global society. The UK ranks highly in the research and development (R&D) of emerging technologies and commercial opportunities for R&D outputs span a wide variety of sectors. The methods used to identify these technologies have fluctuated over the years, but the three primary criteria of historical research strength, comparative advantage, and commercial viability, have remained constant. Once identified, the government plays an important role in providing support for R&D and easing the risk on businesses as they innovate and grow.

Box 1: Definitions

Technology

Technology is broadly defined as the application of scientific knowledge for practical purposes and is therefore closely associated with engineering. Technologies can have niche or broad application in industry. Technologies from which other technologies or processes are built are often referred to as platform technologies.

Sectors

Sectors normally refer to industry sectors, where the sectors produce a closely related set of raw materials, goods or services. There are well-defined industry classifications that account for areas of economic activity that are used for national and international accounting purposes, however these can be critiqued for not keeping pace with new industry areas of economic activity. Examples of sectors include automotive, aerospace and life sciences. It is possible for technologies to become established areas of industry activity and therefore transitions to a 'sector' over time.

Missions / Grand Challenges

Represent significant societal issues that need addressing and that can be used as overarching goals by research and innovation (R&I) and policy organisations. Missions frequently require addressing complex coordination problems or applying whole systems approaches. Typically, they have many interacting causes and solutions that go beyond the support for individual technologies, requiring social and behavioural transformation to affect change. Examples include achieving net zero, healthy ageing and food security.

Challenges

Segment an overarching Mission/Grand Challenge into distinct programmes, each targeting a particular aspect of the problem. These programs pursue concrete goals, representing practical steps toward addressing a Mission/ Grand Challenge and providing a framework for individual projects. These can include R&D funding activities in specific technology areas as a method of incentivising breakthrough solutions.

Strategic capabilities

Strategic capabilities can be defined as capabilities a nation wishes to have as future dependence on non-allied sources of supply carries unacceptable risks to national interests. The own-collaborate-access framework, proposed in the Integrated Review of Security, Defence, Development and Foreign Policy, is a framework to guide government activity to identify and secure strategic capabilities.

The Eight Great Technologies

In 2013, the Minister of State for Universities and Science, David Willetts and the Department of Business, Innovation & Skills launched the strategy to support Eight Great Technologies:[1]

- **Big Data and Energy-Efficient Computing**
- **Satellites and Commercial Applications of Space**
- **Robotics and Autonomous Systems**
- **Synthetic Biology**
- **Regenerative Medicine**
- **Agri-Science**
- **Advanced Materials**
- **Energy and its Storage**

The identification process for the Eight Great drew on advice from across the research community, the Technology Strategy Board (now Innovate UK) and from several technology foresight exercises. These exercises included the Government Office for Science's 2010 Technology Innovation Futures report,[2] the 2010 Emerging Technologies and Industries Strategy[3] and advice from the Research Councils on long-term investment in science infrastructure published in 2012.[4] There were three main criteria for shortlisting:

i) the technologies needed to represent a significant scientific advancement;
ii) the UK had to have distinctive capability (comparative advantage); and
iii) there had to be clearly identifiable commercial opportunities emerging.

In 2023, David Willetts published 'The Eight Great Technologies 10 years on' for Policy Exchange, reflecting on how well the list had fared in the 10 years since their identification and subsequent support.[5] The paper highlighted the overall relevance of many of the technologies to this day and provided evidence for key success areas, ranging from the UK's leading artificial intelligence (AI) research to the continued growth of the life sciences sector.

Model of Ariel scientific research space satellite above Earth. Photo: Alamy

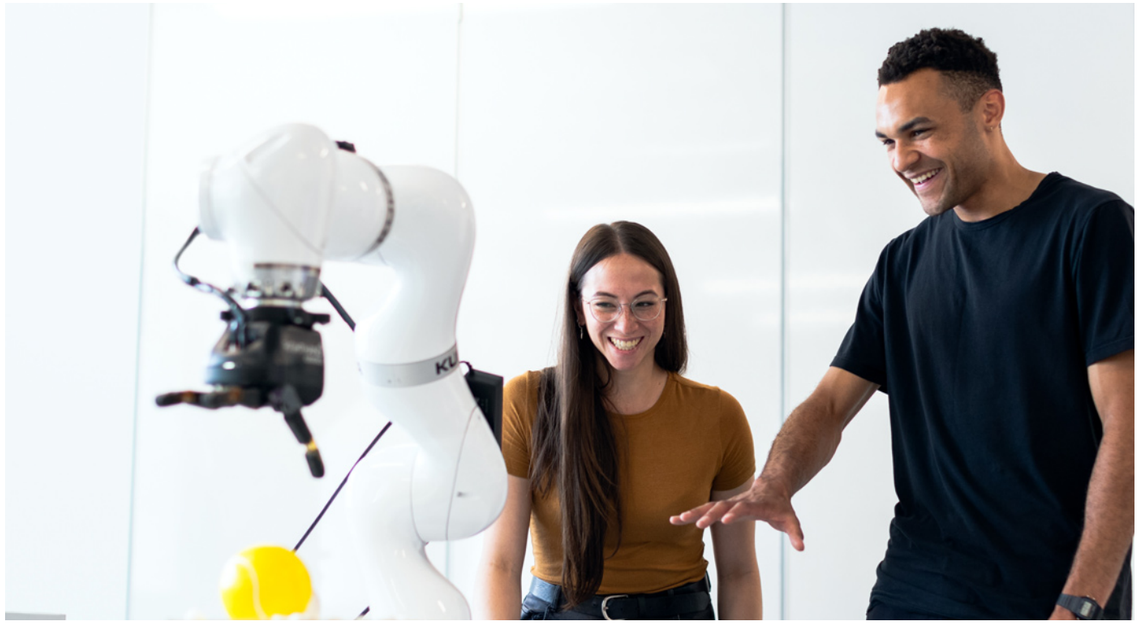
Industrial Strategy and the Grand Challenges

Following the Eight Great, in 2016, the Secretary of State at the Department for Business, Energy & Industrial Strategy Greg Clark led the implementation of the Industrial Strategy and four Grand Challenges (2016-2019).[6] **This new model prioritised addressing broad national challenges:**

- **AI and Data**
- **Clean Growth**
- **The Future of Mobility**
- **An Ageing Society**

The challenges were supported through the Industrial Strategy Challenge Fund (ISCF) and the newly created UK Research and Innovation (UKRI) bringing together the Research Councils, Innovate UK, and Research England. The Industrial Strategy saw a move away from the support of specific technologies towards seeking to meet challenges with broad support and investment in key sectors like the life sciences and automotive industries. However, more specific technologies, innovation areas and projects were supported through the ISCF, with some funds continuing support for those technologies originally identified in the Eight Great:

- Driverless Cars
- Batteries
- Early Diagnosis and Precision Medicine
- Healthy Ageing
- Manufacturing and Future Materials
- National Satellite Test Facility
- Prospering from the Energy Revolution
- Robots for a Safer World
- Transforming Food Production



Engineers work with medical robotic equipment. Photo: © This is Engineering

UK Innovation Strategy

In 2021, the Secretary of State at the Department of Business, Energy and Industrial Strategy Kwasi Kwarteng and the UK Innovation Strategy identified seven key technology families:[7]

- **Advanced Materials and Manufacturing**
- **AI, Digital and Advanced Computing**
- **Bioinformatics and Genomics**
- **Engineering Biology**
- **Electronics, Photonics and Quantum**
- **Energy and Environment Technologies**
- **Robotics and Smart Machines**

The identification process involved two independent analytical ranking and prioritisation exercises. The first identified leading UK technology families that showed large global market opportunities over the next decade, had strong UK academic and industrial interest, deliver societal benefits, and have clear added value from public investment in the technology.[8] The second identified potential UK comparative advantage in technologies by ranking them in R&D funding and R&D outputs, assessing UK market commercialisation and using UK business activity and venture capital trends.[9]

This second process initially identified a longlist of 300 emerging individual technologies by scoring them against funding figures, number of patents published, Technology Readiness Levels (TRLs), time for impact, among others.

The individual technologies were prioritised in a cross-government department process using weightings and then aggregated into 37 broader technologies.

The top 25 emerging technologies were ranked for research strength by evenly weighting the following metrics: public funding, research outputs,[10] private funding [11] and innovation outputs.[12] The top 10 emerging technologies were then ranked for business capability by weighting the following metrics in a 40:30:30 split: companies,[13] equity volume [14] and equity deals.[15] The prioritised 25 emerging technologies were then grouped into the seven technology families.

Genomics: Samples being prepared for a clinical trail.
Photo: Alamy

National security

In addition to the UK Innovation Strategy and the seven technology families, 2021 saw the prioritisation of technologies and sectors for national security reasons, with the publication of two key industrial strategy policy papers from the Cabinet Office.

The Integrated Review of Security, Defence, Development and Foreign Policy [16] identified the importance of sustaining 'strategic advantage through science and technology'. It outlined a vision for the incorporation of S&T into national security and international policy with aims of securing the status of the UK as a 'Science and Tech Superpower' by 2030.

The paper highlighted the need to establish a leading role in critical and emerging technologies where there is a realistic prospect of delivering strategic advantage, citing case studies in quantum computing, engineering biology and AI. Additionally, the National Security and Investment Act [17] summarised 17 areas of the economy that are deemed sensitive to the UK's national security.

The act allows the government to scrutinise and intervene in acquisitions of certain entities in these areas. The 17 areas of the economy are:

- **Advanced Materials**
- **Advanced Robotics**
- **AI**
- **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**

The mine warfare trials vessel APOLLO leaving harbour. The craft will test unmanned technology for military applications.
Photo: Alamy

Science and Technology Framework

The Science and Technology Framework,[18] published in 2023 following the formation of the Department for Science Innovation and Technology (DSIT), outlined five critical technologies:

- **AI**
- **Engineering Biology**
- **Future Telecommunications**
- **Semiconductors**
- **Quantum Technologies**

This list was developed based on a technology foresight exercise that assessed over 50 technologies against eight criteria: sustainable environment, health and life sciences, digital economy, national security and defence, international comparison, foundational, market potential, threats, and resilience.

The announcement of the five critical technologies, follows on from the ex-Chancellor of the Exchequer Jeremy Hunt and HM Treasury outlining a long-term vision for economic growth driven by five targeted growth sectors in January 2023. The key growth sectors were:

- Digital Technology
- Green Industries
- Life Sciences
- Advanced Manufacturing
- Creative Industries

Life Sciences Building, Southampton, UK. Photo: Alamy

Trends and observations

The support for sectors vs. individual technologies has been varied over the last 10 years. In 2013, the Eight Great took steps to prioritise specific technologies while the Industrial Strategy of 2017 saw more broad sector deals supported by the Grand Challenges in areas like the bioeconomy (clean growth) and the automotive sector (future of mobility). Several of the seven technology families in the 2021 UK Innovation Strategy are arguably broad enough to be considered as whole sectors, including manufacturing, computing, and electronics.

Throughout these changes to technology prioritisation and strategies over the last decade, we can observe several key enduring technologies/sectors that have remained in favour throughout. Figure 1 depicts these changes, with support for areas such as AI, data and digital technologies being present in all strategies.

Throughout the changes to technology prioritisation over the last decade, areas such as AI, data and digital technologies have been present in all strategies.

Continued support for the life sciences sector is observed particularly in engineering biology but also in the areas of bioinformatics, genomics and the ageing society Grand Challenge.

Space and satellite technologies and agricultural sciences have not been revived since the Eight Great, but areas such as robotics and advanced materials have only recently been omitted with DSIT's 2023 five critical technologies.

The other notable recent change is the absence of clean growth or energy technologies from the UK Science and Technology Framework, which have been present to some degree since 2013, although green industries are still captured in the 2023 five economic growth areas.

Newer entries for technology prioritisation include electronics, semiconductors, quantum technologies and future telecommunications.

Figure 1 and Table 1 summarise this changing landscape of technology prioritisation in the UK over the last decade.

Looking to the future

The last decade has demonstrated that changes in government often result in the reprioritisation of technologies and sectors.

On 4 July 2024, the general election culminated in a change in leadership and a majority Labour government. Through the Labour Party's 2023 Manifesto [19] and the King's Speech 2024 [20] the government has promised a mission-driven industrial strategy [21] with support for automotive, life sciences, manufacturing, clean energy and creative industries. The government plans to establish an Industrial Strategy Council with a statutory footing aiming to give more certainty to the R&D ecosystem, provide expert advice and help ensure the allocation of longer-term funding for R&D institutions. The new Industrial Strategy is to be supported by five missions: [22]

- Secure the highest sustained growth in the G7
- Make Britain a clean energy superpower
- Build an NHS fit for the future
- Make Britain's streets safe
- Break down the barriers to opportunity at every stage

At the time of writing, the extent to which critical technologies will have a role in achieving the Industrial Strategy and the five missions is yet to be established.

On 8 July 2024, the Royal Academy of Engineering in collaboration with the Foundation for Science and Technology (FST) convened a roundtable on the topic of critical technologies. The roundtable invited science, engineering and technology leaders from academia, industry, government and the investment community to discuss critical technologies and strategies for their prioritisation going forward. It is hoped that the key themes from the discussions outlined below can provide important considerations for the government in its future technology prioritisation efforts. The themes are summarised in a set of principles of technology prioritisation. The four principles cover several key themes including clear objective setting, government and industry collaboration, prioritising national security and resilience, employing an effective technology analysis procedure, the importance of international comparison and building a robust technology ecosystem.

The extent to which critical technologies will have a role in achieving the Industrial Strategy and the five missions is yet to be established.

Principles of technology prioritisation

Purpose

Clear objectives are crucial for achieving the intended outcomes of technology prioritisation. Distinct objectives demand distinct strategies and, depending on the technology involved, variable strategies may be required to achieve the same objective. Both a joined-up approach between government departments and industry collaboration is required to set and meet these objectives. Objectives should be communicated effectively to all stakeholders along with the appropriate implementation strategies and timelines.

Security

Technology prioritisation should be used to achieve both economic advantage and national security. National security and resilience concerns should become integral drivers in the technology prioritisation process, with technologies that provide improvements in sovereign capability weighted appropriately despite lower commercial opportunity. Government intervention and the maintaining of critical supply chains can help to support sovereign capability technologies.

Analysis

A high degree of granular analysis is required during the technology prioritisation process with extensive stakeholder engagement, collaboration from industry and cross-government input. For both economic and security objectives, international comparison should play a key role in the analysis procedure, with areas of comparative advantage being identified and incorporated effectively.

Ecosystem

A robust and inclusive technology ecosystem is required for critical technologies to develop. Addressing issues such as R&D funding, the de-risking of capital investment, talent and skills availability, and support for new and existing infrastructure, will bolster the growth of critical technologies.

Key themes for technology prioritisation

Clarity of purpose and a joined-up approach

In any technology prioritistion exercise, it is critical that there is a well communicated clarity of purpose of the prioritisation.

The objectives of prioritsation need to be made clear, both to those undertaking the prioritisation and to the various stakeholders involved, particularly industry partners. This will help guarantee that a given technology prioritisation has the desired impact, finds key points of convergence, secures stakeholder buy-in and reaches the intended organisations, people and places.

The prioritisation of technologies can be used to accomplish a variety of different objectives. Objectives for prioritisation can seek to achieve progress in the following areas: comparative advantage, national security, economic benefit, job creation, public services, national resilience and sustainability. The objectives identified might overlap or be opposed. Different objectives typically need different approaches for implementation, and even where there is an overlapping objective it will likely need different approaches depending on the technology being used to achieve it. Policy levers for implementation and an appropriate timescale for delivery should therefore be outlined for each objective.

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Prioritisation of technologies can help improve public services. Photo: Alamy

Security, resilience and international comparison

The UK must identify and prioritise technologies that are essential for its national security and resilience, even if these don't offer significant commercial advantage.

There should be a clear set of objectives for the support of these technologies that further the UK in achieving its national security and sovereign capability goals. Work in the area of national security should follow on from the Integrated Review of Security, Defence, Development and Foreign Policy.[23]

National resilience and the concept of 'securonomics' highlight the importance of maintaining critical supply chains within the UK and government intervention is required for building national resilience through sovereign capabilities. Improvements in the resilience of energy supplies and critical minerals in the UK are becoming increasingly important. The prioritisation of critical technologies provides an opportunity to be strategic in addressing these key national resilience areas.

The UK government's Science and Innovation Network (SIN) needs to strengthen its efforts to reflect better the UK's strategic priorities. While SIN has contributed positively to countries in which they are based, a recalibration is needed to identify and address gaps in their approach to ensure that it is fully aligned with the UK's strategy and can input to technology prioritisation.

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Laying an LNG pipeline running from Milford Haven to England. Photo: Alamy

An effective analysis procedure

Technology prioritisation necessitates a rigorous research and analysis procedure, but the information to be analysed and the weighting of the findings will fluctuate depending on the objectives of technology prioritisation.

Granular analysis is required to determine how technologies can contribute to achieving the identified strategic objectives. Such a granular analysis can be resource intensive, particularly for reaching a fine level of detail. Businesses have become increasingly adept at doing granular analysis and the UK government could learn from their methods and approaches through collaboration with industrial partners. In addition to the importance of industry and government collaboration, more cross-government working is required during the prioritisation exercises.

The technology analysis procedure itself must be effective, rigorous and strictly aligned with the objectives of prioritisation. It is important that the analysis and particularly the weighting of different technologies is considered carefully so that no procedural bias is introduced. Ultimately, this relates to the overall selection process in which a balance is required between selecting narrowly useful and broadly useful technologies to ensure that key areas, such as sustainable/green technologies, are considered.

An effective analysis procedure should be undertaken with detailed consideration of international competition and collaboration, assessing how other countries and stakeholders are competing to occupy technology spaces. The UK does not operate in isolation; it is fundamental to monitor and understand the actions of international stakeholders and identify areas of economic or security-related comparative advantage. The UK is vulnerable to falling behind in science and technology intelligence gathering and would benefit from improving its sovereign capabilities in this area.

Granular analysis can contribute to achieving identified strategic objectives. Photo: Alamy

Analysis

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Building a robust technology ecosystem

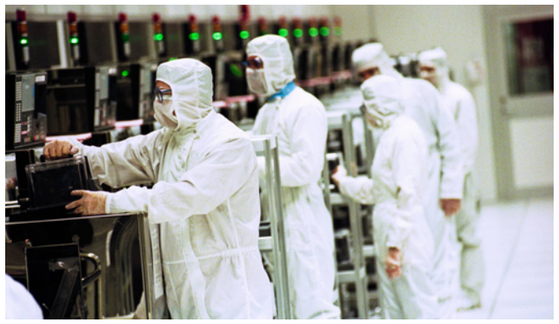
Beyond prioritisation efforts, it is essential to develop a robust and inclusive ecosystem for technology to develop.

This ecosystem should provide favourable conditions for emerging and yet-to-be-developed technologies to thrive and preserve space for curiosity-driven research. In developing the technology ecosystem, it should be recognised that some technologies can serve as 'centres of gravity' to attract value and foster innovation independently (e.g. semiconductor industry). It is also important to ensure that the UK's technology ecosystem is match-fit for the rate at which technologies are developing.

A cross-government approach is essential for developing a robust technology ecosystem that drives economic growth, supports national capabilities and addresses market failure. The five Missions and an Industrial Strategy could facilitate coordination and support a cross-cutting approach for prioritising certain aligned critical technologies. This can include early-stage investment, implementing reforms (such as Mansion House Reforms), de-risking investment opportunities and acting as an early adopter of new technologies through government procurement. It is also important to address potential chokepoints in the technology supply chain (e.g. critical materials) and ensure that manufacturing capability is in place.

Enhancing the skills base through targeted training and improved visa policies is also crucial. The UK has a strong science base; however, the higher education sector is currently in a fragile state with difficulties in retaining research capabilities, particularly in critical subjects such as chemistry and engineering. These areas require more intensive support to produce a well-trained and sustainable workforce.

Building new, and supporting existing, infrastructure are important for a resilient ecosystem and for nurturing emerging technologies. Infrastructure that cuts across several technologies and sectors can provide broad benefits and good value for investment. There are success stories of regional infrastructure hubs that have contributed to strong ecosystems in areas such as photonics in Scotland.



Semi conductor silicon wafer foundry South Wales UK. Photo: Alamy

Ecosystem

A robust and inclusive technology ecosystem is required for critical technologies to develop. Addressing issues such as R&D funding, the de-risking of capital investment, talent and skills availability, and support for new and existing infrastructure, will bolster the growth of critical technologies.

Technologies to consider in future prioritisation efforts

There is no right or wrong choice in the prioritisation of critical technologies. The purpose of the roundtable was not to identify a single set of priority technologies. Insights from the roundtable highlighted several technologies and sectors deemed significant and worthy of consideration in future prioritisaion exercises. These insights are summarised below.

- **Sustainable engineering/technology (green tech) is a key area to include in prioritisation efforts as it can drive economic growth without depleting resources.**
- **Neurotechnology is a field with significant long-term disruptive potential and should be considered as an important component of the future technology landscape.**
- **Robotics is a foundational technology that warrants renewed prioritisation. The prioritisation of robotics aligns with recent government support for AI technologies. Importantly, AI is now not just a critical technology but its own sector in the UK. The narrative around AI and how it is used should be adjusted where necessary. AI should also be seen as a multidisciplinary and cross cutting tool for achieving objectives.**
- **Defence related technologies including Position, Navigation and Timing (PNT) technologies, Radio Frequency (RF) technologies and nuclear applications should be considered for their key role in sovereign capabilities and national security.**

The technology analysis and identification process has varied over the years. However, the overall criteria required for the identification of technologies has largely remained the same and includes historical research strength, comparative advantage and commercial viability.

Irrespective of the final decision, an effective analysis procedure is required, and the choice of technology must be supported with clear objectives for delivery.

The chosen technologies should be supported to achieve economic and national security advantage alongside the required improvements to the UK's technology ecosystem.

Robotics engineer with agricultural robots. Photo: © This is Engineering

Figure 1: Summary of changing trends in priority technologies choices in the UK since 2013.

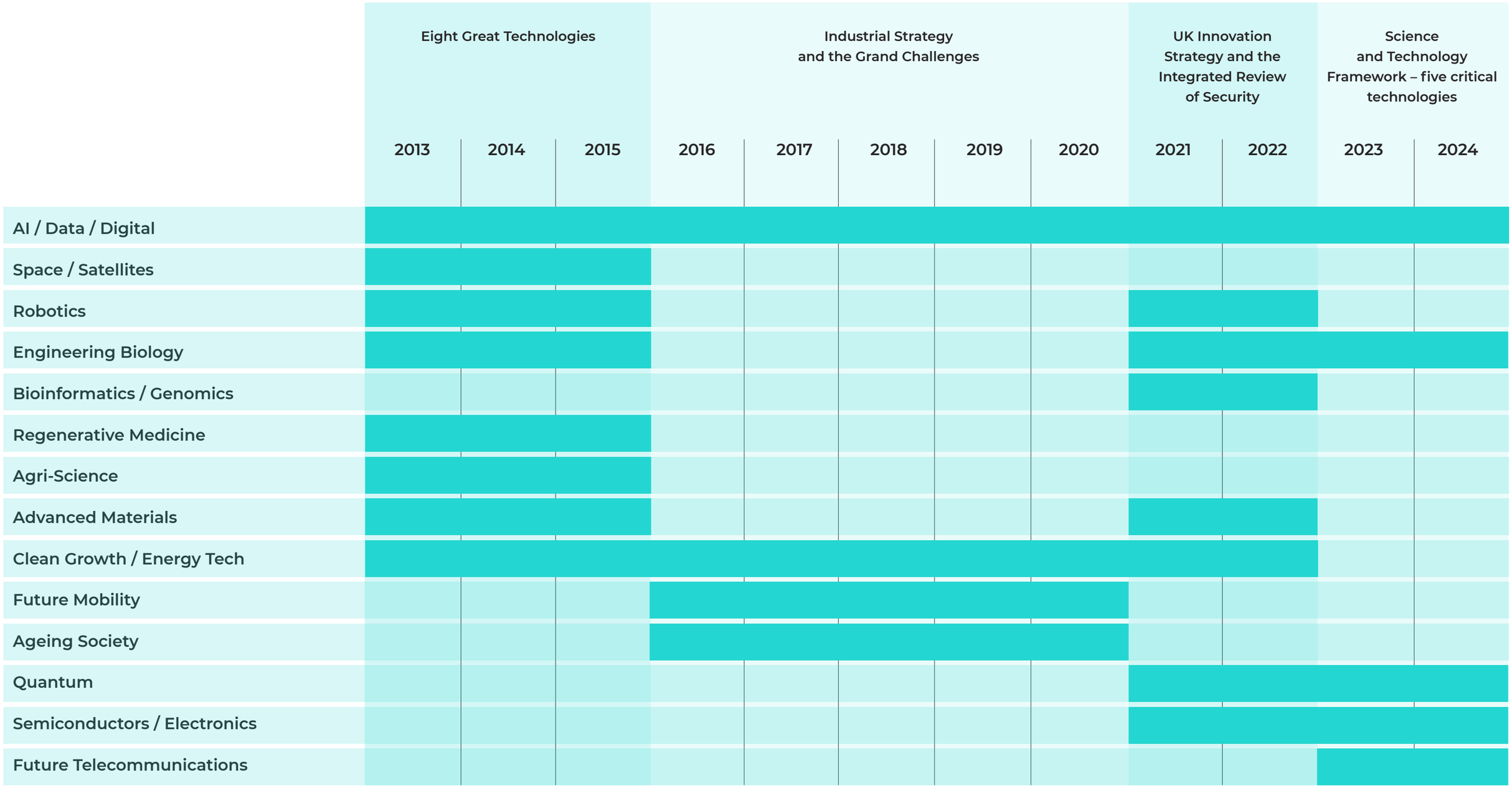


Table 1: Summary of each phase of industrial or innovation strategy in which priority technologies, sectors or challenges were chosen in the UK since 2013.

The intervention examples shown are initiatives or funding announcements provided by the UK Government that are specific to supporting the relevant technology, sector, or challenge. Broader or 'horizontal' policy interventions are not included.

Technologies, sectors, and challenges with significant overlap between strategies are colour coded:

- AI / Data / Digital
- Engineering Biology / Genomics / Bioinformatics
- Clean Growth / Energy Technologies
- Robotics
- Advanced Materials
- Electronics / Semiconductors / Quantum Technology

2013: Eight Great Technologies

Tech / Sector / Challenge	Rationale for choice	Intervention examples
Big Data	• Comparative advantage in IT was associated with research strengths in algorithms, mathematics and computer science. • The UK has one of the most complete datasets in healthcare, demographics, agriculture and the environment. • The growing life sciences sector was also producing a huge amount of data (genomics especially). • The UK funds and is host to the European Bioinformatics Institute outside Cambridge. • Home to big companies like ARM and IBM.	• £150 million allocated for e-infrastructure in 2011-12. • £189 million in allocated for big data and energy-efficient computing. • £23.5 million for an ESRC-led birth cohort study.
Space / Satellites	• Comparative advantage in satellites, in new launch technologies and in industry structure. • Specialism in small satellites. • Surrey Satellites Technologies (roughly 40% of the world's small satellites come from Guildford).	• £10 million National Space Technology Programme launched in 2011, attracting £17 million in matched funding. With an additional £25 million dedicated to expanding the programme.
Robotics and Autonomous Systems	• Comparative advantage in fully autonomous systems associated with research strengths in algorithms for autonomous systems and large data flows. • Specific advantage in marine robotics, medical robotics and nuclear decommissioning.	• £35 million allocated for centres of excellence in and around universities.
Synthetic Biology	• The strong life sciences sector in the UK. • The pharmaceutical industry is responsible for almost 30% of all business R&D in the UK.	• £90 million from the Research Councils and the Technology Strategy Board (TSB) for research and commercialisation. • £50 million to implement the UK Synthetic Biology Roadmap. • £38 million allocated for a National Biologics Industry Innovation Centre.

2013: Eight Great Technologies

Tech /Sector /Challenge	Rationale for choice	Intervention examples
Regenerative Medicine	• 2011 gov report: 'Taking Stock of Regenerative Medicine in the UK' confirmed the UK as having a leading position in the science and commercial translation of regenerative medicine. • The legislative and regulatory framework in the UK is also set up well for emerging technologies in this area. • World class research in centres such as Edinburgh, Cambridge, Leeds, and London. The Medical Research Council is funding centres for clinical grade stem cell lines at Manchester, Sheffield and King's College, London.	• £25 million for the UK Regenerative Medicine Platform from the Research Councils and the TSB. • £75 million for translational research from the Research Councils and the TSB. • £25 million allocated for the UK Regenerative Medicine Platform. • £50 million confirmed for a Cell Therapy Catapult Centre at Guy's Hospital in London.
Agri-Science	• UK has strong research strength ins agricultural research with historic collections of data and samples as well has an extensive university research base. • Food production accounts for 7% of national manufacturing output. • There are significant opportunities in the areas of efficient indoor farming and GM crops.	• £250 million allocated to transform the Pirbright Institute of Animal Health and the Babraham and Norwich research park. • £30 million allocated for BBSRC's world-leading agri-science campuses.
Advanced Materials	• The UK has a strong reputation in materials science, as well as industrial strengths in advanced materials. • Other areas of key strengths include high-performance metals, biomaterials, materials for renewable and nuclear energy, plastic electronics and composites. • UK businesses that produce and process materials have a turnover of around £170 billion pa, represent 15% of the country's GDP and have exports valued at £50 billion. • Materials innovation is crucial for many business sectors such as aerospace and the automotive sector. • Advanced materials will be required for the green energy transition, with most renewable energy technologies requiring advanced materials.	• £28 million expansion of the National Composites Centre. • £45 million for new facilities and equipment in areas of UK strength (advanced composites, high-performance alloys, low-energy electronics and telecommunications, materials for energy, nanomaterials for health).
Energy Storage	• Strong university research strength in nuclear energy R&D with centres of excellence funded by Research Councils and the Technology Strategy Board. • The UK has research strength in small modular nuclear reactors. • UK is leading research into alternative energy storage technologies as well as research into improvements in battery capacity, safety and cost. • Greater capability to store electricity is crucial for alternative power sources to be viable in contribution to the Grid.	• £30 million to create dedicated facilities to develop and test new grid-scale storage technologies. • £65 million allocated for buildings, joint facilities and infrastructure.

2017: Industrial Strategy Grand Challenges

Tech /Sector /Challenge	Rationale for choice	Intervention examples
AI and Data Economy	• AI projected to produce thousands of good quality jobs and drive economic growth. • The UK is already a world leader in AI, with the building blocks to make significant advances. • The UK has a research strength with some of the best research institutions in the world. • The UK has globally recognised capability in AI-related disciplines, including maths, computer science, ethics and linguistics. • The UK has substantial datasets in public institutions where AI can be explored safely and securely. • Strong industrial strengths in the underpinning technologies with companies like ARM for chips and Raspberry Pi in microcomputers.	• Industrial Strategy Challenge Fund used to develop innovative used of AI. • £10 million Regulators' Pioneer Fund to support UK regulators to develop innovative approaches to emerging technologies. • £45 million announced to support additional PhDs in AI and related disciplines, increasing numbers by at least 200 extra places a year by 2020-21. • £406 million allocated for investing in maths, digital and technical skills in England. Includes investing £84 million over the next five years to deliver a comprehensive programme to improve the teaching of computing and drive-up participation in computer science.
Clean Growth	• The UK has had a lead role in the global move towards clean growth. • The UK has a strong presence in smart energy systems and the bioeconomy. • The UK is one of the most successful countries at growing the economy while reducing emissions. • The UK has comparative advantage in EV manufacturing, offshore wind, smart energy systems, sustainable construction, precision agriculture and green finance.	• Publication of the Clean Growth Strategy 2017. • £162 million committed to innovation for low carbon industry and developing a new strategy for the bioeconomy. • Setting up of a Green Finance Taskforce. • £20 million to support a new clean technology early-stage investment fund. • £841 million of public funds for investing in innovation in low carbon transport technology and fuels. • Support innovative energy technologies and processes with £14 million of investment through the Energy Entrepreneurs Fund.
Future of Mobility	• The UK has research strengths in AI and complex vehicle engineering. • Long history of transport innovation. • UK devolution is leading to new ways of addressing transport needs in towns and cities. • The UK is well placed to deal with urbanisation challenges – it has the highest population living in urban areas in the OECD.	• £400 million Charging Infrastructure Investment Fund (£200 million from the government to be matched by private investors); £100 million new funding for the plugin car grant; £40 million R&D funding (matched by industry) for new charging technologies including on-street and wireless projects. • Future of mobility: urban strategy report published. • Investing £5 million in 5G applications and deployment on roads. • £90 million of funding as part of the Transforming Cities Fund. • £1 billion Advanced Propulsion Centre and the £246 million Faraday Battery Challenge.
Ageing Society	• There is a developing global market for innovative age-related products and services. • Innovation in this space could lead to substantial improvements on productivity and personal health in the UK. • Increasing health and social care costs, as well as increased caregiving responsibilities for individuals in the workforce, are major economic challenges associated with ageing.	• Industrial Strategy 'Data to early diagnostics and precision medicine' programme initiated. • £98 million of investment through the Healthy Ageing Industrial Strategy Challenge Fund. • Part-funded the new National Innovation Centre for Ageing in Newcastle. • £130m of investment to support healthcare innovation, including £69.5 million through UKRI's Strategic Priorities Fund to unlock new treatments that allow people to lead healthier and longer lives.

2021: UK Innovation Strategy – seven technology families

Tech/Sector/Challenge	Rationale for choice	Intervention examples
Advanced Materials and Manufacturing	• The UK has strong research strengths in materials science. • UK industry is leading in developing new technologies and processes for the manufacture of materials like metals, polymers and ceramics. As well as finished components and systems for medical, energy and the aerospace sector. • Collaboration between universities and industry is also strong. Examples include the Advanced Manufacturing Research Centre in Sheffield, Warwick Manufacturing Group in the Midlands and the Royce Institute in Manchester. • There is an opportunity space in sustainable design of materials that could drive growth in the UK's advanced manufacturing sector.	• £258 million investment in advanced materials made over five years. • UK Strategic Advantage in Advanced Materials report published. • Advanced materials centre of excellence announced. £42.5 million research partnership lead by The Henry Royce Institute. • National Materials Innovation Strategy.
AI, Digital and Advanced Computing	• AI research and commercialisation is growing at a rapid rate in the UK and could account for a large share of GDP by 2030. • Private investment in UK AI companies continues to rise, currently reaching $1.3 billion.	• Publication of the National AI Strategy 2021. • £1 billion AI sector deal to boost the UK's global position as a leader in developing AI technologies.
Bioinformatics and Genomics	• The UK life sciences sector contributes £14.5 billion PA to UK GDP. • The UK is recognised as the third largest bio cluster in the world, with the genomics sector accounting for 10% of the global market. • The wider UK bioeconomy is estimated to support over 5 million jobs and has a GVA of £220 billion.	• Genome UK strategy published in 2020. • NHS genomics strategy published in 2022. • Cancer 2.0 programme – a £26 million innovative cancer programme to evaluate cutting-edge genomic sequencing technology.
Engineering Biology	• The UK is a world-leader in engineering biology. • There are opportunities in areas such as CRISPR, mRNA, biological modelling and simulation, microfluidics etc., that the UK is well placed to exploit with strong research backing.	• £200 million invested through the British Business Bank's Life Sciences Investment Programme in order to target the growth-stage funding gap. • National Engineering Biology Programme.

2021: UK Innovation Strategy – seven technology families

Tech/Sector/Challenge	Rationale for choice	Intervention examples
Electronics, Photonics and Quantum	• The UK has a strong research base in the design of semiconductors with potential to grown in semiconductor chips and technologies. • Growth in this area could capitalise on increased global demand and support domestic sectors such as health, telecoms and automotive. • Established clusters in Wales, Bristol and Cambridge could play an important role in global supply chains. • The UK is a global leader in photonics, exporting over 30% of Europe's photonics supplies and contributing £14.5 billion to the UK economy in 2020. • There is growing investment in the UK through the National Quantum Technologies Programme (NQTP)	• Continue funding through the National Quantum Technologies Programme (NQTP), which will reach £1 billion by 2024. • Investment in the semiconductor cluster in South Wales, through EPSRC and UKRI, the Compound Semiconductor Applications Catapult and the Welsh Government. • Prosperity Partnerships announced to establish business-led research projects with £59 million of industry, university and government investment.
Energy and Environment Technologies	• The UK has strong research strength in areas such as lithium-ion batteries and solar cell photovoltaics such as advanced perovskite technologies. • The UK is also a leader in nuclear technologies like advanced modular reactors and fusion energy technologies – for example the recent advances in use of the 'tokamak' fusion reactor. • The UK low carbon and renewable energy economy was worth £46.7 billion in 2018 and employed 224,800 people. These have been forecast to rise significantly in the coming years.	• UK Net Zero Strategy first published in 2021. • £1 billion Net Zero Innovation Portfolio fund to accelerate the commercialisation of low-carbon technologies, systems and business models in power, buildings, and industry. • UK Net Zero Research and Innovation Framework focusing on six research and innovation challenges: Power, industry and low carbon hydrogen supply, carbon capture and greenhouse gas removal, heat and buildings, transport and natural resources, waste and F-gases.
Robotics and Smart Machines	• Based on current adoption trends, the total economic impact of RAS uptake is estimated at around £6.4 billion by 2035.	• Robotics Growth Partnership – to set out its vision for Robotics and Smart Machines, and the supporting of cyber-physical infrastructure.

2023: UK Science and Technology Framework – five critical technologies

Tech /Sector /Challenge	Rationale for choice	Intervention examples
AI	• Based on current adoption trends, the total economic impact of RAS uptake is estimated at around £6.4 billion by 2035.	• Robotics Growth Partnership – to set out its vision for Robotics and Smart Machines, and the supporting of cyber-physical infrastructure.
Engineering Biology	• The UK has a strong life sciences sector. • The UK is a global leader in engineering biology. • However, there are signs of a tipping point approaching and heavy investment is now required in the scale up of existing infrastructure and skills. • Strategic investment is also needed to incentivise more business finance to help focus growth at higher technology readiness levels.	• £650 million package for the life sciences sector. • £520 million invested in life sciences manufacturing. • National vision for engineering biology. £2 billion committed over the next ten years.
Future Telecommunications	• The UK Wireless Infrastructure Strategy is required to build a more secure and prosperous future. • Improvements will grow the economy and create better-paid jobs across the whole of the UK. • Better connectivity is seen as a driving force for UK businesses. • Widespread adoption of 5G could see £159 billion in productivity benefits by 2035.	• UK Wireless Infrastructure Strategy. Including £150 million for UK 5G and 6G innovation. • £75 million to boost 4G in Scotland. • UKRI Technology Missions Fund. Including £70 million for advancing next-gen telecommunications.
Semiconductors	• The UK has research and development strengths in compound semiconductors, IP and chip design. • The area of semiconductors is targeted to facilitate technological innovation, boost growth and job creation, bolster the UK's international position in order to improve supply chain resilience, and improve security. • Growth in this area will have positive knock-on impact in areas such as AI, quantum computing and telecommunications.	• National Semiconductor Strategy. £1 billion committed over a ten-year period. • Expert panel appointed for semiconductors to support semiconductor strategy. • ChipStart UK launched. £1.3 million incubator pilot programme for early-stage companies involved in the design of semiconductors.
Quantum Technologies	• The UK is a global leader in quantum technologies. • £1 billion has been invested through the National Quantum Technologies Programme running since 2014. • Comparative advantage in quantum is sought after for improvements in productivity, economic growth, health, sustainability and national security and resilience. • The UK risks being left behind on the global stage as other countries are investing heavily in quantum. • The UK ranks second in the world for number of quantum companies and for attracting private investment. • The UK has industrial strength key quantum supply chain areas such as photonics, electronics and cryogenics. These include the semiconductor cluster in South Wales and the photonics cluster in Scotland. • Collaboration within the UK quantum community is very strong.	• National Quantum Strategy launched. £2.5 billion committed over a ten-year period. • Five Quantum Missions launched. • £70 million invested through the UKRI Technology Missions Fund over 2023-2026 to develop quantum computing and positioning, navigation, and timing technologies.

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