FEBRUARY 2023
JEEGAR KAKKAD
BENEDICT MACON-COONEY
JESS NORTHEND
JAMES PHILLIPS
NITARSHAN RAJKUMAR
LUKE STANLEY
TOM WESTGARTH

A New National Purpose: Innovation Can Power the *Future of Britain*

A joint report by Tony Blair and William Hague

TONY BLAIR INSTITUTE FOR GLOBAL CHANGE

Contents

Idea in Brief

Our Future of Britain project seeks to reinvigorate progressive politics to meet the challenges the country faces in the decades ahead. Our experts and thought leaders are setting out a bold, optimistic policy agenda.

01

Executive Summary

Science and technology have been the driving force of progress for much of our modern age. Our accomplishments have allowed us to live longer, healthier lives, to travel across the world and into space, and to generate food and energy at scale.

The United Kingdom has been at the forefront of many of these breakthroughs and was home to one of humanity's great leaps: the Industrial Revolution. Another revolution is now taking place as developments in artificial intelligence (AI), biotech, climate tech and other fields begin to change our economic and social systems.

Of course, as with the Industrial Revolution, this 21st-century technological revolution carries dangers as well as opportunities.

The challenge for policymakers is to mitigate the former and fully embrace the latter. But this requires a fundamental re-ordering of our priorities and the way the state itself functions.

The UK is starting with real strengths in many areas of emerging technology. It also has assets in its universities and in its private sector that offer significant advantages.

However, as we show in this report, without radical change, we risk decline. We cannot afford to fall behind.

The future of Britain will depend on a new age of invention and innovation. Technological superpowers such as the United States and China are investing heavily in their futures, raising the possibility that everyone else will be trapped behind these two forces – a risk the European Union is belatedly recognising and acting upon.

Britain must find its niche in this new world. To do so requires a radical new policy agenda, with science and technology at its core, that transcends the fray of 20th-century political ideology.

In turn, this requires a fundamental reshaping of the state, from how government itself works to how public services are delivered.

This new “strategic state” needs to embrace the technological revolution.

The private sector is already doing so. Individuals are already doing so. Across the board, the costs of electronic goods and software have been driven down, information has become abundant, and we can access entertainment, book travel or connect with friends and family almost instantly.

Government and public services, on the other hand, face costs increasing, service slowing and the public’s frustration building.

The starting point, then, is to ask how government can harness the benefits of this revolution for our country and use data and technology to drive down the cost of public services while improving outcomes.

The speed of the Covid response – particularly the development and deployment of new vaccines – shows what can happen when the government and the private sector mobilise effectively behind a clear purpose. We need to bring the same laser focus to the agenda we set out here.

Over the long run, a successful British state will likely be smaller in scope but more effective in its delivery. In practical terms, achieving this entails a series of reforms, including:

- **A reorganisation of the centre of government** to drive this science and technology agenda across government and public services, with the full weight of the prime minister's authority behind it and, at the core, the skill set to ensure its effective implementation.

- **Building foundational AI-era infrastructure.** This should include:

    - Government-led development of sovereign general-purpose AI systems, enabled by the required supercomputing capabilities, to underpin broad swaths of public-service delivery.

    - A national health infrastructure that brings together interoperable data platforms into a world-leading system that is able to bring down ever-increasing costs through operational efficiencies.

    - A secure, privacy-preserving digital ID for citizens that allows them to quickly interact with government services, while also providing the state with the ability to better target support.

    - A shift in the government's approach to data, so that it treats them as a competitive asset that can be used to drive down the cost of delivery and build high-value data sets, such as in the biomedical field.

- **Creating an Advanced Procurement Agency (APA)** with a specialised mandate to find opportunities for public-sector innovation, procure promising solutions and manage their deployment and testing.

- **Incentivising pensions consolidation** and **encouraging growth equity** by making the pension capital-gains tax exemption applicable only to funds with over £20 billion under management that allocate a minimum percentage of their funds to UK assets; and combining the UK Pension Protection Fund (PPF) and the National Employment Savings Trust (NEST) to create a single investment vehicle that participates in market consolidation.

- **Reforming technology transfer offices (TTOs)** to encourage more university spinouts.

- **Increasing public research and development (R&D) investment** to make the UK a leader among comparable nations within five years, coupled with reforms to the way our institutions of science, research and innovation are funded and regulated to give more freedom and better incentives.

- **Investing in new models of organising science and technology research,** including greatly expanding the Advanced Research and Invention Agency (ARIA), and creating innovative **laboratories that seed new industries** by working at the intersection of cutting-edge science and engineering.

- **Pursuing broader planning reforms** to ensure infrastructure projects that are critical to the UK's economic transformation can get approval in six months or less, while also creating exemptions and fast-track processes for R&D infrastructure planning.

- **Mainstreaming new technologies in education** to build the skills of the future and develop a workforce capable of rolling out technological advances. This should include a new edtech-training fund to improve teachers' confidence and incentives to adopt innovation as part of learning.

- **Building stronger global partnerships** to avoid being trapped behind the tech superpowers of the US and China. This should include seeking to establish a new informal "T3" coalition between the UK, EU and US to find areas of common ground on global technology standards, enable associate membership of EU research programmes including Horizon, Copernicus and Euratom, and taking leadership of multilateral research initiatives on AI.

With science and technology as our new national purpose, we can innovate rather than stagnate in the face of increasing technological change. This purpose must rise above political differences to achieve a new cross-party consensus that can survive any change of government.

02

A New National Purpose

One of the biggest events in human history started in the UK: the Industrial Revolution.[1] In little more than 200 years, the majority of the world went from extreme poverty to a life of relative material abundance. Some consequences of this shift took generations to distil, but ultimately it transformed almost every part of life in our country. Electricity, aeroplanes, telephones, antibiotics and much more all became mainstream in a single lifetime.

Today, another revolution is underway: one whose consequences will dwarf those of the revolution that built the modern economy. We are now living through a shift to a new age of technological capabilities and their nexus with science. The exponential growth, dictated by Moore's law, that drove the computing revolution is now occurring in other technology domains.

In slightly more than 20 years, the cost of sequencing a full human genome has decreased from $100 million to $100 today,[2] with the potential to forge new frontiers for scientific research, disease diagnosis and preventative treatments at scale. The price of electricity from solar declined by 89 per cent in a single decade (from 2009 to 2019), with renewables accounting for 75 per cent of all new capacity additions worldwide in 2021. Lithium-ion batteries have also seen a similar cost reduction, having declined in price by 97 per cent since 1991.

AI is emerging as a transformative technology that has the potential to radically change economic models, the way businesses are organised and, in turn, how our society functions. It stands poised to transform every industry from education, health care and transport to space exploration and beyond. Progress continues to intensify – the computing power needed to train the most capable AI models has grown by a factor of 10 billion since 2010, and is doubling every five to six months.[3]

With all technologies it is hard to predict the future: the debate around automation a few years ago focused on the potential replacement of factory workers, but countries such as the UK and the US now face manufacturing-labour shortages. With generative AI, fears have now shifted towards its speculated impact on art, music and knowledge workers. This is understandable. At any given juncture any new scientific or technological advances will lead to concerns about society's ability to adapt and the possible friction that the process will cause.

This is rightly an area that requires political leadership, and the provision of support for those most affected by economic shifts. But this must not lead to stasis. The UK has a long track record of invention that extends beyond the Industrial Revolution well into the 20th century, from Bernard Lovell's radio telescope at Jodrell Bank and the RAF's Frank Whittle's development of the jet engine to Robert Edwards's pioneering work on IVF, changing the outlook for families around the world. We now need to be home to the next generation of discovery.

The Technologies Changing the World

Technology companies have defined the past quarter century. Digital giants now surpass countries in terms of their R&D budgets; Amazon spent more than $40 billion on R&D in 2020 alone – approximately double the UK's public annual R&D budget. Companies such as Moderna and Tesla grew fast and redefined their industries, while others such as the Taiwan Semiconductor Manufacturing Company quietly became the engines of the 21st-century economy.

The nations that have made the greatest progress are those that have adopted and adapted to technology. In the US, where software has been most readily developed and adopted, wealth is now in a different order to that of the UK's while Ireland has surpassed us in terms of economic output. California, which has a population equivalent to 60 per cent of the UK's, boasts some of the biggest tech companies in the world and has an economy that is now larger than our own and close to surpassing Germany's.[4] This effectively makes it the world's fourth-largest economy.

Over the coming decades, there will be further acceleration as technological innovation increases. And if the atoms, bits and cells[5] are the foundations of the modern world, three innovations in particular will shape the future: AI, biotech and climate tech. These will be essential to grasp, but others such as space, materials science, quantum and robotics will also be critical – as will others we do not know of yet.

Artificial Intelligence

The promise of AI is to capture and recreate the essence of humanity's most powerful tools – language, creativity, reasoning and intelligence. Current approaches are based on deep learning, a subset of machine learning strongly inspired by the wiring of our own brains but one that, in practice, still produces alien forms of intelligence that we do not fully understand yet.

These advances are finally living up to decades of ambition to collectively become an epoch-defining development. As a general-purpose technology, AI has the potential to make an unprecedented impact that will exceed those of the steam engine and electricity combined during the industrial revolutions. These previous revolutions focused on the harnessing of energy to mechanise physical labour, but our current revolution is the first in history to automate cognition itself.

AI's Potential Impact

Progress is happening at breakneck speed, with the practical impact of AI almost entirely contained to the past ten years, especially since 2019. Breakthroughs over the past few months alone, such as OpenAI's ChatGPT and Stability AI's Stable Diffusion, provide the means for empowering human creativity and productivity in language and art as never before. ChatGPT became the fastest-growing consumer app in history, achieving 100 million users in two months.[6] Advances such as Alphabet-subsidiary DeepMind's AlphaFold are being leveraged to reduce drug-discovery time for cancer from years to just under 30 days.[7] In the words of Matt Clifford, co-founder of Entrepreneur First and Chair of the Advanced Research and Invention Agency (ARIA), we now have "infinite AI interns for everybody", while research from MIT suggests that widespread adoption of AI tools in R&D could triple productivity-growth rates.[8]

The early effects of this disruption are already being felt in education and the creative industries. ChatGPT is able to pass many graduate-level exams and write convincing essays, demolishing standard modes of assessment at a time when educators are already under significant strain.[9] Stable Diffusion has democratised creative expression and the ability to produce world-class art, albeit by training its tool using the work of talented artists who believe their intellectual-property (IP) rights have not been recognised sufficiently.[10] Sudden shocks such as these will continue to occur across fields.

International Standing

The UK has a strong reputation in AI. This is centred around our leading educational institutions in combination with the UK-founded DeepMind's ambition of "solving intelligence, to advance science and benefit humanity". We have a vibrant startup ecosystem that applies AI to strategic domains as well, including firms such as Oxford-based Exscientia, which is operating at the forefront of drug discovery, and Bristol-based Graphcore, which could provide the UK with sovereign capabilities in AI chip design. London-based Stability AI has recently emerged as a disruptive innovator in open-source generative AI, catalysing non-traditional online communities to work on large-scale scientific projects while releasing transformative AI tools for free for general public use.

However, we need to move fast to retain our competitiveness and strategic advantages in this rapidly progressing field.

FIGURE 1

The aggregate computing power of the TOP500 supercomputers in the world, grouped by country

Source: TOP500, November 2022

The US and China are the other powerhouses of this revolution, with more than half the world's public supercomputing power and the highest number of papers published on AI between them.[11] By contrast, the UK contributes only 1.3 per cent to the aggregate computing power of the Top 500 supercomputers, less than Finland and Italy, and was the only leading nation to record a decline in AI publications last year. DeepMind has an outsized global influence in research at AI's frontier, but our universities are otherwise merely comparable to those in other medium-sized states in terms of research output and quality, rather than being genuinely world-leading.

As progress increasingly depends on a blend of engineering and scientific excellence, similar to the "big-science" approaches of other fields such as high-energy physics, disparate academic groups are unable to compete at the frontier of AI without centralisation and access to world-class engineering and computing resources, as well as the billions of pounds in funding needed. As a result, we face an "AI brain drain" of researchers leaving or entirely avoiding academia to instead enjoy significantly better compensation, resources and intellectual environments in the US or at US-owned companies.[12] The siloing of frontier-AI talent and development in these corporations means that the future is already here yet it remains largely inaccessible, and the state lacks the expertise needed to provide democratic oversight of this technology. As Anthropic co-founder Jack Clark observes, for most of us, "the 21st century is being delayed".[13]

We are also unable to support startups when they show potential to grow into industry leaders. Enterprise AI-startup InstaDeep was originally attracted to London from Tunisia, but was recently acquired by Germany-based BioNTech in a £562 million deal.[14] This followed in the footsteps of other promising startups including DeepMind that pursue foreign-investment exits. In aggregate, foreign takeovers of UK companies have risen more than 400 per cent since 2015 as inward investment has fallen,[15] reinforcing the erosion of the UK's sovereign AI capabilities.

The UK government is attempting to grapple with many of these challenges. The Office for Artificial Intelligence is developing a white paper on AI regulation in follow up to the publication of the government's National AI Strategy in 2021.[16] The Centre for Data Ethics and Innovation recently released a well-considered AI assurance roadmap, an important step in building user and business trust in advanced AI tools, and one that ensures UK leadership in the emerging-services industry will deliver on this trust.[17] Prime Minister Rishi Sunak, in his former role as chancellor, launched an independent expert review of the nation's supercomputing needs.[18]

These strategies and reviews indicate a coherent vision that genuinely surpasses that of most of our peers, but they need to be backed up with substantial funding and action to demonstrate serious global leadership. We will not be assessed on the quality of our strategy documents but on our ability to deliver life-changing AI for billions of people. The opportunities and challenges of AI will be shared by all humanity, but UK leadership will ensure our collective response will be steered by and benefit from the values we hold.

Biotech

Biotechnology broadly refers to the combination of both scientific and engineering expertise to understand, heal, harness and improve living systems. From the sequencing of the human genome and rewriting of genetic code to the design of novel proteins using AI and the creation of artificial organs, the bio revolution has been one of the most profound developments of recent decades.

The discovery and development of CRISPR technology is allowing DNA, the code of life, to be edited with a precision that was impossible barely a decade ago, leading to new opportunities in the field of biological engineering that could transform health, agriculture and industrial processes. Meanwhile, mRNA technology and CAR-T cells are changing our approach to health, as seen over the duration of the pandemic, by harnessing the power of human cells to prevent and tackle disease. And while 3D printing is already revolutionising fields such as orthopaedics, innovators are working on pushing the boundaries to recreate complex organs and systems through tissue engineering.

Rapid progress is now also coming about through the confluence of biology and computing, including machine learning and AI. As a16z's Vijay Pande, a biotech expert, has argued, "this new era of industrialised bio — enabled by AI as well as an ongoing, foundational shift in biology from empirical science to more engineered approaches — will be the next industrial revolution in human history".[19]

Biotech's Potential Impact

The impacts of this are already being seen. Drug discovery is being remade by technologies such as AlphaFold, shortening candidate-identification pipelines from years to a few weeks. In combination with other advances, this could reverse the spiralling costs of producing new drugs and enable tailor-made medicines to be developed for rare diseases.

Synthetic organs grown in the lab could also be used for transplantation, abolishing the waiting lists and ensuring anyone who needs a transplant gets one in weeks.

Robotic and virtual-reality (VR) surgery platforms such as CMR Surgical and FundamentalVR look set to make robotic keyhole surgery affordable and accessible, also providing innovative ways to train surgeons via haptic feedback, which could expand both the number of operations available and their safety.

Meanwhile, technology is providing new ways to harvest, understand and use novel health data. Using this, we could detect disease much sooner when it is at its most treatable and even predict its emergence, offering new kinds of medicine prophylactically. Already in the UK, life-sciences firms such as Kheiron are using AI and machine learning to improve imaging and diagnosis, particularly for cancer. Its Mia platform for breast-cancer screening is world-leading and has been adopted in several National Health Service (NHS) trusts. As genome costs drop and wearable technologies continue to develop, ever more granular individual portraits will be used to predict, prevent and treat individuals. These new technologies will allow the NHS to focus on the promotion of national health rather than only the treatment of disease.

And the possibilities of biotech are not restricted to biomedicine.
New materials, for example based on the incredibly strong and flexible spider silk protein, will make new products possible as the invention of plastics did in the 20th century.[20] This would allow the development of new types of medical implants that the body does not recognise as foreign, new forms of clothing and even self-healing materials for manufacturing. Biotech will also create new ways to produce biofuels efficiently without

using large tracts of land, cultivate specialised bacteria to break down toxic chemicals in the environment and make artificial lab-grown meat in a climate-neutral way.

International Standing

This is now a large and rapidly growing field. In the US, Planetary Technologies estimates that the biotech economy generates more than $550 billion in revenue and is responsible for 2.4 per cent of GDP.[21] Globally the pie is bigger still, with the worldwide biotech market forecast to increase at a compound annual growth rate (CAGR) of 17.83 per cent over this decade, to reach a market size of $3.44 trillion by 2030.[22]

The UK is well placed to be at the forefront of this if it makes the right policy interventions. We are home to leading research institutions, which has translated at times into companies. Greg Winter, the Nobel Prize winner and founder of Cambridge Antibody Technology (a Cambridge spinout), invented Humira, which was for years the world's best-selling drug, generating $16 billion per year in sales.[23] Shankar Balasubramanian co-invented a technique for gene sequencing that was implemented by his startup, Solexa. This was subsequently bought by US company Illumina in 2007 for $600 million and has since multiplied its value almost hundred-fold. And Oxford University's Martin Landray, whose RECOVERY trial was essential to fighting Covid, is attempting to revolutionise clinical trials through Protas.

Beyond these examples, the UK's life sciences have a strong foundation to build upon, with £88 billion annual turnover in this industry,[24] raising £1.8 billion in finance in 2022,[25] with clusters spread across the country with over 50 per cent of jobs outside the South East.

In particular, we have major strengths in R&D, data and genomics that we must build upon – and which form the backbone of the UK's Life Sciences Vision and related documents.[26] These sector-wide strategies have led to some tangible progress and a handful of landmark deals. For example, the NHS is conducting large-scale trials for an innovative new early-cancer diagnostic tool while both BioNTech and Moderna have announced long-term investments in the UK.[27] The government has also announced £175 million of additional funding for genomics research alongside £113 million to tackle key drivers of populational ill health.[28] Oxford Nanopore is another example of a potentially world-leading company in the field of genomic sequencing.

However, despite strong foundations our overall performance across the sector continues to fall as international competition hots up. Unfortunately, the key markers of success are now pointing in the wrong direction. For example, we are seeing:

- A marked decline across all phases of UK clinical research.
- A significant decrease in our share of global investment in life-sciences R&D.
- Life-sciences innovators are still unable to access the capital they need to grow. In combination with our lack of sufficient commercial flexibility and novel commercial models, this means that companies such as bluebird bio have been prompted to pull out of the UK and Europe entirely – taking jobs and investment with them.
- In breakthrough relevant science such as synthetic biology, only one of the 27 biggest advances of the last decade in a recent review came from the UK.[29]

Despite these worrying signs, the government and the NHS do not sufficiently recognise the risks, with the situation having deteriorated in recent months. For example, the 2022 Autumn Statement further squeezed smaller life-sciences innovators, with a cut to the small and medium-sized enterprises (SME) R&D tax-relief credits scheme that will reduce its value by 50 per cent. There are also other issues harming the ability of industry and the public sector to interact.[30]

This is creating a growing chorus of concern. Key figures including leading biotech investor Kate Bingham are publishing stark warnings on the sector's future, with commentators questioning whether the government's "science superpower" ambitions can be delivered. The ambition remains but action must be stepped up.[31]

Climate Tech

The transition to a low-carbon economy is like a mountain-climbing expedition: most want to get to the peak, but the argument is about the best way to summit. Some say it needs to be a straight shoot, even if there are strong blizzards. Others believe a slower but safer route is most feasible; such a practical path would not only seem to protect a way of life but also try to improve standards of living.

For decades, energy prices have been relatively constant but the ability to generate this resource at lower costs, and use it much more efficiently, would unlock many secondary benefits, including dropping the cost of transport and energy-intensive manufacturing dramatically while lifting millions out of energy poverty.

This will not depend on one single advance – the range of technology areas underlying our climate response will need to cut across traditional disciplines, ranging from novel materials and AI algorithms through to chemistry and atomic physics.

Climate Tech's Potential Impact

From the mobility and energy sectors to agriculture and heavy industry, the range of tech solutions available to address climate change is growing. While DeepMind was training AI to control superheated plasma inside a fusion reactor, IBM researchers were exploring how to use quantum computing and AI to accelerate the discovery of new materials for carbon capture. Meanwhile, Climeworks and Carbon180 are blazing a new trail in direct air capture, and Redwood Materials and Li-Cycle are considering recycling solutions for lithium-ion batteries. The $2 billion voluntary carbon market, now projected to reach between $10 and $40 billion by 2030, is increasingly relying on digital technologies to source and verify offset projects while tools such as distributed ledger technology are enabling a greater inflow of capital into climate-friendly projects, irrespective of their location.

The annual investment in energy globally rose to $2.4 trillion in 2022, with approximately three-quarters of the growth attributed to low-carbon technologies. More than 450 financial institutions representing more than

$130 trillion in assets have pledged to support the clean-energy transition. With the cost of solar and batteries declining by about 90 per cent, and offshore wind plunging in costs by 70 per cent over the past decade, renewables now account for the most annual additions to global electricity expansion worldwide.

The development and implementation of novel technologies is critical, as decarbonisation targets are extremely ambitious and will be unattainable without them. As the International Energy Agency (IEA) has said: “Roughly half of the reductions that the world needs to swiftly achieve net zero emissions in the coming decades must come from technologies that have not yet reached the market today.”[32] These will need to tackle incredibly difficult challenges such as steel, ammonia, cement and plastics, as well as reforms to food and agriculture.

International Standing

The US has accelerated efforts to be the leader of the field, passing more than $500 billion in clean-energy industrial-strategy legislation over the past year, namely the Inflation Reduction Act (IRA), Creating Helpful Incentives to Produce Semiconductors and Science Act (CHIPS) and Infrastructure Law. Together, these aim to cut emissions by a gigatonne in a decade.

This is drawing clean-tech investors to the US. For example, Northvolt (a Swedish battery startup), Iberdrola (a Spanish energy firm) and BASF (a German chemicals company) have all claimed they will relocate a substantial portion of their investment or production to the US to take advantage of its subsidies.[33] Car companies such as Audi and BMW plan to create assembly plants in the US while Hyundai and Panasonic intend to build battery plants there.[34]

The IRA’s emphasis on domestic production and manufacturing will fundamentally change the global clean-tech market through lower prices and the diversification of supply chains for critical minerals and clean-tech components. Responsive subsidies and other measures by leaders worldwide, especially in the EU, to incentivise clean-tech innovation and production risk leaving the UK behind. China is also making great strides in renewables and electric vehicles and dominates global lithium supplies.

More broadly, global investment in climate tech picked up pace in 2022: the IEA estimated annual growth of 12 per cent in clean-energy investment, rising from about 2 per cent where it had remained five years after the Paris Agreement.[35] Climate tech attracted more than a quarter of total venture-capital (VC) funding in 2022 after growing five times faster than overall VC investment in the years leading up to the pandemic.[36]

This investment is happening all along the clean-energy value chain. Globally, EVs are projected to make up to 90 per cent of new car sales by 2050, nuclear fusion is reaching new milestones and next-generation nuclear technologies, including small modular reactors (SMRs), are changing the outlook on what is possible.[37] In the US, the SMR pioneer NuScale just became the first of its kind to gain regulators' approval for its design.[38] Grid and storage technologies are also attracting consistent investment, from large lithium-ion batteries to thermal storage and power-to-X solutions.

In the UK, climate-tech investment reached approximately £7.5 billion in 2022, up from £4 billion the year before. Exemplified by unicorns such as Octopus Energy and Vertical Aerospace, there is a growing startup scene, with approximately 5,000 companies here compared to more than 14,000 in the US.[39] The challenge and opportunity for the country is to meet demand at home while also winning a share of this globally expanding market. This requires the country to identify and leverage areas of comparative advantage while building strategic alliances to ensure our climate-tech products can compete in a post-IRA market.

A heavily emphasised state-based approach is not going to be the way forward here. Instead, we must focus on creating and facilitating strong tech-enabled markets, infrastructure and incentives that will allow industry, local actors and consumers to drive the change.

The challenge is significant. To decarbonise our economy, the action needed will include:

- The second-largest reduction in gas demand across Europe and the third-largest drop in oil demand.

- An extensive buildout of nuclear power and an increase in the pace of renewables deployment by three and a half times.
- An unprecedented expansion of the electricity grid, building seven times more capacity by 2030 than has been added over the past 32 years.
- An expansion of EV-charging points by tenfold in the next decade and an increase in the number of EVs sold from 15 per cent of total car sales to 100 per cent by 2030.
- A significant ramp-up in zero-carbon heat solutions in homes and businesses, with heat pumps increasing from 280,000 to 13 million by 2035 to meet our domestic carbon budgets.
- Industry to decarbonise through significant electrification of core industrial processes and the increased use of carbon capture, usage and storage (CCUS), taking it from a nascent to commonplace technology in the 2030s.

Getting to this point will not only require developing technology at speed and scale but also focusing heavily on deployment. It will also require bold action, with a level of ambition that often feels missing from the state today. Fusion is one of the areas in which we still project a sense of ambition. It is also one that allows us to strengthen transatlantic ties. For example, in 2022, the UK Atomic Energy Authority signed an agreement with US company Commonwealth Fusion Systems to advance commercial fusion energy.[40] Innovative policies such as pivot-support programmes can ensure spillover effects from research are maximised, but the government should be investing more in our national laboratory, the Culham Centre, to strengthen it as a global centre for fusion.[41]

Fusion has the potential to become a century-defining sector, particularly as the nexus between software and industry develops. We need to ensure that we are laying down the conditions for some of the firms involved to be British.

Today's Powers Are Racing Ahead

Our competitors recognise that these technologies, as well as others such as quantum and materials science, are remaking the global economic order. Accordingly, the tech superpowers are fighting for supremacy by investing heavily in the industries of the future.

President Joe Biden is taking this challenge seriously: last year the US passed the CHIPS Act and the IRA. Together, these and other policies will result in more than $1 trillion invested in clean energy, R&D and the commercialisation of frontier technologies such as quantum computing, AI and nanotechnology.

Europe is trying to meet the moment with its Green Deal Industrial Plan for the Net-Zero Age, which, through a simplified regulatory environment, upskilling, accessible funding and efforts to build resilient supply chains, attempts to drive clean-tech innovation on the continent. The approach of the bloc is often to act as a regulator first, for example by leading on AI regulation,[42] but it is also investing in large-scale data infrastructure such as Gaia-X and frontier tech including cutting-edge satellites.[43]

Beijing is also preparing for a more competitive future. President Xi Jinping placed science and technology at the centre of China's 20th Communist Party congress, greatly increasing its representation on the Politburo and stating that China must "regard science and technology as our primary productive force, talent as our primary resource and innovation as our primary driver of growth".[44] Meanwhile Beijing's military-civil fusion strategy aims to foster greater tech innovation by linking China's civilian and defence economies.[45]

Recent US export restrictions on semiconductors have only reaffirmed Beijing's view that technological self-sufficiency is a matter of political survival.[46] As President Biden has highlighted, President Xi believes that changes in technology strongly favour autocracy.[47] It is the collective task of the world's democracies to disprove him.

In terms of sheer scale, the UK will not be able to compete with the US and China, but it is nonetheless possible to compete on quality. Nations such as Taiwan, South Korea and Israel are smaller than the UK but have nonetheless thrived, with R&D-intensive economies fusing public and private investment. These countries demonstrate a dynamic middle way between purely free markets and top-down state control, predicated on intelligent investment and action on the part of the state and a conducive environment for industry.

The UK will need to do more to remain competitive.

Reinventing the State

It is not too late to define a new path, but we have to be honest about the situation the country finds itself in.

The British people have experienced almost 15 years of stagnant productivity growth, resulting in flat or falling real incomes. Simultaneously, public services are struggling under a trilemma of needing to provide services at scale, at a sustainable cost and at an acceptable quality. As a result, the tax burden continues to rise.

The human cost of this situation is real. Across the country, 16-year-olds from disadvantaged families are 18 months behind their peers by the time they finish their GCSEs, and the picture has failed to improve over the past decade. The long-held assumption that children will be better off than their parents is crumbling.[48] Meanwhile, economic inactivity because of sickness is at its highest level since records began, with 2.5 million working-age adults inactive due to their health.

Any “Brexit dividend” is yet to be fulfilled. Ministers have made a start on considering where UK regulation can be made more nimble and efficient in areas such as gene editing and clinical trials,[49] but regulatory restrictions on innovation remain relatively high. For example, three years on, legislation for autonomous vehicles remains stuck, we kept EU rules on robotics that

Germany has subsequently abolished so that they can build fully autonomous warehouses, while novel food companies are moving overseas due to regulation.[50]

The state also faces a new generation of challenges. Climate is at the forefront of these, but as Covid-19 showed, a deep and broad science and tech base is a vital strategic asset for health and economic prosperity. These problems call into question the ability of the British state not only to meet these challenges, but to leverage innovation to build a better future.

As it stands, the technology sector accounts for less than 5 per cent of the UK's total market capitalisation.[51] In Germany, it is 11 per cent. In the US, it is almost a third. The challenge isn't solely in having good ideas or entrepreneurial spirit: since 2016, the UK has created more "tech unicorns" than France and Germany, though we arguably lack deep-tech unicorns. The problems come at a later stage. Looking at IPOs and acquisitions combined, 44 per cent of all exits from UK tech companies between 2011 and 2021 were by overseas investors, rising to 61 per cent if the company had received overseas investment at the equity-funding stage. We are losing valuable assets from the technology sector to overseas investors.

Seven of the top ten companies in the world by market capitalisation are tech companies (Apple, Microsoft, Alphabet, Amazon, Tesla, NVIDIA, Taiwan Semiconductor Manufacturing Company) and none are British. Our biggest company is Shell – the world's 44th largest by market capitalisation. Only two of the top 100 R&D-spending companies are based in the UK (GSK and AstraZeneca), while Germany has 12 in the top 100 – 500 per cent more than the UK.

The starting point to getting a seat at the top table will be a reinvention of the state. Embedding technology and AI across all operations will be essential – including the NHS, schools, law and order, and reforming the way government functions.

We have shown that this is possible before. Our own life sciences industry did not happen by chance, but by a concerted national strategy of anchoring investment in research organisations such as the Laboratory for Molecular Biology backed by the capabilities of an integrated health-care system. Our Covid-19 success stories relied on investment in these institutions.

Digital technology now provides a new platform and possibilities, and Britain's centralised political system offers a greater chance for executing a coherent reform agenda and national strategy than similar nations. By expanding the potential for collaboration and coordination as well as focusing on the speed and pace of discovery, Britain can build a new model for science and innovation in the modern world.

03

Practical Actions to Drive Our New National Purpose

A 21st-Century State

To seize the opportunities of this century, we need to radically change the way in which our public services are delivered. This isn't just about injecting more tech into our existing approach. Rather, it will require a sustained whole-of-government effort and a new operating model for the British state. This is not about size or outdated left and right debates; it is about building a "strategic state" that provides a platform of opportunity for the British people. In reality, technology is likely to result in a state that is smaller than today's – but with an entirely new operating model and requiring different skills.

A series of reforms are needed to get there, which include:

- Reshaping public institutions and processes to build momentum.
- Building AI-era infrastructure, data capabilities and digital IDs.

Reshaping Public Institutions and Processes to Build Momentum

The UK's response to the Covid-19 pandemic highlighted what can be achieved when science and technology expertise is at the heart of government, people are empowered to drive ambitious programmes and obstacles are overturned to enable focus on a mission.

The increased competition and unpredictable changes that the technology revolution is bringing mean that we must once again prioritise adaptability and speed of execution in government. The pandemic showed that day-to-day government processes are not configured to help us rise to the challenges ahead. It is a sad fact that the greatest success of the UK's pandemic response – the work of the Vaccine Taskforce – was made possible by exempting it from normal government processes, yet there have been no significant operational reforms in response.

To have a chance of remaining relevant and to improve our global and economic position, we will need to deeply reform, reinvent and, in some cases, resurrect core assumptions of how the state should act. Improved state capacity will be central to our nation's success.

The foundational processes and assumptions about how Western states are governed and operate have developed without science and technology innovation being prioritised. We have an incredible opportunity to rebuild the British state with science and technology at its heart by addressing Whitehall's long-standing limitations.

To make the most of this opportunity, we must:

- Foster a long-term, risk-tolerant investment attitude that avoids micromanagement. The state must view R&D spending as an investment with strong returns, not a sunk cost to be traded against other priorities.

- Create a central strategic and delivery unit, optimised for science and technology, to act as a centre of political and state power. It should be independent from vested interests and status-quo forces, and able to devise, drive and unblock a reform agenda.

- Ensure that decision-makers and advisors are experts in the areas within which they are operating, as would be the case in a technology company. The current ministerial system and civil service do not have or produce the relevant expertise required for this, with repeated attempts to change this having failed.

- Enable decision-making and operating at increased speed, recognising that in a tech race going slow may be worse than failing fast. This requires flat, non-hierarchical structures that empower executive decision-makers to manage portfolios (as with the Vaccine

Taskforce), the removal of veto points and the creation of new organisations to institutionalise and support key decisions without micromanagement by Whitehall.

- Introduce a system that prioritises the goals, advice and agency of science and technology experts, rather than an excessive audit and micromanagement culture.

Reorient Our Public Investment Towards Long-Term, Expert-Guided R&D Spending

The Treasury's current mindset exists in part as the result of a healthy desire to control overall levels of public spending. However, this must be balanced against the need for and the requirements of investment. This balance has been off for some time.

We seriously underinvest in direct public R&D investment relative to our competitors, and have done for almost 40 years. Rather than lagging behind on this, we should lead. Public spending on R&D helps attract matching private investment, driving growth and boosting tax returns. For example, every £1 spent on public R&D expenditure brings in £2.50 of private R&D funds.[52] Investing more in public R&D as our economy improves and spending increases become more fiscally feasible can help achieve long-term growth.

In addition, public R&D spending is subject to extensive bureaucracy by the British state, which also micromanages it into small, siloed pots and creates continual annual funding cliff edges rather than facilitating sustainable investment. Recent years of investment have been characterised by single-year spending-review cycles, preventing the creation of meaningful long-term plans or commitments. Increasingly granular decisions on spending are made not by science and technology experts, but by generalists. All of this sharply curtails research organisations' abilities to act effectively.

As recent articles have argued,[53] much of this arises from the culture and mindset of the Treasury whose excessive power creates a system of "policymaking by accountant". This stands at odds with what is required for science and technology investment. Notably, Institute for Government data suggest that the Treasury does not have any dedicated science and technology staff, despite the civil service being a large employer of scientists and engineers.[54] Yet the Treasury strongly micromanages science and technology spending and is the de-facto controller of the UK's national R&D strategy.

We need to reform how investment is made in fields relevant to R&D, and in turn break the control of the "accountant" mindset over the UK government. And as British cosmologist and astrophysicist Lord Martin Rees has argued, many scientific advances require time and freedom to allow unknown ideas to be explored. This does not suit the type of regular audits and performance criteria common in government funding.[55] A bespoke approach specifically designed for the needs of R&D investment would be a major competitive advantage for the UK. A number of core objectives would need to be set as part of this special arrangement:

- Return the monitoring of delivery-body performance to relevant departments, removing opportunities for Treasury micromanagement.

- Review and sharply curtail the business case, "value for money" and similar green-book criteria, with investment decisions instead being guided by the judgement of expert science and technology figures through the new central unit we outline below. Such Treasury processes were investing in building hospitals and roads, not high-risk tech investment, and make little sense in the context of highly uncertain, exploratory work with unpredictable outcomes. Special and separate processes should therefore exist for R&D in recognition of its very unusual nature.

- Embrace expert review, including using international reviewers, as the primary mechanism of performance evaluation for programmes and institutions, rather than audit by generalist officials. Progress, not paperwork, is what should be assessed.

- Place core R&D investment for key delivery agencies such as UK Research and Innovation (UKRI) and ARIA on seven- to ten-year spending cycles. Where necessary, such as for institutions and long-term investments, allow longer spending cycles with light-touch checkpoints based on expert international review.

- Manage major delivery agencies such as UKRI and similar new entities in the same way as ARIA – on single business-case processes – without micromanagement by Whitehall, and enable strong flexibility to reprofile spending across years.

Reforming such deeply ingrained, long-standing functions of the state is challenging, and careful thought will be required on how best to do this. Recent suggestions to split the Treasury should be considered but may not be the only way.

A Science and Tech Policy and Delivery Unit Across Number Ten and Cabinet Office

Devising and delivering a complex, inter-departmental science and technology agenda requires bringing science and technology to the very heart of the British state.

The creation of the Department for Science, Innovation and Technology (DSIT) is a very welcome step – bringing the governance of crucial technologies under one roof, elevating the status of the scientific agenda inside government and providing a single point of contact for global tech to use when interacting with government. It will be crucial to support DSIT in hiring expert technical talent, which may require relaxation of normal recruitment rules due to the global competition for such talent.

Alongside the commissioning of Sir Patrick Vallance's review into regulating emerging technology by the government and Labour's plans to quadruple investment in green technology,[56] this new department shows that both parties are increasingly committed to elevating the status of and focus on science and technology inside government.

The next challenge will be to embed the science and innovation agenda across the whole of government. DSIT will be unable to achieve this alone, given that many of the levers for implementing this agenda lie outside the department and it does not reside in the heart of government.

There needs to be an upskilling at the centre of power to drive this agenda as a top priority, with the full and active engagement of the prime minister. To do this requires creating a central coordinating brain that spans Number Ten and the Cabinet Office, with a high density of expert talent closely connected to the key organs of power in both. This should be a central strategic and delivery unit, along the lines of the White House Office of Science and Technology Policy (OSTP). The OSTP has some of the top minds in the US working there, including former Advanced Research Projects Agency (ARPA) programme managers. A push to create such a unit in the UK in 2021 appears to have stalled, but it should be endorsed on a bipartisan basis.

The unit would have a number of core objectives:

- **Apply a whole-of-government strategy**. Provide a site of synthesis and integration for the government's whole R&D strategy.

- **Attract top advisory talent.** Create high-prestige, empowered positions to attract top science and technology thinkers into government to advise the prime minister and cabinet directly.

- **Devise disruptive policy proposals.** Policies for bold change rarely come from existing stakeholders and consultations, instead they require radical policy thinkers in proximity to power.

- **Run the NSTC process.** Prepare meeting agendas for the prime minister's National Science and Technology Council, the cabinet committee.

- **Empower delivery and unblock problems.** Use the influence of Number Ten to unblock problems within the system, in particular empowering departmental leads and bringing together policy and delivery in the same way that Number Ten empowered Kate Bingham.

Such a unit would be expected to have close working relationships with related departments – especially DSIT – in a similar manner to joint special advisors, making them synergistic rather than in conflict with relevant departments. Over time, functions of the Treasury could also be moved into this structure, or into DSIT, to further this agenda.

Exemptions From Whitehall Controls for Tech

Whitehall's core systems are also not built for competing over top technical talent, or for evaluating science and technology processes. The following actions should be taken to allow science and technology decision-making to take place as efficiently and effectively as possible.

Decision-making in many areas of science and technology requires deep technical knowledge. Very few members of Parliament have the necessary knowledge in this field, putting great strain on the ministerial system. The government should create a new kind of ministerial position to attract expert leaders to run programmes in an executive fashion, similar to how the Vaccine Taskforce was run. These executive ministers would be accountable to Parliament in the normal fashion, but would bypass the usual House of Lords appointment process.

Technical recommendation: Move beyond the standard ministerial system to appoint experts as specialist Whitehall executive ministers.

The government should also act to make it far easier to attract technical talent into the civil service and retain it, bringing world experts into government for meaningful periods of time, not merely to sit on external advisory boards. This should entail minimal friction and require rapid, enabling leadership to build internationally outstanding teams. World-class technical talent is used to being hand-picked and hired, rather than forced through six-month recruitment processes. For example, UKRI should be able to hire people rapidly into key directorial positions without completing the usual public processes. In addition, our top public R&D facilities should be exempt from the 2010 Pay Controls, allowing them to again compete for and retain global talent. Our best institutions are currently losing top talent they have nurtured as a result of these rules.

Technical recommendation: Accelerate existing recruitment processes and exempt R&D facilities from pay controls to attract global tech talent and expertise.

Expert review, including international perspectives, should be used to assess whether a programme has been well conducted and responsibly budgeted, rather than non-specialists carrying out the assessment based on the National Audit Office's "Value for Money" criteria.

Technical recommendation: Assess the success of programmes through expert review, not generalist audit.

Use Procurement to Directly Drive Innovation

From the semiconductor industry in the 1960s through to the reusable-space-launch industry in the 2010s, the US government's willingness to act as a "buyer of first resort" that creates markets for early-stage innovation has consistently accelerated progress for technologies that benefit the whole world.[57] The UK should draw inspiration from this, as well as from its own efforts with the Vaccine Taskforce, and leverage its significant procurement budget towards directly supporting R&D efforts that drive efficiency and greatly improve the quality of public services.

The Vaccine Taskforce used a procurement tool known as an "advanced market commitment" to help secure hundreds of millions of vaccines in an incredibly short window. The taskforce was also willing to take risks, act with urgency, empower expert judgement and adopt a portfolio mindset that tolerated failure. The US equivalent, Operation Warp Speed, saw government agencies guarantee sales for approved vaccines while paying firms to run trials and build vaccine-manufacturing plants at speed.

Similar procurement models could be applied to many domains where there are huge societal benefits, the scaling of relatively known science is required, traditionally significant regulation can be rolled back and pre-existing motivations need to be delivered at scale. As Chris Haley of the

Global Entrepreneurship Network has observed, this will require a significant cultural change towards risk tolerance, as well as greater diversity in "alternative" procurement processes.[58]

Technical recommendation: Update the government's procurement processes to account for the innovative potential of the relevant item. The government should strongly reduce friction to encourage risk-taking and reduce administrative requirements that favour incumbent players rather than SMEs.

An Advanced Procurement Agency

While we must reform broader procurement, we should also recognise the value of a smaller, nimble organisation to provide small-scale procurement of particularly high-risk innovative products and trial them in public services. Such an agency could play the same role as the US Special Forces play for the Defense Advanced Research Projects Agency (DARPA), providing a "buyer of first resort" for proof-of-concept work that is too risky for broader deployment, but which can be a stepping stone to nationwide use.

Technical recommendation: Create an Advanced Procurement Agency (APA) with a specialised mandate to find opportunities for public-sector innovation, procure promising solutions, and manage their deployment, testing and subsequent marketing to the broader ecosystem, with a high tolerance for failure. This should create crucial market opportunities for higher-risk early-stage innovative products.

The APA should be run like an ARPA, with empowered programme managers who can exercise judgement and be autonomous within a flat hierarchy. Each programme manager would have a mandate to innovate in a particular area of public services, driven by a vision for how technology could catalyse progress in that area. This would resemble the role the special forces often play in military-technology deployments and similarly should have a small (less than 2 per cent) share of the overall procurement budget, but act as a "force multiplier" for the broader budget.

For example, a programme manager could aim to trial and apply advanced solutions for diagnostic screening and triage to a single NHS trust, then work with Whitehall to implement this system more widely if it succeeds. Another programme manager could work within a single school or even classroom over the course of a term to trial the use of AI assistants for educators and personalised tutors for learners. Yet another could work on deploying AI writing assistants for use by policy advisors within a single government department.

Beyond introducing visions for programmes that can drive innovation in narrow domains, we also need new mechanisms to present opportunities for innovation to the broader community and also to recognise success so that others can copy it. For example, the government could establish a range of prizes for the best examples of public-service adoption of innovative technology solutions across a range of different fields. Approaches drawn from highly innovative startup ecosystems should also be replicated.

Technical recommendation: The new Office of Science and Technology Policy should conduct frequent foresight exercises that investigate how future technological advances could drive efficiency and improve experiences for services under departmental remits. These findings should enable departments to publish and maintain a "Request for Startups" list, like that used by American tech startup-accelerator Y Combinator, to signal to and incentivise innovators to work on relevant product ideas.[59]

Building AI-Era Infrastructure

The UK government has at times been a frontrunner in digital, with innovations such as the Government Digital Service and Cloud First Policy. But as the world enters this new era, the pace of reform needs to pick up.

Embed AI Across Public Services

While the use cases of generative AI and decision intelligence are still in the early stages of being explored, this technology represents a once-in-a-generation shift in our capabilities. As a cognitive assistant, it will be able to arm every civil servant and frontline deliverer of public services with syntheses of complex data, enabling them to make more informed choices without the need for technical expertise or access to privileged data sets. AI can convert text to designs, which can then be 3D printed, enabling almost-instantaneous experimentation and iteration of physical products in health care, for example.

A more focused use of AI systems in government could be as simple but effective as search tools that help people navigate gov.uk to access public services such as driving licences and tax accounts and make interactions with government a seamless process for citizens. The Estonian government, for instance, has launched Bürokratt, an AI virtual assistant that works on behalf of its citizens, proactively identifying and communicating public entitlements or services they would benefit from while providing them with controls and transparency on the use of their personal data.

AI is also on the cusp of revolutionising the education system. Machine-learning tools are now used to continuously assess students' progress, map strengths and weaknesses, and dynamically adjust the presentation of content. This helps students engage with homework and provides teachers with actionable insights. Emerging large language models, similar to ChatGPT, are being trialled as co-pilots for educators, helping to draft content or stand in as individual sparring partners for students. This, too, will help improve the average quality of instruction and encourage engagement with, rather than rejection of, new tech in the education system.

Sovereign General-Purpose AI Capability

Special focus should be placed on the transformative potential of next-generation, general-purpose AI systems such as ChatGPT, which could underpin considerable public-service delivery.

Given these AI systems will soon be foundational to all aspects of our society and economy, it would be a risk to our national security and economic competitiveness to become entirely dependent on external providers. Since the technology is sufficiently mature, the government should take on a greater role in its direct development to ensure the UK has sovereign capabilities in this field. Leading actors in the private sector are spending billions of dollars developing such systems so there may only be a few months for policy that will enable domestic firms and our public sector to catch up.

Technical recommendation: Develop and procure sovereign general-purpose AI systems that can disseminate innovation throughout our public services. This should at first be done through procurement in partnership with a consortium of domestic AI firms that may be best placed with technical expertise. Simultaneously, an elite public-sector research effort modelled on visionary labs such as OpenAI and DeepMind should be initiated to ensure public-sector expertise and ownership of this technology.

Considering the pace of AI progress, the state will need to adapt to opportunities as they arise and focus on getting research advances into the hands of users as fast as possible. Direct access to and control over general-purpose AI systems can ensure this is possible while also supporting other initiatives, such as levelling up UK academia's access to the frontier of AI and creating a world-leading AI-assurance ecosystem.

Supercomputing Infrastructure

Raw computing power is essential to unlocking advances in AI, so we will need to become global leaders in the area of supercomputing. While the UK has significant technical talent and expertise, it has not been supported with the requisite capital investment, which has left us trailing our peers. Leading AI companies are spending billions of dollars on cloud-computing resources, with the US also poised to invest billions in the creation of a public-sector computing resource dedicated to AI research.[60] An expert panel has been exploring this area for the UK government's Future of Compute review. Their recommendations should be implemented in full and with haste when published. Looking further ahead, we should also move towards managing compute, and even general-purpose AI, as enabling utilities much like our water or energy systems.

Technical recommendation: Ensure we have sufficient supercomputing to support specialist AI researchers in the public sector and universities. Some of this should be specifically reserved for developing sovereign large language models to be deployed in public-service delivery. Government departments could submit bids to access the resource, judged by an expert board convened by Number 10 and the Cabinet Office.

Create Foundational Health Systems

If AI should be embedded across public services, technology should be the centrepiece of a new health-care model. Harnessing both the power of data and advances in biotech can create a more predictive, preventative, personalised and participatory model, with the power to radically improve outcomes, dramatically reduce costs and bring about broader economic benefits.[61] It is no longer sufficient to simply manage rising demands; we must ask how we reduce that demand too.

The technologies of today and tomorrow will be critical in revolutionising health alongside wider reforms. They will include:

- Systems of records that can bring together comprehensive personalised health data in a secure way to reveal unprecedented insights about our own health and the population as a whole.

- Systems of engagement that reimagine how we interact with health-care systems to make them more efficient and accessible.

- Systems of intelligence that can utilise our individual health data to inform personalised treatments.

- Systems of collaboration that can drive clinical research to develop novel treatments and help protect us from global health threats.

Covid-19 underlined the value of data in delivering novel vaccines at record speed, with those people identified as most vulnerable prioritised. We must look to build on this legacy. The NHS already collects a vast amount of data at a local level but since it is often siloed or cannot be easily exchanged across the rest of the health service, the full value is not being harnessed.

In the UK, NHS England is attempting to address a long-standing challenge of data fragmentation across the health service, with legacy systems, data silos and a lack of interoperability impeding improvements in efficiency, delivery and research. For example, while approximately 90 per cent of NHS Trusts will have electronic-health-record (EHR) systems by the end of 2023 (10 per cent will still be paper based), these will be hosted by more than 60 different vendors across platforms that are not interoperable, making it difficult for different trusts to exchange data or for the centre to fully see the big picture. The federated data platform that the NHS is currently seeking to procure solves this requirement by building a platform that can abstract and connect data from different localised databases. This creates a single interface that aims to enable users to seamlessly store and retrieve data from different source databases within the federated system (even if these databases are heterogeneous).

However, a single centralised system would likely be a better option. It would mandate common data collection, data standards and interoperability, enabling the benefits of a connected data system to be fully realised. It would ensure a common standard of EHRs across the NHS, in terms of functionality, resilience and universal coverage. A single database would also be able to connect more easily with external systems to share data such as clinical-trials-management systems, trusted research environments or platforms providing data from devices such as wearables.

Technical recommendation: The NHS is currently tendering for its own federated data platform. Instead, a single national health infrastructure that brings together data into a world-leading system should be developed as a once-in-a-generation attempt to revolutionise health in the UK.

The size of the prize of improving clinical decisions, public-health policy and health-care delivery is significant. In 2019, Ernst & Young estimated that unlocking NHS health data could be worth up to £10 billion a year through operational efficiencies, improved patient outcomes and wider economic benefits.[62]

Treat Data as a Competitive Asset

Data is critical to unlocking the benefits of artificial intelligence. As it stands, huge amounts of public data are distributed, owned by different departments and bodies but only partially connected, often in an ad-hoc manner. While the government has made admirable efforts to address this in core areas of public-service delivery, there is an opportunity to go further. Creating a shared data architecture is a huge lift but it is just as important as the physical infrastructure that has housed our public services over the past century.

It is easy to take much of our existing data infrastructure for granted. The Google Maps Platform is embedded in millions of companies' profiles, improving user search by many orders of magnitude. GitHub democratised coding in a manner previously unimaginable. Both enabled enormous downstream innovation, for their organisations and the wider economy. Yet this is not an area in which the government should sit idly by and let the private sector do all the building. A mindset change is required.

Government must use data as a competitive asset. Historically, publicly available data has been responsible for advances in AI. For example, ImageNet drove rapid progress in computer-vision algorithms while Common Crawl and The Pile have enabled modern language models. These data sets were relatively cheap to produce – in the region of hundreds of thousands of pounds – but have generated spillover value into the billions of pounds. Outside AI, the Human Genome Project birthed modern sequencing and personalised genomics, leading to Iceland's deCODE genome-sequencing project (with a value of $200 million) and the biomedical database and research resource UK Biobank, a benchmark study and a significant value-add to the UK's medical understanding.

Health provides an obvious example. While new secure data environments – which enable approved researchers to access (but not hold) anonymised data in a controlled environment – are a promising start, we must go further and faster. Biobanks have played a crucial role in increasing scientific knowledge in areas where it had previously been costly to collect data. Since 2015, the number of scientific publications using biobank data has increased more than fourfold. UK Biobank is helping to produce the world's largest organ-imaging data set, based on 60,000 participants, to assess disease progression. This is a fundamental 21st-century public good generating enormous public value.

The downstream effects of a more concerted data-collection and curation effort in health could be transformative. In limited trials, we have already seen new AI-driven techniques used in routine scans to help identify and predict more than 50 diseases of the eye, and to improve breast-cancer diagnoses. Careful curation of open-source protein and metagenomics data sets by entire subfields of biology was critical to enabling the training of AlphaFold, which in turn enabled new data sets of predicted protein structures for almost all known proteins.[63] Drug design and discovery could be similarly catalysed when built on massive data sets that the NHS would be among the best-placed in the world to collect.

By building the sort of national health-data infrastructure described above, and expanding access in an appropriate and safe way, we would make more effective use of the NHS's competitive edge over other health systems, providing invaluable data sets that could drive unparalleled progress in UK life sciences to deliver novel treatments and diagnostics. Furthermore, charging for life sciences firms to access national health data, where appropriate, could also generate funding for greater investment in public R&D.[64]

The government should extend these efforts in health and identify similar opportunities in other sectors to enable both sector-specific and more general AI advances.

Technical recommendation: The government should run a "Future of Data Challenge". This should start by announcing a public call for the desired data. Proposals would then be considered during the submission of bids or they would be funded immediately, depending on feasibility. This would be carried out by a small team of mostly technical experts, with a focus on data sets that either directly incentivise AI research in valuable ways or drive down the cost of future ones.

This should involve the crowding in of private co-investment to fund each data set, just as 75 per cent of the UK Biobank was privately funded. Designed well, the benefits could be either solely or primarily extracted for the UK – for example, by generating data sets with immediate UK applicability, such as for self-driving cars.

Digital Identity

Today, many of us can set up a bank account in minutes and pay for shopping at the tap of a watch or phone. For the generation now entering middle age, this level of digital simplicity and streamlining is expected as a default while those in their 20s have grown up in an entirely digital age. Despite this, government records are still based in a different era.

The debate over digital IDs has raged in the UK for decades. In a world in which everything from vaccine status to aeroplane tickets and banking details are available on our personal devices, it is illogical that the same is not true of our individual public records.

Governments are the original issuers and source of truth for most identity documents, from birth certificates to passports. Rather than creating a marketplace of private-sector providers to manage the government-issued identity credentials of citizens, the government should provide a secure, private, decentralised digital-ID system for the benefit of both citizens and businesses. A well-designed, decentralised digital-ID system would allow citizens to prove not only who they are, but also their right to live and work in the UK, their age and ownership of a driving licence. It could also accommodate credentials issued by other authorities, such as educational or vocational qualifications.

This would make it cheaper, easier and more secure to access a range of goods and services, online and in person. A digital ID could help the government to understand users' needs and preferences better, improving the design of public services. It would make it simpler and easier to access benefits, reducing the number of people who are missing out on support they are entitled to. It could even help the government move to a more proactive model, meeting people's needs before they apply for a service, tailoring the services and support they are offered to their individual circumstances and reducing administrative burdens on both individuals and the public sector.

Technologies such as advanced encryption techniques using zero-knowledge proofs allow attributes to be securely shared and verified without exposing the underlying data or sharing unnecessary information, without the need for paper documents or counter-signatures. To date, the UK has made only tentative steps towards sharing data among public-sector organisations, either for policy-making purposes or delivering services. By contrast, in Estonia, a data-exchange layer called X-Road connects these systems and allows citizens to permit certain bodies to access information held on them by other parts of government. This is underpinned by the "Once-Only" principle – a legally binding requirement on the government not to request information from citizens if it is already held by another government entity.

A digital-ID system rooted in a public-sector data architecture like this could pave the way for individuals to make better use of their own data, for instance by using proof-of-mobile bill payments to support their credit rating, or by being able to prove school-attendance records as part of a job application. Far from being a nice-to-have or a question of marginal improvements in online public services, a properly functioning digital-ID system is the cornerstone of a digital-era public sector.

Technical recommendation: Accelerate the implementation of a single digital-ID system for all residents, providing a digital wallet to access it, while ensuring that digital and physical copies of ID have the same legal status (as is the case in Ukraine).[65]

Technical recommendation: Legislate for a wide-ranging "Once-Only" principle as a forcing mechanism to spur secure, proportionate data-sharing between government agencies.

Invest in Education to Build the Skills of the Future

If becoming a leader in science and innovation is central to the UK's new national purpose, every child, whatever their background or circumstances, must be able to get a first-class scientific education. Those children who choose to pursue an academic future must be able to become the UK's next scientists, mathematicians and entrepreneurs. Those who opt for a technical vocation need the skills to contribute to the industries of tomorrow from green manufacturing to retrofitting homes.

Higher education (HE) is already critically important to the UK's economy, which has become progressively more reliant on human capital over the past two decades. The sector's expansion has tracked the economy's shift from vertically integrated manufacturing industries (which required a relatively small number of HE graduates) to knowledge-intensive services (in which demand for graduate skills is high).

The fruits of this expansion are clear. For instance, approximately 20 per cent of the UK's economic growth between 1982 and 2005 flowed directly from accumulated graduate skills, while at least one-third of the increase in labour productivity in recent decades can be attributed to the rising number of graduates.[66]

All the signs are that HE's salience will continue to rise in the years ahead: as the government's own commissioned forecasts show, technological disruption is redefining the jobs market, placing even greater premium on higher-skilled individuals. Future HE expansion could also play a critical role in spreading the seeds of growth and skills development across less economically developed parts of our country.

Accelerate the Rollout of Edtech

Our school systems, which were under significant pressure even before the pandemic, are struggling to provide first-class education. The latest figures show 31 per cent of teachers who qualified in 2016 have left teaching five years on.[67] Workload is a factor in low retention rates, with 37 per cent of secondary-school teachers reporting this is a "very serious problem" for them. Moreover, less than half of a teacher's working hours are actually spent teaching. The latest figures show the average secondary-school teacher spends 49.1 hours a week working, but only 19.9 of these teaching. Most of the rest of their time is spent on lesson planning (7.3 hours), marking (6.3 hours) and general admin (4.8 hours).[68]

Social mobility is also in decline, with the longstanding attainment gap between disadvantaged children and their peers continuing to widen. For example, research by the Education Endowment Foundation suggests the gap in mathematical attainment between disadvantaged primary-school pupils and their peers increased by up to 17 per cent during the pandemic.[69]

Rolling out edtech could help make schools more effective and reduce the attainment gap. Embedding edtech platforms in schools would automate marking and other admin, allowing teachers to focus more of their time on teaching and inspiring their students. Adoption of even basic systems for student records and staff communication would save money and time for administrators and educators by reducing the burden of coordination.

In the classroom and lecture hall, technology can help scale up effective pedagogical practices (such as peer feedback) and new forms of assessment that better reflect the changing expectations of students. Additionally, remote learning can improve access to high-quality teachers. A permanent, portable digital learner ID would enable our education system to keep track of students' progress across different stages, offering tailored support, and giving students more ownership of their personal data.

One AI-powered teaching and learning platform, from UK startup CENTURY, has already been found to cut workloads by an average of six hours a week, freeing up time for teachers and social workers to focus their attention on supporting children while spending less on paperwork.[70] Meanwhile, by expanding access to intelligent tutoring systems, disadvantaged children can be supported to better compete with their privately tutored peers and "disrupt the shadow education system".[71]

Technical recommendation: Accelerate the rollout of edtech in schools across the country. With a recent evidence review commissioned by the government finding that staff confidence is a key challenge to implementation, ministers should introduce a new edtech-training fund that schools can access to pay for one of their teachers to become proficient in specific platforms. These teachers could then help upskill their colleagues to ensure the whole school benefits.

Remove Barriers to Attract the Best Talent in Priority Fields

We cannot shape the future without making Britain a go-to place for leading talent. In a population where 14 per cent of UK residents are born in another country, 49 per cent of the fastest-growing businesses in the country have at least one foreign-born cofounder.[72] However, our visa application process is complicated and Brexit has increased friction for would-be migrants.

The High Potential Individual (HPI) visa is a step in the right direction, but it is not accessible to a big chunk of global talent. For example, its academic criteria mean that Silicon Valley feeder schools such as the Indian Institutes of Technology (IITs) and Canada's University of Waterloo are missed out. This could be remedied by including the earning potential of graduates in the selection criteria for the HPI. Furthermore, when applied to narrower domains such as AI, some of the best graduate schools including the Universities of Montreal, Tübingen and Amsterdam are not covered under this route.

Technical recommendation: Introduce talent visas for strategic science and technology priority areas, which accommodate the specialisms of different universities and their graduate-earnings potentials.

Our current system does not incentivise top-performing international students to stay or return to the UK. Our universities are not included in the criteria for the HPI visa while a student visa does not count as time towards an individual's indefinite leave to remain, even for priority talent such as PhD students in UKRI AI Centres for Doctoral Training. We are training world-class talent only to lose it to Europe and the US.

Furthermore, internship visas are still very difficult to arrange. In many key scientific industries, internships and fellowships act as a prerequisite for getting a full-time role.

Technical recommendation: Create a High Potential Student visa for those studying in strategic science and technology priority areas. This should count as time towards an individual's indefinite leave to remain while also being more lenient in terms of working restrictions to enable these students to more easily work for innovative companies or build their own startups. Additionally, a more comprehensive High Potential Internship visa should be created.

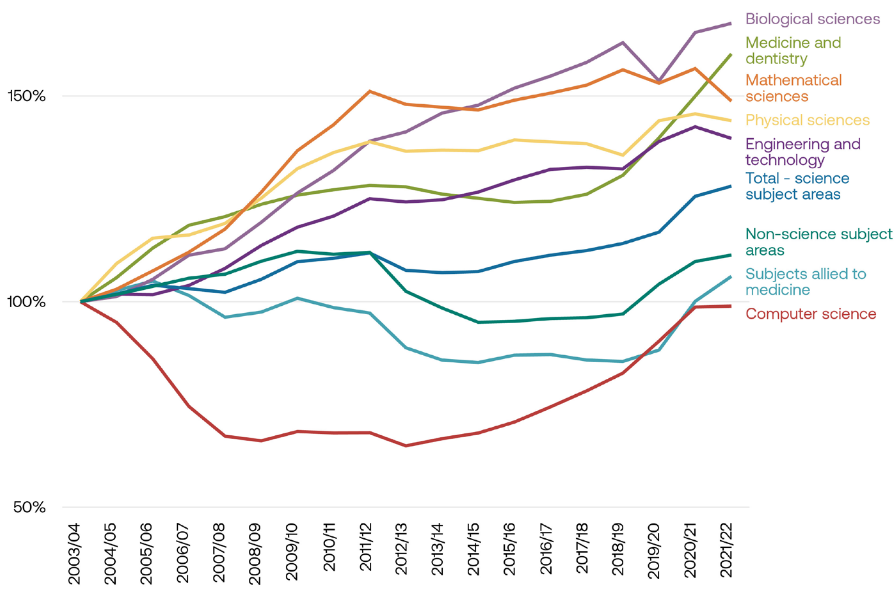
Educate, Train and Retrain Talent to Power the Science Revolution
Realising the UK's science and technology ambitions will be impossible without a large and skilled workforce to discover and roll out technological advances. This will require action on three fronts.

First, more needs to be done to encourage those studying STEM subjects at university to go into professions linked to research and innovation. The latest figures from the Association of Graduate Careers Advisory show that only 8 per cent of physics graduates are working as science professionals 15 months after qualifying compared with 22 per cent in business, human resources and finance. While the figures are better for biology and chemistry students, with more than 30 per cent of each graduate stream becoming science professionals, significant numbers are not using their degree to advance a national innovation agenda.[73]

Second, more must be done to encourage children to study STEM subjects at university. Some progress has been made in recent years, with the number of undergraduates studying STEM subjects having increased 28 per cent over the past 20 years, a growth rate more than double that of non-science-related subjects (11 per cent). Biological sciences and medicine have grown fastest at 68 per cent and 60 per cent respectively, while growth in engineering and technology has been more sluggish, standing at 40 per cent, and the number of computer-science undergraduates has fallen slightly (-1 per cent).

FIGURE 2

The number of UK undergraduates by STEM subject between 2003 and 2022



Source: HESA

Technical recommendation: Boost the number of graduates in engineering and computing by encouraging more women and girls to consider these fields, each of which are currently dominated by men (81 per cent of undergraduates in both are male).[74] Commonly cited barriers for women include stereotyping at school age, a lack of perceived female role models and not enough advice in schools on related careers.[75] Doing more to celebrate female visionaries such as Dr Özlem Türeci (who helped to pioneer mRNA-vaccine innovation for BioNTech) and Kate Bingham could help to elevate the status of female leaders, for example through new public honours for innovators.[76]

Likewise, providing more resources to support women in technology at different stages will help to close the gender gap. Programmes such as Code First Girls, which can be partnered with schools, will help children understand their potential from a young age while expanding doctoral-training support in areas that are experiencing the gender gap the most, such as AI and data science, will also have a similar function.

Although STEM is important for supporting the broader labour market, the elite-level courses already on offer also need reform. There is a supply-side problem at the apex of the technical courses being offered by top UK universities. For example, while Stanford University's computer-science major offers 36 core classes in AI and a further 28 electives, Oxford offers only four and Imperial only one. Oxford continues to offer 32 places for computer science – the same as in 2002. Without scaling up the numbers who can study the best classes in subjects such as computer science, we are limiting our own talent pool and potential.

Additionally, the time taken for UK universities to update their courses holds back students from learning state-of-the-art subject matter. It can take up to three years for a new course to be approved at a UK university. In industries where the pace of progress is measured in months, this means that material could be out of date even before the opening lectures have begun.

Technical recommendation: Reduce the time taken for new courses at UK universities to be approved and scaled to ensure that students have access to cutting-edge research and industrial insights.

Finally, skills training – both for young people and older workers who are seeking to retrain – needs to be mainstreamed. AI and other emerging tech will transform the jobs people do, reducing employment in some sectors and increasing it in others. With the latest government analysis suggesting that approximately 30 per cent of existing UK jobs face a high probability of automation over the next 20 years, ministers will need to provide much more support for workers to retrain.[77]

Technical recommendation: Draw inspiration from cooperative education models such as those pioneered by the University of Waterloo, which incorporates multiple industrial placements into science and engineering undergraduate degrees. This ensures that students have diverse real-world work experience even before graduating. The university has been highly praised by Silicon Valley companies for the quality of its graduates.[78] This approach could be particularly useful in levelling up universities outside the UK's golden triangle of Cambridge, London and Oxford, while increasing the amount of graduates leaving university with applied skills.

Reinvent the Processes of Science and Innovation

To thrive in the 21st century, the UK needs a public R&D ecosystem that can compete with the very best in the world, anchoring global tech networks and attracting international talent. Our location, language, universities and history make us well placed to achieve this goal. But doing so also requires substantially increased investment, reform of our existing funding structures and diversification of our approach.

Increase Public R&D Investment

Public investment is essential to a vibrant R&D system, but the UK public R&D budgets have been among the lowest of any comparable nation for almost 40 years. Public R&D financing is the most reliable predictor of private R&D investment globally, with £1 of public R&D expenditure reliably crowding in £2.5 of private R&D funds at the overall national level.[79]

While the current government's increased R&D investment is very welcome, much of the uplift is the result of taking on the cost of Horizon programmes from the EU,[80] accounting for £6 billion this Parliament, and of an increase to defence R&D, accounting for another £6 billion. Substantially increasing government R&D budgets in other research areas will therefore be critical.

The UK needs to shift its macroeconomic attitude to view public R&D investment as a driver of growth and private R&D financing that pays dividends over time, not as a sunk cost to be traded against other priorities.

Technical recommendation: Increase direct public R&D investment, aiming to become the leader among comparable nations in the metric of public R&D investment as a share of GDP within five years. This should be a key national benchmark, as is our NATO defence-spending target of 2 per cent of GDP and our 2050 net-zero target.

Given the small size of the UK's R&D budget relative to broader government expenditure, this tranche of spending can be markedly expanded without substantial alterations to the national debt. Furthermore, increased spending is likely to pay for itself through economic growth, improved public services and higher productivity, which will increase tax returns. However, such benefits are not immediate and will require patience. Further, it is important to realise that the resulting increase in private R&D investment occurs at the national level, not on an investment-by-investment basis. Expecting direct industry partnership on each individual investment can risk favouring large incumbents or subsiding existing work. Rather, government investment creates a conducive environment in which private industry can grow.

While some may worry about increased investment in difficult economic times, the hidden costs and lost opportunities of inaction and losing the technology competition are much higher – costs that do not factor into current calculations.

In addition to investments outlined in other sections of this paper, increased R&D spending should be directed towards an agenda of reform and diversification rather than a broad expansion of existing options.

Empower Our Universities and Institutions

Government needs to view our nation's key research assets not as employees to be micromanaged but assets to be empowered and nurtured. Every demand for data and metric-based targets reduces the agency, time and freedom of people on the front line, and risks constraining our institutions.

Reform starts with placing greater trust in delivery partners. There is currently far too much bureaucratic control of our top institutions. The Medical Research Council (MRC) Laboratory of Molecular Biology in Cambridge was originally reviewed by one five-page progress report every five years. That report has now grown to 2,000 pages. The Russell Group has even called for a public investigation of this issue.[81] The recent Independent Review of Research Bureaucracy was a step in the right direction, but a wide range of processes from the Department for Education and the Treasury were out of scope and must be addressed.

Technical recommendation: Government should take steps to radically slim down the ever-growing audit culture and reduce the bureaucratic burden it places on our leading research institutions. This should involve removing the Teaching Excellence Framework (TEF), Knowledge Excellence Framework (KEF) and other processes predicated on central management and audit of our top institutions.

The increased number of universities has meant much greater competition for a similar-sized pot of research funding. Furthermore, universities with very different focuses are examined identically through the Research Excellence Framework (REF).

Technical recommendation: Explicitly divide universities into different categories and create special support structures for institutions with an unusual focus, recognising different universities have different missions. This could include specialised arrangements for world-class academic research universities and leading institutions with more specialised technological expertise, such as the University of Strathclyde and Cranfield University.

The cultural challenges outlined above extend beyond universities and institutions to affect UKRI itself. The National Audit Office has identified major challenges in delivery that harm performance caused by excessive control and rules.[82] These should be addressed with ambition and vigour.

Technical recommendation: Commission current and former UKRI CEOs and chairs to report on changes needed to the governance and oversight of UKRI to enable the organisation to perform better. Issues like public-hiring rules and pay scales, Treasury spending controls, and micromanagement by Whitehall should be considered.

Reform Our Funding Approach Through UK Research and Innovation

The UK has a great opportunity to tap into the global appetite for reform and lead on changes to how we organise and fund science.

The notion that there are major challenges with standard research-funding strategies is now mainstream.[83] Commonly cited problems include over-dependence on risk-averse approaches to resource allocation that reinforce the status quo, a short-term funding mindset and a system geared towards funding senior incumbent scientists rather than junior researchers with new ideas.[84] These issues have worsened over time.

As noted above, the system is also highly bureaucratic, with a strong audit culture emphasising paperwork over progress. These challenges are at odds with the need for freedom of exploration, curiosity and scientific creativity that are essential to promoting world-changing innovation, as highlighted by Lord Martin Rees and others.[85] Our research funders are also constrained by legacy academic disciplines and dependent on large institutional bureaucracies renowned for slowness and caution.

The elevated R&D investment that we argue for should therefore be matched by a substantial reform agenda driven by UKRI. This should aim to increase the agency of people and teams on the front line, place greater trust in researchers, and adapt science for the interdisciplinary, technology-intensive research of the 21st century. Some of this will come from the changes to the government's approach to investment outlined above, but there are several other reform directions to promote innovation:

Technical recommendation: Restructure UKRI for 21st-century challenges. UKRI is currently organised as nine separate funding organisations, mostly defined by decades-old academic disciplines. These silos are not appropriate for the challenges ahead. UKRI should use the authority granted in the 2017 Higher Education and Research Act to create new bespoke research councils as needs arise. These councils could focus on strategic challenges and opportunities such as AI while remaining independent from the larger institutional bureaucracy and acting with agility through programme-manager-led approaches.[86] UKRI should also take steps to have a richer diversity of researcher backgrounds, diversifying beyond the academic hierarchy.

Technical recommendation: Reorient the UK funding portfolio to attract and give independence to the large pool of junior talent. Globally, more and more power has moved to senior researchers, resulting in major concerns about the culture of research, an exodus of junior talent and an entrenchment of old paradigms, for example in academic AI.[87] While initiatives like the Francis Crick Institute and the Janelia Research Campus have focused on recruiting and empowering junior talent, this has not been adopted at a national level in the UK.

Technical recommendation: Fund long-term teams, not projects. Our best researchers spend their time applying for many short, incremental grants. Learning from the world's leading non-profit research endowments like the Wellcome Trust and Howard Hughes Medical Institute, as well as Horizon, and the "research centre" approach pioneered at UC Berkeley,[88] we should give sustained, long-term support to world-class research groups, freeing the best research teams from the hyper-competition and pressures of the overall system, with particular focus on early- and mid-career. We should also experiment in Y Combinator and Entrepreneur First-style support programmes for teams of junior talent.

Technical recommendation: Embrace metascience experimentation in funding mechanisms. UK mechanisms of research funding have remained largely unchanged for decades. UKRI should be given a specific objective of experimenting with new approaches to funding, in line with the work of the UK Research on Research Institute.[89] For example, it could introduce funding lotteries to alleviate grant-proposal-optimisation pressure, as well as approaches such as funding-by-variance and "golden tickets" to reward non-consensus ideas.[90] UKRI's Economic and Social Research Council should also embark on a metascience research programme.

Create New Research-Institution Networks and Approaches Adapted to the 21st Century

We need new institutions specifically adapted to 21st-century science. The practice of science and technology has changed dramatically in recent decades, becoming more interdisciplinary, technology dependent, teams focused and globally competitive. Meanwhile, our institutions remain largely unchanged.

The UK once led the world in pioneering new institutional models of organising and convening researchers, such as the Royal Society and the MRC Laboratory of Molecular Biology. However, recently it has not kept pace with institutional innovation in other countries, especially the US.[91] The UK must be at the forefront of reinventing how science and technology is funded and organised to recapture its lost lead.

Countries like Germany and the US have highly diverse institutional landscapes for R&D, with specialised networks of research organisations that have specific missions. Germany has the Max Planck Society, Fraunhofer, Helmholtz Association and Leibniz Association, each with multi-billion-euro government funding annually. This approach recognises that different organisational models are suited to different kinds of challenges and have different incentives, and the approach promotes a diversity of research cultures.

By contrast, R&D budget cuts in the UK since the 1980s have led to the most homogenous research system of any comparable nation with a strong dependence on university research,[92] leading to high-profile calls for a more diverse approach.[93] While universities have many strengths, they are not designed for all kinds of problems,[94] suggesting a need to move beyond a one-size-fits-all model. As noted by research-policy expert James Wilsdon, "if there is an iron law of research policy it is that plurality and diversity are really important".[95]

Technical recommendation: Expand funding for the Advanced Research and Invention Agency (ARIA) to embed nationwide programme-manager-led research. ARIA is the first ARPA-style agency outside the US and the legislation establishing it affords it key legal freedoms and independence to be a genuine ARPA agency, closely modelled on DARPA's independence from the US Department of Defense. ARIA also has the freedom to engage in broader metascience-related experimentation. However, as has been widely noted ARIA has an extremely modest budget averaging only £200 million per year, roughly one-fortieth the annual US ARPA investment and one-twentieth DARPA's alone, barely the size of a single major DARPA project. ARIA should be funded at a much higher level to operate with strategic significance.

Technical recommendation: Create a network of "Lovelace Disruptive Innovation Laboratories" to create industries of the future.[96] Currently, the UK lacks a mechanism to bring a diversity of skilled, world-class talent to bear on nascent fields of technology at the pre-commercial stage. This lack of "mission" or "vision" focused institutions is a major gap. The UK should invest in a network of research institutes tasked with securing our lead in established competitive areas like synthetic biology and AI as well as pioneering new ones with speculative, risky bets as we did in creating the Cambridge Laboratory for Molecular Biology in the 1950s. The proposed institutes should be benchmarked to leading international competitors in core funding and bring together a critical concentration of researchers across science and engineering. This would apply lessons from the historical examples of Bell Labs, Xerox PARC and more recently Google DeepMind and Gerry Rubin's Janelia Research Campus, which share many common features that differ markedly from conventional research environments. This network could be named in honour of a British technological visionary, such as Ada Lovelace, seeking to find and nurture today's equivalents of her vision.

Technical recommendation: Expand the Catapult Network in size and role to empower applied innovation. Modelled on the German Fraunhofer network, the nine leading technology and innovation centres that comprise the Catapult Network have a mission focused on applied research close to industry, but they are currently limited in scope and scale. The Catapults should be broadened in role, given greater independence, diversified in target and expanded in number so they can act as devolved hubs of regional development. New Catapults should be created, for example learning from the "Living Labs" such as the Glasgow Living Lab,[97] which brings together local universities, NHS trusts and industry to experiment and deploy solutions in real-world scenarios.

The new institutional networks should be given a royal charter and placed on a separate legal footing, as they are in Germany, with mission, defining principles and independence codified in legislation. This will help ensure they have the durability and independence to have a lasting impact.

Beyond restoring research diversity by copying the successes of our peers, the UK state should also look forward to entirely new modes of disruptive science. One example is the emergence of distributed research collectives such as EleutherAI, the Large-scale Artificial Intelligence Open Network (LAION) and CarperAI that have pushed the frontier of AI research. These self-organising groups of independent researchers have flat hierarchies, are coordinated on unconventional online forums such as Discord servers and are open for anyone to join without consideration of credentials.

In addition to their work producing highly impactful AI models and data sets for release as public goods, distributed research collectives have served a secondary purpose in finding and empowering otherwise hidden talent that traditional academic systems ignore or fail to support in a timely manner. Researchers discovered through these collectives have gone on to build AI startups or have directly joined elite industrial labs such as OpenAI.

Technical recommendation: Support distributed research collectives to democratise research, uncover talent and broaden opportunities for researchers throughout the UK. The government should empower young, online communities through access to scientific-computing infrastructure or direct funding and explore how to replicate the unconventional approach of these collectives in areas of science and engineering beyond AI.

Incentivise Century-Defining Companies and Industries

Venture capitalist Matt Clifford has written about the need to create greater talent density and a virtuous circle of entrepreneurship. One of the keys to the strength of Silicon Valley as a tech hub, for example, is that successful founders go on to invest in new founders. In his view, efforts need to include raising the "status of entrepreneurship" to become a destination of choice for top technical talent, as well as building more clusters. He argues that if incentives are set up correctly, "the results are self-perpetuating. More high-quality entrepreneurs mean greater network density for the next generation of founders. And entrepreneurs with denser networks have better ideas, get better advisers and generate more revenue."[98]

Improving the density of entrepreneurial talent in the UK requires reforms to education and skills, as mentioned above, as well as political leadership. In recent months the government has cut policies such as R&D tax credits and Business Asset Disposal Relief, decisions that have been met with concern from those building companies in the UK and prompted some to look at options to relocate overseas.[99] This comes as other countries are adopting policies to encourage scale-ups in frontier tech, including new funds such as Germany's Deep Tech & Climate Fund (DTCF) and France's ambition to create 500 deep-tech firms and 100 unicorns.[100]

Unlock Massive Growth Equity

The UK has produced more tech unicorns – young companies valued at more than $1 billion – and secured more venture-capital investment than any country in Europe. Yet we have struggled to turn this entrepreneurship to our advantage.

One of the challenges is encouraging the patient, long-term capital and first-of-a-kind financing that is critical in deep tech, including in climate and biology, as technologies of this kind often face "valleys of death": first, in proving that ideas that come out of the lab can scale; second, in trying to commercialise technologies that have larger capital requirements than software and are not suited to traditional venture capital.

Wider reforms are also needed to encourage entrepreneurship and VC funding, such as passing the London Stock Exchange listing reforms recommended in the UK Listings Review chaired by Lord Hill and the Kalifa Review of UK FinTech, including allowing dual-class share options. Some implementation has begun to happen but given that London accounted for only 5 per cent of IPOs globally between 2015 and 2020, action needs to be quicker.

The British people stand to benefit if we get the incentives right.

One critical issue in taking advantage of our technological strengths is the UK's ability to effectively deploy the capital it does have. Currently, the UK has the second largest pensions market in the world. Despite this advantage, overseas pensions invest 16 times more in venture capital and private equity in the UK than domestic public and private pensions do.[101]

For example, in 2021, the £330 billion Canadian Pension Plan (CPP) invested £300 million in one UK-based company, equivalent to the average size of a UK defined-benefit (DB) pension fund (£330 million) and more than the entire UK pensions system invested in private equity and growth capital (£190 million) that year.

The CPP was started in 1999 with around £9 million in taxpayer funding. At the end of 2022, the CPP Investment Board managed £330 billion in assets, making it 1,000 times the average size of a UK DB private-sector pension fund and 8.5 times the size of the £39 billion UK Pension Protection Fund (PPF).[102]

Despite startup financing being the focus of several government reviews and new funds, the UK has continually struggled to deliver a sufficient scale and volume of patient and growth capital to the country's startup companies.

The UK's DB pensions industry is fragmented, with over 5,300 schemes with an average size of £330 million. Their investment strategies, driven by risk-averse corporate sponsors and finite investment horizons, have typically pursued a zero-risk approach.

According to Michael Tory, co-founder of the advisory firm Ondra Partners, the UK is one of the only major economies where domestic pension funds have in effect abandoned investment in UK companies.[103] The proportion of UK pension funds invested in bonds increased from less than 20 per cent in 2000 to 72 per cent in 2021, even as their investments in UK equities dropped from 50 per cent of their asset allocation in 2000 to just 4 per cent in 2021.[104]

Overall, larger pension funds have generated higher returns for pensioners. The £330 billion Canadian Pension Plan Investment Board's (CPPIB) annualised return for the past ten years (net of its investment costs) was 10.8 per cent and £39 billion PPF returned 9.2 per cent, compared to just 6.2 per cent for the UK's private-sector DB schemes.

These rates of return compound over time and, coupled with new pension contributions, have allowed the CPPIB to diversify its asset allocation and make individual investments that dwarf the capacity of UK pension funds. The PPF generates higher returns because it allocates 41.5 per cent of its portfolio to return-seeking assets, while the rest of the UK pension system invests almost 75 per cent of its portfolio in fixed-income assets and only 5 per cent in private equity and growth capital.[105]

Until recently, defined contribution (DC) pensions have largely avoided investing in private equity because of concerns that performance fees, typically levied by private-markets managers, would put them at risk of breaching the 75 basis-point cap on retirement savers' fees. To date, most of the reforms for pension funds have focused on adjusting the 75 basis-point charge cap for DC pensions to allow fund managers to better accommodate performance fees and allow investment in private markets. Yet fees in other countries are often lower,[106] raising questions about the extent to which the fee structure is the problem and suggesting the fragmented nature of the UK DC pensions industry is a bigger issue.

The UK could use pension consolidation, as recommended by Sir John Bell, Martin Wolf and Michael Tory, to generate a £100 billion UK Pension Plan Investment Fund that would provide funding across multi-decade horizons with independent oversight.[107] Done right, it could give future generations a stake in Britain's success as a science and tech superpower.

Technical recommendation: Incentivise consolidation in the UK pensions system. The DB system should be consolidated from over 5,000 schemes to 100 or less and the DC system should shrink from over 27,000 individual employer schemes to a smaller set of master trusts. To encourage consolidation, the pension capital-gains tax exemption should only remain for funds with over £25 billion under management and that allocate 25 per cent of their funds to UK assets (for example infrastructure, equities or growth companies).

Technical recommendation: By combining PPF and NEST to create a single investment vehicle that participates in market consolidation, the UK could create a £100 billion UK Pension Plan Investment Fund with a mandate to invest 25 per cent of its assets in UK infrastructure, equities and growth companies. The fund should be managed independent from government oversight.

Eliminate Barriers to Academic Spinouts

Taking cutting-edge research from university labs to commercial success remains a critical challenge in the UK. This has long been identified as a problem, and the government has commissioned multiple reviews in recent years (MacMillan, Rees, Dowling, independent research commissioned by BEIS, Lambert).[108] Air Street Capital's Nathan Benaich has argued[109] that technology transfer offices (TTOs) are more of a hindrance than a help and should be reformed, and has put forward suggestions to do this.[110]

Technical recommendation: The options for how TTOs manage intellectual property can be simplified and made more transparent. Introducing a "Simple Agreement to Spinout" (SAS) would give TTOs a one-off payment for any patents used by the spinout and the option to select from the following options: 1) a common equity stake, 2) a small per cent royalty on net sales (direct or sub-licensing based) in the case of clearly identified

IP over a drug molecule or medical device, or 3) a small per cent on exit. If the spinout does not use licensed IP for 24 months, it must return it to the university for recycling. No other fees are levied.

Technical recommendation: The goal and assessment criteria of TTOs should be recast as maximising the number of spinouts formed under the SAS, with a commitment to complete the process in no more than three months.

Reform Planning – Including Tech Infrastructure Exemptions

The limitations of current planning regulations for economic growth and inequality are well known.[111] This is a particular issue in science and technology. New infrastructure is vital for R&D endeavours, but the current planning system is a major time and resource constraint. It curtails the ability of entrepreneurs to build the infrastructure they need and attract talent due to high costs and delays. For example, there is currently demand for around a million square feet of laboratory space in Cambridge, but only 10,000 square feet available.[112] Long delays also curtail endeavours in areas like nuclear fusion and advanced manufacturing where international competition for attracting partners is intense.

Technical recommendation: Pursue broader planning reforms to ensure infrastructure projects that are critical to the UK's economic transformation can get approval in six months or less. This will mean reviewing, modernising and streamlining every step of the process, including the 2008 Planning Act, the process for setting out and updating National Planning Statements, and the process for local consultation and environmental audits. There must also be greater flexibility for amending a development-consent order once it has been submitted. A minister could be given responsibility for bringing together state actors – from local authorities and community groups to grid operators and planners – to speed planning approval and project delivery.

The construction of tech-relevant infrastructure such as laboratories is a very small part of overall building but has a disproportionate impact on the economy. It is an area where speed is vital.

Technical recommendation: Create exemptions and fast-track processes for R&D infrastructure planning. This would allow rapid clearance of planning proposals in technology areas, prioritisation in planning and potentially access to sites otherwise not deemed available for development.

Build International Partnerships to Scale Our Efforts

To be a world leader in science, the UK will need to work with other countries to boost international innovation, set global standards for the responsible use of technology and share the benefits of technological advances to help improve the lives of the world's most vulnerable people.

Boosting International Innovation

It is clearly not feasible for the UK to cultivate a strategic advantage in every aspect of future technology. Even in areas in which we are well placed to succeed, like AI and the life sciences, we will need to cooperate with other countries. The government is seeking new bilateral science partnerships to replace the kind of research links we enjoyed within the EU – in the past three months alone this has included deals with Saudi Arabia on space-based solar power and critical minerals, the launch of a new International Science Partnerships Fund with Japan and a set of projects with South Africa to tackle antimicrobial resistance.[113] But without a strategy to connect these kinds of deals and outline the broad contours of our domestic and international priorities on innovation, we risk a scattergun approach to this agenda. Ministers should take action on two fronts to address this.

First, the government should secure structured cooperation on science and innovation with our most important partner in this space: the EU. From Horizon to Euratom, the bloc has some of the most successful science programmes in the world, and these have been enhanced by the UK's involvement as a member state. The UK and EU agreed to discuss structured cooperation in science and research, particularly on

Copernicus, Horizon, Euratom and the European component of international nuclear-fusion megaproject ITER,[114] but this has not been possible due to the dispute over the Northern Ireland Protocol.

Associate membership of Horizon Europe, the world's largest collaborative research programme, would help the UK build stronger research links both inside and outside Europe. Under Horizon Europe's predecessor, Horizon 2020, the UK established more than 237,000 collaborative research links in 163 countries, with 12 per cent of the individual links outside the EU.[115] Although the government is right to try and replace Horizon funding while awaiting certainty over the UK's participation,[116] the true value of the programme lies in these cross-border research collaborations, which are harder to replace. Meanwhile, participation in Copernicus would help the UK stay at the forefront of Earth-observation technology, and involvement in Euratom will help ministers deliver on their UK fusion strategy. With the Conservatives, Labour and scientific institutes in both the UK and the EU all keen to see British involvement in these schemes,[117] ministers should seek to secure participation as a matter of urgency.

Furthermore, ministers should also consider seeking participation in the European Defence Fund (EDF). Industry figures have expressed their concerns about the impact of non-participation on the UK's defence sector,[118] and the European Commission's plans to launch a new European Defence Investment Programme are likely to damage our domestic sector further.[119] Given the benefits of closer defence alignment for European security and the commitment in the 2019 Political Declaration to explore the UK's participation,[120] the EU would likely be receptive to an application to take part in the EDF.

Technical recommendation: If the government can resolve the Northern Ireland Protocol dispute, it should seek associate membership of EU research programmes, including Horizon, Copernicus and Euratom, as a matter of urgency. It should also consider seeking participation in the EDF.

The second action ministers should take is to publish a long-term strategy for their planned approach to international partnerships on science and innovation. Using the Integrated Review's "own–collaborate–access" structure, this strategy should identify the areas in which the UK will seek to establish ownership of technological advances, collaborate with other countries on joint research endeavours and access critical science and technology from others.[121] Setting this out in a clear strategy will provide investors with greater confidence about which aspects of the UK's tech sector they should invest in, as well as making it easier to monitor government efforts to reduce tech reliance on strategic competitors like China.

As part of this strategy, the UK should in particular prioritise research links with Japan, given both countries' expertise in science and innovation and their desire to strengthen ties in response to growing uncertainty in the Indo-Pacific. Supercomputing in particular would be a strong area for greater cooperation: to lead in this sector, the UK needs Japan's expertise in advanced manufacturing, electronics hardware and robotics, while Japan needs the UK's experience in the commercialisation of both AI and quantum. A government-led national-innovation partnership covering these areas would help both countries leverage their complementary strengths in supercomputing.[122]

Technical recommendation: The government should publish a long-term strategy for international partnerships on science and innovation, using the "own–collaborate-access" framework to identify approaches for different sectors.

Setting Global Standards for the Responsible Use of Technology
While scientific and technological innovation can transform the world for the better, used in the wrong ways by hostile states or terrorist groups it can also be a tool of repression and authoritarianism. Take, for example, the Chinese Communist Party's use of surveillance technology to facilitate their oppression of ethnic minorities in Xinjiang. The UN has highlighted reports that the monitoring of the Uyghurs is being driven by "an ever-present network of surveillance cameras, including facial-recognition capabilities" and "broad access to people's personal communication devices and financial histories, coupled with analytical use of big-data technologies".[123]

As innovation accelerates, the potential capabilities of digitally enabled authoritarianism will only increase. Countries like the UK that value human rights and democratic norms need to do more to embed safeguards for responsible use of these emerging technologies within global frameworks. True leadership on science and innovation is therefore as much about developing frameworks for moral governance of new technology as it is about developing technology itself.

But China is currently shaping these frameworks, not the UK. As the Foreign Affairs Committee noted, that Beijing made 90 per cent of the standards proposals for surveillance technologies at the International Telecommunication Union between 2016 and 2019 shows China's firm intention to set the rules of the road for future technology.[124] But with a new national purpose underpinning science and innovation, coupled with our existing soft power, the UK should also play an important role in setting these rules.

The best way to achieve this would be to develop some form of structural cooperation on tech standards with the US and the EU, who regularly liaise on this issue through their Trade and Technology Council.[125] The informal E3 diplomatic coalition of the UK, France and Germany, with semi-regular meetings to discuss shared foreign-policy objectives, offers a potential model for what this kind of structural cooperation could look like. Meeting regularly to coordinate positions on tech standards, a "T3" of the UK, US and EU would be in a powerful position to influence international-standards bodies.

Technical recommendation: The UK government should seek to establish a new informal "T3" coalition between the UK, EU and US to find areas of common ground on global technology standards.

Leadership on the global regulation of AI is particularly crucial, given the technology's potential for use by authoritarian governments. The UK has a natural advantage in this space due to the co-location of both technical and governance expertise in London, which does not exist in either Brussels or Washington, DC. The UK should serve as a mediating ground for aligning the AI approaches of our allies and agreeing standards that help to solve immediate challenges in a low-risk way, for instance by allowing governments negotiated access to their citizens' private medical data. As progress in this space is currently driven by private-sector actors, there will also need to be much better information sharing between these leading innovators, as well as with government and academia. The government should enable interfaces between these innovators and other aspects of civil society – for instance through citizens' assemblies, external ethics oversight and ombudspersons.

While we currently have an absolute advantage over all other countries except the US and possibly China in the field of AI, it is in our best interests to prevent a "race to the bottom" in which the speed of progress in AI would outstrip our ability to oversee and control it in a safe manner. We may only have a limited window of opportunity in which to leverage our leadership towards this. We should pursue more ambitious and multilateral science diplomacy in AI, drawing inspiration from initiatives in other areas such as the International Space Station, CERN and ITER, in a way that embeds our leadership and values into the frontier of this field.

Technical recommendation: The UK should initiate and lead a multilateral scientific effort at the forefront of AI to ensure that this technology is developed safely, in alignment with our values, and has liberal democratic oversight and control.

As the impacts of AI may emerge suddenly and unexpectedly, the UK should also lead on its proactive and anticipatory governance. In particular, we should look beyond sector-specific regulation and focus attention on general-purpose AI systems. These systems will underpin progress across many sectors at once, and will require significantly more technical expertise than downstream sectoral users will possess to deal with these impacts.

Technical recommendation: The UK should develop proactive and anticipatory governance of general-purpose AI. This would require better benchmarking of AI progress, even against speculative concerns, as well as improved oversight of the development of advanced systems, such as through monitoring and reporting on compute infrastructure used for training AI.

The UK, in partnership with its allies, should also consider using export controls on AI to prevent authoritarian countries using our technological advances to commit human-rights abuses; many experts are now calling for such controls.[126] Here we can learn from the US, which recently introduced export controls to prevent AI computer-chip designers from selling to China.[127] The UK also has an opportunity to lead R&D developments such as compute monitoring and verification that will be necessary to uphold such controls, and future treaties on the training and deployment of advanced AI. The UK's National Security and Investment Act 2021 and its associated regulations already allow for government intervention in AI-related business transactions that could impact national security.[128] However, some experts have criticised ministers for being reluctant to use these powers.[129]

Technical recommendation: The government should work with other liberal democracies to introduce export controls on AI to authoritarian countries, and show more willingness to intervene in takeovers of and investment into UK AI companies by groups linked to authoritarian states.

Sharing the Benefits of Technological Advances

Alongside the benefits that science and technology can bring for the country's people, UK leadership on innovation can also help improve the lives of the most vulnerable people across the globe. For example, UK leadership on gene editing could present opportunities for developing countries to grow crops without having to buy expensive seeds from multinational firms, or help to increase crop resistance to adverse weather conditions as climate change accelerates.[130]

Leaving aside the moral argument for a more innovation-centred approach to international aid, there are strong geopolitical benefits. During the Covid-19 pandemic, while Western countries hoarded their vaccines, Beijing saw the potential to enhance its reputation by donating vaccines to target countries such as Cambodia and Ethiopia.[131] Although the soft-power benefits of this vaccine diplomacy were blunted by the comparatively low efficacy of the vaccines, as China's technological prowess advances across multiple sectors the soft-power benefits of technological aid to other countries will only increase.

The UK needs to learn from China's approach and focus more of its international aid on sharing the benefits of technological advances. While the proportion of international aid earmarked for research and innovation increased year-on-year between 2016 and 2020, overall cuts to aid have disproportionately affected this area. Regardless of whether the government should reinstate the UN-recommended 0.7 per cent target for aid (having reduced the target to 0.5 per cent from 2021), ministers should consider prioritising more of the UK's international-aid budget for boosting science and innovation in developing countries.

FIGURE 3

Official development assistance for research and innovation, 2016–2021[132]

	2016	2017	2018	2019	2020	2021
BEIS – Research and innovation ODA (£m)	337	443	533	622.5	607	368
Total government ODA (£m)	12,377	14,051	14,542	15,176	14,477	11,423
Percentage spent on R&I	2.5%	3.2%	3.7%	4.1%	4.2%	3.2%

Source: FCDO, Statistics on International Development: final UK aid spend 2021, 23 Nov 2022; BEIS, Annual reports and accounts, 2016–2021

As we advance our global leadership in AI in particular, we should safeguard this technology against harmful use, while sharing access to our supercomputing resources and advanced AI technologies with developing countries for their benefit and ours, as US President Dwight D Eisenhower's "Atoms for Peace" campaign sought to safely share nuclear technology 70 years ago.

Technical recommendation: Significantly increase the proportion of international aid spent on research and innovation, including through in-kind access to supercomputing resources and advanced AI technologies with developing countries for geopolitical and social benefit.

Conclusion

The British people need a new national purpose – one that is bold and optimistic. It must recognise the principles of ambition, invention and compassion that characterise our collective spirit.

We have the opportunity to shape a radically different future for Britain. One that embraces technology to restore our natural environment, helps people live longer, healthier lives and creates well-paid, internationally competitive jobs across all four nations of our country. Achieving this will require a once-in-a-generation shift in our operating model and a whole-economy transformation in how we work and innovate.

While there are many challenges to confront, we must not be pessimistic about our future. Ahead of us is the opportunity to make the UK a force for the next century – it's an opportunity we must seize.

Acknowledgements

The authors would like to thank Nathan Benaich (Air Street Capital), Ben Johnson (University of Strathclyde), Jack O'Meara (Ochre Bio) and James Wise (Balderton Capital) for reviewing the report.

Endnotes

1 https://institute.global/policy/industrial-revolution-politics-and-public-policy

2 https://www.ultimagenomics.com/blog/ultima-genomics-delivers-usd100-genome/

3 https://epochai.org/blog/compute-trends

4 https://www.bloomberg.com/opinion/articles/2022-10-24/california-poised-to-overtake-germany-as-world-s-no-4-economy

5 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4803755/

6 https://www.reuters.com/technology/chatgpt-sets-record-fastest-growing-user-base-analyst-note-2023-02-01/

7 https://www.utoronto.ca/news/researchers-use-ai-powered-database-design-potential-cancer-drug-30-days

8 https://www.wired.co.uk/article/ai-labor-interns; https://arxiv.org/abs/2212.08198

9 https://www.ft.com/content/7229ba86-142a-49f6-9821-f55c07536b7c

10 https://www.theverge.com/2023/1/17/23558516/ai-art-copyright-stable-diffusion-getty-images-lawsuit

11 https://www.top500.org/statistics/list/; https://www.stateof.ai

12 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1079959/DCMS_and_OAI_-_Understanding_UK_Artificial_Intelligence_R_D_commercialisation__accessible.pdf

13 https://jack-clark.net/2023/01/30/import-ai-316-scaling-laws-for-rl-stable-diffusion-for-160k-yolov8/

14 https://www.ft.com/content/6670acad-8a5b-4c4a-b6a8-48dc307b6d4d

15 https://institute.global/policy/brexit-discount-leaving-uk-firms-vulnerable-foreign-takeovers

16 https://www.gov.uk/government/publications/establishing-a-pro-innovation-approach-to-regulating-ai/establishing-a-pro-innovation-approach-to-regulating-ai-policy-statement; https://www.gov.uk/government/publications/national-ai-strategy/national-ai-strategy-html-version

17 https://www.gov.uk/government/publications/the-roadmap-to-an-effective-ai-assurance-ecosystem

18 https://www.gov.uk/government/publications/future-of-compute-review

19 https://a16z.com/2021/10/04/the-age-of-tech-x-bio-the-industrial-bio-complex; https://a16z.com/2018/11/12/how-to-engineer-biology

20 https://www.tsungxu.com/p/materials-paradigm

21 https://www.planetarytech.earth/bioeconomy-dashboard-1?utm_source=substack&utm_medium=email

22 https://www.biospace.com/article/biotechnology-market-size-to-worth-around-us-3-44-trillion-by-2030/

23 https://www.airstreet.com/blog/spinouts

24 https://www.gov.uk/government/statistics/bioscience-and-health-technology-sector-statistics-2020/bioscience-and-health-technology-sector-statistics-2020

25 Sector employment is also widely distributed, jobs have a high gross value added (GVA) and creation usually comes in tandem with significant capital-expenditure (capex) investment. https://biotechfinance.org/

26 https://www.gov.uk/government/publications/life-sciences-industrial-strategy; https://www.gov.uk/government/organisations/accelerated-access-review; https://www.gov.uk/government/publications/life-sciences-vision

27 https://grail.com/clinical-studies/nhs-galleri-trial-clinical/; https://investors.biontech.de/news-releases/news-release-details/biontech-announces-strategic-partnership-uk-government-provide; https://www.gov.uk/government/news/uk-cements-10-year-partnership-with-moderna-in-major-boost-for-vaccines-and-research

28 https://www.gov.uk/government/news/over-175-million-for-cutting-edge-genomics-research; https://news.sky.com/story/rishi-sunak-wants-vaccine-taskforce-style-strategy-to-tackle-nhs-missions-like-cancer-and-obesity-12756632

29 https://www.nature.com/articles/s41467-020-19092-2

30 There has been disappointing news on the rollout of a flagship commercial partnership between the NHS and Novartis as a result of insufficient resources within primary-care contracts, lack of trained staff to administer the treatment and insufficient local oversight. This means that thousands of patients have missed out on access to an innovative new treatment and investor confidence has been further damaged. Finally, rising rates of reimbursement under the UK government's flagship commercial agreement with industry for branded medicines (the Voluntary Scheme for Branded Medicines Pricing and Access, or VPAS) is causing many pharmaceutical companies to turn to other markets to launch new drugs, resulting in some leaving the scheme entirely.

31 https://institute.global/policy/setting-pace-accelerating-race-clinical-research-and-drug-development-post-pandemic; https://institute.global/policy/reviving-global-health-systems-how-technology-can-improve-quality-and-quantity-life

32 https://www.iea.org/reports/net-zero-by-2050

33 https://www.brusselstimes.com/328633/us-protectionism-poses-existential-challenge-to-europe-eu-leaders-claim

34 https://media-publications.bcg.com/BCG-Executive-Perspectives-US-IRA-Global-Implications.pdf

35 https://iea.blob.core.windows.net/assets/b0beda65-8a1d-46ae-87a2-f95947ec2714/WorldEnergyInvestment2022.pdf

36 https://www.pwc.com/gx/en/news-room/press-releases/2022/state-of-climate-tech-report-2022.html; https://techcrunch.com/2020/09/23/new-report-finds-vc-investment-into-climatetech-growing-five-times-faster-than-overall-vc/

37 https://www.morganstanley.com/articles/ev-investment-adoption

38 https://www.canarymedia.com/articles/nuclear/a-small-modular-nuclear-reactor-just-got-us-approval-a-big-milestone

39 https://technation.io/climate-tech-report-2022/#key-statistics

40 https://www.gov.uk/government/news/ukaea-and-commonwealth-fusion-systems-sign-agreement-to-advance-fusion-energy

41 https://institute.global/policy/gaining-more-bang-fusions-buck-pivot-support-programmes#:~:text=Pivot%2Dsupport%20programmes%20harness%20technology,Instead%2C%20they%20are%20a%20complement

42 https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai

43 https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html; https://ec.europa.eu/commission/presscorner/detail/en/IP_22_921

44 https://www.nature.com/articles/d41586-022-03414-z

45 https://www.cnas.org/publications/reports/myths-and-realities-of-chinas-military-civil-fusion-strategy

46 https://www.csis.org/analysis/assessing-new-semiconductor-export-controls

47 "[Xi Jinping] does not believe democracy can be sustained in the 21st century because things move so rapidly, technologies changing so much, democracies don't have time to arrive at a consensus, that's where autocracies will succeed." – President Joe Biden, March 2022 https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/03/17/remarks-by-president-biden-at-the-annual-friends-of-ireland-luncheon/

48 https://www.mckinsey.com/featured-insights/employment-and-growth/poorer-than-their-parents-a-new-perspective-on-income-inequality

49 https://bills.parliament.uk/bills/3167; https://www.gov.uk/government/consultations/consultation-on-proposals-for-legislative-changes-for-clinical-trials

50 https://vegconomist.com/cultivated-cell-cultured-biotechnology/cultivated-meat/ivy-farm-production-facility-international-expansion/

51 https://www.ft.com/content/2b40824f-69c6-4768-b313-a544fc1a00d7

52 https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins ukgrossdomesticexpenditureonresearchanddevelopment/2020

53 https://www.economist.com/britain/2022/08/25/reducing-the-power-of-the-treasury-is-a-good-idea

54 See Figure 7 in link, https://www.civilservant.org.uk/library/2021-IfG-civil-service-skills.pdf

55 https://www.aei.org/economics/why-freedom-and-creativity-are-crucial-for-scientific-progress-my-long-read-qa-with-don-braben/; Lord Martin Rees, If Science is to Save Us, 2022

56 https://www.gov.uk/government/publications/terms-of-reference-for-the-review-of-regulation-for-emerging-technologies; https://www.theguardian.com/politics/2021/sep/27/labour-promises-spend-28bn-year-tackling-climate-crisis

57 https://www.worksinprogress.co/issue/buyers-of-first-resort/

58 https://institute.global/sites/default/files/2021-07/Tony%20Blair%20Institute%20%26%20The%20Entrepreneurs%20Network%2C%20The%20Way%20of%20the%20Future%2C%20July%202021_0.pdf#page=11

59 https://www.ycombinator.com/rfs

60 https://www.ai.gov/wp-content/uploads/2023/01/NAIRR-TF-Final-Report-2023.pdf

61 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3962497/

62 https://www.digitalhealth.net/2019/07/nhs-data-worth-9-6bn-per-year-says-ernst-young/

63 https://www.embl.org/news/science/alphafold-using-open-data-and-ai-to-discover-the-3d-protein-universe/

64 https://www.ft.com/content/e9cc9889-5711-4842-8e3c-bcb752e2c598

65 https://www.atlanticcouncil.org/blogs/ukrainealert/ukraines-digital-revolution-continues-with-enhanced-legal-status-for-e-passports/

66 https://www.gov.uk/government/publications/graduates-and-economic-growth-across-countries

67 https://explore-education-statistics.service.gov.uk/find-statistics/school-workforce-in-england#dataBlock-9b2ede01-e72f-429f-bf74-8b334e403fa6-charts

68 https://www.gov.uk/government/publications/teacher-workload-survey-2019

69 https://educationendowmentfoundation.org.uk/projects-and-evaluation/projects/covid-19-disruptions-in-primary-schools-attainment-gaps-and-school-responses

70 https://www.unesco.org/en/articles/century-ai-powered-teaching-and-learning-platform

71 Tom Moule, Cracking Social Mobility: How AI and other innovations can help to level the playing field, 2021

72 https://www.tenentrepreneurs.org/immigrantfounders

73 https://graduatemarkettrends.cdn.prismic.io/graduatemarkettrends/71145492-99f4-4134-9e6f-8e694edb398f_what-do-graduates-do-2023.pdf

74 https://www.hesa.ac.uk/news/19-01-2023/sb265-higher-education-student-statistics/subjects

75 https://www.pwc.co.uk/women-in-technology/women-in-tech-report.pdf

76 https://antonhowes.substack.com/p/age-of-invention-honours-for-innovators

77 https://www.gov.uk/government/publications/the-potential-impact-of-ai-on-uk-

employment-and-the-demand-for-skills

78 https://www.wsj.com/articles/why-silicon-valley-recruiters-are-flocking-to-ontario-1462385408

79 https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgrossdomesticexpenditureonresearchanddevelopment/2020; https://www.nesta.org.uk/report/the-missing-4-billion/

80 Funding previously went from the Treasury to the EU and did not count as public R&D expenditure. This accounts for £6 billion of spending during this spending review.

81 https://guildhe.ac.uk/guildhe-regulation-briefing-regulation-of-higher-education-in-england-is-there-another-way/; https://russellgroup.ac.uk/news/higher-education-mission-groups-call-for-inquiry-into-the-office-for-students/; https://www.thetimes.co.uk/article/russell-group-universities-call-for-inquiry-into-office-for-students-8d8ds5ltb

82 https://www.nao.org.uk/wp-content/uploads/2021/02/UK-Research-and-Innovations-management-of-the-Industrial-Strategy-Challenge-Fund.pdf (see for example point 15 on page 9 and point 17 on page 10)

83 https://scienceplusplus.org/metascience/index.html

84 https://www.wsj.com/articles/stagnant-scientific-productivity-holding-back-growth-11668700829; https://www.theatlantic.com/ideas/archive/2022/01/scientific-funding-is-broken-can-silicon-valley-fix-it/621295/

85 https://www.researchprofessionalnews.com/rr-news-uk-views-of-the-uk-2022-11-uk-universities-are-losing-their-edge-in-research/; https://wellcomecollection.org/works/nabj5v7x; https://www.aei.org/economics/why-freedom-and-creativity-are-crucial-for-scientific-progress-my-long-read-qa-with-don-braben/; Lord Martin Rees, ***If Science is to Save Us***, 2022

86 https://americanaffairsjournal.org/2022/11/but-seriously-how-do-we-make-an-entrepreneurial-state/

87 https://wellcome.org/reports/what-researchers-think-about-research-culture

88 https://www2.eecs.berkeley.edu/Pubs/TechRpts/2013/EECS-2013-123.html

89 https://researchonresearch.org/

90 Instead of funding grants that get the highest average score from reviewers, a funder should use the variance (or kurtosis or some similar measurement of disagreement) in reviewer scores as a primary signal: only fund things that are highly polarising (some people love it, some people hate it); https://sciencebusiness.net/news/us-national-science-foundation-looks-shake-funding-golden-ticket-pilot

91 https://www.theatlantic.com/ideas/archive/2022/01/scientific-funding-is-broken-can-silicon-valley-fix-it/621295/

92 This is reflected, for example, in the composition of Whitehall Chief Scientific Advisers, of whom at least 75 per cent are or were until recently university professors.

93 https://www.kcl.ac.uk/policy-institute/assets/the-road-to-2.4-per-cent.pdf

94 https://www.worksinprogress.co/issue/the-rise-and-fall-of-the-american-rd-lab/

95 https://www.ft.com/content/df0887ee-a0bc-4467-a457-72a83c7ddf32

96 https://jameswphillips.substack.com/p/lovelace-vision-document-arias-proposed; https://ifm.eng.cam.ac.uk/uploads/Resources/Disruptive_Innovation_Laboratories_Whittle_Cambridge_3_Nov_2022.pdf

97 https://www.gla.ac.uk/colleges/mvls/livinglab/ourprogramme/

98 https://www.tenentrepreneurs.org/the-way-of-the-future#9.5

99 https://www.ft.com/content/f9b8a08a-2e98-4e10-9dd1-188d30408c36

100 https://sifted.eu/articles/germany-1bn-deeptech-climate-fund-news/?utm_medium=social&utm_source=twitter&utm_campaign=content&utm_content=amy_lewin; https://www.eetimes.eu/france-to-invest-e500m-in-deeptech-startups-by-2030/

101 https://www.bvca.co.uk/Portals/0/Documents/Research/Industry%20Activity/BVCA-RIA-2021.pdf

102 https://www.thepensionsregulator.gov.uk/en/document-library/research-and-analysis/db-pensions-landscape-2022; https://www.bing.com/search?q=size+of+the+PPF&cvid=920fb4dbb3424f83b41e19c6b32a0c6c&aqs=edge..69i57j0l8j69i11004.2201j0j1&pglt=41&FORM=ANSAB1&PC=U531

103 https://www.ft.com/content/477318a9-5b05-4305-9e0d-f605431692db

104 https://www.ft.com/content/f4f78487-0e9d-4dea-afe7-425b11e83a4d

105 Ondra Partners and TBI

106 https://newfinancial.org/paper-a-reality-check-on-big-bang-2-0/

107 https://www.ft.com/content/791876ae-7ce2-4c0b-9f7a-c12b4f39f6d5

108 https://www.praxisauril.org.uk/resource/university-knowledge-exchange-ke-framework-good-practice-technology-transfer-mcmillan-2016; https://www.ncub.co.uk/insight/independent-advice-on-university-investor-links-mike-rees-report/; https://www.gov.uk/government/publications/business-university-research-collaborations-dowling-review-final-report; https://www.gov.uk/government/publications/commercialisation-of-university-intellectual-property; https://www.ncub.co.uk/insight/lambert-review-of-business-university-collaboration/

109 https://www.ft.com/content/a2cb4877-c50e-4353-a697-cd5343eaae2d

110 https://www.airstreet.com/blog/spinouts

111 https://www.worksinprogress.co/issue/the-housing-theory-of-everything/

112 https://www.thetimes.co.uk/article/dont-blow-britains-great-life-sciences-chance-tgnr2ksp8

113 https://www.gov.uk/government/news/uk-and-south-africa-to-work-more-closely-on-tackling-pandemics-and-climate-change

114 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/948105/EU-UK_Declarations_24.12.2020.pdf

115 https://russellgroup.ac.uk/media/6090/horizon-briefing-6-oct-2022.pdf

116 https://www.gov.uk/government/news/government-commits-nearly-half-a-billion-pounds-for-uk-research-to-cover-eu-shortfall

117 https://www.thetimes.co.uk/article/europes-science-elite-appeals-for-uk-return-to-horizon-programme-gpnkchljt

118 https://www.researchprofessionalnews.com/rr-news-uk-innovation-2020-3-uk-opting-out-of-multi-billion-eu-defence-r-d-fund/

119 https://www.reuters.com/world/europe/eu-leaders-push-defence-investment-programme-december-summit-draft-2022-11-30/

120 https://www.gov.uk/government/publications/new-withdrawal-agreement-and-political-declaration

121 https://www.gov.uk/government/publications/global-britain-in-a-competitive-age-the-integrated-review-of-security-defence-development-and-foreign-policy

122 https://www.techuk.org/resource/build-an-anglo-japanese-net-zero-computing-capability.html

123 https://www.ohchr.org/sites/default/files/documents/countries/2022-08-31/22-08-31-final-assesment.pdf

124 https://committees.parliament.uk/publications/22998/documents/168554/default/

125 https://digital-strategy.ec.europa.eu/en/policies/trade-and-technology-council

126 https://blogs.microsoft.com/on-the-issues/2020/11/10/openai-partnership-digital-export-controls/; https://www.csis.org/blogs/strategic-technologies-blog/ai-export-controls-national-security; https://cset.georgetown.edu/wp-content/uploads/Recommendations-on-Export-Controls-for-Artificial-Intelligence.pdf; https://www.atlanticcouncil.org/blogs/geotech-cues/the-west-china-and-ai-surveillance/; https://www.brookings.edu/wp-content/uploads/2019/08/FP_20190827_digital_authoritarianism_polyakova_meserole.pdf

127 https://www.csis.org/analysis/choking-chinas-access-future-ai

128 https://www.legislation.gov.uk/ukdsi/2021/9780348226935/schedule/3

129 http://uktech.news/news/government-and-policy/flusso-acquisition-alicia-kearns-20230118

130 https://institute.global/policy/gene-editing-food-production-charting-way-forward

131 https://www.aa.com.tr/en/asia-pacific/china-gives-ethiopia-10m-covid-19-vaccine-doses/2623625

132 Note, due to the nature of international aid and the projects funded, authoritative definitions of the amount of ODA spent on science and innovation are difficult to conclude. This table shows aid specifically designated for research and innovation by BEIS.

TONY BLAIR INSTITUTE FOR GLOBAL CHANGE

Follow us

facebook.com/instituteglobal

twitter.com/instituteGC

instagram.com/institutegc

General enquiries

info@institute.global