

UK Research and Development Roadmap



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Foreword

The UK is internationally recognised for our leadership in research, the excellence of our scientific institutions, and the innovation in our economy. We can proudly claim to be the nation that gave the world the steam engine and the jet engine. We discovered graphene and we decoded the structure of DNA. Today, we are by far the top destination in Europe for venture capital, with inward investors attracted by our talented and diverse workforce as well as our cutting-edge technologies and services.



The COVID-19 pandemic has shown all of us the vital importance of science and innovation. British researchers are at the forefront of global efforts to find a vaccine and are working hard to map out the impact of the pandemic on our lives and livelihoods. Organisations of all shapes and sizes have worked tirelessly to respond to the crisis in innovative new ways.

In March, the Chancellor announced a record increase in public investment in R&D – committing to reaching £22bn per year by 2024/25. Just a few months on, this commitment has added importance. We will need to be even more creative and innovative to adapt to the ‘new normal’, and to recover swiftly from COVID-19. It is our duty to build a future which is greener, safer and healthier than before.

This means revitalising our whole system of science, research and innovation to release its potential – to unlock and embrace talent, diversity, resilience and adaptability, and to tackle our biggest challenges, such as achieving net zero carbon emissions by 2050. We have a once-in-a-generation opportunity to strengthen our global position in research, unleash a new wave of innovation, enhance our national security and revitalise our international ties.

We will use this opportunity to pursue ambitious new goals – the “moonshots” that will define the next decade and beyond. By stretching our ambitions and engaging with and learning from people and communities all over the UK, we will create long-lasting economic and societal benefits for our country.

People are at the heart of this. By making the UK the very best place in the world to be a researcher, inventor or innovator, we will inspire the next generation of engineers, biologists, designers, historians and entrepreneurs. We want to send a powerful signal to talented people around the world: come to the UK, be part of this exciting new future.

The pandemic has been the greatest disruption to our lives and livelihoods for a generation. But this is not a moment to stand still. This is a moment of great reinvention. By confidently embracing the power of science, research and innovation, we will leap forward and build a brighter future for all.

The Rt Hon Alok Sharma MP
Secretary of State for Business, Energy and Industrial Strategy

Executive Summary

From the industrial revolution to the invention of radio, from vaccines to the World Wide Web, the contribution that science, research and innovation make to the world and people's lives is unquestionable. Through a mix of curiosity and application, we have increased our understanding of ourselves, each other, and the world around us. Through inventiveness comes great progress.

In light of the COVID-19 crisis, the importance of being able to find ingenious, practical and timely solutions to the most challenging problems is even clearer. Research and development will be critical to economic and social recovery from the impacts of COVID-19, enabling us to build a greener, healthier and more resilient UK. Science and innovation have helped drive major progress in global development over the past two decades and are vital to achievement of the UN's Sustainable Development Goals. Our goal is to further strengthen science, research and innovation across the UK, making them central to tackling the major challenges we face, and taking advantage of opportunities.

Our commitment to increasing UK investment in R&D to 2.4% of GDP by 2027 and to increase public funding for R&D to £22 billion per year by 2024/25 will allow us to make major strides towards this goal. We will use this investment to raise domestic and international business investment into UK R&D, increasing economic productivity and prosperity through new products, services and jobs and helping to transform our public services. Across the UK government and the devolved administrations, working with businesses, academia, charities and wider society across the UK, we will tackle some of our biggest societal challenges, advancing our understanding of the world and translating that delivering benefits to people, communities and places around the UK and globally.

We will unlock improvements in health, wellbeing and prosperity, and maintain the security of our citizens. We will tackle some of the big challenges of today and tomorrow, including achieving net zero carbon emissions, investing in world-class assistive technology, building resilience in our economy, environment and society, and improving security, productivity and quality of life for all. We will work closely with the devolved administrations as we seek to achieve our ambitions, taking action together across the UK where appropriate, and learning from each other when action is tailored to the needs of each nation.

Our mission is to inspire and enable people from all backgrounds and experiences to engage and contribute to research and innovation and show that science is for everyone. We will nurture the whole system of innovation that will improve lives, services and businesses right around the UK and beyond – creating a fairer, healthier, more prosperous and more resilient society. And we will celebrate our successes far and wide, showcasing our strengths, and promoting the UK as a destination for talent and investment, and a partner of choice.

World-class research and dynamic innovation are part of an interconnected system; they depend on talented people and teams working in a supportive and diverse culture across multiple sectors, with access to the right funding, infrastructure, data and connections – locally, nationally, internationally – to do their best work. We will examine how this system is working across government, academia, universities, research institutes and technology organisations, businesses, charities, domestic and international investors, global networks and partners.

Drawing inspiration from how the research and innovation community has responded to COVID-19, driving collaboration and partnership, we will make the bold changes needed to

ensure our system is fit for purpose now and for the future. This will require tackling fundamental and challenging questions about our R&D priorities and addressing long-term problems in the system. We will not be afraid to make tough choices to achieve this ambition. Many of these are for the UK Government and we will address these as we prepare for the Spending Review.

Through this Roadmap, we will be testing in detail how we can:

- **Increase our investment in research**, unlocking new discoveries and applying research to solving our most pressing problems in government, industry and across society. We will embrace the idea that transformative research has a high chance of failure but can produce the greatest long-term rewards, especially when combined with support for applied research, development and implementation. We will **nurture a diverse culture** where people with a wide range of experiences and insights are confident to lead, participate and engage. Longer-term, we will review how we fund and assess discovery and applied research, to **cut unnecessary bureaucracy**, pursue ambitious “**moonshots**”, and ensure that institutional funding and international collaboration can support our ambitions.
- Become world-class at securing the economic and social benefits from research. We will set up an **Innovation Expert Group** to help review and improve how we support the whole innovation system, including **strengthening the interactions between discovery research, applied research, innovation, commercialisation and deployment**. This will take account of the different innovation support systems across the four nations. It will be critical to stimulate private sector investment and support public services to get the most out of our excellent research base.
- Support entrepreneurs and start-ups and increase the flow of capital into firms carrying out R&D enabling them to scale up. We will exploit competitive and comparative advantage where the UK can lead the world in **key industries, technologies and ideas**. And we will ensure we have the **best regulatory system** to support research and development.
- Attract, retain and develop the talented, diverse people and teams that are essential to delivering our vision. We will do this through a new **R&D People and Culture Strategy**. We will increase the attractiveness and sustainability of careers throughout the R&D workforce – not just for researchers, but also for technicians, innovators, entrepreneurs and practitioners. We will set up an **Office for Talent** which will take a new and proactive approach to attracting and retaining the most promising global science, research and innovation talent to the UK.
- Take greater account of place-based outcomes in how we make decisions on R&D in the UK, ensuring that our R&D systems make their fullest contribution to our levelling up agenda. We will work collaboratively across the UK, fostering greater collaboration and networks between funders, researchers, practitioners and civic leaders to embed a system that delivers stronger local economic benefit and improved quality of life outcomes from R&D. We will do this through publishing a new **UK R&D Place Strategy** later this year to unlock local growth and societal benefit from R&D across the UK.
- Provide **long-term flexible investment into infrastructure and institutions**. This will allow us to develop and maintain cutting-edge research, development and innovation infrastructure, with agile and resilient institutions able to play their fullest role. We will build on the UK’s system of universities, public sector research establishments and

other publicly funded laboratories, developing our large-scale infrastructure, facilities, resources and services to make them world-leading.

- Be a partner of choice for other world-leading research and innovation nations, as well as strengthening R&D partnerships with emerging and developing countries. We will develop a **new funding offer for collaboration to ensure the UK can further benefit from the opportunities of international scientific partnerships**. This will create new opportunities for collaboration, trade, growth and influence. We will ensure that the UK's science and innovation community, people, institutions, and infrastructure are outward-facing and attract collaboration and investment from across the globe. We aim to maintain a close and friendly collaborative relationship with our European partners, seeking to agree a fair and balanced deal for participation in EU R&D schemes. If we do not associate to programmes such as Horizon Europe, we will meet any funding shortfalls and put in place alternative schemes.
- **Engage** in new and imaginative ways to ensure that our science, research and innovation system is responsive to the needs and aspirations of our society – delivering better quality of life, economic growth and environmental improvements. We will ensure future generations are inspired to pursue careers in R&D in a wide range of sectors and show that science is for everyone.

This Roadmap is the start of a big conversation on what actions need to be taken and how. We want to know:

- **How can we best increase knowledge and understanding through research, including by achieving bigger breakthroughs?**
- **How can we maximise the economic, environmental and societal impact of research through effective application of new knowledge?**
- **How can we encourage innovation and ensure it is used to greatest effect, not just in our cutting-edge industries, but right across the economy and throughout our public services?**
- **How can we attract, retain and develop talented and diverse people to R&D roles? How can we make R&D for everyone?**
- **How should we ensure that R&D plays its fullest role in levelling up all over the UK?**
- **How should we strengthen our research infrastructure and institutions in support of our vision?**
- **How should we most effectively and safely collaborate with partners and networks around the globe?**
- **How can we harness excitement about this vision, listen to a wider range of voices to ensure R&D is delivering for society, and inspire a whole new generation of scientists, researchers, technicians, engineers, and innovators?**

Over the coming months we will develop the proposals in this Roadmap in a comprehensive R&D plan working very closely with the devolved administrations where plans cover or impact on their devolved policy responsibilities. This plan will only be effective if it is developed with people and organisations across the UK. We welcome responses to the high-level questions. An online survey is available at: <https://beisgovuk.citizenspace.com/innovation/r-and-d-survey>.

Swift recovery after COVID-19

Following the COVID-19 crisis, we want to build a future which is greener, fairer, healthier, more resilient and more innovative than ever before. Research and innovation will be critically important to achieving this, through creating new ideas and new technologies and applying them, driving continuous improvement and supporting productivity, generating a better understanding of people and communities, supporting exciting new careers and vibrant new businesses, and helping to improve public services.

Research has rapidly improved our understanding of COVID-19. Supported by rapid action by funding bodies, scientists around the world have directed their efforts to this global priority, working collaboratively across countries and disciplines, and sharing findings openly and quickly. Rapid targeted funding has enabled researchers and policy makers to join up to clarify and tackle pressing questions and has enabled businesses to collaborate in new ways to address national needs. For example, the COVID-19 Genomics UK consortium has achieved rapid sequencing of over 50% of all the SARS-CoV-2 genomes in the world. The UK has led the world's largest randomised control trial for COVID-19, with findings helping the sickest patients not only in the UK but all around the world. We should aspire to this level of openness, connectivity and pace across our whole R&D system.

Many businesses have recognised that they will need to innovate to thrive in this new economic reality. Companies who innovate are more resilient in a crisis, more likely to expand into new markets during disruptions and more likely to be able to hold on to staff and grow in difficult trading conditions. We will partner with and help businesses, working with them to identify new opportunities and providing a full range of support to help them compete and win in reshaped global markets.

Beyond the immediate imperative to overcome COVID-19, the greatest challenge facing the UK and the world is that of decarbonising our economies and building resilience to the impacts of climate change. COVID-19 has been a powerful reminder of the world's vulnerability to systemic risks; climate change, habitat and biodiversity loss pose a major threat to our prosperity and security. UK R&D will boost efforts to build resilience to these risks by developing the potential of technologies such as hydrogen, carbon capture use and storage, zero-emission vehicles and zero-carbon industrial processes as well as nature-based solutions including habitat recovery, afforestation and innovations in building sustainable agricultural and food supply chains.

The pandemic has radically changed people's behaviours and risk perceptions. Social science expertise is already being used to understand how behaviours are changing as a result of the coronavirus pandemic, and how they might potentially be sustained to facilitate a green recovery. Alongside this, research is looking at how different people, including those from Black, Asian and Minority Ethnic groups, have been affected during the lockdown.

The pandemic has also brought long-standing issues in our R&D system into sharp relief. We will seize the moment to harness the ingenuity, creativity and agility shown by the R&D system over the last few months, in turn making the system faster and more responsive, resilient and sustainable, driving up confidence and securing rapid and long-lasting benefits for people and businesses right across the UK. We will take a whole systems approach to ensure that we make the bold changes needed to ensure our system is fit for purpose now and for the future.

Being honest about where we need to improve

Our UK R&D system is world-leading, but that means we should be taking the lead in addressing problems which are visible in the R&D systems of all the leading nations and also address those which are specifically holding back the UK.

These issues are centred around levels of public and private investment, bureaucracy, work culture and careers, development and innovation, regional imbalances, and our international context. Some of these issues are for the UK Government to spearhead and we will address these as we prepare for the Spending Review. Others are the responsibility of universities, research organisations, academies and representative groups and individual researchers and innovators, and we expect to see change here too. We must look hard at the processes between researchers, institutions, UKRI and its councils, and the UK government to see where we can speed up and reduce burdens significantly.

On public funding, we acknowledge that short-term spending settlements can limit people's ability to develop long-term plans. Working with funding agencies and the devolved administrations, we accept the need to reverse the decline in funding for the long-term, fundamental research on which the entire system depends. And we need to take a systematic and consultative view of research priorities, ensuring that public funding is not spread thinly across multiple funding schemes and that truly transformative opportunities are not missed.

British business invests less in R&D compared to similar nations, and this investment is concentrated in major players in just a few sectors. We need to do more to ensure our world-leading strengths in research are complemented by strengths in development, to bring in more investment from overseas as well as improve access to finance for early-stage firms. This means ensuring that the UK has a world-leading research and innovation system with the infrastructure, skills and regulation which can support the development, demonstration and deployment of new technologies and solutions towards commercial success or practical application. We can do more to support new businesses at the technological frontier to scale, and we must learn lessons from other countries on how to improve diffusion of innovation throughout the economy.

As in other countries, we know bureaucracy in research is a problem. It can take too long for funding or approvals decisions to be made and scientists are distracted from doing what they do best: science. Dedicated funding for investigators and teams – people not projects – is the exception, not the rule. Researchers may currently be compelled to play safe to sustain a career. The focus on publishing results in 'top' journals may be narrowing the research process. Most publicly funded research is published behind paywalls, with the underlying data unavailable. These practices slow down research and put its validity at risk, reducing trust and impact.

Some parts of R&D exhibit features of an unhealthy work culture, including evidence of bullying, harassment and discrimination. Progress to address these issues has been too slow. Only 29% of early career researchers feel secure pursuing a research career,¹ and most doctoral candidates exit the profession once they have completed their training. Opportunities to transition between academia, industry and other roles are unclear or unavailable, and our

¹ <https://wellcome.ac.uk/reports/what-researchers-think-about-research-culture>

technical workforce lacks the visibility, recognition and career development it deserves. We must not be afraid to tackle these issues. To ensure we have the talent we need to underpin our ambitions, we need to go further to attract top talent, at all career stages, to come to the UK.

Despite strong national performance in science, research and innovation, UK R&D intensity and funding is concentrated in some regions. Regions outside of the 'Golden Triangle' of London, the South East and the East of England, lag behind our competitors in Northern Europe and some of our cities underperform. Weak innovation systems lead to low productivity economies. All these are long-recognised issues and it is time to take steps to rebalance and level up.

Emerging science powers and new technologies are changing the landscape of international science collaboration. National security issues are threatening the UK's research base and its economic impact. Not enough focus is given to how we can build partnerships with other like-minded developed countries outside Europe and with emerging science superpowers – where stronger strategic partnerships could bring major benefits to the UK.

The COVID-19 pandemic also has shown us the fragility of the funding system, with large sections of our national research activity dependent on third-party funding sources, including international student fees. We have taken action to stabilise the system, and looking towards the Spending Review we will consider its sustainability so that researchers and businesses can make long-term, ambitious plans.

This Roadmap goes on to set out our ambitions for tackling these problems. We are starting from a position of great strength and see this as the start of a big conversation on what actions need to be taken and how.

The terms 'research' and 'science' are usually used in the context of the entire academic landscape, reflecting the Latin root, 'scientia', meaning knowledge. All academic disciplines contribute to the vigour of the research endeavour, including the natural sciences, technologies, medicine, the social sciences, the arts and the humanities. Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge.

Raising our research ambitions

Where are we now?

Researchers are driven by curiosity – by a desire to ask fundamental questions about how the world works and why – and by a drive to solve problems at the intersection of knowledge and societal need. By supporting research, we advance the frontiers of knowledge, increasing our understanding of the world and of each other. We form global collaborations and alliances. We invent the highly disruptive new technologies which can transform the world around us, improving living standards and health outcomes. And we use these insights to tackle the greatest challenges facing the world – those that cross boundaries and impact on our whole society.

The UK has a deep and broad research base with demonstrable excellence across many areas including science, engineering, mathematics, physics, medicine, social sciences, humanities, design and cultural research. This is the result of sustained investment over many years into this ecosystem, but our investment level is relatively low, with problems emerging in the system. Through increased investment we see a major opportunity to build on our successes while tackling these problems.

This requires having a healthy and vibrant ecosystem of institutions in which researchers are free to follow their curiosity, to test radical new ideas, to tackle complex societal problems, and to form new connections, collaborations and networks. It requires a broad span of approaches, from people developing new theories and insights into natural phenomena and the application of research in technological and industrial settings, through to systems research to improve patient care or tackle the barriers to inclusivity in society.

Researchers tell us that there is not sufficient funding for truly transformational opportunities, alongside other barriers to interdisciplinary research. Constrained resources require them to spend excessive time competing for funding, sometimes focussing on ‘safe’ research topics rather than bold new ideas that can have the greatest long-range impacts on knowledge and society. We will also be asking how we can best place our ecosystem of institutions on a sustainable footing, so that they can adapt to the future.

What are we going to do? And how will we work with people to deliver our ambitions?

The unprecedented increase in public investment announced at the Budget signals a step change in our overall ambitions for UK research, and will enable us to push harder at the frontiers of knowledge, unlocking brilliant new technological breakthroughs and enabling applied research to create transformative benefits for government, businesses and communities right across the UK.

There are different types of research endeavour, which require a mix of different funding approaches and institutions to support them. We will diversify our funding approaches, learning from what works well and what does not. We will free up researchers to pursue ideas which can go on to have unpredictable benefits without starting with a specific goal in mind. There is also value in incremental progress – multiple smaller advances that create a new body of

knowledge on which bigger insights can emerge. Challenge funds, competitions and contracts all play a role in supporting this mix. We will put our research system to work in solving the most critical challenges facing the world, including identifying and tackling “moonshots”. And we will establish a unique and independent funding body for advanced research.

Through this Roadmap, we are asking how we can:

- **Provide the most effective forms of funding and management for researchers and research organisations, incentivising work of the highest quality.**
- **Most effectively support applied research that can help tackle the most complex and pressing challenges of government, industry and wider society.**
- **Take “bigger bets” – on a small number of ambitious programmes and institutes in genuinely transformational areas of science and research.**
- **Be more prepared to take risks to achieve potentially greater gains from research, and adopt long-term approaches to investing in research.**
- **Engage with people and in places across the country, to strengthen and improve our research and innovation system and inform our priorities and choices to enable us to build a better future after the COVID-19 crisis.**
- **Embed horizon-scanning to identify early and prepare to exploit our emerging strengths effectively, including discoveries that are ready for development, exploiting these for the prosperity and security of the UK.**
- **Improve our funding and decision-making approaches, embracing light-touch, ultra-fast and flexible processes with minimal red tape.**
- **Enable international collaboration of UK R&D and strengthen current collaboration mechanisms.**
- **Remove barriers to interdisciplinary research to realise the benefits of diverse perspectives and technologies.**

Supporting long-range, fundamental, underpinning science and research

We have set out an ambitious commitment to increase public investment in R&D by 2024/25. A significant proportion of this will be to restore and increase our support for long-range discovery research. We will diversify the way we fund discovery research to enable researchers to embrace the cutting-edge techniques and approaches needed to solve the most complex and difficult questions. This could include more support for investigator-led and team-based funding, supporting projects for a longer timeframe, and introducing lighter-touch and quicker ways to fund good research ideas. We should be prepared to take risks. Research by its very nature has uncertain outcomes, but we need to accept this uncertainty, and the risk of failure, if we are to garner the successes. We are committed to supporting the most creative, innovative and radical ideas for the long term, accepting inherent risk where there is transformative potential.

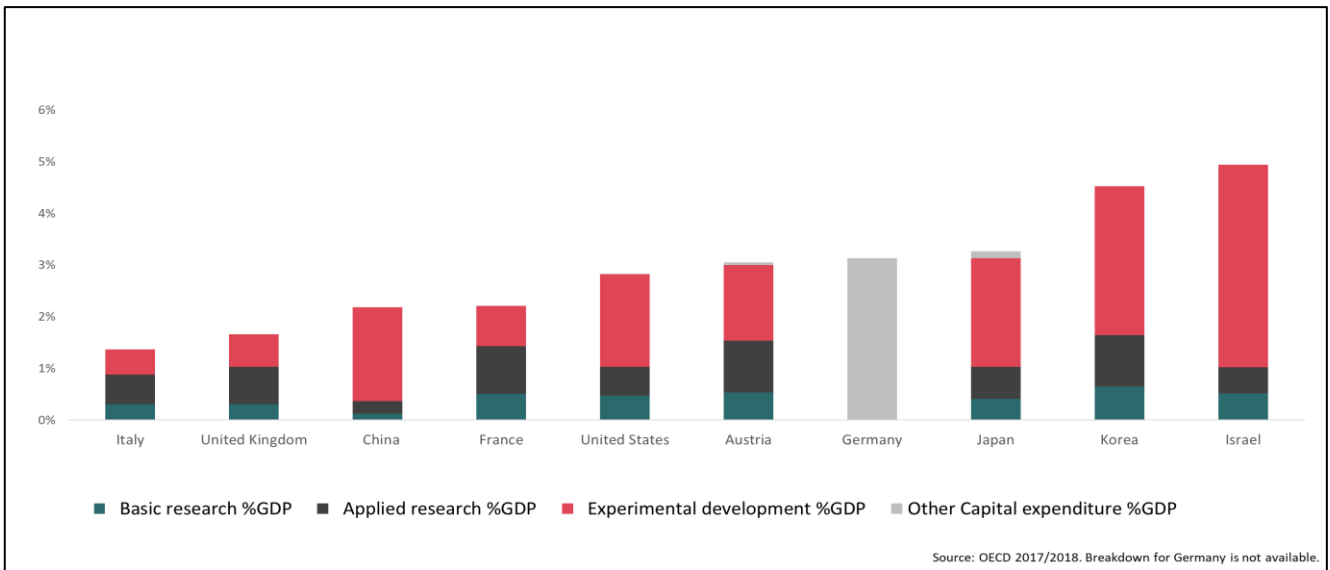


Figure 1 - Basic research, Applied research and Experimental Development as % of GDP

Case study: Laboratory of Molecular Biology

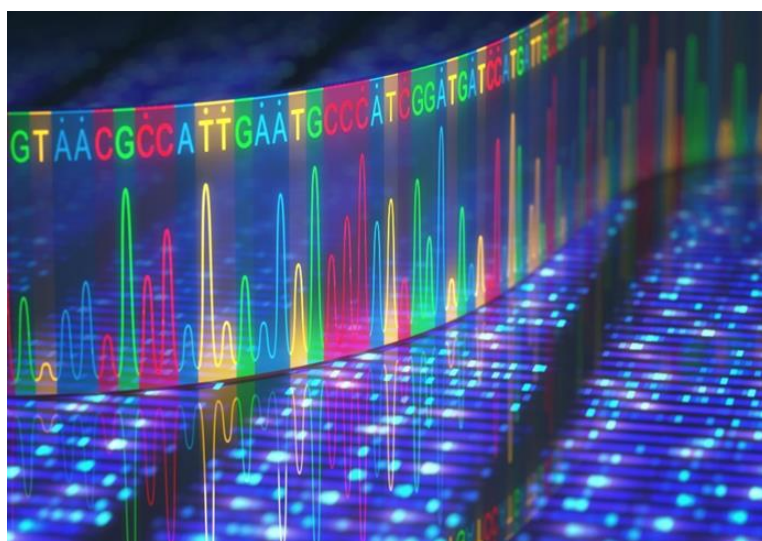
The Medical Research Council Laboratory of Molecular Biology (LMB) is a world-class research laboratory in Cambridge, dedicated to understanding important biological processes at the molecular level – with the goal of using this knowledge to tackle major problems in human health and disease. Set up in 1947 as a ‘Unit for Research on the Molecular Structure of Biological Systems’, the LMB’s main source of funding comes from the Medical Research Council (MRC). The MRC provides a fixed single budget, set for five years at a time, which can be allocated with great flexibility. This central funding helps give scientists the freedom to tackle difficult and fundamental problems in biology.

The LMB is one of the birthplaces of modern molecular biology. Many techniques have been pioneered at the laboratory, including DNA sequencing, methods for determining the three-dimensional structure of proteins and the development of monoclonal antibodies. And in 2019 scientists synthesised the entire genome of a commonly used model organism, the bacterium *E. coli* for the first time. This landmark discovery one day may lead to organisms that produce novel medicines or other valuable molecules, as living factories.

Over the years, the work of LMB scientists has attracted 12 Nobel prizes. In addition, many LMB scientists have succeeded in exploiting their discoveries through technology transfer generating over £700 million of commercial income, to help support UK science.

Supporting innovation, application and deployment

Research is critically important in helping to address significant issues, such as healthy ageing, achieving net zero carbon emissions, and addressing climate change. Applied research plays a vital role in ensuring that resilience, efficiency and effectiveness of public services is improved, that healthcare outcomes are advanced, and that evidence is deployed to solve real world problems and address threats to our security.



This needs to be underpinned by engagement with the users of research and the wider public, as well as investment in the necessary facilities, capacity and expertise required to meet these challenges and enable discoveries to be translated, for example into new products, improved services or better policy outcomes. This is how we will come up with solutions to the big problems, deliver efficient and effective public services and improve lives. We will ensure that the needs of industry, public services such as the National Health Service (NHS), National Security and society inform the interventions we make. These could include:

- investing in priority cross-cutting technologies to harness their potential to transform the way all of us do business and live our lives, and to support our security and prosperity goals;
- increasing investment to explore the questions that will yield the transformational changes of tomorrow and keep the research base vibrant and sustainable;
- increasing investment to build and strengthen collaborations with scientists, researchers, engineers, innovators and entrepreneurs across the world;
- engaging with businesses to understand emerging priorities, needs and areas of potential coordination and collaboration; and
- engaging with the users of research and with the wider public, including those it may impact on, to inform our research agendas. We will engage with the public on potential applications and incentivise the institutions we fund to do the same.

UK Research and Innovation (UKRI) will engage across the research and innovation landscape, and with users of research and the wider public, to inform prioritisation of this increased investment.

Case study: Synthetic Phonics

Basic literacy is an essential skill for living in a modern society. However, many people struggle to learn to read and a significant proportion of the population has poor literacy skills, which constrains their lives and leads to a range of poor health, social and economic outcomes. The Economic and Social Research Council (ESRC) funded research that led to new discoveries about what reading is and how it is learnt. This led to an entirely new approach to reading called 'synthetic phonics', which has led to a significant improvement in outcomes. Importantly, the method is particularly helpful for the children who struggle the most. Being taught synthetic phonics up to the age of 7 leads to a 0.1 standard deviation improvement in reading scores at age 11. This effect is about the same as reducing class sizes by a third and is worth between £3,300 and £8,800 per student in present discounted value based on how their future earnings will increase. This impact has transformed lives and created billions of pounds of additional value in the UK economy each year and is now being adopted around the world.

Supporting our World-Leading Defence and National Security Industrial Base

The pace of technological change has profound implications for UK defence and security. Emerging and disruptive technologies such as automation and artificial intelligence will have far reaching implications for society, data will be increasingly important and environmental issues such as climate change and changing demographics raise complicated geopolitical and security challenges. This Roadmap will complement the national security priorities and objectives that we will set out through the Integrated Review later this Autumn, including ambitious plans to help the UK academic and industrial base to anticipate, invest in and exploit at pace the technologies that will be critical to maintain our edge and build competitive advantage.

Government funds roughly 85% of military research and development – in 2018 defence made up 5% of total spending on research and development at £1.9 billion, a 6.9% increase from 2017. This spending delivers benefits to the wider research and development ecosystem for example by providing an extensive programme of training and support to high-technology industries. It also brings economic benefits by maintaining key capabilities to provide peace and security and vital support to the civil sector; supporting 395,000 jobs in the private and public sector; and providing £9.7 billion of support to GDP through spending with UK industry and commerce.

Collaboration with industry and academia will continue to be at the fore of Defence and Security R&D. Through the work of the Defence and Security Accelerator (DASA) we will continue to expand our reach across the innovation landscape, working with suppliers who have not previously worked with us before. For example, DASA is working closely with the Institute for Security Science and Technology (ISST) at Imperial's White City Campus to bring together government, academia, industry and small and medium sized enterprises (SMEs) to look at developing the next generation of solutions for security and defence problems.

Case study: Defence Science and Technology work with UK industry and academia to develop the next generation of training infrastructures

Rapid maturity of immersive technologies, such as virtual and augmented reality, provides UK Defence with an opportunity to revolutionise training delivery to where and when it is needed; leading to efficiencies through economies of scale and allowing access to a wider, more diverse talent pool.

A networked and integrated training infrastructure will realise the benefits of modelling & simulation, immersive technologies, data analytics and AI to deliver challenging and engaging training. Armed Forces personnel will be able to use state-of-the-art simulation, tailored to their specific needs, in order to prepare them for the complex world that we are asking them to operate in.

Working in parallel with UK industry and academia such as the University of Southampton, Cranfield University and University of Exeter allows us to access the best talent, whilst also providing stimulus to this industry. When fully combined and integrated, these technologies and methods will bring efficiency benefits across the entirety of the Defence training system-of-systems, as well as the opportunity to apply them to a multitude of non-defence training needs in the civilian sector.

Delivering “moonshot” ambitions and proposing the key challenges we want to address

Some major research and innovation challenges require a coordinated, multi-disciplinary approach. “Moonshots” – ambitious, measurable goals which could have a significant impact on an important societal issue – can galvanise actors from across disciplines, government, academia and industry. Government-backed moonshots are a choice about issues that we care about addressing, are prepared to support and fund over a sustained period, that can inspire people, and that create opportunities for unexpected discoveries, rapid development and ground-breaking benefits. If we get this right, moonshots could give us new focus to solving some of our key challenges in the decade ahead, going beyond blue sky thinking to ensure great ideas can be used to solve the biggest problems.

We need to be clear what a moonshot is, and how it differs from other important ways of funding work across the research and innovation system. The PM’s Council for Science and Technology has identified seven central principles to guide the development of a moonshot. Moonshots should:

1. Excite and inspire the public, academia, and industry
2. Help solve an important societal issue
3. Be truly disruptive and ground-breaking
4. Focus on areas where the underpinning science is at a stage to make a major breakthrough feasible
5. Be specific and well-defined in what it sets out to achieve, with a clear timeframe for completion
6. Take advantage of areas where the UK is, or is poised to be, a world leader

7. Generate significant additional benefits.

It will be important to take a systemic approach. Government, scientists and industry will all have a part to play. We will work with CST to convene a group of experts and stakeholders to review what moonshots we could pursue, looking at where government-backed missions and challenges are already working well and can be built upon, what we might stop doing, and where else we should prioritise our efforts. This advice will support our planning for the spending review.

Creating an ARPA style body to boost transformative research in the UK

As we announced in the Queen's Speech, we will invest at least £800 million to set up a unique and independent funding body for advanced research, modelled on the US' Advanced Research Projects Agency (ARPA). This body will back breakthrough technologies and basic research by experimenting with new funding models across long-term time horizons.

By reducing bureaucracy and using innovative funding mechanisms, we will invest in new ideas and empower researchers to deliver radical technological advancements. This new research body will target areas where the UK can gain competitive advantage and lead the world in the creation of new technologies. R&D funding should benefit the whole of the UK, as such we will be engaging with the Devolved Administrations to ensure this new body aligns with the interests of all four nations.

This £800 million represents a relatively small proportion of the overall public spending on R&D funding but will be a critical part of the UK's investment portfolio alongside other funding bodies. The new body will collaborate internationally, championing bold and transformative R&D.

Case study: Robotics for a Safer world

Through the £93 million Industrial Strategy Challenge Fund (ISCF) 'Robots for a Safer World' programme, the UK is developing world-leading nuclear robotics technology that helps keep people out of harm's way and could unlock significant economy opportunities both in the UK and globally. For example, the CARMA robot was the first ever fully autonomous robot to be deployed into an active area at Sellafield. Developed at the University of Manchester as a part of the Robotics and AI in Nuclear Hub, CARMA autonomously maps floor spaces to locate alpha, beta and gamma radioactive contamination. Without requiring people to enter the harmful environment, it can detect alpha radiation with extreme precision – something that requires the sensor to be within 2cm of the radiation source. Capitalising on this success, they are now working with nuclear specialists Nuvia to look at commercialising the CARMA robot.

Inspiring and enabling talented people and teams

Where are we now?

To achieve our ambitions for UK science, research and innovation, we must be world-leading in the way that we inspire and enable talented people. This means being the best place in the world for attracting, training and retaining diverse, talented people and teams across the whole spectrum – from excellent scientists, researchers, engineers and technicians, through to entrepreneurs, business leaders and investors.

We need to nurture and support talent from all backgrounds and experiences, embracing all cultures and respecting all viewpoints. As a nation, we must be diverse, inclusive and brilliant – a place where people can play with ideas and achieve great things, building on and enhancing our worldwide reputation. We want science to be for everyone no matter what their background.

We must create opportunities for people around the UK to pursue diverse and flexible careers in R&D. The UK has an internationally recognised higher education system attracting high quality students, a strong research base, excellent research across disciplines, entrepreneurs, practitioners and a high level of international collaboration and investment but there are areas where we know we can do more.

There are a number of issues and challenges we face. Careers in research and development are not as attractive as they should be due to lower salaries and an overdependence on competing for short-term funding. There is an unclear career pathway for many technicians, graduates, early stage researchers and those re-entering research after a break. We do not do enough to support people to move between academia, industry, the public sector and charities, or to move creatively between research and development roles. There are barriers and costs for international researchers and entrepreneurs wanting to come and work here. Creating the right culture is also key.

We must also challenge ourselves to recognise when our R&D system may be failing to attract, grow, retain and champion exceptionally talented people, especially those with protected characteristics or from disadvantaged backgrounds. For example, there are approximately 7% BAME managers, directors and senior officials in academic and non-academic higher education positions.² We must remove any barriers and dismantle any inequalities in the system that limit the ambitions, inclusion and participation of people from any background.

What are we going to do? And how will we work with people to deliver our ambitions?

Over the coming months, we will work with the devolved administrations and key stakeholders including the major funders of research – UKRI, NIHR, the devolved funding bodies, Public Sector Research Establishments (PSREs), the National and Devolved Academies, academics,

² <https://www.hesa.ac.uk/data-and-analysis/staff/working-in-he/characteristics>

universities, businesses and charities – to develop a comprehensive new **R&D People and Culture strategy**. This will put the UK at the forefront of attracting, retaining and developing diverse, talented people and the teams that will be critical to delivering the Government's science superpower vision. Underpinning all of this we must have inspirational leadership, making the UK a great place to work where courage, talent and innovation is rewarded and recognised.

Through this Roadmap we are asking how we can:

- **Ensure the scale and models of training meet the requirements of our R&D workforce, including technical and postgraduate routes.**
- **Support early career researchers and innovators into the next stage of their careers, and provide more support for retraining over their entire careers.**
- **Attract and retain a diverse pool of talent, nationally and internationally at all levels.**
- **Support businesses in attracting, growing and developing their R&D workforce, matching their needs with provision and upskilling their management practices and leadership teams.**
- **Supporting greater mobility of the research and innovation workforce between business and academia, between research and development, between industrial sectors, and between the UK and other countries.**
- **Support research and innovation teams of all sizes to be vibrant, impactful, ambitious and diverse.**
- **Align UK government and devolved administration activity on advanced R&D, data and digital skills to support vibrant career pathways, attracting talent.**
- **Raise the recognition and reward of research technical professionals, addressing skills gaps and retention challenges.**
- **Support action to enhance the UK research culture based on current strengths, so diverse people can work in a research environment that supports them to produce the highest quality research.**



Improving the culture of research

The vitality of the UK's research culture will be central to this success. The culture of research is an area that the UK has historically led the way internationally, from our reputation for assessment on research quality, to our early recognition of the importance of public engagement and the embrace of open research. However, there is still work to be done to improve research culture and make the most of the wealth of talent in the UK.

We also have an opportunity to recognise and maintain some of the positive behaviours we have seen as a result of COVID-19 – collaboration, knowledge-sharing and support for colleagues feeling the impact. Reward and recognition of these positive changes will be central to the ongoing evolution of UK research culture, ensuring we continue to set the benchmark globally. We must ensure assessment systems and processes are fair, efficient and free of bias, eradicating disparities where found to ensure our system is as meritocratic as possible.

Equality, diversity and inclusion (EDI) is a critical aspect of research culture and improving EDI requires a multifaceted response. UKRI will develop and launch bold initiatives to increase the participation, retention and promotion of a diversity of talent into R&D. We will drive transparency and accountability through working with the sector to establish targets and standards aimed at reducing ineffective practices, ensuring that research and innovation benefits from the full creative reach of all parts of the population. We recognise that we cannot and absolutely will not wait until we have perfect data or conclusive evidence before taking action, and will continually pilot, intervene, assess and evaluate.

Through developing our strategy, we will **review the impact of COVID-19 on UK government-funded researcher productivity and portfolios**. This will ensure funders are still unleashing the full potential of people from a range of diverse backgrounds, and that those individuals experiencing higher levels of disruption to their research are not unduly impacted.

We will work with funders to set clear expectations of research organisations in supporting safe and open research cultures that lead to high integrity of research. This includes prevention strategies to tackle bullying and harassment. It is clear that the current environment can drive these behaviours and we will work with devolved administrations, funders and regulators to coordinate policies that will deliver the change we need to see.

Growing the research talent pipeline

We will invest in developing inspiring leaders who will then nurture and develop future talent. Our strategy will allow us to **create a new deal for funding postgraduate research** – increasing the investment in research training, numbers supported, models of delivery, stipend levels and helping graduates transition successfully into the next stage of their career, whether that is in academia, industry or in the public sector.

We will also identify actions we can take to **increase support for early career researchers** and giving them the skills, knowledge and experience needed to progress their careers inside or outside academia. We will bring fresh thinking and an increased diversity of



perspectives from a breadth of disciplines to support the development of policy and research funding across the UK government and devolved administrations.

Case study: UKRI Future Leaders Fellowships

The UKRI Future Leaders Fellowships is a £900 million fund that is helping to establish the careers of world-class research and innovation leaders across UK business and academia. This scheme supports early career researchers and innovators with outstanding potential to tackle ambitious and challenging research and innovation and to develop their own careers.

To date, more than 200 fellows are participating in this programme across the UK. Fellows work in a wide range of areas from revolutionising mobile networks to help meet the ever-growing demand for connected devices and data, to developing scalable and sustainable adolescent maternal mental health interventions in Kenya and Mozambique.

With 40% of the awards going to non-UK nationals, it is attracting and retaining global talent to the UK. UKRI has developed new approaches to allow more fellows to work with and in businesses, facilitating movement of people and ideas across and between sectors, and has created a fully open remit so that there are no barriers to novel and interdisciplinary projects.

The technical workforce is essential to research and innovation – from contributing new knowledge, developing and maintaining equipment and vital national infrastructures to training future researchers and innovators. Their role in research and innovation has been undervalued for too long, but this is beginning to change.³

As the first funder to sign the Technician Commitment, UKRI will build upon existing examples of what works, by expanding delivery of experiential learning and training across its network of institutes, centres and the Catapults. It will work with training providers, including higher and further education, and local and national industry sectors to identify skills needs for academia and importantly, industry, where skills gaps are already known to exist. This will be particularly important in the necessary continuous reskilling of the technical workforce at all levels. For example, through a £1.5 million Industrial Strategy Challenge Fund investment, the Cell and Gene Therapy Catapult launched the first apprenticeship programme focussed on Advanced Therapy Medicinal Products (ATMP) aimed at building the skills base needed to maintain the UK's leadership position in the development of these disruptive, potentially curative therapies.⁴ This investment is already paying off – as these skillsets and techniques are capitalised in the pursuit of vaccines.

³ This includes through sector-wide initiatives such as the Technician Commitment (TC) and the National Technician Development Centre (NTDC)

⁴ <https://ct.catapult.org.uk/news-media/general-news/addressing-sector-skills-gap-first-apprenticeship-programme-advanced>

Case study: UKAEA Oxfordshire Advanced Skills Centre

The UK Atomic Energy Authority (UKAEA) runs the Oxfordshire Advanced Skills (OAS) Centre at its Culham Campus, in partnership with the Science and Technology Facilities Council. Since 2019, the expanded OAS Centre trains up to 350 technical apprentices per year for UKAEA and a host of industrial partners, with 80% of apprentices going to local industry. Specialising in areas such as power engineering, AI, robotics and nuclear design, OAS apprentices routinely win local and national awards.

UKAEA is now creating new OAS centres beyond Culham. A new OAS facility at Harwell will focus on meeting skills shortages in the Space sector. Another new OAS centre is expected to be sited alongside UKAEA's planned fusion power plant, Spherical Tokamak for Energy Production (STEP), in order to develop a local pool of technicians and engineers.

Working with government, UKAEA will also be using OAS to pilot new approaches to attracting and supporting apprentices from underrepresented and/or disadvantaged backgrounds.

Attracting and retaining talent

We want the UK to become the top destination for international talent. In February we launched the Global Talent Visa, providing a new route for talented and promising individuals to come and work in the UK. Alongside this Roadmap we are expanding the eligibility criteria for the Global Talent Visa to allow highly skilled scientists and researchers from across the globe to come to the UK without needing a job offer. We have introduced changes to the Graduate Route to make it easier for some of the best, young international graduates to secure skilled jobs in the UK and contribute to our economy and society. International students who complete a PhD from summer 2021 can stay in the UK for three years after study to live and work. And, as announced previously, students who have successfully completed undergraduate and master's degrees will be able to stay for a further two years after study. We will continue to make these routes simpler and faster.

These reforms are just the start. We will now radically improve our approach to attracting global talent to the UK by setting up a new **Office for Talent**. This will make it significantly easier for top global science, research and innovation talent to come to the UK and make it their home, and for exceptionally talented Brits across the world to be welcomed back.

Working with UKRI, other public funders of research training and the National Academies, we will review our overall talent offer, ensuring that it is on the strongest possible footing to support our future skills needs. This includes continuing with **Global Talent Visa Reform**, building on the changes introduced earlier this year. We will now look across users' needs, uptake of different routes by established talent and those on the cusp of success, and reviewing restrictions and costs.

We will develop a new offer **linking research and innovation talent to our ambitions on levelling up**, building on the work UKRI is doing through its network of institutes and centres to deliver high-level skills for technicians, working with their sectors and skills providers to identify future skills needs and develop the relevant training modules. This will focus on working with and through institutions including universities, PSREs and UKRI research institutes to strengthen their role in skills and talent development in their local context.

Case study: National Physical Laboratory

The National Physical Laboratory (NPL) hosts both a Postgraduate Institute and an apprentice programme that provide outstanding science and technical education, and deliver a broad programme of skills, from communication, business knowledge and intellectual property (IP).

The Postgraduate Institute for Measurement Science (PGI) hosts approximately 200 postgraduate researchers from across the UK. They are co-supervised by NPL staff in collaboration with more than 30 UK universities and industrial partners. The PGI provides students with industry-relevant experience and enables a smoother transition into an industry role, improving the knowledge and skills transfer from university to industry. Students at the PGI work across a variety of sectors and often on projects that directly collaborate with industry.

We want to ensure our talent offer is strong enough to attract those with the most talent, potential, enthusiasm and creativity. And so alongside the Office for Talent and visa reform we will be working to review the talent offer across all career stages to make sure that the coverage and attractiveness of programmes is among the best in the world.

In some areas, national security means we need to keep our research safe.⁵ And in particular national security-sensitive areas we need to protect and encourage a UK skills base. Where we need to rely on UK talent in sensitive research and technology areas, we will be ambitious and clear in setting out how we intend to cultivate and maintain UK talent.

⁵ Our Trusted Research guidance offers support to research organisations on how to do this: <https://www.cpni.gov.uk/trusted-research-guidance-academia>

Driving up innovation and productivity

Where are we now?

Innovation is the process by which ideas are turned into economic growth – where discoveries are translated into new products, services and jobs, creating positive change in businesses, public services, government and wider society. The UK is ranked 5th in the Global Innovation Index 2019 and in the top 10 best countries worldwide to start, locate and scale a business.⁶ We already attract significant venture capital – at a level that exceeds that of Germany, France and Sweden combined.⁷ We are home to 77 unicorns (start-ups valued over US \$1 billion), more than a third of the total across Europe and Israel.⁸ And yet, we underperform in innovation compared to research.

We need to do more to make the most of our world-class research base and to increase the productivity of UK businesses all over the UK. We need to ensure our excellence in discovery research, design, engineering, data science, and creative arts translates into commercial applications – increasing the productivity of our existing industries and creating new growth opportunities for the UK. The UK has lower levels of R&D activity by businesses compared to our competitor nations, and that investment is focussed on large investors in a few sectors.

We must boost business-led innovation activity and incremental innovation across the UK. We need to capture the opportunities provided by innovation, including those presented by the imperatives of decarbonisation and building climate resilience. We need to identify what works well in the different innovation support systems and share these lessons to realise improvements across the UK. The UK Government and the devolved administrations influence innovation and its uptake in a wide variety of ways, from direct programmes and specific facilities to the rules, regulations and systems that underpin the whole economy:

- Sectoral, technology and challenge level programmes.
- Funding for translational and applied research, for example to develop new medicines and treatments and the next generation capabilities for our military.
- Support for business through UK government agencies such as Innovate UK, the Defence and Security Accelerator, the UK Space Agency, the Intellectual Property Office, and our Public Sector Research Establishments such as the National Physical Laboratory and Solutions from HSE, and through devolved structures such as the devolved enterprise agencies and, in Scotland, Interface.
- Broader support for businesses to start, scale-up, or invest in innovation such as a competitive R&D tax credit scheme, responsive regulation system and access to growth finance, including through co-investment from the British Business Bank and devolved equivalents.
- Support for particular sectors including through structures such as sector councils, the Scottish Innovation Centres and knowledge exchange collaborations around the UK.

⁶ *Ease of Doing Business Index*, World Bank (2019)

⁷ *UK Tech Extends Lead over Europe*, TechNation (2018) <https://technation.io/news/uk-tech-extends-lead-over-europe/>

⁸ <https://technation.io/report2020/#key-statistics>

- The public sector acting as an intelligent customer through procurement practices.

What are we going to do? And how will we work with people to deliver our ambitions?

We want to have a world-leading system that unlocks innovation and growth throughout all parts of the economy across the UK. This chapter identifies some of the areas where we think action is needed. We need to work with businesses of all sizes to understand the challenges they face and the opportunities they see. We will convene an **Innovation Expert Group**, comprised of people with the deep knowledge, experience and clear vision to help shape innovation policy, drawing from industry, public services, the investment community and across the relevant disciplines of the research community. The Group will provide advice to government on the priority actions and early opportunities that need to be taken to boost innovation.

Through this Roadmap we are asking how we can:

- **Ensure that the systems, rules, regulations and networks that underpin the UK economy promote competition, innovation and diffusion.**
- **Capture the economic and social benefit from research through improvements to innovation, knowledge exchange and scale-up.**
- **Build on our innovation infrastructure, e.g. enhancing our Catapult and Accelerator Network, and investigating mechanisms to make data more available for innovation.**
- **Incorporate strong pro-innovation voices from around the world and from all parts of the UK in innovation policy-making to implement systemic change.**
- **Achieve greater demand for innovation through the right mix of incentives and policies, including the role of social research in understanding how and when society wants to use innovation, and strengthening government's role as a customer of innovation and through public procurement practices.**

Businesses dominate UK R&D: the £25 billion invested by the business community in 2018 represented over two-thirds of all R&D funding⁹ although the picture differs across the four nations. Continued domestic and international business investment will be critical to our economic and social recovery and future productivity gains. Research shows that the R&D carried out by private firms is influenced by a wide range of rules, systems and interactions, from the tax regime, to our intellectual property system and the networks of contacts and exchanges that promote the sharing of ideas. We want to ensure that these underpinning rules and systems support innovative companies of all sizes to establish themselves and grow in the UK. And we want to encourage businesses in all sectors to adopt new innovations and technologies and innovate themselves.

⁹ Office for National Statistics, Business Enterprise Research and Development 2018 - <https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/businessenterpriseresearchanddevelopment/2018>

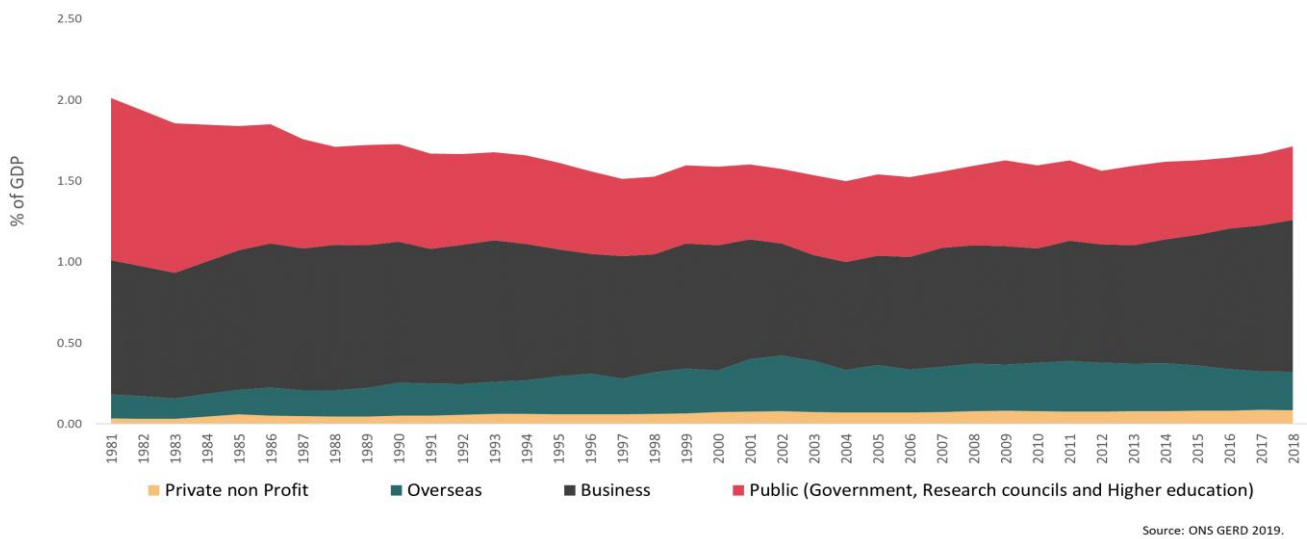


Figure 2 – Breakdown of R&D funding by source as a share of GDP

We want to understand whether the tax system encourages innovation. For example, building on the announcement at Budget 2020 to increase the Research and Development Expenditure Credit (RDEC) rate and review the scope of qualifying costs for R&D tax reliefs, we will ensure that the regime reflects the changing reality of R&D and remains globally competitive.

We want to ensure that our regulatory regimes support and promote innovation. The UK’s regulatory approach and the quality of its regulatory policy rank among the highest internationally,¹⁰ and through the reforms set out in the White Paper on ‘Regulation for the Fourth Industrial Revolution’¹¹ we are further reforming the UK’s regulatory system to support innovation while protecting citizens and the environment.

Taking a forward-leaning approach and setting the international agenda on regulation and standards, alongside R&D and infrastructure investments in emerging technologies, we will provide a comprehensive environment that can build on UK strengths. This will allow SMEs and industry to grow and flourish, attract international R&D investment and talent to the UK, and ultimately make the UK a world leader in new sectors while securing societal benefits on the ground. One example is the Centre of Connected and Autonomous Vehicles, which has led the world in regulatory reform and guidance, which will help assure the safety and security for self-driving vehicles for mainstream use.

However, specific regulations still have the potential to slow down and stop innovation. For example, in healthcare, while the regulatory system is integral in preventing the misuse and diversion of harmful drugs, we need to have proportionate controls around access to controlled drugs in the area of legitimate R&D. Working with key industry and regulatory stakeholders, we will review the current regulatory system around controlled substances for scientific research to ensure it does not inhibit the development of new therapies and the full potential of the innovative life sciences industry. More broadly, we recognise the need to build a dialogue with the public to ensure that these new products, processes and services meet the needs of

¹⁰ The UK is ranked 8th among 190 economies for the ease of doing business, with the quality of our regulatory practices given the highest overall country score by the Organisation for Economic Co-operation and Development (OECD)

¹¹ <https://www.gov.uk/government/publications/regulation-for-the-fourth-industrial-revolution>

society, taking into account that views and policies across the four nations may differ on particular issues.

We want to maximise the use of trusted data in innovation. Building on the National Data Strategy (NDS),¹² and devolved equivalents, we are seeking views on how to ensure data availability and accessibility across the UK.

Access to Finance

We want to improve access to finance, in particular for small and start-up companies, and especially for the high-impact firms that bring so much innovation to market. This will involve reviewing how private capital and public support initiatives give high-potential businesses the support and access to the finance they need to succeed. We want to make sure that finance is available for innovators from all backgrounds and will consider how access to finance can be improved for women and BAME business founders.

A high proportion of UK business R&D is also financed from abroad: 14% of the total in 2017. We want to grow international investment in R&D in the UK from the world's most innovative companies, to encourage them to do their research and embed value chains here. We will include an R&D focus in our investment strategies with other countries.

We are committed to work together with the devolved administrations in supporting high-growth smaller businesses across the UK to access the finance they need to scale up and achieve their full growth potential. The UK remains the top destination for venture capital investment in Europe, attracting 38% of the total European VC investment in 2019. The 2017 Patient Capital Review¹³ recognised this but identified a gap in the availability of long-term growth finance for innovative businesses. We want to see a strong cadre of specialist investors in the UK with a focus on areas of key national interest backed by significant funds.

At Autumn Budget 2017, the Government announced a 10-year action plan to unlock over £20 billion to finance growth in innovative firms. This package of measures included:

- **Creating British Patient Capital**, a new £2.5 billion investment programme incubated within the British Business Bank, to unlock a total of £7.5 billion new investment.
- **Investing in a series of private sector fund of funds of scale** through the British Business Bank's Managed Funds programme.
- **Expanding the Enterprise Investment Scheme and Venture Capital Trust tax reliefs** and redirecting low-risk investment supported by the reliefs to unlock over £7 billion.
- **Backing the next generation of fund managers** through the established Enterprise Capital Fund programme, to unlock at least £1.5 billion.
- **Backing overseas investment into UK venture capital** through the Department for International Trade, expected to unlock a further £1 billion.

We have looked at the barriers to institutional investment in patient capital and want to remove any final barriers that key investors, such as defined contribution pension schemes, face for

¹² <https://www.gov.uk/guidance/national-data-strategy>

¹³ <https://www.gov.uk/government/publications/patient-capital-review>

investing in venture capital and growth equity as part of a balanced portfolio. We are taking action at a UK level in three areas:

- **Tackling regulatory barriers:** In March 2020, the Financial Conduct Authority updated their rules governing contract-based pensions investment in illiquid assets, which facilitate investment while ensuring effective consumer protection. In 2019 the Government launched a consultation on enabling the use of performance fees while maintaining the charge cap. Performance fees are often used in private markets, such as venture capital, private equity and growth equity but the current charge cap compliance mechanism can restrict the performance fees schemes can pay which risks deterring investment in these asset classes. Our next steps are to consult on regulations that amend the way compliance with the charge cap is measured so that such performance fees, where charged, can be accommodated within the cap. This will remove this barrier to accessing asset classes that have those fee requirements and encourage wider investment opportunities while still protecting the saver.
- **Working with the industry:** Good progress has been made in implementing the actions coming out of the Patient Capital Review,¹⁴ and we have worked with industry to identify opportunities for further targeted measures. For example, in the recent Budget we announced the Life Sciences Investment Programme, a new £200 million dedicated investment programme to unlock the potential of the UK's best health and life science innovations. Furthermore, the British Business Bank (BBB) collaborated with some of the UK's leading pensions providers to explore the case for encouraging defined contribution pension scheme investment in venture capital and growth equity, and potential solutions to overcoming key risks and challenges to access. Next steps include nudging smaller occupational defined contribution pension schemes that do not present good value to their members to consolidate into larger schemes. This will bring more members into better governed schemes where they will benefit from economies of scale and have access to a more diverse range of investment opportunities, including growth equity and illiquids. We also continue to work with industry through the review of the UK funds regime announced at Spring Budget.
- **Support through COVID-19:** Launched in May 2020 and delivered by the British Business Bank, the Future Fund¹⁵ is helping equity backed companies raise additional finance to withstand current market conditions, which have been affected by the COVID-19 outbreak. For innovative SMEs a £750 million package of support including targeted grants and loans is available delivered by Innovate UK.

Making sure we have the right pro-innovation measures

We need to optimise the support that the Government provides to unlock innovation in the sectors and technologies that can drive the UK's future growth and prosperity. In the short term, this will include identifying the most effective programmes, with input from the Innovation Expert Group.

¹⁴ <https://www.british-business-bank.co.uk/research/the-future-of-dc-pensions-enabling-access-to-venture-capital-and-growth-equity/>

¹⁵ The Future Fund provides convertible loans to UK-based companies ranging from £125,000 to £5 million, subject to private investors providing at least equal matched funding. We committed an initial £250 million for the Future Fund and have since made further funding available reflecting strong demand.



In some cases, “challenge-based” funding programmes like the Industrial Strategy Challenge Fund may be the most appropriate lever to address the UK Government’s top priorities, such as achieving net zero carbon emissions and supporting healthy ageing. In other cases, innovation grants or loans – or even taking equity stakes – may be more effective. We want to review the evidence on all of these approaches, including from abroad.

We want to build on our support for traditionally R&D intensive sectors, alongside longer-term ambitions to put the UK at the forefront of wholly new sectors that are emerging around transformational new technologies such as Artificial Intelligence (AI), Quantum Technologies and Robotics, and in the applications where they combine. For example, a new UK Space Strategy will establish a dedicated innovation programme to build the skills, technologies and supply chains that will put cutting-edge British

innovation in robotics and satellites, including earth observation to tackle climate change, at the heart of the world’s space economy and exploration. We will also build on the UK’s strengths in sectors like life sciences, digital and creative industries.

Case study: Supporting disruptive technology through the i4i programme

The NIHR’s Invention for Innovation (i4i) programme funds the development of disruptive early-stage medical technologies to accelerate the translation of innovations into the NHS and the wider healthcare market.

Globally gastric carcinoma (GC) is the fourth most common cancer worldwide and remains the second leading cause of cancer-related death. 10-15% of cases are referred for colorectal surgery, which has a 6% mortality rate, long recovery time and may require the patient to wear a colostomy bag for life. Creo Medical developed a less invasive and safer method to remove complex polyps without surgery. NIHR i4i funding supported Creo Medical’s development of a range of instruments and securing of CE marking. Creo Medical has gone on to secure a significant amount of private investment and FDA approval as well as being listed on the London Stock Exchange in December 2016, raising £20 million and raised an additional £48.5 million in August 2018.

Using the device realised NHS savings of £5,000 per procedure completed when compared to surgical intervention costs and can also reduce the length of hospital stays – equivalent to estimated savings for the NHS in the region of £111 million per year.

Creo Medical has now established sites in Bath and Chepstow that employ 50 people in development and manufacturing. Clinical use commenced in 2019 via multiple distributors including Diagmed Healthcare as the UK distributor and others in Asia, South Africa, Spain and Benelux. Creo Medical is also marketing the technology directly to US physicians.

We will take an investor-like approach to look across the whole system: increasing support in areas showing promise and stopping programmes when they are not working.

Another underutilised lever is procurement, in which government and public service providers can act as an early adopter and first customer for new technologies and ways of working. Recently published guidelines for Government Artificial Intelligence procurement provide an example of how we can support this.¹⁶ We want to improve how we use UK government procurement to support innovation and in turn use innovation to improve public services for example, through programmes such as the Small Business Research Initiative (SBRI)¹⁷ and the use of innovation tools such as the Spark CCS Framework¹⁸ (a new market place for innovation to support cutting edge products and markets that aren't catered for in traditional commercial arrangements). We will also use NHS England as one of the world's largest single procurers of technology and health innovation to take a greater role in seeding and adopting innovation. This will start with our **Innovative Medicines Fund** but also through the work of the Accelerated Access Collaborative (AAC), supported by the National Institute for Health Research (NIHR) so that doctors can use the most advanced, life-saving treatments.



We want to make support for innovation available more quickly, easily and flexibly by improving signposting (including to devolved support schemes), reducing red tape and providing flexible funding arrangements which support a broader range of businesses at the right time. We will explore experimental funding models, building on approaches developed by venture capital firms, enabling us to take more calculated risks.

Capturing the economic benefit from our research through innovation

Accelerating the journey between concept and commercial application is critical to securing the contribution of our world-class research base to productivity, growth and social benefits. But a common concern with the UK innovation landscape is that, while support is available for early stage research and development, this support falls away before ideas are commercialised and brought to market. Commercial and entrepreneurial skills and a mindset of enterprise and innovation are important across all academic disciplines to effectively leverage R&D investments. Productive interaction between the business and academic communities is often impeded by a shortage of the relevant knowledge and skills in research translation and entrepreneurship.

¹⁶ Guidelines for AI procurement - <https://www.gov.uk/government/publications/guidelines-for-ai-procurement/guidelines-for-ai-procurement>

¹⁷ <https://www.gov.uk/government/collections/sbri-the-small-business-research-initiative>

¹⁸ <https://www.crowncommercial.gov.uk/news/new-technology-innovation-marketplace-spark-opens>

Case study: Cyber Academic Start-Up Accelerator Programme (ASAP)

Through the National Cyber Security Programme, we have collaborated with the Knowledge Transfer Network to equip academics with the skills and tools to transform their research into a cyber security business. Cyber security threats are constantly evolving, and UK organisations need access to innovative products and services to help them manage their cyber risk. The UK's excellence in cyber security research provides an exciting foundation for new ideas to better secure the UK.

Since 2016, over 92 academic teams have taken part in the Cyber ASAP. The first two cohorts resulted in nine companies being created attracting £3.2 million in funding and delivering new capability to market to solve business challenges including security and reliability testing for Graphics Processors, incident response and forensics for critical national infrastructure and advanced manufacturing, and future-proofing communication security using quantum.

To promote university commercialisation in England, we have increased Higher Education Innovation Funding (HEIF)¹⁹ and established the Connecting Capability Fund²⁰ and are implementing a new Knowledge Exchange Framework²¹ and the sector have developed the Knowledge Exchange Concordat.²²

We want to ensure powerful incentive structures are in place to encourage universities and businesses to work together effectively across the UK, and that businesses can collaborate as well as compete. This will help tackle productivity gaps and reduce regional imbalances in R&D intensity. Key themes may include improving start-up support, providing skills and improved access to finance, considering the incentives for commercialisation posed by funding streams and ways to maximise the impact of our intellectual property system on innovation.

We welcome views on how to unleash the potential of the UK's scale-ups (start-up businesses showing good commercial growth), for instance by boosting the adoption and diffusion of innovation. This could include interventions to encourage diffusion and adoption of innovations in regional clusters of firms in particular sectors, as used in transport through Transport Technology and Innovation Grants.

¹⁹ <https://re.ukri.org/knowledge-exchange/the-higher-education-innovation-fund-heif/>

²⁰ <https://re.ukri.org/funding/our-funds-overview/the-connecting-capability-fund-ccf/>

²¹ <https://re.ukri.org/knowledge-exchange/knowledge-exchange-framework/>

²² <https://www.keconcordat.ac.uk/>

Case study: Compound Semiconductor ‘Valley’

South Wales is home to a growing ecosystem cluster centred around compound semiconductor technology. The new generation of world economic growth drivers, such as connected autonomous vehicles, 5G communications and the Internet of Things, rely fundamentally on this key enabling technology for tasks such as proximity sensing, 3D sensing for face recognition and LiDAR for environmental mapping. South Wales is growing fast as the UK’s leading focus for compound semiconductor technologies and applications and this growth spurred on by collaborative partnerships between industry (e.g. IQE, SPTS Technologies) and academia and UK Government through UKRI and Welsh Government. Funding includes £50 million from Innovate UK to support a Compound Semiconductor Applications Catapult, the EPSRC funded Institute for Compound Semiconductor Technology at Cardiff University, the Cardiff Capital Region’s £38 million wafer foundry and major investments in compound semiconductor research capacity at Cardiff through the Welsh Government’s Sêr Cymru programme.

Build on our innovation enabling infrastructure

Innovation happens throughout the UK, but access to the right support and facilities is not consistently available. Wherever we have high-quality R&D infrastructure we need to take full advantage of this, by encouraging the creation of new innovation zones and clusters of innovative firms around existing infrastructure around the UK. We will consider the full range of levers in doing so, from direct funding, to business support, to government’s ability to convene different actors and promote new opportunities.

We want to build on our Catapult Network’s existing performance, boosting the benefits the network brings to local economies and addressing major challenges such as net zero carbon emissions. We will review whether they should all continue in their current form, exploring the potential to seize new opportunities.

We will consider the opportunities provided by Public Sector Research Establishments (PSREs) and other publicly funded research institutes, including establishing how government can best drive innovation through these organisations, for example through proof of concept for innovations and better sharing of ideas. To support publicly funded research infrastructures to make the most of their innovations, we will establish a fund to invest in innovative public sector ideas and a new unit to scout for and develop these opportunities.

Case study: Satellite Applications Catapult

The Satellite Applications Catapult, working with the UK Space Agency (UKSA), has established a network of regional centres of excellence which connect researchers, businesses and customers, helping to turn ideas for satellite data into successful products used in sectors as diverse as agriculture, healthcare, transport, sustainable development and communications.

In 2020, the Satellite Applications Catapult announced a ground-breaking project to build the UK's first private standalone 5G network in Milton Keynes, embedding satellite connectivity into the network to ensure access and reach for all. The project will see the Catapult explore how this could improve health and social care in the community, including early diagnosis and screening, home monitoring and telemedicine, while Milton Keynes Council will look at how 5G could transform the town's transport, by connecting together autonomous vehicles such as delivery robots – which have been providing food deliveries for those shielding during the COVID-19 pandemic.

Incorporating pro-innovation voices from across the UK in innovation policy-making

Innovate UK delivers a range of programmes to support innovation. But we can go further to help it fulfil its potential. Innovate UK can and should evolve further to be a true national champion for innovation: acting as a thought leader in championing new and disruptive businesses and technologies; promoting policy and regulatory changes needed for these to flourish; catalysing private sector partnerships, venture capital and inward investment; as well as directly funding innovation programmes and maximising the commercial potential of the UK's exceptional science base. We welcome views on how to strengthen significantly the contribution of Innovate UK, including its remit and its relationship with devolved administrations and agencies, other funders and partners, making the most of Innovate UK's knowledge and expertise.

In partnership with the devolved administrations and local government, we also want to support local leaders in co-creating effective innovation approaches for their local economies, building on their unique local strengths and assets and ensure their voices are heard in making national innovation policy.

Levelling up R&D across the UK

Where are we now?

The UK’s research and innovation system has remarkable strengths right across the UK. From precision medicine in Glasgow to marine innovation in the Western Gateway, from compound semiconductors in South Wales, to future food processing in the Midlands and eco-Innovation in the North West Coastal Arc, the UK has centres of excellence in research and innovation across the country. At a local level R&D investment can transform areas by acting as a driving force for social innovation, local growth and improved productivity.

We know, however, that research and innovation activity and funding is highly concentrated in certain parts of the UK. This makes the businesses in these areas more adaptable and innovative, and provides more opportunities for high-skill employment and training, directly benefitting communities through improved productivity and resilience.

To unlock these benefits in more areas of the UK, we should do more to build on a wider range of R&D strengths. We should also do more to enable places all over the UK to thrive and to fulfil their potential in R&D. Our R&D system will have a bigger impact on the recovery and long-term economic growth and prosperity if it can unlock the potential found in more areas of the UK.

Our commitment to R&D effectively supporting the wider levelling up agenda runs through this Roadmap. Ensuring we are making the most of all our strengths across the UK will allow us to capitalise on longer-term economic opportunities and tackle longstanding regional inequalities. We are challenging ourselves to consider how a greater focus on place outcomes in decision-making and new, proactive and coordinated approaches with devolved administrations and key funders could address regional imbalances in R&D intensity as part of our levelling up ambition. We are also examining how our aims for levelling up of funding in R&D interact with other priorities and investments, such as infrastructure investment, education and skills.

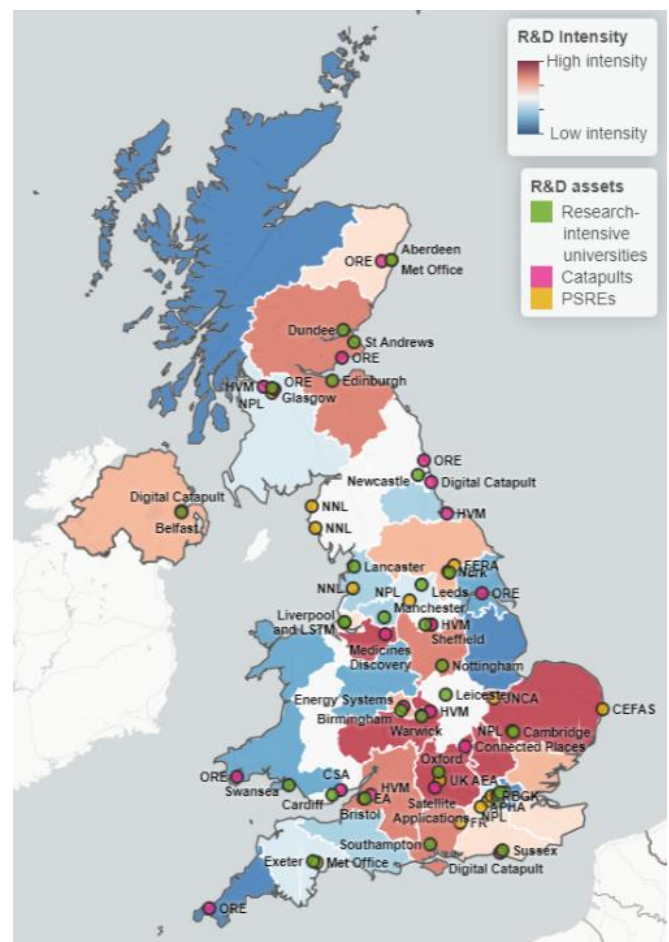


Figure 3 - Selected UK government funded R&D assets²³

²³ Regional R&D intensity is calculated in Figure 3 as Gross Domestic Expenditure on R&D divided by Gross Domestic Product.

What are we going to do? And how will we work with people to deliver our ambitions?

We have already committed to developing a comprehensive and ambitious **UK R&D Place Strategy** together with the devolved administrations over the coming months. Our goal in developing the Place Strategy will be to drive place-based outcomes from our R&D system – accelerating our economic recovery, levelling up across the UK.

Through this Roadmap we will be testing how our strategy should, in principle:

- **Build on existing and emerging strengths, irrespective of scale, ensuring that we can maximise the benefit from public investment.**
- **Go further and faster in supporting areas with untapped potential for future growth.**
- **Provide tailored support for less R&D-intensive regions to develop new capability and absorb new technology and innovations.**
- **Support increased collaboration between local, regional and devolved institutions on science, research and innovation, and ensure a strong role for local civic and business leaders in defining and delivering on local opportunities.**
- **Ensure that R&D interventions are in concert with wider improvements made in support of levelling up areas across the UK.**
- **Simplify our systems and reduce red tape to lower the barriers to participation so that places which currently secure less research funding can now make a greater contribution to UK R&D reaping the benefits for their local economies.**

Investing for places

Our Place Strategy will set out how we will invest research and innovation in places around the UK and align this with devolved priorities and initiatives. This could include building on the Strength in Places Fund, where the strong projects we are funding represent just a handful of the great ideas out there – and where further funding could unlock opportunities tailored around local economic strengths in more places. Evolving the programme would support our economic recovery by protecting and backing our most promising regional R&D clusters.

We must also ask whether our existing, core funding schemes deliver sufficient economic benefit to places across the UK. And we must carefully consider the case for developing new schemes and initiatives in consultation with place-based representatives to achieve our ambitions – new forms of funding, new investments, new partnerships.

We will also work with devolved administrations, businesses, academics, universities, charities and local leaders on how we can ensure that more parts of the UK are attractive to private investment – including from overseas – to unlock their full potential for R&D growth. This might include support for onshoring and learning from the experiences of existing localised initiatives such as Sci-Tech Daresbury and the Cheshire Science Corridor. We will look at the place-focused innovation offer both from the UK and devolved perspective, and whether it could be improved to provide holistic innovation and growth support to emerging clusters of innovative businesses.

Case study: Centre for Secure Information Technologies, Belfast

The Centre for Secure Information Technologies' (CSIT) mission is 'to couple major research breakthroughs in the field of secure information technologies, with a unique model of innovation to drive economic and societal impact', and achieves this through world-class research, new value and venture creation and entrepreneurial approach in the area of cyber security.

Funded by EPSRC, Innovate UK, and Invest NI, and based in Belfast's Titanic Quarter, this flagship Centre has helped attract over 50 high-tech start-up companies and Foreign Direct Investments (FDI). These companies employ more than 2,000 people and is evidence of the wider economic benefits to be gained from translating science into wider business and economic opportunity. CSIT works with large multinational partners including Allstate, BAE Systems, eBay, First Derivatives, Thales, and Seagate.

Attracting new commercial partners to work collaboratively on these new technologies is fostering international collaboration with leading Institutes in the USA, South Korea, Singapore and Europe. International issues require international solutions and this global innovation hub at CSIT has a unique approach in facilitating speculative blue-skies and industrial informed research projects within the same Institute.

Taking greater account of place when making decisions

We will consider how to optimise the benefit to places in our R&D decision-making processes. This could mean reviewing the geographical balance of decision-makers and advisory boards – ensuring that we are seeking diverse views and perspectives. We will find new ways to track the development of R&D capacity across the UK to improve our understanding of how funding systems across the UK are supporting levelling up but without adding to unnecessary bureaucracy.

We will work with the devolved administrations and stakeholders across the UK to explore what more we can do to leverage our R&D assets, for example by exploring how to provide more flexibilities to research and innovation infrastructure. This includes public sector research establishments, Catapult Centres, Innovation Centres, science and innovation campuses and university infrastructure. We will also ask what more we can do to support impact-focused activities such as SME outreach, business incubation, technology diffusion and talent development. We will rigorously assess how local economic impact could be factored into future infrastructure investment decisions by government at all levels. We will ask how we can achieve effective join-up between local and devolved growth funding and R&D funding, to improve coherence and achieve stronger outcomes across the UK.

We will consider how levelling up can be more embedded into our approach to R&D talent, looking closely at building regional capacity to make decisions on talent schemes – including doctoral training, and vocational and further education provision. We will assess how research culture might differ across places, and where differences help or hamper levelling up outcomes.

Case study: Creative Industries Clusters Programme

From screen industries and digital storytelling to fashion and videogames, some of the UK's best-performing and world-renowned creative businesses have received a major boost thanks to the £80 million Creative Industries Clusters Programme, which is being funded by the Industrial Strategy and delivered by the Arts and Humanities Research Council.

The Creative Industries Clusters Programme comprises nine research and development partnerships, which are led by universities, based around clusters in the four nations of the UK, and an independent Policy and Evidence Centre led by Nesta with partners. The programme aims to transform the extent and quality of interactions between our leading research-intensive universities and creative businesses, bringing together world-class research talent from across the UK in a first-of-its-kind R&D investment.

The four immersive technology demonstrators that sit at the heart of the Audience of the Future programme are pioneering new ways of telling stories through interactive and immersive technologies in live performance, visitor experience, the screen industries, and esports. Together these two programmes have already almost doubled in size through leveraged industry and devolved administration funding.



Fostering greater co-creation and collaboration

At present, most of the system for R&D is highly centralised, which has limited the scope for either local insights to truly inform national decision-making or for national expertise to deeply support the identification and development of opportunities to build local R&D capacity and capabilities. To address this, we will investigate how to include more direct local influence over national economic decisions as well as place-focused decisions.

We will work with the devolved administrations, UKRI, other R&D funders and representatives of local bodies to explore new place-based advisory functions. We are keen to explore how we can significantly expand the regional presence of our national R&D funders, improving their local footprint. We will look at opportunities to deepen the relationships between national

bodies, devolved bodies and local areas to better inform the development and delivery of both national, devolved and local economic growth plans.

We will be asking how we can support local R&D leadership to play a greater role in supporting the local economy, for example through stronger advice and support, or establishing new requirements for areas with devolved authority to create local innovation strategies in England. We will work closely with stakeholders to consider the role that ringfencing R&D funding for specific places might play.

Taking forward our National Data Strategy, we will improve the access to trusted data resources at local and regional levels to improve the availability of evidence at those levels to give local leaders what they need to build robust R&D ecosystems.

Next steps to develop the Place Strategy

Place is one of the central themes of this document and an R&D Place Strategy should allow us to bring together the issues that matter to places, as well as ensure we are taking a place lens to broad issues such as talent, innovation and infrastructure. Our R&D Place Strategy will only be effective if it is developed with people and organisations across the country and supported by the devolved administrations. We will continue our significant programme of engagement over the summer to inform how we take forward changes to national policy, before publishing the ambitious new Place Strategy in the autumn after the Spending Review.

We will also set up a ministerial **R&D Place Advisory Group**. Comprised of expert stakeholders, this group will propose and interrogate opportunities, challenges and analysis to inform decision-making. The advisory group will consider how engagement systems can provide for more direct local influence and input over place-focused decisions, will explore how we can significantly expand the regional presence of our national R&D funders, improving their local footprint, and will look at opportunities to deepen the relationships between national bodies, devolved bodies, and local and regional areas.

Case study: Strathclyde's Innovation Ecosystem

Strathclyde is home to a range of industrial research centres, four Catapult Centres and four Innovation Centres. It is the base for Fraunhofer UK, a host site for the National Physical Laboratory and the Laboratory of the Government Chemist, and to many collaborating companies, large and small.

Its regional impact is driven through two key initiatives: Glasgow City Innovation District (Scotland's first), an initiative driven by Strathclyde with Glasgow City Council, Scottish Enterprise, Entrepreneurial Scotland and Glasgow Chamber of Commerce; and the National Manufacturing Institute Scotland, co-located with the Advanced Forming Research Centre and the new Medicines Manufacturing Innovation Centre.

These initiatives are attracting significant numbers of companies and organisations looking to nurture and accelerate growth, improve productivity and access world-class research, technology and talent from the University of Strathclyde.

Being at the forefront of global collaboration

Where are we now?

Research and innovation are inherently global, and international collaboration and mobility of talent are associated with more impactful research. The UK's leading researchers and innovators want to collaborate with the best talent in the world, in the best facilities in the world, regardless of borders. These international collaborations lead to new advances and discoveries, pushing the frontiers of knowledge faster and further. They underpin the UK's position as a world-leading knowledge economy and support trade, investment, diplomacy, defence and security.

The COVID-19 pandemic has thrown a spotlight on international research and innovation co-operation, demonstrating its importance in tackling global challenges and underscoring that high-quality, impactful research and innovation is increasingly a global endeavour. While the full impact of COVID-19 on global research and innovation networks remains uncertain, the time is right to put international connectivity at the heart of how we support the sector to rebuild, improve and grow as a cornerstone of global Britain.

UK researchers and innovators think globally. 54% of all their publications result from international collaboration, significantly higher than the OECD average of 31%.²⁴ From 2012-14, 35% of innovative UK SMEs engaged in international collaboration, the second highest rate among OECD countries.²⁵ And our researchers and innovators are becoming ever more globally connected, with the UK's share of international collaboration increasing every year since 2010.²⁶

The Government has supported internationally collaborative research and innovation through our involvement with European framework programmes. In low- and middle-income countries, we work through Department for International Development (DFID) Research Programmes, NIHR Global Health Research Programmes, the Newton Fund and Global Challenges Research Fund (GCRF) programmes. We are growing new partnerships with the rest of the world through our Fund for International Collaboration and would like to grow these further. We invest in over 30 international research and innovation infrastructures, ranging from big physics experiments to distributed projects tackling societal challenges.

Our Official Development Assistance (ODA) R&D investments bring together UK and international partner country research expertise to alleviate poverty, create jobs, and secure more sustainable economic growth and stability. It leverages soft-power influence to position the UK as the partner of choice, securing access to future markets, beyond aid.

As the global economy continues to develop, more players are entering the scene: bringing potential collaborators as well as competitors. Digitisation and shifting attitudes towards air travel are driving innovations in the mechanisms of collaboration. Our priorities and mechanisms of collaboration need to adapt to this changing world.

²⁴ Scopus data retrieved 18/5/20

²⁵ OECD (2017), Science, Technology and Industry Scoreboard

²⁶ International comparisons of the UK Research Base 2019 - <https://www.gov.uk/government/publications/international-comparison-of-the-uk-research-base-2019>

What are we going to do? And how will we work with people to deliver our ambitions?

The UK must collaborate globally if we are to remain at the forefront of cutting-edge research and innovation. We benefit from strong international partnerships with a range of countries, at different stages of economic and scientific development. As set out in the 2019 International Research and Innovation Strategy,²⁷ the UK wants to remain a partner of choice for other world-leading and emerging research and innovation nations, attracting global talent and supporting our world-leading researchers to collaborate with the best in the world. However, increasing competition means we will need to work harder to sustain this position, while our ambitions to form new collaborations have grown. We will lead work to enable UK researchers and innovators to boost existing and forge new global partnerships where they see the greatest scientific and innovation opportunities and manage risks.

Through this Roadmap we are asking how we can:

- **Set out an ambitious offer creating opportunities for partnership with researchers and innovators around the world.**
- **Use new funding approaches, which enable us to rapidly seize emerging opportunities and better respond to emerging threats.**
- **Strengthen and grow our collaborations with overseas governments and international funders through strategic bilateral co-operation and renewed leadership of multilateral research and innovation organisations and networks, supporting UK's soft power, and mutual economic growth and prosperity.**
- **Balance strong international collaboration with effective protection for UK intellectual property, sensitive research, personal information, and academic values.**

Growing our global collaborations with a new, agile offer

We recognise that research and innovation are global endeavours and our aim is to sustain, improve and grow opportunities for international collaboration. We will do what is needed to enable our researchers and innovators to join and lead networks and collaborations, and push forward frontiers with their colleagues across the globe. We will achieve this by upgrading the UK's offer for global collaborative research and innovation through the development of **a new, agile offer for growing global collaboration**. This will bring together new and existing opportunities with partners across the globe to provide a coherent UK offer to our partners overseas, delivering a responsive, strategic and truly global approach for UK's international R&D funding.

This new portfolio approach will enable us to:

- Grow new strategic collaborations and support existing ones with the world's leading research nations and with emerging science nations.

²⁷ <https://www.gov.uk/government/publications/uk-international-research-and-innovation-strategy>

- Work across ODA research and development to deliver ambitious and equitable partnerships with partner countries, sharing research expertise to tackle the Sustainable Development Goals.
- Demonstrate the UK's leadership in existing multilateral research and innovation organisations and develop new consortia in areas of strategic importance.
- Enhance and develop new trading partnerships and link our people to the expertise, markets, infrastructure and ecosystems needed to advance their work.
- Be agile to seize fast moving international opportunities as they arise.
- Balance discovery research with more applied research tackling major global challenges.

Supporting new and growing existing collaborations

The UK has strong bilateral collaboration arrangements with well over 50 countries. These countries range from the research powerhouses of the USA, China and Europe through most of the industrialised nations, a significant number of middle-income countries and emerging economies. These relationships are supported by 100 Science and Innovation Network officers in 40 countries across the globe who promote UK research and identify strong collaboration opportunities. In Africa, three UK science, technology and innovation platforms in regional hubs link UK researchers, innovators and entrepreneurs to African policy makers and innovation ecosystems.

We see major potential both to strengthen our collaborations with existing R&D-intensive nations as well as to build new partnerships with emerging knowledge economies and developing countries. We want to partner with countries with similar expertise and those with complementary or niche capabilities. A greater ability to invest in global partnerships and respond in a more agile way to fast-moving international opportunities will allow the UK to better capitalise on new and existing regional strengths, and UK-based researchers to seize opportunities as they arise.

Official Development Assistance

Through our commitment to spending 0.7% gross national income in aid, ODA funds have greatly enhanced the capacity of UK researchers and innovators to tackle global challenges. This funding ensures that UK expertise takes a leading role in tackling the UN Sustainable Development Goals – such as climate change, conflict, mass migration, extreme poverty and diseases. UK led research has helped reduce under-five mortality in Africa, developed more productive and nutritious crops to feed growing populations, and resulted in a strengthened arsenal of interventions to tackling infectious diseases such as Ebola and malaria.



ODA funds also support the development of researchers and R&D ecosystems in ODA eligible countries – these are our partners of today and for tomorrow. Through these partnerships we are supporting future markets and promoting the world’s prosperity. We will continue to develop this approach.

Case study: The Ayrton Fund – Energy Storage Challenge

When the Prime Minister announced the £1 billion Ayrton Fund for clean energy innovation in September 2019 it signalled a new level of ambition, but built on a strong track record. Energy storage is a clear priority for the energy transition to allow higher penetrations of renewables and to reach where the grid does not. In the last two years we have built on the UK Faraday Battery Challenge, using the new battery science and capabilities created to help address developing country needs.

An early success is Birmingham-based Aceleron which has developed a new circular economy Lithium Ion battery pack, enabling faulty cells to be quickly tested and replaced. An initial order of 2000 has been sold to BBOXX, a Chiswick-based leader in the African solar market. Aceleron was first supported to work internationally via Innovate UK’s Energy Catalyst, and we have since supported a further £17 million of energy storage innovations starting in April 2020.

Through the Faraday Institution, we have supported a new international strand in the NEXGENNA research programme led by the University of St Andrews into Sodium Ion technology. This technology could offer lower cost, improved recyclability and increased safety in static applications in developing countries.

European collaborations

The UK is a top five collaboration partner for 26 of the 27 EU countries participating in Horizon 2020 and it is in the interests of both the UK and EU that these networks continue to flourish, supporting universities, research institutes and businesses of all sizes across Europe. We aim to maintain a close and friendly relationship with our European partners and are in negotiations with the EU to participate in the next generation of European research and innovation programmes starting in 2021: Horizon Europe and Euratom R&T.

It is our ambition to fully associate to both programmes if we can agree a fair and balanced deal, but we will make a final decision once it is clear whether such terms can be reached. If we are formally associated to Horizon Europe, the funding for UK participants will be allocated to the relevant UK organisations by the EU. In this scenario, if there were any gap before we became formally associated, we would implement short-term alternative funding arrangements through proven, attractive UK schemes. During any gap, we would provide funding to UK partners who are successful in bidding to programmes open to third country participation.

If we do not formally associate to Horizon Europe or Euratom R&T, we will implement ambitious alternatives as quickly as possible from January 2021 and address the funding gap. As a first step we will launch an ambitious new Discovery Fund offering sizeable grants over long periods of time to talented early, mid and late-career researchers, whether already in the UK or coming here from anywhere in the world, to pursue discovery-led, ground-breaking research. We will also scale up and enhance our most prestigious domestic schemes, providing funding to allow UK researchers and innovators to seize opportunities and to allow our institutions to attract and retain international talent. We will make funding available to allow UK partners to participate in European schemes open to third countries.

Under all scenarios, it is our aim that UK organisations and entities continue to participate in Horizon Europe collaborative projects open to third countries, as well as in wider international collaborations. We therefore strongly encourage research talent, businesses, and innovators in the UK and worldwide to work together in establishing global consortia with UK partners now and in the future. Alongside this the UK will continue to invest in our cutting-edge Nuclear Fusion science including through our ambitious Spherical Tokamak for Energy Production programme to accelerate the delivery of sustainable fusion energy.

The Government will also pursue strategic opportunities to strengthen our research and innovation relationships with individual European nations. These will range from highly advanced research nations to those who offer exciting opportunities for collaboration in niche areas.

Demonstrating the UK's leadership in existing key multilateral research and innovation organisations

The UK's Presidency of the G7 in 2021 will provide us with an even stronger international voice. We will use this opportunity to show global leadership in science, research and innovation, promoting areas of clear importance to us, showcasing our expertise (for example in intellectual property and standards for new technology) and supporting intellectual freedom and gender equality in research and innovation across the world. Through our membership of all the major international and multilateral initiatives, we will continue to be a leading voice in important areas such as global research governance, Open Science and research ethics.

Multilateral organisations offer opportunities to bring expertise from across the world to tackle global challenges such as climate change and the transition to a low-carbon economy. We will continue our leadership in this area through our COP26 Presidency. We will also investigate further investment in strategic multilateral innovation networks such as EUREKA, providing our smaller innovative firms with opportunities to access partners and supply chains worldwide. We will also work through multilateral organisations to lead the way on digital technical standards, ensuring the competitive, safe and ethical development of technology.

Developing and maintaining international collaboration is essential to the strength and success of UK R&D, enabling the UK's world-leading research and innovation sector to get the most out of international scientific collaboration while protecting intellectual property, sensitive research

and personal information. The Government has already produced advice called Trusted Research to support the UK's research and innovation sector to manage the risks that can occur and will continue to support a sector-led work programme, spearheaded by Universities UK, to raise awareness of these risks through the publication of guidelines in the next academic year. We will deepen our engagement with the sector, provide further advice and guidance to individual institutions, and launch an online portal that will make it easier for individual researchers to contact the Government for advice. UK institutions are not alone in managing risks and we will expand our engagement with international partners, including with our Five Eyes allies and EU countries, to share and inform our approach.

We will also ensure that where there is a national security case, strategically important organisations remain under UK control, and protect the UK's position in capabilities and skills necessary for national security.

Case study: Trusted Research campaign

The Trusted Research campaign, designed by the Centre for the Protection of National Infrastructure (CPNI) and the National Cyber Security Centre (NCSC), aims to secure the integrity of the system of international research collaboration, which is vital to the continued success of the UK's research and innovation sector.

The campaign aims to help UK universities and research institutions make informed decisions about international collaboration and, in doing so, protect their own researchers and academic values. The advice has been produced in consultation with the research and university community and:

- Outlines the potential risks to UK research and innovation.
- Helps researchers, UK universities and industry partners to have confidence in international collaboration and make informed decisions around those potential risks.
- Explains how to protect research and staff from potential theft, misuse or exploitation.

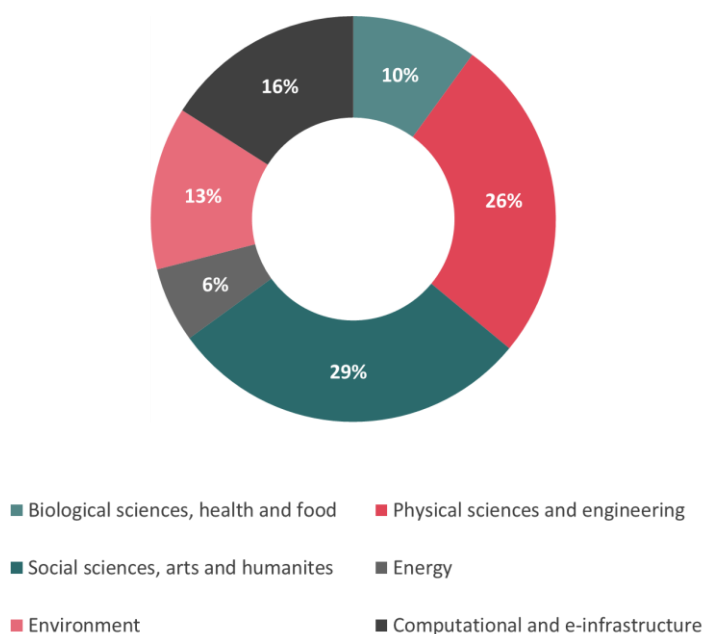
Developing world-leading infrastructure and institutions

Where are we now?

Our future success in R&D will rely on a diverse network of infrastructure: internationally competitive, high-quality and accessible facilities, resources, data and services. For example, the UK hosts the Joint European Torus (JET), the world’s most powerful nuclear fusion experiment. Our world-leading infrastructure is a national asset, acting as a magnet for international talent, contributing to local and national economic growth, and generating knowledge and capability critical to UK policy, security and wellbeing.

The UK has substantial expertise and collaboration in research and innovation infrastructure through international facilities hosted in the UK and overseas. Our ambition is to maximise the opportunities for UK researchers to access the best research and innovation infrastructure around the world.

The UK is home to over 500 nationally and internationally significant research and innovation infrastructures, providing us with a breadth of expertise across sectors. Almost all of these infrastructures work with international partners and have an international user base, emphasising their important role in attracting leading researchers and innovators from across the world.



Over **500** national and internationally significant infrastructures

A breadth of expertise: **92%** work across more than one topic domain

Three quarters work with UK business and **42%** with public policy organisations

Infrastructures employ just under **25,000** staff

Figure 4 – The breadth of expertise across the UK’s research and innovation infrastructures

But there is more that we can do to give our researchers and innovators the capabilities they need to do their ground-breaking work. We need to take a flexible approach to supporting

research infrastructure to deliver better value for money and keep assets continuously maintained and cutting-edge. Higher quality infrastructure will help attract and retain the best staff and create a more vibrant research environment.

What are we going to do? And how will we work with people to deliver our ambitions?

We want to ensure the UK remains a partner of choice for collaboration, demonstrate that the UK is a global leader in infrastructure, and put our infrastructure to use in tackling global challenges. We want to invest more in our existing infrastructure and use opportunities such as those identified in the UKRI report “Research and innovation infrastructure: opportunities to grow our capability”.²⁸ If seized, these opportunities could create a step change in the next generation of infrastructure capability – both within the UK and through international partnerships. We will work closely with the devolved administrations to ensure we take an approach to infrastructure that fits with devolved approaches and priorities.

Through this Roadmap we are asking how we can:

- **Develop a long-term investment plan that enables us to invest in new and existing infrastructure more flexibly and efficiently for greater regional, national and international benefit.**
- **Make the most of our capabilities to ensure they truly become national assets.**
- **Ensure these assets are on a sustainable financial footing to build for the future, including ensuring maintenance and upkeep costs are considered.**
- **Invest in skills with an emphasis on key, scarce research technology professional skills, including data science skills, as well as academic roles.**
- **Develop our digital research infrastructure capability – data, supercomputers, software, and people – by building an internationally leading national digital research infrastructure, bringing digital transformation to the research sector.**
- **Invest in a step change in the capability that research and innovation infrastructure enables to promote economic growth and discovery across sectors and disciplines, ensuring the UK is partner of choice for international collaboration.**
- **Reduce the barriers to growing campuses and clusters – which provide unique ways to combine public and commercial capabilities to promote growth.**

²⁸ UK’s Research and Innovation Infrastructure: Opportunities to Grow our Capability-
<https://www.ukri.org/research/infrastructure/>

Case study: ISIS Neutron and Muon Source

UK researchers at ISIS, the Science and Technology Facilities Council's (STFC) world-leading neutron and muon source in Oxfordshire, have created NOTT-300, a new, low cost material that offers an exciting breakthrough in combating atmospheric pollution and reducing fossil fuel emissions. NOTT-300 can selectively capture carbon dioxide and sulphur dioxide, both environmentally harmful gases that contribute to acid rain, a major cause of building corrosion and acidification of our waterways, and climate change. Reducing the levels of both gases is an important step in meeting our 2050 net zero target and creating a clean, sustainable planet. NOTT-300 also has other significant advantages over its competitors. It is cheap and easy to produce. It is also re-useable, with captured gases being released after a change in pressure is applied.

Investing in infrastructure for the long term

We will put in place new mechanisms which allow us to prioritise infrastructure investment and work with the devolved administrations and a wide range of partners to ensure that investment aligns with the priorities in this Roadmap.

Our goal is to take the best decisions on where we should support new infrastructure in the UK or internationally, as well as where we should increase funding to maintain and upgrade our world-class infrastructure and assets to ensure they retain their status as world-class labs at the cutting edge of research and meet the needs of the research community. UKRI is developing a new scoping fund to support pilot and design studies. And we want to develop a National Digital Research Infrastructure to link supercomputers, clouds, networks, software and people.

We will also look at new funding approaches, cutting financial red tape to ensure a sustainable, long-term approach to funding but with built-in flexibility and agility to fund different types of organisations.



Catalysing Innovation

We will enhance collaborations between business and R&D infrastructure. There are already good examples: our infrastructures including PSREs and Catapults work closely with large businesses and SMEs, as do the Innovation Centres in Scotland. We will do more to facilitate

access to these facilities and capability, stimulating long-term private investment in our national assets and supporting new innovation tie-ups.

Case study: Offshore Renewable Energy

The Offshore Renewable Energy (ORE) Catapult network plays a key role in delivering the UK's largest clean growth opportunity, through its mission to accelerate the creation and growth of UK companies in the offshore renewable energy sector. Active throughout the UK, it has operations in Glasgow, Blyth, Levenmouth, Aberdeen, the Humber, the East of England, the South West and Wales, and operates a collaborative research partnership in China. Independent and trusted, with a unique combination of world-leading test and demonstration facilities, engineering and research expertise, ORE Catapult convenes the sector and delivers applied research, accelerating technology development, reducing risk and cost and enhancing UK-wide economic growth. To date, it has supported over 800 SMEs; over 320 active research projects; and over 180 companies in their product development.

Ensuring a healthy R&D system

Where are we now?

The “R&D system” is what connects universities, research institutes, government labs, charities and businesses to each other and to sources of funding. It supports the UK’s wider ecosystem of public, private and third sector organisations to push the boundaries of knowledge and turn great ideas into economic, environmental and social benefits. We need an efficient and effective system that enables strategic decision-making, provides the right incentives to enable research and innovation to inform each other, and ensures that money flows to the best researchers, innovators and entrepreneurs with the least friction possible.

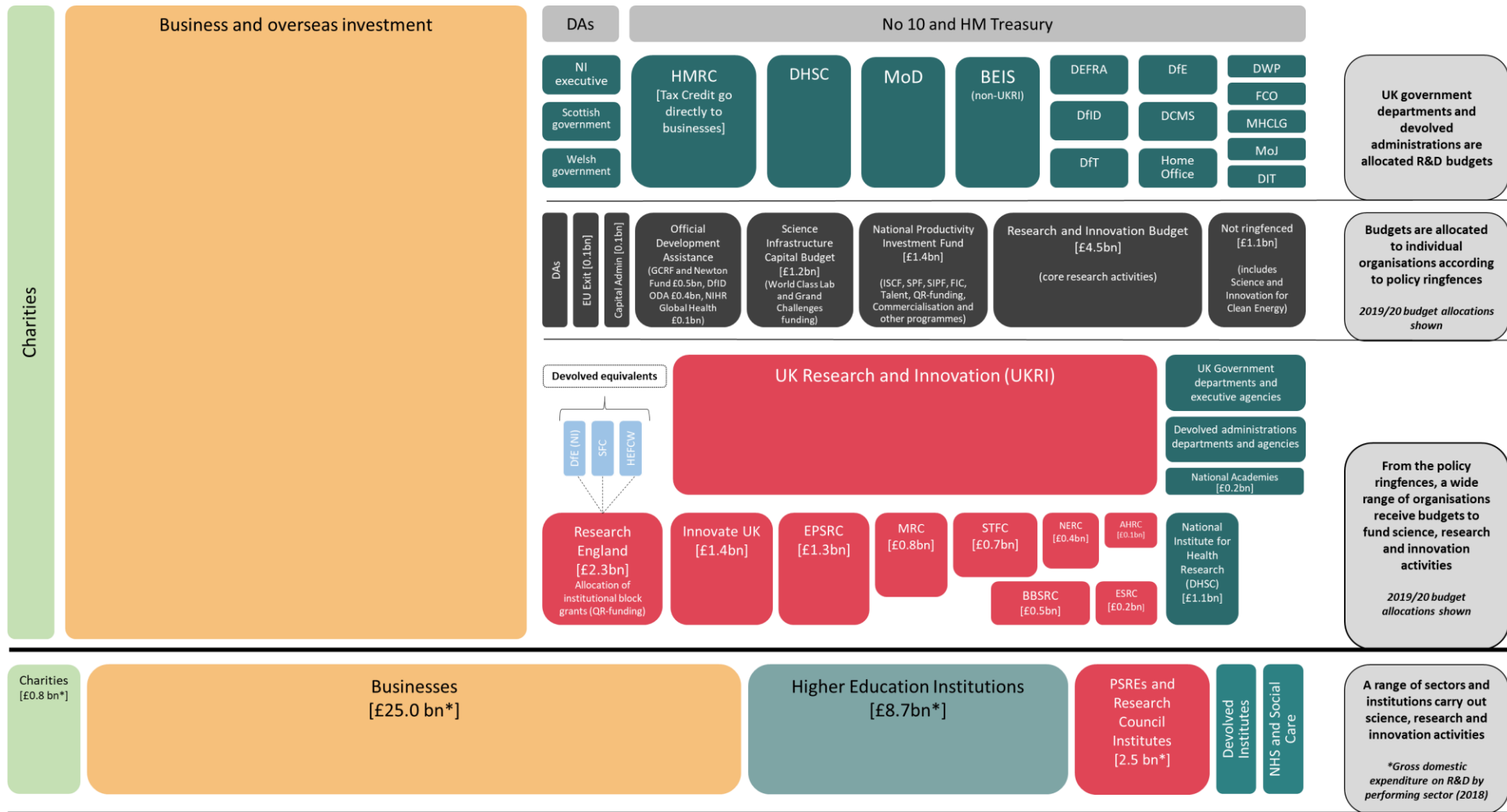
The UK’s R&D system is internationally recognised, but, like many research-intensive nations, we face systemic challenges that can make it harder for us to produce, translate and use great research. We know unnecessary bureaucracy is constraining the research process, making it risk-averse and inefficient. It can take too long for funding or approvals decisions to be made, slowing and frustrating the discovery process. Data that could drive new discoveries or innovation is not always as available as it could be. It is difficult for innovative firms to access finance required to scale, and our patterns of investment are concentrated on specific places and sectors. Our research and innovation system could be more resilient and more efficient. The disruption caused by COVID-19 has highlighted the extent to which the research and innovation ecosystem involves multiple public and private funders working together and, in the case of universities, also relies on other income sources.

The UK public funding system is complex with multiple players with overlapping objectives. The establishment of UKRI has helped, but its transformation into a mature organisation is still ongoing. We want to support an effective and efficient R&D system that draws on a diverse range of voices and perspectives to make the most of existing strengths as well as addressing any weaknesses or gaps.

What are we going to do? And how will we work with people to deliver our ambitions?

We will be launching a major review of research bureaucracy and methods in UKRI to free up and support the best researchers to focus on ground-breaking research that goes on to make a difference, for example curing diseases or improving our transport networks. UKRI’s ‘Reforming our Business’ programme has focused on the processes that affect all applicants for UKRI funds, from first advertised calls through to evaluation (end to end). The aim is to harmonise and reduce burden of processes, raise quality levels and enhance equality, diversity and inclusion. To date the programme has delivered the removal of Pathways to Impact on grant application forms, with the goal of finding better ways of looking at impact.

UK Research and Development Roadmap



In 2018 GERD figures, business and overseas investment accounted for £25bn of R&D funding and charities accounted for £1.9bn.

Acronyms: DAs (Devolved Administrations), NI Executive (Northern Ireland Executive), HMRC (HM Revenue and Customs), DHSC (Department of Health and Social Care), MoD (Ministry of Defence), BEIS (Department of Business, Energy and Industrial Strategy), DFE (Department for Education), DfID (Department for International Development), MHCLG (Ministry of Housing, Communities and Local Government), DfT (Department for Transport), DEFRA (Department for Environment, Food and Rural Affairs), DWP (Department for Work and Pensions), DCMS (Department for Digital, Culture, Media and Sports), FCO (Foreign and Commonwealth Office), MoJ (Ministry of Justice), DIT (Department for International Trade), GCRF (Global Challenges Research Fund), ISCF (Industrial Strategy Challenge Fund), SPF (Strategic Priorities Fund), SIFP (Strengths in Places Fund), FIC (Fund for International Collaboration), QR (Quality-related), HEFCW (Higher Education Funding Council for Wales), SFC (Scottish Funding Council), DfE (NI) (Department for the Economy (Northern Ireland)), EPSRC (Engineering and Physical Sciences Research Council), MRC (Medical Research Council), STFC (Science and Technology Facilities Council), NERC (Natural Environment Research Council), AHRC (Arts and Humanities Research Council), BBSRC (Biotechnology and Biological Sciences Research Council), ESRC (Economic and Social Research Council), PSREs (Public Sector Research Establishments)

Figure 5 - The UK funding landscape

Through this Roadmap we are asking how we can:

- **Make sure the R&D system and public institutions are set up in the best way to deliver the greatest impact across the UK and internationally.**
- **Make the most of Public Sector Research Establishments (PSREs), which have the potential to deliver broad public policy objectives and help innovation translation.**
- **Enable work across institutions to solve the grand challenges of our time.**
- **Make the most of our institutions, to use research to improve both UK and devolved policy outcomes and to measure and refine programme performance.**
- **Minimise bureaucracy while maintaining flexibility, diversity and necessary accountability.**
- **Support resilience and improved collaboration across the research and innovation sector.**

Minimising bureaucracy in the public funding system

We will eradicate unnecessary bureaucracy – keeping in place only those checks and approvals necessary to effectively manage public money and take informed decisions about the system. Where high-quality valuable information can be captured without researcher input, it should be. We will look at new, smarter approaches to evaluation. In partnership with the devolved administrations and their funding bodies, UKRI, NIHR and other funders, we will tackle the broader issues that are often causes of unnecessary bureaucracy.

This is also an opportunity to shift the research sector to more modern methods of research, which will help cut red tape too. This means embracing modern methods of peer review and evaluation. It also means tackling the problematic uses of metrics in research and driving up the integrity and reproducibility of research.

Crucially, we must embrace the potential of open research practices. First, we will require that research outputs funded by the UK government are freely available to the taxpayer who funds research. Such open publication will also ensure that UK research is cited and built on all over the world. We will mandate open publication and strongly incentivise open data sharing where appropriate, so that reproducibility is enabled, and knowledge is shared and spread collaboratively. Second, we will ensure that more modern research outputs are recognised and rewarded. For example, we will ensure that digital software and datasets are properly recognised as research outputs, so that we can minimise efforts spent translating digital outputs into more traditional formats. Third, we will consider the case for new infrastructure to enable more effective sharing of knowledge between researchers and with industry to accelerate open innovation where possible.

High-quality R&D funding decisions need input from high-quality researchers and innovators. UKRI will reinvigorate participation in the peer review system through ensuring the process is easy to work with, well supported and incentivised in the R&D community. An agile and creative R&D system must support diversity of expertise, approaches, ideas, ways of working and delivery mechanisms.

Increasing clarity and coherence in public R&D funding

The government has committed to increasing UK investment in R&D to 2.4% of GDP by 2027. To achieve this target, government has committed to raising public investment to £22 billion per year by 2024/25: a record increase in spending. We will set out details of this historic investment at the Spending Review, giving researchers and innovators confidence through our long-term investment.

This gives us the opportunity to consider what the balance of funding should be. We will continue to strongly back our excellent discovery research but we also need to invest across the whole R&D system increasing investment in applied research, development and implementation, and ensuring these findings then inform further discovery research. We will take a higher risk approach to public investments, recognising that ‘failures’ can be useful and further the pursuit of knowledge. By getting the balance right, the UK can fully capitalise on our strengths and ensure it translates its research and innovation into tangible benefits for citizens across the UK and the economy.

The R&D ecosystem is complex and we should look to ensure that it is coherent and efficient, with the right incentives for institutions to collaborate and not duplicate. We will look at how we can enable agile funding so we can tackle urgent issues and more flexibly deliver on national priorities. For example, Innovate UK trialled a rapid, light touch calls process as part of their response to COVID-19, and UKRI partnered with NIHR to ensure rapid funding for new vaccine development. Internationally and complementing this, we nimbly flexed existing partnerships in order to invest in critical COVID-19 vaccines, diagnostics and treatments development. The streamlined Innovate UK call received 8,600 applications in 6 weeks, compared to 8,300 across all Innovate UK competitions over the whole of the 2019/20 financial year. Streamlining these calls will be delivered by moving to UKRI’s new grants funding process.

Strengthening the role of our research and innovation institutions

Government

We will ensure that the implementation of UK government strategies and policies that impact on R&D – for example the Science Capability Review, National Data Strategy, Geospatial Data Strategy, Integrated Review, the Defence and Security Industrial Strategy and Sector Deals, along with devolved administration equivalents – align to make the UK the best place to do research, development and innovation.

We will look at how institutions can work together on shared objectives, for example achieving net zero carbon emissions. We will map the UK’s research and innovation organisations to identify potential synergies and to ensure they have the right relationships across the whole of the UK government and devolved administrations. We will identify where capabilities could be strengthened, linked strategically or where a new organisation may be required to tackle a particular mission.

We will initiate a cross-government review of how we fund, govern and set direction to institutions in order to strengthen the network, share best practice, encourage cost effective international collaborations, eliminate poor practices and identify R&D funding opportunities and risks.

UK Research and Development Roadmap

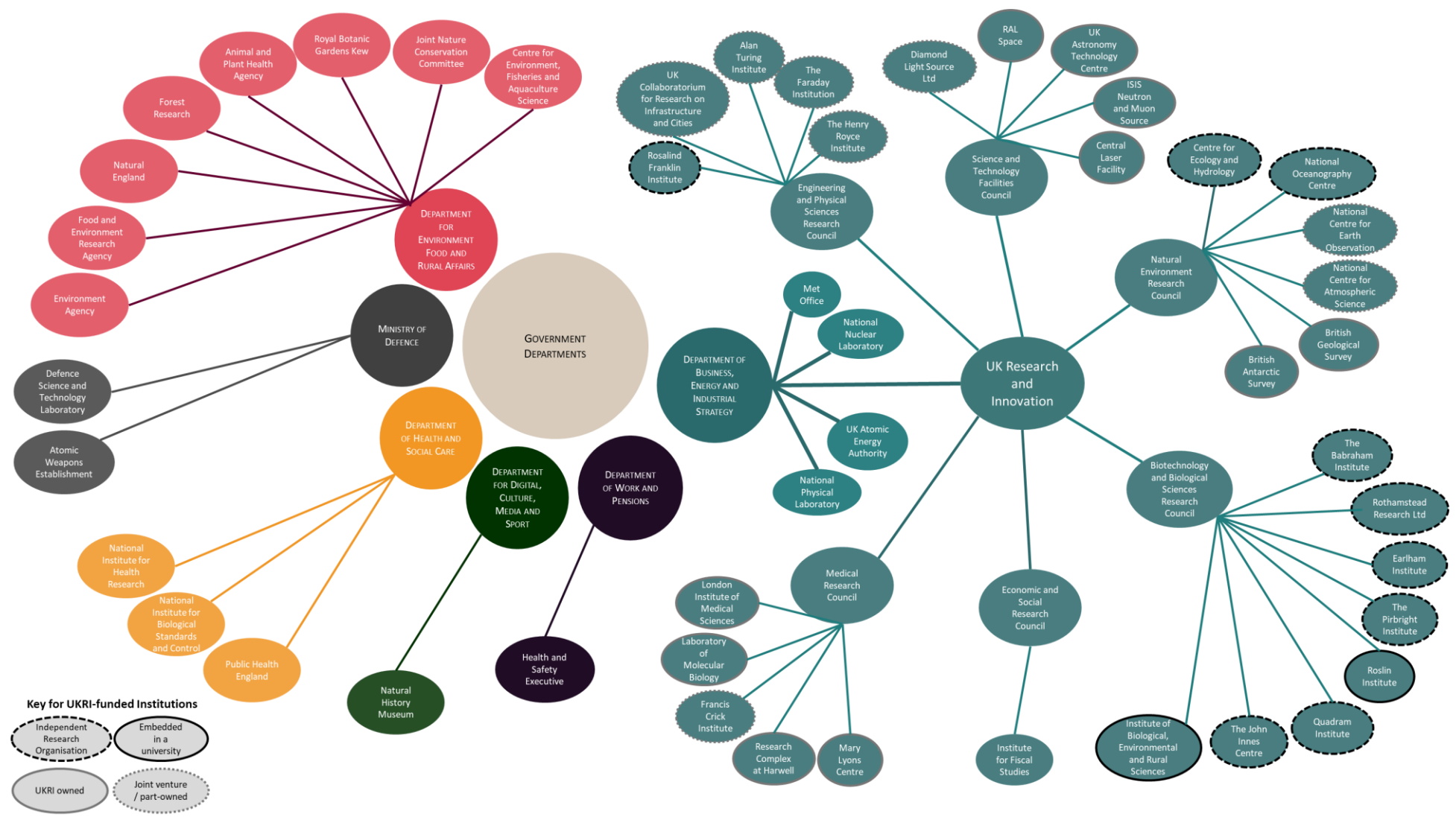


Figure 6 - The UK government's Public Sector Research Establishments and UK Research and Innovation-funded Institutes. Devolved administrations also fund research and innovation institutes which are not shown.

We will trial new approaches to institutions, including developing a unique and independent funding body for advanced research, modelled on the US' Advanced Research Projects Agency.

We will continue to implement the Government Science Capability Review,²⁹ which had several key messages:

- While there are pockets of excellence, science activity and expenditure are variable across government – with reduced science budgets in many departments.
- To improve the impact of our science, it is necessary to work across government and the wider scientific community in academia and industry, both in the UK and internationally.
- In our public laboratories, we have an extraordinarily valuable asset, and we need to do more to nurture them.
- New models for working with private sector innovative companies will be required to meet the science needs of government.
- The government science and engineering profession, analysts and policy professionals will need to be part of defining the problems to be addressed by science and using science to improve performance and outcomes.
- We need to strengthen the government science and engineering profession, bring more STEM graduates into government to improve the diversity and ensure that the civil service has the skills required to meet the challenges of the 21st Century. This includes being able to access, challenge and understand external expertise where necessary.

We have taken some steps, but there is further to go. We have strengthened the science system within the UK government focusing on the role of Departmental Chief Scientific Advisers (CSAs). Departmental CSAs are accountable for the whole range of science activity conducted within the department and at arm's length from it. This includes how cross-government science priorities and non-government funded R&D will be used and incentivised and the publication of Departmental Areas of Research Interest to catalyse activity in the research base. The establishment of a strong network of CSAs across government has helped take forward cross-cutting work such as net zero carbon emissions and engagement with the external research base. We have strengthened the provision of science advice across government. The Science and Engineering Fast Stream has doubled in size and there is a commitment to increasing the number and diversity of STEM graduates entering the civil service.

²⁹ <https://www.gov.uk/government/publications/government-science-capability-review>

Case study: Data First

Data First is an ambitious, pioneering data-linking programme led by the Ministry of Justice (MoJ) and funded by UKRI through the Economic and Social Research Council (ESRC) and Administrative Data Research UK (ADR-UK). Subject to MoJ and the judiciary's data governance, the projects will enable researchers in government, universities and other institutions to securely access anonymised extracts of linked administrative datasets held by MoJ and its executive agencies. The data will further be connected to data in other large government departments, such as the Department for Education. Data First will allow researchers to understand how people interact with courts over time, and what characteristics influence patterns of frequent use, to build a much better understanding of what MoJ policies and services are most effective. Researchers will be able to explore how justice system users interact with other government services. This will enable deeper understanding of how the economic, social and educational backgrounds of people who use the justice system influence their needs, the pathways they follow through the system (for example, between the civil and criminal courts) and the outcomes they experience. Such understanding will enable more evidence-informed, targeted support and lead to lower cost, higher quality public services for everyone in the UK. Data access will be facilitated by the controlled circumstances of the ONS Secure Research Server (SRS); an accredited processor under the Digital Economy Act (2017) which complies with the highest standards of data security and protection outlined by the principles of the Five Safes.

UKRI

Since launching in 2018, UKRI is building on the strengths of its nine councils to deliver more ambitious, interdisciplinary research and innovation, enabled by new investment through the Strategic Priorities Fund and the Industrial Strategy Challenge Fund. As the largest public funder of R&D in the UK, and with a statutory role to advise government, UKRI has a central role to play in delivering the outcomes of this Roadmap. We will support UKRI to develop a stronger voice for research and innovation and support the whole system to become more than the sum of its parts. We will work closely with UKRI to identify areas where performance can be improved, with a focus on interactions and outcomes across the whole R&D system and more broadly and taking into account sensitivities around the fact that UKRI combines UK-wide and England-only responsibilities.

PSREs and other publicly funded research institutes

Public sector research establishments (PSREs) and other publicly funded institutes – including UKRI-funded institutes and institutes funded by the devolved administrations, are a diverse collection of bodies carrying out research. This research supports government objectives, including informing policy-making, statutory and regulatory functions and providing a national strategic resource in key areas of research. They can also provide emergency response services. They interact with businesses around a wide array of innovation-related functions. We want to get the most value out of the whole range of PSREs and publicly funded institutes, laboratories and campuses.

The current PSRE and institute landscape is complex. There is an opportunity to raise awareness and support development of strategic national laboratory capability, develop closer relationships across the network of PSREs and institutes to address cross-cutting priorities and develop more consistent and co-ordinated, accessible funding for PSREs. Most programmes do not include funding for the full costs of overheads – this sometimes prevents our national

laboratories from participating in UK government priority programmes without making a loss. A more flexible approach and funding a higher proportion of the economic costs would increase spending efficiency and encourage more effective investments and maximise their benefits.

Building on the 2019 Science Capability Review, we will:

- champion the development of a truly strategic, national laboratory capability and identify opportunities to strengthen their capabilities and ability to collaborate, especially with the private sector, devolved administrations and local civic authorities.
- work to understand current capacity and capability, including spare capability, and to ensure that national labs, PSREs and other publicly funded institutes are working together as part of business as usual rather than only in times of crisis.
- explore the potential for all PSREs to have access to more funding opportunities from UKRI so that PSREs are viewed as national assets rather than the property of UK government departments.

Case study: Defence Science and Technology Laboratory breakthrough work on treatment for sepsis

A ground-breaking innovation was developed by the Defence Science and Technology Laboratory (a government executive agency) to detect symptoms of sepsis before they appear. Sepsis affects around 30 million people every year worldwide and is responsible for more deaths than bowel, breast and prostate cancer combined. The test was developed following more than a decade of work by the Ministry of Defence and its partners, including the US Department of Defense. It provides fast and accurate results to give medical team's hours or even days of critical extra time to treat this life-threatening condition, rather the current bacterial diagnosis method, which needs the patient to show symptoms of having sepsis by which time the condition is already well-advanced. The test could one day be used on the frontline to save the lives of troops, and in hospitals in the UK and beyond.

National and Devolved Academies

Independent of but supported by the UK Government, the national academies (the Royal Society, British Academy, Royal Academy of Engineering and Academy of Medical Sciences) and supported at a devolved nation level (the Royal Society of Edinburgh, the Royal Irish Academy and the Learned Society of Wales) and their Fellows represent the very best of UK science, research, innovation and engineering excellence. They all play a major role in nurturing and retaining research talent. Their global reach, networks and reputations are valuable assets as we seek to build new and stronger international partnerships. We will work with the academies in the delivery of the priorities set out in this Roadmap.

Higher education institutions

We will refresh our relationship with universities in England to ensure that their research activities are sustainable and delivering even greater impact, and that their diverse roles in innovation and regional growth are supported and strengthened. We will review how we fund university research, ensuring that we support the highest quality research areas to grow efficiently with the minimum of bureaucracy.

We will work with the higher education sector in England to agree a set of reforms to support university research and knowledge exchange to become more resilient, more efficient and ensure better outcomes from public funding. A new 'compact' between government and universities in England could strengthen accountability for discretionary funding, potentially bringing together existing separate higher education research concordats, reducing bureaucracy for institutions and their staff. We will work with the devolved administrations to ensure coherence of approaches across the UK.

Alongside this, we will be reviewing the mechanisms which we use to support university research in England and the incentives that these create within the R&D system. This includes the core block grant funding known as Quality-related Research (QR), which is used at universities' discretion to fund a broad range of activities, including the work which universities undertake with businesses and other partners, and the nurturing of higher risk and emerging areas of research – especially early career research. We will continue to work closely with UKRI and the devolved administrations to achieve a healthy balance between QR (and its devolved equivalents) and the more directed funding that we provide to projects and people, ensuring that we maintain a vibrant and diverse research base which can respond flexibly to economic and societal challenges. And when we evolve the Research Excellence Framework after the current exercise is complete, we should aspire to run a system which is fair, unbureaucratic and rewards improvement.

In addition, we will work with other funders to consider opportunities to fund a greater proportion of the full economic cost of research projects in universities. This includes asking whether government should fund at a higher rate, to safeguard the sustainability of the research we fund. We must balance this with the need for research funding to be efficient and to protect universities' ability to deploy their own resources strategically on research issues of particular importance to them.

Next Steps

This Roadmap is the start of a conversation. We want to explore how we can build on the UK's strengths, learn lessons from how the R&D world has responded to COVID-19, and ensure that we make the bold changes needed to ensure our system is fit for purpose now and for the future.

Over the coming months we will work with the devolved administrations to develop the proposals in this Roadmap in a **comprehensive R&D plan**.

This plan will only be effective if it is developed with people and businesses across the UK. As we develop this plan, we will engage with a wide range of stakeholders, including:

- Universities, businesses and charities
- Research funders
- Public sector research establishments and other publicly funded institutes
- The National and Devolved Academies, learned societies and subject associations
- Scientists and researchers at all career stages,
- Entrepreneurs, business leaders and investors
- Communities, local government organisations, local and civic leaders, regional organisations
- Representative organisations
- Members of the public

We will convene a series of Ministerial chaired meetings over the next two months to hear from a range of stakeholders from across the UK. We will work at pace with the devolved administrations to establish the structures we need to deliver this plan, including the R&D Place Advisory Group, the Innovation Expert Group and new mechanisms for prioritising our infrastructure investments.

Alongside this, we will continue our work to safeguard the sustainability of R&D through COVID-19, including through the University Research and Knowledge Exchange Sustainability Taskforce, jointly chaired by the UK Science Minister and UK Universities Minister and involving their devolved counterparts.

We welcome responses to the following high-level questions. An online survey is available at: <https://beisgovuk.citizenspace.com/innovation/r-and-d-survey>.

- **How can we best increase knowledge and understanding through research, including by achieving bigger breakthroughs?**
- **How can we maximise the economic, environmental and societal impact of research through effective application of new knowledge?**

- **How can we encourage innovation and ensure it is used to greatest effect, not just in our cutting-edge industries, but right across the economy and throughout our public services?**
- **How can we attract, retain and develop talented and diverse people to R&D roles? How can we make R&D for everyone?**
- **How should we ensure that R&D plays its fullest role in levelling up all over the UK?**
- **How should we strengthen our research infrastructure and institutions in support of our vision?**
- **How should we most effectively and safely collaborate with partners and networks around the globe?**
- **How can we harness excitement about this vision, listen to a wider range of voices to ensure R&D is delivering for society, and inspire a whole new generation of scientists, researchers, technicians, engineers, and innovators?**

This publication is available from: <https://gov.uk/government/publications/uk-research-and-development-roadmap>

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