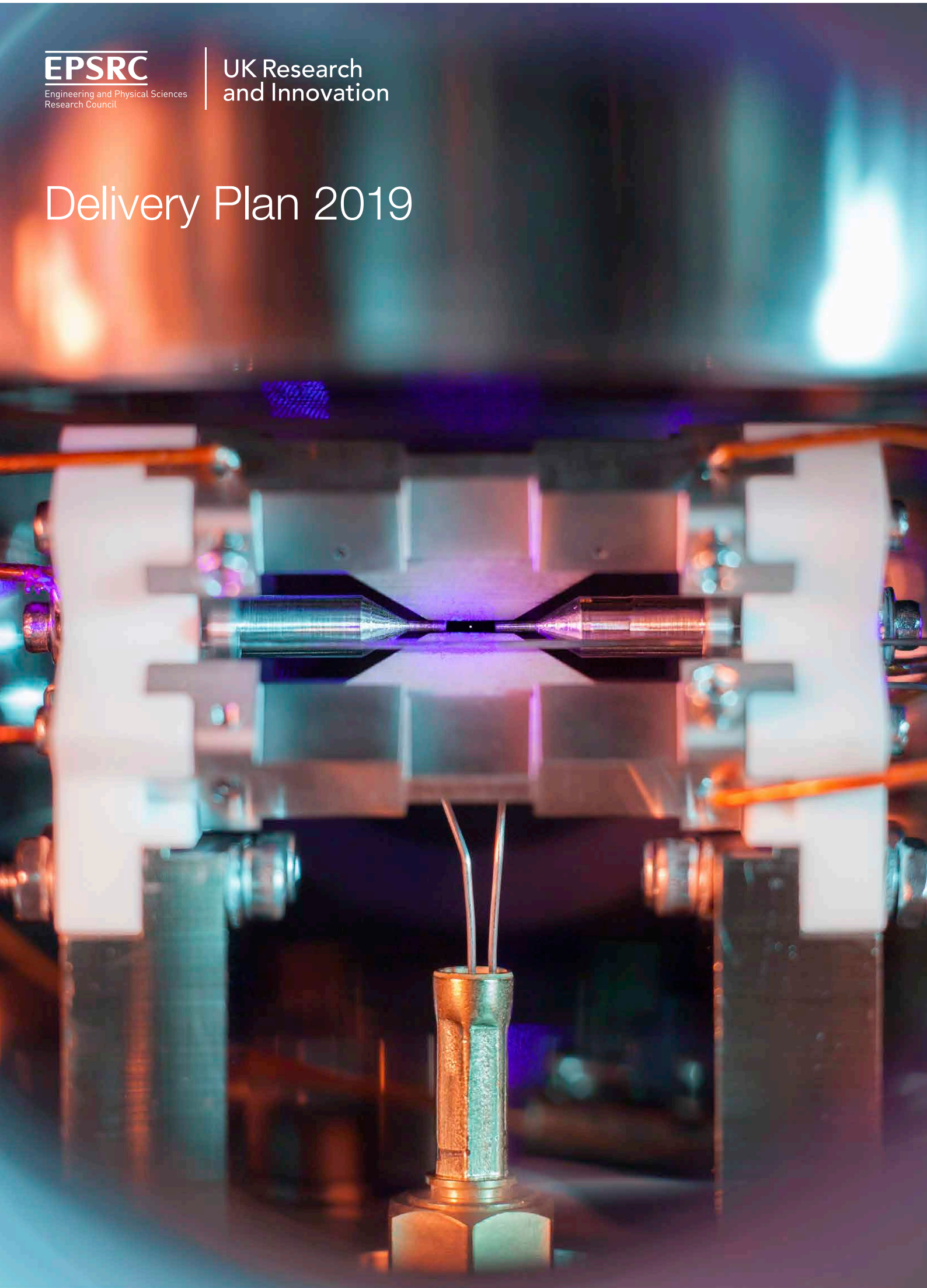
EPSRC
Engineering and Physical Sciences Research Council

UK Research and Innovation

Delivery Plan 2019



FRONT COVER *David Nadlinger, University of Oxford*
INSIDE COVER *Mark Mallett, EPSRC*

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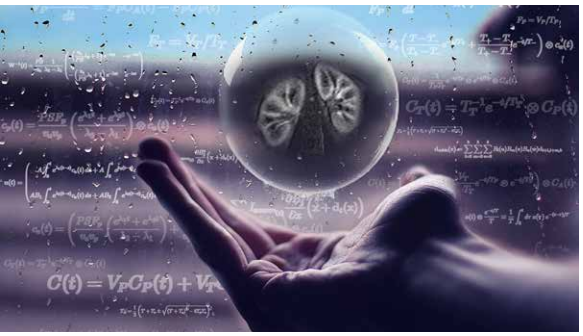
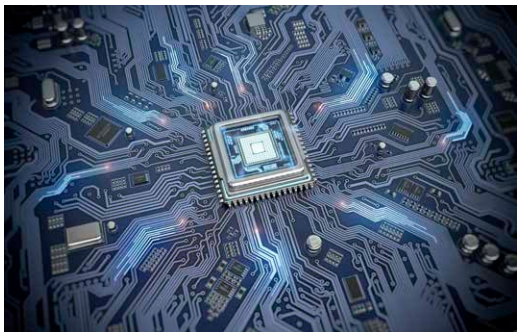




1. Foreword

Lynn F. Gladden
Executive Chair, EPSRC

Engineering and physical sciences play a crucial role in underpinning modern economies and societies. Driving progress through human curiosity and experimentation, they deliver affordable solutions to national and global challenges. EPSRC provides the research base which underpins the manufacturing, engineering, telecommunications and computer programming sectors, amongst others, which contribute over £300 billion per annum Gross Value Added and over 4 million jobs to the UK economy.

This is an exciting time for engineering and physical sciences research. With EPSRC support, researchers continue to advance the frontiers of knowledge and understanding, whilst partnerships with business and other stakeholders build on these breakthroughs to deliver transformative technologies. Since 2015, we have established our first institutes: The Alan Turing Institute in data science; The Faraday Institution in battery science and technology; The Sir Henry Royce Institute in advanced materials; and most recently The Rosalind Franklin Institute, which focuses on transforming life science through interdisciplinary research and technology development. These institutes represent a total financial investment of around £478 million.

We have also engaged enthusiastically and successfully with the opportunities offered by the National Productivity Investment Fund (NPIF) to support science, research and innovation. In addition to investing around £750 million per year in the research base, we have won over £400 million of NPIF awards, including Industrial Strategy Challenge Fund and Strategic Priorities Fund projects and support for 650 doctoral students and 80 innovation fellows. Our new Prosperity Partnerships scheme, meanwhile, has introduced a new way of working with business, with investment of £156 million that includes £90 million leveraged from industry and university partners.

We want to make the UK recognised as the place where the most creative researchers can deliver world-leading engineering and physical sciences research. We exist within a research ecosystem that includes our partner councils in UKRI, the R&D base within business, SMEs, government departments, charitable organisations and international partnerships. UKRI's formation offers an unprecedented opportunity for multidisciplinary working as well as the ability to identify and tackle new research challenges and enhance delivery of societal and economic impact from our world-leading science and engineering research base. Furthermore, in a global economy where technological expertise drives economic growth, we are central to delivering the government's Industrial Strategy commitment of increasing investment in R&D across the whole economy to 2.4% of GDP by 2027 and 3% in the longer term.

To realise our vision, this delivery plan (DP) identifies three complementary high-level objectives. First, we aim to generate economic impact and social prosperity by exploiting our existing and future research base to deliver a productive, connected, healthy, resilient nation. Second, we will unlock the potential of engineering and physical sciences research by stimulating and challenging the research community to open up new areas of science, as well as by supporting talented people and strengthening engagement with research users and business. Third, we aim to enrich the engineering and physical sciences landscape by providing the foundations for world-class research, which means attracting the most talented researchers, providing state-of-the-art research infrastructure at laboratory and national scale, and managing our portfolio so we can rapidly position ourselves in new, ground-breaking areas. We have also identified four priorities associated with each of these three high-level objectives and developed a suite of near-term actions for each priority.

I look forward to working with all our partners to realise our vision and deliver our ambitions.

2. Vision and objectives

We deliver outstanding, creative discovery research that drives growth and prosperity in the UK and globally. Breaking through boundaries of current knowledge and understanding to produce the next generation of world-leading solutions to real-world problems, we provide the platform for achieving technological advances that are relevant, robust, secure and sustainable. Throughout our portfolio, we will continue to promote responsible research and innovation, with sound ethical values at the heart of everything we do.

Our vision is to ensure the UK is the place where the most creative researchers can deliver world-leading research with genuine economic and societal impact, supporting the Industrial Strategy ambition to make the UK the most innovative economy by 2030. Along with a focus on harnessing the many opportunities that UKRI's formation presents, we will lead on the UKRI cross-cutting theme of identifying and implementing activities that increase opportunities to commercialise advances made by the research councils, ensuring UKRI investments offer a strong platform to meet the challenge of growing R&D investment across the whole to 2.4% of GDP by 2027 and 3% in the longer term.

In terms of our own portfolio, we will focus on three complementary objectives which underline what we want to achieve, how we will achieve it and the tools that will enable us to do so:

Objective 1: Delivering economic impact and social prosperity

This objective identifies four priorities essential for future UK prosperity. Collectively, they articulate a strategic expression of how research and skills in engineering and physical sciences add value for our nation:

- **Productive nation: Catalysing growth (3.1.1)**
  We will help deliver a more agile, creative, competitive UK economy sustainable for the longer term, and complement our support for discovery research with investments to ensure rapid knowledge exchange and commercialisation. In 2019-20 we will:
  - Explore establishing with stakeholders a centre focusing on the Circular Economy
  - deliver, with NERC and Innovate UK, the activities within the Plastics Research and Innovation Fund – both of the above will support delivery of the Clean Growth Grand Challenge
  - deliver new investments in projects, networks and fellowships in manufacturing
  - establish the National Quantum Technologies Programme, including the National Quantum Computing Centre.
- **Connected nation: Enhancing future digital technologies (3.1.2)**
  We will ensure the UK remains at the forefront of creating new digital technologies and innovation pathways. In 2019-20 we will:
  - refresh the Digital Economy research centres
  - invest in calls on natural language processing and software engineering, which are essential to adoption of artificial intelligence (AI) technologies, and therefore deliver on the AI & Data Grand Challenge's ambitions
  - scope joint investments in cyber-security with UKRI partners and the Defence Science and Technology Laboratory (Dstl), Ministry of Defence (MoD), Government Communications Headquarters (GCHQ) and National Cyber Security Centre (NCSC).
- **Healthy nation: Transforming healthcare (3.1.3)**
  We will work with partners in UKRI, the National Institute for Health Research (NIHR), charities and the NHS to invest in research that transforms healthcare delivery and supports healthier living in the UK and worldwide. This is relevant to the Ageing Society Grand Challenge and AI & Data Grand Challenge's early diagnosis mission.

In 2019-20 we will:

- scope a call, co-branded with NIHR, focusing on the application of engineering and physical sciences expertise to population health challenges
- launch a call for transforming community health and care
- generate new multidisciplinary research partnerships in early cancer detection and improved patient outcomes
- explore, with MRC and NIHR, opportunities to research the 'body-technology interface'.

- **Resilient nation: Enabling adaptable solutions (3.1.4)**
  We will invest in research which enables society to anticipate, adapt to and respond to change, whether natural or manmade, short or long-term, local or global. An overarching emphasis will be on supporting society's decarbonisation.

In 2019-20 we will:

- work with NERC as part of the joint research activity between UKRI and the US National Science Foundation (NSF) to deliver the Signals in the Soil project
- invest in multidisciplinary research and community-building in decarbonisation and new energy technologies
- focus on improving knowledge and expertise transfer between EPSRC and Innovate UK to maximise science, technology and commercial delivery from Industrial Strategy Challenge Fund investments in the energy sector, catalysing progress on new energy solutions to support the Clean Growth and Future of Mobility Grand Challenges
- work across UKRI and with the Home Office to identify new research opportunities.

Objective 2: Realising the potential of engineering and physical sciences research

We aim to stimulate and challenge the research community to open up new areas of science, engineering and technology, and will promote excellence, accelerate impact and provide new ways of working with business to deliver the 2.4% target:

- **Promoting excellence in research (3.2.1)**
  We will pilot a New Horizons call to fund high-risk discovery research delivering tomorrow's transformational engineering and physical sciences, and review/reposition our larger grant-funding mechanisms and identify where to make our next critical-mass investments

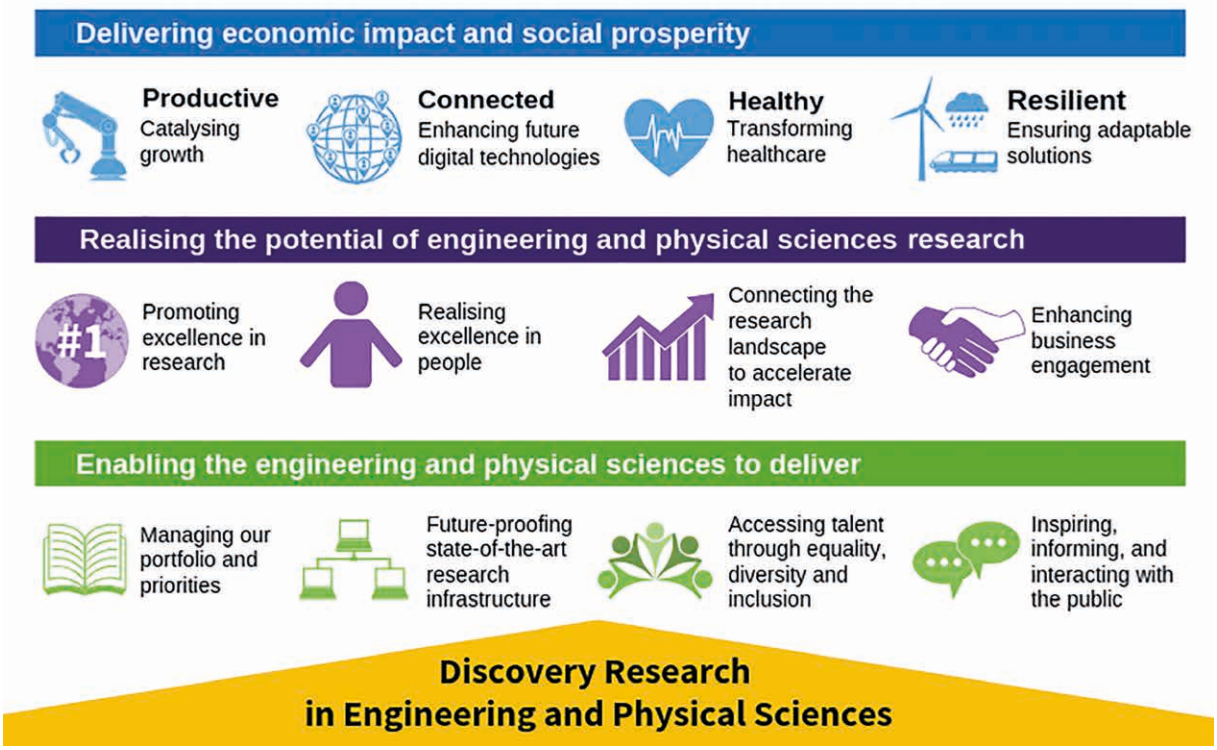
- **Realising excellence in people (3.2.2)**
  We will work with our business partners and others in UKRI to train a diverse population of researchers who can work effectively across academia and business
- **Connecting the research landscape to accelerate impact (3.2.3)**
  As part of UKRI, we will shape a landscape where we can enhance knowledge exchange, enable mobility of skilled people, build world-class collaborative research and innovation environments, and develop nascent technologies emerging from the new science and engineering we support. To do this we will expand our Innovation and Knowledge Centres and Impact Acceleration Account activities
- **Enhancing business engagement (3.2.4)**
  Prosperity Partnerships will be key to deepening our engagement with business and we will extend them to new sectors, such as services and the creative industries, and evolve the scheme to form partnerships with SMEs.

Objective 3: Enabling the UK engineering and physical sciences landscape to deliver

We aim to provide the foundations on which to undertake world-class research, using investments wisely to enable the UK to engage in new opportunities in a timely and effective way, allowing bandwidth for the creative thinking central to discovery research. We must provide our researchers with state-of-the-art laboratories and access to national facilities, and we must access all available talent. Engagement with the public is also essential:

- **Managing our portfolio and priorities (3.3.1)**
  We will keep using and improving our tools to monitor our investments and will continue to be aware of the UK's position relative to global competitors, enabling evidence-based analysis of where investments are most effective so we can rapidly position ourselves in new, ground-breaking areas
- **Future-proofing state-of-the-art research infrastructure (3.3.2)**
  We will provide researchers with the world-class infrastructure they need
- **Accessing talent through equality, diversity and inclusion (EDI) (3.3.3)**
  Mobilising all available talent is vital to maximising effective delivery of research for economic, social and cultural impact. We will continue to embed equality, diversity and inclusion in everything we do
- **Inspiring, informing and interacting with the public (3.3.4)**
  We will communicate outcomes of our research and innovation in ways that instill trust. We will target activities to inform and educate, to inspire people to engage with engineering and physical sciences and understand its importance to their wellbeing and success, and to encourage bright minds into engineering and physical sciences careers.

EPSRC Delivery Plan: The Priority Framework



3. Research and innovation priorities

3.1 Objective 1: Delivering economic impact and social prosperity

3.1.1 Productive nation: Catalysing growth

As set out in the Industrial Strategy, the UK economy critically depends on the ability to develop and commercialise new products, processes, services and technologies. Ensuring future growth and increasing UK productivity and earning power means investing in potentially disruptive research that can drive business innovation or trigger development of new business models. The UK does this already, but must do it even better.

Cross-disciplinary working and business engagement are key to the way we exploit the pivotal role engineering and physical sciences has in enabling impact from the biological, environmental and medical sciences through to the social sciences and humanities. One example is our activities in whole-systems approaches such as the circular economy, particularly in plastics, where we work with almost all UKRI councils.

Improved productivity is also underpinned by a highly skilled, numerate UK workforce. Our training investments in industrially relevant PhDs, fellowships and early-career researchers will target needs, to develop such a workforce that draws on a diverse talent pool (see Sections 3.2.2 and 3.3.3).

To deliver this priority, EPSRC will invest in:
Achieving sustainability through circularity of resources: Adopting a more circular use of resources to deliver improved productivity while reducing supply risk, pollution, CO_2 emissions and waste, an area of importance for the Clean Growth Grand Challenge.

Manufacturing futures: How do we exploit advances in industrial digitalisation and automation to transform manufacturing processes and business models to build a more competitive UK industry?

Commercialisation and application of quantum technologies: Extending the UK's world-leading position in Quantum Technologies and making the UK first choice as a place to research, innovate and commercialise Quantum Technologies as identified in the AI Sector Deal.

Identification of new opportunities in materials research and technology: Working with academic leaders and business stakeholders to identify where new thinking in materials research is needed to open up new opportunities across business sectors.

Long-term ambitions
We will build on our strong relationships with business, universities, the Catapults and other intermediary bodies to work with UKRI partners to maximise our investments. Our long-term aspiration is to ensure that:

- new UK-manufactured products, processes, services and technologies are demonstrably and routinely derived from investments in engineering and physical sciences research enabled by friction-free, and in some cases more rapid routes from discovery to commercialisation, and the development of effective business models. Success will be reflected in an increase in the volume of innovation and quicker translation from insight to innovation.
- a stronger role in the shaping of industrial/government policy on new technologies, such that it is informed and strengthened by our investments. Success will be reflected by an increased involvement in policy development across our community.

Near-term actions
In 2019-20 we will:

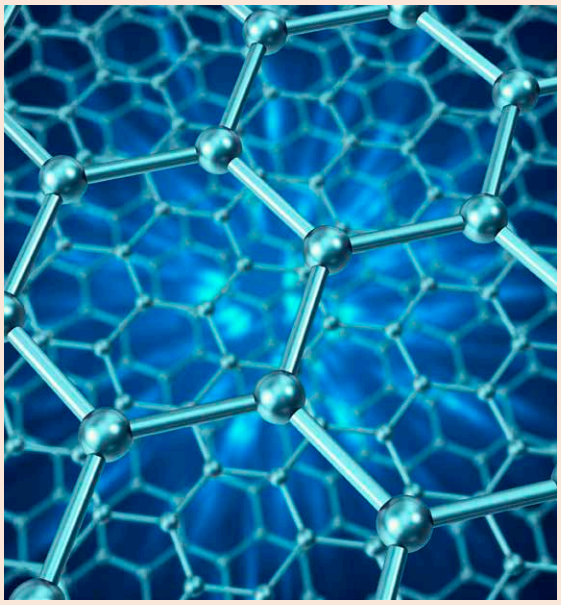
- work with the materials research community, business partners, Innovate UK and the Henry Royce Institute to identify emerging opportunities in materials. Develop at least one Strategic Priorities Fund bid and one Industrial Strategy Challenge Fund bid in the next six months
- deliver, with NERC and Innovate UK, the £20 million Plastics Research and Innovation Fund to explore new ideas and innovations that can bring changes to plastics manufacturing and consumption patterns in the UK
- support UK-US collaborative proposals in engineering, ICT and manufacturing via the lead-agency agreement with the National Science Foundation. We will commit up to £5 million/year and the NSF up to US$3 million/year through this scheme

- lead on quantum technology and collaborate with partners in the National Quantum Technologies Programme to recommission the Quantum Hubs and establish the £77 million National Quantum Computing Centre to help tackle the AI & Data Grand Challenge
- invest up to around £20 million across projects, networks and fellowships in manufacturing and in supporting cross-sector working between universities and business. Manufacturing futures will be a particular focus
- deliver with colleagues across UKRI (lead Council underlined – values quoted are total for UKRI):

  Industrial Strategy Challenge Fund (all with IUK): Robots for a Safer World; (EPSRC: £93 million) and Quantum Technology (EPSRC: £20 million).

Modelling software shapes industrial breakthroughs

Originally developed by physicists at Cambridge with our funding, CASTEP is a modelling code based on quantum mechanics that has transformed the development of new and better materials. Over 1,000 companies, in the chemicals, pharmaceuticals, semiconductor manufacture, oil and gas and other sectors, are using the software. There have been over 10,500 citations to date, while over 300 patent applications refer to CASTEP. In 1995, it was licensed to Cambridge-based software company Accelrys (now BIOVIA) and is currently quoted to be worth around US$42 million in sales. In tandem with 'real' experiments, the 'virtual' experiments that CASTEP enables mean R&D teams can model anything based on atoms, understand how it works and generate ideas on how to improve it.



Testing tool helps transform transport

EPSRC-funded research at Loughborough led to a novel measurement technique for accurate, reliable testing of the shear properties of advanced composite materials for lighter, more fuel-efficient transport. Composites could save billions of pounds and are widely used but need to perform in challenging environments. Current standard tests include a big built-in error margin, resulting in components either being manufactured heavier or costing more than necessary. The new testing methodology, Double Beam Shear (DBS), delivers more precise and reliable results, so composite aircraft and cars can be designed without the need to add excess weight, without compromising safety. Working closely with industrial partners such as GKN Aerospace, DBS successfully underwent proof-of-concept testing across seven independent sites. It has now become a new ISO standard and Loughborough offers a DBS testing consultancy service.

3.1.2 Connected nation: Enhancing future digital technologies

Digital technologies underpin much of modern life and advances will continue to transform society and play a critical role in delivering prosperity. We will take the lead within UKRI in generating scientific and technical advances that ensure the benefits of digital technologies can be realised for the UK, whilst working closely with UKRI partners to ensure risks such as security and privacy are understood and managed responsibly.

We will build on the UK's world-leading position[1] in research in areas as diverse as AI, data analytics, communications networks, mobile technologies and next-generation electronic hardware and materials, and at the interface between these technologies and society. We will capitalise on the UK's strengths across engineering, the physical sciences, and the computational and mathematical sciences to develop innovative technologies with the potential to deliver transformational impact. For instance, we will harness the concentration of excellence at The Alan Turing Institute to help put the UK at the forefront of the AI and Data revolution. We will also extend our investments in PhD training through, for example, the AI Centres for Doctoral Training (CDTs), to train tomorrow's research leaders.

To deliver this priority, EPSRC will invest in:

Digital technologies for creativity, discovery and innovation: Exploiting the potential and power of computation and automation, alongside new computational and mathematical approaches, to advance our creative industries, make new scientific discoveries, and transform approaches to innovation. Collaboration with AHRC in working with the creative industries sector represents an exciting opportunity.

Trustworthy and accountable data, AI and autonomy for a successful society: Enabling widespread industrial and social adoption of autonomous systems, by developing decision-making methodologies that are verifiable, transparent, and trustworthy. Currently, autonomous systems and data analytic tools designed to make decisions are developed and deployed without users understanding the basis of those decisions. We are engaging closely with ESRC in this field.

Secure and connected infrastructure for national resilience to risk and threat: Positioning the UK at the forefront of new communications infrastructures such as the next generation of communications networks, and ensuring that critical national infrastructures, frequently operating on outdated or 'legacy' systems, are secure and resilient to attacks through innovative computational technologies and advances in cyber security.

New ways of powering future digital technologies for continued innovation: Designing future digital technologies (both computational and hardware) within an energy-aware context to ensure that they will be deployed and adopted across society. Many of the world's current cutting edge digital technologies (autonomous cars, data analytics, mobile devices) have significantly higher energy demands than traditional technologies to an extent that could limit their broad adoption and further development.

Long-term ambitions

We will build upon EPSRC's investments to ensure the UK is a global leader in developing and adopting digital technologies, and a go-to location for potential partners seeking to work with talented innovators operating within a world-class innovation system. Our long-term aspiration is to ensure that:

- there are strong interdisciplinary and multidisciplinary communities which have a fundamental understanding of the challenges relating to technology use, security, acceptability, trust and risk, including legal and economic barriers facing transformative research. Success will be reflected in the number of researchers with the skillset to drive responsible digital innovation and engage with policy and regulation
- advanced digital technology, including AI, is routinely used and UK industry's adoption of autonomous systems has accelerated. Success will be reflected in the level of adoption of advanced digital technology initiated by our research community
- we reduce the risks and negative impacts of new digital technologies while increasing investment in technologies for public good. Success will be reflected in greater public understanding of the benefits and opportunities offered by technologies such as AI
- EPSRC plays a leading role in delivering relevant aspects of e-infrastructure and exascale computing capacity to meet the aspirations of our researcher base.

[1] Based on citation analysis of relevant research areas

Near-term actions

In 2019-20 we will:

- refresh the Digital Economy critical-mass research centres through a scoping workshop and a £20 million research call
- work with government and industry on AI and related fields, particularly through the AI & Data Grand Challenge and the AI Sector Deal. Review the AI research landscape with UKRI colleagues and wider stakeholders to produce an investment strategy enabling AI to realise its full potential
- work with The Alan Turing Institute, the Office for AI and colleagues at DCMS and BEIS on the design and delivery of the £50 million Turing Fellowships
- with colleagues across UKRI, deliver the £100 million investment in 16 AI CDTs; the first cohorts start in October 2019
- invest in calls on natural language processing (£4 million) and software engineering (£4 million), both of which are central to adoption of AI technologies and delivering the AI & Data Grand Challenges
- deliver a £0.3 million call to identify new Centres of Excellence in cyber-security research, sponsored by the National Cyber Security Centre and UKRI, to enhance academic cyber-security research and training
- scope a joint cyber-security activity of up to £10 million with UKRI partners, Dstl, MoD, GCHQ and NCSC, to reduce cyber-attacks on UK businesses and citizens
- deliver with colleagues across UKRI (lead Council underlined):

  Strategic Priorities Fund: AI and Data Science for Science, Engineering, Health and Government (EPSRC, BBSRC, STFC, MRC, NERC (being delivered by the ATI): £39.3 million) and Ensuring the Security of Digital Technologies at the Periphery (SDTaP) (EPSRC, IUK, AHRC, ESRC: £30.6 million).

  Industrial Strategy Challenge Fund (all with IUK): Audience of the Future (AHRC, EPSRC: £33 million); and Next Generation Services (ESRC, EPSRC: £20 million).

Commercialising cyber-security research and technology

The Centre for Secure Information Technologies (CSIT) at Queen's University Belfast has grown into one of the world's largest centres in cyber-security and a recognised global leader in cyber-security research. Established in 2009 as one of seven EPSRC-sponsored IKCs, and with co-funding from Innovate UK and Invest Northern Ireland, this flagship centre has helped to attract significant high-tech foreign direct investment and to support start-ups that are on course to employ over 1,600 people. CSIT has developed a global innovation hub with a range of industrial partners such as Allstate, BAE Systems and Infosys, and spin-outs delivering new benchmarks for content inspection, visual speech recognition, cryptography, intrusion detection and platforms for automatic and intelligent image and video processing.

Seventeen start-ups have graduated from the CSIT incubator programme and CSIT also leads the £5 million UK Research Institute in Secure Hardware and Embedded Systems (RISE), as well as being a delivery partner on the £13.5 million London Office for Rapid Cybersecurity Advancement (LORCA).

Making the high-speed connected world a reality

Internet users now exchange over 2,000 petabytes of data every month. Most travels through optical fibres using erbium-doped fibre amplifiers (EDFAs) developed at the University of Southampton. Invented in 1987, the EDFA resulted from EPSRC-funded blue-skies research and, in 1989, we also funded the Optoelectronics Research Centre (ORC) at the university. The ORC is now a world-leading centre for photonics, optical telecommunication and high-power lasers and has, for example, developed non-toxic glass fibres for use in key-hole surgery; thanks to ORC research, the number of surgical stents manufactured with

fibre lasers worldwide has increased by 30%. Overall, ORC technologies have been spun-out into 10 companies, generating revenues of over £100 million and creating over 500 jobs.

3.1.3 Healthy nation: Transforming healthcare

Quality of life, productivity and the resilience of communities all depend on people's mental and physical wellbeing. Our research delivers the new materials, new sensors and imaging modalities, novel analytical techniques and innovation needed to improve prediction, diagnosis and treatment of disease that will deliver better quality of life and ensure higher standards of affordable healthcare. These advances also drive economic growth by bringing new products and services to market that help tackle national and global health challenges. This work is pivotal to delivering the Ageing Society Grand Challenge's mission to ensure that people can enjoy at least five extra healthy, independent years of life by 2035, while narrowing the gap between the experience of the richest and poorest.

We will work in partnership with, for example, NIHR, MRC, Cancer Research UK (CRUK), the Wellcome Trust, the British Heart Foundation and the NHS to build on initiatives such as the UK Regenerative Medicine Platform, the UK Prevention Research Partnership, Technology Touching Life and Physics of Life. As delivery partner for The Alan Turing, Rosalind Franklin and Henry Royce institutes, we will ensure the large-scale multidisciplinary effort required to deliver the engineering and physical sciences research that transforms health and wellbeing. We will also encourage and support researchers at all career stages to appreciate real-world complexities and impact/translation pathways in health by promoting discipline-hopping and reinforcing the principles of responsible innovation.

To deliver this priority, EPSRC will invest in:

Next-generation digital healthcare systems: Driving forward the development of the next generation of digital systems, including artificial intelligence, machine learning, and interfaces and algorithms for data analytics, for the benefit of all aspects of health. Consideration of and research into, the risks associated with these new technologies will be an integral part of this work.

Engineering healthier environments where people live and work: Investing in built environment, infrastructure and urban systems research to build critical mass of leadership in engineering a healthier integrated care environment. Utilising a 'system of systems' approach to ensure overall wellbeing is improved, and illness prevented, for individuals and populations.

Future affordable healthcare solutions: Leading the discovery, development and deployment of cutting edge, affordable technologies, ranging from medical diagnostics/imaging systems to targeted therapeutics, to realise a truly cost-effective healthcare system which is available to all.

Technologies to improve healthcare treatment: Investing in novel chemical and physical approaches to improve drug delivery to increase the effectiveness and reduce the costs of existing treatments. This will allow the development of affordable and safe novel therapeutic agents into medicines which deliver the right concentration of drug, for the right duration to the right tissue.

Long-term ambitions

We will work across UKRI and with other industry, public sector and charity partners to generate effective solutions to current, emerging and future health challenges and to improve wellbeing across society. Our long-term aspiration is to ensure that:

- the frontiers of knowledge and understanding in every field of engineering and physical sciences research have been extended to generate effective solutions to current, emerging and future health challenges and to improve wellbeing across society. Success will be reflected by a growth in the number of EPSRC researchers working with healthcare partners, especially in the medical and clinical sciences, and with clinicians, patients and businesses to deliver effective healthcare, wellbeing and social-care solutions
- improvements in healthcare based on quantitative understanding rooted in and inspired by the availability of health data, systems thinking and new tools/technologies have been delivered. Success will be reflected in the extent to which key treatments and policy interventions draw on tools and techniques developed through our investments

Near-term actions

- address the challenge of earlier cancer detection and improved patient outcomes through a series of sandpits (a facilitated peer review process) for up to £1 million, delivered with CRUK and aiming to generate new multidisciplinary collaborations
- deliver a £1 million call to identify research collaborations addressing prevention of non-communicable diseases, under the MRC-led UK Prevention Research Partnership
- build on learning from the Healthcare Impact Partnerships to scope out a further £20 million call co-branded with NIHR. Areas currently being discussed include applications of AI and machine learning in application to software and hardware solutions for: fast stroke diagnosis; analysis of breast screening and chest X-ray data; interpretation of multi-morbidity data
- with MRC, deliver a digital healthcare study mapping current and future required UK capabilities, emerging areas and stakeholder priorities to provide a clear forward investment plan
- work with MRC and NIHR to explore future research opportunities on the body-technology interface, building on our expertise in sensors, device miniaturisation, remote data collection and data analysis, and applying it in healthcare
- launch a £25 million call on Transformative Healthcare for 2050, aiming to transform community health and care by exploiting opportunities at the frontiers of physical intervention
- support the healthcare community in using Tier 1 and 2 High Performance Computing (HPC) to bring the power of sophisticated modelling to healthcare. Launch a call for multidisciplinary Collaborative Computational Projects in 2019-20 for funding in 2020-21 (up to £5 million depending on available budgets)
- deliver with colleagues across UKRI (lead Council underlined):

  Strategic Priorities Fund: Physics of Life (EPSRC, MRC, BBSRC: £31.2 million).

  Industrial Strategy Challenge Fund (all with IUK): Medicine Manufacturing (MRC, EPSRC, BBSRC: £188 million); and From Data to Early Diagnostics and Precision Medicine (MRC, BBSRC, EPSRC: £210 million).

A spin-out solution for diabetes

Diabetes costs the NHS around £10 billion per year, with 3.7 million people in the UK diagnosed with the disease. With BBSRC, we have funded basic multidisciplinary biological chemistry that will lead to better treatment and control for people living with diabetes. For example, cutting-edge research at the University of Bristol was taken forward with IUK funding and led to the creation of spin-out Ziylo, which developed innovative glucose-binding molecules that can be used in medical devices and in therapeutics such as glucose-responsive insulins. Pharma giant Novo Nordisk recognised the potential and acquired Ziylo's innovative technology platform for a record deal that exceeds US$800 million.

3.1.4 Resilient nation: Enabling adaptable solutions

Being a resilient nation means meeting every citizen's needs in three areas: provision of sustainably managed resources, provision of reliable infrastructure and protection against natural and manmade threats. The key is to bring together the right research, innovation and people to develop integrated solutions that anticipate, adapt and respond to change.

We deliver new products, processes and technologies that ensure the reliability of UK infrastructure, underpin energy security and enable timely, effective responses to acute cyber, financial, health, defence and other threats.

As part of UKRI, we will enhance the existing multidisciplinary approach needed to meet the challenges of resilience by, for example, working with ESRC to ensure our research is grounded in behavioural science research, working with IUK to facilitate the knowledge exchange that allows autonomous systems and battery technology to be taken to market, and working with NERC to enable improved monitoring and modelling of climate change and air quality.

To deliver this priority, EPSRC will invest in:

Engineering responses to changes in the environment: Utilising the mathematical modelling, digital tools and technological solutions to adapt to and mitigate against climate change events and effects.

Enabling the transition to low-carbon heat: Addressing the major challenges identified by BEIS, by developing new ultra-low-carbon heating and cooling solutions across different sectors through the deployment of novel technologies and business models.

Developing future transport solutions, as part of our Future of Mobility Grand Challenge: Developing solutions using engineering and physical sciences research across modalities to improve transport system effectiveness, reducing delays, failures and carbon emissions.

Preparing systems to withstand extreme events: Utilising solutions to achieve security in UK infrastructure systems which ensure maintenance of production and supply.

Long-term ambitions

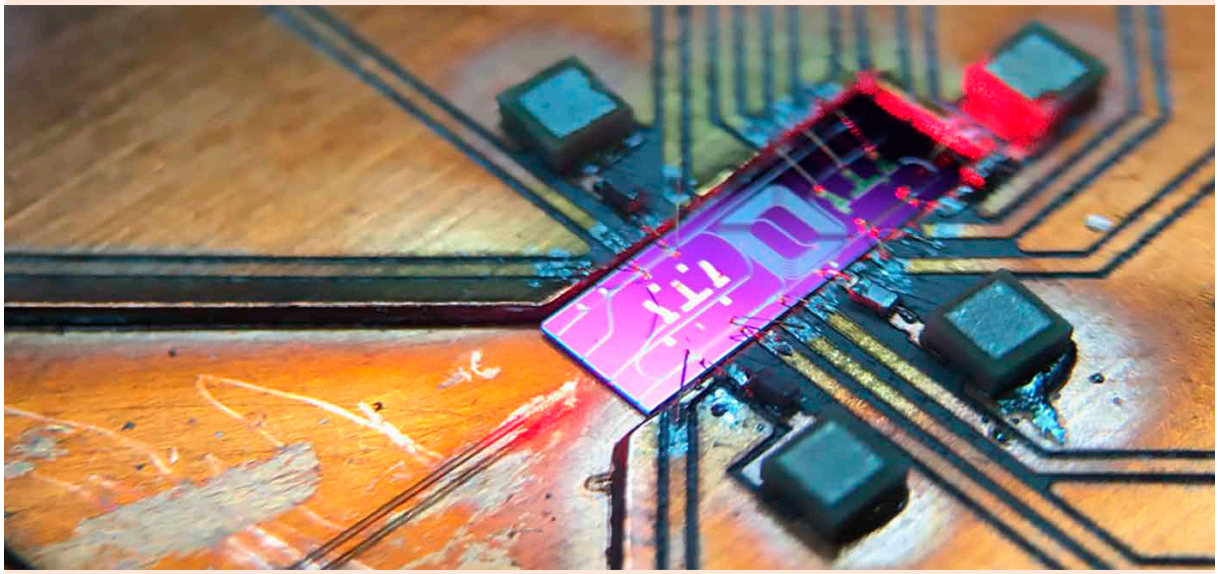
We will work with our UKRI partners to ensure that technical, environmental and social solutions to resilience challenges draw upon work on mathematical models, digital tools and wider engineering and physical sciences technologies. Our long-term aspiration is to ensure that:

- our resilience portfolio informs and is informed by UKRI's international development strategy and activities, with success reflected in the number of our investments that help tackle significant policy challenges identified in international as well as UK strategies
- the products of our investment inform and influence policy and strategy, and lead to regulation in construction, finance, urban/city planning, risk management, utility management, cyber-security and other areas. Success will be reflected by regulatory bodies drawing directly on our research as a source of evidence and a means of remediation. Collaboration with ESRC is widely relevant here and is already manifested in ISCF partnerships
- across UKRI, government and regulatory bodies, there is a better understanding of a whole-systems approach and its benefits, including the human dimension of resilience. Success will be reflected in the growth of a new generation of experts who can build a resilient nation by embracing the provision of robust evidence, analytical and diagnostic approaches and effective translation of research into real-world solutions.

Near-term actions

In 2019-20 we will:

- provide engineering (sensors and wireless systems) and ICT (through mathematical modelling and analytics) research, in collaboration with NERC science, to deliver the £8 million Signals in the Soil call funded through the UKRI Fund for International Collaboration as part of a UKRI-NSF joint research activity
- enable multidisciplinary research and community-building, focusing on calls in decarbonising heating/cooling (£8 million), decarbonising transport (£4 million), and end-use energy demand (up to £10 million), and on the Supergen Programme, which includes sustainable hydrogen production activities (up to £8 million)



Keeping data safe and secure

Our investments in fundamental quantum research are enabling the UK to develop quantum technologies offering ground-breaking opportunities in areas such as cyber-security. For example, supported by the Quantum Communications Hub, EPSRC-funded researchers at the University of Bristol founded KETS Quantum Security, a firm at the forefront of quantum-secured encryption technology. The company is developing future-proof, cost-effective technologies for quantum-secured communications, based on integrated optical encryption, which can improve secure transmission of data such as banking details and medical records. It was one of three SMEs that recently won a major venture capital competition led by BT, the Telecom Infra Project and Facebook; as a result, the company will have access to investors with funds totalling £125 million, enabling it to work towards large-scale adoption of quantum encryption in a multitude of applications including defence, telecoms and critical infrastructure.

- align our fellowship priority areas to real-world resilience challenges in decarbonising heat, decarbonising transport and resilient energy systems (£2 million)
- work with UKRI partners and the Home Office to establish an independent body to convene and coordinate stakeholders from across the research, public and private sectors to connect the justice system with high-quality science, enabling collaboration and identifying emerging areas to explore. Work with our partners to determine the body's scope, set terms of reference, and convene stakeholders representing all parts of the justice system and set a forward plan for the group
- deliver with colleagues across UKRI (lead Council underlined):

  Strategic Priorities Fund: Clean Air: Analysis and Solutions (NERC, Met Office, EPSRC, MRC, ESRC, IUK, NPL: £19.6 million); Climate Resilience (NERC, Met Office, EPSRC, ESRC, AHRC: £18.7 million) and Landscape Decisions (NERC, ESRC, BBSRC, AHRC, EPSRC: £10.5 million).

  Industrial Strategy Challenge Fund (all with IUK): Faraday Battery Challenge; (EPSRC: £246 million); Prospering from the Energy Revolutions (EPSRC, ESRC, NERC, STFC: £102.5 million) and Transforming Construction (EPSRC, ESRC £170 million).

3.2 Objective 2: Realising the potential of engineering and physical sciences research

3.2.1 Promoting excellence in research

We will continue to invest in research in ways that are optimised to the specific researcher base and research outputs desired. As part of this strategy, we propose investing in the following three research funding delivery vehicles, which we believe will maintain and enhance the UK's ability to remain a world-leader in engineering and physical sciences research and the technologies derived from it. Prior to launching new calls, our overall funding landscape will be reviewed with a view to simplification, where possible:

- **New Horizons:** This will comprise funding for researcher-led, high-risk discovery research focused on advancing knowledge and securing the pipeline of next-generation innovations. It will include funding for completely new ideas, which are essential to future-proof our research base, so it generates solutions to the as yet undefined problems confronting society
- **Centres of Excellence:** This will comprise support for single- or multi-organisation activities building on a world-leading skills base that underpins existing and nascent technologies
- **Institutes:** Support will focus on longer-term multi-organisation activities which take a nationally/ internationally leading role in developing the research base and technologies derived from it.

By drawing together people, expertise and facilities from across institutional boundaries, our Centres of Excellence and Institutes will allow the UK to leverage and build world-leading research strengths, providing a national focus with international impact. The proposed introduction of a science, engineering and technology board (see Section 4) into the EPSRC Governance and Advisory Board Structure, evolving from our 'Big Ideas' initiative, will enable the EPSRC community to engage in the identification of candidate areas for these large-scale investments.

Long-term ambitions

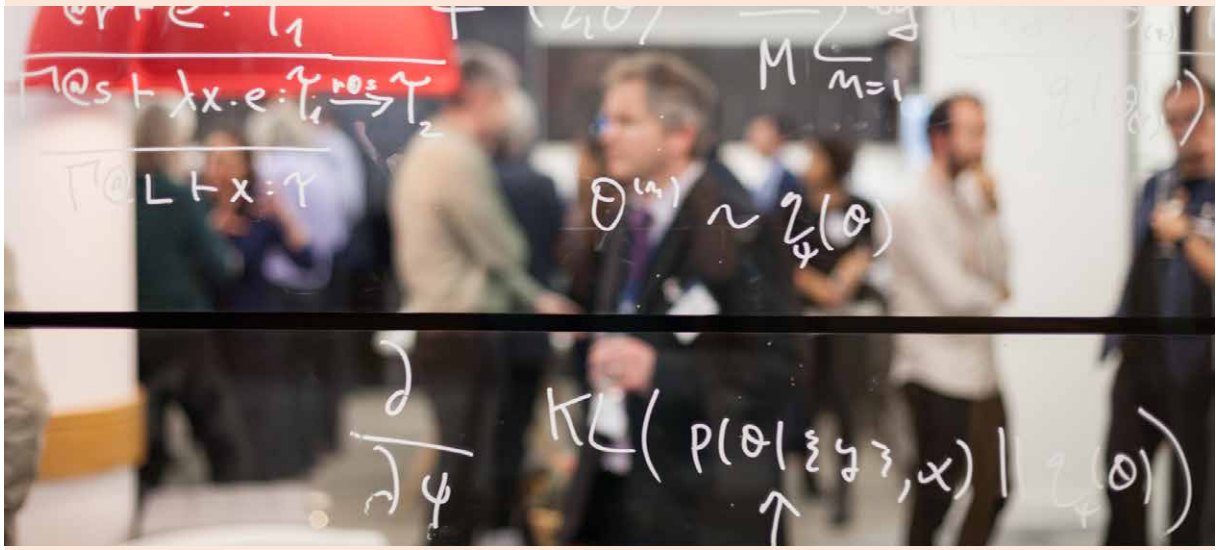
Our long-term aspiration is to ensure that:

- the UK is seen as a place where the brightest minds can access funding for entirely novel research ideas that deliver new insights and understanding and may open up new technology sectors. Success will be reflected in our ability to make high-profile hires and retain leading researchers in the UK
- our Institutes and Centres of Excellence enhance the capability, volume, profile and visibility of our research base internationally. Success will be reflected in the international recognition of their research, the strength of their international links and levels of engagement with industry, business, government and the wider public
- a wider range of businesses invest in new relationships with the research base to address the real-world problems they face and which allow them to explore fundamental research questions that impact on their future success in a safe space. Success will be reflected in the diversity of new partnerships formed with the business community
- researchers and businesses across the country have been connected to local clusters to capture the full value from national infrastructure and build communities of practice.

Near-term actions

In 2019-20 we will:

- challenge the engineering and physical sciences community to formulate high-risk discovery research proposals to deliver 'New Horizons' in the EPSRC landscape. Scope a pilot to invest up to £10 million in 2020-21
- harnessing our partnerships with research organisations and industry, develop a pipeline of at least five thematic areas per year for future investment in Centres of Excellence and Institutes.
- launch a second international centre-to-centre call for up to £15 million, to provide opportunities for leading UK research groups to work with the best international researchers.



The Alan Turing Institute

We established this institute in 2015 to build on the UK's existing strengths and position the UK as a world-leader in 'big data' and algorithm research. Headed by the universities of Cambridge, Edinburgh, Oxford, Warwick and UCL, it has been attracting the best data scientists and mathematicians from the UK and worldwide, growing a strong collaborative network with partners in academia, industry, government and the third sector and promoting development and use of advanced mathematics, computer science, algorithms and big data. For example, the ground-breaking GUARD project, funded by GCHQ, is creating complex network models that can predict conflict. These can measure the strength of causal mechanisms, assign risk factors to specific geographic areas and translate research into impact in developing countries suffering from prolonged conflict. This will help automate the identification of future conflict areas for high-fidelity analysis and policy/action advice.

3.2.2 Realising excellence in people

To be productive and competitive, the UK needs a diverse workforce with the right skills. Moreover, as it aspires to deliver an ambitious Industrial Strategy and increase investment in R&D to 2.4% of GDP, a major expansion in people with research and innovation training and experience is needed. This comes at a time of a widening skills gap in the science, technology, engineering and mathematics (STEM) sector, with companies struggling to recruit people able to lead and deliver innovation, particularly in rapidly expanding areas such as AI and data science.

We support around 9,000 doctoral students through three distinct routes: Doctoral Training Partnerships (DTPs) with universities across the breadth of discovery research; Centres for Doctoral Training (CDTs), which develop students as part of a multidisciplinary cohort, often working with business and other partners; and Industrial CASE awards, where businesses select university partners and projects. We also support over 6,000 post-doctoral researchers. All these people are key to the research landscape and have huge potential to engage more in innovation across academia and business.

Long-term ambitions

We will maximise people's contribution to UK success in research and innovation and enhance the career development and mobility of post-doctoral researchers, so they have the experience to apply their skills across sectors. Our long-term aspiration is to ensure that:

- those we support have an excellent appreciation of the context in which research and innovation operates, including responsible innovation, research integrity, cross-sectoral working, equality, diversity and inclusion and of alternative career paths that build on engineering and physical science skills

- our researchers should have the opportunity to be trained at the interface of science, engineering, technology and finance so they can move seamlessly across research and business sectors. Success will be reflected in the UK research base commercialising its research far more effectively
- the role of outstanding leaders, teams and contributors who deliver UK research and innovation is valued and supported. In particular, the essential contribution of technical and software experts should be recognised by establishing funding mechanisms to support their career progression.

Near-term actions

In 2019-20 we will:

- work with UKRI partners to deliver the UKRI's cross-cutting Talent and Skills agenda, with the initial focus on delivering Innovation Scholarships which include opportunities for researchers to work across the university and business sectors
- review our support for post-doctoral researchers in light of the recommendations of the review of the Concordat for researchers[2] and our work on the role of people in innovation
- work with UKRI to improve the quality of data and analysis to understand the outcomes of supporting people at different career stages, focusing on post-doctoral research assistants (PDRAs) and technical support staff
- evaluate the introduction of our New Investigator Awards, two years after their introduction, to understand and clarify their impact and their future role in supporting the development of our early-career researchers
- to aid rapid expansion in doctoral student numbers and greater industry engagement:
  - invest £180 million in the DTP for students starting in October 2020 and 2021
  - invest £17 million in Industrial CASE studentships starting in 2020 (see Section 3.2.4)
  - review current investments, such as CDTs, DTPs, Industrial CASE awards, NPIF studentships and innovation placements, to support development of a skilled workforce contributing to the 2.4% aspiration
- develop an action plan to benchmark and improve the profile of our 'responsible innovation' approach and ensure greater usage by the researchers we fund. Increase training in responsible innovation for future researchers through CDTs.

Talented PhD students drive research and innovation

We support almost a third of the UK's engineering and physical sciences PhD students, with 40% of our doctoral graduates going on to work in the private sector. Their contribution to UK innovation and growth is extensive and varied. For example, students from the EPSRC Scottish CDT in Condensed Matter Physics are developing skills in organic semiconductors that are being used in everything from solar cells, TVs and smartphones to healthcare and sensing. The EPSRC CDT in Industrial Functional Coatings at the University of Swansea, meanwhile, is developing skilled researchers in areas such as resource recovery of precious metals from laptops, tablets, mobile phones and other waste electronic devices; the Welsh Government has used knowledge and expertise at the CDT to inform its policy on the circular economy. A significant number of spin-outs have also arisen from the work of the PhD students we fund. For instance, digital animation company NaturalMotion is commercialising work on computer simulations of nervous systems. The result, Dynamic Motion Synthesis, has been used in Hollywood films and, in 2014, gaming giant Zynga acquired the company for £320 million.

[2] https://www.vitae.ac.uk/policy/vitae-concordat-vitae-2011.pdf

3.2.3 Connecting the research landscape to accelerate impact

We will use our partnerships with universities, other innovation funders, business and government to embed timely, appropriate support for impact activities across all our investments. Working with IUK and other UKRI partners, we will build on two activities, Impact Acceleration Accounts and Innovation and Knowledge Centres, to contribute to the government's 2.4% R&D target. We believe they are key to supporting researchers to exploit their research outcomes and developing the beginning of the pipeline through to economic impact in emergent and rapidly developing new science areas.

We will continue to invest £20 million per year in Impact Acceleration Accounts. Growing annual investment to £40 million, however, would build on the momentum of recent funding (investment of £95 million EPSRC during 2012-17, leveraging an additional £85 million from other sources) and success to enable universities, business and other partners to further benefit from discovery research. Even more importantly, these accounts enable immediate-response, agile funding to support translation opportunities. We will look for alignment with similar activities across other UKRI councils to achieve greater impact by enabling partnerships, sharing best practice and developing new ideas.

Our current investment of £56 million in five Innovation and Knowledge Centres (within a total UKRI investment of over £80 million from EPSRC, IUK and BBSRC), has leveraged over £96 million from project partners at the outset of the grants, plus significant contributions from host institutions, regional funds and business during the course of the activities. Investing in new Innovation and Knowledge Centres (each new Centre is funded at around £10 million over five years) would allow us to capture more value from cutting-edge research in emerging technologies and accelerate the creation of emerging technology-based industries in the UK with a focus on the importance of place. This investment and the new skills and technologies it supports could increase local economic growth, enabling places to build on local strengths, reach their full potential and contribute to the UK economy.

Long-term ambitions

We will strengthen our collaborations with universities, users and innovation partners to maximise the benefits of our research outcomes, creating more streamlined support for knowledge exchange, commercialisation and innovation across UKRI. Our long-term aspiration is to ensure that:

- the Innovation and Knowledge Centres act as a powerful vehicle for accelerating emergent research through to innovation, providing a training and de-risking forum for business partners and an environment for university-

Impact Acceleration Accounts: three examples of success

University of Bristol spin-out Ultrahaptics has translated knowledge from EPSRC-funded research on ultrasonic wave phenomena. Having received £10.1 million from investors to grow globally, the firm now employs 41 people. Its technology creates the sensation of touch in mid-air without wearing special equipment, and has healthcare, gaming and other applications.

Fundamental research at Loughborough University has led to a new fault-tolerant points mechanism for railways. The Repoint system, also supported by the UK Rail Safety and Standards Board, uses concepts derived from the aerospace and nuclear industries to improve safety, cut maintenance costs and enhance network capacity. The technology was ready for its first in-track demonstration in January 2019.

A partnership between Microsoft and the University of Strathclyde created a testbed and demonstrator network harnessing unused parts of the radio spectrum to provide affordable internet access for communities in Glasgow and Kenya. The pilot network in Kenya has begun connecting schools, clinics and businesses to the internet, with over 30,000 users currently connected in rural and remote areas.

IKC delivers medical innovations

The University of Leeds Medical Technologies IKC, which we fund with BBSRC and IUK, has underpinned development of a range of medical and health care advances, benefitting patients, health services and UK plc. These include a portable heart scanning device, surgical technologies, a virtual microscope, longer-lasting joint replacements, advances in dentistry and stem cell development, with many innovations targetting the ageing population. The IKC has developed a culture of innovation involving over 250 researchers, with over 40 UK universities and 50 companies collaborating in 236 projects since the IKC was set up. Mature projects are now achieving significant impact, producing 45 patents and six spin-outs and leveraging over £148 million of private sector investment to date. New products include: VitalScan, a portable scanner using the heart's electromagnetic signals to help clinicians quickly rule out serious heart disease in patients; decellularised scaffold platforms commercialised as dCell® through spin-out Tissue Regenix; and Theagen™, a regenerative therapy for corneal transplantation resulting from collaboration between the University of Nottingham and spin-out Nuvision.

business co-working. Success will be reflected in increased industrial investment and business creation around each Centre

- the capacity and capability for innovation has increased. In particular, increasing researcher mobility across the innovation landscape by, for example, strengthening university-Catapult interactions. Success will be reflected in increased researcher mobility between academic and industrial settings.

Near-term actions

In 2019-20 we will:

- identify and implement low-cost funding options to help highly successful Innovation and Knowledge Centres coming to the end of their block EPSRC funding to continue to thrive and generate third-party income
- pilot an expansion of our portfolio of Innovation and Knowledge Centres into emerging areas of research and technology that will help anchor more exploitation of new knowledge in the UK. We plan to establish one or two Innovation and Knowledge Centres, but if additional funding is available this will increase to up to five. Potential topics include AI, new markets for novel materials and novel Energy Vectors
- draw on our learning from the 2018 Impact Acceleration Account Mid-term Review to develop options on how further funding could increase the impact from our research portfolio, alongside the streamlining of approaches across UKRI
- partner on the IUK-led Knowledge Transfer Partnerships Programme (£2 million EPSRC contribution) for a further year and support partnerships to exchange knowledge, skills and/or technology arising from our funded research through Impact Acceleration Accounts and programmes such as the Industrial Strategy Challenge Fund
- develop an approach to monitoring and evaluation of the Researchers in Residence pilot, which aims to increase connections between the UK research base and the Catapults by providing support for university academics to spend time embedded in Catapult teams
- improve Embedding Impact tools for staff and researchers, enabling sharing of knowledge and learning from impact activities across UKRI. Share good practice in the use of Pathways to Impact, Impact Acceleration Accounts and Innovation and Knowledge Centres by researchers and institutions
- scope methods to train researchers in aspects of business and finance relevant to their research base, within the envelope of the Impact Acceleration Account and Innovation and Knowledge Centre schemes.

3.2.4 Enhancing business engagement

Enhancing engagement with business in fundamental research and training is the key element of our contribution to the government's 2.4% R&D investment target. We will build on our proven track record in partnership with businesses, small and large, to secure further co-investment in outcome-driven research and much-earlier-stage fundamental, discovery research. Over half of our portfolio involves collaboration with business and other non-academic partners, providing around £1.2 billion of leverage on our portfolio of £4.6 billion. This close partnership and co-delivery ensures our research outcomes generate enhanced economic and social benefit.

We engage with businesses as long-term partners and act as both co-investor and domain specialist. The creation of Prosperity Partnerships in 2016-17, is a key example. These are a unique concept across UKRI in which businesses work with their longstanding strategic partner universities to co-develop and deliver user-inspired research. Businesses also co-invest an equal amount of cash, as a minimum, to that invested by EPSRC. To date, we have funded 23 partnerships, representing a total investment of £156 million of which £90 million was leveraged from industry and university partners. These partnerships span a range of sectors with strong overlap with the UK's Industrial Strategy Grand Challenges and are starting to attract further inward R&D investment to the UK from business.

Building on our track record, we will develop a suite of integrated approaches that enable the UK to reach the 2.4% target and lead to greater private investment, growth in business capability and the unlocking of research benefits for growth.

Long-term ambitions
Our long-term aspiration is to ensure that:

- business and user engagement with the research base has been energised through dynamic large-scale challenge-led collaborations with diverse partners, working to address pre-competitive topics defined by industry to deliver economic/social impact. Success will be reflected in the size and scale of the collaborations we support
- the Prosperity Partnerships portfolio has been expanded to achieve: increased volume, increased sector coverage, more leverage and a greater link to the supply chain. Success will be reflected in the diversity of organisations involved and the amount of leverage achieved
- an increased ability for small and medium sized companies to engage in bottom-up business-led research collaborations through new, agile approaches. Success will be reflected in an increased number of SMEs engaging directly with our portfolio.

Near-term actions
In 2019-20 we will:

- increase the number of strategic business partnerships from 11 to 24 within 12 months of the launch of this DP, with a specific focus on the creative industries and service sectors. Intrinsic to this approach will be engagement with IUK and other UKRI partners, especially AHRC
- strengthen joint working with our principal business partners Arup, AstraZeneca, BAE Systems, BT, GSK, Tata Steel, Jaguar Land Rover (JLR), Procter & Gamble, Siemens, Rolls-Royce and Shell through strategic bilateral meetings, site visits and shared objectives
- pilot new partnership models between universities, businesses and national labs, with active technical/project management delivering tangible industrial outcomes in a fixed timeframe. Invite businesses to lead in identifying topics for major industrial challenges within these partnerships. Shortlist two challenges (one in a mature sector of the economy and another in an emerging sector) for £20 million pilots based on national strategic need and the excellence of the underpinning basic engineering and physical sciences research required.

  The pilots will be run in 2020-21, these will require a minimum of matched financial leverage from the business partner. Success will be reflected in the ability of these partnerships to rethink the ecosystem in support of the 2.4% target, by aligning the research base and delivering specific, time-bound industrial outcomes from the research
- work with IUK, university and business partners to pilot new opportunities for SMEs to access our research, people and technologies. The pilots will focus on building the capacity of research-led SMEs, with the first set being run with a total investment of £20 million in 2020-21. As an input to this, a series of town meetings will draw on the expertise of partners and stakeholders to scope specific interventions with most impact,

and will be followed by a high-profile launch event. Success will be measured by the extent of diffusion of engineering and physical sciences research expertise within the SMEs and the adoption of innovations that arise

- expand the volume and coverage of our Prosperity Partnerships and explore growing this activity across UKRI. A call is already under way with guaranteed matched financial contributions from business, and there is an ambition to fund up to eight further partnerships in 2019. If funds are available, our aspiration is to transform the landscape in both scale and coverage of Prosperity Partnerships, going from around £20 million to £80 million per year, running multiple annual calls and targeting all sectors of the economy.

Partnership drives growth in the automotive sector

JLR, the UK's biggest automotive manufacturer, is also its largest manufacturing investor in R&D, investing £12 billion over the last five years. The company is a member of our Business Engagement Forum, which promotes regular engagement between us and our key business stakeholders. In 2011, JLR was involved in just one EPSRC-supported project but today it provides support or direct funding for over 100 postgraduate researchers and around 50 EPSRC-supported research projects across 19 UK universities; projects include developing autonomous sensors, optimal use of data for autonomous vehicles and intelligent infrastructure, and systems designed to adapt to their users' personal characteristics. This expansion has helped supply JLR with the tools and people to support growth. Anthony Harper, former Director of Research at JLR, said: "EPSRC plays a vital role in enabling and supporting some of the world's most advanced academic research. We stand on the brink of the mobility revolution and see EPSRC as key in fostering the science and innovation infrastructure to help bring about that change".

3.3 Objective 3: Enabling the UK engineering and physical sciences landscape to deliver

3.3.1 Managing our portfolio and priorities

We will continue to actively manage our research and training portfolio in order to maintain the UK's world-leading position in engineering, the physical sciences and computational and mathematical sciences research; the UK is currently ranked first or second in the world based on citation impact for all relevant disciplines[3].

To understand the research landscape, the international context and the expected future development of research fields, our portfolio management not only draws on our management information capability but also integrates this with evidence publicly available worldwide and with input from researchers and businesses. We use this information to adjust our research and investment priorities, subject to emerging research opportunities and changing UK needs, to make most effective use of available funds in developing research leadership and protecting key capabilities.

Long-term ambitions

We will target our investments to ensure the UK strengthens its world-leading position in engineering and physical sciences research and is partner of choice for collaboration. Our long-term aspiration is to ensure that:

- stronger relationships with existing and new partners are in place, ensuring we have current

[3] https://epsrc.ukri.org/newsevents/news/publicationsanalysis/

knowledge, up-to-date evidence and expert insight into the research landscape to enable timely responses to changes and challenges as the portfolio continually refreshes. Success will be reflected in a more extensive, richer knowledge base

- enhanced two-way communication in priority-setting to demonstrate the positive outcomes of our approach and the use of management information to influence future investment decisions. Success will be reflected in our community's further engagement with our portfolio management approach
- the UK's international research standing has been enhanced by encouraging best-with-best international collaboration (around 25% of the current portfolio involves international collaboration) and building strong partnerships with world-leading research nations, to strengthen UK and global research outcomes. Success will be reflected in the level of international involvement in our portfolio.

Near-term actions

In 2019-20 we will:

- seek community/stakeholder input to enable further evolution of our portfolio, our strategic priorities and approaches to delivery by engaging our strategic advice streams, strategic partnerships with universities, business and government, and input through the Balancing Capability Open Call for Evidence in November and March, enabling us to establish future Centres of Excellence (see Section 3.2.1)
- connect across UKRI and wider stakeholders to identify emerging multidisciplinary areas to realise impacts from our investments
- publish updates to our research area strategies to acknowledge changes in the research and funding landscape
- explore the use of state-of-the-art tools, such as visualisation and evidence analysis, to improve understanding of our portfolio, the wider landscape and impacts of engineering and physical sciences research, enabling more informed interactions with our key stakeholders

Active portfolio management generates powerful research

Catalysis has a major role to play in developing more efficient processes that are environmentally and economically sustainable. With our funding, the UK Catalysis Hub was set up to bring together researchers across chemistry, engineering and manufacturing in a coordinated way and encourage multidisciplinary working. It was based on the Harwell campus close to facilities such as Diamond Light Source, whose successful exploitation for catalysis research has been a major feature of its activities. The hub has delivered excellent science, high international visibility and leadership/coordination of the research community. It has project partnerships with over 20 companies, including Unilever, Johnson Matthey and GSK, and SMEs across the energy, pharma and chemicals sectors. 2018 saw announcement of £14 million funding for another five years, allowing pursuit of exciting research that will help deliver clean growth.

3.3.2 Future-proofing state-of-the-art research infrastructure

As the UKRI Infrastructure Roadmap recognises, in engineering and physical sciences research a world-class infrastructure comprises not just large high-specification equipment and access to central facilities, but also the distributed investment in laboratory-based equipment and the technical support needed to ensure its productivity. Use of computational approaches such as modelling and simulation, meanwhile, is a ubiquitous feature of research; encompassing computing facilities, data analysis capabilities, modelling/simulation software and expert support, this pervasive component of 21st century research infrastructure is critical to sharpening the UK's industrial competitiveness.

All our investments acknowledge the relationship between laboratory-based, distributed facilities and large-scale campus-based facilities. We also seek to ensure maximum availability and sharing of equipment across organisations, to realise the benefits from our infrastructure investments.

Long-term ambitions

We will provide researchers with the world-class infrastructure they need, at all sizes and scales, to deliver world-leading discovery and translational research. Our long-term aspiration is to ensure that:

- we have a stronger understanding of, and vision for, the impact of major infrastructure investments on the research landscape, such as through longer-term planning and improved appreciation of sustainability issues. Success will be reflected in the widespread use of monitoring and assessment frameworks for infrastructure investments
- productivity of research infrastructure has been maximised by working with our university partners and businesses, including relevant Catapults, to optimise sharing and usage, ensuring access for the right teams with the right skills to tackle specific challenges. Success will be reflected in patterns of use and increased links to scientific impact
- recognition of the essential roles of research technical professionals and research software engineers across all scales of infrastructure becomes business-as-usual in the laboratories we invest in
- there is a sustained world-leading computational research community which has access to an integrated HPC ecosystem and the required software infrastructure. Success will be reflected in our community's use of infrastructure and the quality of research outputs
- our e-Infrastructure capability has been enhanced in accordance with the e-Infrastructure Roadmap, ensuring there is enough computing power and capability to support our community's needs.

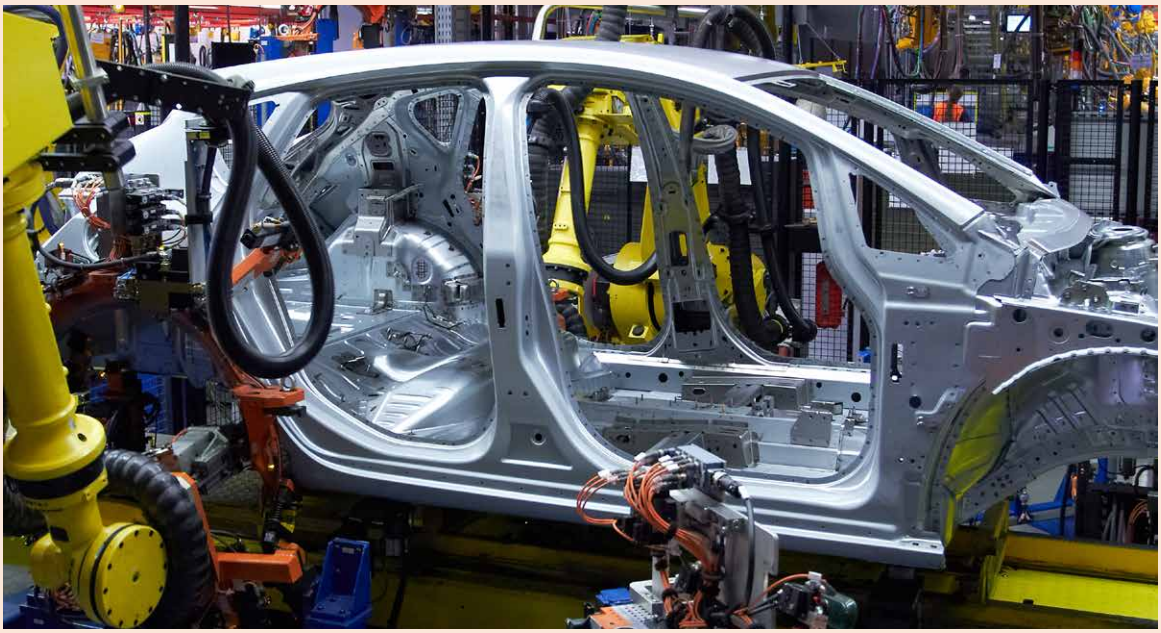
Near-term actions

In 2019-20 we will:

- with NERC, deliver the next national HPC service, ARCHER2, with a managed transition that minimises the effect on users. The UKRI Investment Committee has approved a £40 million capital budget plus an annual operational resource budget of £8 million for four years
- work across UKRI to deliver the long-term opportunities identified within the UKRI Infrastructure Roadmap. Work with STFC on the e-Infrastructure Roadmap to identify the most effective e-Infrastructure solutions and support for engineering and physical sciences research
- ensure effective delivery of strategic equipment and national research facilities as part of our £50 million/year World Class Labs portfolio, in response to emerging research needs
- scope capital support of up to around £40 million (subject to budget) for our CDTs, for funding in 2020-21
- scope, for funding in 2020-21, a further £4 million for institution-based capital awards to support early-career researchers building on an evaluation of the £8 million pilot launched in 2018-19
- work with UKRI partners to develop a coherent strategy for use of the research facilities at the Research Complex at Harwell, and identify opportunities arising from co-location of the Rosalind Franklin Institute with STFC facilities at Rutherford Appleton Laboratory
- deliver a call for multidisciplinary collaborative computational projects, for funding in 2020-21 of up to £5 million. Our aim is to make this a joint call with other UKRI partners
- refresh the Tier 2 HPC Centres with investment of up to £15 million.

Revolutionising UK car manufacture

The Advanced Metal Casting Centre (AMCC), an academic/industry facility at Brunel University, is driving development of innovative technologies to make automotive components lighter and completely recyclable. A £3.9 million EPSRC investment in metal casting equipment was key to its establishment, with co-investments from project partners JLR, IUK and global aluminium producer Constellium. Equipped with state-of-the-art scale-up facilities, the centre turns lab-proven concepts and processing technologies into commercial reality. As well as helping Constellium cut R&D times by at least 50%, AMCC's revolutionary casting technologies have enabled the company to introduce a new generation of high-strength alloys that achieve weight savings of 15-30%; several car manufacturers, including BMW, are using the alloys. In addition to supporting collaborative research, AMCC helps develop skills across the automotive industry, academia and the supply chain, and expanded from under 50 staff in 2015 to nearly 100 in 2017.



3.3.3 Accessing talent through equality, diversity and inclusion (EDI)

Creating a research and innovation environment which fully supports equality, diversity and inclusion for all is critical to the ability to respond to current and emerging research challenges. A truly inclusive environment will help us attract growing numbers of people into research and innovation careers and increase the diversity of researchers, leading to greater creativity of ideas and increased achievement of excellence.

We will work in partnership and take an ambitious, holistic approach to EDI that builds on existing activity within the engineering and physical sciences community and shared expertise across UKRI. We will address challenges specific to our community, ensuring fairness and inclusivity for all in everything we do, and develop and implement new interventions to bring about change and evaluate their effectiveness. We will share our knowledge, experiences and ideas while listening to and learning from others.

Long-term ambitions

We aim to make EPSRC recognised as a funding agency which is fully aware of the EDI agenda and which is putting in place training and processes to achieve zero differentiation in participation or success rates within our researcher community. Our long-term aspiration is to ensure that:

- there is improved understanding of EDI issues by EPSRC through robust evidence-gathering and engaging with representative voices
- creative and effective interventions have been delivered in engineering and physical sciences, providing leadership in the research and

Promoting EDI through leadership and flexibility

We have already made significant progress in promoting EDI. For instance, we have increased female membership of peer review panels from 17% to 34% in the last five years, while we have also delivered training on unconscious bias for all our staff, Council members and advisory boards. We continue to lead and support change in the research community, encouraging flexible approaches such as awarding a 'job share' fellowship to two academics who have been jointly running the Cambridge Centre for Medical Materials on part-time contracts that fit in with their family commitments. As part of UKRI's collective approach to promote EDI, we launched the Inclusion Matters initiative, the first of its kind to improve EDI within engineering and physical sciences; this has funded 11 projects totalling £5.5 million at UK universities which, through innovative approaches, will inform and shape significant cultural change across institutions and share their learning with the whole sector. By furthering and embedding EDI values, we will help researchers from all backgrounds and groups to fulfil their talent and ambitions.

innovation community and bringing about a more diverse community and a more inclusive research culture. Success will be measured through a systematic evaluation of the effects of our interventions

- strong partnerships have been established with other stakeholders to share ideas and approaches and to implement effective actions across UKRI and the wider UK and international community.

Near-term actions

In 2019-20 we will:

- aligning with UKRI's EDI agenda, use and continue to evolve our diversity data capabilities to monitor our advisory structures, grants portfolio and peer review process, such as through thematic deep dives, and identify areas for further exploration and action. Explore appropriate approaches and methodologies to measure our interventions' impact
- explore and evaluate new ideas related to peer review, drawing on emerging research and good practice across UKRI, other funding agencies and the wider community to control bias and safeguard the quality of decision-making
- work within UKRI to identify and deliver shared goals and related activities, and in particular better understanding of issues in race, ethnicity, bullying and harassment. We will hold workshops with BBSRC and AHRC
- implement new ideas and mechanisms to improve participation of under-represented groups, particularly at the established-career stage. Work with the Royal Society of Chemistry and Institute of Physics to introduce a new fellowship opportunity in physical sciences to tackle lack of diversity in research leadership
- work with Inclusion Matters teams (see Case Study above) to share and use emerging findings, creating a network to bring together teams and key stakeholders (including the Learned Societies) through a series of workshops. Learning from successes, prepare for further investments in 2021-22.

3.3.4 Inspiring, informing and interacting with the public

We will align our activities with the UKRI cross-council initiative in public engagement and continue to invest in activities targeted at the engineering and physical sciences space. In particular, we will seek to inspire the public by facilitating and encouraging STEM researchers to enthuse others about the outputs of their research. We will showcase the range and desirability of STEM careers to attract people, thereby enabling the UK to build a strong, inspired engineering and physical sciences workforce. Our role is also to enable our research community to collaborate and interact with the wider society throughout the research process, so taxpayers understand and value the investments we make on their behalf.

As a public funder of research, we have a clear responsibility to ensure our investments align with the principles of responsible innovation and create genuine value for society, ethically and responsibly. We also recognise the importance of helping to inform public opinion, objectively and constructively, and contributing to a wide, inclusive public debate on potentially controversial topics such as robotics and AI or other Grand Challenges, such as AI & Data, Ageing Society, Clean Growth, etc. Effective, timely public dialogue brings increased accountability of public investment, increased legitimacy for decisions and a richer understanding of public views on and perceptions of new technologies. Decisions informed by public dialogue are more likely to be robust, publicly acceptable, socially informed, cost-effective and easier/quicker to implement.

Long-term ambitions

We will enhance the public understanding and appreciation of the importance of investment in engineering and physical sciences research and ensure we and UKRI are viewed as trusted, responsible organisations through broad inclusive engagement with the public. Our long-term aspiration is to ensure that:

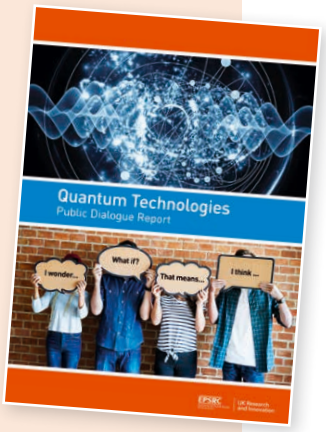
- public engagement strategies function coherently across UKRI's remit. Success will be reflected in a more engineering and physical sciences-literate public with strong awareness of what our investment of their taxes produces on their behalf, and the number of young people inspired to pursue STEM careers
- responsible innovation is business-as-usual for researchers, and there is more comprehensive recognition of the opportunity it offers in exploring and opening up new, more sustainable, more socially desirable pathways for innovation
- research investments are appropriately informed by public concerns and values, via public dialogue.

Near-term actions

In 2019-20 we will:

- work closely across UKRI on provision for public engagement with schools and science festivals with a focus around our productive, connected, healthy and resilient nation priorities
- pursue one strategic intervention with external partners per year when key opportunities arise. In 2019-20, pilot Public Engagement Fellowships to link with the Year of Engineering and the Women's Engineering Society centenary. In 2020-21, partner on public engagement activities relating to AI.

Encouraging public dialogue on quantum technologies



We commissioned social research agency Kantar Public to carry out a public dialogue on quantum technologies in 2017. The aim was to better understand how the public views and feels about such technologies now being developed by researchers. Held in Oxford, Glasgow, Birmingham and York, workshops designed to capture a diversity of views generated a highly exploratory dialogue that produced the first substantive knowledge of public attitudes to quantum technologies and their applications. A key finding was that limited exposure to information about these technologies has led to an initial feeling of neutrality towards them. More exposure to information saw many participants become more engaged and excited by the range of potential benefits, especially those associated with health and humanitarian applications. The findings and recommendations are informing research and innovation priorities in the next phase of the UK National Quantum Technologies Programme.

Inspiring the public on robotics

Robots, a major 2017 exhibition held at London's Science Museum, explored humanity's 500-year quest to reimagine ourselves as machines. Featuring a unique collection of over 100 robots, ranging from a 16th century mechanical monk to robots from science fiction and modern-day research labs, the exhibition explored how religious belief, the Industrial Revolution, popular culture and dreams about the future have all shaped society. Recent developments from robotics research were on show and visitors could explore how and why roboticists are building robots that resemble us and interact in human-like ways. The exhibition attracted over 187,000 visitors and extensive national and international media coverage, before touring other UK and international venues. We supported the exhibition, along with the Heritage Lottery Fund, Switzerland's Federal Department of Foreign Affairs, the Daiwa Anglo-Japanese Foundation and the Great Britain Sasakawa Foundation.

4. Delivering and being accountable as an outstanding organisation

Efficient and effective operations

Over the past 20 years, we have delivered a broad, diverse portfolio of research and training investments through an agile approach that has enabled efficient, effective innovation and continuous improvement. Compared to 25 years ago, we are servicing more than double the budget with two-thirds of the staff.

We operate an agile operating model that allows us to transform and adapt quickly to new opportunities. Features that particularly help us do this are:

- an outcomes-focused approach that covers everything we do, defining plans according to outputs and outcomes and realising benefits through appropriate monitoring plans
- an agile, flexible management structure
- a culture of information-sharing and free exchange of business knowledge, empowering teams and frontline staff to make decisions
- detailed current knowledge of our portfolio, alongside horizon-scanning activities and sector-specific analysis of UK research capability in a global context
- effective relationships with other research councils and IUK, enabling us to collaborate quickly and bid successfully when new funding opportunities arise.

Measuring progress against the UKRI success framework and our plan

We will proactively manage delivery of our delivery plan in the following ways:

- appointment of a member of our executive leadership team as champion for each of our 12 priorities, who will own delivery and leadership of this priority across EPSRC
- use of the long-term ambitions for each priority to design a monitoring and evaluation framework with critical performance measures articulated for each priority
- routine presentation to our Council of progress against our priorities, for advice and guidance
- invitations for our advisory groups to comment on and review progress on each priority.

In terms of evaluation tools, all our funded researchers currently use ResearchFish®, which enables collection of evidence about outcomes of research investments at all scales from individual researcher awards to researchers working within our Institutes. Key outcome indicators include research outputs, innovation impacts, training outcomes and public engagement.

Management boards oversee evaluation of investments of over £10 million. Our portfolio managers undertake active monitoring, for example through attendance at these boards. Key indicators used are bespoke to the plans and milestones of the programme in question. The proposed creation of a science, engineering and technology board will enable greater transparency and engagement with academic and user communities in the evaluation process.

At the level of overall programmes, our thematic managers gather intelligence on portfolio outcomes via active engagement with our community, including regular university visits and interaction with relevant representative bodies. At the level of our total portfolio, key intermediate indicators will show how our interventions have made a difference. These include: quality and international standing of research outputs; volume of multidisciplinary research across our portfolio; amount of business leverage secured; number of council partnerships

across UKRI; number and quality of partnerships with academia, business and government departments; diversity of our researcher community, decision-making and advisory structures; and number of new spin-outs and start-ups.

How will UKRI-EPSRC evolve to deliver its vision?

An important part of UKRI's formation will be reorganisation of the partner councils to comply with a common organisational model, characterised by clarity of line management and responsibility for delivery. One benefit will be easier cross-council working and collaboration. Putting in place an effective structure for development, organisation and delivery of cross-UKRI activities and especially the Industrial Strategy Challenge Fund will be an important part of this process.

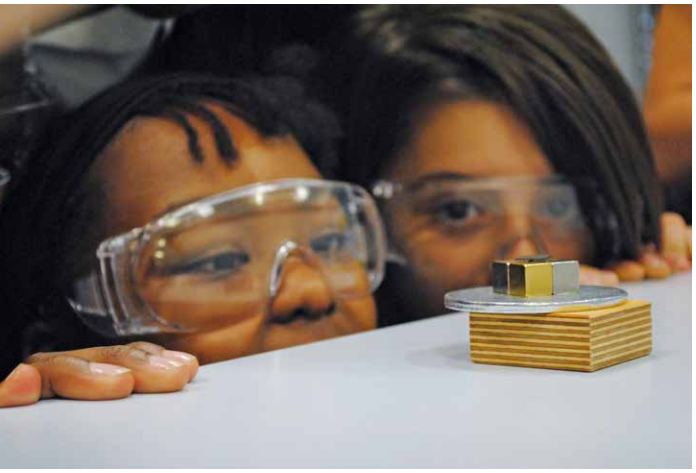
One characteristic of the UKRI and recent EPSRC landscape has been increased investment in large funding awards of over £10 million. We will be proactive and transparent in how we identify and develop cases for funding, and rigorous and transparent in the way we assess progress and delivery against objectives during and beyond the end of the grant. We must also access new skills to enable robust economic analysis of the value of the investments. In the next 12 months, we will therefore make a number of changes:

(i) In consultation with Council, we will create a science, engineering and technology board to:

- provide advice and scientific guidance to the EPSRC Executive regarding critical mass investments such as, Centres of Excellence and Institutes. Specifically, to:
  - understand the benefits and scientific outputs of our large investments, using this to inform future priorities
  - assess and prioritise ideas for investments for consideration by Council, providing scientific assurance
- maintain an overview of and contribute to the pipeline of ideas to identify strategic opportunities for additional funding streams
- champion multidisciplinary and emerging scientific research challenges
- work with EPSRC Executive and other EPSRC advisory bodies to make the case for fundamental, discovery research, helping to identify and publicise scientific breakthroughs in the engineering and physical sciences domain
- improve the two-way communication between EPSRC and the research community

(ii) To engage more effectively with the academic and business communities, we will:

- appoint up to three Deputy Executive Chairs with internationally respected expertise in different areas of our portfolio. An important role for them will be to communicate our vision and funding opportunities to the academic and business community and act as an additional source of advice to us in developing/implementing new funding opportunities
- appoint a Director of Commercialisation to coordinate commercialisation of university research across UKRI and act as the interface for these activities with IUK and Research England.



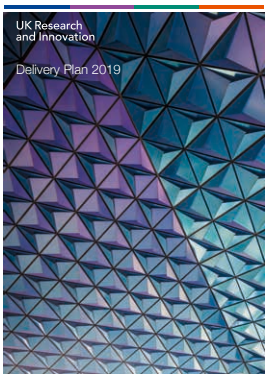
International context

Many of today's research challenges are global in nature and need a global response. The formation of UKRI offers exciting opportunities to enhance and extend our international partnerships. We will ensure the best UK researchers can work effectively and efficiently with the best researchers worldwide, wherever they are based. We will continue to embed opportunities to work internationally in our programmes and approaches and look to build on our international centre-to-centre call and strengthen our relationships with colleagues in overseas agencies. We will maintain a focus for collaboration with the USA, Europe, Japan, China and India, while the UKRI Global Challenges Research Fund provides opportunities to reach out further. We are also conscious of Brexit and its potential impact on engineering and physical sciences research, and wider UKRI policy and its implementation will guide our actions.

5. Financial allocation

EPSRC, £m		2019-20
Research and Innovation Budgets		**763.7**
Science Infrastructure Capital		**189.3**
ODA		**23.0**
o/w	GCRF	20.2
	Newton Fund	2.8
NPIF		**118.9**
o/w	ISCF	49.7
	Skills	43.8
	Plastics Research & Innovation Funding	5.5
	Strategic Priorities Fund	19.9
EPSRC Programme		**1,094.9**

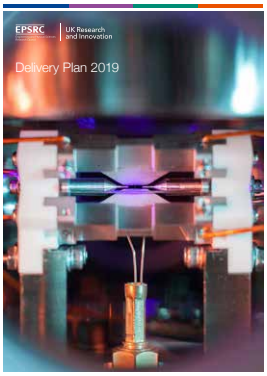
UK Research and Innovation Delivery Plans



UKRI

AHRC

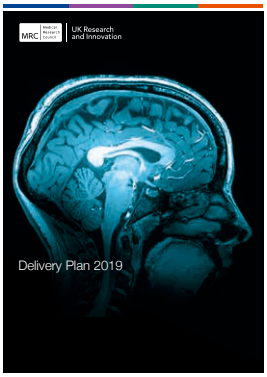
BBSRC



EPSRC

ESRC

Innovate UK



MRC

NERC

Research England

STFC

EPSRC
Engineering and Physical Sciences
Research Council

UK Research
and Innovation