Informing drug design at Diamond: These dehydrated crystals of membrane protein enzyme were grown at Diamond’s Membrane Protein Lab and studied on Diamond’s crystallography beamlines. These proteins are studied in crystal form because it makes it easier to work out their atomic structure. This information can then be used to design new drugs, in this particular case to treat multidrug-resistant bacterial infections.

Credit: Isabel De Moraes, Membrane Protein Laboratory at Diamond Light Source and Alice Vrielink, University of Western Australia
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Front cover: This fused silica glass fibre laser pulling machine was built by the University of Glasgow to prepare the ultra-pure glass fibres that were used for the first detection of gravitational waves. Four fibres suspend each of the 40kg test mass optics in the aLIGO detectors, minimising seismic and thermal noise so that fluctuations a thousand times smaller than a diameter of a proton can be detected. Credit: University of Glasgow.

Note: All images are courtesy of STFC unless otherwise stated.
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1. Executive summary

The Science and Technology Facilities Council (STFC) is one of the seven UK Research Councils. Our research seeks to understand the universe from the largest astronomical scale to the tiniest constituents of matter, yet creates impact on a tangible level. From clean energy to crop protection, dementia research to data-centric computing, our impact is felt across many aspects of daily life. Public investment in science supports economic growth, improves productivity and creates a highly skilled workforce. Through collaboration with industry and long-term research and development we underpin sectors that contribute billions of pounds annually to the UK economy, including space, pharmaceuticals, digital communication, microelectronics and physics-based manufacturing.

From April 2018, operating across the whole of the UK with a combined budget of more than £6 billion, UK Research and Innovation will bring together the seven Research Councils, Innovate UK and a new organisation, Research England. UK Research and Innovation “intends to be an outstanding organisation that ensures the UK maintains its world-leading position in research and innovation”1. We are currently refreshing our corporate strategy – this will reflect the opportunities afforded by the strategic direction of the newly formed organisation and the changes that are taking place within the national and international science and innovation landscape.

Our strategy builds on our longstanding strategic goals of world-class research, innovation and skills and sets the direction for the forthcoming decade. It also provides an opportunity to reflect on our incredible achievements over the last 10 years, many of which are highlighted in this report. Our refreshed strategy will showcase our new vision: “Discovering the secrets of the universe, developing advanced technologies, solving real world challenges”. And by including three new strategic themes – data-intensive science, advanced technology development and research and innovation campuses – to sit alongside our enduring strategic goals, we better reflect our current mix of capabilities and future strategic direction. Underpinning these are a set of strategic enablers which will be pivotal in delivering our strategy and creating the best opportunities for our organisation.

By monitoring and evaluating our impact, we track our progress towards delivering our strategy. In this, our seventh impact report, we present quantitative data and case study examples that illustrate the breadth and depth of our economic and societal impact against each of our strategic goals. By its nature, relatively short-term performance monitoring

STFC’s corporate strategy, showing our strategic goals, themes and enablers

“Discovering the secrets of the universe, developing advanced technologies, solving real world challenges.”
cannot be expected to provide a full picture of the broader economic and societal benefits our organisation delivers. Therefore, we also carry out studies on the longer-term impacts of significant strategic investments. The year 2017 was STFC’s 10th anniversary and the 60th anniversary of the Rutherford Appleton Laboratory (RAL) at our Harwell Campus. The introduction to this report contains key highlights over the past 10 years and some of the significant scientific legacy of the organisation stretching back many decades, including the 40th anniversary of our Central Laser Facility (CLF). We also highlight our unique place in the UK’s research and innovation landscape and Section 3 ‘Our Evaluation Studies’ provides initial results on evaluations of the early benefits of the Square Kilometre Array (SKA) and the Hartree Centre. The report is then structured around our three strategic goals of world-class research, innovation and skills, and illustrates how our work generates a range of impacts over varying timescales. Highlights from this year’s report are summarised below.

**World-class research**

- The ultimate recognition of the impact of gravitational wave research came with the award of the 2017 Nobel Prize in physics to Professors Kip Thorne, Barry Barish and Rainer Weiss. The first detection in 2015 was made possible by Advanced LIGO (aLIGO), which relied heavily on initial UK capital funding and on technical expertise from UK universities and our own laboratories. The facility has now gone on to make multiple detections of gravitational wave events.

- The 2017 Nobel Prize in chemistry was awarded to British biochemist Dr Richard Henderson ‘for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution’, alongside Professors Jacques Dubochet and Joachim Frank. Dr Henderson and STFC have collaborated for the past decade on the development of the sensors for the cryo-electron microscopy he pioneered. The revolution in cryo-electron microscopy is continuing at STFC’s Diamond Light Source, where researchers used the technique to investigate the structure of a new, plant-based polio vaccine.

- CERN continues to break new ground, with five new particles discovered this year adding to the total since the announcement of the detection of the Higgs boson in 2012. Thanks to the incredibly sensitive LHCb experiment at CERN, the detection of new particles will help physicists better understand the ‘strong force’ which glues nucleons together, as well as open up entirely new avenues in particle physics.

- STFC researchers are working on global issues, from mapping the structure of the Ebola virus molecule and tracking Amazonian biodiversity through techniques developed by astronomers, to engaging with the UK’s aid strategy through astronomy to help drive economic growth in southern Africa.

- The government this year announced that two new high-profile research headquarters will be established at the Harwell Campus: The Faraday Institution, formed by seven university partners, will have a budget of £65 million over four years to fund research into battery technology, while a £100 million investment in the new Rosalind Franklin Institute will help to transform our understanding of disease and speed up the development of new treatments.
World-class innovation

- Our Sci-Tech Daresbury Campus won the UK Science Park Award for Best Science Park ‘Setting the Pace’, reflecting the significant national and international growth achieved by the 120 companies on site. With more than 80 companies onsite at Sci-Tech Daresbury, this year 75 new products (829 in total since 2010) were developed by campus companies, with 20% of companies filing patents.

- This year 13 new inventors were identified across the National Laboratories and £7.7 million was generated from patents and intellectual property. Since 2002, 19 spin-outs have been created from our National Laboratories, raising more than £73 million in third-party investment.

- One such spin-out, Cobalt Light Systems, was sold this year to Agilent Technologies Inc. for £40 million. Amongst its international customer base are eight of Europe’s 10 largest airports and over 20 of the 25 largest Pharma companies, using their specialist technology to determine the composition of chemical substances through opaque containers.

- The Harwell Campus will be home to the new National Satellite Testing Facility (NSTF) from 2020, after £99 million was won from the Industrial Strategy Challenge Fund (ISCF) to provide this unique national facility. The new capability will allow the UK to construct future satellites and deliver payloads into orbit, and supports the government’s ambition for UK industry to capture 10% of the global space market by 2030.

- This year, UK company Teledyne e2v won a contract to supply the European Southern Observatory (ESO) Extremely Large Telescope (ELT) with 28 sensor modules. The multi-million pound contract consolidates STFC’s long-term relationship with e2v, valued by the company to be worth at least £400 million to their business.

World-class skills

- We are continuing to invest in PhD students, delivering over 14,000 training days to PhD students at our large UK facilities. This year STFC will be supporting nearly 100 additional students through Centres for Doctoral Training (CDT) in support of the UK’s industrial strategy. CDT students will be trained to analyse data from astrophysics, accelerator science, nuclear or particle physics research, bringing the total number currently supported to 867.

- STFC is investing £23 million per year in postgraduate training and fellowships in particle physics, nuclear physics and astronomy, helping to equip our graduates with a breadth of skills needed for both academia and industry. Of the 941 PhD students included in the latest ‘First Destinations’ report, 45% of these went onto postdoctoral positions, 28% into the private sector and the remainder mainly into research institutes, other university jobs, school teaching and other parts of the public or charitable sectors.

- In 2016/17, our National Laboratories and university-funded engagement programmes communicated the inspiring nature of our science to 1.4 million members of the public, including 336,623 school and further education students. We have extended our reach to those demographics traditionally less well served by STEM, aiming to increase diversity in STEM and the arts and joining 23 other countries in marking Dark Matter Day through a nationwide suite of engagement events.

- Some 397 members of our staff have received significant awards or recognition in the past year for exceptional contributions to science and innovation.
2. Introduction

2.1 About STFC
STFC was created in 2007 as an inherently multidisciplinary science organisation. We operate at six sites across the UK and are involved in international collaborations on a global scale. We deliver our mission through three inter-related, long-term strategic programmes.

1. Frontier research: Developing and exploiting a world-leading programme of frontier research in particle physics, astronomy and nuclear physics supporting research, innovation and skills development in our partner universities and research institutes and through a range of international facilities.

2. Scientific facilities: Planning, designing, constructing and providing stewardship for world-leading, large-scale UK facilities used by academic and industrial researchers, enabling and driving research, innovation and skills training to deliver multidisciplinary research priorities and help address industrial and societal challenges such as those in energy, healthcare, security and climate science.

3. National research and innovation campuses: Built around our National Laboratories and facilities to promote academic and industrial collaboration, Sci-Tech Daresbury and Harwell Campuses are locations for national and international investment in business technology clusters that capitalise on our multidisciplinary research strengths and facilities, supporting economic growth and highly-skilled jobs.

These three inter-related, long-term strategic programmes are underpinned and linked by five world-leading capabilities in technology that cannot be cost-effectively and reliably procured on the open market, specifically in: detectors and instrumentation, accelerators, specialist engineering, optics and e-infrastructure.
STFC operates at six sites across the UK

Daresbury Laboratory, Cheshire

Chilbolton Observatory, Hampshire

UK Astronomy Technology Centre, Edinburgh

Polaris House, Swindon

Boulby Underground Laboratory, North Yorkshire

Rutherford Appleton Laboratory, Oxfordshire
Our scientific facilities – using synchrotron X-rays, neutrons and lasers – involve challenging technology often at the leading edge of what is possible technically and in engineering terms. Their conception, development and operation are typically decades-long endeavours and, at the largest scale, are beyond the resources of a single nation, requiring international collaboration. To deliver these programmes successfully we must sustain a critical mass of technology and engineering capabilities in our UK facilities, our partner universities and in our own laboratories.

Facilities provided by STFC in the UK include Diamond Light Source, ISIS Neutron and Muon Source and CLF – the national synchrotron, neutron and laser facilities. In addition, we provide High Performance Computing (HPC) and data-intensive science capabilities across our programmes, for example, at the Hartree Centre.

The range and global reach of facilities supported by STFC is broad, comprising over 80 locations, covering all five continents and spread across 17 individual countries. These include facilities developed, funded and operated by partnerships that include STFC; facilities developed by international collaborations to which STFC has contributed technical expertise and finances; and facilities that are accessed and exploited by members of the community that we support.

STFC manages the UK’s participation as a partner in the European Synchrotron Radiation Facility (ESRF) and the Institut Laue-Langevin (ILL) neutron source in addition to the European X-Ray Free-Electron Facility (XFEL), the Facility for Antiproton and Ion Research (FAIR) and the European Spallation Source (ESS). We also oversee the UK’s membership of the European Southern Observatory (ESO), the UK’s subscriptions to CERN and the Square Kilometre Array (SKA), and manage the UK’s participation in the Deep Underground Neutrino Experiment (DUNE) in the US.

Beyond these 80-plus facilities, our global reach extends wider still, with many international collaborations seeking our knowledge, which we provide pro bono to support the health and expertise of the global community, and technical expertise which we provide through contracts with scientific and industrial organisations engaged in our areas of science across the world.

Our role in the UK research and innovation landscape

The external landscape in which we are operating continues to change, not least because of the preparations that are required for the UK to leave the European Union. The government’s Industrial Strategy will form a critical part of the UK’s plan for a post-Brexit Britain, alongside the commitment to a £4.7 billion increase in research and development funding up to 2021. A new Industrial Strategy Challenge Fund (ISCF) for collaborative research between industry and academia, targeted at priority technologies, is forming the largest part of this additional funding alongside other initiatives to boost UK capacity in research and innovation.

As part of UK Research and Innovation, STFC will play a pivotal role in developing opportunities to invest in local science and innovation expertise and in providing increased support for commercialisation. We are also leading work on the development of a UK Research and Innovation Infrastructure Roadmap to be launched in 2018, to ensure that UK research remains internationally competitive through long-term strategic planning and investment.

STFC is committed to ensuring that we continue to use the skills, expertise and infrastructure developed through our strategic programmes to maximum benefit in order to bolster UK productivity, and create the greatest economic and societal benefit. STFC already has a significant impact on the science and innovation landscape, in particular through the themes of place and our scientific infrastructure and through the work we do at an international scale. Our contribution is summarised in the following infographic and these themes are highlighted, using specific examples and case studies, throughout this report.
STFC’s impact on the UK’s Science and Innovation Landscape

**UK PRODUCTIVITY**

**INDUSTRIAL STRATEGY**

- Commercialising STFC research and STFC-funded science, for example, producing patents, creating spin-outs and licensing technology
- Continuing to expand our Research and Innovation Campuses as key assets to support local and national growth
- Increasing the industrial use of our facilities, supporting cutting edge R&D for businesses across a range of sectors
- Fostering the development of economically productive clusters of technology-related businesses, such as the Space Cluster at Harwell
- Ensuring that the UK’s large research infrastructure supports the country’s leading international research reputation and delivers facilities and experiments supporting industrial R&D
- Attracting multinational businesses to locate on STFC Campuses, increasing international collaboration and industrial funding
- Promoting the UK’s global influence by increasing the number of international science and technology projects with substantial UK involvement
- Providing solutions for global challenges, with staff and funding dedicated to advancing key areas such as energy generation and security
- Funding influential international research programs, for example through Newton and GCRF
- Promoting opportunities for UK companies to win commercial contracts from international science facilities and organisations, for example £140 million in contracts has been won from CERN over last 5 years
- Providing business incubation for start-up companies at our Research and Innovation Campuses
- Supporting the provision of early-stage venture capital as a lead partner in the Rainbow Seed Fund, which has so far leveraged co-investment of more than £320 million
- Developing the talent needed to support UK excellence in research to understand the universe, maintain world class facilities and promote economic growth

**PLACE & INFRASTRUCTURE**

- Providing personalised business support for campus tenants, minimising business failure and supporting campus collaboration
- Growing our work with forward-looking businesses, addressing scientific and industrial challenges, driving productivity and growth
- Encouraging local growth by providing national and international focal points for business R&D, for example through the Hartree Centre and the National Satellite Test Facility
- Promoting the UK’s global influence by increasing the number of international science and technology projects with substantial UK involvement
- Attracting multinational businesses to locate on STFC Campuses, increasing international collaboration and industrial funding
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**INTERNATIONAL WORK**

- Promoting the UK’s global influence by increasing the number of international science and technology projects with substantial UK involvement
- Ensuring that the UK’s large research infrastructure supports the country’s leading international research reputation and delivers facilities and experiments supporting industrial R&D
- Fostering the development of economically productive clusters of technology-related businesses, such as the Space Cluster at Harwell
- Providing solutions for global challenges, with staff and funding dedicated to advancing key areas such as energy generation and security
- Funding influential international research programs, for example through Newton and GCRF
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- Developing the talent needed to support UK excellence in research to understand the universe, maintain world class facilities and promote economic growth
2.2 Ten years of STFC

STFC is a world-leading multidisciplinary science organisation which delivers economic, societal and scientific benefits for the UK and on a global scale. STFC was created from the merger of two successful Research Councils – the Particle Physics and Astronomy Research Council (PPARC) and the Council for the Central Laboratory of the Research Councils (CCLRC). The year 2017 marks Diamond Light Source’s and STFC’s 10 year anniversaries and we are celebrating both the achievements and the heritage of our organisation.

The laboratories and facilities that STFC manage have long and illustrious histories dating further back still. For example, CLF celebrated its 40th anniversary this year and the Rutherford Appleton Laboratory has been involved in cutting-edge science and space missions for 60 years at our Harwell site. Our Chilbolton Observatory in Hampshire also celebrated its 50th anniversary in 2017.

This legacy has given STFC extremely strong foundations, and we have built on this over the past 10 years, delivering pioneering discoveries and ground-breaking research. To celebrate our 10th birthday we look back at key events in our history and some highlights of our achievements over the last 10 years, and look forward to the future programmes that we are already working on. The following timeline highlights some of these achievements.

In addition to the 10th anniversary of the organisation, many of our world-leading science programmes and facilities have had significant milestones this year. We highlight some of these throughout the body of the report.
Diamond Light Source 10th anniversary

This year Diamond Light Source is celebrating its 10th anniversary since the Queen officially opened its doors to scientists in 2007. Since then the national synchrotron facility has been involved in cutting-edge science, from research into the structure of medicine to the mapping of the chemical composition of meteorites.

Most recently, Diamond has become home to two new state-of-the-art electron microscopes for the physical sciences, providing broad, cost-effective access to Nobel Prize-winning cryo-electron microscopy technology. An evaluation study is currently under way on Diamond, the findings from which will be shared in next year’s impact report.

Diamond’s memorable moments and discoveries. Credit: Diamond Light Source
The 40th anniversary of the Central Laser Facility

STFC’s CLF is one of the world’s leading laser facilities, providing scientists with unparalleled state-of-the-art technology to carry out a range of fundamental and applied research. CLF is a multidisciplinary facility, supported across many of the UK Research Councils, and covers sectors including energy, environment, healthcare and security. This year CLF is celebrating its 40th anniversary and here we highlight just a few examples across the facility’s remit over the past 40 years.

World-class research from CLF

CLF began operations in 1977 with the construction of the Vulcan laser. CLF now has five of the world’s most powerful or advanced lasers and has facilitated thousands of experiments from institutes around the world.

The facility is internationally leading and available to the UK and global research communities. Research topics range from investigating complex biological reactions within cells to examining new ideas for future energy production. Many of the research groups working with us are supported by other Research Councils, including EPSRC, BBSRC, MRC and the Royal Society. Some key examples of research from CLF include:

- CLF was used by York University and AWE to develop a laser technique to improve the safety of nuclear weapons. The technique ensures safer, cheaper stockpiling of nuclear weapons; no underground testing is needed. The research led to the construction of the £150 million Orion laser at AWE (2013), in support of the UK’s nuclear deterrent programme. Similar French and US lasers each cost billions of pounds, while CLF’s route was truly innovative and delivered significant savings.

- CLF demonstrated the world’s first high-energy electron ‘dream beams’ by driving the facility’s Astra laser into a puff of supersonic gas. The research demonstrated that high-intensity, focused lasers that fit into a laboratory are possible, which could lead to significant advances in both medicine and material science. A Nature paper detailing the results of the research has achieved over the landmark 1,000 citations.

- CLF developed novel, non-invasive breast cancer and bone disease diagnostic tools. Spatially Offset Raman Spectroscopy (SORS) provides a method for identifying the chemical composition underneath the surface of materials, including beneath the skin and liquids in bottles. The science that underpins SORS has led to the very successful spin out company, Cobalt Light Systems, detailed in the section below on world-class innovation from CLF.

Users of CLF have recorded close to 3,000 papers, receiving over 19,000 citations collectively. Recent citation analysis on papers from STFC facilities published between 2011 and 2015 showed that CLF papers had a higher citation impact compared with the world average during the same period. The analysis also showed that in multidisciplinary materials science, condensed matter physics and multidisciplinary physics, CLF-related papers achieved over twice the world average citation impact.

CLF has a long tradition of collaborating with its European and global partners in both access to the lasers and in the delivery of new facilities – around 30% of CLF’s users are from international institutions. In 2016 CLF received a £10 million contract to deliver the most advanced high power laser of its kind in the world to the HiLASE research facility in Prague. They have also received funding for important international projects though the Newton Fund, for example, a joint innovation project between CLF and Tata Institute of Fundamental Research to build high power lasers in India with the aim of developing new energy sources, ionising radiation for cancer therapy and improved biomedical imaging and diagnosis.
HISTORICAL FOUNDATIONS OF STFC

1954
- CERN is created by the UK and 12 founding states, the world’s largest centre for research in particle physics.

1957
- Rutherford High Energy Laboratory is established.

1960s
- UK company e2v begins long-term collaboration with STFC and its predecessors.
- Daresbury Laboratory is established.

HIGHLIGHTS TO CELEBRATE 10 YEARS OF STFC

2007
- Hinode is launched.
- Diamond Light Source opens with its first seven beamlines.
- STFC is formed through the merger of PPARC and CCLRC.

2008
- Cobalt Light Systems, an STFC spin-off, is founded.
- At Diamond scientists studied samples brought back from a comet.

2009
- Sci-Tech Daresbury, a National Science and Innovation Campus, is established.
- Herschel Space Observatory is launched.

2010
- Cella Energy, a STFC spin-off, is founded.

FUTURE PLANS

2020s
- SKA begins operation.
- European Spallation Source begins operation.
- Extremely Large Telescope begins operation.

2020
- Launch of the James Webb Space Telescope.

2025
- High Luminosity LHC at CERN begins operation.

2026
- First results from the Deep Underground Neutrino Experiment (DUNE).

2017
- Nobel Prize in Physics awarded for gravitational waves detection.
- Nobel Prize in Chemistry awarded for work on cryo-electron microscopy, drawing on sensor development with STFC.
## Present and Future

### Historical Foundations of STFC

- **1954**
  - Rutherford High Energy Laboratory is established.

- **1957**
  - UK company e2v begins long-term collaboration with STFC and its predecessors.

- **1967**
  - Chilbolton Observatory opens.

- **1974**
  - Radio and Space Research Station is renamed the Appleton Laboratory.

- **1981**
  - The UK’s national facility, the Synchrotron Radiation Source opens at Daresbury Laboratory.

- **1985**
  - ISIS Neutron and Muon source begins operating on the Harwell Campus.

- **1996**
  - Nobel Prize in Chemistry is awarded for the characterisation of ‘buckyballs’, based on work carried out at ISIS.

- **1997**
  - Radio and Space Research Station is renamed the Appleton Laboratory.

- **1990**
  - Research starts at Boulby.

- **2002**
  - Rainbow Seed Fund is founded.

- **2008**
  - Cobalt Light Systems, an STFC spin-off, is founded.

- **2009**
  - Herschel Space Observatory is launched.

- **2011**
  - Discovery of the Higgs boson.
  - STFC’s 200th instrument launched into space.

- **2012**
  - Discovery that atomic nuclei can be ‘pear’ shaped.
  - New foot-and-mouth vaccine advances global disease control.

- **2013**
  - UK announces the intention to become a full member of the European XFEL project.
  - The Rosetta Spacecraft lands a probe on the surface of a comet.

- **2016**
  - First detection of gravitational waves announced.

- **2017**
  - Construction starts on ALMA.
  - UK becomes the global headquarters for the Square Kilometre Array (SKA).

- **2018**
  - Nobel Prize in Physics awarded for gravitational waves detection.

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  - STFC’s 200th instrument launched into space.

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- **2025**
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- **2026**
  - First results from the Deep Underground Neutrino Experiment (DUNE).

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**Future Plans**

- **2025**
  - High Luminosity LHC at CERN begins operation.
  - European Spallation Source begins operation.
  - Extremely Large Telescope begins operation.

- **2026**
  - First detection of gravitational waves announced.

**STFC Milestones Past, Present and Future**

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  - Chilbolton Observatory opens.

- **1974**
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World-class innovation from CLF

CLF also has a strong track record in innovation and working with industry over many decades. The facility provides access for a number of industrial users every year. In the last two years more than 20 companies have engaged with CLF across sectors including aerospace, automotive, defence and security, pharmaceuticals and consumer goods.

For example, CLF’s Octopus instrument is used to investigate the effectiveness of cancer treatment drugs. Another significant user of the facility is Johnson Matthey, a global leader in sustainable technologies, which has been working with CLF and other STFC facilities for a number of years. Reporting the benefits of their relationship at the recent 40th anniversary celebration, the company stated that CLF provides Johnson Matthey with cutting-edge, ultra-fast spectroscopy and imaging capabilities, and a key factor in the relationship is CLF’s world-class scientists who relish working on industrial challenges. The relationship helps to develop expertise in core Johnson Matthey areas, applicable across their various divisions. It will also underpin their ongoing research and development with the aim of facilitating technology transfer and making a significant contribution to ongoing product development. “The facilities at RAL, such as Diamond, the Central Laser Facility and ISIS Neutron and Muon Source, are world class. Coupled with the presence of many high-impact researchers at the site and the commitment of STFC management to foster collaboration, the site is very attractive to industry.” Dr Paul Collier, Johnson Matthey Senior Research Fellow, Johnson Matthey Technology Centre12.

The diagram below illustrates the involvement of CLF through each stage of Johnson Matthey’s research and development roadmap:

CLF’s Centre for Advanced Laser Technology and Applications (CALTA) was set up in 2011, to develop new laser technology and carry out new commercialisation. CALTA has won contracts, worth around £20 million, to supply technology to leading research institutes in Germany and the Czech Republic. The facility also has a strong tradition of technology transfer and the creation of spin-out companies. CLF research has directly resulted in 18 patent families, of which 63 patents have been filed and 10 spin-outs formed as a result of research conducted at CLF. These include:

- Exitech – specialising in high-specification industrial laser micromachining tools and systems supplied to the display, solar and semiconductor markets for over 22 years. At its peak, it employed more than 120 people and had a turnover of more than £20 million per annum. It was bought by Oerlikon in 2006.

- Scitech Precision – Scitech Precision Ltd was setup in 2009, capitalising on several decades of accumulated CLF expertise in the fabrication of specialist micro-targets for high-power laser experiments. Its work has enabled leading-edge science to be carried out at international facilities such as LULI in France, Gekko in Japan and LCLS in the US13.

One of the first successful methods of laser eye surgery was developed in the 1980s at CLF as part of a unique collaboration with the Institute of Ophthalmology (UCL). The company, Summit Technologies, was formed as a result and the technology developed over the next 10 years. The company went on to become one of the top global manufacturers of eye surgery lasers, helping to establish this now popular surgery across the world. It was acquired by the Alcon division of Nestle for $893 (£66914) million in 200015.
One of the most recent success stories from CLF’s cohort of spin-outs is Cobalt Light Systems Ltd, spun out in 2008 using the SORS technique outlined above which makes it possible to identify the chemical composition underneath the surface of materials, including beneath the skin and liquids in bottles. The technology can be applied in devices, both static and hand-held, for real-time analysis of obscured chemicals. Cobalt’s customers include more than 20 of the largest 25 global pharmaceutical companies, utilising one of Cobalt’s products for fast chemical analysis for security purposes. The company has 52 employees and has recently been acquired by Agilent Technologies Inc. for £40 million. Agilent’s global centre for Raman spectroscopy will be based on the Harwell Campus.

World-class skills from CLF

CLF is home to a team of highly skilled, expert staff, many of whom are regarded as world-leading in their field. The facility has grown from a handful of people working on a single laser to a facility with more than 100 full-time staff, involved in hundreds of international collaborations. This makes CLF a hub for skills and excellence within its scientific arena, exemplified by its skills training programme.

The facility provides one of the most diverse and advanced training environments available for skills that span the spectrum from apprentice to postdoctoral position, producing valuable STEM skills for the economy. Their skills training programme provides an opportunity for new PhD students and established scientists new to the field to learn the key skills they will need to run high-power laser experiments and meet other members of the community. Training weeks are run at the request of other international facilities such as Extreme Light Infrastructure (ELI), the only European and International Centre for high-level research on ultra-high-intensity lasers.

Approximately 70% of the individuals that use CLF’s facilities every year are PhD students and over the last five years 814 PhD students have been trained at CLF. More than 4,000 training days are provided to PhD students annually. As part of the research undertaken with Johnson Matthey and UCL, CLF also jointly funds a number of studentships, which enables the students to participate in industrially relevant research. The facility also runs a Sandwich Student Scheme which offers undergraduates the chance to take a year out from their respective degree courses in order to use and develop the skills they’ve acquired at university within a working environment. This year 12 students were hosted. CLF has also played a major role in STFC’s apprenticeship programme. CLF recruits new apprentices every year, thereby contributing to the UK’s skilled workforce.
3. Key findings from our evaluation studies

The Research Councils regularly carry out evaluations of our science and technology programmes and STFC’s impact evaluation studies can be found on our website. More information on STFC’s ongoing evaluation activities is detailed in Section 7.

Given the long-term nature of the research that STFC funds, we have historically focused on whole lifetime impact studies of our major investments. We are now extending the focus of our evaluation studies to earlier on in the lifetime of these long-term projects, both to provide interim evaluations and to ensure that key data is collected throughout the lifetime of the project to demonstrate long-term scientific and economic impact.

In this section we present interim evidence from the current evaluation studies on the Hartree Centre and the Square Kilometre Array (SKA). The Hartree Centre has been operational for three years whilst the SKA is in the design phase with operations expected to commence in the 2020s. Whilst these projects are both still in the early stages of delivery, they have already been creating impact. The evaluations will report on this impact and crucially will provide recommendations on appropriate monitoring data to demonstrate the outputs and impacts generated over the lifetime of the projects.

3.1 The evaluation of the Hartree Centre

This year we launched an evaluation of the Hartree Centre to provide an early view of the benefits it is delivering to its industry partners and the wider UK economy. The evaluation will also develop a Benefits Realisation Framework to support Hartree to maximise its contribution going forward.

The Hartree Centre was opened in 2013, at the Sci-Tech Daresbury Campus in Cheshire, to help transform the competitiveness of UK industry by accelerating the adoption of data-centric computing, big data and cognitive technologies. The Centre’s facilities include state of the art supercomputing facilities for simulation, modelling and data intensive projects, plus a range of emerging technology demonstrator systems.

It has been the focus of three rounds of government funding totalling £172 million between 2012 and 2015, to set up the centre, develop large-scale data analytics and energy efficient computing and most recently to establish the UK centre of excellence in cognitive computing and big data. In recognition of Hartree’s national standing, IBM Research signed a strategic partnership agreement and is actively supporting the centre through providing privileged access to its global IP in Cognitive Computing (valued at circa £200 million). IBM Research has also embedded a research team at Daresbury, with 25 IBM Research staff now working on a range of big data and cognitive computing projects with Hartree.

This evaluation is a follow-up to the evaluation of the Daresbury Campus which we reported on in last year’s impact report. In that evaluation, the Hartree Centre was recognised consistently and clearly by stakeholders as being the key asset in terms of securing the Campus’ future success, and is increasingly seen as being of national and international significance, as demonstrated by IBM’s decision to site its first-ever UK research presence alongside Hartree. A cluster is developing on campus for a new generation of data-intensive enterprises to help drive national economic growth and productivity gains, and Hartree is key to this cluster.

The initial findings from the current evaluation are also positive, with industry users confirming the relevance of the Hartree Centre’s approach to working with UK industry on advanced software and simulation projects. Several of the country’s largest technology firms have signed collaborative agreements with Hartree, underlining the importance of the facility to their business development efforts. Others explain that the Centre’s combination of world-class HPC facilities with specialist computational scientists differentiates between Hartree’s business-support and the type of HPC services available commercially. The facility provides access to infrastructure and development programmes that would normally be beyond the reach of the very great majority of individual businesses, in terms of both affordability and capability. The codification of these experiences in new tools supports the Centre’s outreach work and the diffusion of HPC advice and capability development to the wider business community.

The evaluation found that Hartree is working with many tens of businesses and public bodies, large and small, on HPC projects designed to facilitate improvements in business processes (e.g. digitalisation of research and development).
and boost innovation more generally. The evaluation suggests industry users are benefiting from their relationship with Hartree, with more effective, faster and more efficient product development processes. Hartree is also busy with the development of next-generation HPC tools and has created an in-house research programme working with many of the UK’s leading academic research groups, as well as public sector research organisations like the Met Office and the National Physical Laboratory (NPL).

In the time it has been fully operational, the Hartree Centre has completed over 100 collaborative projects with industrial partners including some of the largest UK-based companies such as Dyson, GSK, Rolls Royce and Unilever. The centre is also working closely with many smaller software developers and other high-growth potential digital SMEs, from Albatross Financial Solutions through to Global-365 and Zenotech Simulation.

The evaluation is developing a series of case studies to illustrate the working relationship between Hartree and its clients. They will illustrate the kinds of benefits realised at this relatively early stage, and will encompass the spectrum of benefits types. The following examples will be included:

- AstraZeneca and others from the UK pharma industry are working together with Hartree on ways to enhance their ability to digitally design new therapeutic compounds.
- GSK is working with Hartree on the enhancement of its big data analytics and visualisation capabilities, allowing its drug development teams to spot patterns and correlations that might otherwise have been overlooked.
- Knownow has developed a proof-of-concept for a new data service that would provide local authorities and emergency services with more precise early warnings about potential weather-related incidents.
- Renuda and other engineering design consultancies are using Hartree’s systems and computer scientists to support their ability to deliver more sophisticated design solutions to their own blue chip clients.
- Rolls-Royce is working with Hartree to optimise several of the company’s engineering design packages to run on larger, multi-core computers, allowing faster simulations to be run on the one hand and on the other moving the company forward with its ambition to run whole-engine design ‘in silica’.
- Unilever’s work with Hartree has brought new laundry products to market earlier and is supporting improvements in its manufacturing processes.

More details on these case studies will be given in the full report. The study is entering the final stages and will be published in 2018.
3.2 Square Kilometre Array evaluation

This year we launched an evaluation of the Square Kilometre Array (SKA) Radio Telescope. The SKA is an international project to build the world’s most sophisticated radio telescope, which will test some of the key questions of physics. The UK is hosting the headquarters of this prestigious project which will see telescopes built in South Africa and Australia. Thousands of dishes will provide over a million square metres of collecting area using the highest speed communications network ever in the field of astronomy. Its unique configuration will give the SKA unrivalled scope in observations, exceeding the image resolution quality of the Hubble Space Telescope. The project is currently in the design phase, with operations due to start in the 2020s.

The UK will benefit from three distinct aspects of the project: hosting the global headquarters, the design and technology work needed for the project, and the science carried out on the SKA and its precursors. Our evaluation will focus on the first two, with the third potentially the focus of a future review.

SKA Global Headquarters

Hosting of the Global HQ of the project will bring the UK many benefits including international influence, impact to the local area through creation of infrastructure, jobs and expertise and opportunities to inspire interest in STEM subjects. The construction and operation of the SKA Global Headquarters at Jodrell Bank near Manchester has been ongoing since 2013. STFC invested £11 million in the construction of the headquarters and a £16.5 million extension is currently under way, funded by STFC, the University of Manchester and Cheshire East Council. Our evaluation has found evidence of a positive local impact through the construction and operation of the headquarters. The study has calculated that the construction spend has £13.6 million of Gross Value Added (GVA) and 791 person years of employment associated with it. There are currently 57 staff based at the headquarters, and this is expected to rise to 135 staff by 2020, once the extension is completed. Over the period 2012-18, the total cumulative GVA impact of the headquarters’ operations is estimated at £27 million, with the operational activity directly and indirectly supporting 97 jobs in the UK over this period.
Design and technology

The UK is involved in the extensive programme of design and technology development that will allow the SKA to be constructed and operated. STFC-funded design and technology work is being carried out in the UK at UCL, Cambridge, Manchester, Oxford and Southampton universities and at all three of STFC’s major UK sites: the Rutherford Appleton Laboratory, the Daresbury Laboratory, and UK Astronomy Technology Centre (UKATC). Two major work packages in the design of the SKA are being led from UK universities, helping the UK to bolster its reputation in disciplines related to hardware, software and data processing.

This design work represents a significant opportunity to benefit UK industry. STFC is actively working to ensure that they are best placed to win contracts as and when they arise.

There is very significant interest from UK companies in future contract opportunities in areas such as telecoms, computing, data storage, electronics, programme and project management and civil and mechanical engineering.

Some 55 UK companies have already been awarded contracts in areas such as systems engineering, project management and software development, worth a combined value of £5.9 million. There are also opportunities to utilise the technology that has been developed in adjacent industries and markets.

A survey of UK companies that received 59 responses has shown that they see working on the SKA as an opportunity to expand their knowledge, grow their business, provide interesting work for their employees and benefit from the prestige of being associated with a world-class landmark project.

Covnetics Limited

Established in 2010, Covnetics specialises in the design and development of bespoke digital solutions and projects, and has a total of nine staff.

Pulsar astrophysics is one of the key science goals of the SKA. As part of the Central Signal Processor (CSP) workpackage, the Universities of Manchester and Oxford are leading a Pulsar Search Sub-element.

Covnetics has been involved in the implementation of the Integrated Circuit (IC) design, working to ensure the theoretical scientific specification can actually be delivered. The timeframes of the SKA are very long compared with the rate at which ICs evolve, and so Covnetics have been looking at how to avoid future redundancy and how to benefit from improved future specifications.

Each of the main areas above will be covered in detail in the evaluation. We are also developing a framework for tracking the future scientific, economic, skills, technological, and public awareness-related benefits.

Covnetics has gained a number of benefits from being involved in SKA:

- The company has been able to diversify into working with the UK research base.
- The cachet attached to working with a top university and on leading-edge research will help Covnetics win future contracts.
- Covnetics has broken into new areas of circuit design that it was not so familiar with previously. This may prove important to the company as traditional telecoms work declines.
- The company has developed new contacts through SKA networking events such as the recent Science Data Processor (SDP) event in Cambridge. In time this may well lead to other contract opportunities.
- The SKA contract from University of Manchester has helped maintain jobs.

The framework will prepare for the future assessment of benefits once the SKA becomes fully operational in the late 2020s. The study is entering the final stages and will be published early in 2018.

*Signal and Data Transport (SADT) is being led by the University of Manchester and Science Data Processor (SDP) is being led by Cambridge University.*
4. World-class research

4.1 Introduction

Our ambition is to help maintain the UK’s position as one of the world’s leading research nations. This section demonstrates our progress towards this goal, starting with research statistics to show the scale, context and quality of our research. STFC creates direct impact by generating new knowledge from frontier research in our university partnership programmes and at our facilities. In addition, we demonstrate how we harness our strengths and capabilities to find solutions for global challenges and detail how STFC is helping to address global goals for sustainable development.

4.2 Research quality

Key statistics relating to our research programmes are represented in the world-class research infographic on the opposite page.

We measure the strength of our university research base by research volume and citation impact. Our latest citation analysis for particle physics, nuclear physics and astronomy research between 2014 and 2016 shows the UK is amongst the leading nations in relation to citation impact in the fields of astronomy, particle physics and nuclear physics (see Appendix 1 for details).

Our sixth data collection of outputs from our university partnership programme was completed in 2017 using the Researchfish on-line data collection system with 98% compliance and over 32,000 outputs submitted. The latest analysis of publications submitted to us via Researchfish shows that STFC publications perform better than UK physical sciences as a whole (see Appendix 2).

Some 81% of STFC’s outputs in Researchfish are publications, 72% of which are international collaborative papers. A separate report will be published on the key findings from Researchfish. The following data indicates the research quality from our programmes:

- The most highly cited paper with only UK authors has been a key enabler for physicists using the LHC to simulate and model the data coming from the experiment. Published in 2009, it currently has 1,909 citations.

- The most highly cited paper with UK and international authors was a review of particle physics from 2008, which summarises searches for particles such as the Higgs boson. It currently has 4,309 citations.

- The biggest increase in citations and citation impact between 2014 and 2016 was for the initial results from the Planck mission. Published in 2014, it currently has 3,790 citations.

4.3 New facilities and centres

To retain the world-class standing of our facilities, STFC has a programme of long-term strategic capital investment, which finances new instruments, upgrades and new facilities in the UK and abroad.

- The government has announced a major new £100 million investment for the development of the Rosalind Franklin Institute; an innovative multidisciplinary science and technology research centre that will have a hub based at STFC’s Harwell Campus. Managed by EPSRC, it will bring together UK expertise to develop new technologies that will transform our understanding of disease and speed up the development of new treatments.

- CLARA is currently under construction at Sci-Tech Daresbury. This facility is designed to develop, test and advance new technologies for the next generation of Free Electron Laser accelerators. Free Electron Laser science is advancing rapidly and has the potential to generate competitive advantage for UK companies, for example in pharmaceuticals, energy and security. CLARA will significantly advance global understanding in this field and in November 2017 it generated its first electrons, a significant milestone in its development.

- STFC RAL Space are celebrating the successful launch of a next-generation geostationary weather satellite. The Geostationary Operational Environmental Satellite-R Series (GOES-R) was launched in 2016, with RAL Space contributing to the build of the on-board solar telescope. RAL Space worked with UK companies e2v and Lockheed Martin to deliver the telescope.

- The headquarters for the world’s biggest radio telescope, the SKA, is undergoing expansion. The SKA HQ is based at the University of Manchester’s Jodrell Bank site and will not only be a flagship facility for UK science but will also provide a boost to the regional economy. The SKA HQ will eventually be home to more than 135 staff from more than 13 countries, tasked with managing the construction and operations of the SKA telescopes, located in Southern Africa and Western Australia.

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1 UK only papers relate to a UK address listed for all authors of the publication.
2 Parton Distributions for the LHC publication – DOI number: 10.1140/epjc/s10052-009-1072-5
3 The most highly cited International paper has at least one PI address which is outside of the UK.
5 Definition of ‘The field (or category) normalised citation impact’ http://ipsciencehelp.thomsonreuters.com/inCites2Live/indicatorsGroup/aboutHandbook/using
6 CitationIndicatorsWisely/normalizedCitationImpact.html Dec 2016
7 Planck 2013 results. XVI. Cosmological parameters publication – DOI number: 10.1051/0004-6361/201321591
STFC creates direct impact by generating new knowledge and technology from frontier research in our university partnership programmes and at our facilities.

**STFC's programme of word-leading discovery science**

- STFC-funded researchers are among the leading nations in particle physics, nuclear physics and astronomy.
- 5,700+ Papers from university programmes and STFC facilities
- 90 Universities engaged in our partnership programme
- 1,000+ Members of the academic community

This ranking is based on our latest citation analysis for period 2014-2016.

**Large-scale research facilities in the UK**

In 2016/17, Diamond, ISIS and the CLF were used by:

- 5,000 unique users to carry out
- 2,000 experiments, which produced
- 1,600 papers in peer-reviewed journals

**International subscriptions**

- 170 Million total international subscription payments
- 700 UK particle and nuclear physicists carried out research at CERN
- 355 UK astronomers using ESO telescopes
- ESRF and ILL were accessed by:
  - 700 UK users who made
  - 1,000 visits to these facilities

Statistics refer to FY 2016/17 unless otherwise stated.
UK signs £65 million science partnership agreement with the US

The UK is investing £65 million in a $500 million flagship global science project based in the United States that could change our understanding of the universe\(^{38}\). The investment, made under a new UK-US Science and Technology agreement, further secures the UK’s position as the international research partner of choice.

In September 2017, UK Universities and Science Minister Jo Johnson signed the agreement with the US Department of Energy to invest the sum in the Long-Baseline Neutrino Facility (LBNF) at Fermilab and the Deep Underground Neutrino Experiment (DUNE), based at SURF. DUNE will study the properties of particles called neutrinos, which could help explain more about how the universe works and why matter exists at all.

The UK is a major contributor to the DUNE collaboration, with 14 UK universities and two STFC laboratories providing essential components to the experiment and facility. The DUNE Collaboration is currently made up of over 1,000 scientists from 174 institutions in 30 countries, and provides an opportunity for enlarging the UK base of international scientific partners\(^{39}\).

- A UK-designed and built laser delivered by STFC under a £10 million contract to the Czech Republic has become the most powerful laser of its kind in the world. DiPOLE 100 was provided to the HiLASE centre, a new multi-million pound project under construction near Prague. The laser was designed and built by STFC’s Central Laser Facility\(^{35}\). This has led to a new collaboration between the Czech Institute of Physics and CLF on a ‘Centre of Excellence’ for the industrial exploitation of new laser technology in Prague. The €45 million venture is one of the first ‘Widespread Teaming’ projects to be granted within the European Commission’s Horizon 2020 funding programme\(^{36}\).

- Construction will begin on a next-generation dark matter detector with the UK taking a leading role and providing vital hardware for the project thanks to £3.8 million of funding from STFC. The LUX ZEPLIN experiment will be built nearly a mile underground at the Sanford Underground Research Facility (SURF) in South Dakota\(^{37}\).
4.4 Generating new knowledge

One of the important ways that we create impact as an organisation is through supporting new research across our wide ranging remit. This research is generally globally relevant and delivered in partnership with a range of international stakeholders. Recent highlights from advances in our research programme include:

Gravitational waves Nobel Prize awarded

More than 100 years since they were first theorised by Albert Einstein – and two years since they were first detected here on Earth – the study of gravitational waves has been awarded a Nobel Prize. The 2017 Nobel Prize in physics has gone to Professors Kip Thorne, Barry Barish and Rainer Weiss, key figures in detecting the long-theorised ripples in space-time, for ‘for decisive contributions to the LIGO detector and the observation of gravitational waves’.

The detection was a truly international effort, with the UK playing a leading role, and captured headlines across the world ushering in an entirely new era of astronomy research. Key technological and computing advances were made in the UK which enabled the historic first detection.

Former UK Science Minister, Jo Johnson, said: “The detection of gravitational waves has been made possible by technology designed and built in the UK, and the expertise of our leading researchers and engineers. The acknowledgement of this contribution in today’s Nobel Prize announcement is recognition of our place as a world leader in science and research.”

Key early contributions to the Laser Interferometer Gravitational-wave Observatory (LIGO) project came from the late Scottish physicist Professor Ron Drever. Professor Drever, who passed away earlier this year, co-founded LIGO with Professor Kip Thorne at Caltech and Professor Rainer Weiss at MIT in the US over the period from 1984 to 1994. LIGO is operated by Caltech and MIT with funding from the US’s National Science Foundation (NSF), and supported by vital input from more than 1,000 researchers around the world – including the Universities of Glasgow, Cardiff and Birmingham and STFC’s Rutherford Appleton Laboratory amongst others in the UK. Scientists from the University of Glasgow’s Institute for Gravitational Research led on the conception, development, construction and installation of the sensitive mirror suspensions in the heart of the LIGO detectors.

The first detection in 2015 was made possible by a technical upgrade to Advanced LIGO (aLIGO), relying heavily on initial UK capital funding and on technical and manufacturing expertise from UK universities – especially the advanced mirror-suspension systems.

In addition to the announcement of the Nobel Prize, aLIGO has produced more groundbreaking science. News that a third gravitational wave detector is operating alongside aLIGO and is already delivering thrilling results has been met with equal excitement. From 1st August aLIGO was joined in operation by a European detector – the advanced Virgo (aVirgo) detector located in Italy. The same month, a black hole collision was detected simultaneously by the three existing aLIGO and aVirgo detectors. The addition of the aVirgo detector alongside the aLIGO instruments allowed the location of colliding black holes to be pinpointed on the sky for the first time.

On the heels of this announcement was the news that aLIGO had detected gravitational waves from a pair of colliding neutron stars. This event was not only detected by aLIGO but was also seen by several ground and space based telescopes, making this the first time a cataclysmic astronomical event has been detected by both gravitational and light waves. UK scientists continue to contribute to the design and development of future generations of gravitational wave detectors, and are using this technology to help develop a technique to turn stem cells into bone cells, which could have a profound impact on the treatment of bone injuries.

British scientist scoops Nobel Prize for revolutionary microscope

British biochemist Dr Richard Henderson was awarded the 2017 Nobel Prize in chemistry, alongside Professors Jacques Dubochet and Joachim Frank, for their pioneering work with cool microscope technology. Dr Henderson, of the MRC’s Laboratory of Molecular Biology, was awarded the prize ‘for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution’. STFC has been working with Dr Henderson to continue the revolution in cryo-electron microscopy. The research means we may soon have detailed images of life’s complex machineries in atomic resolution.
During the past decade, STFC and Dr Henderson have collaborated on the development of sensors for the cryogenic electron microscopy that he pioneered – supporting increased availability and impact of the technique. See ‘The Resolution Revolution’ in Section 5 of this report for further details.

CERN continues to discover outstanding physics
CERN have made another series of groundbreaking discoveries following the announcement of the discovery of the Higgs boson in 2012. Five new particles have been discovered this year, thanks to the incredibly sensitive LHCb experiment at CERN. The LHCb confirmed their existence, which has been theorised but never before proven, and will help physicists better understand the ‘strong force’ which glues nucleons together, as well as opening up entirely new avenues in particle physics. The LHCb experiment at CERN has also announced a result that could be an early indication of new physics beyond our current understandings of the universe and could revolutionise a basic feature of the Standard Model – blowing wide open our existing understanding of particle physics.

The grand finale – Cassini’s last dive
This year scientists across the UK said a fond farewell to the landmark Cassini space mission, which was launched almost 20 years ago. The probe ended its journey with a dramatic dive into Saturn’s atmosphere, where it was crushed and vaporised. The Cassini-Huygens mission launched in October 1997, with the involvement of teams of scientists from across the globe, with various UK universities and STFC contributing hardware and expertise. Cassini has made some significant discoveries, not least finding three of Saturn’s 62 moons – and gathering evidence of water on one of these. In 2005, Cassini released the European Space Agency’s (ESA) Huygens probe which became the first probe to reach the outer solar system. It gave scientists their first look at the surface of Titan, the largest moon of Saturn. STFC’s RAL Space played a role in developing and building Cassini-Huygens, a huge collaboration between NASA, ESA and ASI, the Italian Space Agency.

Development of drug to stop Ebola
A team of scientists from the University of Oxford has successfully mapped the structure of the deadly Ebola virus molecule. The Ebola virus has caused more than 12,000 deaths since 2000 including more than 11,000 during the 2014-2016 outbreak, making research into the virus timely and imperative. Using the powerful X-rays produced at Diamond Light Source, the researchers were able to determine the structure of the virus in its native state. The team will now be exploring new drugs to prevent the spread of Ebola, making further use of Diamond Light Source to understand how the virus responds, with the aim of saving lives if there are further outbreaks of the disease.

4.5 Solutions for global challenges
Solving many of this century’s challenges requires multidisciplinary solutions delivered through the application of the best scientific minds. Innovative science, technology and expertise developed through STFC-supported science, facilities and laboratories is being harnessed to provide solutions to challenges in areas such as energy, environment, healthcare, security, food security, agri-tech, resilience and urbanisation.

Technology to help solve the world’s food crisis
STFC Food Network+ is bringing together hundreds of researchers to investigate how to ensure a safe, sustainable, nutritious and affordable supply of food for all. STFC is supporting this interdisciplinary community through our UK large facilities and drawing on expertise in big data and precision instrumentation from our fundamental research. For example, techniques originally developed to image galaxies are now being used to identify signs of weed infestation in fields of wheat.

Greenhouse gas removal
New research is investigating ways to remove greenhouse gases from the atmosphere, and to meet the goals set out in the 2015 Paris Climate Agreement. An £8.6 million research programme is looking at solutions, including increasing carbon storage on land and new ways to remove methane gas from the air on a local scale. STFC and the Met Office are supporting the programme, which is jointly funded by NERC, ESRC, EPSRC and BEIS. Four interdisciplinary multi-institute consortia have been awarded funding, involving around 100 researchers from 40 UK universities and partner organisations.

ISIS Neutron and Muon Source contributes to renewable energy breakthrough
Using ISIS Neutron and Muon Source, scientists from the University of Manchester and East China University of Science and Technology have overcome the challenge of breaking down raw biomass without the need for chemical pre-treatment, producing record high amounts of clean liquid hydrocarbon fuel. The use of plant material for energy could create an alternative fuel that is almost carbon neutral.

Using plants to produce a new vaccine against poliovirus
Plants have been used to produce a new vaccine against poliovirus in a major step towards global eradication of the disease. This groundbreaking interdisciplinary work was led by a team from the University of Leeds, and involved BBSRC’s John Innes Centre, MRC-funded researchers from the University of Oxford, and STFC’s Diamond Light Source, supported by the World Health Organisation and the Bill and Melinda Gates Foundation. The team used the cryo-electron microscopy pioneered by Nobel Prize winner Richard

Science and Technology Facilities Council
Henderson at Diamond’s Electron Bio-Imaging Centre to obtain a clear look at the structure of the vaccine. The research paves the way toward a novel synthetic vaccine that will be quicker, easier and safer to produce.

**Newton Fund and Global Challenges Research Fund**

The Newton Fund and the Global Challenges Research Fund (GCRF) are important components of the UK’s Aid Strategy, tackling global challenges in the national interest. They both form part of the UK’s Official Development Assistance. Launched in 2014, the £735 million Newton Fund aims to develop science and innovation partnerships that promote economic development and social welfare in projects across 15 partner countries. STFC has awarded over £9 million in Newton Funding for projects so far. Examples include:

- **Development for Africa through radio astronomy** – UK researchers are providing training that will help drive economic growth in southern Africa\(^5\). South Africa is partnering with eight other African countries that will host part of the SKA project. The UK and South African team is providing training for local people to use and help run radio telescopes. With skills applicable across a range of industries such as telecommunications, space science, land management, computing and big data, the resulting pool of local talent will help drive economic growth.

- **Agri-Tech in China** – STFC Newton Agri-tech programme is supporting projects that use spacebased remote sensing technologies, data and modelling capabilities to aid farming practices in China and other developing countries. The programme is linking interdisciplinary research communities together to tackle food security. To date the programme has funded research projects that have brought together 38 academic and industrial partners in the UK with 33 partners in China\(^5\).

The five-year £1.5 billion GCRF is supporting challenge-led disciplinary and multidisciplinary research and strengthening capacity for research and innovation within both the UK and developing countries\(^5\). Projects funded by STFC include:

- **Biodiversity in Amazonia** – Researchers at the University of St Andrews are using remote sensing and spectral analysis combined with aerial survey data to develop a method for analysing local biodiversity in the Amazon. This will enable analysis of the impact of past human activity on biodiversity and will also enable investigation of that human footprint across a larger landscape\(^5\).

- **Astronomy and conservation biology** – Researchers from Liverpool John Moores University are adapting software developed by astronomers to monitor and manage animal populations over large areas. The project will help address major challenges facing developing countries, such as food security, animal health and ecosystem monitoring, protection and conservation\(^5\).
5. World-class innovation

5.1 Introduction
Our ambition is to realise the innovative capacity of STFC’s science and research facilities to support the growth of the UK economy. This section demonstrates progress against this ambition. We deliver considerable impact through our national research and innovation campuses, which contain leading-edge technical expertise and offer a dynamic environment for innovation to flourish. We support universities in collaborating with industry and commercialising research through a range of schemes and we also work to commercialise intellectual property from our National Laboratories. We support UK industry by encouraging access to our large-scale facilities to help solve their business problems and by creating new business opportunities to supply products and services to our UK and international facilities. Appendix 5 contains further information about industrial and academic use of UK large facilities. Key data relating to our innovation and commercialisation activities are represented in the world-class innovation infographic on the opposite page.

5.2 Delivering impact through the national research and innovation campuses
The Sci-Tech Daresbury and Harwell Campuses, with their heritage of world-leading scientific infrastructure, are valuable national assets. The campuses currently host over 300 high-tech enterprises and support more than 6,700 jobs. Both in designated Enterprise Zones, they continue to grow as locations of national and international prominence. STFC has a crucial role to play in leveraging our inspirational science to deliver economic development, employment and inward investment at our campuses. Our public/private joint venture partnerships are boosted by links with a range of other stakeholders. Together we promote growth, with the combination of world-class scientific capabilities and first rate business support providing a compelling proposition for start-ups, SMEs and blue chip companies. Both campuses are growing, with new investment and new organisations locating on site, and both have ambitious plans for the future. Added to this are the plans to expand the UKATC’s innovation activities with the opening of the Higgs Centre for Innovation in 2018, providing business incubation for the growing number of high-tech start-up businesses in Scotland.

Sci-Tech Daresbury
More than 120 research organisations and high-tech businesses are located on campus, with the fields of advanced engineering and materials, biomedicine and healthcare, and digital/ICT strongly represented. In 2017, Sci-Tech Daresbury won the UK Science Park Award for Best Science Park: ‘Setting the Pace’ reflecting the significant national and international growth achieved by the companies on site. High-tech clusters continue to grow on site: the data-centric technology cluster has grown from 28 to 30 organisations with 408 employees, attracting and growing companies with capabilities in HPC, artificial intelligence and related technologies which complement STFC’s existing capabilities in these areas.

The first meeting of the Cabinet outside Downing Street this year was held in the Campus Technology Hub, where the Prime Minister Theresa May MP launched the Industrial Strategy Green Paper with the aim of increasing productivity and driving growth across the whole country.

The 2016 Sci-Tech Daresbury Campus survey, completed by 92% of companies (81 companies), provides a snapshot of performance. Campus companies:

- Employed 679 people (620 FTE), of whom 75% are educated to bachelor degree or above (the UK average for science and engineering subjects is 10%);
- Created 76 jobs in the companies surveyed taking the total up to 588 since 2010, with companies forecasting recruitment of 173 jobs in 2017. Ten companies are now employing 12 apprentices;
- Attracted investment of £17 million, up from £15 million in 2015 and a total of £199 million since 2010;
- Delivered £95.3 million sales, up 3% from last year, a total of £386 million since 2010;
- Exported £38.9 million or 41% of their sales, an increase from £37.9 million last year, nearly three times the amount in 2013;
- Developed 75 new products (829 in total since 2010), with 20% of companies filing patents and 63% of these approved. The amount of revenue from patents/IP was £7.7 million.

Sci-Tech Daresbury
STFC delivers considerable impact through the UK’s Research and Innovation Campuses, supports universities in collaborating with industry, and commercialises research to grow the UK economy.

**Commercialising from STFC’s National Laboratories**

Our Innovation team are responsible for the protection and exploitation of STFC’s intellectual property portfolio. Since 2002:

- 19 spin-out companies created
- £73 million of third-party investment, 230 jobs created
- Delivered 45 royalty-bearing licences
- Distributed £860,000 in 14 awards for the proof of concept fund in 2016

**Supporting SMEs**

STFC facilitates the right environment for start-up companies, between 2010-2015 incubation companies reported:

- £110 million invested
- 300 new jobs created
- £95 million delivered in sales
- £40 million goods and services exported
- 75 new products created
- 110 collaborations between Campus companies

STFC’s portfolio at the end of FY 16/17 comprised:

- Granted 152 patents
- Pending 75 patents
- Total trademarks 33
- Pending 1 trademark
- Registered 32 trademarks

Sci-tech Daresbury Campus survey completed by 92% of companies provides a snapshot of performance in 2016:

- £95 million delivered in sales
- £40 million goods and services exported
- 75 new products created
- 110 collaborations between Campus companies
The Hartree Centre

The Hartree Centre aims to transform the competitiveness of UK industry, by accelerating the adoption of data-centric computing, big data and cognitive technologies. In 2015, government investment of £115.5 million over five years was provided to support this mission, augmented by a package of technology and onsite expertise worth up to £200 million from research collaborator IBM\textsuperscript{59}. A recent government report concluded that big data could contribute £216 billion to our economy over a five year period and, if businesses made better use of their data, UK productivity could increase by 3\%\textsuperscript{60}. The Hartree Centre is playing a key role both in supporting UK industry and in helping to address gaps in HPC and associated skills and knowledge.

The Liverpool City Region was successful in its bid to participate in Wave 2 of the government’s Science and Innovation Audits (SIA), with STFC leading on the High Performance and Cognitive Computing theme, focussing on the strengths of the Hartree Centre and the scientific computing heritage of the Campus. We are also an important partner in the Liverpool City Region (LCR) 4.0 project\textsuperscript{vii}.

Global firm Hitachi chooses Sci-Tech Daresbury to expand UK presence

An international leading technology company has chosen Sci-Tech Daresbury as its scientific base in the UK. Hitachi High-Technologies (Europe) is part of Japan’s Hitachi Group and is taking laboratory space in the Campus’s newest building, Techspace One. The company, which has locations throughout Europe, is creating a brand new applications lab in Techspace One to house their latest Electron Microscopes and Scanning Probe Microscopes in four dedicated microscope rooms. The new lab will have a special focus on collaborations, both with academia and industry, not only in the North of England, but also across the UK and Europe.

The Hitachi High-Tech Group handles a variety of products from scientific instruments and systems, electronic devices, to industrial machinery and advanced materials. Mike Dixon, Nanotechnology Section Manager, said:

“Our aim for the new laboratory is to be a demonstration facility for our latest instrumentation as well as a collaboration hub where we can undertake a wide range of activities including fundamental research and method development. What really appealed about Techspace One was its strong impact and flexibility, allowing us to design the space in the way that works for us best. The move also means that we will be adding new staff to strengthen the company’s applications and technical team, and increasing our commitment to microscopy in the UK.”

The collaborative LCR 4.0 project will support 300 SMEs across the region to adopt industry 4.0 technologies and processes over the next three years. It aims to create opportunities for manufacturers to implement digital technology across their organisations from production to management, building industry connections and fostering innovation. See http://lcr4.uk/ for more details.
In 2017, the Hartree Centre purchased the UK’s first Bull Sequana supercomputer system as part of a major collaboration with digital services company Atos. The Bull Sequana is one of the most powerful supercomputers in the world, capable of performing 3.4 quadrillion calculations per second. It will allow both academic and industrial organisations to take advantage of the latest advances in artificial intelligence and high performance data analytics, without having to become experts in the underlying technology. Some recent highlights from the Hartree Centre include:

### Ensuring high performance research meets industrial needs
Working with Cambium LLP, the Hartree Centre has pioneered a process that uses direct insights from businesses to help translate pioneering data-centric research into commercial benefits for the UK. A structured process called InCEPT™ has been developed which is enabling the Hartree Centre to map its research capabilities onto industry needs more effectively than ever. Developed and delivered with Cambium, InCEPT™ is applicable to any sector, any field of science and engineering, or any specific challenge (e.g. drug development, food security). The InCEPT™ process ensures a strong link between the creation of digital assets to address real business problems. Companies can then reap the commercial benefits of these digital assets via a range of routes, through licensing agreements, spin-outs or service offerings.

### Transforming traffic modelling with Atkins
In a pioneering collaboration funded by Highways England and Atkins, the Hartree Centre’s expertise is ensuring that key simulation software can meet the intense demands of a £15 billion road construction and improvement programme. Highways England has invested in five new Regional Transport Models, which use Atkins-distributed traffic modelling software to help predict the economic impact of the extensive road network investments up to 2020 and beyond. Highways England and Atkins therefore initiated the UK’s first major traffic modelling collaboration spanning public and private sectors – the Transport Systems Catapult, University of Sheffield and Hartree Centre – to see if traffic modelling software could be improved. The project has resulted in enhanced, energy-efficient software that runs up to 30 times faster – with potential to increase speeds still further. This means that a greater number of more complex simulations can be carried out to provide greater investment certainty, and that bigger problems can be solved without a time penalty. These are the first steps to more efficient traffic modelling and ultimately this project will help to maximise benefits and minimise disruption from necessary investment in the road network.

### Harwell Campus
The Harwell Campus is home to several billion pounds’ worth of world-leading research infrastructure available to both the research base and industry. The Campus currently hosts a vibrant community of over 5,500 staff within over 200 organisations, including start-ups, SMEs, venture capitalists and large corporates. The Harwell Joint Venture has completed its first new building as part of the phase one development (the Genesis building, comprising offices and labs) which has now been fully let out to SMEs. The first phase of a new quadrangle of the building is due for completion at the end of 2017, with additional offices, laboratories, a restaurant and residential accommodation scheduled to be opened in 2018. The Harwell Campus is developing a number of clusters built around its core strengths and growth areas of the economy including space, healthcare and energy. The clusters are designed to create a vibrant ecosystem in which large and small companies can flourish and interact with brilliant academics and public sector researchers to exploit and commercialise advances in research and technology. The clusters will push, assist and enrich each other, creating a powerful multidisciplinary environment tailored to problem solving that will allow the UK to continue to compete with the best in the world.
Since 2010 Harwell Space Cluster has grown from 3 space-related organisations to 80.

The UK Space Cluster at Harwell now comprises 80 different organisations with 800 people, with many space sector SMEs expanding rapidly. Construction of the new £99 million National Satellite Test Facility (NSTF) will be commencing shortly, adjoining the existing RAL Space building (see section 5.4 on NSTF).

The HealthTec cluster is also developing fast: it now includes over 40 organisations with over 1,000 people, and some of the existing companies are planning major expansion on Campus. As a result of cluster initiatives, such as the industry-focused, proof-of-concept call, a number of HealthTech related SMEs on the Harwell Campus and from around the UK have started to work closely with MRC staff based at Harwell as well as with Diamond Light Source, the Research Complex at Harwell, Public Health England and others. In addition, the new Rosalind Franklin Institute, a multi-disciplinary science and technology research centre will be located on Harwell Campus. The aim of the centre is to transform our understanding of disease and speed up the development of new treatments.

The government also announced a major new initiative for energy storage research, the Faraday Institution, which will also have its home at the Harwell Campus. The institution, formed by seven university partners, will have a budget of £65 million over four years with which to set up the institution, establish a battery technology training programme designed in conjunction with industry, and to fund a series of research challenge projects carried out in the academic sector under the Institution’s direction.

5.3 Business incubation

STFC has a range of business incubation initiatives which address the specific challenges faced by early stage businesses. By supporting entrepreneurs and start-ups, STFC plays a key role in increasing productivity and securing the UK’s future in an increasingly competitive marketplace. In 2016 alone, the companies involved in our business incubation initiatives created over 70 jobs and raised £11.3 million in funding. Over half of the companies who are trading have experienced sales growth with 84% of those exporting to Europe, North America, Latin America and Asia.

STFC provides laboratory space, office space and funding support packages with partner organisations (ESA and CERN). These are currently available at the Harwell Campus and Sci-Tech Daresbury and will be extended to our Edinburgh site when the Higgs Centre for Innovation opens in 2018. The Business Incubation team provides start-ups with guidance on business models and access to STFC’s fundamental research programmes and facilities, to help them drive innovation in disruptive technologies.
ESA Business Incubation Centre

The European Space Agency coordinates a network of 16 Business Incubation Centres (ESA BICs) across Europe, to create new business opportunities and jobs, through the development of technologies for use in space and the transfer of space technologies into the non-space market. The ESA BIC Harwell is the UK centre and is managed and co-funded by STFC. Since opening in 2011 the ESA BIC Harwell has supported 61 companies with a programme of development funding, technical and business support, and access to the partnership opportunities on the Harwell Campus. These companies now employ more than 200 people and have raised a total of £14.1 million in equity investment. An example of current incubatee activities includes Open Cosmos as detailed below.

Open Cosmos launches first satellite

ESA BIC Harwell incubatee Open Cosmos aims to enable simple and affordable space missions, with early clients including government, research and private-sector organisations. By taking care of the complex technology and the burden of paperwork associated with a space mission, the company can help reduce total mission costs from millions of pounds to as little as half a million, enabling clients to focus on the more technical aspects of the mission. A major milestone was reached in 2017, when Open Cosmos’s first nanosatellite was successfully launched from Cape Canaveral after only six months from concept to flight readiness. The team in Harwell has recently doubled in size, more missions are scheduled for 2018 and it has won its first contract with ESA.

5.4 Industrial Strategy Challenge Fund

The Industrial Strategy Challenge Fund (ISCF) was created by the government to bring together the UK’s world-leading research with business, to meet the major industrial and societal challenges of our time. The fund is directed towards industrial challenges where the UK has a world-leading research base and businesses ready to innovate, and there is a large or fast-growing and sustainable global market. The first six challenges selected to receive funding support are in:

- Healthcare and medicines
- Robotics and artificial intelligence
- Clean and flexible energy
- Driverless vehicles
- Manufacturing and materials of the future
- Satellites and space technology
STFC has so far had two projects funded through the ISCF:

**National Satellite Test Facility**

STFC’s RAL Space won £99 million of funding to deliver a new satellite test facility, meeting a national need by providing the manufacturing and testing capabilities that will allow the UK to construct future satellites and deliver payloads into orbit. The UK space economy is worth £11.8 billion per annum to the UK; has been growing by an average of 8.6% year-on-year since 2010, and is now estimated to support over 115,000 jobs. The UK space ‘Innovation and Growth Strategy’ aims to secure a 10% share of the global space market by 2030, estimated to be worth £400 billion p.a. by that time.

The facilities and skilled staff provided by the NSTF will allow UK industry to bid competitively for national and international satellite and associated infrastructure contracts, addressing the future needs of the space industry and supporting potential new markets which will deliver economic impact, jobs and growth across the country. Each £1 of government investment in the NSTF is predicted to give a return on investment of £3.90. The NSTF will be located adjacent to the main RAL Space building, complementing the existing test facilities there. It will form a key part of the rapidly growing Harwell Space Cluster which forms the focal point for UK, European and world-wide space industry within the UK.

**Analysis for innovators and Bridging for Innovators**

Thirty companies had access to world-leading facilities as well as business and science know-how thanks to a competition supported by STFC. Analysis for Innovators (A4I) was a £6.5 million competition run by Innovate UK in 2017/18 in partnership with STFC, the National Physical Laboratory, LGC and NEL. This competition gave businesses the opportunity to use these organisations’ facilities and expertise to tackle existing productivity or product performance issues.

One example of a successful project was led by The Coconut Collaborative, an innovative manufacturer of Coconut Yoghurts. Supported by LGC and STFC, the company were able to trial imaging and spectroscopy techniques to screen coconut cream quality. The outcome is likely to have wider applications in the UK since coconut cream is becoming an alternative to dairy ingredients in an increasing number of foods.

Bridging for Innovators (B4I) is an £8 million programme now being run by STFC over four years. It will build on the initial success of A4I by providing access to STFC’s expertise and facilities for a larger number of UK companies from a wide range of industries, especially SMEs in manufacturing sectors.

STFC plans to expand the geographical reach of B4I by opening regional centres in the Midlands and South Wales, as well as providing training to UK companies. By utilising the UK’s scientific facilities and expertise to boost business’s skills and commercial opportunities, the programme aims to drive growth and improve UK productivity.

**The Faraday Institution**

Harwell Science and Innovation Campus has been selected as the site of the flagship Faraday Institution Headquarters. The new £65 million research institute, funded by the EPSRC and ISCF, has been charged with leading the UK’s research into energy storage and battery technology.

Energy storage is an area of critical research in the government’s Industrial Strategy Challenge Fund with £246 million to be invested over four years to help UK businesses seize the opportunities presented by the move to a low carbon economy. The multidisciplinary setting at Harwell Campus, which supports start-ups, SMEs and corporates, will accelerate the exploitation and commercialisation of the Faraday Institution’s research. Electric vehicles will be the initial research target for the Harwell Campus-based HQ but at a global level effective storage technology could deliver energy to tens of millions of people across south Asia and Sub-Saharan Africa.

### 5.5 Knowledge exchange and commercialisation

#### 5.5.1 Commercialisation from STFC’s university partnership programmes

Working with key partners in academia, industry and knowledge exchange professionals, we fund innovation projects and skills development to support the commercialisation of technology with our university partners. We provided the following direct funding this year:

- **Our Innovation Partnership Scheme (IPS) awarded £2.8 million across nine projects. These projects are in conjunction with 11 companies that are contributing over £1.1 million of support in areas from proton beam imaging to the production of thermoelectric micro-generators for energy harvesting.**
- **The user-led Challenge Led Applied Systems Programme (CLASP) called for challenges in the security sector funded five projects for £1.3 million, attracting £425K from five different companies.**
- **We supplied 20 universities each with £50K of Impact Acceleration Account (IAA) funding. This money can be used to leverage funding from other sources, to give STFC scientists opportunities to work with companies, and to help kick-start innovation and fund small projects using STFC technology and know-how.**
Lasers keep greenhouse gases on the radar

Whether it’s carbon dioxide emissions from power stations or methane leaks from natural gas wells, greenhouse gases continue to make headlines. However, they remain difficult to measure accurately, making the fight against man-made climate change more difficult. University of Edinburgh scientists have developed a laser-based radar (LiDAR) system to measure the amount and location of greenhouse gases in the atmosphere using STFC telescope technology, and funding from STFC’s IPS. The project has gained £800k in support from the EU, NERC and Scottish Enterprise.

The LiDAR system is designed to measure the quantity of gases given off at sources like factories or power stations. Emission monitoring could improve the accuracy of carbon credit trading where businesses buy permits to emit a limited amount of greenhouse gases. The European carbon credit market was worth €56 billion in 2012 alone and covers over 11,000 installations. “With help from the IPS Scheme, our Carbon Telescope promises to be a game-changer in studying climate change’s driving forces.” Professor John Moncrieff, University of Edinburgh.

Impact Acceleration Accounts promote investment

The University of Southampton has used their IAA funding to set up the ‘Astronomical Estimates’ project to strengthen their relationships with IBM Zurich and to leverage future funding from other avenues. For example, additional funding has been leveraged from the Networked Quantum Information Technologies (NQIT) Quantum Hub Cambridge, and further grant funding of £6.7 million has also been leveraged.

The University of Sheffield undertook collaborative work with The Shadow Robot Company, which designs and manufactures state-of-the-art anthropomorphic robot hands. Shadow Robot has benefited through securing a lucrative £4.8 million contract with a Ukrainian Nuclear Company.

5.5.2 Commercialisation of STFC Intellectual Property from our National Laboratories

Our Innovation team is responsible for protecting and exploiting the portfolio of intellectual property that has been generated from STFC’s National Laboratories. This includes supporting new inventors, spinning out companies, providing proof of concept funding and transferring knowledge and technology to industry. Key figures from 2016/17 include:

- Thirteen new inventors identified from across the National Laboratories.
- Five new priority patent applications filed, increasing the total number of patent families to 65.
- At the end of the year 43% of STFC’s portfolio of intellectual property was commercially active.

STFC spin-out companies

Companies spun out from STFC continue to demonstrate their economic impact as they leverage investment, provide highly skilled jobs and export their products and services around the world. Since 2002, 19 spin-out companies have been created. Together they have raised more than £73 million of third-party investment and created over 226 jobs. Thirteen of STFC’s spin-out companies are currently trading and employ more than 136 people. Recent highlights include:

The Electrospinning company launch their first commercial products

In 2017 the Electrospinning company secured a £650k investment, establishing itself as a leading provider of specialist biomaterials to the medical device industry. The investment builds on the company’s launch of the first electrospun biomaterial onto the market in 2016. The electrospun fibres, which are 100 times thinner than a human hair, are woven to create a synthetic scaffold, which can be used in a range of therapeutic applications. The company is already supplying the first FDA-approved medical device containing an electrospun scaffold in the US and is involved in a Phase I clinical trial for corneal repair in India. The company is also building a portfolio of contract development projects with regenerative medical device customers. The company was spun out of STFC in 2010, was the first ESA BIC inubatee, and is currently based on the Harwell Campus.

Keit concentrates on commercial success

Based on novel technology developed at STFC’s RAL Space, Keit has developed a product that allows process industries to measure the chemical composition of their liquids in real time. Process chemists, from brewers and dairy operators through to oil and gas, petrochemical and pharmaceutical companies all operate liquid processes which require them to know the composition of their mixtures with great accuracy in real time. Many current analytical methods are either unreliable or need to be performed off line in a laboratory, costing money. Keit’s new product is small, robust and can be fitted directly into the production process, saving time and delivering better results. Keit closed a £1.4 million investment round in 2016, with several investors including the Rainbow Seed Fund. Customer trials are going well and the company is ramping up production and sales capability to commercialise the technology.

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The resolution revolution: technology innovation in imaging

This year British biochemist Dr Richard Henderson was awarded the 2017 Nobel Prize in chemistry, alongside Professors Jacques Dubochet and Joachim Frank, for pioneering work with cooled microscope technology. The research carried out by Henderson, Dubochet and Frank means we may soon have detailed images of life’s complex machineries in atomic resolution. Cryo-electron microscopy allows researchers to freeze biomolecules mid-movement and visualise processes not previously seen, which has huge benefits for both the basic understanding of life’s chemistry and for the development of pharmaceuticals.

In recent years, STFC has been working with Dr Henderson to enable this revolution by developing the high-resolution electron camera systems required for this technique. This has led to a ‘resolution revolution’, made possible by replacing existing detectors in the microscope with modern CMOS image sensors that greatly improve their resolving power.

However, being directly exposed to high-energy electrons is a harsh environment for such detectors, due to the radiation damage the imaging electrons cause in the device. Designing a sensor that can withstand this damage is no small task. STFC’s CMOS Sensor Design Group applied the expertise they had developed for CERN’s LHC programme in the design of large area, radiation-hard sensors to produce the first high-resolution CMOS devices for this application.

In 2003, in a collaboration with Dr Henderson, STFC trialled its first general purpose radiation-hardened image sensor, that had been developed for STFC’s space programme, in an electron microscope. The success of those trials led to a consortium including STFC, the Max Planck Institutes of Biochemistry and Biophysics and FEI, a commercial supplier of microscopy systems, which was led by Dr Henderson to fund STFC to build an optimised electron direct detection CMOS camera.

Today the sensors developed by STFC are an integral part of all FEI’s flagship transmission electron microscopy products and are found in a wide range of the world’s leading electron microscopes. This includes those in the recently established Bio-Imaging Centre at Diamond Light Source.

Amongst the many major advances made possible by the combination of cryo-electron microscopy and STFC CMOS Image Sensors, researchers at the Bio-Imaging Centre were recently able to create a new synthetic polio vaccine (see case study in Section 4.5). This work was also supported in the UK by the MRC and the Wellcome Trust.

STFC’s Scientific Computing Department is now part of a collaboration to develop the community and support users and developers of the software employed in this field, to widen the impact of this new technology.
5.5.3 Rainbow Seed Fund

Started in 2002, the Rainbow Seed Fund (RSF) is a £27 million early-stage venture capital fund dedicated to kick-starting promising technology companies. STFC is a lead partner in the fund, along with the BBSRC, NERC and DSTL. Rainbow has recently extended its coverage to include Innovate UK’s Catapult Network. To reflect this wider remit, it is changing its name to the UK Innovation and Science Seed Fund (UKI2S). The Fund is run by private-sector fund manager Midven Ltd. It holds investments in some of the UK’s most innovative companies in areas as diverse as novel antibiotics, research into Alzheimer's disease, ‘green’ chemicals and airport security. By investing risk capital in the form of equity investment, this fund helps to ensure that Research Council innovation is captured and commercialised – supporting businesses with early stage technologies.

Over the past decade, the RSF has supported 35 technology start-up companies and leveraged co-investment of more than £320 million, a ratio of almost £34 for every £1 invested by the RSF. The fund continues to generate a strong economic impact with the value of GVA, exports and jobs created all growing by more than 20% per annum over the period since 2012-13. The total number of jobs created grew to 319 in 2016-17. These are high-value jobs, with an average salary of more than £50,000.

Examples of companies that have benefited include Cobalt Light Systems and Keit. Cobalt Light Systems was spun out from STFC in 2008. RSF was the first investor, allowing the company to validate and develop the commercial potential of its technology. The £40 million sale to Agilent Technologies Inc. in 2017 gives Cobalt access to higher levels of investment funding and stronger routes to market. The sale of Cobalt is a validation of the RSF model. It has provided a substantial uplift in portfolio value, and has enhanced the fund’s ability to maintain current levels of investment. Agilent is a world leader in analytical laboratory technologies and its Global Centre for Raman Spectroscopy will now be based at the Harwell Campus.

Proof of concept funding

In 2017 the Innovation team awarded £850k to 14 ‘proof of concept’ projects from within the National Laboratories to stimulate the creation of new capabilities and products. One of these projects, a collaboration between the UKATC and Cardiff University, aimed to develop a unique optometry device known as MacuMap. The rate at which the eye responds to light changes as we age, but also due to a number of diseases including age-related macular degeneration, the leading cause of blindness in the developed world. MacuMap tracks the response of the eye to light, a key indicator in disease diagnosis and ongoing assessment.

Transferring knowledge and technology to industry

STFC also supports companies in bringing innovative products to market, helping to transfer technology to industry. Since 2002, 44 royalty-bearing licences to use technology developed by STFC have been granted (six of them this year), directing the income back into scientific research. One example is VivaMOS, a rapidly growing STFC spin-out which started trading in 2015, using an image sensor exclusively licensed from STFC. This sensor has commercial applications in medical imaging, nondestructive testing, and security. VivaMOS now employs eight people, and has sales revenues in excess of £1.5 million.

5.6 Supporting UK business

STFC engages with UK industry on many levels, in addition to our commercialisation activities described in the preceding sections. We offer our skills, products, services and facilities, including consultancy by STFC staff and the co-development of technology with industrial partners. Industries that benefit from our expertise include security, healthcare, oil and gas, pharmaceuticals and manufacturing to name a few. We collaborate extensively with industry and our top industrial collaborators include Rolls Royce, Astrium, e2v, Intel, Selex Galileo, Siemens, Oxford Instruments, Unilever and IBM. During the financial year 2016/17, STFC’s external income was £77 million, of which 14% was direct from industry. This section details industrial usage of our UK and international facilities, and contracts won to provide products and services to these facilities.

5.6.1 Industrial use of large-scale facilities

Our facilities play a critical role in supporting industrial research and development for companies ranging from SMEs to multinational organisations. Overall we estimate that around 15% of time on our facilities is used by industry. The most common way for industry to access our facilities is through working with academics at UK and international universities, funded through grants awarded by Research Councils. Companies can also access our facilities by paying for proprietary access, which ensures that commercially sensitive research outputs are kept out of the public domain. In 2016, 91 UK industrial customers used our largescale facilities this way. In addition, 25 UK companies paid to access the ILL and ESRF in France. Several companies have used our facilities over many decades for their long-term industrial research programmes such as Unilever, Rolls-Royce and Johnson Matthey. Appendix 5 shows the range of industrial and academic users of our large facilities. A recent example of how industry uses our facilities to solve problems is given overleaf.
From hand-warmer to house-warmer

SME Sunamp has taken the principle behind hand-warmers and turned it into a battery that can heat a house using solar power\(^7\). Their innovative new battery provides heat and hot water for about half the cost of gas and has recently been installed in 650 homes. The batteries use the same gel material that is used in gel hand-warmers, melting with heat from solar panels on the roof of a house, in turn producing more heat. When developing the battery, Sunamp had to find just the right gel formulation to ensure maximum heat transfer and battery life. They used the Diamond Light Source to screen a huge number of possible gel formulations through a partnership with Edinburgh University before they found the right one. This product has the potential to have a major impact economically, improving people’s quality of life and also reducing CO\(_2\) emissions – and highlights the key and unique role that large facilities can play in this.

Improving the efficiency of our large facilities

We always seek to improve the efficiency of our large facilities and have been working on an ongoing project to reduce helium costs. Helium is a vital component in many of the experiments in our large facilities. The cost of helium has increased by 350% over the past seven years, which has been driving up the cost of delivering our research. A team at our ISIS Neutron and Muon Source facility has designed and built a helium recovery system, working with other facilities and industry to allow them to develop an effective system based on existing technology. As a result, ISIS Neutron and Muon Source’s annual expenditure on liquid and gas helium has reduced by £350k, amounting to a cost reduction of around 50% per litre of helium. This development by ISIS Neutron and Muon Source will allow similar systems to be implemented at facilities such as Diamond and has also attracted interest from UK companies looking to reduce their expenditure on helium.

ISIS Neutron and Muon Source supports industry

The examples on the following double spread are from our ISIS Neutron and Muon Source facility, taken from a recent study on the economic and social impact of the facility. These show a range of industrially relevant projects undertaken at the facility and estimate the future economic activity that these will create. Further information on these calculations are given in the report itself\(^7\).
5.6.2 New business opportunities for UK companies

We help UK companies to access contract opportunities at the international facilities supported by STFC, in a wide range of sectors across all technology levels, from computing through to precision engineering.

Over the past 10 years, UK companies have won over £220 million in contracts from our UK supported international facilities.

For example, the UK’s return from CERN in terms of industrial contracts has increased in recent years and we are focused on growing this further through a range of activities to ensure UK companies are positioned to take advantage of relevant opportunities. The HiLumi upgrade project on the Large Hadron Collider has recently started and we are working to ensure UK industry is aware of the tender opportunities available. Recent examples of UK industry winning contracts from our international facilities are given below:

Imaging for the ELT
Teledyne e2v has been awarded a multi-million pound contract to produce imaging sensors for use on ESO’s Extremely Large Telescope (ELT). The four-year contract consists of design and manufacture of prototypes, leading to the manufacture of 28 sensor modules at Teledyne e2v’s Chelmsford facility. The sensors will enable the telescope’s adaptive optics systems to make tiny adjustments around 700 times a second to maintain a sharp, high-resolution image as atmospheric conditions vary. The contract award reinforces the UK’s place as a world leader in the development and manufacture of very high performance imaging detectors. It also builds on e2v’s long history of providing state of the art imaging sensors for astronomy instruments and telescopes around the world and in space, often in collaboration with STFC-funded institutes and programmes. STFC and its predecessors have a long-term relationship with e2v, valued by the company to be worth £400 million. The synergies and commonalities between large international facilities mean that being awarded a contract with one facility can provide companies with access to a larger market.

Tesla Engineering wins Extremely Brilliant contract
Tesla Engineering Ltd has recently won €7.8 million worth of contracts to supply 500 high-tech magnets as part of the ESRF’s Extremely Brilliant Source upgrade. The ESRF have been working in collaboration with Tesla on the pre-production phase assisting with the processes and tooling and they will continue to work closely together throughout the contract. This contract has allowed Tesla Engineering to invest in new machinery and gain new knowledge and experience which it can use in other contracts in the future. As a direct result of this contract Tesla Engineering have also recruited a significant number of technicians from the local area. Working at the cutting edge of technology helps Tesla Engineering to continue to improve their business plus the experience gained puts them in a good position to win future contracts from other international facilities.

Centerprise provide cutting edge solutions for CERN
In 2016, Centerprise won two contracts at CERN totaling £2.3 million. For the first contract Centerprise built, tested and delivered 25 petabytes of storage units alongside a three-year support contract. It then won a second contract for a total of 120 servers, which was followed by a further order of 15 higher specification servers. For both contracts Centerprise worked in partnership with E4 Computing Engineering and tested different solutions to find the best option to meet CERN’s requirements. Centerprise Business Development Manager, Ramsey Razzak, said: “This is a prestigious contract win for Centerprise that validates our ability to build, configure and deliver computational equipment to highly educated customers with specific configurations and strict deadlines.”

UK industry has won £221,625,807 in industrial contracts from 2007-2017 from CERN, ILL, ESRF and ESO. This amount has been converted into pounds from Euros and Swiss Francs using the average annual exchange rates from the Bank of England for the past 10 years.
### Examples of industrially relevant projects undertaken at ISIS Neutron and Muon Source

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<th>Project Description</th>
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<td><strong>Bioactive coatings and improved hip replacement implants</strong> – Research at the ISIS Neutron and Muon Source ENIGN-X instrument has enabled the creation of a test model of orthopaedic implant coatings, which industry can use to assess the quality of coatings to improve implant reliability. For hip replacements alone, this may represent total future savings for the UK NHS of £100 million between 2015 and 2025. The UK market for coated metal implants is around £500 million a year, and growing steadily. Innovative coatings may help UK businesses improve on their existing small market share, delivering perhaps £20 million in additional economic activity for UK producers up to 2025.</td>
<td>£1 million</td>
</tr>
<tr>
<td><strong>Novel antiferromagnetic (AF) materials for data storage</strong> – An international team used ISIS Neutron and Muon Source to characterise a series of new antiferromagnets – materials which could one day increase computing speed, efficiency and memory capacity through use in spintronic devices. The value of such a new material is expected to run into billions of dollars annually; the market for spin-RAM was expected to account for $9.37 billion of a $16.08 billion next-generation memory industry by 2017. Assuming there is new IP and startups linked with UK research, future sales (turnover, royalties and shares) are likely to run into the tens of millions, given the critical role these technologies could play in what is an enormous and rapidly growing global market. Assuming the UK may see £100 million in additional income related to AF spintronics over the next 10 years, and given ISIS Neutron and Muon Source’s long-run and substantial contribution to the field, we estimate 5% (£5 million) of that new economic activity as being attributable to ISIS Neutron and Muon Source. The benefits for global businesses may be very much larger, however, UK business and private consumers will also benefit from continuing advances in the price-performance of their ICT systems (unpriced spillovers).</td>
<td>£5 million</td>
</tr>
<tr>
<td><strong>Forensic science</strong> – Research at ISIS Neutron and Muon Source has helped to develop a colour-changing fluorescent film which can be used to detect and visualise fingerprints from crime scenes. This method could lead to higher confidence identifications from latent (hidden) fingerprints on metal surfaces (such as knives and guns). The global market value of conventional fingerprint detection powders was around $90 million in 2013; the new method could capture some of this market. In addition, the method could lead to significant savings for the UK by facilitating crime investigation and lowering crime rates.</td>
<td></td>
</tr>
<tr>
<td><strong>Pollutant gas filtering</strong> – Research using ISIS Neutron and Muon Source has yielded important information on the mechanism by which solid materials known as “metal-organic frameworks” (MOFs) trap gases, helping researchers at Nottingham University develop a new material, NOTT-300, which has the potential to radically improve the performance of carbon capture as compared with current technologies using amines. This may help make carbon capture and storage (CCS) commercially viable for large coal-fired power stations here in the UK (and globally) and in so doing facilitate the roll-out of CCS and reduce the cost of delivering the UK’s target of cutting CO₂ emissions by 80% by 2050. NOTT-300 could accelerate the roll out of CCS globally with resulting increased sales of specialty chemicals (c. £200 million up to 2025) along with an increase in exports for UK-based engineering and manufacturing firms selling engineering design services and specialist plant and equipment into global markets.</td>
<td>£1 million</td>
</tr>
</tbody>
</table>
### Examples of industrially relevant projects undertaken at ISIS Neutron and Muon Source

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Economic benefits attributable to ISIS Neutron and Muon Source up to 2025</th>
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<tbody>
<tr>
<td>Cleft palate hydrogel — Using ISIS Neutron and Muon Source, researchers have developed a hydrogel that expands in a highly controlled manner when surgically implanted, providing a scaffold for tissue re-growth tailored to the needs of individual patients. A spin-out company, Oxtex Limited, is now developing applications for cleft palate and dental repair. The future economic potential for such hydrogels is likely to run into the many hundreds of millions globally within 10-20 years, and may result in £50 million additional economic activity for the UK.</td>
<td>£0.5 million</td>
</tr>
<tr>
<td>Nanotube ink — Using ISIS Neutron and Muon Source, researchers developed a separation and purification process for nanotube ink, a cheaper and better performing material for touch screen devices compared to the current industry standard. The process was licensed by The Linde Group that launched the first commercial product in 2013. The global market for transparent conductive films in high-tech displays is forecast to reach $5.86 billion by 2020; capturing even 1% of this market could add £50 million a year to the UK economy by 2020, and as much as £0.25 billion between 2015 and 2025.</td>
<td>£2.5 million up to 2025</td>
</tr>
<tr>
<td>Organic semiconductors — A range of ISIS Neutron and Muon Source facilities has enabled UK-based researchers to advance our understanding of the fundamental physics of organic semiconductor materials, which has the potential to boost the growth in the global market for organic semiconductors; they are already used in OLEDs (organic light-emitting diodes) for use in novel low-cost applications such as solar panels or display screens, a market exhibiting rapid growth with the massive semiconductor industry. Given these markets are dominated by other countries, UK research is most likely to be valorised through licensing agreements and trade sales rather than substantial additional economic output from our small (and declining semiconductor industry). Notwithstanding this limitation, strong academic activity in OLED research in the UK could produce additional income running into the many tens of millions of pounds annually, and as much as £500 million over the next 10 years through to 2025.</td>
<td>£5 million up to 2025 Large spillovers from improved price-performance of ICT systems</td>
</tr>
<tr>
<td>Spider silk and medical devices — Researchers used to gain insights into how spiders transform silk feedstocks from stored gel to solid fibre at the atomic level. The group spun out Oxford Biomaterials Ltd (OBM) – a company developing spider silk technologies for medical applications, which could reduce usage of oil-based fibres and result in a net benefit of around £150 million for the UK economy through to 2025.</td>
<td>£3 million</td>
</tr>
<tr>
<td>Keeping nuclear power plants safe — Research using the ENGIN-X instrument at ISIS Neutron and Muon Source has enabled the direct measurements of stresses introduced into materials by welding and allowed the refinement of simulations to validate and predict potential issues. The new understanding of weld repairs and refined life analysis methods underpinned by these measurements has allowed generators to persuade the national regulator that the plants can be safely refurbished, which is expected to enable EDF to extend the lifespan of the UK’s entire fleet of nuclear power plants (15) and safeguard 2,000 power-generation jobs and generate substantial new economic activity (£650 million a year) for the refurbishment of those plants. These developments will help with energy security and reduce the need for the country to switch to cheaper but less green gas-fired power stations, with substantial savings in CO₂ emissions.</td>
<td>£65 million 3 million tonnes of carbon dioxide saved, 60 jobs safeguarded</td>
</tr>
</tbody>
</table>

Total across these examples £84 million up to 2025
6. World-class skills

6.1 Introduction
STFC facilitates the growth of the world-class scientific and technical skills needed to ensure that the UK maintains its international status as a destination of choice for collaborative, interdisciplinary science, technology and innovation. We aim to inspire people of all ages with the scientific and technological excellence that we support. We encourage young people to follow STEM-related careers, fund and train postgraduates and provide training for apprentices and undergraduates, and enable continuous professional development for educators. We also enable our own highly-skilled employees to work with and transfer skills to industry. In so doing, we are helping to sustain and advance the vital skills, knowledge and expertise needed to underpin the UK's national and regional economies, and to tackle the grand challenges facing society.

6.2 Inspiring and involving
STFC is recognised as a leader in STEM engagement in the UK, reaching hundreds of thousands of members of the UK public every year with our engagement activities. Add in the activities of our wider community, whom we support with grant funding, networking, and the sharing of best practice, and our reach extends into the millions.

In 2016, we published our new Public Engagement Strategy, which outlines five key aims for the five years to 2021. This was accompanied by an evaluation framework that helps us to report, improve, and celebrate our work. We also commissioned a review of STFC community’s prevailing attitudes towards public engagement: the Public Engagement, Attitudes, Culture and Ethos (PEACE) report.

Since the publication of our strategy, we have introduced:

- **New and improved grants:** We have updated and revised our public engagement grant schemes, maintaining the strongest features of our previous schemes while making changes to the funding mechanisms that reinforce our strategic aims.

- **Leadership Fellows in Public Engagement scheme:** This pioneering new scheme replaces our Public Engagement Fellowships, and is designed to support passionate academics and STFC facility-users in undertaking their own engagement and to increase the skill and confidence of their colleagues when engaging others with their research.

6.3 Developing STEM understanding
Our engagement strategy focuses strongly on developing and supporting the people who can most effectively engage with audiences that we ourselves would otherwise struggle to reach. One of our objectives for engagement is to spread the message that a STEM-related career is accessible to as wide a range of individuals as possible, coordinating our approach and aims with those of other major STEM providers in our field. By spreading good practice amongst our community, we are helping to ensure that ever greater numbers of young people understand that STEM is for them. The following are examples of our activities:

- **Developing STEM influencers:** This year, via our National Laboratories engagement programme, we have trained almost 300 ‘influencers’, who are expected to reach more than 30,000 students/people with STFC STEM areas each year. Our ‘train the trainer’ Continued Professional Development (CPD) programmes for teachers use STFC science and technology as a context within which school teachers can inspire their students in school science, technology and mathematics lessons.

- **The James Webb Space Telescope Campaign:** STFC and the UK Space Agency are working in partnership with a range of other organisations to plan and deliver a coordinated national campaign of STEM engagement focused on the UK’s major contributions to the James Webb Space Telescope.

- **STFC Fellowship-holder Dr Marek Kukula became the new Public Astronomer at the Royal Greenwich Observatory in 2008. Since then, Marek has helped to establish the Observatory as a focus for engagement with contemporary astronomy, highlighting cutting-edge UK science and technology, and fostering innovative collaborations between the sciences and the humanities. He and his colleagues have been particularly successful in engaging with young adults, a demographic group that is traditionally difficult to reach. In 2015-16, for example, some 40,000 students were reached through the Royal Greenwich Observatory’s schools programme. According to Marek “STFC’s expertise and wider community network have all helped us improve the quality of our work for the hundreds of thousands of visitors we receive each year, as well as millions more that we reach with our media activities.”**
STFC develops current and future generations of scientists, engineers, and technologists to support the growth of the UK’s high-tech economy, as well as inspiring young people and the general public in the benefits of science.

**Inspiring and involving**

In 2016/17, our National Laboratories and university-funded engagement programmes communicating the inspiring nature of our science:

- **1.4 Million** Members of the public
- **337,000** School and further education students
- **36 grants and 3 Fellowships** with a value of **£630,000**

We ran **400 events** at our National Lab sites which reached **36,000 people**, including **9,700 pupils** and **1,300 teachers**.

**Engineering Open House initiative at Daresbury in July 2017:** attracted nearly **700 members** of the public and staff family members.

**Open weekend at ROE, September 2017:** attracted more than **3,000 people**.

**Developing STEM understanding**

- **190** Young people per annum
  - Our work experience placements for 14-18 year olds at our National Laboratories
- **60+ STEM Graduates** on STFC’s 2-year graduate programme scheme
- **100+ Undergraduates** from universities work at STFC on the internship programme

**Developing skills for the UK research base**

- **3,000** Sixth Form Students from over **60** schools
- **14,000** Training days provided to postgraduate students
- **37 New CERN fellows** selected from the UK totalling to **222** to date

All statistic from 2016/17
• National Space Academy: STFC provides funding to the National Space Academy, headquartered at the National Space Centre in Leicester, which engages young people with mathematics and the sciences using the inspirational context of space, and facilitates entry into space-sector careers by working with industry and academia. Since January 2014:
  - 27,120 students have participated in Academy masterclasses across the UK
  - 3,337 teachers have participated in nearly 9,000 hours of Continued Professional Development (CPD) training
  - 3,635 students in the 15-19 age range have participated in Careers Conferences.
Internationally, the Academy leads the skills, education and training strand of STFC-led UK-China programme of strategic collaboration on space science and technology and has established, at the request of China’s space sector, a new Sino-UK Centre for Space Education and Space Culture. The Academy also leads the UK’s support for space education and skills development, in partnership with the UAE Space Agency.

• Physics Masterclasses are one-day events hosted by universities and laboratories across the country. They are aimed at students taking particle physics modules at AS- or A-level, but are open to any student interested in studying particle physics. A small number of universities also offer masterclasses in nuclear physics. Nearly 3,000 students attended an STFC-supported masterclass in 2016/17.

• Science in Your Future workshops: STFC has been working with its partners at Diamond Light Source to support the drive to encourage girls to pursue STEM subjects by leading a series of workshops for 14-16 year-olds. In March 2017, almost 100 girls visited STFC’s Harwell Campus to see first-hand what a career in cutting-edge science involves.

• Visits to CERN: In the year to the end of March 2017, 11,865 UK pupils and teachers visited CERN from 493 different schools, and 51 UK teachers took part in additional training programmes.

• Increasing audience diversity: Supported by our public engagement grants, SMASHfestUK is a festival designed to widen participation and increase diversity in STEM and the arts. Launched in south east London, and aimed at young people and their families, the award-winning SMASHfestUK is now in its fourth successful year and engages visitors with STEM through comedy, music, interactive workshops and performances, games and experiments. The festival reached a direct audience of 4,000 young people and families in 2016; the following year, it attracted 9,500 people, from demographics currently under-served by STEM engagement.

• Laboratory open days: In July 2017, Daresbury Laboratory held a public-access event in collaboration with the Engineering Open House Day initiative. Over two days, nearly 700 members of the public and staff family members enjoyed tours of Daresbury’s engineering facilities and a science fair of engineering demonstrations and interactive activities. A couple of months later, more than 3,000 people of all ages attended an open weekend
at the Royal Observatory Edinburgh to glimpse work undertaken there by STFC’s UK Astronomy Technology Centre and the University of Edinburgh’s Institute for Astronomy. During this annual event, visitors were able to explore the history of the site, discover how comets are created, and submerge themselves in virtual reality in order to explore the sky at night. In October 2017 Chilbolton Observatory’s doors were also opened to the public, when 300 visitors were equipped with maps and given the rare opportunity to roam about the site and meet experts stationed at the major facilities including radars, lidars, meteorological instruments and the iconic radio telescope.

- Dark Matter Day on 31 October, 2017 saw events in 24 countries to highlight one of the universe’s greatest enigmas. Dark matter has never been observed but, together with dark energy, it is believed by scientists to make up 95 percent of the total universe. In the UK, Dark Matter Day included a well-attended event in Parliament which attracted many MPs and several Lords, an exhibition at the Department for Business, Energy and Industrial Strategy, and numerous lectures, talks and displays at UK universities. At STFC’s Daresbury Laboratory, families with young children attended a special Talking Science Lecture and family workshop; the UK Astronomy Technology Centre hosted a special public astronomy evening, including a presentation, tour and stargazing activities; and, at Rutherford Appleton Laboratory, 180 school students made their own dark matter particles and had a live lesson in dark matter broadcast online from STFC’s Boulby Laboratory.

### 6.3 Developing skills for the UK research base and the wider economy

STFC continues to play an important role in encouraging young people to follow STEM careers. For example: there were 27,675 applications to university physics courses in 2016 – around 900 fewer than in 2015 but up from 18,225 in 2007; and we are investing more than £23 million per year in postgraduate training and fellowships in particle physics, nuclear physics and astronomy.

One of STFC’s key roles is to support the development of skilled people for academic, business, and other employment through postgraduate training. By investing in postgraduate university students, STFC is creating not only the scientists of tomorrow, but also a highly skilled workforce for both the UK economy and international markets. The following highlight our work in this area:

- First destinations for PhD students: Between 2012 and 2015, 941 PhD students were funded by STFC in astronomy, nuclear physics and particle physics, according to an STFC study published in early 2017. Of these, 45%
went on to a postdoctoral position; 28% took up positions in the private sector, with more than 70% working in software development, data analysis, engineering and finance; and the rest went mainly into research institutes, other university jobs, school teaching and other parts of the public or charitable sectors. The study also showed that of the 45% who moved into postdoctoral positions, around half were in the UK and half were overseas, split between both EU and non-EU countries.

- Industrial Cooperative Awards in science and technology (CASE) studentships provide support for PhD students to work in collaboration with a non-academic partner on projects that fall within STFC's core science programme, or which aim to apply technologies or techniques developed within the programme in other areas. CASE studentships are for a minimum of three-and-a-half years; and Industrial CASE-Plus enables students to spend a further year employed full-time by the non-academic partner.

- Industrial Strategy studentships: With effect from October 2017, STFC is supporting 123 additional studentships (over and above its normal allocation) in areas aligned with the government's Industrial Strategy. Some 88 of these studentships have been included in STFC's network of eight new Centres for Doctoral Training, which will offer comprehensive training in data-intensive science through cutting-edge research projects, a targeted academic training programme, and secondments to national and international partners. The eight new Centres bring together 19 universities and involve over 100 industrial and other non-academic partners. A further two studentships have been awarded through the Industrial CASE scheme; and 34 are being supported from other sources of funding, including industry.

- Paid internships for STEM undergraduates: More than 100 STEM undergraduates work as paid interns at STFC for periods of three months to one year. This benefits both parties, providing the students with valuable work experience, and STFC with much-appreciated additional resources.

6.4 Developing our people

Across six sites, STFC employs more than 1,900 staff, the majority of whom are scientists, engineers and technical staff. We recruit apprentices, undergraduate students and graduates and support them in developing technical, analytical, research and other capabilities. We employ more than 60 STEM graduates on an accredited two-year structured graduate scheme, all of whom are working towards becoming qualified with a professional institution. We also offer graduates and undergraduate students training in communication, creativity, leadership, team-working, and other organisational skills. Many members of STFC's staff and the academics we support in universities are world-leading in their respective fields, and a number hold honorary academic positions and joint appointments with universities or companies in the UK or overseas. Nearly 400 members of staff have received significant awards or recognition in the past year including, for example, prizes for exceptional contributions to science, and for leading collaborative partnerships between academia and industry. STFC is also upskilling its staff through a vibrant and growing apprenticeship programme, recruiting and training apprentices in engineering, project management, computing and ICT. Currently, STFC employs more than 40 apprentices.

UK apprentices assist in recycling hospital MRI scanner to study the stuff of stars at CERN

A superconducting magnet from an old MRI scanner was shipped from Australia to CERN in Switzerland, where it was modified for use on the laboratory's ISOLDE instrument, a nuclear physics facility which provides both low-energy and high energy re-accelerated radioactive beams to observe the properties of atomic nuclei. The team responsible for reconfiguring the magnet included two apprentices from STFC's Daresbury Laboratory. This recycling project cost around £130,000, whereas a bespoke magnet would have cost more than £1 million.

Image overleaf: ‘Fine balancing act – can we strive to eliminate the notion that only professional science communicators can communicate science?’

Illustration by Helen Towrie at CLF, for the STFC-sponsored INTERACT Physics Engagement Symposium at the University of Birmingham. Helen Towrie is an Impact and Engagement officer at the CLF. An Illustrator by background, she often produces visual media such as this for STFC's public engagement and communications, to help make science feel more approachable to a wider audience.
7. Methodological developments

By their nature, short-term output metrics cannot provide a full picture of the broader economic and societal benefits derived from STFC’s programmes. Our evaluation programme therefore includes impact studies and case study evaluations. Evaluation of science and innovation policy can feed back in to a better understanding of the routes to impact, as well as supporting public trust in science, and we remain committed to the pursuit of robust methodologies within our evaluation studies. This year we are progressing evaluation studies on the early benefits of the SKA and Hartree Centre and have presented initial results earlier in this report; both of these full reports will be published in early 2018 and will include recommendations on capturing the full benefits from these facilities in the future. We have also kicked off an evaluation study of the Diamond Light Source in collaboration with our colleagues from the facility.

STFC works closely with Research Council colleagues on the evaluation agenda as members of the cross-council Performance Evaluation Network. This year we have been collectively working with BEIS in the development of their new Appraisal and Evaluation Framework for large capital investments.

Hartree Centre Evaluation Study

In 2017 we commissioned an evaluation of the Hartree Centre which aims to demonstrate and measure benefits and impacts from the Hartree Centre to date, as well as producing a Benefits Realisation and Evaluation Framework with a range of appropriate indicators to monitor and measure future progress. This evaluation supports the theme of ‘data-intensive’ science within our revised Corporate Strategy and will provide a framework for assessing the return from the £115.5 million awarded to establish Hartree as the UK centre of excellence in cognitive computing and big data.

Square Kilometre Array Evaluation Study

Similarly, in support of our evaluation plans for programmes of significant capital spend, we are also conducting an initial benefits evaluation of the SKA Headquarters. The SKA HQ has received a recent £16.5 million investment to enable the current capacity of 60 staff to be extended to 135 staff. The Headquarters coordinates the entire global effort to design and build the SKA Radio Telescope. This study aims to demonstrate the socio-economic impact that the SKA HQ has had both locally and to the UK economy, alongside the development of a Benefits Realisation Framework that will include a set of metrics to measure the current and future impact.

Diamond Light Source Evaluation Study

In close collaboration with our partners at the Diamond Light Source, we have started a study to measure and demonstrate the economic and social benefits of Diamond. This will include both the construction and the operation of the facility; looking at the benefits already realised and those that are likely to be realised in the future. An evaluation framework will also be developed for the facility. This framework will provide a structure for benefits realisation approaches and monitoring and evaluation, reflecting the outputs, outcomes and impacts in the facility’s logic model. It will also provide guidance for any ongoing data collection for project management and future evaluation purposes.

Researchfish

Researchfish is the online data collection system that we use to collect data from our university partnership programmes. This covers a wide cross-section of key areas of importance to demonstrate impact: publications, collaborations, further funding, staff development and next destinations, technology development, intellectual property and licensing, spin-outs, measures of esteem, public engagement, and use of facilities. In 2017 we published reports on this data for the first time to showcase the breadth of impacts across the whole of our university partnership programmes.
Public Engagement Evaluation Framework
Evaluation is a key part of STFC’s Public Engagement strategy and new methodologies have been designed to report, improve and celebrate the programme in a more consistent and meaningful way as described in STFC’s Public Engagement Evaluation Framework, published in 2017. These methodologies are now being implemented by the National Laboratories Public Engagement teams and piloted in summer 2017 with holders of public engagement grants and awards. They will be supported in collecting data on a range of public engagement dimensions; namely inputs, outputs, reach, outcomes, and processes. Crucially, an emphasis is put on the consideration of how the data will be collected and measured from the start of the project.

A key element is the evaluation of ‘outcomes’. This uses a system adapted from the museums sector called Generic Learning Outcomes, which looks at evidence of learning in its broadest sense – not just an increase in knowledge and understanding, but changes in a participant’s values, skills, how they feel and what they intend to do next as a result of the engagement.

Future Programme
Our evaluations of SKA, the Hartree Centre and the Diamond Light Source will be published in 2018. We are currently scoping new evaluations on CERN and the Collaborative Computing Projects to commence in 2018.
8. Appendices

Appendix 1 – STFC publication and citations analysis

Introduction
STFC commissioned summary bibliometric analysis, conducted by Clarivate Analytics, in the subject areas of astronomy and planetary science, particle physics, and nuclear physics between 2014 and 2016. The aim of the analysis is to assess the research performance of these fields by country. Comparator countries were chosen by STFC. A summary of the analysis for each subject is given below and definitions of impacts are given in the following section.

• Astronomy and planetary science
In 2016 the UK was ranked 4th in terms of field-normalised citation impact for astronomy, following closely behind Italy, France and Germany. This has varied from 3rd in 2014 to 1st in 2015, with annual variations in the rankings of these leading nations evident. In terms of research volume, the UK is ranked 2nd behind the US in 2015 and 2016. The distribution of highly cited papers in astronomy also shows very similar distribution between the UK, Germany, France and Italy and indicates that the UK had more highly cited papers than these counties between 2014 and 2016.

• Particle physics
In 2016 the UK was ranked 3rd in terms of field-normalised citation impact for particle physics, following France and Switzerland. This has remained constant over the period 2014-2016. In terms of research volume the UK is ranked 4th behind the US, Germany and Italy. The distribution of highly cited papers in particle physics also shows very similar distribution between the UK, Germany, France and Italy and indicates that the UK is performing well in relation to other leading scientific nations in particle physics, with only Switzerland out-performing the UK in terms of highly cited papers between 2014 and 2016. The UK also has the least amount of uncited papers compared to other nations in these years.

• Nuclear physics
In 2016 the UK was ranked 2nd in the world for nuclear physics in terms of Field-Normalised citation impact behind France. This has varied from 2nd in 2014 to 1st in 2015 and has been the most stable compared to the other leading nations where we see annual variations in the rankings. In terms of research volume, the UK is ranked 7th in nuclear physics behind most of the other leading nations. In terms of highly cited papers, the UK is leading the other leading scientific nations in nuclear physics and has the least amount of uncited papers.

Details of analysis
The impact metric used to demonstrate research performance is the field-normalised citation impact (NCIf). This is defined as the average number of citations for papers published in the most recent five-year period divided by the number of papers published during that period, normalised to the world average citation impact. For example, for 2016, this is the sum of the citations of the papers published from Jan 2012 to Dec 2016 divided by the numbers of papers published in that period, normalised to the world average of 1.0. Any paper with an NCIf greater than 1 is therefore performing above world average.

The analysis undertaken by Clarivate Analytics, also included impact profile graphs and citation distribution tables. These show the percentage of papers that are uncited and the percentage that fall within each of eight categories of relative citation rates. Examining the distribution of NCIf provides further information such as the proportion of uncited papers, the proportion of papers either side of the world average of 1, the location of the most common (modal) group near the centre and the proportion of the papers in the most highly cited categories to the right (x4 and x8 the world average).

The tables below present the number of publications, NCIf by year and country and the position for each in relation to the other comparator countries. The impact profile and accompanying table is also given for each subject. The distribution percentages shown in the graph and tables below have been averaged across the years 2014-2016.

It should be noted that for particle physics and nuclear physics, over 60% of papers attributed to Switzerland are from authors based at CERN.
**Astronomy**

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<tr>
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<tr>
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<td>Italy</td>
<td>2.05</td>
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<td>1.52</td>
</tr>
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</table>

**Impact profile for astronomy**
The impact profile and table shows that the UK is performing well in relation to other leading scientific nations in astronomy. The distribution of highly cited papers in astronomy also shows very similar distribution between the UK, Germany, France and Italy and indicates that the UK have more highly cited papers than these counties between 2014 and 2016. All of the leading nations have a similar level of uncited papers.
COUNTRY UNCITED ≥0 <0.125 ≥0.125 <0.25 ≥0.25 <0.5 ≥0.5 <1 ≥1 <2 ≥2 <4 ≥4 <8 ≥8 Citation impact equal to or greater than world average
UK 19.7% 1.3% 5.0% 8.1% 22.5% 20.3% 14.7% 6.2% 2.1% 43.4%
USA 21.3% 1.7% 6.3% 8.7% 23.2% 19.3% 13.0% 5.0% 1.4% 38.7%
Germany 19.4% 1.5% 5.9% 8.5% 22.6% 19.8% 14.5% 6.0% 1.8% 42.1%
France 20.0% 1.4% 5.8% 8.2% 22.4% 20.2% 14.0% 5.7% 2.3% 42.2%
Italy 21.0% 1.6% 5.9% 8.7% 21.7% 19.8% 13.7% 5.6% 2.1% 41.1%

Number of publications and position

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Field-normalised citation impact and position

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Particle physics

Impact profile for particle physics

The impact profile and table shows that the UK is performing well in relation to other leading scientific nations in particle physics, with only Switzerland having more highly cited papers between 2014 and 2016.

The UK also has the least amount of uncited papers compared to other nations in these years. The analysis shows that the UK had less than 8%, 15% and 48% of uncited papers in 2014, 2015 and 2016. The percentage was lower than that of all the other countries in each year (2016 shows a higher percentage due to a time lag in citations).
COUNTRY  UNCITED  >0<0.125  ≥0.125<0.25  ≥0.25<0.5  ≥0.5<1  ≥1<2  ≥2<4  ≥4<8  ≥8  Citation impact equal to or greater than world average
---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---  ---
UK  22.1%  0.0%  4.8%  7.7%  17.2%  18.9%  18.2%  7.4%  3.5%  48.1%
USA  25.4%  0.0%  4.7%  8.1%  16.9%  18.2%  16.8%  6.9%  3.0%  44.9%
Germany  23.8%  0.0%  4.9%  8.6%  16.3%  19.4%  16.9%  6.8%  3.2%  46.4%
Italy  24.2%  0.0%  4.9%  8.7%  17.1%  19.2%  15.6%  7.1%  3.2%  45.1%
Japan  30.8%  0.0%  5.7%  9.3%  15.9%  16.9%  13.7%  5.5%  2.2%  38.3%
Russia  36.8%  0.0%  6.3%  9.4%  14.5%  15.2%  10.7%  4.8%  2.4%  33.0%
France  23.7%  0.0%  4.6%  8.2%  16.0%  18.8%  16.8%  7.8%  4.0%  47.5%
Switzerland  22.8%  0.0%  4.4%  7.1%  16.0%  18.0%  17.1%  9.5%  4.9%  49.6%
Nuclear physics

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Field-normalised citation impact and position

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Nuclear physics impact profile

The impact profile and table shows that the UK is performing well in relation to other leading scientific nations in relation to nuclear physics. In terms of highly cited papers, the UK is ahead of the other leading scientific nations in nuclear physics and has the least amount of uncited papers.
### Nuclear physics 2014-2016

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<th>COUNTRY</th>
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<th>≥0.25 &lt;0.5</th>
<th>≥0.5 &lt;1</th>
<th>≥1 &lt;2</th>
<th>≥2 &lt;4</th>
<th>≥4 &lt;8</th>
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<td>14.1%</td>
<td>7.1%</td>
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<td>2.6%</td>
<td>8.3%</td>
<td>10.5%</td>
<td>19.4%</td>
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<td>4.3%</td>
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<tr>
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<td>9.9%</td>
<td>15.4%</td>
<td>11.2%</td>
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<td>7.8%</td>
<td>10.9%</td>
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<td>20.4%</td>
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<td>11.8%</td>
<td>20.2%</td>
<td>15.4%</td>
<td>7.1%</td>
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<td>10.1%</td>
<td>16.8%</td>
<td>15.1%</td>
<td>9.3%</td>
<td>6.2%</td>
<td>47.3%</td>
</tr>
</tbody>
</table>
Appendix 2 – STFC publications compared with UK physical sciences

STFC commissioned an analysis by Clarivate Analytics of publications submitted to the Researchfish online outputs system. The impact profile shows that STFC papers perform better than UK physical sciences research as a whole. Nearly half (49.3%) of STFC-supported papers published between 2009 and 2015 had a citation impact of at least the world average at the end of 2015. This compares with 39.6% of UK physical sciences research. The results of this are shown below:

Principal Investigators (PIs) from our university partners inform us annually of the publications relating to their research. This information is collected via the online outputs collection system, Researchfish. STFC commissioned Clarivate Analytics to undertake bibliometric analysis on these papers in order to understand how STFC are performing against the rest of UK physical sciences:

- Nearly half (49.3%) of STFC-supported papers published between 2009 and 2015 had a citation impact of at least the world average at the end of 2016. This compares to 39.6% of UK physical sciences research.
- More than eight percent (8.5%) of STFC-supported papers published between 2009 and 2015 had a citation impact of at least four-times the world average at the end of 2016. This compares with 5.6% of UK physical sciences research.
- The impact profile shows that STFC papers perform better than UK physical sciences research as a whole. The profile curve for STFC shifted toward the right of that for UK physical sciences research indicating fewer less well-cited papers and more well-cited papers.

The data in Appendix 2 indicate that STFC is succeeding in its ambition to deliver world-class research and sustain scientific excellence and leadership.
### Appendix 3 – Cross-council common indicators

<table>
<thead>
<tr>
<th>Item</th>
<th>Metrics</th>
<th>Units</th>
<th>2012/13</th>
<th>2013/14</th>
<th>2014/15</th>
<th>2015/16</th>
<th>2016/17</th>
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<td>580</td>
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<td>628</td>
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<td>37</td>
<td>44</td>
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<td>3</td>
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<td>9 of which other</td>
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<td>93</td>
<td>89</td>
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<td>25</td>
<td>44</td>
<td>34</td>
<td>22</td>
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<tr>
<td>Item</td>
<td>Metrics</td>
<td>Units</td>
<td>2012</td>
<td>2013</td>
<td>2014</td>
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<td>------</td>
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<td>------</td>
<td>------</td>
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<td>Knowledge generation(^c)</td>
<td>Publications</td>
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<td>41</td>
<td>Instances of journal articles</td>
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<td>9,926</td>
<td>10,877</td>
<td>10,916</td>
<td>10,648</td>
<td>8,281(^d)</td>
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<td>Instances of books</td>
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<td>32</td>
<td>33</td>
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<td>Instances of artistic and creative outputs</td>
<td>#</td>
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<td>13</td>
<td>14</td>
<td>29</td>
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<tr>
<td>45</td>
<td>Instances of research databases and models reported</td>
<td>#</td>
<td>6</td>
<td>7</td>
<td>10</td>
<td>11</td>
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<td>46</td>
<td>Instances of software and technical products reported</td>
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<td>14</td>
<td>27</td>
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<td>32</td>
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<tr>
<td>47</td>
<td>Instances of research tools and methods reported</td>
<td>#</td>
<td>2</td>
<td>5</td>
<td>12</td>
<td>7</td>
<td>10</td>
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<tr>
<td></td>
<td>Instances of medical products, interventions and clinical trials</td>
<td>#</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>2</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>48</td>
<td>Instances of IP reported</td>
<td>#</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>49</td>
<td>Instances of spin-outs/start-ups</td>
<td>#</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
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<tr>
<td>Metrics with a 5 year lag(^e)</td>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td>43</td>
<td>Number of awards that gave rise to at least one example of a publication within five years of award start date</td>
<td>#</td>
<td>220</td>
<td>237</td>
<td>254</td>
<td>234</td>
<td>396</td>
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<tr>
<td></td>
<td>Proportion of awards that gave rise to at least one example of a publication within five years of award start date</td>
<td>%</td>
<td>61</td>
<td>65</td>
<td>62</td>
<td>63</td>
<td>65</td>
</tr>
<tr>
<td>45</td>
<td>Number with at least one instance of further funding within 5 years of the start date</td>
<td>#</td>
<td>74</td>
<td>83</td>
<td>67</td>
<td>70</td>
<td>118</td>
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<tr>
<td></td>
<td>Proportion of with at least one instance of further funding within 5 years of the start date</td>
<td>%</td>
<td>21</td>
<td>23</td>
<td>16</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>46</td>
<td>Number with at least one instance of engagement within 5 years of the start date</td>
<td>#</td>
<td>101</td>
<td>127</td>
<td>108</td>
<td>126</td>
<td>198</td>
</tr>
<tr>
<td></td>
<td>Proportion with at least one instance of engagement within 5 years of the start date</td>
<td>%</td>
<td>28</td>
<td>35</td>
<td>26</td>
<td>34</td>
<td>33</td>
</tr>
<tr>
<td>49</td>
<td>Number with at least one instance of policy influence within 5 years of the start date</td>
<td>#</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Proportion with at least one instance of policy influence within 5 years of the start date</td>
<td>%</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
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</table>

\(^a\) Funds leveraged by research projects include case and in-kind contributions.
\(^b\) Year the collaborations were first reported.
\(^c\) Year the outcome is realised. Numbers revised annually.
\(^d\) 2016/17 figure is expected to be revised up in future years.
\(^e\) These figures are within five years of the start date and only available for grants that started between 2006/7 and 2011/12. They represent outcomes from grants awarded in the specific year, not the outcome of all grants during one year.
\(\dagger\) Due to the timing of the destination of leavers survey taking place there is a 1 year lag in the data. Therefore the data refers to the year those surveyed left higher education. 2017 data will be reported in next year’s report.
\(\text{x}\) Historical data unavailable due to changes in method of data collection.
Appendix 4 – STFC-specific output metrics

All data are collected from STFC internal sources unless otherwise stated

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>New depositions in the Protein Databank from ESRF and DLS[1]</td>
<td>#</td>
<td>1,390</td>
<td>1,380</td>
<td>1,480</td>
<td>1,760</td>
<td>1,639</td>
</tr>
<tr>
<td>Number of UK researchers accessing CERN</td>
<td>#</td>
<td>674</td>
<td>614</td>
<td>645</td>
<td>651</td>
<td>672</td>
</tr>
<tr>
<td>Number of unique users accessing STFC’s large facilities</td>
<td>#</td>
<td>4,250</td>
<td>5,280</td>
<td>4,400</td>
<td>5,120</td>
<td>5,039</td>
</tr>
<tr>
<td>Cumulative value of contracts placed with UK companies from CERN since 2008</td>
<td>£mil</td>
<td>60</td>
<td>75</td>
<td>100</td>
<td>120</td>
<td>141</td>
</tr>
<tr>
<td>Commercial organisations accessing STFC’s UK facilities</td>
<td>#</td>
<td>89</td>
<td>96</td>
<td>83</td>
<td>89</td>
<td>91</td>
</tr>
<tr>
<td>Sci-tech Daresbury – total employees within companies on site</td>
<td>#</td>
<td>448</td>
<td>474</td>
<td>569</td>
<td>547</td>
<td>679</td>
</tr>
<tr>
<td>ITAC, ESA BIC and STFC CERN BIC: No of new jobs created in year</td>
<td>#</td>
<td>42</td>
<td>69</td>
<td>56</td>
<td>57</td>
<td>71</td>
</tr>
<tr>
<td>New patent family applications filed[3]</td>
<td>#</td>
<td>8</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Total number of patents granted worldwide[4]</td>
<td>#</td>
<td>23</td>
<td>7</td>
<td>8</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>Spinouts/new businesses created</td>
<td>#</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number employed in STFC spin-outs</td>
<td>#</td>
<td>120</td>
<td>108</td>
<td>112</td>
<td>95</td>
<td>121</td>
</tr>
<tr>
<td>Licences</td>
<td>#</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Income from IP activity</td>
<td>£mil</td>
<td>0.07</td>
<td>0.07</td>
<td>0.9</td>
<td>0.11</td>
<td>0.29</td>
</tr>
<tr>
<td>Rolling cohort of PhDs</td>
<td>#</td>
<td>782</td>
<td>766</td>
<td>773</td>
<td>796</td>
<td>854</td>
</tr>
<tr>
<td>STFC staff who received awards per year</td>
<td>#</td>
<td>359</td>
<td>403</td>
<td>447</td>
<td>226</td>
<td>397</td>
</tr>
<tr>
<td>Number of apprenticeships</td>
<td>#</td>
<td>24</td>
<td>37</td>
<td>40</td>
<td>54</td>
<td>42</td>
</tr>
<tr>
<td>Training days to postgraduate students at our facilities and departments across a range of disciplines</td>
<td>#</td>
<td>16,800</td>
<td>14,280</td>
<td>9,971</td>
<td>22,970</td>
<td>14,435</td>
</tr>
<tr>
<td>Number of grants assessed for reporting</td>
<td>#</td>
<td>358</td>
<td>271</td>
<td>325</td>
<td>299</td>
<td>300</td>
</tr>
<tr>
<td>Refereed publications[6]</td>
<td>#</td>
<td>5,523</td>
<td>5,523</td>
<td>5,162</td>
<td>5,572</td>
<td>5,667</td>
</tr>
<tr>
<td>Number of STFC site based public engagement (PE) events</td>
<td>#</td>
<td>200</td>
<td>330</td>
<td>209</td>
<td>456</td>
<td>412</td>
</tr>
<tr>
<td>The public audience reached by STFC (millions)[7]</td>
<td>#</td>
<td>2</td>
<td>1.1</td>
<td>2.1</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Number of school and further education students</td>
<td>#</td>
<td>X</td>
<td>334,000</td>
<td>294,800</td>
<td>566,400</td>
<td>336,600</td>
</tr>
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</table>
Appendix 4 – STFC-specific output metrics

All data is collected from STFC internal sources unless otherwise stated

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>The number of teachers involved with STFC PE per year</td>
<td>#</td>
<td>17,500</td>
<td>18,000</td>
<td>19,000</td>
<td>1,030</td>
<td>1,279</td>
</tr>
<tr>
<td>Number of PE grants (awards and fellowships)</td>
<td>#</td>
<td>27</td>
<td>32</td>
<td>31</td>
<td>33</td>
<td>36</td>
</tr>
<tr>
<td>Value of PE grants (awards and fellowships)</td>
<td>£k</td>
<td>520</td>
<td>626</td>
<td>649</td>
<td>489</td>
<td>629</td>
</tr>
<tr>
<td>Number of UK schools that visited CERN</td>
<td>#</td>
<td>305</td>
<td>369</td>
<td>418</td>
<td>427</td>
<td>493</td>
</tr>
<tr>
<td>Number of UK pupils that visited CERN</td>
<td>#</td>
<td>9,500</td>
<td>8,740</td>
<td>9,350</td>
<td>9,990</td>
<td>11,865</td>
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</table>

**Facility usage**

<table>
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<tr>
<th>Description</th>
<th>Unit</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station days</td>
<td>#</td>
<td>6,724</td>
<td>7,003</td>
<td>5,474</td>
<td>8,810</td>
<td>8,356</td>
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<tr>
<td>Unique users</td>
<td>#</td>
<td>4,254</td>
<td>5,276</td>
<td>4,402</td>
<td>5,122</td>
<td>5,039</td>
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<tr>
<td>Experiments</td>
<td>#</td>
<td>2,376</td>
<td>2,688</td>
<td>2,340</td>
<td>3,105</td>
<td>2,996</td>
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</table>

[2] Companies that are no longer located at the Sci-Tech Daresbury Campus are not included in that year’s total investment figures.
[3] A patent family is a set of patents taken in various countries to protect a single invention. It can take a number of years from first filing to the patent being granted.
[4] Patents can be awarded in different countries; this number does not represent the number of inventions, but the number of patents held across all countries and across all inventions.
[5] Due to additional resource provided to CLF this year for access to the ULTRA and OCTOPUS lasers, the number of access weeks increased and consequently the volume of on job training saw a significant increase.
[6] The number of refereed publications reflects those reported from both our grants in Researchfish, and for STFC facilities.
[7] These figures represent both Public Engagement activity at STFC’s National Laboratories and our University Partnership Programme as reported by our Principal Investigators into Researchfish.
[8] These figures previously represented both Public Engagement activity at STFC’s National Laboratories and our University Partnership Programme. As no final reports are submitted from public engagement awards, and Researchfish data does not capture the number of teachers reached, the 2016 figure is purely for those teachers engaged by our National Laboratories.
Appendix 5 – Academic and industrial use of UK large facilities

This appendix provides examples of recent industrial and academic users across STFC facilities (from information provided by CLF, Diamond and ISIS Neutron and Muon Source on their most significant industrial and academic users). Industrial use of STFC facilities can be either proprietary – those companies who have directly paid for and used the facility – or non-proprietary – those companies who access facilities via academics at UK and global universities and research institutes.

For commercial reasons, industrial proprietary users of the facilities often do not wish to have their names disclosed. Recent industrial users come from a wide range of important UK industrial sectors including for example: pharma, advanced technologies, steel manufacturing, chemical engineering, energy including nuclear, consumer goods, transport, and defence and aerospace.

There are a wide range of funders who support the academic use of STFC facilities including the other Research Councils (particularly EPSRC, MRC and BBSRC), Innovate UK, the Royal Society and also independent funders (such as the Wellcome Trust).

<table>
<thead>
<tr>
<th>Recent industrial users of facilities (only includes users whose names can be disclosed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFC Energy</td>
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<tr>
<td>Airbus</td>
</tr>
<tr>
<td>AkzoNobel</td>
</tr>
<tr>
<td>Alcoa</td>
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<tr>
<td>Alstom Power</td>
</tr>
<tr>
<td>AMEC Nuclear UK Ltd</td>
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<tr>
<td>Acura GMBH</td>
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<tr>
<td>Areva</td>
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<tr>
<td>Ashland Speciality Products</td>
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<td>Astra Zeneca</td>
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<td>AWE</td>
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<tr>
<td>BAE Systems</td>
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<tr>
<td>Baosteel Co. Ltd</td>
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<tr>
<td>BMW-mini</td>
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<tr>
<td>Boeing</td>
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<tr>
<td>Borealis</td>
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<td>Borgwarner</td>
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<tr>
<td>BP</td>
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<td>British Energy</td>
</tr>
<tr>
<td>Bruker UK</td>
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<tr>
<td>Cambridge Ltd</td>
</tr>
<tr>
<td>Case New Holland</td>
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<tr>
<td>Cella Energy</td>
</tr>
<tr>
<td>ChemGreen innovation</td>
</tr>
<tr>
<td>Chimet</td>
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<tr>
<td>Cisco Systems Inc.</td>
</tr>
<tr>
<td>Corus</td>
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<tr>
<td>Croda</td>
</tr>
<tr>
<td>DePuy</td>
</tr>
<tr>
<td>Domino UK Ltd</td>
</tr>
<tr>
<td>DPI Biosensors</td>
</tr>
<tr>
<td>DuPont Teijin Films</td>
</tr>
<tr>
<td>Company Name</td>
</tr>
<tr>
<td>--------------------------------------</td>
</tr>
<tr>
<td>DPI Biosensors</td>
</tr>
<tr>
<td>DuPont Teijin Films</td>
</tr>
<tr>
<td>E.On</td>
</tr>
<tr>
<td>EADS</td>
</tr>
<tr>
<td>Eastman Chemicals</td>
</tr>
<tr>
<td>EDF Energy</td>
</tr>
<tr>
<td>ESAB AB</td>
</tr>
<tr>
<td>ESAB Ireland</td>
</tr>
<tr>
<td>European Space Agency</td>
</tr>
<tr>
<td>European Thermodynamics Ltd</td>
</tr>
<tr>
<td>European Thermoelectrics Ltd</td>
</tr>
<tr>
<td>Evonik Industries</td>
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<td>Evotec</td>
</tr>
<tr>
<td>Farfield</td>
</tr>
<tr>
<td>Fujifilm</td>
</tr>
<tr>
<td>GE Oil and Gas</td>
</tr>
<tr>
<td>General Motors</td>
</tr>
<tr>
<td>GlaxoSmithKline</td>
</tr>
<tr>
<td>Gooch and Housego</td>
</tr>
<tr>
<td>Heptares Therapeutics</td>
</tr>
<tr>
<td>Hieta</td>
</tr>
<tr>
<td>Honeywell UK</td>
</tr>
<tr>
<td>HP</td>
</tr>
<tr>
<td>Infinieum</td>
</tr>
<tr>
<td>Johnson Matthey</td>
</tr>
</tbody>
</table>

Recent significant University/Academic users of facilities (UK only)

<table>
<thead>
<tr>
<th>University Name</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiff University</td>
<td>University of Exeter</td>
</tr>
<tr>
<td>Cranfield University</td>
<td>University of Glasgow</td>
</tr>
<tr>
<td>Imperial College London</td>
<td>University of Kent</td>
</tr>
<tr>
<td>Keele University</td>
<td>University of Lancaster</td>
</tr>
<tr>
<td>King's College London</td>
<td>University of Leeds</td>
</tr>
<tr>
<td>Loughborough University</td>
<td>University of Leicester</td>
</tr>
<tr>
<td>Queen Mary University of London</td>
<td>University of Liverpool</td>
</tr>
<tr>
<td>Queen's University of Belfast</td>
<td>University of Manchester</td>
</tr>
<tr>
<td>Royal Holloway University of London</td>
<td>University of Nottingham</td>
</tr>
<tr>
<td>The Open University</td>
<td>University of Oxford</td>
</tr>
<tr>
<td>University College London</td>
<td>University of Reading</td>
</tr>
<tr>
<td>University of St Andrews</td>
<td>University of Sheffield</td>
</tr>
<tr>
<td>University of Bath</td>
<td>University of Southampton</td>
</tr>
<tr>
<td>University of Birmingham</td>
<td>University of Strathclyde</td>
</tr>
<tr>
<td>University of Bristol</td>
<td>University of Surrey</td>
</tr>
<tr>
<td>University of Cambridge</td>
<td>University of Liverpool</td>
</tr>
<tr>
<td>University of Durham</td>
<td>University of Warwick</td>
</tr>
<tr>
<td>University of East Anglia</td>
<td>University of York</td>
</tr>
<tr>
<td>University of Edinburgh</td>
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</tr>
</tbody>
</table>
### Appendix 6 – Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLAS</td>
<td>A toroidal LHC apparatus</td>
</tr>
<tr>
<td>BBSRC</td>
<td>Biotechnology and Biological Sciences Research Council</td>
</tr>
<tr>
<td>BIC</td>
<td>Business Incubation Centre</td>
</tr>
<tr>
<td>BEIS</td>
<td>Department for Business, Energy and Industrial Strategy</td>
</tr>
<tr>
<td>CERN</td>
<td>Conseil Europ. en pour la Recherche Nucl. aire – European Organisation for Nuclear Research</td>
</tr>
<tr>
<td>CI</td>
<td>Citations Impact</td>
</tr>
<tr>
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<td>XFEL</td>
<td>X-ray Free Electron Laser</td>
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Appendix 7 – References

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Informing drug design at Diamond: These dehydrated crystals of membrane protein enzyme were grown at Diamond’s Membrane Protein Lab and studied on Diamond’s crystallography beamlines. These proteins are studied in crystal form because it makes it easier to work out their atomic structure. This information can then be used to design new drugs, in this particular case to treat multidrug-resistant bacterial infections.

Credit: Isabel De Moraes, Membrane Protein Laboratory at Diamond Light Source and Alice Vrielink, University of Western Australia.

Tunnels under Chilbolton Observatory house the cables that link the iconic 25m antenna to the observatory’s control room. Credit: STFC/Katherine Barnes