The background features a dark, almost black, space filled with vibrant bokeh effects in shades of blue and green. Numerous bright, out-of-focus circular spots of light are scattered throughout, some appearing as sharp points of light while others are soft, glowing discs. Thin, dark lines radiate from these points, creating a sense of depth and movement, reminiscent of a star field or a complex network of light paths.

Inspirational physics
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Introduction

The UK faces numerous policy challenges over the next five years, from threats to national security to improving economic productivity to securing our energy supply.

Science and technology have an essential part to play in meeting these challenges. The examples presented in this booklet, drawn from the impact case studies submitted to HEFCE's Research Excellence Framework exercise demonstrate this.

There is strong evidence that investment in science drives economic growth, but the outputs of research are so much more than that. The technologies developed for particle accelerators have already found their way into less invasive, targeted cancer treatments in hospitals, improving diagnoses and speeding recovery. Curiosity-driven research into optical fibres has revolutionised telecommunications and the global finance industry and also provided new opportunities for machine tooling and industrial supply chains in the UK.

The current strength of UK research is built upon sustained and secure investment over previous decades. It is the returns of that past investment that we are seeing today, and the impacts and benefits from this research are the best arguments for continuing to invest in science both today and into the future.





Aerospace, defence and security

The UK faces multifaceted security threats and maintaining modern and effective military and security services are essential for Britain's safety. Advances in materials science and sensors have demonstrated their worth in the past through technologies such as reactive armour for personnel carriers and through instrumentation such as terahertz body scanners for use in airports. In the future there will be a need to keep pace with new and emerging threats around the world, as well as developing the UK's nuclear deterrent.

Detecting a dirty bomb

Radiation detectors were once unable to distinguish between radioactivity from environmental sources and that from possible threats such as a dirty bomb. Responding to calls from the US government for the development of technology capable of detecting suspicious radioactive material at ports, University of Southampton spinout company Symetrica adapted a gamma ray detector originally developed for astronomy. Its spectroscopic capabilities allow it to distinguish between radiation sources and identify threats

hidden in shielded containers, and Symetrica's resulting product, the RadSeeker, is now the US Department for Homeland Security's main handheld radiological detector. Other radiation detectors subsequently developed by the company are in use in the European Illicit Trafficking Radiation Assessment Program and in a portal monitor trialled at the Port of Felixstowe. The company employs 26 people in the UK and US and has a turnover of £10m.

Safeguarding the UK's nuclear weapons stockpile

Swansea University physicists have established a specialist laboratory at the Atomic Weapons Establishment that has become one of the main analysis suites used to ensure the integrity and reliability of the UK's stockpile of nuclear weapons and chemical explosives. The Swansea team's innovative laser spectroscopy techniques are used to analyse the abundances of different isotopes of uranium in samples, as well as the chemical composition of conventional explosives, which have sometimes performed poorly in desert environments after exposure to heat.

Supplying space science missions

University College London's Mullard Space Science Centre has worked with CCD manufacturer e2v Ltd, helping it to secure contracts worth a total of €30m (£22m) to supply digital imaging cameras for two European Space Agency missions. The research group develops high-specification cameras for space missions and carries out fundamental research on imaging. The group has collaborated with e2v since 1995 and has been pivotal in enhancing their standing in the market. The company, headquartered in Chelmsford, is now Europe's preferred supplier for digital imaging cameras for space science applications, employs around 1600 people, and has annual sales of about £250m.

“By working closely with sensor manufactures we have been able to help them improve their products and play a significant role in developing the market, at the same time increasing both the range and understanding of very high quality optical sensors.”

Professor Alan Smith

Mullard Space Science Laboratory,
University College London



Energy

The next decade will be critical for the future and security of the UK's energy supply. Challenges, including the need to replace capacity as nuclear power stations near the end of their design lifetimes as well as the requirement for the UK to reduce carbon emissions and meet climate change targets, will mean that the UK will need to take a new approach to its energy generation mix.

Extending nuclear power stations' lifespans

University of Bristol researchers' insights into how graphite in nuclear reactor cores degrades during service, and how material fractures, allowed Magnox Ltd, the nuclear management and operations contractor, to make the case for keeping Oldbury power station operating for an extra four years, and the Wylfa plant for up to six years longer. As well as saving some £5bn, the power stations' extended lifespans meant that their electricity generation wouldn't need to be immediately replaced by high-carbon sources – playing a significant role in helping the UK meet its carbon reduction targets.

Prospecting for gas and oil

The University of Glasgow's Optics Group has applied its research in absorption spectroscopy to prospecting for gas and oil. Their 14-year collaboration with oil company Shell resulted in the development of LightTouch, a novel prospecting technique capable of detecting tiny concentrations of ethane gas – one of the best indicators of hydrocarbon reserves. Discoveries of new oil and gas reserves are increasingly rare, and sources or reservoirs themselves are often remote. LightTouch has been used in seven explorations to date, contributing to investment decisions worth hundreds of millions of pounds.

Spinning out for solar power

Widespread uptake of solar energy requires a significant reduction in the cost of materials and manufacturing. Oxford Photovoltaics Ltd was spun out of the University of Oxford in 2010 and has developed solar cells that are manufactured from cheap, abundant materials and printed directly onto glass. Production costs are around 30% of the previous lowest cost thin-film cells. To date, the company has attracted more than £3m of investment and has grown to employ 11 people. Its business model is to have their solar cells printed onto windows that are integrated into office buildings. Global revenues in the building-integrated photovoltaic sector are forecast to rise to £11bn by 2017.

“Impact-generation is a two-way process, and our work has both lead to the creation of a new tool for oil prospecting in the field and inspired us to develop new expertise to solve important problems in the lab.”

Professor Miles Padgett
University of Glasgow



Healthcare

To achieve greater capacity and efficiency, the UK's health system will need to adopt new approaches and technologies. In recent years novel imaging techniques and particle beam therapies originally developed for physics research have led to quicker diagnosis of cancers and less invasive care, saving money and improving outcomes for patients.

Developing new drugs

Interdisciplinary work at the University of Leeds has contributed to the development of techniques and technologies to improve the testing of new drugs. Researchers at the university have helped to create platforms that reduce drug stability screening by a matter of months, speeding up the emergence of drugs and saving the biopharmaceutical industry millions in R&D costs.

Diagnosing disease

3T MRI scanners developed at the University of Nottingham are now the highest resolution, industry standard MRIs, and are used extensively in the UK and globally, significantly improving health outcomes through improving the quality of clinical diagnostic scans. The scanners now represent a global investment of around £3.4bn.

Meanwhile, researchers at the University of Kent have pioneered new instrumentation to effectively image the eye, now used in eye clinics worldwide. Their instrumentation, combining two existing techniques, provides rapid images at a higher resolution than previously available, improving patient outcomes and saving money through more effective and earlier diagnoses of eye diseases.

Treating cancer

Researchers at the University of St Andrews and University of Dundee have developed a wearable light source for the treatment of skin cancer, which can be used either at home or in unspecialised clinics. The mobility and ease of use of the devices often avoids the need for hospital-based care, freeing up hospital space and time, and providing effective treatment for patients.

At the University of Bath, meanwhile, researchers have pioneered new treatments for cases of excessive bleeding and cancers by developing precision microwave treatments that allow practitioners to pinpoint tumours and sites of bleeding. The treatment has been deployed both in the UK and abroad, and has greatly reduced the time patients spend in hospitals while also providing cost savings compared with more invasive surgeries.

“The development of fast imaging techniques at the Sir Peter Mansfield Magnetic Resonance Centre in Nottingham led to a dramatic increase in the uptake of this technology for clinical research and practice.”

Professor Peter Morris

Sir Peter Mansfield Imaging Centre,
University of Nottingham



Manufacturing and commerce

A rebalanced UK economy must be built on high skilled, high productivity jobs and industries. UK physics-based sectors already account for £77 bn in GVA, with worker productivities twice the national average. The development of new products, techniques and processes opens up a wealth of opportunities for the UK economy, allowing the country to lead the way in new markets.

Creating new manufacturing processes and clusters of companies

Work at the University of Southampton has resulted in new manufacturing processes used in the automotive, aviation, defence and medical device sectors. Their research on ytterbium-doped silica fibre was behind an entirely new business sector based around efficient industrial fibre lasers. As well allowing the industries in which these lasers are used to reduce their carbon footprint, it has given the UK a foothold in an industrial laser market worth £1.3bn through two spin-out companies, Fianium and SPI Lasers, which have a combined turnover of £50m and employ around 300 people.

Meanwhile, University of Strathclyde's research into solid-state lasers and non-linear optics has led to the creation of innovative laser companies. Coherent Scotland and M Squared Lasers have generated £135m worth of sales of products since 2008, with applications in biomedical imaging, security, defence, and pollution monitoring.

Maintaining a world-leading market share for scientific instruments

Research at the London Low Temperature Laboratory at Royal Holloway, University of London, has been a principal driver of improvements in scientific instrumentation, refrigeration and thermometry, including the development of new commercial scientific instruments. The main beneficiary is Oxford Instruments Nanoscience, a global company that creates high-performance cryogenic environments for applications in physics, chemistry and materials science. Products developed jointly with Royal Holloway have enabled them to maintain a world-leading market share. Revenues from two models of cryogenic fridge produced since 1997 are more than £8m, and the global market for their latest product is expected to surpass £600m by 2025.

Saving jobs in lighting manufacturing

Durham University and an industry consortium have patented an alternative to mercury-based fluorescent lamps based on the university's research into light-emitting polymers. The companies are investing in scaling up production to a full commercial supply chain, and the success of the project was behind the decision by Thorn Lighting, the largest lighting manufacturing employer in the north east of England, not to close its County Durham site, saving around 600 jobs.

“Opening access to ultralow temperatures, and measuring those temperatures precisely, underpins the exploitation of new disruptive quantum technologies, and our curiosity-driven programme of research has inspired innovation and instrumentation development.”

Professor John Saunders

Royal Holloway, University of London



Spurring a new multimillion-dollar industry

New optical fibres based on photonic crystals pioneered at the University of Bath form a world market worth an estimated £23–47m a year. The unique properties of the fibres opened up new ways to control light, and led to the creation of new companies, new sectors for established companies, and stock products for component suppliers. Applications for academia and industry include physical and biomedical imaging, microscopy, spectroscopy, sensing, metrology and laser gyroscopes.

Designing new supercomputers

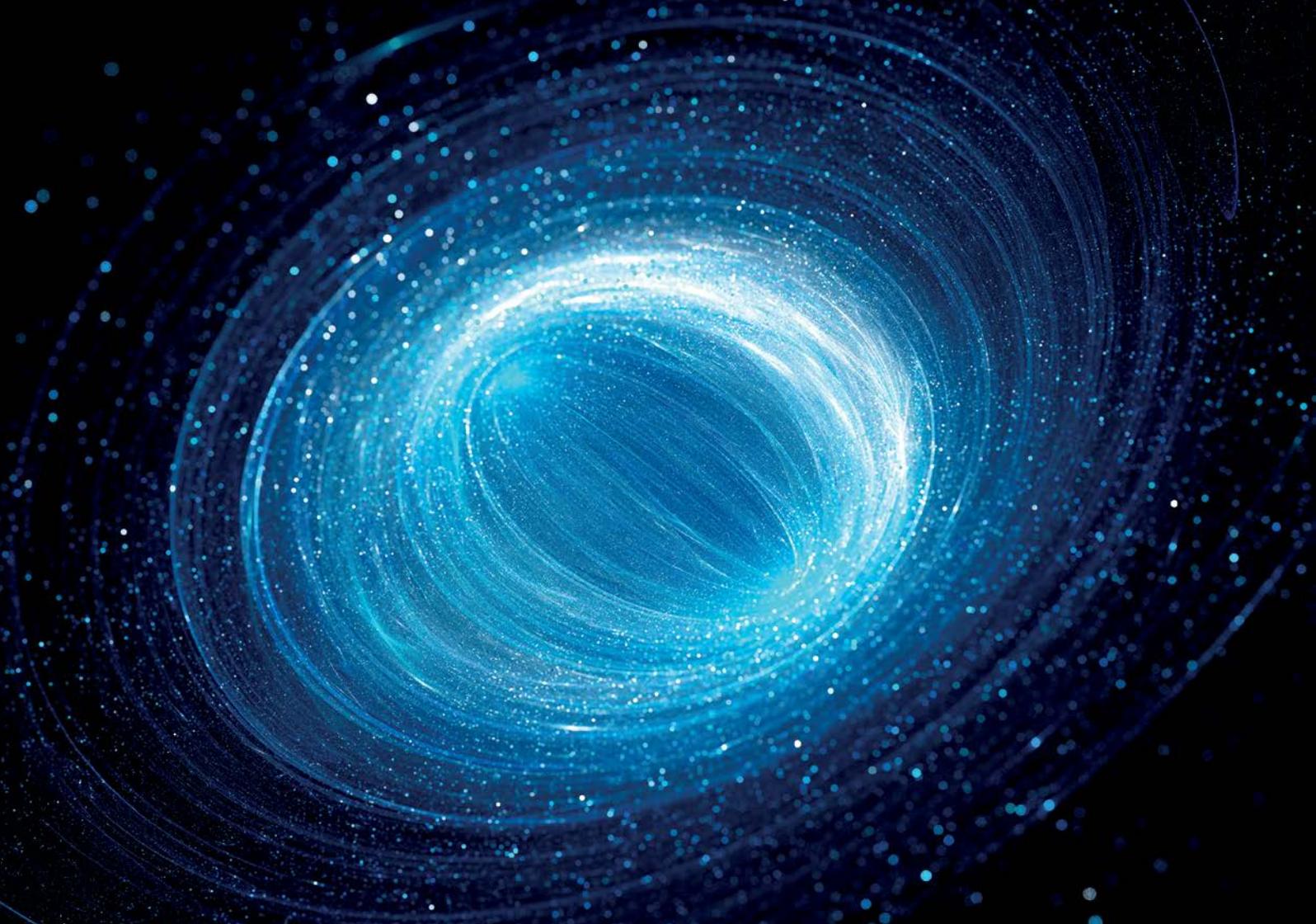
Collaboration between the University of Edinburgh, Columbia University and IBM has led to the development of a new generation of supercomputers now adopted by IBM and Fujitsu. Originally designed to aid physics research, £335m worth of the technology has been installed in labs in the UK, US, EU and Japan and is accelerating computer science and advanced manufacturing all over the world.

Pinpointing positions

Novel radio-location technology developed at the University of Cambridge by Cambridge Positioning Systems (CPS), acquired by Cambridge Silicon Radio (CSR) in 2007, is behind an enhanced GPS system that's both faster and more accurate than its predecessors. It's used in mobile devices and computer server technology, the latter of which is central to CSR's 'location as a service' business, through which users' locations are provided to businesses for purposes such as asset tracking or location-based advertising. CSR's system powers 40% of that market, and in 2012 the company reported revenues of more than £680m.

“Cambridge Positioning Systems Ltd was set up to develop and exploit an entirely new radio location technology, which arose from radio astronomy research at the Cavendish Laboratory during the 80s and 90s. CPS location technology has since underpinned developments including improving positioning performance in mobile phones.”

Peter Duffett-Smith
University of Cambridge



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