ISIS Neutron and Muon Source Lifetime Impact Report - Summary
Setting up a measurement on the IMAT instrument at ISIS. IMAT provides imaging and stress measurement capabilities for engineering applications. Credit STFC.
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Executive Summary

This report summarises our main findings from the ISIS Lifetime Impact study, which outlines the economic and social impact of the ISIS neutron and muon source, a major centre for research in the physical and life sciences (using data from 1985-2014). The ISIS Lifetime Impact study was commissioned using data by the Science and Technology Facilities Council (STFC) in response to the recommendations of the BEIS “Big Science and Innovation Report”1, to produce more ambitious and far-reaching evaluations of large-scale facilities. It is also part of STFC's ongoing programme of data capture and impact evaluations. For full analysis and discussion see our full report; the ISIS Lifetime Impact Study.

ISIS is funded largely by the UK Government and is operated by STFC on the Harwell Campus, near Oxford. The facility has been in operation since 1984, annually supporting a national and international community of 3,000 researchers from academia and industry. From the outset, it has been one of the most advanced spallation1 neutron sources in the world, and has demonstrated to the global scientific community the feasibility and benefits of using a spallation source for the production of neutrons for science. The only facility of its kind in the UK, ISIS allows scientists to study materials at the atomic level using a suite of instruments. Research is undertaken in a wide variety of subjects including Physics, Chemistry, Materials Science, Geology, Engineering and Biology. The facility was originally expected to have an operational life of some 20 years (1985 to 2005), but its success prompted further government investment and significant refurbishment, including the construction of a second target station, intended to advance the facility and extend the life of ISIS through to 2030.

In the ISIS Lifetime Impact Report we have estimated the immediate direct economic impact of ISIS over 30 years, and have also characterised the wider economic impacts among industry users and suppliers for example. To better assess the wider economic impact, we have gone beyond conventional approaches; in particular using research case studies and direct estimates of value from industry to estimate wider economic benefits.
Overall we have estimated:

• **ISIS will deliver at least £1.4 billion in net economic impact, based on what has already been achieved up to 2014.** This total comprises £1 billion of past economic impacts estimated from the research, innovation and skills that have been generated by the facility and the direct impact to the local economy that comes from employment and supply chain effects. It also includes £0.4 billion of future economic impact up to 2025, generated from research already completed.

• **ISIS has delivered a healthy Return on Investment (RoI) of at least 214%.** Our conservative analysis indicates that ISIS has already paid for itself twice over, thus clearly demonstrating how publically funded research and innovation drives economic growth, as outlined in the Government’s Science and Innovation Strategy.

• **ISIS will generate a further £1.4 billion of economic impact, based on predicted future achievements up to 2030.** This includes what we expect ISIS to generate from likely new work in the future. With an expanding instrument set and planned upgrades, we estimate the impact of the next 15 years of ISIS operation could easily match the output seen in the first 30 years. ISIS also remains as a capital asset worth £0.5 billion to the UK, with additional value in the associated skills base.

The numbers presented here are a conservative estimate of the impact of ISIS and in reality are likely to be higher. Gaps in historical impact data, as well as the time and cost challenges of researching all impact case studies fully for a report such as this inevitably results in limited estimates. Therefore, this kind of study can only ever provide an outline of the impact that such facilities provide academically, socially and economically. Figure 1 represents all our estimates of the different types of social and economic impact which are attributable to ISIS. Further information on each aspect of the analysis is highlighted and colour coded throughout the report. Further information is also detailed in the Appendix.

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**Figure 1; Past and future Economic Impact of ISIS**

2. Spallation is a process in which fragments of material are ejected from a body due to impact or stress. Nuclear spallation is one of the processes by which a particle accelerator may be used to produce a beam of neutrons.
Other highlights from our study include;

• **ISIS research is world-class.** ISIS publications comfortably outperform the UK average and it is not uncommon for selected ISIS publications to achieve several hundred citations within a three-year window. Academics using ISIS have produced more than 10,000 publications and our study has shown that research undertaken on the facility is world-class. ISIS allows scientists to work on the frontiers of biomedical research, chemistry, pharmaceuticals and fundamental biochemistry, for applications including clean energy, the environment, nanotechnology and materials engineering. For example, developing a new method of cleft palate treatment, or identifying better solutions for waste water treatment.

• **ISIS is an internationally recognised facility, attracting researchers from across the globe.** ISIS is renowned for the quality of its instruments; with its tradition of innovation and leadership in technical developments. ISIS is the first major facility of its kind in the world, has played a critical role in demonstrating the feasibility and benefits of spallation sources. This has secured its highly regarded international reputation and its work has changed the global landscape, opening up fresh opportunities internationally; with a number of neutron sources (such as the Spallation Neutron Source in the US, J-PARC in Japan and the European Spallation Source or ESS currently being built in Sweden) based on ISIS.

• **The facility has long-established industrial links with more than 100 companies** including household names such as Rolls-Royce, Unilever, Airbus and BP. Over the past 30 years, UK and global industries have benefited directly with their research on ISIS supporting advances in a wide range of products. Industrial products developed have included catalysts, aeroplane components, shampoos and lubricants to name but a few. For example, Unilever has developed personal care products and UK start up Orla Protein Technologies has developed new health diagnostics devices.

• **ISIS creates innovation impacts.** UK industry also benefits from being awarded contracts for the construction, maintenance and development of ISIS, benefiting sales, reputation and productivity. ISIS users and staff have also generated intellectual property including spin-outs, patents and licences. ISIS plays an important part in the local economy and is central to the success and attractiveness of the Harwell Science and Innovation Campus.

• **ISIS nurtures scientific talent in the UK.** ISIS provides ‘on-the-job’ training to 500-800 early career researchers each year, who go on to work in academia and industry. A large majority of ISIS users also judge ISIS to have helped them to make a significant contribution within their field; as well as having had a strongly positive impact on the skills of their research teams and their international reputation.

• **ISIS provides valuable skills to industry.** Industry recruit staff with specialist skills developed from ISIS and also benefit directly from knowledge exchange and collaboration activities. For example, the Siemens’ ONIAC facility (short for ONIon ACcelerator) was a collaborative development with ISIS which aimed to test accelerators for medical isotope production.

ISIS has created substantial long-term impact. From the original vision over 30 years ago, ISIS has become one of the UK’s major scientific achievements. As the world’s leading pulsed neutron and muon source, ISIS has changed the way the world views neutron scattering and has delivered major social and economic benefit for the UK and other economies. Our study has backed up the findings of the 2013 International Peer Review of ISIS which stated –

> “ISIS operations are providing an excellent capability to the user community, and are certainly world-class. ISIS has, since its creation, been able to create a culture of innovation that has had profound impact on, and will continue to change, the way neutron scattering is performed world-wide. Very few research institutions have demonstrated similar drives toward innovation and spread of the resulting technological development.”

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4 Independent panel review of ISIS conducted in 2013. see www.stfc.ac.uk/news/uk-science-facility-praised-by-international-review/
Introduction

The ISIS pulsed neutron and muon source, run by STFC, is part of the Rutherford Appleton Laboratory (RAL) at the centre of the Harwell Campus, one of the UK’s Science and Innovation Campuses. The ISIS facility was originally expected to have an operational life of some 20 years (1985 to 2005), but its evident success led to further government investment and a process of ongoing and significant refurbishment; extending the life of ISIS through to at least 2025. It has a staff of around 370 people and hosts around 1,500 individual scientific visitors each year, carrying out more than 700 experiments entailing more than 3,000 user days annually (as of 2014).

We have calculated the impact of the ISIS facility over 30 years, since its inception up to 2014 and have estimated its future impact up to 2030. We detail the spectrum of social and economic impacts realised across ISIS, quantifying those benefits where possible, and summarising the overall impact. To do this, we have taken a broad approach, comprising in-depth research on the ISIS facility and its resultant impacts using both primary and secondary data gathered from a variety of sources. We summarise both quantitative and qualitative evidence that demonstrates the wide range of impacts that ISIS has made possible over its lifetime.

Figure 2 presents a schematic of the kinds of social and economic impacts we believe can arise from investment in facilities like ISIS, and which are used to organise our impact methodology.

Figure 2 - Social and economic impacts flowing from large research infrastructures. Source: Technopolis (2014), adapted from “Big Science and Innovation” (Technopolis, 2013)
3. Impact from ISIS research

ISIS has underpinned fundamental and applied research in numerous fields throughout its lifetime. It supports an international community of several thousand scientists from academia and industry, who use the facility to support research including Physics, Chemistry, Materials Science, Engineering and Biology. Over the past 30 years, these fields have seen wide-ranging advances which have improved our understanding of the world. As a result, the facility has supported key advances which affect people’s lives in areas including healthcare (drug delivery, antimicrobial resistance and lung health), engineering and materials (sensor technology, industrial coatings and bone replacement materials) and the environment (water pollution, atmospheric pollution and climate change).

Economic impact of research

ISIS research produces significant economic impact for the UK. Conservatively estimated, ISIS research has delivered £340 million over the lifetime of the facility (1985-2014) and research already completed will deliver a future benefit of £140 million (up to 2025), totalling at least £480 million.

In order to estimate the wider economic impacts associated with ISIS’s scientific achievements, we looked in depth at 10 case study examples. This group of 10 extended impact case studies was identified following consideration of the 50 most promising examples selected from within a larger catalogue of 150 cases. There is no definitive means by which to relate this group of 10 cases to ISIS’s total research endeavour over the past 30 years, however, we came to a view based on what this represented within ISIS’s archive of case studies. These case studies describe how ISIS research has supported significant technological innovation and commercialisation, the benefits of which will be felt to 2025 and beyond. Some examples of the case studies are detailed below including the value we believe is attributable to ISIS directly. For more information see the Appendix or the full ISIS Lifetime Impact Study.

Improved orthopaedic implants could save the NHS £200 million and support £20 million of additional UK sales to 2025. Some 5% of those savings and 5% of this projected additional economic activity is attributed to ISIS, due to the critical contribution of neutron scattering. ISIS has also contributed to the creation of new, more durable, bioactive implant coatings, as well as an associated patent application that has strengthened the technology portfolio of a UK-based spin-off company, Taragenyx.

Patented technology helps meet the UK’s greenhouse gas emission targets and grow a market worth a potential £3 billion a year to UK business by 2030. Failure to deliver carbon capture and storage will have profound implications for the UK economy. ISIS helped to develop a new material for carbon capture and storage, called NOTT-300, which is more efficient than current products. The global market for this is valued in the hundreds of millions of pounds annually, and perhaps £2 billion in total through to 2025. Given the critical role played by ISIS in the design of NOTT-300, at least 1% of this figure is attributable to ISIS.

ISIS has contributed to world-class research in organic electronics, with a global market value over £13 billion. The overall future revenue for the UK is likely to run into the many tens of millions of pounds, and may be as much as £500 million over the next 10 years through to 2025. ISIS has contributed to our understanding of these materials and will continue to be critical. 1% of estimated total future economic output for organic semiconductors in the UK is attributed to ISIS.

ISIS enables advances in forensic science which could help reduce the cost of crime, currently more than £124 billion a year in the UK. A 1% improvement in the cost-effectiveness of the national criminal justice system would amount to £20 million plus indirect savings over 10 years. With a 0.1% reduction in national crime rates attributable to these scientific advances, this would yield a further £23.4 million in savings. The contribution of ISIS to the evolution of the new fluorescence technique for fingerprint detection has been significant, and so we attribute 5% of the anticipated future UK social and economic benefits.
Energy generation - keeping nuclear power plants safe. Working with the Open University, EDF Energy saved £3 billion by extending the life of nuclear power stations by five years. ISIS was used to predict the lifetime of welds and the knowledge gained enabled the life extensions to 15 nuclear reactors. Benefits included providing low carbon energy to two million homes, £650 million a year in contracts for mostly UK-based businesses to carry out the repair work, and the safeguarding of 2,000 jobs in the nuclear power industry. We give ISIS a 1% attribution of the very large amount of additional economic activity that will result from this major refurbishment work over the next decade.

ISIS has improved fundamental research

The economic and social benefits of ISIS are wide-ranging. ISIS underpins a significant fraction of science subjects and has created significant long-term impact. ISIS research supports big opportunities such as technologies based on new materials, advanced manufacturing and bio-engineering, as well as the big challenges we face such as energy generation, antibiotic resistance and global warming.

ISIS has advanced fundamental research in many areas ranging from quantum magnetism and superconductivity to the behaviour of surfactants and the mapping of residual stresses in materials. These fields are major, long-term and fundamental global areas of research in which...
Grace Ronnie, University of Leeds and Infineum UK Ltd, prepares samples for an ISIS experiment. Credit STFC
ISIS plays a key role, along with other research bodies. The social and economic impact of such fundamental research unfolds over many decades and through the combined efforts of hundreds and possibly thousands of scientists and engineers. Therefore it is not straightforward to put a figure against the economic impact of such work and although we sought out statistics about relevant global markets, we did not attempt to go as far as to claim any attributable share of those markets for ISIS. However, we looked at a number of important ISIS case studies and examples of long-term, global research impacts including:

- **Bucky balls**: The crystal structure of C_{60}, a novel form of carbon also known as bucky balls, was first discovered in 1985. However, their discovery was only accepted in the early 1990s, when their crystal structure was determined at ISIS. As a result the scientists involved won the 1996 Nobel Prize for chemistry. Bucky balls are now recognised as one example of a group of carbon forms called fullerenes, and this created an entirely new branch of chemistry. 300 new patent applications relating to fullerenes have been made with thousands more pending. Currently, they are being utilised in high-performance lubricants, innovative fuels, and new classes of superconductors and magnets. This is benefiting UK companies with the global market for products which use fullerenes estimated as £200 million in 2008, a figure which was expected to rise to £3 billion in 2015.

- **Magnetism**: From electric motors to computer hard disks, magnetism underpins much of modern technology and ISIS has enabled a wide variety of studies of magnetic materials for 30 years. The worldwide market for permanent magnets alone reached £7.5 billion in 2013 and is expected to grow to £10 billion by 2018. A better understanding of magnetism will drive the creation of new materials with applications in energy management, memory storage, and multifunctional devices. It also holds the potential to reduce the global demand for rare-earth elements that is currently outstripping supply.

- **Superconductivity**: Superconductors are materials that exhibit no electrical resistance below a certain critical temperature. ISIS has determined the structure of numerous superconductors: for example, the world’s first high-temperature superconductor in 1986. This work at ISIS will provide the basis for future developments, with promising application areas including new power storage devices, improved electric power transmission, and more efficient electric motors.

- **Surfactants**: Surfactants improve the efficiency of home and personal care products such as detergents, shampoos and cosmetics, and can be found blended with a range of ingredients. Research on ISIS has led to new breakthroughs in these products and the development of major new techniques to study them. At the inception of the facility, ISIS was the only place in the world where such research could be carried out and new instruments have opened up an even larger spectrum of research. Much of this work is industrially relevant for the UK: for example, the development of more environmentally friendly solvents.

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5 By researchers, Robert F. Curl, Harold W. Kroto and Richard E. Smalley
ISIS contributes to UK research standing

ISIS publications outperform the UK average and it is not uncommon for selected ISIS publications to achieve several hundred citations within a three-year window\(^{11}\). Academic users also rate ISIS as critical to their scientific understanding, research quality and experiment skills and that of the UK research field as a whole.

ISIS has produced more than 10,000 publications and our study has shown that research undertaken on the facility is world-class. ISIS was subject to an international peer review in 2013 which concluded that ISIS was one of the most productive research centres of its type in the world, benefiting from experience, skills and knowledge developed over three decades of operation. Physics and Materials Science have dominated ISIS research; however, there is a clear increase in the disciplinary diversity of publications over time. The quality of the research can be confirmed through analysis of the publications from the facility. Analysis of citation counts in selected years show ISIS publications receive around four to eight citations on average within a three-year window, while only 20-30% go un-cited. The most cited ISIS journal articles achieve several hundred citations, often outperforming the UK average for the fields in question and often appearing within the higher-impact journals.

Another indicator of the quality of ISIS research is our survey of 200 academics who have used ISIS. The results of the survey were conclusive with users rating ISIS as having been critical to their scientific understanding, research quality and experimental skills, and that of the UK and international research fields as a whole. Respondents stated that ISIS played a critical or significant role in improving their research productivity (over 85%) and the quality of their research (over 90%). The survey indicates the value of ISIS as a powerful, unique, research facility:

> ‘ISIS has some of the best-engineered instruments in the world and several of the neutron scattering experiments we have successfully performed at ISIS and have obtained extremely high-quality data would simply not have been possible anywhere else in the world.’

ISIs at the forefront of technology development

ISIS has had an innovative approach to instrument design and technology development. Without the existence of ISIS, numerous research applications and new technologies may have gone unexplored, both in the UK and internationally.

The technology used to support ISIS has been developed continuously in order to maximise the research potential of the facility. This has enabled numerous advances in instrumentation, target materials, analytics and software. Many of the instruments developed at ISIS are world firsts which have gone on to be widely adopted at other large-scale facilities around the world. For example, the development of the Paris-Edinburgh cell, a specialised high pressure sample container, enabled a new understanding of materials at high pressures. The international significance of this technology is demonstrated by its proliferation – adopted not only by neutron facilities but also used in X-ray scattering applications and beyond, so that there are now ~90 worldwide. The multi-million dollar high pressure neutron diffraction facilities recently developed in the USA and Japan are directly inspired by this technology. ISIS is also closely involved in the development of similar capabilities at the ESS, the next generation neutron source in Europe.

\(^{11}\) A ‘highly cited paper’ (as defined by Thompson Reuters) is paper that belongs to the top 1% of papers in a research field published in a specified year. The 1% is determined by the highly cited threshold calculated for the research field in the specified year. Usually 100 citations over 3 years is considered significant and would usually class the research paper as ‘highly cited’ in a physics field although this may vary. Reference: http://ipsscience-help.thomsonreuters.com/incitesLiveESI/glossaryAZgroup/g2/8251-TRS.html Accessed August 2016
**ISIS is a globally recognised facility**

ISIS has been essential for the UK’s international reputation. Without the existence of ISIS, numerous research applications and new technologies would have gone unexplored, both in the UK and internationally. Between 1987 and 2009, ISIS received £56 million in international contributions, some 14% of total income, underlining the attraction of the facility and the UK for international researchers.

ISIS is a national research facility, designed to meet the needs of UK scientists in the first instance. However, it has always had an international outlook, with access to its instruments awarded through open competition to the best scientific proposals. As the world’s first facility of its kind, ISIS has attracted international interest from its inception, and has enjoyed long-term strategic relationships with many scientific nations. These agreements provide contributions to ISIS instruments, benefiting the whole international user community. In 2014, ISIS had 26 live agreements with research institutes, laboratories, and government departments in 12 countries across the world.

A notable example is the 20-year collaboration with the RIKEN institute in Japan, resulting in tens-of-millions of pounds of investment by Japan in a new ISIS facility (the RIKEN-RAL Muon Facility). In 2010, Japan and STFC signed their third international collaborative agreement, under which Japan provides funds and staff to operate, maintain and upgrade the facility, its instruments and beamlines. It has involved researchers from over 50 Japanese institutes and resulted in around 300 published papers.

In our academic survey, over 70% of respondents also stated that ISIS was critical in improving the international reputation of their research group. Between the early 1990s and 2013, the number of countries affiliated to ISIS publications has increased significantly from 10-20 to over 50 in 2013. This is a good indication of ISIS’ increasing international reputation and the global reach of its research.
4. ISIS innovation impacts

Over the past 30 years, UK and global industries have benefited through interactions with ISIS. The facility has wide-ranging and long-established industrial links with more than 100 companies involved in collaborative work, including household names such as Rolls-Royce. Businesses have benefited through long-term usage of the facility to help solve industrial problems in areas ranging from consumer goods, automotive, oil and gas, aerospace, energy and pharmaceuticals. ISIS is the only place in the UK where industry can access this kind of facility and expertise. For example, Unilever is ISIS’s biggest industrial user since it opened in 1985 and they have detailed its commercial importance in a letter to Government. Industry also benefits from being awarded contracts for the construction and maintenance of such a highly technological facility, benefiting sales, reputation and productivity. ISIS users and staff have also generated intellectual property thanks to the facility, including spinouts, patents and licences. Finally, ISIS is an important part in the Harwell Campus, playing a key role in strengthening the cluster and attracting a range of collaborators.

Economic impact to industry

The industrial use of ISIS has and will continue to be of direct benefit to the UK economy. Companies who use ISIS report increased productivity, competitiveness and share value. We conservatively attribute around £200 million of net economic impact directly to ISIS over the lifetime of the facility, and a future net economic impact of £200 million (up to 2025).

Industry can either directly buy proprietary access to the facility or, more commonly, access the facility in collaboration with academics at universities. Proprietary access provides companies with a means of using ISIS privately. This allows them to keep results out of the public domain when commercially sensitive, helping UK business remain competitive. Our report estimates that both modes of access equates to 2–3% of the total beam time over the lifetime of the facility, and that companies presently account for 10-15% of time on ISIS. The top industry users of ISIS include Unilever, Toyota, BP, Johnson Matthey, General Motors and EDF Energy. Several of these companies have used the facility for over 30 years. The majority of the top industry users are large multinational companies, many of which are PLCs headquartered in other countries elsewhere in Europe or the US but often with research laboratories in the UK. This underlining both the importance of ISIS and the quality of UK science as an attractor to global companies.

To estimate the impacts of industrial usage of ISIS, companies own estimates of value were used through proposals to the new Industry Collaborative Research and Development (ICRD) programme. All ICRD proposals are required to include a description of anticipated benefits, and 15 of the 36 proposals (42%) also attempted to quantify future benefits. For those who were able to quantify benefits of working with ISIS, together they forecast more than £500 million in additional income or savings for the participating companies and their supply chains. In several cases, benefits are anticipated to accrue each year, many years into the future, suggesting that this group of current ISIS experiments may help secure or expand national economic activity by several billions over the next decade. This provided a means to extrapolate the likely impact of direct industrial usage of ISIS over its lifetime. For details of how this was calculated please see the Economics Analysis in the Approach and Methodology section.

Some ISIS examples of industrial use include:

- **INEOS ChlorVinyls** is Europe’s largest manufacturer of chemicals, used to produce materials such as PVC, which are important components of many everyday products, from window frames to pharmaceuticals. The company used ISIS to eliminate undesirable by-products from their manufacture process. The results enabled the surface of the catalyst used in the process to be modified, leading to improvements in manufacturing and a significant reduction in the unwanted side product. The new catalyst has been used successfully at INEOS’s Runcorn site for 10 years.

- **Rolls-Royce** has been a regular user of ISIS since its inception and has co-authored a number of scientific publications involving ISIS. Rolls-Royce needs to constantly develop new engines with improved fuel
efficiency and reduced environmental impact in order to retain its competitive edge and this requires developing new techniques beyond the cutting edge. For example, modern aircraft incorporate a range of high performance alloys which often cannot be welded by traditional techniques. Rolls-Royce and the University of Manchester have used ISIS to test new welding techniques. This allowed Rolls-Royce to use inertia friction welding to build Trent engines, which now power a range of the Airbus and Boeing aircraft. By 2014 more than 1,500 of the Trent XWB engines have been ordered exceeding a value of £60 billion.

• **Unilever** is a multinational company and one of the world’s leading suppliers of personal care and food products. Unilever has been using ISIS regularly for more than 30 years and has purchased beam time to better understand and manipulate surfactants used in fabric and hair conditioners, paints, coatings, cosmetics, foodstuffs and drug delivery systems. Although, for reasons of commercial sensitivity, the details and value of ISIS research is not publically available from Unilever, the value of this research can be indicated by the fact that Unilever are currently the heaviest industrial user of ISIS. They have also written a confidential letter to Government in support of the facility, which provides an example of the value of ISIS research to their business. This letter describes how using scattering techniques at ISIS improved product quality and optimised processing conditions, significantly increasing the turnover of their business.

• **Airbus** is the world’s leading commercial aircraft manufacturer, generating revenues of £59.3 billion in 2013. Some 100,000 jobs are generated in the UK by Airbus wing production, both directly as well as indirectly through an extended supply chain of over 400 companies. Since 2006, experiments at ISIS have enabled Airbus engineers to improve their manufacturing processes and produce safer aircraft at a lower cost.

• **BP** is a long-term user of the ISIS facility and the second heaviest industrial user of ISIS between 2012-2015. BP is one of the world’s largest manufacturers of lubricants and has been using ISIS to continuously improve its lubricant products. Millions of tons of lubricants are consumed worldwide on an annual basis, and technology improvements are one of the key ways that companies like BP deliver value in this business. It is estimated that the value of new knowledge from scientific research in this market sector could amount to 0.4% of GDP in industrialised countries.

A survey of proprietary industrial users was also carried out for our study. Respondents reported a significant impact in their domain knowledge, the ability to work successfully with academia and positive impacts on their company’s approach to R&D. Users also reported a positive impact on their productivity, competitiveness and share value. A few companies also stated benefits adding up to millions of pounds per year.

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14 This confidential letter is available to Government on request
15 Lubricants and lubrication. 2nd Edition. Edited by Mang, T. and Dresel, W.
ISIS offers advantages to its suppliers

Suppliers reported that working with ISIS had increased sales, improved the quality and productivity of their business and helped them grow both nationally and internationally.

Big science facilities constitute a major market for the global scientific instrumentation sector. They are also important markets for suppliers of generic products and services, demanding a high level of precision and quality which can provide positive spillovers to suppliers. Some 180 suppliers provided high value equipment for ISIS Target Stations 2 (TS2) during its construction in 2005, and several hundred companies have provided equipment, and benefited from this relationship over the years of ISIS construction and operation.

A survey of suppliers to TS2 illustrated that companies derived substantial benefits in numerous areas of their business. The majority of suppliers suggested that their sales to ISIS had a positive impact on new products or services (83%), increased domestic sales (73%), increased quality (71%) and increased productivity (62%). Around 40% of the 46 responding suppliers reported some degree of positive impact on third-party sales of products/services originally developed for ISIS, 30% reported an increase in international sales and 20% reported an increase in employment. For many suppliers, the capabilities, products and reputation developed through supplying to ISIS were incredibly important – often leading to wider opportunities and sales. Improved capability and this kind of reputational benefit is widely reported by companies serving large international scientific facilities like CERN. Benefits stated in the survey include:

- “Increase in sales turnover.”
- “Employment of more people within the company.”
- “ISIS as a customer is a prestigious organisation and is good to have within our customer portfolio; ISIS is a well-known company and hence a valuable reference for us when trying to find new customers.”
Although the following examples indicate that the benefits to the companies have been substantial, not all of the companies in the case studies below were able to estimate the value of the financial impact from the role that ISIS directly played in their business:

- **Oxford Instruments** is a leading UK technology company with a £350 million turnover in 2012/13. It designs and manufactures high-technology tools for the science, energy, environmental, health and security industries. Oxford Instruments and STFC (and its predecessors) have collaborated for over 30 years on the development of many technologies including superconducting wire and magnets, particle accelerators and applications of cryogenic technology. The company estimates that it has gained financial benefit in excess of £100 million, although this figure could be considerably higher, from this long-standing relationship. Sales of superconducting magnets and associated equipment directly supplied to ISIS, Synchrotron Radiation Source and Diamond has amounted to more than £2 million.

- **Applied Scintillation Technologies** (AST) is a UK SME employing 45 staff, which has been supplying ISIS for more than 25 years. It provides specialist detector materials which are employed in the majority of ISIS’s current 26 neutron scattering instruments. The close relationship between AST and ISIS scientists has helped it remain at the forefront of neutron detection technologies and contributed to the company’s five-fold increase in employment over the last 15 years. As a direct result of supplying ISIS, AST now supply to neutron scattering facilities in Japan and the USA. The substantial history of sales and development work with ISIS has helped to provide a respected track record for their products which is underpinning sales internationally. Working alongside ISIS and the wider neutron scattering community helps drive AST’s product development and opens new doors, through direct introductions or indirectly through citation in academic papers.

- **Prototech Engineering** is a small precision engineering company set up in 1991, located a mile away from ISIS. In 2009, Prototech was awarded a four-year, £400k contract to manufacture the neutron moderators for ISIS Target Station 2, equipment which is critical to the performance of the facility. The proximity to ISIS enabled close collaboration between the facility scientists and the manufacturer, ensuring an economical and high-quality product to be delivered. This contract gave the company the stability and reputation to bid for large contracts with other large research facilities.
Intellectual property is created through ISIS research

There are numerous examples of the successful commercialisation of ISIS research. New technologies, patents and spin-offs have benefited or arisen as a result of ISIS, with 10% of academics surveyed reporting patents linked to ISIS research.

ISIS consciously pursues an open access strategy and the majority of users publish their work, unless they pay for proprietary access. Any intellectual property generated by ISIS users is likely to be owned by the university or company in question and would not necessarily be known to ISIS. Nevertheless, there are numerous examples of technologies, patents and spin-offs that have arisen as a result of work done at ISIS either directly by ISIS staff, or through the work of ISIS users. Respondents to the academic survey were asked to estimate the number of knowledge transfer-related outputs for their group linked to research done at ISIS. Around 10% of respondents indicated that they had applied for patents (28 in total with 10 from one research group) and 128 research contracts had been won at a value of over £5 million. There are also 18 start-ups companies mentioned in this survey, spread across 12 research groups. Collectively these commercial outputs indicate a relatively high knowledge exchange and commercialisation rate for research involving ISIS. One respondent cited the following example:

• “Studies on energetic materials have been of significant benefit to UK MOD/DSTL and have provided the UK Government with leverage in exchanging information with US and other NATO partners.”

Orla Protein Technologies is one example of a spin-out from Newcastle University which has benefitted from ISIS work. The company has been developing protein surfaces suitable for use in biosensor devices since 2002 and ISIS was critical in their technology development. In 2008, Orla established a spin-out company with a multinational electronic communications supplier, creating a miniature wireless sensor that can rapidly detect infectious diseases and send information using a smart phone. This low-cost device could be used for consumer diagnostic applications in remote or rural areas, and the technology is now ready for pilot production.

ISIS also employs researchers directly, who, as well as supporting ISIS users, undertake experiments either in collaboration with external researchers or on their own by applying for beamtime through the same routes as external users. Therefore there are examples of technology, intellectual property and spin-outs generated directly from research by ISIS staff, an example of which is given below:

• **Cella Energy** is a STFC spin-out, launched by Professor Stephen Bennington from ISIS, together with Stephen Voller in 2011. Cella Energy was developed on the back of ISIS research, has expertise in materials and hydrogen storage and owns unique patented technology in safe, low-cost hydrogen storage materials. In 2014 the company employed 11 staff and had offices and a laboratory at the Harwell Campus, as well as at the NASA Kennedy Space Center in the US. Cella Energy has attracted millions of pounds of external investment from a number of sources since its launch. Hydrogen as a fuel has the potential to dramatically reduce dependence on oil – an environmentally friendly alternative to fossil fuels, which could revolutionise energy generation in a number of markets projected to be worth billions of pounds in future decades.

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16 This figure is not included in the overall economic calculations due to only a small number of businesses (10) answering our survey, reducing the reliability of this number.
ISIS plays a key role in the local innovation ecosystem

Harwell is a leading Science and Innovation Campus with research infrastructure collectively worth around £1 billion. It has been in existence in different forms for over 60 years and ISIS has been a central part of the site for 30 years. Over 5,000 people are now part of this vibrant, fast-growing community, working in some 200 organisations. These include Research Councils, other facilities such as the Diamond Light Source and the Central Laser Facility, and start-ups and multinational businesses that focus on a range of commercial applications. ISIS sits at the heart of the Campus, with ISIS staff and visitors rubbing shoulders with scientists and engineers from other facilities and tenant companies. Multiple informal links are common, with people becoming involved in collaborative projects and joint ventures, meeting new suppliers and customers as well as securing privileged access to insight and ideas about emerging technology.

The Research Complex at Harwell, opened in 2009, currently hosts more than 100 long-term scientific visitors. Offices and lab space are available to Research Council grant holders who use the large facilities at Harwell (Diamond, ISIS, CLF). Part of a national research infrastructure which attracts and retains global companies; the ability to remain on the Campus and carry out research is a strongly positive development. This has also prompted several universities to consider building their own labs at Harwell. These developments have helped seed a proposal to create a Harwell university quarter, which ISIS is supporting actively.

The role of ISIS in Harwell is also significant to businesses such as Infineum, who have taken this into account when locating at the Campus. In addition, the facility has played a role in helping some local businesses which supply to the facility grow and expand over the years. For example, the Spanish company AVS, which has supplied to ISIS in the past, has now opened an office on the Campus in order to develop its relationships with ISIS into a broader set of interests with all the co-located facilities. ISIS has also contributed to local investment and the expansion of several technology companies, including Tessella and Prototech. ‘Place’ makes a difference in the success of science and innovation initiatives in the UK, clustering resources and industries, and enabling collaboration and advances that would not be possible in isolation17.

5. ISIS skills impacts

ISIS enables UK scientists and organisations to carry out world-leading research. The facility has a clear focus on user service, supporting academics to achieve exceptional results. ISIS also leads or contributes expertise to other neutron facilities and programmes worldwide. Internationally recognised facilities such as ISIS help the UK drive a knowledge-based economy, supporting skills development in a number of ways. For example, benefits include ‘on-the-job’ training given to several hundreds of early career researchers and research students each year, who go on to work in academia and industry. The facility is also of critical importance to the career development and academic standing of users, with the facilitation of high-quality publications as a factor particularly cited by users. Industry also benefits from ISIS, often recruiting staff with the specialist skills the facility generates and benefiting from knowledge exchange and collaboration activities. ISIS also functions as a leading training provider, delivering high-quality, specialised educational experiences to hundreds of UK and international learners at all levels, from schoolchildren to undergraduates.

ISIS develops skills for the UK research base

ISIS nurtures scientific talent in the UK, the value of which is estimated to be £30 million to the UK economy. Over 60% of the academics surveyed report that ISIS has made a significant contribution to UK skills in science; and over 50% report that ISIS has been essential to their own career success. ISIS’s provides a significant level of ‘on-the-job’ training for early career researchers. Some 500-800 students gain experience each year working alongside ISIS users and staff, delivering approximately 2,000 days of training each year. This type of capacity building is judged to be significant by the great majority of respondents to the academic survey. ISIS also offers specialist training schools on neutron- and muon scattering techniques which are free of charge, normally accepting 45 students annually. In addition, in 2014 ISIS funded over 60 PhD level scientists in total, who conducted their own research programmes, usually in collaboration with external researchers. To give an idea of the economic value of the facility-enabled training delivered by ISIS, we assumed that an
average of 1,000 post docs/students have received the equivalent of five days of experimental training each year at a conservative unit price of £200 a day, which gives a figure of £30 million across ISIS’s 30-year lifetime.

The 200 replies to the survey of ISIS academic users provided an excellent profile of the importance of ISIS to them. The results are conclusive, with users rating ISIS as being of critical importance to their own career. Over half stated that ISIS had had a positive influence on their career progression. A large majority (80%+) judged ISIS as having helped them to make a significant or decisive contribution within their field, while around 60% judged work at ISIS to have been very important in winning subsequent research grants. Some 43% of respondents also attributed ISIS as having made a significant or critical contribution towards their promotion to a senior academic post. Respondents who had rated their use of ISIS as ‘critical/decisive’ or ‘significant’ were asked to explain briefly what the achievement was. Around 55% of respondents answered, citing a diverse range of achievements. Many quoted high-quality publications as a major achievement. For example:

• “About 98% of my publications are coming from the results of my experiments in RAL.”

• “I have 13 papers cited 100 times or more: nine of these arose from neutron diffraction studies, most of these at ISIS.”

• “100% of my publications in the last 24 months have relied on, or been made possible by, experiments performed at ISIS.”

• “My h-index is 19, in less than nine years after my first publication, all but one [of the contributing papers] featuring some ISIS input.”

ISIS provides valuable skills to industry

ISIS upskills industry in a number of ways. This is widely acknowledged among industrial users, highlighted through case studies and the results of two industrial and supplier surveys.

ISIS staff and users, who learn skills through ISIS research and training programmes, often work in or for industry during their career. ISIS also provides valuable skills to industry directly through collaborative research and knowledge exchange programmes. Industry receives support directly from ISIS staff, receiving training to carry out research or support to develop particular technologies. An example of how ISIS has provided unique skills support to industry is given below:

• Siemens ONIAC, short for ONIon ACcelerator, is a prototype particle accelerator which creates radioisotopes that could help scientists offer better cancer diagnosis. In 2009, Siemens built the ONIAC test facility at ISIS Target Station 2, to enable direct access to the expertise of ISIS staff and provide the infrastructure needed for the project. The production of such radioactive tracers is currently performed by central facilities, which are large, heavy, complex and expensive to maintain. Siemens’ proposed technology is potentially revolutionary and could provide a simple, lightweight alternative to current technologies. The global market for radioisotopes was valued at around £2.7 billion in 2012, and was expected to grow steadily at 5-10% a year over the next five years. The global market for compact accelerators could be worth hundreds of millions of pounds a year within the next five-10 years. It is expected that the ISIS/Siemens collaboration will extend to other high-risk development projects in the future. The partnership is also having a direct impact on other UK businesses. Over 80% of the manufacturing for the ONIAC facility is contracted from UK companies, mostly locally in Oxfordshire.
“There is always pressure to locate Siemens research in Germany. However, I believe that Siemens could not get the same level of support in German national facilities as they do at ISIS. Input to a national laboratory is also mutually beneficial. STFC is getting a first-hand view of some of the intellectual property and novel technologies developed by Siemens. Siemens can develop and test new ideas rather quickly in close relationship with STFC and utilise their existing expertise.” Professor Paul Beasley, Head of Strategic Development at Siemens Corporate Technology.

We also included several open questions in the academic user survey, inviting academics - some of whom work for or with companies - to briefly describe the benefits derived from their work at ISIS. A significant minority elected to list industrial skills and relevant training. For example:

- “The students that pass through ISIS learn important practical skills that are critical to industrial research, in terms of study design and the efficiency of our methodologies. In many cases, companies struggle to know how to proceed with a question may be forced to try every technique (blindly), which costs a fortune and takes forever. The ISIS scientists can work out how to get things done.”

- “My research is not about inventing but about understanding and this is critical for industry, as they have to transfer from empirical to mechanistic understanding. Many of my research students now work in industry and use the knowledge we have generated. Our research also educates industrial researchers who we collaborate with.”

Several open questions were also included in the supplier user survey; here skills development was also important – for example in increased technical capability:

- “We gained expertise in working with unusual materials, such as titanium zirconium.”

Robert Selway from Siemens and Dan Faircloth from ISIS in front of the resonant transformer which powers the ONIAC shells. Credit STFC
The most important factor for us is the ability to develop new products and resolutions for problems we may not face in normal industry.

ISIS staff are nationally and internationally recognised for their work

We analysed various measures of scientific esteem and skill level that indicate ISIS staff are essential in the national and international importance of ISIS.

The analysis of various measures of scientific regard and skill level indicate that ISIS staff are held in extremely high esteem nationally and internationally; this benefits ISIS as an organisation giving it credibility worldwide. Many ISIS staff members have roles in external scientific and technical advisory committees, peer review, scientific/technical meetings and external talks, and ISIS staff members have received numerous awards and scientific prizes. The facility also has an essential role supporting and contributing to other neutron sources around the world, with ISIS staff working for, advising or transferring to other facilities. For example, ISIS has had substantial influence on the ESS design and strategy, with current and former ISIS staff involved in the facility’s steering committee as well as its overarching scientific and technical committees.

ISIS inspires young people to pursue STEM careers

ISIS trains and inspires the next generation of scientists and engineers, estimated to be worth £3 million to the UK economy. ISIS has a broad and highly regarded education programme, engaging with many students and young people over the last 30 years.

ISIS provides training, delivering high-quality, specialised educational experiences to hundreds of UK and international learners at all levels, from schoolchildren to doctoral students. ISIS inspires young people to pursue STEM careers; initiatives include a new Teacher Training School, and placements for vacation and sandwich students and training for apprentices and graduates.

School children and students at ISIS. Credit STFC
Appendix

A.1 Economic Analysis

Below is more information on our economic analysis. Figure 3 also provides more detail on what we were not able to directly analyse. For full information please see the ISIS Lifetime Impact Report.

Net immediate economic impact to the UK

ISIS expenditure generates substantial immediate economic benefits, through its direct employment and its purchases (suppliers) estimated at £400 million.

ISIS currently employs around 370 mostly full-time staff, a number which has increased from 200 in 1995 as TS2 was constructed and additional instruments were built. The direct impact of ISIS is measured as the Value Added of its activity, which can be approximated by the value of its gross payroll, including all elements of remuneration. Based on this approach, between 1982 and 2013, ISIS has had a gross direct impact of £355 million. To estimate the total immediate impact, we made use of multipliers to quantify the further economic activity stimulated by ISIS’s direct impacts, and estimated that the accumulated gross intermediate economic impact of ISIS to the UK economy, over the last 30 years, is £497.4 million. After applying a discounting factor related to the location of its suppliers (assuming 80% are UK based and 20% overseas), we estimate that the net immediate economic impact of ISIS is £400 million.

Wider economic impact to the UK

ISIS has delivered numerous positive outcomes for the UK in terms of new knowledge, new analytical techniques and new skills, which have in turn facilitated the realisation of numerous wider economic impacts to the UK in terms of technological innovations and new products and processes. To better assess the wider economic impact, we have gone beyond conventional approaches in the research and innovation areas. We have also been conservative in our estimation of likely impacts and our attribution of a share of those benefits to ISIS, in recognition of the high levels of uncertainty as regards the scale and duration of wider impacts, the scale and duration of any displacement or crowding out, and the difficulty in determining attribution. Our approach to analysing the economic impact to the UK of academic research and industrial use at ISIS is described below;

Wider impacts of research

In order to get a better sense of the scale of the wider economic impacts (spillovers) associated with ISIS’s numerous scientific achievements, we looked at a series of specific examples in depth, where advances in understanding made possible by ISIS are supporting technological innovation and commercial deployment beyond that. To do this, 10 impact examples were analysed in depth to estimate the wider economic benefits attributable to ISIS research. Taken together, these 10 extended impact case studies suggest that ISIS research already completed will underpin a substantial increase in national economic activity over the next 10 years, running into the hundreds of millions of pounds sterling and possibly billions if the geographical scope were extended to the global scale. These figures have been arrived at through consideration of various global market research data as well as consideration of UK markets and industries:

• In order to arrive at estimates of likely additional economic activity for the UK, we attempted to determine net effects. Using rather conservative multipliers (1-5%), we feel confident that ISIS should directly claim several millions of pounds sterling for that increased economic activity in every case, and possibly as much as £85 million in total future benefits across the 10 cases.

• The 10 extended impact case studies have produced very little economic impact to date, and are expected to deliver the bulk of the very substantial projected benefits over the next 10 years through to 2025. Hence we have applied a net present value (NPV) adjustment to that future cash flow projection that amounts to around £70 million in NPV terms, using an inflation rate of 3% over the 10-year period to 2025.

• There is no definitive means by which to relate this group of 10 cases to ISIS’s total research endeavour over the past 30 years which totals 10,000 research papers; however, we have come to a view based on the size of the archive of case studies. The group of 10 extended impact case studies was identified from...
within a larger catalogue of 150 cases. Working with the kind of Pareto (skewed) distribution derived from consideration of various other empirical studies of research impact, we expect to see 20-30 examples of major impacts within the 150. We also estimate that the 150 cases accounts for perhaps a third of all possible cases. Using a conservative approach, we estimate a total future benefits at £140 million in NPV, up to 2025.

- Using the extended impact case studies to guide our thinking on past wider benefits, we assume that the £85 million can be doubled to approximate for the larger number of high-impact cases and doubled again to account for the previous 20 years’ of ISIS research outputs assuming a 10-year time lag to impact. Giving a total estimate for past wider economic impact of around £340 million. This gives a total economic impact of £480 million overall due to ISIS research.

**Wider innovation impacts**

To estimate the impacts of industrial usage of ISIS, companies own estimates of value were used through proposals to the new ICRD programme. This has also provided a means to extrapolate the likely impact of direct industrial usage of ISIS over its lifetime:

- All ICRD proposals are required to include a description of anticipated benefits, and 15 of the 36 proposals (42%) also attempted to quantify future benefits. For those who were able to quantify benefits, together they forecast more than £500 million in additional income or savings for the participating companies and their supply chains. In several cases, benefits are anticipated to accrue each year, many years into the future, suggesting that this group of current ISIS experiments may help secure or expand national economic activity by several billions over the next decade.

- Adjusting these gross estimates of increased sales in line with likely displacement of economic activity elsewhere in the UK economy, depreciation over the 10 years to 2025 and conversion to GVA, we arrived at an estimate of future net economic impact of between £330 million and £660 million. Given the critical contribution of ISIS to the realisation of those future benefits, 30% of the higher bound was attributed to ISIS, or £200 million.

- The ICRD programme is a reasonable approximation to the close working relationship that the facility has had with a core group of industrial users across its 30-year life, and we have used these detailed financial projections as the basis for estimating historical benefits to industry users.

- Using historical information we estimate that 20-30 companies - from an overall cohort of 100 - have seen similar benefits from a sub-set of their ISIS experiments across a 20-year period. This approach allows for ISIS start-up and commercialisation time lags. Therefore, the ICRD projections suggest that ISIS will have made possible new sales on the order of £500 million a year, or around £10 billion overall. When adjusted for additionality, displacement and attribution, this produces an estimate of total net economic impact of somewhere between £200 million and £750 million. Given the use of the ICRD projections as the basis for these estimates of likely historical benefit, we elected to include the most conservative figure of £200 million in our overall estimate of ISIS’s total economic impact.

- Therefore the total increased economic activity, deriving from past industrial research usage of ISIS, is estimated to be £200 million from 1985 to 2014 and £200 million from 2014 to 2025, or £400 million overall.
Economic estimates of on the job training
ISIS is delivering many thousands of days of ‘on-the-job’ training to research students and post docs each year: post-docs and doctoral students constitute the great majority of all ISIS scientific users. To monetise the value of their facility-enabled training delivered by ISIS scientists, in addition to the post docs’ professors and academic co-workers, we assumed an average of 1,000 post docs / students have received the equivalent of 5 days experimental training each year at a unit price of £200 a day. This gives a figure of £30 million across ISIS’s 30-year lifetime.

Economic estimates of education provision
With ISIS staff delivering somewhere in the range 500-1,000 days of education and training support each year, we estimate that this contribution might be conservatively priced at between £100k and £200k. Estimating ISIS has delivered on average 500 training days each year over its lifetime, at an equivalent price of £200 a day\(^{18}\), we arrived at a total estimate of £3 million.

Overall impacts
The following table summarises in detail all of the estimates of the different types of social and economic impact which are attributable to ISIS across its 30-year history, and outlines where we have been able to put a figure against the impacts.

Where it has been possible to monetise evident impacts, they are not simply additive. For example, the net immediate economic impact is an estimate of the financial value of past activities; the estimate of impacts of the ICRD programme is anticipated future income. We have sought to overcome these difficulties by computing the net present value of estimates of future benefit flows so they can be added to past benefits. Upper and lower bounds have also been estimated for several categories of impact and, in the main, we have used the more conservative estimate in its overall summation.

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\(^{18}\) Where pricing data was found, for summer schools for example, charges range from around £100 a day for Oxford’s neutron summer school through to £300 a day for non-academics attending statistics courses. The price – and cost of delivery – varied depending upon the educational programme in question, with post-16 apprenticeships for example costing rather less in proportionate terms as compared with PhD supervision.
<table>
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<tbody>
<tr>
<td>Direct economic impacts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net immediate economic impacts</td>
<td>ISIS expenditure generates substantial immediate economic benefits, through its direct employment and a snapshot of its purchases (TS2 build suppliers). Note: Data on all suppliers used across the life of the facility were unavailable.</td>
<td>£400 million</td>
<td>Not able to estimate</td>
<td>£400 million</td>
<td></td>
</tr>
<tr>
<td>Visitors economic impact</td>
<td>Several thousand academic/industrial user visitors each year, spending money on travel, food and accommodation in the local economy</td>
<td>£20 million</td>
<td>Not able to estimate</td>
<td>£20 million</td>
<td></td>
</tr>
<tr>
<td>Economic benefits attributable to completed ISIS research (past and future)</td>
<td>ISIS research is underpinning innovation in the wider economy, within the UK and internationally. Our extended impact case studies suggest this wider benefit is substantial and that the net present value of future income may be as much as £140 million. Working from the £140 million above, historical data suggests that ISIS's past research outputs may be associated with wider economic benefits on the order of £340 million.</td>
<td>£340 million</td>
<td>£140 million</td>
<td>£480 million</td>
<td></td>
</tr>
<tr>
<td>Economic benefits of fundamental research</td>
<td>The economic benefit of long-term, global and fundamental research programmes such as bucky balls, surfactants and magnetism. Due to the nature of this impact we have not attempted to value it</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
</tr>
<tr>
<td>Economic benefits of technology development</td>
<td>Many of the techniques and technology developed on ISIS to support its research programme have been world firsts that have then been adopted by other facilities around the world. Again, due to the nature of this impact, we have not been able to value it</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
</tr>
<tr>
<td>Economic benefits of international influence</td>
<td>ISIS attracts users from across the globe and we have used international investment into the facility as a proxy of international importance, amounting to around £2 million - £3 million a year</td>
<td>£56 million</td>
<td>Not able to estimate</td>
<td>£56 million</td>
<td></td>
</tr>
<tr>
<td>Innovation</td>
<td></td>
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<tr>
<td>Future impact of industrial usage attributable to completed research (2015 - 2025)</td>
<td>Future projections: ISIS experiments are expected to support UK economic activity that will run into the billions (gross) through to 2025. We arrive at a range of estimates between £50 million and £200 million, by adjusting those gross estimates to reflect ISIS's contribution and also the net present value of that future income stream. Past estimates: ICRD programme is a reasonable approximation for industrial use across ISIS's life. Discounting for additionality, attribution and depreciation (and allowing for commercialisation time lags), we arrive at a range of £200 million to £750 million. We have elected to use the more conservative figure.</td>
<td>£200 million</td>
<td>£200 million</td>
<td>£400 million</td>
<td></td>
</tr>
<tr>
<td>Wider benefits to industry from industrial supply</td>
<td>ISIS has had wider benefits to industry like effects on additional sales, reputation and capabilities in addition to direct funding from equipment supply (which is accounted for under immediate economic impact)</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
</tr>
<tr>
<td>Impacts from IP generation</td>
<td>Economic benefits from the licences, patents and spin-outs resulting from users of ISIS and ISIS staff</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
</tr>
<tr>
<td>Impacts due to Harwell Oxford Campus cluster</td>
<td>Impacts from ISIS being a main attractor to companies locating onto the campus or working with the campus</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
<td>Not able to estimate</td>
</tr>
</tbody>
</table>

Figure 3 – Overall economic impact (past and future effects) achieved by ISIS across its lifetime
<table>
<thead>
<tr>
<th>Type of socio-economic impact</th>
<th>Description of impact</th>
<th>Estimated impact of work already completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wider economic impacts</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Skills</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skills-related valuation of on the job training</td>
<td>Estimated value of 500+ trained research students / post docs annually</td>
<td>£30 million</td>
</tr>
<tr>
<td>Value of training to industry</td>
<td>Value of direct training for industry and wider benefits from trained staff and staff transfers</td>
<td>Not able to estimate</td>
</tr>
<tr>
<td>Value of educational</td>
<td>Estimated value of 100+ trainees, 1,000 training days, annually</td>
<td>£3 million</td>
</tr>
<tr>
<td>Training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>£1,049 million</td>
</tr>
</tbody>
</table>

**Future economic benefits attributable to future predicted work of ISIS**

The table above looks at the impact of ISIS based on what has already been achieved, i.e. research already undertaken. However, ISIS continues to operate and we would expect to see substantial further scientific and economic benefits in the longer term through to 2030 and beyond based on new research or other work not yet started. With an expanding instrument set and planned upgrade to TS1, the next 15 years of operation could easily match the order of magnitude of benefits seen in the first 30 years, e.g. another £1.4 billion.
A.2 Methodological challenges

This is a summary of the methodological challenges of the ISIS Lifetime Impact Report.

Research impact assessment is widely understood to be a challenging field of social science research, confronting several classic measurement issues of impact pathways that are traversed across decades by multiple parties, producing tacit and codified knowledge along the way. The measurement challenge is all the more difficult when the question relates to research infrastructure and the role of such a facility in the technical underpinning of thousands of experiments conducted by tens of thousands of scientists and engineers in universities, institutes and business throughout the UK and around the world.

Conventionally, analysts have tackled the measurement challenge by focusing on the immediate impacts, counting direct employment and expenditure over time and using standard economic multipliers to arrive at an estimate of the direct and indirect effects. The better studies work with GVA to arrive at a more robust view of the value of additional economic impact and also make adjustments for leakage to other regions or countries. Occasionally, these economic impact assessments are accompanied by a more qualitative description of selected impact case studies and very rarely those case studies are monetised and included within an overall estimate of total economic impact, attributable to the facility both ‘spending money’ and advancing understanding (knowledge spillovers).

We have followed the same broad approach here, on the one hand working with ISIS’s financial and HR figures to arrive at an estimate of the immediate economic impact of the facility’s operation over the past 30 years, and on the other, running surveys to profile and characterise impact distributions among industry users and suppliers and using case studies to trace effects and estimate the likely quantum of benefits. We have gone beyond conventional approaches in several areas, taking advantage of the estimates of future impacts prepared by ICRD users to provide a more comprehensive basis for estimating likely future benefits for users. Secondly carrying out substantial desk research to estimate and forecast wider economic benefits attributable to ISIS’s research. We have been conservative in our estimation of likely impacts and our attribution of a share of those benefits to ISIS, in recognition of the high levels of uncertainty as regards the scale and duration of wider impacts, the scale and duration of any displacement or crowding out and the difficulty in determining a fair attribution for ISIS.

The case study methodology is a laborious and costly process, given the time over which the research is carried out and the advances in understanding which percolate through to new techniques or technologies and which find their way into new products and processes. The effects spill over in many areas, and this diffusion brings its own challenges in respect of the scope of the investigation and the potential for new developments and feedback loops. Nevertheless, this kind of in-depth, longitudinal impact case study remains the best means we have for tracing and estimating the social and economic impact of research. Grossing up those individual cases remains somewhat problematic; however, we feel confident that we were able to come forward with a reasonable but conservative estimate using ISIS’s case study archive to size the population and the typical shape of skewed distributions reported in the wider innovation literature.

In this particular exercise, the study team has been helped greatly by the earlier work of the ISIS and STFC evaluation units and their active preparation of research case studies for inclusion in annual reports and on the website. The study would have taken very much longer and cost rather more money without that support. Notwithstanding this bedrock of preparatory material, the study faced a number of methodological challenges that have been wrestled to the ground, but not always fully overcome, including:

• The central importance of the science and the global scope of its influence, which requires a broad knowledge of multiple scientific domains and an international reach. The solution here has been to work closely with ISIS staff, several of whom kindly drafted field-level reviews describing the work at ISIS over the past several decades and picking out key advances.

• The time span over which the facility has been delivering manifold benefits, which extend over several generations of scientists as well as many organisational and information system changes. In this case, we have relied on historical records to capture the main milestones. For our economic impact assessments,
however, we used income data as a proxy for expenditure data and have made certain assumptions about the relationship between income and payroll in order to extrapolate for the earlier years.

• The intangible nature of many of the benefits; and, where phenomena are quantifiable, they are not necessarily monetisable and therefore cannot always be aggregated.

• Temporality. The nature of research impact pathways means there will always be a timing issue, with primary research tending to produce wide-ranging evidence of substantial anticipated future benefits, but far less extensive / fewer data about past benefits. This reflects people’s preoccupations with the here and now, to some extent, but it also reflects the way in which benefits unfold over many years and possibly decades.

• Our survey of industry users had to be implemented indirectly, through an open request to academic users in the hope that they would refer the study and survey to their industrial partners. This kind of approach gives very little control over response rates and ultimately produced only a small number of substantive replies. This feedback was valuable; however, it fell some way short of a comprehensive response and as a result did not provide the statistically robust platform for which we had hoped. This left the team with a tantalising glimpse of some really quite striking impacts, but with the small number of responses it was simply unreasonable to seek to generalise from the few to the many. It was reassuring that several of the respondents were prepared to be candid about the nature and extent of the benefits realised as a result of the research being performed at ISIS by their academic partners. That said, there is a sense that in many cases the real benefits go way beyond individual experiments and are both strategic and commercially sensitive. Our follow-up interviews quickly revealed that although industrial scientists and engineers were pleased to discuss their current or recent ISIS projects, much of which was work still a very long way from market, and they were unable or unwilling to discuss the benefits of past engagements. This is a classic ‘research impact’ measurement paradox, whereby respondents can speak at length about their current research – why, what and how – but its impact on products or processes or the bottom line is many years in the future and the nature and extent of such benefits is a matter of conjecture. Benefits realised are invariably based on work that stretches back very many years, and cloudy corporate memory tends to cause people to speak in only the most general terms, and few people are confident enough in their view of matters to quantify or attribute some proportion of those benefits to ISIS.

• Our supplier survey was rather more successful than the industry-user survey, even though we had to contend with a limited database with few named contacts. The tactical decision to focus on the larger work packages linked with Target Station 2 was well judged, and there is clearly substantial goodwill among suppliers generally. Our supplier case studies also suggest that ISIS does provide reputational and lead market benefits to perhaps 20% of its suppliers and, as such, this is an aspect of value that could be monitored or reported on going forward.

A.3 Recommendations for ISIS

This is a summary of the recommendations for ISIS following the ISIS Lifetime Impact Report.

In terms of lessons learned for future impact assessments, several points stand out:

• ISIS should continue to improve its information systems in support of more robust monitoring and evaluation. Clearly good progress is being made, and the ability to look at near term events is greatly improved by ISIS surveys and case studies, however, there may be value in doing more.

• Research activity. It would be helpful if ISIS could maintain a better view of the composition of the research it is supporting, in terms of broad scientific disciplines at least. It would also be useful to maintain a better view of the volumes of related research, which is in some way dependent upon access to ISIS. We understand ISIS research is typically linked with around £100 million in current EPSRC grants, and while EPSRC may well encompass the lion’s share of the disciplines using ISIS, its also clear there
is a long tail of other users with grants from other research councils, from BBSRC to MRC and NERC. The combined value of this linked research might easily amount to several hundreds of millions, which would underline the extent of the dependency upon ISIS across the whole of the UK research base. A more accurate view of these issues ought to improve awareness of ISIS’s significance across all research councils.

- Industry links. It would be helpful if ISIS could find a practicable means by which to maintain better records of their manifold industrial relationships, whether that is the co-sponsors of academic users of ISIS or the suppliers of higher-value goods and services. It would be helpful if STFC’s standard contracts and partnership agreements could include a clause obliging the signatories to support future evaluations and impact assessments, perhaps including a clause about confidentiality and non-disclosure to reassure people that they will have the final say in level or timing of any disclosure of benefits realised.

- Impact case studies. ISIS and STFC have responded robustly to the government’s impact agenda and have amassed a large number of excellent scientific and industrial case studies. These essays are invariably well written and provided an excellent platform for the extended case studies presented in this report. Having a second-phase, to follow-up on those case studies perhaps two or three years later would allow the ISIS team to develop a more fulsome account of the wider benefits, for both research and industry. This programme might also be extended to include a small number of (ad hoc) longitudinal (tracking back) impact case studies focusing on the ‘jewels’ in the ISIS crown. These might take the form of an edited book, whereby different authors with deep knowledge of the field are invited to write a chapter on the importance of ISIS contributions to the topic.

- It may also be helpful for ISIS to develop a programme of field-level international reviews, which would provide a more robust and fine-grained assessment of contributions and breakthroughs, set in the context of a more thorough-going review of wider international efforts. The EPSRC and ESRC have both been advocates of such international reviews, and have well documented procedures. These exercises can be costly in staff time and cash, but the process can be made more affordable by running one or two reviews each year so that a programme cycle may take around five years. This would be an excellent platform for future impact assessments, say in 2020, as well as supporting STFC’s annual reports to BEIS.

- Career tracking survey. ISIS alumni / community may provide a platform for this kind of exercise, going forward, or possibly using social media like linked-In to run data mining exercises to track the progression of its academic users and their post docs. An alumni programme or some other community-based network may be a way forward, providing value to the community on an ongoing basis while providing a platform for ISIS to research issues (in the manner of a local authority ‘citizens panel’ which are widely used for omnibus surveys).

- ISIS has run various user surveys down the years, and there may very well be value in running an annual user survey to invite people to share information on new developments (from awards to prizes to spinoffs and commercial sales). This is all likely to require more administrative resources and possibly additional budget too, which we appreciate will be a challenge in the current financial environment. On the upside, expanding and strengthening the ISIS evidence base may help to secure additional funding to allow the facility to return to its full utilisation levels and continue its upgrading programme and planned activities through to 2025. We believe that would constitute excellent value for money for both STFC and the UK taxpayer.