Department for
Science, Innovation
& Technology

UK Strategy for Engagement with CERN

Unlocking the full potential of UK membership of CERN

October 2023


number of collisions

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Acknowledgements

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All photos and diagrams throughout the document are credited to CERN unless stated otherwise.

Foreword by the Minister of State for Science, Research and Innovation

The UK has always excelled in research. We have nurtured some of the world's greatest minds whose ground-breaking discoveries have changed the way we live our lives. The recently established Department for Science, Innovation and Technology (DSIT) will cement the Government's focus on science and research as an enabler of our growth, talent and leadership.

We are committed to ensuring that Britain is a science and technology superpower by 2030, and the Science and Technology (S&T) Framework[1] identifies ten interventions to accelerate towards, emphasising the significant value that we place on both domestic and international research infrastructure and the plethora of benefits that they bring to the UK, including access to world class equipment and training opportunities. This strategy reflects our ambitions to make the most of access to physical and digital infrastructure, in line with our overarching ambitious goals set out in the S&T Framework.

The UK is an integral member of many international research infrastructure - collaborations with other countries that facilitate world class research across a diverse field of subjects ranging from life science to particle physics. The benefits of membership to these international facilities can be far reaching, including access to unique infrastructure, innovative spin-outs from development of the technologies, access to training opportunities to grow our talent as well as forging new partnerships and alliances. This would not be achievable without international collaboration.

The UK is one of twelve founding members of CERN; whose mission is to uncover the mysteries of the universe, including what it is made of and how it works. As the world's pre-eminent particle physics laboratory, it makes available complex particle accelerators and detectors, as well as computing technology, for its global research community. When I visited in 2022, I was inspired by the abundance of bright and dedicated UK talent across science and engineering, and the breadth of work and discovery that takes place at CERN. Famously, CERN is the home of the World Wide Web, invented by British scientist Tim Berners-Lee, as well as other pioneering contributions to the development of medical scanners and the ubiquitous touchscreen.

Through our membership of CERN, we have access to exceptional, one-of-a kind instrumentation and experiments, access to commercial opportunities to deliver services and technical kit to CERN, and the opportunity to apply for training programmes and employment

[1] UK Science and Technology Framework https://www.gov.uk/government/publications/uk-science-and-technology-framework

across a broad range of subjects. This aligns with our DSIT mission of stronger growth, better jobs and bold discoveries.

I am proud that the UK has been a critical contributor to all major experiments and discoveries at CERN, including the discovery of the Higgs boson in 2012, with many UK researchers holding influential senior scientific positions. The UK leads in many aspects of the CERN scientific programme and is able to attract the highest quality talent to universities, institutes and national laboratories in all corners of the UK.

As the second largest contributor to CERN, our return on investment is below where we would like it to be, with much more we can still do to ensure we take full advantage of all opportunities that are afforded by CERN membership. This will allow us to continue being a key member and critical friend at CERN and to unlock the full potential our membership. This paper sets out our strategy to maximise the benefits of our membership of CERN.

We have identified five key ambitions in the areas of research excellence, skills, commercial impact, international leadership, and inspiring our communities, and have outlined steps that we will take to excel in these areas. I am grateful to the UK@CERN community, CERN, and all others who have been instrumental in the development of this strategy and who will be critical to its implementation and success.

Whilst this strategy is targeted at CERN, it reflects the strategic thinking that we will apply across the entire international research infrastructure portfolio in which the UK participates, ensuring we maximise every opportunity and realise the full potential that arises from our memberships.

George Freeman MP
Minister of State, Department for Science, Innovation and Technology

Foreword by the Executive Chair of the Science and Technology Facilities Council

CERN is a truly pioneering and inspiring organisation and is the ultimate paradigm for international scientific collaboration. By working together at CERN, scientists and engineers from across the world are able to explore the fundamental nature of the universe in a manner that would not be possible by an individual country alone. CERN provides globally unique facilities that enable researchers to push the frontiers of our knowledge, develop technologies that are shared openly for the benefit of all, train new generations of scientists, engineers and technicians, and inspire the public in demonstrating the cultural value of science at its deepest level. The spirit of collaboration across CERN's diverse and thriving international community is second to none and is something I experienced first-hand during my six years at CERN as a fellow and then as a staff research physicist.

The Science and Technology Facilities Council (STFC) funds research in particle physics, nuclear physics, astronomy, space science and particle astrophysics. This includes funding and managing UK participation in numerous international research infrastructure, the largest of which is CERN. As stewards of the UK particle physics research community, we provide strategic leadership and technical expertise within CERN's governance structures, with support and oversight from DSIT. We invest in frontier research and support UK-based researchers to participate in and lead CERN's experimental and computing programmes, which leverages the scientific and wider value from the UK membership of CERN. We also have unique capability in our national laboratories and universities that enables UK scientists and engineers to design and build critical components for CERN's accelerator complex and experiments.

Membership of CERN supports the strength of our national research communities and indeed a high proportion of the UK particle physics programme is focused on research using the unique facilities at CERN. Every year almost 1000 UK-based researchers from over 50 institutes carry out work at CERN and in the past decade over 20,000 UK scientific papers have cited CERN articles, including many of the UK's most influential physics papers. With the UK as a key partner, CERN has made some of the most fundamental scientific discoveries of the last fifty years that have changed the way we understand the universe, including the remarkable discovery of the Higgs boson, which is a completely new type of "matter".

We strive to leverage CERN membership to inspire the next generation to pursue careers in science, technology, engineering and mathematics (STEM) subjects. Every year around 12,000 pupils from 500 UK schools visit CERN and on average each year there are around 2,000 mentions of CERN in the UK media. Promoting STEM skills in the context of the excitement surrounding scientific discovery at CERN is part of our critical mission in addressing UK's STEM skills gap and engages people about the importance of science to society and the economy.

Given the strong role of the UK in CERN since its inception, we are in an excellent position to drive future scientific and technological progress at CERN and to benefit from the continued mutual sharing of best practice and exchange of ideas. However, when it comes to leveraging wider value from CERN membership such as skills and industrial returns, there is room for improvement for the UK relative to other nations. To make the most of our investment in CERN, the UK needs to work with CERN to increase the benefits to the UK of CERN membership. This is an essential component of achieving the Government's ambitions to be a science superpower on the global stage.

I greatly welcome the government's strong and continued support of UK involvement in international research infrastructures, including CERN, and am delighted that the development of this strategy has been a collaborative effort between STFC and DSIT. We have also worked hand in hand with the UK particle physics community and CERN to bring this strategy to fruition and I would like to thank everyone who has contributed to this process.

This document presents an incredibly exciting and ambitious plan outlining our goals over the next ten years to unlock the full potential of our CERN membership. The hard work starts now to deliver on the goals set out in this strategy.

Professor Mark Thomson
Executive Chair of the Science and Technology Facilities Council

Contents

Executive Summary

The European Laboratory for Particle Physics, CERN, is the world's pre-eminent particle physics research facility. Located on the French-Swiss border, CERN is an unrivalled centre of global scientific and technical excellence and is home to the largest and most complex experiments ever constructed. It houses purpose-built particle accelerators, detectors, and computing infrastructure of unprecedented scale that enable researchers to study the basic constituents of matter and advance our understanding of the universe.

The UK was one of the twelve founding members of CERN in 1954 and is now the second largest contributor to the CERN budget with a subscription of around £160M per year. Additional funding to UK researchers working on CERN experiments is around £20-30M per year. The UK plays a prominent role in many aspects at CERN, including leadership roles in some of the most prestigious international science projects as well as two Directors General over the course of our membership.

The UK is committed to CERN, however our current return on investment needs improvement. This strategy is the result of renewed focus on CERN membership by the Department for Science, Innovation and Technology (DSIT) and the Science and Technology Facilities Council (STFC). It sets out our ambitions to maximise the benefits of investment in CERN, both economically and more broadly, over the next ten years. This will be advantageous not only for the UK but also for CERN as an organisation, its communities and the other member states. The development of this strategy has been a consultative process, reflecting perspectives of stakeholders from across the UK CERN community.

Our vision is to unlock the full potential of our investment in CERN and remain central to its continued success by working with our partners to lead scientific discovery and inspire the next generation.

To achieve this vision, we have identified five goals (see Table 1): Research Excellence, World Class Skills, Commercial Impact and Innovation, International Leadership and Engage and Inspire. Together these goals will unlock the full potential of our investment in CERN delivering significant benefits to the UK.

Research Excellence is the primary goal and is supported by the remaining four goals (see Figure 1). Throughout the delivery of the objectives and actions outlined in this strategy we will champion our principles for engagement: sustainability, diversity and inclusion, transparency and continuous improvement.

Table 1: Goals of the strategy

Goal	Impact
Research Excellence	More high-impact papers and maintenance of the UK's global research ranking, contributing to the Government's science superpower ambition.
World Class Skills	Increased numbers of highly skilled technicians, engineers and scientists whose skills and expertise can be deployed in a variety of fields, advancing industrial capability and attracting world class talent to study and work in the UK.
Commercial Impact and Innovation	Increased uptake of innovation and commercial opportunities that drive growth in the UK and for the UK to be the partner of choice for international collaboration.
International Leadership	Increased championing of our principles for engagement including diversity and inclusion, on the international stage, and more UK nationals in positions of leadership.
Engage and Inspire	Increased awareness and appreciation of the profound impact that science and technology has on everyday life and more students pursuing STEM subjects.

Implementation of some of the actions set out in this strategy are already underway, including increasing investment in early career researchers to improve the pipeline of talent in particle physics, strengthening the UK's CERN industrial liaison function to improve our industrial return, and enhancing coordination across UK Research and Innovation (UKRI) and government to bolster our partnerships with CERN and its member states.

As we continue to implement this strategy over the next decade, we will monitor progress against the goals set out within this document, with the aim to:

- maximise the mutual benefits and impact of our investment -for CERN and the UK;
- align and coordinate all UK CERN stakeholders behind one vision; and
- raise awareness of the opportunities afforded by our membership of CERN.

The success of this strategy relies on continued collaboration across the UK CERN community and CERN, and we will coordinate its implementation by working with these stakeholders. The audience of this strategy is therefore broad and includes government, research and innovation communities, and industry, both in the UK and internationally.

We will use this ambitious strategy as a model for our engagement with other multilateral international organisations and research infrastructure. This strategy will play an important role in helping to fulfil the government's science superpower ambition – putting research, innovation and technology at the heart of international partnerships.

Figure 1: Our Vision, Goals, Objectives and Principles

Scope of this strategy

This strategy focuses on how to maximise the benefits of UK CERN membership and does not comment on particle physics research goals. We will, however, work closely with our research community to deliver the ambitions of this strategy. This strategy sits alongside STFC's Strategic Delivery Plan[2], which itself aligns with the European Strategy for Particle Physics[3] and is consistent with the applicable recommendations of the 2022 UK Strategic Review of Particle Physics[4].

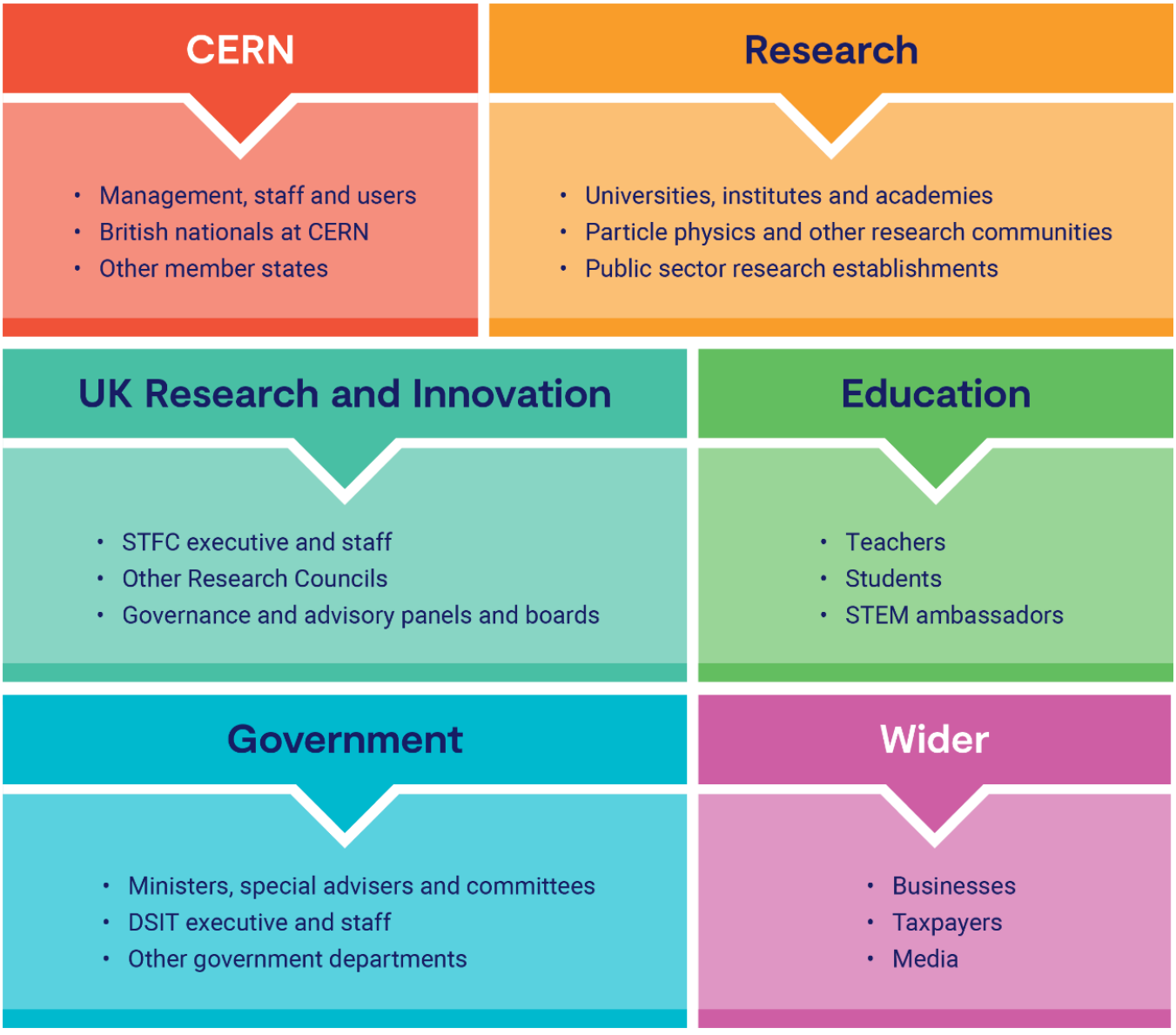
The National Science and Technology Council (NSTC) have identified ten system interventions within the UK Science and Technology Framework[5] that the UK should prioritise to achieve Science Superpower status by 2030. One of the ten interventions is 'Access to physical and digital infrastructure'. The strategy and its delivery will be reported to NSTC and will raise the profile of this work with senior decision makers in government.

[2] STFC Strategic Delivery Plan 2022 to 2025; https://www.ukri.org/publications/stfc-strategic-delivery-plan/
[3] 2020 Update of the European Strategy for Particle Physics; https://home.cern/sites/default/files/2020-06/2020%20Update%20European%20Strategy.pdf
[4] 2022 UK Strategic Review of Particle Physics; https://www.ukri.org/publications/strategic-review-of-particle-physics/
[5] UK Science and Technology Framework; https://www.gov.uk/government/publications/uk-science-and-technology-framework/the-uk-science-and-technology-framework

UK CERN stakeholders

This strategy makes several references to UK CERN stakeholders. The figure below maps out the stakeholders we will work with to implement the strategy, or who may benefit from it, but it is by no means exhaustive.

Figure 2: UK CERN stakeholders



The role of DSIT and STFC in delivering this strategy

This strategy is jointly owned by DSIT and STFC. STFC, as stewards of the UK particle physics research community, coordinates and manages the UK's membership of CERN. DSIT is the sponsor government department of UKRI and represents the UK alongside STFC on CERN governance bodies.

To deliver this strategy STFC will:

- lead on the implementation of goals one (Research Excellence), two (World Class Skills), three (Commercial Impact and Innovation) and five (Engage and Inspire) of this strategy,
- support DSIT in the implementation of goal four (International Leadership),
- coordinate all UK CERN stakeholders involved in the implementation of this strategy, and
- share the governance of the strategy with DSIT and nominate a senior responsible owner (SRO) for the strategy.

To deliver this strategy DSIT will:

- lead on the implementation of goal four (International Leadership),
- support the implementation of the remaining four goals and involvement of other government departments,
- raise awareness of CERN and this strategy across government, encouraging other government departments to take advantage of the opportunities offered by CERN membership, and
- share the governance of the strategy with STFC and nominate an SRO for the strategy.

A group of key UK CERN stakeholders, known as the UK CERN Strategic Advisory Board, will oversee and steer the delivery of the strategy, with DSIT and STFC reporting progress under each of the pillars every six months. Further information on this can be found in the implementation section at the end of the document.

Background

What is CERN?

CERN seeks to advance our understanding of the universe. It hosts the largest and most complex experiments ever constructed and is widely regarded as a global centre of scientific and technical excellence and a pioneer in international research collaboration. CERN was founded upon principles of open access to research and science for peace. It is recognised as an international flagship for science and a driver of talent, technology, innovation, collaboration, and inspiration.

CERN in numbers

- Founded in 1954 by twelve member states, including the UK.
- Currently 23 member states and 10 associate member states.
- Employs over 2,600 staff.
- Community of over 12,000 researchers representing over 110 nationalities.

CERN's mission[6] is to:

- provide a unique range of particle accelerator facilities that enable research at the forefront of human knowledge.
- perform world-class research in fundamental physics.
- unite people from all over the world to push the frontiers of science and technology, for the benefit of all.

"Openness is a fantastic strength of CERN which has international collaboration in its DNA. Everyone involved works together in the pursuit of common goals, irrespective of nationality, beliefs or even career stage. The diversity of CERN's community and their perspectives fosters great creativity and pushes the frontiers of human knowledge."

Prof. Dave Charlton FRS, Professor at the University of Birmingham and former Spokesperson of the ATLAS Collaboration

CERN's research

Particle physics, CERN's scientific focus, is an area of science that investigates the universe at the smallest, quantum scales. This is a regime where matter is seen to be made of tiny fundamental particles, whose behaviour is dictated by a small number of fundamental forces. The underpinning theory, the Standard Model of Particle Physics, represents humankind's best understanding of how the universe works at this level and has successfully and precisely predicted almost all experimental results from CERN (and elsewhere).

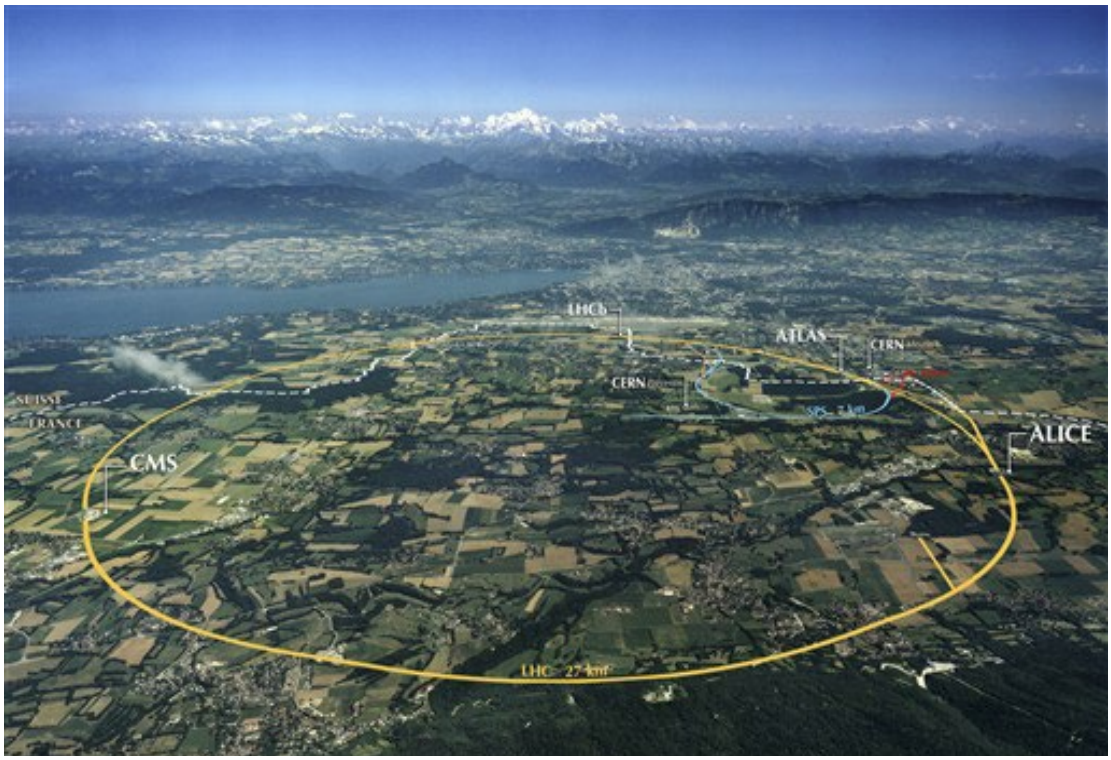
The primary research infrastructure at CERN is the Large Hadron Collider (LHC); the world's largest and highest energy particle accelerator. The LHC accelerates particles at close to the

[6] What is CERN's mission?; https://home.cern/about/who-we-are/our-mission

speed of light before they are made to collide together. About one billion particle collisions occur per second at the LHC. This recreates the conditions of the early universe and provides insights into the fundamental laws of nature. CERN's accelerator complex serves not only the LHC, but also a diverse programme of almost 30 experiments spread across multiple underground and surface experiment halls and facilities.

The LHC tunnel

In 2012, experiments at CERN's LHC announced the discovery of the Higgs boson almost five decades after it was theorised by British scientist Peter Higgs and separately by François Englert and Robert Brout. The Higgs boson explains how fundamental particles get their mass and was the last missing particle predicted by the Standard Model. However, the discovery does not mean our understanding of particle physics is complete; for example, we have no explanation for observations of 'dark matter' and why there is more matter than antimatter, and no understanding of how gravity (which is currently missing from the Standard Model) fits in. Now scientists pursue even more forensic investigations of the Higgs boson and other fundamental particles to find flaws in the Standard Model, and to develop a deeper understanding of nature to be able to explain these observations. These are questions that current and future generations of CERN experiments will seek to answer.

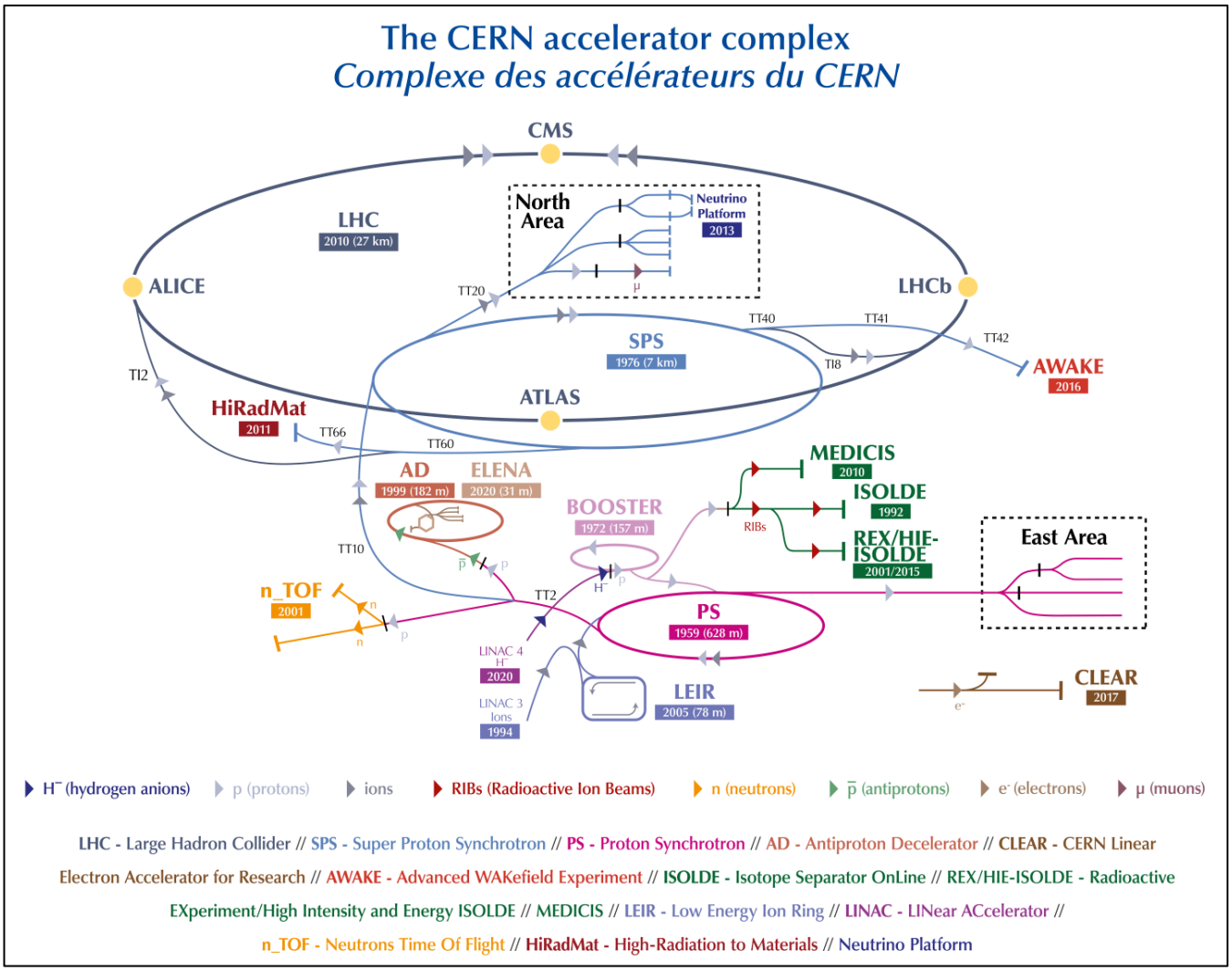


Aerial view of a schematic of the LHC looking south towards Lake Geneva and the Alps

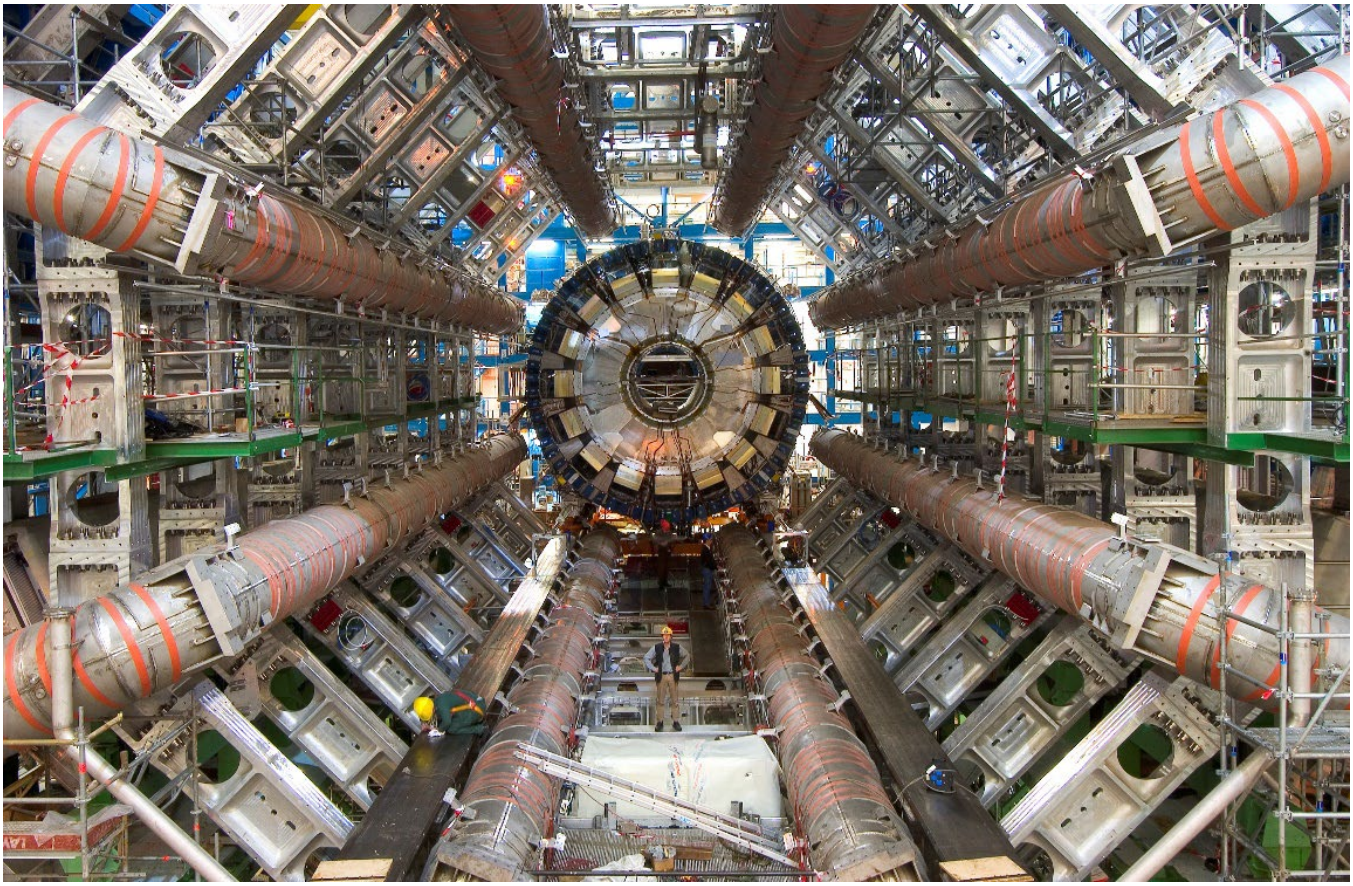
CERN’s accelerator complex

The accelerator complex at CERN is a succession of machines that accelerate particles to increasingly higher energies. Each machine boosts the energy of a beam of particles before injecting it into the next machine in the sequence. In order to reach the LHC at very high energies, particles are first accelerated in the Linear Accelerator 4 (Linac4) before being injected into and further accelerated by the ‘Booster’, the ‘Proton Synchrotron’ (PS), the ‘Super Proton Synchrotron’ (SPS), and finally into the LHC. The source of particles for the entire 27 km length of the LHC is a single bottle of hydrogen gas that is only replaced twice per year.

The accelerator complex serves not only the LHC, but also a rich and diverse experimental programme. Most of the other accelerators in the chain have their own experimental halls where beams are used for experiments at lower energies. The accelerator complex goes through alternating periods of data-taking runs and shutdowns usually around two-three years each. During shutdown periods the complex and its experiments undergo maintenance, consolidation and upgrade work. The third run of the LHC, called Run 3, began in 2022 and will last until 2025. It will collect data from more collisions than in the previous two runs combined.



CERN’s accelerator complex



The LHC ATLAS detector

ATLAS is one of two general purpose detectors at the LHC (the other being CMS). It investigates a wide range of physics, from the Higgs boson to extra dimensions and particles that could make up dark matter. It is located 100m below ground and is the largest detector ever constructed for a particle collider at 46m long and 25m in diameter. It weighs 7,000 tonnes, similar to the weight of the Eiffel Tower. Almost 6,000 people from 182 institutions in 42 countries work on the ATLAS experiment.

“CERN's greatest strength is fostering an environment where scientists of different ages, experiences and backgrounds can work together to understand the fundamental constituents of our Universe. CERN achieves this by cultivating collaborations between physicists, engineers, technicians and computer scientists who are all motivated to do great science, engineering or technology development, knowing that their scientific results, developments and creations will be shared globally.”

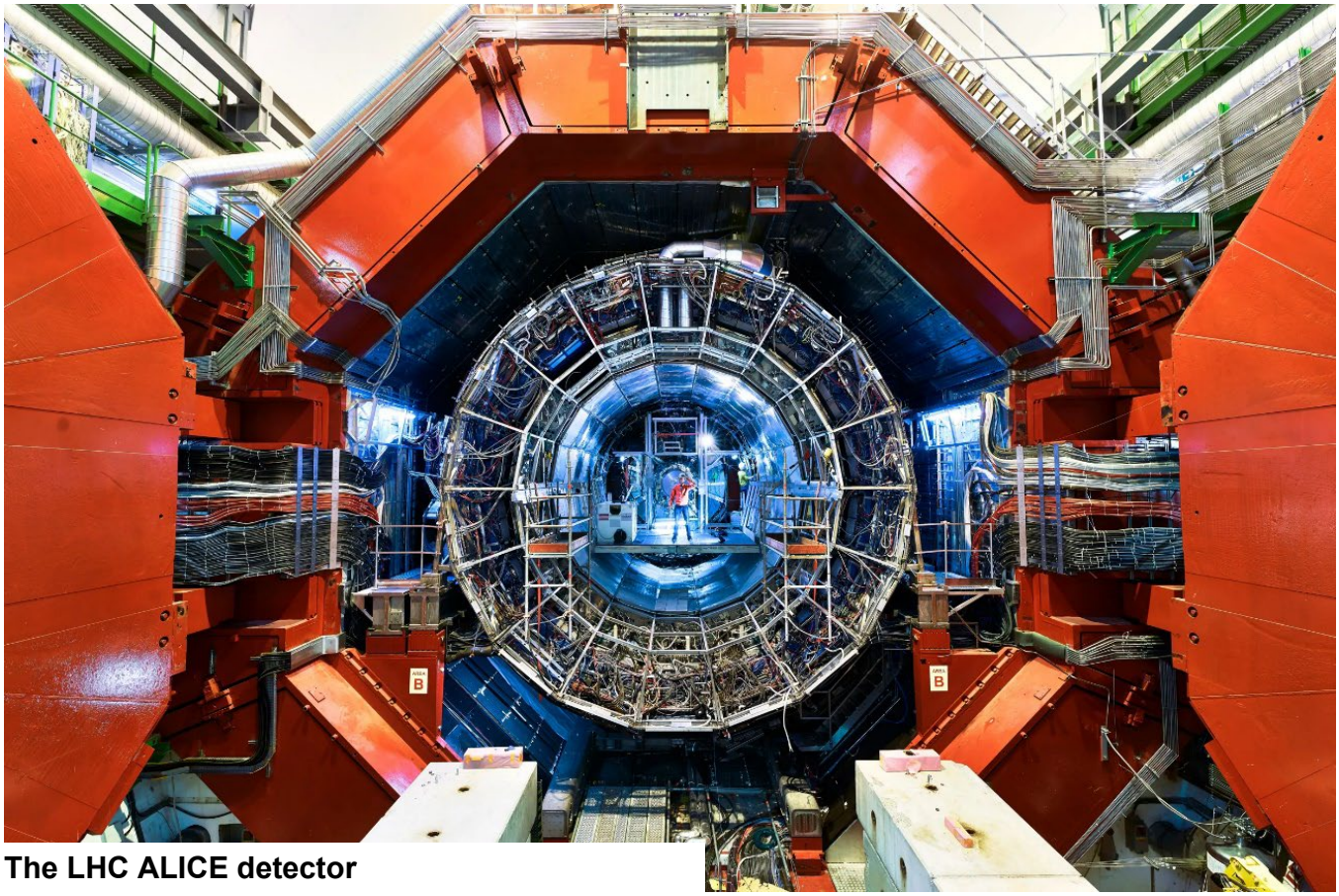
Prof. Victoria Martin, Professor at the University of Edinburgh and member of the ATLAS Collaboration

CASE STUDY: University of Liverpool contributions to LHC experiments

The University of Liverpool is one of many UK institutions that collaborate in the LHC experiments. Scientists at Liverpool form a crucial part of the international effort to build and upgrade three of the LHC's four main experiments - LHCb, ATLAS and ALICE. Liverpool specialises in developing the technology for and constructing silicon particle detectors. Their scientists made major contributions to building the first silicon detectors for LHCb and ATLAS, and the recently installed, upgraded detectors for ALICE and LHCb. Besides exploiting the data from all three experiments, scientists are now constructing new detectors for ATLAS and prototype future detectors for LHCb for the high luminosity phase of LHC (luminosity measures how many collisions are happening in the accelerator).

The LHC upgrades allow the experiments to collect significantly larger data sets with data of higher quality than in previous runs. The ATLAS detector is expected to record more collisions during 'Run 3' than runs one and two combined, LHCb is expected to increase its data-taking rate by a factor of ten and ALICE is aiming to increase the number of recorded collisions by a factor of 50.

Professor Monica D'Onofrio, team leader for the ATLAS experiment group at the University of Liverpool said: "We will be able to probe the nature of the Higgs boson with unprecedented precision, test whether it decays to new particles, for example those that could make up dark matter, and search for new physics at the highest energy ever reached by an accelerator."



The LHC ALICE detector

CERN's contributions to society

CERN's world-leading science programme is made possible by highly talented and highly skilled people, supported by cutting-edge engineering and technology. Achieving CERN's ambitious research objectives requires the development of advanced instruments and new technologies that often have spin-off applications in a diverse range of sectors, including robotics, aviation, banking and medicine. Technological development at CERN has made major contributions to medical diagnosis and therapy through its use in Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) scanners. CERN was also an early developer of capacitive touch screens that were made to replace the thousands of buttons and switches in CERN's Control Centre required to operate its machinery.

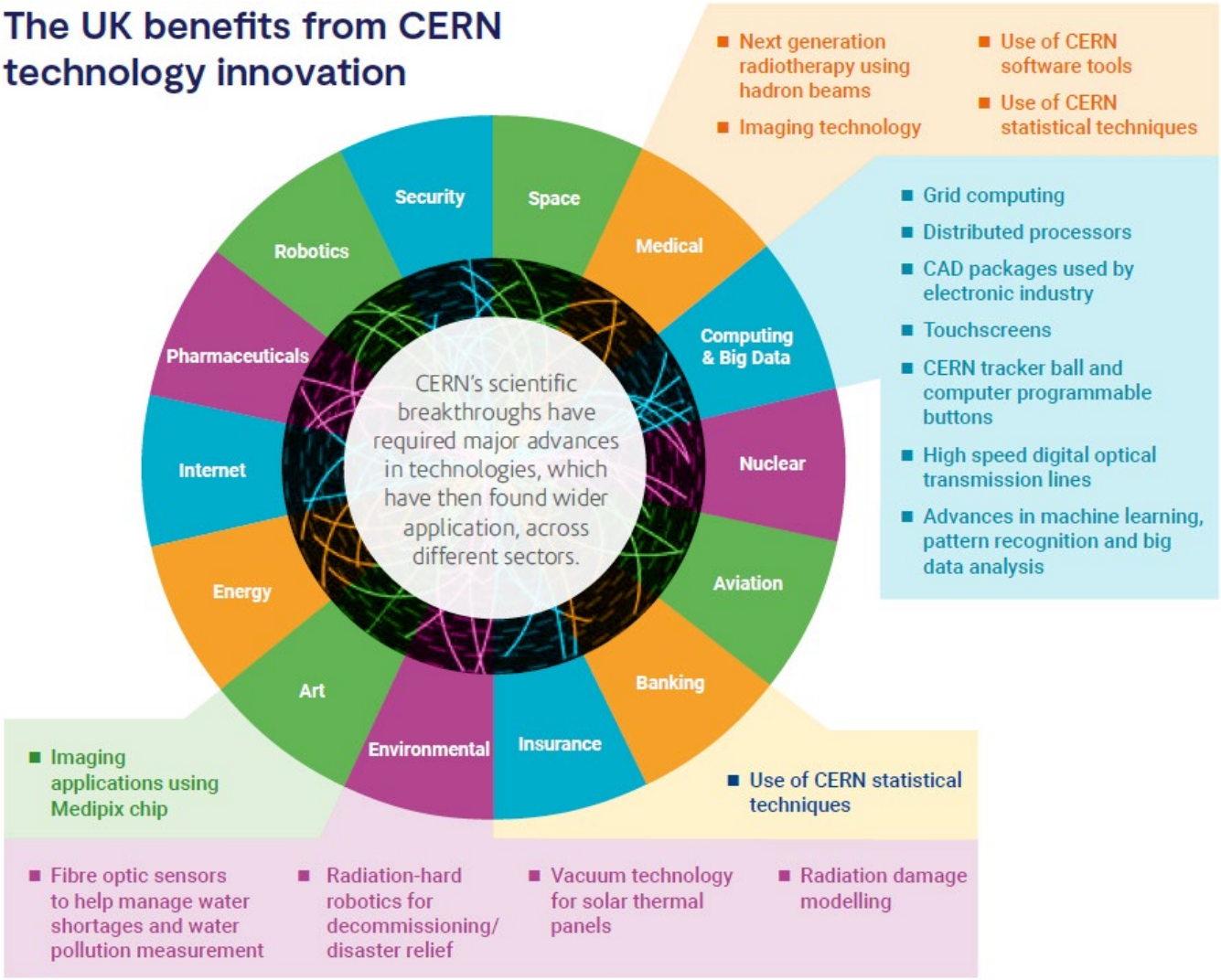
CASE STUDY: Smart Technologies to Extend Lives with Linear Accelerators (STELLA)

Radiotherapy is one of the most effective treatments for cancer. It typically uses X-rays, produced by colliding an electron beam from a linear accelerator (linac) into a target, to destroy or damage tumour cells. By 2040 it is projected that two thirds of cancer incidences will be in low-and-middle-income countries, however access to radiotherapy treatment in these countries is often poor due to the high cost of radiotherapy linacs and the challenges of operating, servicing and maintaining radiotherapy equipment.

Motivated by this, a multidisciplinary collaboration project was initiated between CERN, UK universities and the International Cancer Expert Corps, called STELLA. Using technical expertise and seed funding from CERN, STFC, Lancaster University and the University of Oxford, the STELLA project aims to develop a novel medical linac technology that improves the efficiency, reliability and serviceability of radiotherapy treatment in low-and-middle-income countries and challenging environments.

CASE STUDY: UK CERN technology innovation

Having successfully operated business incubation centres (BICs) for other technology sectors, STFC pioneered the first BIC focussed on assisting UK-based entrepreneurs and small business in taking CERN technologies and expertise to market. The programme provides a package of funding and business support to accelerate innovative business concepts. The programme has helped to bring a range of technologies to market including biosensors for applications in research, biotechnology and medicine, advanced coating technologies for heat transfer and the design, manufacture and supply of modular, autonomous, ground-based robots. As a result of this success, there are now CERN BICs in nine different member states. Going forward CERN is moving to the CERN Venture Connect Programme to build on the success of the BICs. This new programme will also benefit from the excellent UK expertise in this area.



Examples of technology advancement at CERN serving wider application, credit: STFC and Technopolis[7]

"Working at CERN I always felt that my skills as a technician were valued throughout the organisation. I made connections with people that influenced my career and personal life greatly."

Joel Davies, Technician in the CERN Data Centre

[7] STFC-Technopolis benefits of the UK's membership of CERN infographic; https://www.ukri.org/wp-content/uploads/2021/12/091221-STFC-BenefitsOfUK-CERNPartnership-infographic.pdf.

CERN brings nations together

Around the world, many research infrastructure and science experiments look to CERN as an exemplar in international research collaboration and governance. CERN's pioneering approach to international collaboration has its roots in uniting Europe after the Second World War, built on the pursuit of common goals and the neutrality of science. In 2012, CERN was granted Observer status to the United Nations (UN), demonstrating the importance the UN attaches to science and its role in society and recognising CERN's contributions in this space. Today CERN continues to attract scientific communities worldwide, as evidenced by the use of CERN's expertise, technologies and facilities by almost every global particle physics experiment with UK participation.

CERN Esplanade des Particules with member state flags and the new Science Gateway visitor centre in the background

"CERN is a testament to international cooperation and collaboration, an endeavour fostered on the belief that together we can answer some of the biggest questions in science and technology."

Dr Sudan Paramesvaran, Senior Lecturer at the University of Bristol and former Run Coordinator for the CERN LHC CMS experiment

CASE STUDY: CERN's leadership and influence in international collaboration: The Synchrotron-Light for Experimental Science and Applications (SESAME)

The SESAME light source in Jordan opened in 2017 and follows the CERN governance model for international research collaboration, promoting scientific partnerships in the Middle East. SESAME member states include Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine and Turkey. It is an autonomous intergovernmental organisation, where its members have full control over its development, exploitation and financial matters. CERN's constitution and reputation were crucial to securing support for the SESAME project both locally and across the international community. Today SESAME has five operational beamlines and an additional two beamlines are due to come online by 2024. SESAME's user community represents nearly 1,000 scientists across the region and in the latest round, there were over 150 high quality proposals for use of its beamtime from user groups in twelve different countries.

UK contributions to the project have included donations of beamlines and associated equipment from Daresbury Laboratory, the University of Liverpool and the Diamond Light Source which had a value (if bought new) of more than £17M, and training of young SESAME researchers through a Diamond-SESAME fellowship training programme. Furthermore, UK scientists were among those named in the American Association for the Advancement of Science 2019 Award for Science Diplomacy for their contribution to this project.

Benefits of CERN membership

Investment in CERN delivers clear long-term societal and economic impact to the UK, as evidenced in a 2020 impact report[8], including:

Research

- access to world-leading research and international leadership opportunities that enable UK scientific achievements, excellence and leadership
- access to the unique instruments, facilities and infrastructure that could not be developed by one country alone
- international presence and reputation in science and technology which attracts research funding and world-class talent to the UK

People and Skills

- access to exceptional training and employment opportunities across a broad range of disciplines and career stages for UK talent
- young people inspired to pursue careers in STEM through educational visit programmes and outreach for UK students and teachers

[8] 2020 report by Technopolis: Evaluation of the Benefits that the UK has derived from CERN; https://www.ukri.org/publications/evaluation-of-benefits-of-the-uk-cern-partnership/

- increased public interest in science and technology and support for investment in research, as a result of high-profile CERN achievements

Industry and Innovation

- access to commercial contracts for UK businesses that enhance their reputation
- increased global competitiveness of UK businesses through opportunities for innovation, upskilling and international collaboration
- development of novel technologies and expertise that can have wider applications and deliver benefits to society

International Partnerships

- relationships are built and science diplomacy is conducted at the highest level using this unique global platform for international collaboration
- the UK's reputation as a science powerhouse is supported through a prominent role in the world's preeminent international research facility
- best practise is shared and developed in universal issues such as diversity and inclusion and environmental sustainability

CERN and the UK

- The UK is the second largest contributor to the CERN budget (behind Germany).
- The UK subscription to CERN is around £160M per year. This fee is calculated annually and supports the construction and operation of CERN facilities.
- Additional funding to UK researchers working on CERN experiments is around £20-30M per year.
- Over the course of our membership, there have been two British Directors General and many major leadership roles in CERN's prestigious scientific experiments.
- UK scientists have contributed to Nobel Prize winning results at CERN, most notably in 2013 for the discovery of the Higgs boson.
- The UK has played a central role in developing novel technologies for the current and next generation of CERN experiments, particularly at the LHC, and is taking a leading role in exploiting innovative solutions developed at CERN.
- The UK is championing important matters at CERN including environmental sustainability, transparent and robust governance, and diversity and inclusivity.

“CERN is the UK's major international laboratory for particle physics and the exciting breakthroughs that people read in the news, like the Higgs boson discovery and flash electron cancer therapy, aren't just 'other people doing things somewhere else', but come with major contributions from researchers based at UK universities, working through CERN."

Prof. Aidan Robson, Professor at the University of Glasgow and Spokesperson of CERN’s CLIC Detector and Physics Collaboration

Preeminent British individuals throughout CERN’s history

John Bell FRS worked at CERN in the 1960s and was the originator of Bell’s theorem which helps to describe the fundamental nature of the physical world. This theory was later built on by John Clauser, Alain Aspect and Anton Zeilinger who won a Nobel Prize in 2022 for their work.

Peter Higgs FRS theorised the existence of the Higgs boson, an elusive particle that gives matter mass, in the 1960s. Following its discovery by researchers at CERN in 2012, he received the Nobel prize in Physics in 2013 alongside François Englert.

Lyn Evans CBE was the Project Director for the design and construction of the LHC during 1994-2008.

Professor Sir Chris Llewellyn Smith FRS was CERN Director General (DG) during 1994-1998. During this time the LHC was approved and construction started.

Sir Tim Berners-Lee KBE FRS wrote the software for the first Web server and the first Web browser at CERN in 1991.

Sir John Adams KBE FRS was CERN DG during 1960-1961 and co-DG during 1971-1980. He led the design of the Super Proton Synchrotron particle accelerator that is still used today as the final injector of high-intensity proton beams for the LHC.

Forward look for CERN and the UK

CERN and its global research community are already developing ambitious plans for the post-LHC era of CERN with potential research programmes stretching decades into the future. These will continue to push the frontiers of scientific discovery and further the development of cutting-edge technology and engineering. They will also ensure that CERN continues to lead the way in international research collaboration and governance and drive forward its agenda in a variety of areas including environmental sustainability and knowledge transfer. In short, CERN will continue to bring nations together, inspire the next generation and deliver high impact for science and society.

The UK is committed to being a key partner in CERN's future and has firm ambitions to leverage further value and societal impact through its membership, and in line with commitments set out in both the Integrated Review[9] and the UK Science and Technology Framework[10]. This strategy sets out a ten-year programme of coordinated activities and shared goals across government, research and innovation communities and industry that will strengthen our partnership with CERN and its member states and maximise the UK's return on investment in CERN.

[9] Integrated Review Refresh 2023: Responding to a more contested and volatile world; https://www.gov.uk/government/publications/integrated-review-refresh-2023-responding-to-a-more-contested-and-volatile-world

[10] UK Science and Technology Framework; https://www.gov.uk/government/publications/uk-science-and-technology-framework

Goal 1: Research Excellence

"To me, CERN is the world's leading particle physics laboratory. It's where you go if you want to test the furthest limits of our understanding, access amazing experiments, and work with fantastic people from all over the world. CERN is the place that brings talent, expertise, skills and ambition together to tackle the biggest questions in science."

Prof. Tara Shears; Professor at the University of Liverpool and Researcher on the LHCb experiment

CERN's science programme has delivered major advances in our understanding of the universe. CERN's research focuses primarily on particle physics – studying the fundamental constituents of matter – but the broader programme includes isotope chemistry, studies of antimatter atoms and even the formation of clouds.

The UK is a world leader in particle physics, accelerator science, nuclear physics, engineering and computing, borne out of centres of research excellence in our universities and national laboratories. CERN benefits from our skills and expertise and in turn our researchers have access to CERN's diverse research programme and can collaborate with the best minds in physics. Indeed, a high proportion of our particle physics programme is focused on CERN research.

Our goal is to ensure that our researchers continue to push the frontiers of global science by delivering our current commitments to CERN programmes, ensuring long-term UK leadership in high energy physics, publishing their work in high impact journals and strategically investing in future research and infrastructure. This will enable our researchers to remain central to activities at CERN and in turn will support CERN to remain at the frontier of particle physics. This will strengthen our scientific partnership with CERN and its member states, helping to develop future generations of global leaders in physics.

The CERN LHCb experiment collaboration 100m underground

Research Excellence – facts and figures

- Over 900 researchers from the UK work at CERN every year.
- Over 50 UK institutes are involved in CERN research representing all three devolved nations and all areas of England.
- In the QS World University Rankings 2023, the UK has 17 of the 100 top universities in the world, 15 of which participate in CERN research.
- Recent examples of UK leadership in CERN's science programmes include:
    - leading contributions to the upcoming LHC upgrade to the High Luminosity LHC, which will produce five times as many Higgs bosons as the LHC and help researchers probe the limits of the Standard Model further.
    - the UK is a key partner in the ATLAS and CMS collaborations with UK university staff and students playing important roles in the leadership, development and operation of the detectors. The contributions of ATLAS and CMS in the discovery of the Higgs boson were highlighted in the 2013 Nobel prize for physics, jointly awarded to Peter Higgs and François Englert.
    - members of the UK research community have been spokespersons for major CERN experiments including LHCb, ATLAS, CMS and ISOLDE.
- STFC national laboratories and UK universities play a major role in the management, development and maintenance of the Worldwide LHC Computing Grid, the digital infrastructure that enables particle physicists to analyse vast quantities of LHC data

We will achieve our Research Excellence goal through our objectives:

Objective 1.1: Deliver UK technical contributions to CERN experiments and computing.

We want to support UK researchers to fulfil their technical commitments to the current and future generation of LHC and non-LHC experiments and computing at CERN and to ensure they are recognised for their contributions. This will require sustained strategic investment in CERN's research and computing programmes and use of our expertise and capability in both universities and STFC national laboratories.

We will:

- support UK researchers to deliver our current and future commitments to CERN's scientific and computing programmes, including the delivery of upgrades to, and maximising the scientific return from the LHC experiments.
- work with researchers on CERN experiments to ensure transparent and robust governance of UK CERN experiment collaborations, as well as promoting sustainability through efficient use of resources and value for money in delivery of our commitments.
- work in partnership with UKRI research councils, and higher education partners, to promote and encourage UK investment in the full breadth of research opportunities at CERN.

Objective 1.2: Ensure long-term UK expertise and leadership in high energy physics.

We want CERN to remain at the forefront of particle physics research. This will enable future generations of UK researchers to be at the cutting-edge of frontier science discoveries and to be global leaders in particle physics. We should continue to shape and drive both theoretical and experimental research at CERN, and enable CERN to benefit from a vibrant and diverse research community.

We will:

- ensure continued UK strategic leadership in experimental and theoretical particle physics research and R&D programmes and develop leadership in the full breadth of next-generation experiments at CERN through investments in the UK programme.
- support our researchers to influence and engage in activities to define the future science strategy of CERN, for example through future updates to the European Strategy for Particle Physics.
- support UK-based researchers to publish their work in high-impact journals and work with CERN to overcome any barriers they may face.

- support initiatives in the UK and at CERN to improve the diversity and inclusivity of the UK CERN community, for example CERN's '25 by 25' initiative[11].
- encourage UK researchers at CERN to demonstrate the value and exciting nature of CERN research to attract students and early career researchers into the field.
- identify and support promising early career researchers in particle physics to develop into future leaders, such as through UKRI Future Leader Fellowships.

Objective 1.3: Advance scientific discovery for both the UK and CERN, through future investment in UK research and infrastructure.

We want to facilitate strategic investment in our research, infrastructure and people to enhance our particle physics ecosystem and leverage further value for both the UK and CERN. This will contribute to the UK's position as an attractive place to carry out research and as an international partner of choice.

We will:

- identify opportunities to further develop, improve and increase our research expertise and technical capability across our programmes.
- develop and sustain a technology R&D portfolio that aligns to the European particle physics technology roadmaps and includes investment in computing, feasibility studies for new projects, and improving the environmental sustainability of accelerator technologies.
- promote UK research expertise and national facilities, which are complimentary to CERN, to global audiences in order to promote further international collaboration and attract the best researchers to the UK.

We will measure success towards our Research Excellence goal through:

- the quantity and quality of high impact particle and nuclear physics research taking place in the UK and by researchers at CERN.
- successful delivery of committed UK technical contributions to CERN experiments.
- numbers of UK institutions and researchers, including students, involved in CERN research over time.
- the number of UK individuals in scientific positions of leadership at CERN.
- the scale of investment in the domestic particle physics programme relative to the CERN subscription.

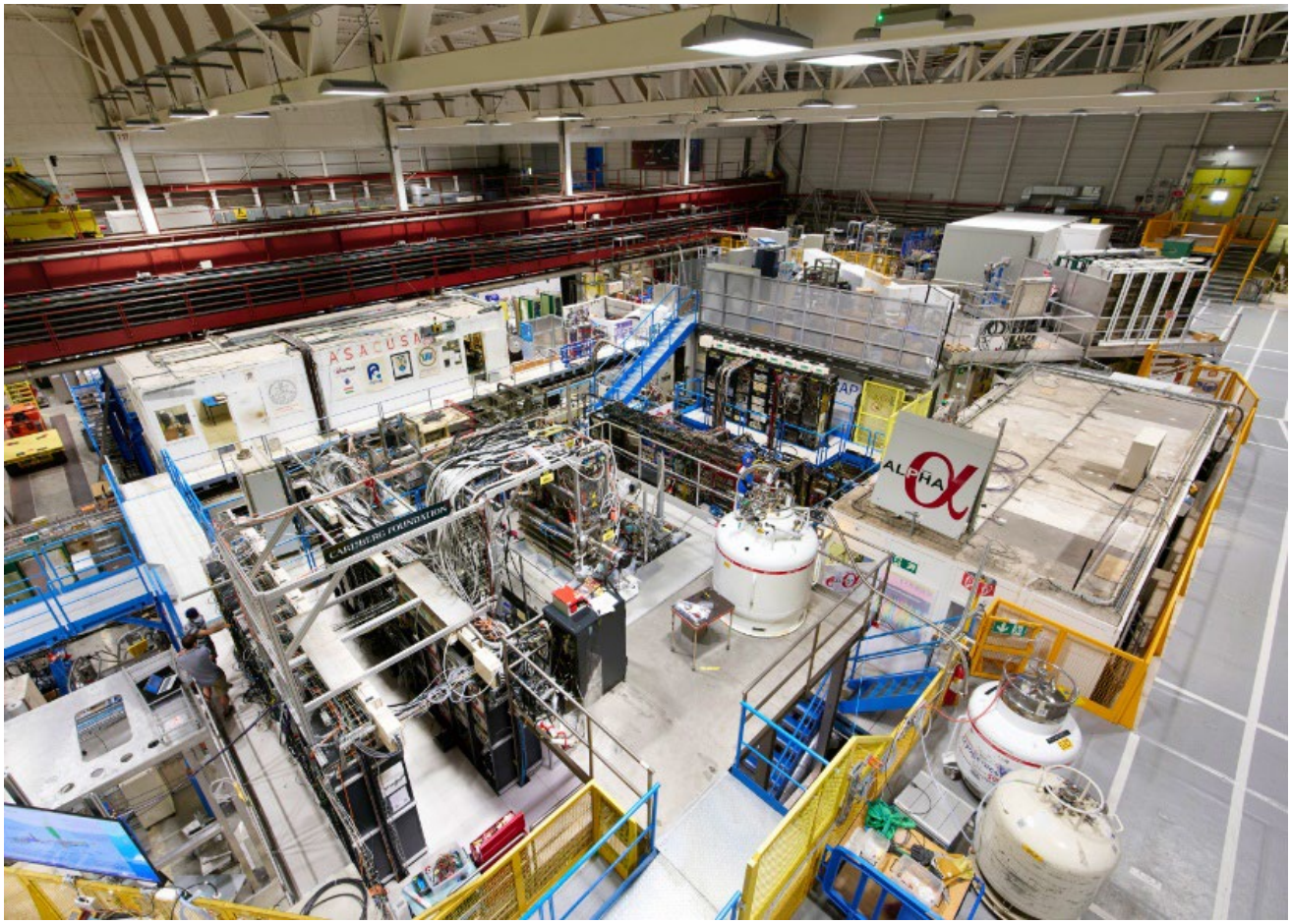
[11] CERN 25 by 25 initiative; https://diversity-and-inclusion.web.cern.ch/actions/25-25

- UK involvement and strategic leadership in defining the future of European particle physics.

CASE STUDY: EPSRC funds UK contributions to CERN antimatter experiment

The Engineering and Physical Sciences Research Council (EPSRC) funds antihydrogen research at the 'Antimatter Factory' at CERN, including the UK's participation in the ALPHA experiment, which is led by Swansea University. ALPHA works with trapped antihydrogen atoms, the antimatter counterpart of the hydrogen atom, to study the fundamental symmetries between matter and antimatter. It is thought that matter and antimatter were created in equal amounts at the Big Bang. The expectation is that when matter and antimatter meet, they annihilate each other, yet today antimatter seems to be virtually absent from the visible universe. Understanding why this is the case is one of the major challenges in particle physics.

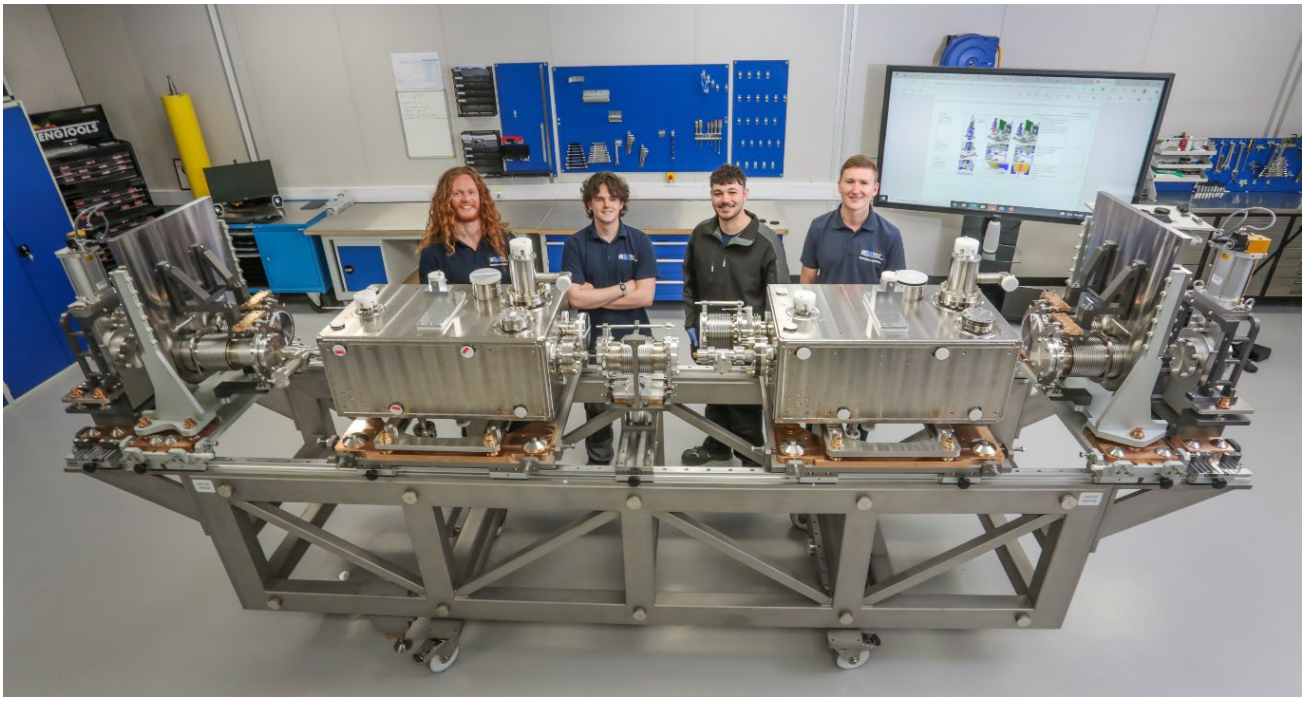
In 2021 the ALPHA experiment made the front cover of *Nature* after it successfully cooled down antihydrogen atoms by a factor of ten using lasers, opening new possibilities for more precise measurements and studies of antimatter. Deputy Spokesperson for the ALPHA experiment Professor Niels Madsen (Swansea University), said: "Our goal is to investigate if the properties of our antihydrogen match those of ordinary hydrogen as expected by symmetry. A difference, however small, could help explain some of the deep questions surrounding antimatter."



The ALPHA experiment in the 'Antimatter Factory' at CERN

CASE STUDY: STFC national laboratories and the Cockcroft Institute deliver critical technology breakthrough for CERN High-Luminosity LHC

Experts in STFC national laboratories and the Cockcroft Institute, working with colleagues at CERN, developed a novel technology called ‘crab cavities’ that will be key to maximising the scientific exploitation of the High-Luminosity LHC (HL-LHC), a major upgrade of the LHC. The HL-LHC, which is scheduled to start operating in 2029, will increase the luminosity of the LHC by a factor of five to ten. Luminosity is a crucial indicator of a collider’s performance – the higher the luminosity, the higher the number of collisions and the more data the experiments can gather. The superconducting crab cavity cryomodules, which are being built by engineers and technicians at STFC’s Daresbury Laboratory, will play a crucial role in delivering the higher luminosities of the HL-LHC by rotating the particle bunches before and after they intersect so as to maximise the number of collisions.



STFC Daresbury Laboratory technicians alongside Crab Cavity String

Goal 2: World Class Skills

2

World Class Skills

Develop a pipeline of highly skilled technicians, engineers and scientists.

2.1. Achieve a representative return for the UK in CERN's training and employment opportunities.

2.2. Encourage the exploitation of skills developed at CERN by UK institutions and businesses.

"CERN has given me the training, networks and leadership skills necessary to pioneer world-leading research activities in the UK. It has allowed me to form collaborations with outstanding researchers across the world and provided me with a unique and tailored environment in which to conduct and share research."

Dr Conor Fitzpatrick, UKRI Future Leaders Fellow at the University of Manchester and member of the LHCb collaboration

CERN offers training and employment in a diverse range of disciplines including science, engineering, computing and technical roles, as well as in non-STEM fields such as translation, finance, communications and even firefighting.

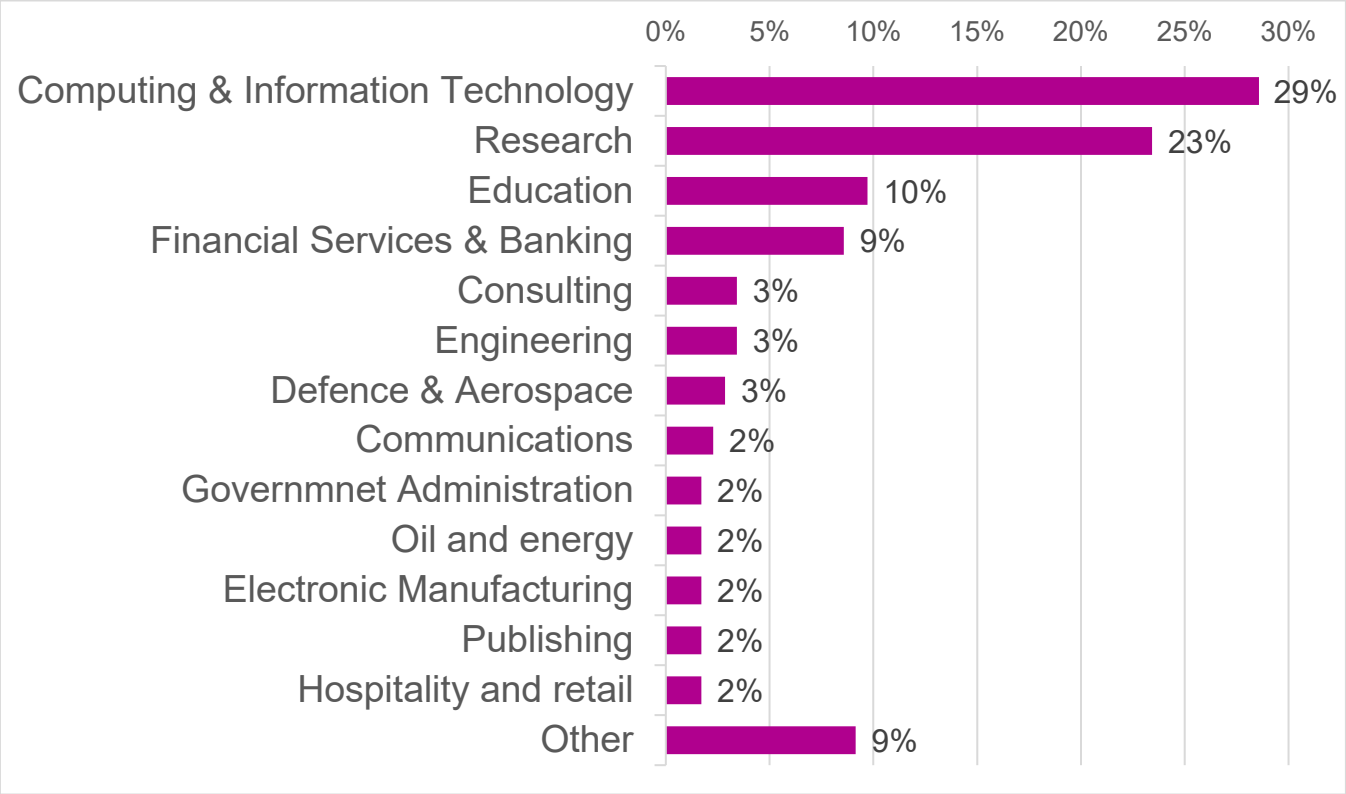
Regrettably, when comparing the number of people studying, training and working at CERN by nationality against member state contributions, the UK is outperformed by many other member states. This means we are not taking full advantage of the opportunities provided by CERN membership to teach, train and upskill UK nationals.

Membership of CERN enables UK nationals to compete for CERN training and employment opportunities and develop highly sought-after skills in a stimulating environment. Around half of British CERN alumni return to the UK and contribute their skills to society in a range of sectors including financial services, defence and space, computer software and services, and higher education, as well as continuing within research (see figure 3). Membership of CERN also helps to attract high-calibre talent at all levels from apprentices and graduates through to senior scientists and technicians. To take full advantage of these far-reaching opportunities, a comprehensive and sustained approach is required of all stakeholders, as outlined in this section.

Our goal is to develop and maintain a sustainable pipeline of uniquely skilled technicians, engineers and scientists by maximising uptake of training and employment opportunities at CERN, supporting CERN alumni to contribute to the UK economy, and encouraging diverse, young talent to pursue STEM careers. These interventions will not only benefit the UK but will also help CERN to access future generations of talent, lead international research discovery and to maintain its position at the forefront of research. This goal is upheld by our belief that diversity in people, ideas, skills and disciplines is key to the future success and vibrancy of

research. Achieving this goal will contribute towards addressing the challenges described in the government's R&D People and Culture Strategy[12].

Figure 3: Chart showing distribution of destination sectors of UK CERN alumni 2017-2023



'Other' destination sectors include Biotechnology, Healthcare, Marketing and Insurance, Law, Utilities and Food Production

World Class Skills – facts and figures

- CERN employs over 2,600 staff with approximately 150 new recruits each year. Over 75% of CERN staff are in engineering and technical roles.
- In 2023 UK nationals comprised 8% of CERN staff.
- Each year around 1,000 CERN training contracts are available in a variety of disciplines and at all levels from undergraduates through to senior academics.
- Since 1966, CERN has operated a successful apprentice programme offering apprenticeships in technical and non-technical fields such as library apprentices.
- In the UK, over 65% of applicants to particle physics fellowships are from overseas and over 90% of fellows remain in the UK following completion of their fellowship.

[12] R&D People and Culture Strategy; https://www.gov.uk/government/publications/research-and-development-rd-people-and-culture-strategy

We will achieve our World Class Skills goal though our objectives:

Objective 2.1: Achieve a representative return for the UK in CERN's training and employment opportunities.

We want to increase the uptake of CERN's training and employment opportunities by UK nationals, and provide continued career support for those in positions at CERN. This will increase our talent pool, contribute to a vibrant, diverse research community in the UK and at CERN, and support efforts to improve our industrial return from CERN by increasing the number of UK industry contacts at CERN. CERN's training and employment opportunities are available in a broad range of high-demand STEM disciplines at all levels of experience, including apprenticeships, studentships, fellowships and professional roles.

We will:

- work in partnership with Research Councils within UKRI, and with higher education partners, to increase awareness of employment and training opportunities at CERN, particularly in engineering, computing and technical disciplines, and with a focus on reaching individuals who would not usually consider CERN as a place to work.
- work with CERN and UK institutions to identify and break down barriers in applying to CERN employment and training opportunities to ensure an inclusive and transparent process, leading to the best talent working at CERN. We will also seek opportunities to improve support for UK applicants.
- work in partnership with the UKRI and STFC apprenticeship and placements teams to encourage and support applications to the breadth of placements offered both at CERN and within UK based research facilities.
- set up a network of 'CERN Ambassadors' in UK universities drawing on the expertise of UK CERN alumni to promote CERN training opportunities and provide guidance to all prospective applicants.
- continue to deliver programmes of Long-Term Attachments (LTA) to CERN for STFC-funded students, researchers and staff.
- support UK staff who are employed at CERN to drive sustainable career pathways, by showcasing the diverse opportunities in employment that CERN offers.

"Alumni are about the power of the beehive. We want to put their collective wisdom and their collective energy together and motivate them to help us get the message across how wonderful science is."

Dame Anne Richards DBE; CEO at a private finance services company and Chair of the CERN & Society Foundation

Objective 2.2: Encourage exploitation of skills developed at CERN by UK institutions and businesses.

We want to raise awareness in UK institutions and businesses about the benefits of collaborating with CERN in order to make the 'CERN experience' sought-after by employers and investors. This will upskill our workers, strengthen knowledge exchange and drive long-lasting impact from the activities taking place at CERN and in the UK.

We will:

- develop a targeted engagement approach to support and increase collaborations between CERN and UK universities and businesses.
- explore the potential for secondments or internships from our institutions and businesses to CERN, and for CERN staff to the UK.
- identify and increase awareness of the transferrable skills of CERN alumni that can benefit UK commerce and universities in a varied range of disciplines.

"It's difficult to quantify the impact my time at CERN has had on me and my subsequent career. The confidence, experience and knowledge I gained there, have been invaluable in getting me to where I am today and without it, I have no doubt that my career would not have taken such a fruitful path. I owe an enormous debt of gratitude to CERN and, who knows, maybe I'll return for a second spell as the first was so enjoyable!"

Elliot Rose, former Electronic Technician at CERN and the first person from the UK to be enrolled in CERN's Technician Fellowship programme

We will measure success towards our World Class Skills goal through:

- the number of UK nationals in training and employment at CERN.
- the number and size of collaborations between CERN and UK businesses and institutes.
- the impact of CERN alumni in their post-CERN careers.
- the diversity of UK applicants to CERN training and employment opportunities.
- the number of UK-based students and researchers on long-term attachment and placements at CERN.

CASE STUDY: CERN technicians

Jamie Pinnell from Malmesbury, Wiltshire

Jamie first heard about CERN while studying for his A-levels in 2008 but never thought about working there. Towards the end of his advanced apprenticeship in engineering at STFC, he learned of the technician opportunities at CERN as a result of connections made through his role as a STEM Ambassador. Jamie joined CERN's technician training programme in 2014 and is now a full member of staff.

Jamie contributed to the design, building and installation of one of the largest detector assemblies in the ATLAS experiment cavern, the New Small Wheels. He is one of only two people in the world able to pilot the precise opening and closing operations of the ATLAS detector, and is now fluent in a second language. He recommends the CERN experience as "fantastic, challenging and varied" and highlights the friendships he has made and maintained with people from all over the world.

Abigail Lee from Warrington, Cheshire

After completing a Level 3 BTEC in engineering and then an engineering apprenticeship, Abigail was contacted by CERN's talent acquisition team on LinkedIn and encouraged to apply for CERN's technician training programme. Since joining CERN in 2020 Abigail has undertaken design and maintenance work for new and existing instruments in radio frequency and beam instrumentation that are essential for the safe and efficient operation of CERN's accelerator complex.

She said: "The highlight for me would definitely be the people I have met along the way; you get the chance to work with so many international people from many different backgrounds, and you learn a lot from them. Working at CERN is also a great opportunity to develop your future career path - each day is different and brings a new challenge." On completion of CERN's technician training programme in late 2023 Abigail is looking forward to starting her new role as a mechanical technician a STFC's Daresbury Laboratory.

CASE STUDY: CERN alumni

Kitty Liao

Former Applied Physics Fellow at CERN, Kitty Liao is founder of IDEABATIC, a UK-based start-up that works on critical last-mile cold chain issues for delivery of vaccinations to remote areas. Determined to improve access to basic vaccinations and reduce their spoilage rates, Kitty created SMILE, the world's first foolproof cooling system designed to reduce vaccine wastage. SMILE has won twelve innovation awards worldwide and is supported by the Royal Academy of Engineering and Innovate UK among others.

During her time at CERN, Kitty worked in the Beams Department designing and developing diagnostics systems for equipment performing at -271°C. Later she took part in a humanitarian hackathon at CERN and learnt about the challenges of keeping vaccines cold in the final stages of distribution to patients in remote areas. Kitty decided to use her expertise in low-temperate systems to try and solve these issues and started IDEABATIC. She described her time at CERN as "absolutely fantastic" and said: "working on my start-up in some aspects is similar to working at CERN - huge responsibility, the freedom to create, working independently and finding the right people to work with to achieve projects."

Rocio Perez Ochoa

Rocio Perez Ochoa spent time at CERN during her PhD. She is now based in London and co-founded and runs Bidhaa Sasa, a social enterprise in Kenya and Uganda that serves rural women, providing life improving goods for their homes and farms, including cooking, lighting and agricultural solutions.

Rocio said: "The years spent at CERN were formative for me, since then I have always approached my professional life with the highest standards possible and always searching for excellence in whatever sector I have worked. As an entrepreneur I have tried to replicate in my own organisation CERN's flat hierarchical structures and its diverse and open organisational culture. At CERN it is completely normal if a student shares an office with a Nobel prize winner!"

Goal 3: Commercial Impact and Innovation

3 Commercial Impact and Innovation

Win valuable business. increase technical capability and promote collaborative innovation.

3.1. Increase returns for UK businesses by winning CERN contracts.
3.2. Use business engagement with CERN to drive technological capability and innovation.
3.3. Develop international business partnerships and promote UK business growth in research and commercial markets beyond CERN.
3.4. Support CERN in striving towards best practice in business opportunities and continuously improving its procurement processes.

"The stimulating international environment and concentration of expertise is a driver for technology developments in industry and universities in the participating countries, with applications far beyond particle physics. For example, significant elements of the LHCb Upgrade detector, that has recently been installed at CERN, were built in collaboration with UK industry and the project provided high-technology skills training across eleven participating universities and institutes."

Prof. Chris Parkes, Professor at the University of Manchester and former Spokesperson of the CERN LHCb experiment

CERN issues commercial contracts in all areas of its work including civil engineering, information technology, electrical engineering and magnets, chemical and radiation equipment, electronic design and manufacture, cables and fibre optics, vacuum equipment, vehicles and office supplies.

CERN calculates an 'industrial return coefficient' comparing the economic value of contracts won against a member state's contribution to CERN; the return coefficient for the UK has historically been poor. This means we are not taking full advantage of the wide-ranging opportunities provided by CERN membership to maximise commercial impact and innovation opportunities described below.

Our membership of CERN enables companies to bid for commercial contracts, earning valuable business and driving innovation, however the total value of working with CERN is much broader than simply economic return. Working with CERN increases the exposure of our businesses to international markets and enables them to exploit opportunities in the wider big science marketplace and in other technical markets. Working with CERN drives innovation, capability and upskilling, catalyses international partnerships, and promotes collaboration with research and innovation communities to help bridge the gap between research and real-world impact. Winning CERN contracts bestows a degree of prestige on our businesses and improves their economic and global competitiveness, thereby helping to nurture a strong UK economy.

Having identified barriers the UK faces in this area, recent efforts by the UK and CERN to boost industrial return are seeing improvements. However, in order for this trend to continue and to take full advantage of the commercial opportunities presented by CERN, a

comprehensive and sustained approach is required of all stakeholders, as outlined in this section.

Our goal is to be a global partner of choice, winning valuable business, driving innovation and developing capability in key sectors in the UK. Industry collaboration will solve the technical and pioneering challenges arising from CERN's research programme. This will contribute to the government's ambitions to stimulate innovation and drive capability in key technologies, through enhancing collaborations between business and R&D infrastructure as outlined in the UK Innovation Strategy[13] and UK R&D Roadmap[14].

Commercial Impact and Innovation – facts and figures

- 120 commercial contracts ranging in value from around £45k to £9m are issued by CERN each year with an average total value of £440m, with many hundreds of contracts issued with a value below £45k.
- Over 500 UK companies have sold goods or services to CERN in the last decade.
- Over 75% of UK suppliers report a benefit to their reputation and global brand value from work with CERN.

We will achieve our Commercial Impact and Innovation goal through our objectives:

Objective 3.1: Increase returns for UK businesses by winning CERN contracts.

We want to support UK businesses to be more successful in bidding for CERN commercial contracts and increase our industrial return from CERN.

We will:

- utilise the UK CERN community, including the alumni network, to promote CERN commercial opportunities to businesses, raise awareness of the wider value of business opportunities at CERN beyond the monetary value, and flag potential future opportunities arising from major CERN activities to increase UK success.
- strengthen strategic relationships between UK and CERN technical and procurement teams to promote business engagement with CERN and remove barriers.
- optimise the STFC Industrial Liaison Office (ILO) function and leverage wider business opportunities expertise within UK government, particularly the Department for Business and Trade, to better support businesses tendering to CERN.

[13] UK Innovation Strategy: leading the future by creating it; https://www.gov.uk/government/publications/uk-innovation-strategy-leading-the-future-by-creating-it/uk-innovation-strategy-leading-the-future-by-creating-it-accessible-webpage#at-a-glance

[14] UK Research and Development Roadmap; https://www.gov.uk/government/publications/uk-research-and-development-roadmap/uk-research-and-development-roadmap

- develop and share varied case studies of UK business success at CERN to highlight the wider value of working with CERN.

Objective 3.2: Use business engagement with CERN to drive UK technological capacity and innovation.

We want to develop knowledge and capabilities in the UK that are required by CERN's research and experimental programmes through building long-term business partnerships. This will help to grow capability in the big science marketplace and drive innovation and technological development, thereby supporting our businesses to be globally competitive.

We will:

- coordinate people and activities in the STFC and UK research communities to engage UK businesses with CERN programmes. This should include early-stage R&D for future CERN projects, thereby helping to establish long-lasting productive relationships between UK businesses, research and innovation communities and CERN.
- use in-house expertise in STFC, DSIT and across the wider UK research and innovation community to fully exploit mechanisms, such as the CERN Business Incubation Centre or seed funding, to increase collaboration between UK businesses, research and innovation communities and CERN.
- work with partners across the UK innovation landscape, including Innovate UK's Knowledge Transfer Network and Catapults, to help more UK businesses capitalise on innovation opportunities by taking technology developed at CERN beyond its original application or into new markets.
- work across government to explore mechanisms to de-risk technology development for UK businesses working with CERN.

Objective 3.3: Develop international business partnerships and promote UK business growth in research and commercial markets beyond CERN.

We want to support our businesses to use CERN as a catalyst for innovation and growth, leading to sustainable long-term enhancement and increased competitiveness in markets beyond CERN, such as at other research facilities and in wider technical markets. We want to build on CERN opportunities to help our businesses develop international commercial partnerships in other CERN member states to yield export opportunities.

We will:

- work with UK business development and innovation experts to identify international partners for collaboration in CERN business opportunities and develop mechanisms to enable increased collaboration between UK businesses and international partners on CERN opportunities.

- identify and connect UK businesses to potential technical markets and export opportunities beyond CERN.

Objective 3.4: Support CERN in striving towards best practice in business opportunities and continuously improving its procurement processes.

We want to maximise opportunities afforded by UK membership of CERN to learn from CERN expertise in business opportunities, and to share UK best practice with CERN. We want to support CERN to continuously improve its procurement processes, for example to consider environmental sustainability, and to achieve its objective of improving the balance of industrial returns across its member states.

We will:

- share best practice and promote cross-pollination of ideas between CERN and STFC national laboratories in common organisational challenges, such as improving environmental sustainability through co-development of sustainable accelerators.
- work with CERN management and industrial liaison officers from other CERN member states to identify and implement opportunities to continuously improve the balance of industrial returns across member states and ensure transparent and inclusive procurement processes.
- work with CERN's Procurement and Industrial Services Group and governance structures to explore opportunities to include factors such as environmental sustainability and value-for-money into CERN procurement.
- develop relationships between CERN's Knowledge Transfer Group and UK innovation partners, including STFC's Business and Innovation Directorate, to uplift complementary knowledge exchange activities and develop innovation networks.

We will measure success towards our Commercial Impact and Innovation goal through:

- the number and value of contracts won at CERN by UK businesses.
- the wider value for UK businesses stemming from winning CERN business such as upskilling and access to new markets.
- intellectual property or technology developments owned or led by UK institutions resulting from CERN collaboration.
- collaborations and contracts between UK business and research and innovation communities driven by CERN projects or procurements.
- reaching new businesses with the potential to successfully tender to CERN commercial opportunities, e.g. through the government's Contracts Finder Service.

CASE STUDY: UK companies licensed to provide the light along CERN's tunnels

Safety is a priority at CERN and lighting in the network of tunnels that contain its particle accelerators is a key feature. Although people are not allowed in the tunnels when the accelerators are operating, the lighting remains in situ and has to be able to survive high levels of radiation.

Before 2019, CERN faced the prospect of paying high unit costs for ordering replacement radiation-resistant lighting from the only suitable commercial supplier in Europe. Efforts by CERN electrical engineer James Devine and colleagues to research and test alternative technologies produced a lighting solution that delivered a 75% reduction in cost. These designs were licensed under the CERN Open Hardware Licence and made publicly available.

James Devine showing the LHC tunnel lighting

Working to CERN's design UK companies Thorlux and Isocom then won contracts to supply over 1000 replacement lights in some of CERN's tunnels, saving CERN more than 2 MCHF.

CASE STUDY: UK company BIOS-IT outfitting new CERN data centre

Computing is central to CERN. The current LHC run (2022-2025) is expected to produce more than 600 petabytes of data that will need to be stored and analysed. This is the equivalent to over 20,000 years of 24/7 HD video recordings. CERN's Worldwide LHC Computing Grid (WLCG) combines the computing resources from more than 170 data centres in more than 40 countries, providing over 12,000 physicists around the world with near real-time access to this data, and the power to process it.

In order to meet the increasing computing demands of the LHC as it is continuously upgraded, CERN is building a new state-of-the-art data centre on its Prévessin site; it will come online in late 2023 and be at the heart of the WLCG. UK company BIOS-IT has won several multi-million-pound contracts to outfit the new data centre with thousands of Central Processing Unit (CPU) cores and is working with CERN to develop mutually beneficial solutions that reduce power consumption and operational costs whilst enhancing the scalability of CERN's IT infrastructure. The new data centre will also make use of the latest cooling technologies and will recuperate heat energy for warming other buildings on site, thus helping to keep costs down and contributing towards CERN's commitment to protect the environment.

CERN's new data centre design

Goal 4: International Leadership

"CERN is one of the most significant research labs in the world and constantly sits at the cutting edge of technological development. As a member state, the UK both contributes to that research and helps decide what will be pursued."

Dr Simon Albright; Accelerator Physicist at CERN

CERN is an unrivalled centre of global scientific and technical excellence with a unique international platform. In 2012, CERN was granted Observer status to the United Nations (UN), demonstrating the importance the UN attaches to science and its role in society. CERN's organisational approach is a successful example of international collaboration that bridges political barriers through the pursuit of common goals. CERN is considered an exemplar among international research infrastructure and across research more widely.

CERN membership contributes to the UK's international presence and reputation in research and beyond, aligning with DSIT's responsibilities and priorities[15] for 2023 including positioning the UK at the forefront of global scientific and technological advancement. It enables our research to benefit from the organisational expertise and prowess of the most renowned research infrastructure in the world. It also enables the UK to collaborate internationally and champion, on a global stage, its expertise in areas such as environmental sustainability, research security, equality, diversity and inclusivity, and robust governance, helping to shape the international environment as set out in the Integrated Review Refresh[16].

Our goal is to be a strong voice at CERN, champion our principles for engagement and bolster relationships with key international partners, whilst ensuring UK researchers have access to the best infrastructure for R&D. This will ensure CERN remains world-leading, not just in science and technology but also on environmental, social and governance matters. This aligns with the ambitions set out in the UK Science and Technology Framework[17] and will help propel the UK to Science Superpower status.

[15] DSIT Responsibilities and priorities; https://www.gov.uk/government/organisations/department-for-science-innovation-and-technology/about
[16] Integrated Review Refresh 2023: Responding to a more contested and volatile world; https://www.gov.uk/government/publications/integrated-review-refresh-2023-responding-to-a-more-contested-and-volatile-world
[17] UK Science and Technology Framework; https://www.gov.uk/government/publications/uk-science-and-technology-framework

We will achieve our International Leadership goal through our objectives:

Objective 4.1: Leverage CERN's global platform to build and enhance constructive international partnerships.

We want to utilise the unique international composition of CERN to enhance links with key partners and help sustain the UK's strategic advantage through science and technology.

We will:

- take advantage of all CERN events and engagements, such as the inauguration of the Science Gateway in 2023 and CERN's 70th anniversary in 2024, to nurture and strengthen relationships with CERN member states and partners.
- strategically identify opportunities in international engagements with CERN member states and partners to set out our principles for engagement and strengthen links.
- support CERN in its ambition to secure sustained political and financial support.

Objective 4.2: Champion our principles for engagement on a global stage.

We want to ensure that CERN is an excellent, inclusive place to work, which protects the integrity of the system of international research collaboration. We will draw on our principles for engagement and expertise to help achieve this, for example in environmental sustainability and diversity and inclusion. We want to utilise CERN's global platform to develop best practice and share as an example to other organisations.

We will:

- strengthen strategic relationships between CERN and the UK and promote open dialogue in best practice and the sharing of ideas.
- provide UK expertise and leadership through CERN governance structures on organisational, financial, security and strategic matters, ensuring transparent, effective and robust governance and supporting CERN to deliver organisational excellence, and financially sustainable decision making.
- work with UK CERN stakeholders to identify opportunities for continuous improvement at CERN and in the UK by sharing expertise and ideas, for example around business and training opportunities at CERN.

Objective 4.3: Encourage strong UK representation in CERN staff and positions of leadership.

We want to maintain our strong representation in senior staff and governance positions at CERN to guide the next generation of work, be a strong voice for the UK, and actively contribute to CERN's future successes.

We will:

- identify future leadership opportunities at CERN and coordinate UK CERN stakeholders to provide support to candidates where appropriate.
- work with UK CERN stakeholders to support potential future leaders at CERN to develop and fulfil their potential, for example through mentorship.
- build strong relationships with UK nationals at CERN and seek their engagement in activities to improve UK returns from CERN, as set out in this strategy.
- ensure continuity of UK expertise in CERN's international governance structures to maintain delivery of sound, evidence-based advice. This will help to ensure the organisation is effective and governed in line with our principles.

We will measure success towards our International Leadership goal through:

- UK representation in positions of leadership at CERN.
- development of best practice and shared learnings from our partnership with CERN and its member states.
- international partnerships bolstered through CERN engagements that align with government priorities.

The international collaboration of CERN's CMS experiment comprises almost 6,000 physicists, engineers, technicians, students and support staff from 256 institutes across 59 countries

Goal 5: Engage and Inspire

"It was eye-opening for the students to see the range of skills and expertise being employed at CERN as well as the vast collaborative network between universities and other research facilities globally."

Henry Pickett, Physics Teacher at Kingsbridge Community College, Devon

CERN is an international centre of excellence that shapes global science and delivers real-world impact. Through showcasing its research and the resulting benefits, CERN helps bridge the gap between science and society. CERN has education and outreach programmes that cater for students of all ages, teachers and members of the public with in-person and virtual activities as well as a wealth of online resources.

Funding councils, institutions and researchers in the UK run outreach and public engagement programmes in collaboration with, and complementary to, CERN's own. These programmes seek to inspire people of all ages and backgrounds to pursue careers in science, technology, engineering and mathematics (STEM) subjects, engage people about the value of frontier research to society, and inspire individuals everywhere to be champions for STEM. This work helps the public to understand the positive impact that science and technology has on all our lives[18].

We believe that STEM is for everyone and that increasing the inclusivity of STEM to attract more diverse people, ideas and skills is critical for the future of STEM research. Public engagement activities related to CERN play an important role in growing the UK's STEM talent pool, helping young people and their families to see STEM as exciting, relevant and accessible to all. It will also inspire the next generation of scientists, engineers and technicians to pursue opportunities at CERN, as well as further raise the profile of the exciting work that takes place within CERN.

Our goal is to engage and inspire diverse audiences across society through scientific discovery and technological advancement at CERN and in the UK, inspiring more individuals to pursue STEM careers and ensure scientific endeavour is relevant and accessible to all.

[18] UK Science and Technology Framework - taking a systems approach to UK science and technology; https://www.gov.uk/government/publications/uk-science-and-technology-framework

Engage and Inspire – facts and figures

- 500 schools with 12,000 pupils visit CERN each year from the UK, which is the most of any CERN member state.
- STFC organises numerous outreach events across the year to discuss CERN and big science, including in schools, at festivals, and with government departments.
- CERN averages around 2,000 mentions per year in the UK media with peaks for events such as the LHC switch-on in July 2022.
- A survey of 673 physics undergraduates in eight universities in the UK showed 95% were attracted to study science because of activities in particle physics (such as CERN), with over 50% saying they were inspired by the discovery of the Higgs boson.

We will achieve our Engage and Inspire goal through our objectives:

Objective 5.1: Encourage people of all ages and backgrounds to pursue careers in STEM through the inspiration of CERN's discovery science and technology.

We want to showcase the breadth and impact of CERN's inspirational scientific programmes to inspire people of all ages to engage and pursue careers in STEM, particularly those who have been historically underrepresented within these disciplines, and young people who are the decision makers, researchers and innovators of tomorrow.

We will:

- deliver a diverse programme of CERN outreach and public engagement activities in the UK including for schools, teachers, industry, professional bodies and the public through innovative and inclusive dialogue.
- promote and support CERN's school visit and teacher programmes, including new opportunities to visit and engage with CERN provided by the opening of the Science Gateway in late 2023.
- collaborate with other organisations, such as the Institute of Physics, the Institute for Research in Schools and the Wellcome Trust to develop and promote outreach activities and funding opportunities.
- encourage inclusion of CERN research and technology in school and university courses to promote educational engagement and career opportunities in STEM.
- develop a targeted engagement approach aimed at increasing representation within groups that have been historically underrepresented within STEM subjects and careers e.g. through the STFC Wonder Initiative[19].

[19] STFC Public engagement: Wonder Initiative; https://www.ukri.org/what-we-offer/public-engagement/public-engagement-stfc/our-support-for-public-engagement-stfc/public-engagement-wonder-initiative/

Objective 5.2: Engage the public about the importance of STEM research and its societal impact.

We want to leverage the international renown of CERN to engage people in frontier science, engineering and technology, and inspire the nation to increasingly value and participate in scientific discovery.

We will:

- support and provide UK public engagement teams and individuals with CERN outreach materials and connections to improve the quality, reach and impact of our engagement even further.
- encourage innovative and inclusive approaches to public engagement both within the UK and CERN to increase reach and ensure that more people value STEM research, for example through events at festivals, galleries and museums.
- strengthen strategic public engagement relationships between CERN communities based in Geneva and the UK to encourage collaboration and sharing of best practice.
- maintain strong connections to the UK media to promote exciting CERN news and societal impact.
- facilitate Ministerial and senior government official visits to CERN to inspire decision makers about the breadth of opportunity STEM research offers and the benefits this brings to the UK.

Objective 5.3: Motivate all UK CERN stakeholders to act as ambassadors for the opportunities afforded by big science to people of all backgrounds.

We want to empower everyone involved in the UK's membership of CERN, from apprentices to particle physicists and business owners to government officials, to champion CERN and the importance of STEM.

We will:

- increase awareness of the value and diversity of work carried out by UK researchers at CERN within UK government and UKRI.
- fund and incentivise the academic communities we support to develop and participate in outreach and public engagement to maximise the wider value of UK science investments in CERN.
- encourage and support all UK CERN stakeholders to champion and be ambassadors for STEM research and its positive impact on society, using CERN as an example.

We will measure success in our Engage and Inspire goal through:

- Number and impact of school, teacher and public visits to CERN (in-person and virtual).
- Number and impact of outreach and public engagement events in the UK involving CERN science or researchers.
- Prominence of CERN in the UK media.
- Inclusion of CERN science in school and university curricula.
- Students studying STEM subjects in the UK who were inspired by frontier research such as that undertaken at CERN.

CASE STUDY: UK school visits to CERN

Annually, more schools visit CERN from the UK than from any other member state, with approximately 12,000 pupils visiting each year. These visits educate and inspire pupils and teachers through the breadth of work that takes place at CERN, seeing first-hand how the topics they study at school translate into real-world science and research.

- "Students feel inspired and motivated to excel at their forthcoming science and mathematics examinations. In addition, a number of students have indicated that they would now like to work at CERN. Many have continued a deep interest in the topics discussed at our visit."

  Cyfarthfa High School and The College Merthyr, Wales

- "Students have always enjoyed the visits. They have described them as being fun, enlightening and enjoyable. In recent years I have taken some non-science students as well as A level physicists, and both types of student have enjoyed the experience. In our most recent visit, our students were impressed by their visit to the CERN control centre and they could see some of the physics they have studied for A level being applied when we visited LHCb."

  St Philomena's Catholic High School for Girls, Surrey

- "Our visits to CERN were inspiring. For many (if not all) of our students this was the first glimpse of a professional working environment dedicated to physics research, certainly on that scale. We also had a lecture on applications of particle physics in medicine and were treated to some extra bits including a visit to the synchrocyclotron which was the icing on the cake for all of us"

  Kingsbridge Community College, Devon

Implementing the Strategy and Monitoring Progress

This strategy sets out how, over the next ten years, we will build on our partnership with CERN and its member states to unlock the full potential of our investment, lead scientific discovery and inspire the next generation. The strategy is ambitious, using five goals to cover the breadth of benefits available to us through our membership of CERN.

Achieving the goals of this strategy will rely on regular engagement with all members of the UK CERN community to seek their input and deliver actions. This will be developed within the implementation plan.

Over the next twelve months we will deliver:

- An internal implementation plan for how the goals and objectives will be achieved. The plan will be dynamic and reviewed regularly to ensure successful implementation. Within this plan we will set out a timeframe of delivery, as well as the key stakeholders we will work with to maximise success.
- An internal monitoring and evaluation plan which will track our progress for each of the objectives. To ensure success and continuous monitoring we will develop a timeframe to assess our progress.

At the end of each year we will:

- Develop an internal annual report detailing our progress against the strategy over the past year and our focus for the year to come. The findings will be presented to the UK CERN Strategic Advisory Board for comment and recommendations.

After three years we will:

- Review the UK Strategy for Engagement with CERN to assess whether it is still fit for purpose and refresh the strategy if necessary. We will also publish a summary of our achievements over the three years that the strategy has been in place in addition to setting out our ambitions for the next three years.

After ten years we will:

- Publish a report detailing our progress under each pillar, identify opportunities for the future and set out our ambitions for the next ten years.

This strategy has set out our ambition to enhance our partnership with CERN and its member states and maximise the resulting benefits for all involved. Whilst this strategy has focused on the UK’s aspirations, its success is heavily dependent on working together with CERN and its international partners to continue delivering world leading scientific research.

Annex – Strategy outputs, outcomes and impacts

Inputs	Goal	Activities	Outputs	Outcomes	Impact
The UK provides…		We will…	Leading to…	Meaning that…	Leading to…
Financial: subscription, contributions to CERN experiments **People**: researchers and students, technical and support staff, UK CERN relationships **Existing research knowledge from**: research community, governance expertise	**Research Excellence** Enable UK researchers to push the frontiers of global science discovery.	Deliver UK technical contributions to CERN experiments and computing Ensure long-term UK expertise and leadership in high energy physics Advance scientific discovery for both the UK and CERN, through future investment in UK research and infrastructure	Continued strong participation of UK researchers in domestic and international research projects, including those in CERN's science programme	UK expertise in particle physics experiments and infrastructure is maintained or increased World-class researchers and teams are attracted to and stay in UK particle physics Global partnerships and collaborations are facilitated to support big inspirational science projects	More high-impact papers and maintenance of the UK's global research ranking, contributing to the government's science superpower ambition

Inputs	Goal	Activities	Outputs	Outcomes	Impact
Infrastructure and capability: industrial capability, universities and institutes, national laboratories	**World Class Skills** Develop a pipeline of highly skilled technicians, engineers and scientists.	Achieve a representative return for the UK in CERN's training and employment opportunities Encourage exploitation of skills developed at CERN by UK institutions and businesses	Increased numbers of UK nationals taking up CERN training and employment opportunities Increased recognition of benefits of CERN training, employment and collaboration	Skills and capability of engineering, technical and scientific UK talent are developed in a unique and world-leading research infrastructure Larger talent pool in the UK	Increased numbers of highly skilled technicians, engineers and scientists whose skills and expertise can be deployed in a variety of fields, advancing industrial capability and attracting world class talent to work and study in the UK
	Commercial Impact and Innovation Win valuable business, increase technical capability and promote	Increase returns for UK businesses by winning CERN contracts Use business engagement with CERN to drive UK technological capability and innovation	Increased value of CERN contracts won by UK businesses Increased number of SMEs and new companies winning contracts from CERN	Increased jobs, learning, innovation and growth in UK businesses UK businesses are more productive and globally competitive	Increased uptake of innovation and commercial opportunities that drive growth in the UK and for the UK to be the partner of choice for

Inputs	Goal	Activities	Outputs	Outcomes	Impact
	collaborative innovation	Develop international business partnerships and promote UK business growth in research and commercials markets beyond CERN Support CERN is striving towards best practice in business opportunities and continuously improving its procurement processes	Mutually beneficial international collaboration and innovation		international collaboration
	International Leadership Champion our principles for engagement on a global stage and enhance constructive international partnerships	Leverage CERN's global platform to build and enhance constructive international partnerships Champion our principles for engagement on a global stage Encourage strong UK representation in CERN	Stronger UK representation in senior leadership positions at CERN, on its committees and in its experiments Sharing and development of best practice	UK helps CERN's position as flagship research infrastructure that influences other research infrastructures CERN reflects our principles for engagement and	Increased championing of our principles for engagement including diversity and inclusion, on the international stage, with more UK nationals in positions of leadership

Inputs	Goal	Activities	Outputs	Outcomes	Impact
		staff and positions of leadership		delivers value for money UK strengthens links with key partners	
	Engage and Inspire Engage the public in science and technology and inspire young talent to pursue STEM	Encourage people of all ages and backgrounds to pursue careers in STEM through the inspiration of CERN's discovery science and technology Engage the public about the importance of STEM research and its societal impact Motivate all UK CERN stakeholders to act as ambassadors for the opportunities afforded by big science to people of all backgrounds	Increased awareness and understanding of CERN amongst general public, in schools and in the teaching profession Increased representation of CERN in UK media	Better understanding of the importance and value of big science for society Emphasis on CERN within school and university courses	Increased awareness and appreciation of the profound impact that science and technology has on everyday life and more students pursuing STEM subjects

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