Evidence from the Institute of Physics (IOP) to the House of Lords Science and Technology Committee's inquiry on delivering a UK science and technology strategy

What would a "science superpower" look like?

Becoming a "science superpower" means cultivating a thriving physics R&D system which cements the UK's global leadership in science and innovation, drives economic growth, delivers the transition to a green economy, and improves living standards.

An important step to achieve this will be to meet and then exceed target levels of public and private investment in research and development (2.4% of GDP in the UK) and to focus more of that investment on ground-breaking research in physics, cutting-edge innovation, skills development, facilities and infrastructure.

Physics research, innovation, knowledge and skills can play a defining role in making the UK a science superpower and the realisation of the wider ambitions set out in the Government's Innovation Strategy and Plan for Growth.

Physics is indispensable to social and economic progress. From building particle detectors, sensors and advanced satellite platforms to better understand our universe, to using new materials and nanotechnology to drive engineering advances, to developing new cancer diagnostics and treatments to improve outcomes for patients, UK physics has been indispensable to many of the world's most impactful and successful innovations, and is expected to drive many of the key innovations we expect in the coming decades. These include not only transformative new technologies such as quantum technologies including quantum sensors, cryptography and computing, and zero-carbon energy generation using nuclear fusion, but also step-change improvements resulting from advances in, for example, laser-based photonic systems and next-generation multi-layer silicon devices.

Physics delivers substantial economic benefits. In 2019, physics-based industries generated £229bn in gross value added (GVA), equivalent to 11% of UK GDP.[1] These industries employed 2.7m full-time equivalent (FTE) employees – 10% of total UK employment – in productive, rewarding careers, with an average salary of £42,000 and labour productivity of £84,000.

The IOP is currently developing an R&D roadmap for physics, which will set out how core elements of the R&D system can be strengthened, and the conditions and policy environment for R&D improved, so that we can create a thriving physics R&D ecosystem and realise the full societal and economic benefits of the new industrial era. This will centre on four pillars: scientific discovery; business; people and skills; and infrastructure. We would be happy to share the outputs of this work with the Committee once available in the autumn.

What could be done to ensure that the Government's science and technology strategy is long-term and pursued across administrations?

Given the timescales involved in physics research and innovation it is essential that the science and technology strategy is long-term. In particular, the development of new products or services based on physics-related technologies – from the 'ideation' stage, through prototyping, production and scaling up – is typically much longer than for other technology areas and can take many years. Building cross-party support for the high-level aims of the strategy is therefore critical to the continued success of UK science.

Successful delivery of a science and technology strategy also requires close co-operation across the four nations of the UK. While economic development, science and research are devolved policy areas, critical aspects of the UK's R&D landscape such as the Research Councils and UKRI are reserved. Engagement between governments and R&D bodies across the nations is needed when new initiatives are developed, to avoid confusion and minimize administrative burdens. Similarly, access to funding should be as easy as possible; the underpinning capacity

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[1] Centre for Economics and Business Research (2021). Physics and the Economy: Measuring the value of physics-based industries in the UK https://www.iop.org/strategy/productivity-programme/physics-and-economy#gref

and infrastructure in some regions and nations does not always allow for swift absorption of funds. Schemes should not deter nations and regions with a large proportion of SMEs, such as Wales, where 99% of enterprises are micro or small-sized.

Appropriate representation from the UK's nations and regions within UK-wide research and funding organisations is essential. As an example of current gaps in representation, there is no representation from a Welsh or Northern Irish organisation on either the UKRI Board or Executive Committee. Consent has been granted for the Advanced Research and Invention Agency Bill (ARIA), which will include a memorandum of understanding for all four governments on the agency. The success or otherwise of that memorandum could prove instructive. An alternative route for meaningful engagement is the new Inter-Ministerial Groups and Inter-Ministerial Standing Committees, which could allow for better co-ordination when relevant.

How should the Government balance support for bottom up, curiosity-driven research with support for research focused on its strategic priorities?

The UK's track record in physics is remarkable. The intellectual and technical leadership of the UK physics community has delivered breakthroughs in our understanding of the nature of fundamental particles, quantum mechanics and advanced materials, and physicists in the UK have played key roles in major discoveries from the Higgs boson to gravitational waves. The historic leadership that the UK has been able to demonstrate in physics will only be sustained if investment is at levels that match or exceed international comparator nations.

The IOP welcomes the increases in UKRI funding allocated to physics research over the last decade, in part through establishment of the Industrial Strategy Challenge Fund and increases in funding for applied science. Increasingly, mission and challenge-led innovation is fundamental to UK physics – delivery of the Industrial Strategy Challenge Fund, for example, has been powered by physics innovators across the country. The R&D ecosystem is broad and complex, and mission- and challenge-led innovation is vital to bring together cross-disciplinary researchers and innovators to help solve some of our biggest challenges, such as achieving net zero. Continued investment in mission- and challenge-led innovation is needed in areas that will build strategic advantage.

At the same time, the apparent balance of funding for discovery, applied and experimental development research has shifted in recent years – between 2009 and 2019, the proportion of total R&D funding from civil government departments, the Research Councils and Innovate UK allocated to discovery research decreased from 42% to 31%.[2] Total discovery research expenditure in the UK was 0.32% of GDP in 2018, significantly lower than many of our international competitors – half that of South Korea (0.64%) and well behind the US (0.49%), France (0.5%) and Japan (0.41%).[3] Commensurate increases in funding for discovery research are necessary if the UK is to sustain and grow the research fields and skills that will be needed to secure the UK's status as a science superpower.

How should state funding for research and development be allocated between different organisations?

Physics underpins world-leading research and innovation activities across the R&D landscape, whether it be in businesses, public sector research establishments (PSREs) or universities. Continued support and investment across all parts of the R&D landscape is required to enable a cohesive, productive ecosystem.

What role should public sector research establishments play?

PSREs are crucial infrastructures which facilitate private and publicly funded research and innovation, from blue skies research to cross-TRL (technology readiness level) work and

[2] ONS (2021). Research and development expenditure by the UK government: 2019 https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgovernmentexpenditureonscienceengineeringandtechnology/2019

[3] OECD Main Science and Technology Indicators https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB

business-driven late-stage development. Investment in PSREs directly progresses domestic innovation activities, supporting the UK's high standing on the world stage. In particular, equipping R&D-active businesses with good access to publicly owned research expertise and facilities can improve their R&D outcomes, leading to greater levels of private investment.

What role should universities play?

UK universities are among the top performing in the world. Research by physics departments within UK universities has enabled transformative developments in our society, and will be fundamental to supporting the seven technology families of UK strength and opportunity in the UK's Innovation Strategy. UK universities also play a crucial role in training the highly-skilled people needed to deliver the Government's science superpower vision[4]; their capacity to deliver high-quality physics training must be preserved, otherwise employers will become increasingly reliant on overseas recruitment. To ensure UK physics maintains its world-leading standing and continues to drive transformative developments, funding for universities needs to be put on a sustainable footing.

Both elements of the UK's dual support system – the block grant largely comprising quality-related (QR) funding and Research Council funding to support specific research projects and programmes – provide essential support to the world-leading research that takes place in UK universities. However, analysis from the Russell Group reveals there has been a 17% real-terms decline in QR since 2010, and that the balance of funding between QR and Research Council funding has fallen from 80p in the pound in 2007 to 64p in the pound in 2021/22.[5] The Government – working in partnership with the higher education funding councils – needs to address the decline in the value of QR funding and return support to at least 2010 levels. As additional investment is made as part of reaching the target of 2.4% of GDP, a more sustainable balance between QR and Research Council funding will allow universities to continue to forge new partnerships with business and industry, invest in the talent pipeline, build research capacity and use R&D to power future economic growth.

In addition, research in the UK's universities is currently funded at levels below the full cost of performing that research, with the total deficit for research activity in universities in England and Northern Ireland reaching more than £4 billion in 2019/20.[6] In particular, universities only recovered 71% of the full economic costs (FEC) of research funded by the Research Councils, substantially less than the 80% committed to. This deficit requires universities to cross-subsidise research from other income-generating activities and leads to an unsustainable system in which research capacity is dependent on factors, such as tuition fee income from overseas students, which have been negatively impacted by the Covid-19 pandemic and which vary between institutions.[7] The Government should increase the proportion of FEC recovered on all publicly-funded research grants to safeguard the sustainability of the world-leading research that takes place within the higher education sector and ensure long-term capacity exists in all universities, in all parts of the UK, to deliver an increase in research activity.

What more should be done to encourage private-sector investment in research and development in the UK?

As the most significant investor in UK R&D, businesses have a critical role to play in reaching the 2.4% investment target and securing the UK's status as a science superpower. Physics is a key enabler of private sector investment in R&D, with the most physics-reliant industries performing

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[4] Research by Emsi Burning Glass, commissioned by the IOP, shows that high-skill level roles (i.e. those typically requiring a bachelor's degree or higher qualification) are seeing the fastest growth among physics-related roles – with the number of jobs for physical scientists, for example, growing by 40% between 2010 and 2020 – as well as the significant demand for high-level physics skills in roles that are critical to the digital revolution such as data scientists and software engineers. Further details can be found in: Emsi Burning Glass (2021). Physics in Demand: The labour market for physics skills in the UK and Ireland https://www.iop.org/strategy/productivity-programme/workforce-skills-project
[5] Russell Group (2021). Spending Review 2021: Science, Innovation and Skills – a smart investment for Britain https://www.russellgroup.ac.uk/media/6004/russell-group-spending-review-2021-submission.pdf
[6] Office for Students (2021). Annual TRAC 2019-20 https://www.officeforstudents.org.uk/publications/annual-trac-2019-20/
[7] HEPI (2021). Regional policy and R&D: evidence, experiments and expectations https://www.hepi.ac.uk/2021/05/13/regional-policyand-rd-evidence-experiments-and-expectations/

34% of UK business R&D in 2019, with their expenditure increasing by 74% between 2010 and 2019. Increases in public investment intended to help the UK reach the 2.4% investment target by 2027 should be delivered at the earliest opportunity in the coming years, rather than through a more significant uplift towards the end, to boost businesses' confidence and incentivise them to increase investment in R&D early in the UK's emergence from the Covid-19 pandemic. Evidence suggests that £1 of public R&D investment stimulates between £1.96 and £2.34 of private R&D investment in the long run, with the majority of private investment crowded in five years after the public investment.[8] Increased public investment is therefore needed now to maximise the amount of private R&D investment leveraged by 2027 and beyond.

Physics-based businesses are innovators by nature and they plan to increase investment in research and innovation in the coming years. As evidenced by the CBI Economics report 'Paradigm Shift'[9], commissioned by the IOP, business activities built on physics skills and expertise are associated with high levels of innovation. Across the UK, physics-based firms are making innovation central to everything they do: actively investing in scientific discovery and technology, driven by the goal of developing new products or services and growing their businesses. 89% of physics innovators agreed that R&D/innovation is a strategic priority that is incorporated into their business plans. Given the right conditions, 59% of physics innovators expect their R&D/innovation spending to increase over the next five years relative to the previous five years, thereby accelerating progress towards the 2.4% target and unlocking associated economic and societal benefits.

However, physics innovation is costly, risky and development times for physics technologies are typically much longer than for other technology areas. The report identifies the challenges that businesses face in supporting the direct and potential costs of innovation, and in accessing the necessary finance, skills, equipment and external expertise – areas where government support is needed to enhance capability and economic return. Physics innovators most commonly reported significant costs pressures during the large-scale prototyping and production/scaling up stages, the latter also reflecting the phase when it is most difficult to secure funding. Skills shortages threaten to derail plans to increase investment in physics-based R&D/innovation, causing delays to projects, missed targets and missed opportunities. Skills shortages are particularly acute at the production/scaling up stage of the R&D/innovation pipeline, with two thirds of physics innovators reporting suspending or delaying R&D in the past five years because of skills shortages. This points to a risk that technologies developed in the UK end up being manufactured abroad, not only deepening the loss of skills but also hindering the UK's ambitions to be a science superpower.

Policy enhancements that physics innovators agreed would enable them to undertake more R&D in the next five years included greater access to direct funding for early-stage R&D, long-term funding schemes, and a more attractive tax rate for R&D activity. The Government should increase support for physics-based business innovation with additional funding for early-stage R&D and development-stage activities, a focus on long-term funding schemes (supporting technology-driven, challenge-led and high-risk, high-reward research), and a more attractive tax environment to promote the commercialisation of new technologies, manufacturing and exports.

What more could be done to incentivise collaborations between academics and industry?

The CBI Economics report 'Paradigm Shift' shows that, while many physics innovators reported engagement with universities, there may be scope to increase collaboration further, with PSREs and public/private innovation partnerships such as the Catapult centres, which can help support late-stage development activities such as testing and demonstration, as well as with other businesses within their supply chains. New forms of collaboration may be needed to realise the

[8] Department for Business, Energy & Industrial Strategy (2020). BEIS Research Paper Number 2020/010: The relationship between public and private R&D funding https://www.gov.uk/government/publications/research-and-development-relationship-between-public-andprivate-funding
[9] CBI Economics (2021). Paradigm Shift: Unlocking the power of physics innovation for a new industrial era https://www.iop.org/strategy/productivity-programme/innovation-survey#gref

full potential of innovative supply chains and deepen business-university links. Potential barriers to collaboration include a lack of suitable facilities/equipment and limited awareness of available opportunities. More than half (57%) of physics innovators surveyed by CBI Economics reported that public R&D funding encouraged more collaboration with external partners. Initiatives which provide public investment for areas where scientific excellence and industrial capability intersect (such as the Eight Great Technologies programme) can be successful in increasing collaboration. The UK Research Partnership Investment Fund has, over several years, been very successful in leveraging private funding for university research facilities at a rate of 1:2.[10]

How well does the UK collaborate on research with international partners and what can it learn from other countries?

Science is a global endeavour. Openness to scientific talent and ideas has allowed the UK to build strong international ties and benefit from productive research collaborations and world-class shared infrastructure. A strong international presence must be maintained, if we are to remain in the vanguard of scientific discovery and innovation.

Long-term research collaborations between countries offer important scientific, strategic and, sometimes, political benefits. The infrastructure required for next-generation innovation is expensive and many of the global challenges we face, from climate change to public health crises, are too big, complex or costly for one country or community to tackle alone, so long-term, large-scale collaborative research programmes offer advantages of scale, efficiency and cost. Such relationships often benefit from long-term, stable funding commitments from partners, which enable more risks to be taken and allow for the development and maintenance of valuable technical skills and knowledge, benefitting partner nations. Scientific relationships (formal or informal) can also play a critical role in international relations, supporting traditional diplomacy or negotiations and, in some cases, substituting for them. For example, 'science diplomacy' has been a mainstay in the politics and international governance of atomic weapons and, in different forms, biodiversity, climate change and chemical, biological and toxin weapons.

The UK is a member of a number of significant international physics programmes, which are essential to UK physicists' leadership and influence within global science, and provide valuable opportunities to contribute equipment, instrumentation and other technologies to the development of the experimental facilities. Examples include the ITER nuclear fusion research programme and the European Organization for Nuclear Research (CERN).

Continued support for physicists' participation in major international programmes is essential to the UK cementing its status as a science superpower. In particular, the IOP calls for the UK government to secure the UK's association to the Horizon Europe programme as a priority. Continued access to the collaborations, funding and infrastructure provided through Horizon Europe is of vital importance to the continued success of the UK physics community, and to securing the UK's status as a science superpower. Further delays to the UK's association will significantly limit the economic returns the programme creates and damage the UK's international standing.

About the IOP

The Institute of Physics (IOP) is the professional body and learned society for physics in the UK and Ireland. It seeks to raise public awareness and understanding of physics, inspire people to develop their knowledge, understanding and enjoyment of physics and support the development of a diverse and inclusive physics community. As a charity, it has a mission to ensure that physics delivers on its exceptional potential to benefit society.

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[10] Every pound of public funding in UKRPIF has been matched by £2 of private sector funding https://www.ukri.org/what-we-offer/browse-our-areas-of-investment-and-support/uk-research-partnership-investment-fund/