fst journal

The Journal of The Foundation for Science and Technology

Volume 23 Number 10
March 2025

Quantum Technologies

How can we make the transition from research into real-world applications?

Dame Angela McLean

In conversation with Foundation chair Lord Willetts

Budget devolution

Why place matters when it comes to science and tech

Conference report

Foundation Future Leaders on national and global challenges

PLUS:

Guest editorial: The future of our national infrastructure by Professor Jim Hall FREng

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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The Foundation for Science and Technology is a registered charity established in 1977. Its role is to facilitate debate between parliament, Whitehall Departments, the Devolved Administrations and the business and research communities on policy issues that have a science, engineering or medical element.

The Foundation holds regular discussion events and policy roundtables, debating issues such as AI, Net Zero, STEM skills, fusion, quantum technologies, and equity and diversity in the STEM workforce, among many others. It explores both how science, innovation and technology feed into all policy areas (such as transport, environment and energy), and the policy for funding and delivering science and innovation in the UK. All discussion events are free and open to all, with recordings available on our website.

The Foundation runs the Foundation Future Leaders programme, which each year brings together a cohort of around 35 mid-career professionals drawn equally from the research community, industry, and the civil service and wider public sector. Over a 12-month period, the group meet and discuss with senior figures from government, parliament, universities, large industry, SMEs, research charities and others. Just as importantly, Future Leaders present their own expertise, develop skills and make future contacts. The programme includes external visits and the development of an annual conference.

The Foundation for Science and Technology runs a regular podcast, publishes blogs, and produces this Journal. In addition, it provides advice on governance and operational matters to Learned and Professional Societies.

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FST Journal publishes summaries of all the talks given at its meetings. Full audio recordings are available at www.foundation.org.uk/events

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A Charitable Incorporated Organisation registered with the Charity Commission of England and Wales, number 274727.

This Journal is also available in electronic format at www.foundation.org.uk/journal (ISSN 2756-0619)

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DOI: 10.53289/RHYV2480

New Silman Fund to boost inclusion for FST participation

Some of our best events have looked at issues of equity, diversity and inclusion in STEM, but are we doing enough to support diversity and facilitate participation in our own events? We have recognised that there is more we can do, and in this spirit we have launched The Silman Fund.

Named after Harold Silman, one of the driving forces behind the creation of the Foundation for Science and Technology in 1977, the Silman Fund aims to help cover additional costs associated with attending our events, particularly for early career professionals with caring responsibilities and those who are disabled. You can learn more in this blog by our Chief Executive, Gavin Costigan.

Forthcoming events

We have a series of exciting discussion evenings coming up over the next few months including:

- **UK space policy**, Wednesday 30th April 2025
- **Decarbonising the built environment and delivering the Warm Homes Plan – the role of social science and engineering**, Wednesday 21st May 2025
- **How can R&D collaboration with Africa support an agenda for sustainable growth in the UK and beyond**, Wednesday 11th June 2025

More information will be available on our events page soon.

Welcoming a new cohort of Foundation Future Leaders

We are delighted to welcome a new cohort of Foundation Future Leaders who come to us from across academia, Government and industry. From DEFRA, The Scottish Government, The UK Space Agency, Liverpool Hope University and many more, this diverse group of early to mid-career professionals will soon be diving into a year of learning, networking, day trips and knowledge sharing. You can find out who our 2025 Foundation Future Leaders are here.

Sold-out event on governing AI for humanity

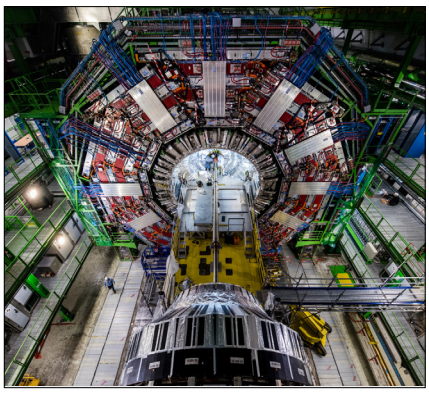
In January we held a sold-out discussion event on 'Governing AI for Humanity' at The Royal Society. Our expert panel comprised the Minister for AI and Digital Government, Feryal Clark MP; Professor Dame Wendy Hall; Dr Douglas Gurr; and Adrian Joseph OBE. Together they gave our audience a range of perspectives on the fast-moving world of Artificial Intelligence, UK regulation and global governance. As always, there was a fascinating range of questions during the discussion period, and it can all be watched again via our events page.

Science, technology and industrial strategy

After the UK Government published a Green Paper entitled *Invest 2035: the UK's modern industrial strategy*, we hosted an evening discussion in December 2024 about the UK's Industrial Strategy and how science and technology can contribute to it. Our expert speakers included Dr Julia Sutcliffe, Chief Scientific Adviser, Department for Business and Trade; Professor Mariana Mazzucato, Professor in the Economics of Innovation and Public Value, University College London; Dr Peter Waggett, UK Director of Strategic Relationships, IBM Research Europe, IBM UK; and the Rt Hon Greg Clark, Executive Chair, Warwick Innovation District, and former Secretary of State for Business, Energy & Industrial Strategy. You can watch the event again here.

Future Leaders head to CERN for field trip

CERN was the destination of a field trip finale in January for our 2024 Foundation Future Leaders. A selection of the group headed to Switzerland with our CEO, Gavin Costigan, to embark on a guided tour of the famous site, and learn about the scientific questions which CERN is able to ask, the remarkable technology which makes it possible, and how the UK benefits scientifically and industrially from participation in the world's biggest particle physics laboratory.



BRICE, MAXIMILIEN; CERN

From AI to animal testing and DEI

New episodes of the FST podcast are available to listen to on demand on our website and across all major streaming platforms such as Spotify and Apple music. Listen to some of our expert guests discuss AI and regulation, animal testing and diversity and equity in STEM.

GUEST EDITORIAL

The future of the UK's National Infrastructure presents exciting prospects and challenging issues. Costs, skills, capacity and environmental legislation are all factors that must be considered for major new projects. How will the National Infrastructure Service Transformation Authority (NISTA) play a part in things?

The future of our national infrastructure

Jim Hall

"The High Speed Two (HS2) programme has become a casebook example of how not to run a major project" – that was the verdict of the House of Commons Public Accounts Committee in its latest update on HS2. Yet the government's plans for growth and clean energy rely upon upgrading the nation's infrastructure: from East-West rail to unlock the potential of the Oxford-Cambridge Growth Corridor, to the Great Grid Upgrade that will connect renewable energy supplies with demand. The Chancellor's growth speech, delivered at the Siemens facility in Oxfordshire in January 2025, triggered yet more speculation in the press about whether Britain could build big things anymore.

Actually, if you look at the data for infrastructure costs, as the National Infrastructure Commission (NIC) did carefully in its recent study of the cost drivers of major infrastructure projects in the UK, the UK does not compare particularly badly regarding infrastructure cost outcomes, relative to comparable countries and projects, though like-with-like comparisons are challenging. In the roads sector, for example, projects in England are typically delivered within budget and the sector has improved its cost performance over time. But some of the largest projects are outliers – notably HS2 (for which there is not yet an agreed cost estimate for Phase 11) and the Hinkley C nuclear reactor which EDF estimates could cost £46bn, when taking price rises into account, up from the 2022 estimate of £26bn.

The NIC's study of infrastructure costs identified four root causes that can contribute to cost over-runs on major infrastructure projects. The reasons start with clients, which for major infrastructure always involves the Government – even for privatised infrastructure including energy supply, water and telecommunications, where Government still sets the strategic direction and regulatory regime. Across the board, stop-start decision making has shaken investors and driven up costs.

Second, the NIC identified challenges with leadership and management by the client. Successful projects have clear responsibility and retain leadership expertise, while their Government sponsor empowers project leaders rather than interfering with them.

Third, as the NIC had previously identified in its review of the planning system, consent for major projects in Britain has ground to a snail's pace, increasing from 2.6 years on average in 2012 to 4.2 years. Some of the blockers were already being addressed by the last government – for example by strengthening capacity in the Planning Inspectorate – and more will be done in the Planning and Infrastructure Bill. Meanwhile, infrastructure constraints on new development, notably connection to the power network, are being addressed by connection reforms.

Prof Jim Hall FREng is Professor of Climate and Environmental Risks at the University of Oxford. He is President of the Institution of Civil Engineers, a commissioner of the National Infrastructure Commission and a member of the Prime Minister's Council for Science and Technology.

Better green outcomes

Complying with environmental regulations has proved to be a particular fraught, as there's been a tendency to lose sight of the 'big picture' goal which is to improve the quality of the nation's environment and biodiversity overall. A much more strategic approach is required, to map out how and where environmental goals can best be achieved. The creation of the Nature Restoration Fund in the Planning and Infrastructure Bill, to fund larger strategic interventions for nature, should provide better outcomes for the environment while also speeding up infrastructure delivery.

The final reason for infrastructure cost over-runs which was identified by the NIC is a lack of capacity in the construction industry and supply chain, which is driving up costs. Some of the cost increase is due to global inflationary pressures, but the UK's construction sector is particularly

A key reason for infrastructure cost over-runs is a lack of capacity in the construction industry and supply chain, which is driving up costs.

Infrastructure projects are becoming more complex, not least because of the ever-greater integration of digital systems within them.

fragile compared to other large European countries. France, for example, is dominated by only three big multinational firms: Vinci, Bouygues and Eiffage. Even Britain's largest construction firm (Balfour Beatty) is quite a lot smaller than France's third firm, and it competes with more than half a dozen similar-sized UK firms, who hire multiple layers of small and medium sized subcontractors. There is dreadful inefficiency in all of those contractual interfaces, which too often become litigious, plagued by a culture of blame. Such a fragmented industry inevitably finds it hard to retain the profits to invest in innovation, and faces recalcitrant barriers to driving productivity in the supply chain.

Meanwhile, infrastructure projects are becoming more complex, not least because of the ever-greater integration of digital systems within physical infrastructure. Digitisation provides tremendous opportunities for more efficient and tailored service provision – just think about the amount of energy supply that will be saved by smart management of electricity demand. Technology provides the opportunity for infrastructure to constantly monitor itself, to optimise asset management and enhance resilience. Yet this requires new skills and advanced systems engineering capabilities.

Infrastructure operates as a system that delivers services to people and the economy – not as a disconnected stack of projects.

Skills shortage

The construction industry faces well-known and persistent skills issues, in particular in the construction trades. Migrant labour from the EU is hardly a reliable solution, but there has not been a meaningful strategy for home-grown construction skills. The Government body Skills England is still being set up, and its alignment with the embryonic industrial strategy remains to be seen. What's needed is investment in regionally led and employer-guided skills provision, along with new modes of delivery to accelerate training and qualification in sectors facing critical gaps.

The newly created National Infrastructure Service Transformation Authority (NISTA) is central to the Government's plans for prioritising and speeding up infrastructure delivery to drive economic growth. NISTA will merge the strategic infrastructure advisory function of the National Infrastructure Commission (NIC) with the Infrastructure and Projects Authority's (IPA) role of supporting the delivery of major projects. As the Chief Secretary to the Treasury said in his speech in October 2024, NISTA "will bridge the gap between what we build and how we build it". Significantly, NISTA will have responsibility for social infrastructure (hospitals, schools, prisons etc.) as well as the economic infrastructure (energy, transport, water, telecommunications, waste, flood risk management) that the NIC advised upon. This is an attractive proposition, creating an organisation with end-to-end responsibility, from long-term infrastructure strategy (in the Government's forthcoming 10 Year Infrastructure Strategy (10YIS)) through to project prioritization, creation of a credible project pipeline, and driving delivery. As someone who has been a Commissioner of the National Infrastructure Commission for the last three years, the prospect of having a greater role in making infrastructure happen – and not just advising on what it should be – is an appealing one.

However, the need for impartial advice on long-term strategy is not going to go away once the 10YIS has been published. The economic, technological and political landscape which infrastructure decision-making inhabits is constantly changing, and no doubt there will be unfinished business once the 10YIS has been published. For example, the Government's reforms of land use are at different stages, so housing, industrial strategy, regional energy plans and the rural land use framework will need to be harmonised. There is a growing recognition of the need for better spatial planning, making use of all of the spatial data and geospatial tools at our disposal.

The NIC was created to build long-term consensus around the UK's economic infrastructure needs, to try to avoid infrastructure becoming a political football, plagued by stop-start decisions and vanity projects. Looking back over almost a decade of the NIC's existence, the extent to which it achieved that aim is debatable, though when you analyse the NIC's advice, the vast majority of its recommendations have been accepted and adopted by Government. Some of that has taken a while: the NIC set out its strategic vision for the Cambridge-Milton Keynes-Oxford arc in 2017, and this year the Chancellor has committed to realising the obvious economic growth potential. Infrastructure takes a long time to materialise – across multiple parliaments – so it is important that the long-term impartial advisory role that the NIC embodied persists into NISTA.

Though project delivery – from planning, to finance, contracting and progress monitoring – is going to be an important part of NISTA's remit, we must not lose sight of the fact that infrastruc-

HS2

The High Speed Two (HS2) programme has become a casebook example of how not to run a major project, according to the House of Commons Public Accounts Committee.

ture operates as a system that delivers services to people and the economy – not as a disconnected stack of projects. That's why the words Service Transformation in NISTA's name are so consequential. They put the focus on the infrastructure services that will be needed in the future. For example, before committing to building new hospitals, we should be asking what healthcare services will be needed decades hence, and what are the options for their provision. Healthcare practitioners and managers may be too immersed in the day-job to spare time for future-gazing, but NISTA needs to examine these questions before committing to new social infrastructure.

Asset performance

NISTA also has the opportunity to shine a light on asset management – the whole-life performance of infrastructure so that services continue to be delivered reliably and efficiently. It's all too easy for maintenance budgets to cut, which gradually erodes infrastructure performance and resilience. On the other hand, modern asset management systems, combining real-time monitoring with predictive modelling to optimise interventions, reduce whole-life cost and safeguard system performance.

The infrastructure project pipeline, for which NISTA will be responsible, is fundamental to enabling the supply chain to plan for the future, and to providing confidence to infrastructure investors. Vast chunks of British infrastructure are in the private sector: energy, water, telecoms, ports and airports. Whilst the UK has traditionally been regarded as a stable, low-risk jurisdiction, investor confidence has been shaken over the past decade. Investor confidence needs to be patiently rebuilt, so private finance can be accessed at a reasonable cost for the major infrastructure investments that are needed in the coming years, not least to deliver the government's Clean Power 2030 mission.

Which brings me to the final, and arguably most crucial, success factor for Britain's infrastructure ambitions, which is securing public support – and going beyond that to build public enthusiasm. Transformative changes to our infrastructure – from eliminating fossil fuel dependence in the power sector, to cleaning up rivers – have become mired in controversy and protest. There are remarkable feats of engineering going on, which will make people's lives cleaner, more efficient, and more affordable – yet these success stories are not getting the attention they deserve. There is no single or simple solution to building public support, so everyone with a passion for technology and a concern about Britain's industrial future – from professional engineering institutions to industrialists who are called upon to speak in the media – needs to find a clearer and more persuasive voice to explain the exciting future for our national infrastructure. □

DOI: 10.53289/EHZQ3711

Modern asset management systems, combining real-time monitoring with predictive modelling to optimise interventions, reduce whole-life cost.

CONTEXT

Quantum technologies have a potential role in both national security and civil society, as well as commercial opportunities. The UK has huge research strengths in quantum technologies and a burgeoning quantum start-up ecosystem. While some potential uses of quantum technologies are still a way from commercialisation, others are right here.

On Tuesday 24th September 2024, we explored where the UK currently sits in quantum technology and what is needed to transition from research into real-world applications – both in the public and private sectors. The evening's speakers included Professor Sir Jim McDonald, Principal and Vice-Chancellor of the University of Strathclyde, and President of the Royal Academy of Engineering; Dr Dame Frances Saunders, Chair of the Royal Academy of Engineering's Quantum Infrastructure Review 2024; Professor Melissa Mather, Professor of Quantum Sensing and Engineering and Royal Academy of Engineering Chair in Emerging Technologies, University of Nottingham; Simon Andrews, Executive Director, Fraunhofer Research UK Ltd and Rachel Maze, Head of Quantum Technologies Policy, Department of Science, Innovation and Technology.

A video recording, presentation slides and speaker audio from the event are available on the FST website at: **www.foundation.org.uk/Events/2024/Quantum-Technologies-%E2%80%93-from-research-to-reality**

Filling the gaps in quantum

Frances Saunders

Following her graduation from Nottingham University, Frances Saunders worked as an electronic engineer in the motor industry before joining the Royal Signals and Radar Establishment at Malvern to undertake research into liquid crystal devices. Her career then included a wide variety of research and science and technology management roles within MOD and also in BEIS (now DSIT), where she was responsible for the interface with the Research Councils. In that role she set up the Diamond Light Source, supported the activities of the British Antarctic Survey and represented the UK at the Council for CERN.

Where are we now with quantum? We have had 10 years of The UK National Quantum Technologies Programme, including two phases of the current hubs, covering everything from quantum computing and quantum sensing to quantum communications. The thing I am most proud of for the hubs is the way they have managed to get technologies out of the laboratory towards the hands of users. If you had asked me 10 years ago if I had expected to see cold atoms on ships, trains and vehicles, I would have said 'no way', but that's the sort of level of demonstration we are now getting.

We are seeing these technologies working outside the laboratory, and that is an amazingly good result. The hubs have proven to be a good model for getting industry engagement with support and funding from different parts of UKRI (UK Research and Innovation) as well as other government departments, and we are seeing a number of very good training opportunities for people in applied research. They are not just doing PhDs in fundamental physics, but actually looking at PhDs based on the application of quantum technologies. Those people are then also going out into the workplace and some of the hubs are keeping tabs on where they are going so that we can track their impact. A large number of them are either going into academic appointments, engineering departments or into industry, so we are seeing the beginnings of the availability of higher level skills that the quantum ecosystem will need if it is to be successful going forward.

SUMMARY

- The hubs have proven to be a good model for getting industry engagement alongside support and funding from different parts of UKRI
- We now need to see how much of this progress gets picked up by the new Government
- It's important to think of the challenge of translational research from the academic community as a team game
- Quantum technology is really about how we harness the quantum effect using a range of technologies
- We want to have a continuing discussion and dialog with the STEM, policy and industry community on the role that infrastructure has in helping quantum deliver promises.

The hubs have strengthened the alignment within the academic community, bringing together universities with different skill sets and in different regions. This has proven, (with alignment of funding) to be a very successful model. It is good to see that the new hubs, to be launched by the end of 2024, already have a strong level of industry engagement and industry commitment and we also had an ongoing commitment from the last Government through its quantum technology strategy and the missions they launched. We now need to see how much of that strategy and set of ambitions gets picked up by the new Government.

I think that there was a lot of skepticism around the world about whether quantum technologies were going to get there. However, I think that that skepticism is now reducing. Now everybody wants to pile in on the initial successes and there is a lot of money going into quantum around the world. What we need to do now is make sure that we continue to accelerate the benefits from the investment that the we have made in the UK over the past 10 years.

The challenge of translation

There is, of course, still a challenge of translating research from the academic community into industry. It's important thing to think of it as a team game (see Figure 1, p7) . We have the universities, which are very good at discovery, research and lab-based technical demonstrations. We have industry, which wants products. They want things that they can manufacture or exploit in other ways to make money from. The hubs have been good at doing proof of concept demonstration and starting to look at the technology development that's necessary on this trajectory towards products and services.

However, there is still often a gap in the middle and you need to go around a loop of analysis that says, "Is this technology ready yet?"; "Is it good enough for this application?"; "Can I make it?". A lot of this is about reducing risk, whether it is a technology risk or it is the manufacturability risks, and it can go horribly wrong. I've got lots of examples in other technologies of where things have gone horribly wrong, because you cannot throw this ball over the fence from university to industry, and assume that somebody will pick it up. You have to work together in the space in between. You have to look at working as a team.

Sometimes, that gap is a bit too big for a university department to talk to a big company but there are organisations, that I would consider third sector, who can facilitate this process. I was visiting the Fraunhofer Centre here in Glasgow today, and that is an organisation that can speak the language and understand the needs of industry. It can also look into academia and understand that language and therefore it can solve problems. In turn, this problem-solving helps to close the gap.

We need to keep opportunities open for joint working. There has been progress made but I do think the potential role for third-tier organisations is important. We must speed up the iteration around the loop and help take it from an exciting-looking technology to something that somebody might want to buy. You have to do that a number of times to reduce the risk. So how can we speed that process up?

There is a lot of money going into quantum around the world. We must continue to accelerate the benefits from the investment made in the UK.

First, we must make sure that we understand the difference between performance and effectiveness of quantum technologies; performance is what is often asked for but the effectiveness of a technology in a given application is what is actually needed. We also need to understand the trade-offs in areas such as risk and cost. And I say "quantum technologies" because people do generally think it's a single technology. It's not. Quantum technology is really about how we harness the quantum effect using a range of technologies.

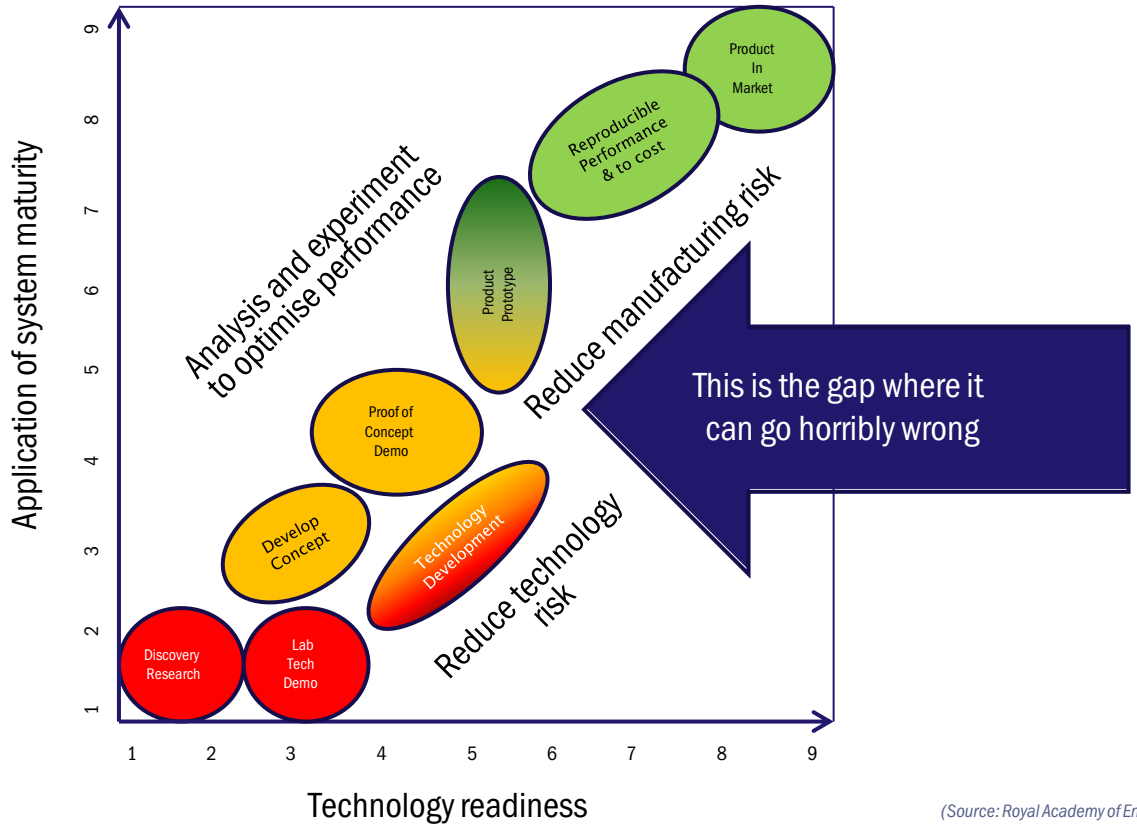
Second, we need to do advanced prototyping. That prototyping needs to be done in a way that industry can visualise how they could pick it up and continue to develop it with manufacturing capabilities that are available, ideally, off the shelf. It's also about how we build confidence that we can get things out of the lab and keep them running out of the lab reliably. I also think that testing and evaluation of advanced prototypes will become an important part of the next phase.

The quantum landscape is getting more complicated. There are more moving parts and how we reorganise the hubs will change that landscape. There are more people entering it and there are more institutions working in that space. If you're a small or medium enterprise, how on earth do you find your way through that landscape? There is more we need to do to signpost to people about where expertise lies, who they can talk to and how they can move technology forward. Another part of that is how you facilitate access to prototyping and facilitate access to skills. Improvement in coordination is something we picked up in the Quantum Infrastructure Review.

But how do you start to move along that journey of being able to design the sorts of components and subsystems that are necessary to bring together and integrate to develop a quantum-based system? First, it needs to be made more cost-effective for people to begin that journey. Design tools can be an important first step. It becomes an even more important first step if those design tools are in some way integrated with the development of the prototyping and fabrication capabilities that we need. Things become more seamless that way.

In the Quantum Infrastructure Review, we have talked about the need for open-access facilities to be truly open-access. Costs of accessing some of these fabrication facilities can be something that puts off small companies, so is there

Figure 1. The challenge of translation – a team game



(Source: Royal Academy of Engineering

Universities are good at discovery, research and lab-based technical demonstrations. Industry wants products to make money from. However, there is often a gap in the middle which requires reducing technology risk or manufacturability risk.

more we should be doing to make those truly open-access? What more do we need to do to reduce the gap between one-off or small batch devices made within a university environment, and being able to confidently make these things out in industry?

We have a set of capabilities for advanced manufacturing of many of the underpinning technologies for quantum in the UK, but a lot of them have been built up around other application areas such as telecommunications. The requirements of quantum are different, and people need to understand that current technological challenges in quantum far exceed the current level of capability we have in manufacturing. There needs to be a discussion about whether or not our current capabilities in manufacturing can be evolved into something that is of value for quantum and we need to think about how we support industry in doing that.

Packaging problems

Another issue we have looked at (which has had some pushback) is the issue of packaging and heterogeneous integration. A lot of people's view is that packaging is something industry just does. However, in quantum when you have to pull together lots of different technologies, reduce loss levels and reduce noise, then heterogeneous integration may be the only way you are going to get to the size, weight and power capabilities that industry is going to find attractive.

You could invest in compound semiconductors; you could invest in silicon photonics; you could invest in heterogeneous integration, but these are not easy choices, and we didn't try to place our bets in the report. However, I think it is worthy of further discussion about where the opportunities are that would be synergistic with UK skills and existing capabilities, and where there might be opportunities for the UK to take a leading position.

It's always a challenge to bring together a group of people from very different backgrounds and get them to think about something that is of common interest. The team at The Royal Academy of Engineering did a lot of consultation with small companies, large companies and in academia. We've done the best we can in pulling together this story, but what we need is continuing engagement to really understand what would be the best option for the UK right now. We want to have a continuing discussion and dialog with the STEM, policy and industry community on the role that infrastructure could make in making sure that quantum technologies really deliver their promise. □

DOI:10.53289/YTYQ9871

Collaboration is key to embrace the quantum challenge

Melissa Mather

SUMMARY

- International partnerships and collaboration are crucial to unlocking the full potential of quantum technologies
- The UK is at the forefront of quantum sensing research
- Although the quantum landscape is brimming with potential, it cannot exist in isolation
- To realise the transformative impact, we need to embrace adjacent technologies such as precision manufacturing
- There are many transferable skills that we could consider to efficiently develop the workforce in the short term.

I want to give an academic's viewpoint on where we are with quantum, particularly focusing on quantum sensing, since that is an area I am currently working in. Taking quantum technologies from research to reality is a challenge for many communities to investigate, and with that in mind, I wanted to take you back in time and consider who has been involved.

Take this image from the fifth Solvay Conference (see p9), a renowned physics conference series. If we think about 1927 when this was taken, there was real progress in quantum physics and theory. There is a quote from Heisenberg from this meeting which says that this conference had contributed extraordinarily to clarifying the physical foundations of quantum theory. It formed, so to speak, the outward completion of quantum theory. I think that the fact that today, in 2024, we are still talking about quantum technologies and quantum physics suggests that we are still very much on a journey. I think that journey is really taking what these pioneering minds had thought and delivering it from research to reality.

Back in 1981, in Boston, there was the first conference noted to have combined physics and computer science. To us now, it may seem unusual that physics and computer science were very separate disciplines, but this was truly a pivotal moment where physicists and computer scientists joined together. And it was at this time when Richard Feynman said, "Nature isn't classical, and if you want to simulate it, you'd better make it quantum mechanical". The seeds were planted all the way back here, and the next step was to nurture interdisciplinary ways of working, even at this early point.

Most recently at the Quantum World Congress in Washington we saw collaboration and international partnerships at the centre of conversation and an important piece of the puzzle to achieving the full potential of quantum technologies.

If we reflect on this journey in time, we have gone from the world's best minds in physics and chemistry and are now moving towards being in a position where we are talking about international policy and trade. The quantum ecosystem is blooming from the early seeds planted.

In the UK, we are fortunate to have tremendous strengths in quantum sensing, both in the research domain and in development. I think we can safely say that the UK is at the forefront of quantum sensing research. A good example comes from the University of Glasgow, where there has been a major breakthrough in quantum gravimetry. They are harnessing these compact, portable devices which are going to have applications in civil engineering, environmental engineering, and many more. This exemplifies world-class applications and the commitment to addressing real-world challenges.

To be honest, Scotland could be a quantum country in its own right. For example, there is a Single-Photon Avalanche Diode (SPAD) camera being developed jointly by the University of Glasgow and Heriot-Watt University. So, you have a camera that captures light at extremely low-light conditions. You can see the unseen by seeing obscured objects, and this has the potential to transform things such as vehicle navigation and even assist people in locating things in disaster zones.

Further south, the University of Birmingham has been working in the area of gravimetry and has spun out a company called Delta G. They have been using atom interferometry to enable tiny changes in gravity to be measured that will have a real impact on looking at hidden infrastructure in civil engineering applications, for example find-

Professor Melissa Mather obtained a Bachelor of Applied Science, majoring in physics, and a PhD in the Centre for Medical, Health and Environmental Physics at the Queensland University of Technology, Australia. She then undertook research positions within the Faculty of Engineering, University of Nottingham, the National Physical Laboratory, and Keele University, UK. She is currently a full professor in the Faculty of Engineering, University of Nottingham, where she holds the Royal Academy of Engineering Chair in Emerging Technologies. This is a 10-year programme of work focused on developing integrated diamond photonic platforms for the next generation of quantum sensors.

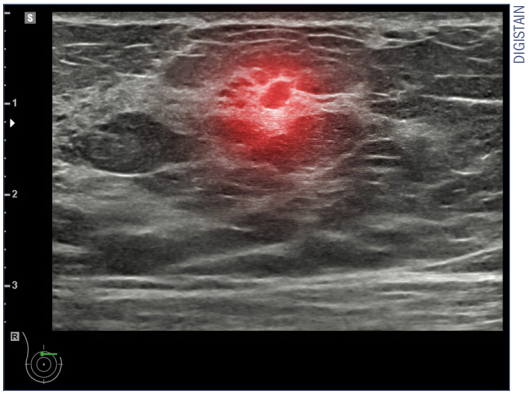
Fifth conference participants, 1927. Institut International de Physique Solvay in Leopold Park.

ing groundwater levels, and indeed in general exploration underground. A decade ago, we could not have anticipated this to be a reality, but we are now in a position where we have these types of quantum sensors out and about.

Another example is the National Physical Laboratory (NPL), which is looking at a sort of radio-frequency (RF) electric field probe. NPL has a whole set of resources dedicated to quantum technologies, and as well as having quantum devices, the UK is in a great position to be able to offer calibration services and set standards for quality products. I do not think you can look much further than NPL, with its long history in this area.

Closer to where I am, at the University of Nottingham, there are optically pumped magnetometers that can map the very weak magnetic fields in the brain. This overcomes the use of cryogenic-based Superconducting Quantum Interference Device (SQUID) magnetometers and enables people to move while they are being scanned. This will have benefits, particularly for younger people, who would find the confinement of SQUID-based systems quite challenging.

There is another example from Imperial College London and its spin-out company, Digistain. It has applied the approach of undetected photons, employing quantum entanglement to observe how they can detect the interaction of light with tissue samples. This system can provide objective measures, helping to stratify types of cancer treatment for people. In this case, they have been focusing on breast cancer.



Digistain has employed quantum entanglement to detect the interaction of light with tissue samples, helping to stratify types of cancer treatment.

These examples showcase some of the significant outputs that have already emerged, but I think we need to accelerate things further. Although the quantum landscape is brimming with potential, it cannot exist in isolation. To realise this transformative impact, we need to embrace adjacent technologies. I think we need to look at areas such as precision manufacturing. Quantum devices have intricate architectures and nanoscale components, so we need to consider the demand and capability for manufacturing at this level. The packaging of electronics and the heterogeneous integration of components is going to be key. I also often think that, with many of the quantum technologies, at some point we are trying to interchange between a photon and an electron, or the other way around, so having the capabilities and skills for that will be quite important.

We also need to build a quantum-ready workforce. We need a holistic approach, and we are fortunate that there are young people who are interested in becoming scientists and engineers and working in technology. The university curriculum is expanding to incorporate quantum technologies beyond just a physics degree, for example, and we have Centres for Doctoral Training (CDTs), which are producing PhD-ready people. However, I think we need a more holistic approach, considering that there are already people in the workforce who possess the capabilities we need. I think there are many transferable skills that we could consider to efficiently develop the workforce in the short term. We are at a precipice with quantum technologies and how they will impact the next generation of technologies, so we need to seek collaboration and work together to embrace the quantum challenge. □

DOI: 10.53289/RFUG8310

Opportunities in quantum

Simon Andrews

SUMMARY

- The industrial strategy challenge fund (ISCF) and the academic hubs have been a big part of why the UK has got the position it has
- We have a chicken and egg situation trying to create mature products in quantum technologies and a manufacturing supply chain and this is an exciting space
- We need to see things rolled out so that everyone around the world are influenced to create their own quantum cluster
- The low number of medium-sized companies involved in quantum projects is where some of the opportunity lies in the UK
- The quantum sector is very collaborative and clusters, Research and Technology Organistions (RTOs) and universities can have enormous impact.

When mathematics becomes real, we call it physics, and when physics becomes useful, we call it engineering. When engineering becomes successful, we call it manufacturing. I love the framing of quantum technologies from research to reality, because quantum is such an overused word now, all that noise tells us that there is a huge opportunity, but there is also a lot more to be done. When quantum is truly successful, we will not call it quantum anymore. We are beginning to explore a new level of nature, entanglement and superposition. All these amazing effects, manipulating single ions and single atoms, exploring new avenues – there is a huge amount of excitement there that I would like to explore, about the reality and where we fit into that system.

At Fraunhofer Center for Applied Photonics, I have about 80 colleagues, staff and students who are immersed in the world of photonics. Using lasers and optical systems, we embrace a wide range of applications. We are problem-solvers that are making new lasers for sensing, measuring, imaging, communications and computing- all similar words we hear in the world of quantum. We are on a journey from research to reality, whether that is making things that look like ray guns to detect explosives at a distance, helping the local space industry with CubeSats (small satellites) using mid-infrared lasers, to checking pharmaceuticals to ensure the right amount of ingredients in every tablet are working correctly. Pointing to processes, the tools and techniques to integrate photonics and miniature photonics is also a big part of the journey that we are on.

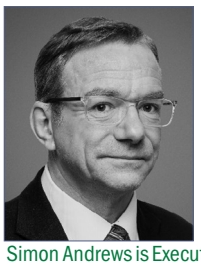
The challenge of funding

The industrial strategy challenge fund (along with academic hubs), has been a big part of why the UK has got the position it has.

We carried out an experiment just outside the University of Strathclyde, on the edge of the Technology Innovation Centre. This was a quantum key distribution system where we sent quantum keys from the top of the John Anderson building down to another building. We did that with British Telecom and a wide range of micro- and medium-sized companies. We have created equipment for position, navigation and timing with British Aerospace Systems, and a hydrogen detection system which measures tiny amounts of hydrogen at tens of metres away. We also have a new project with British Petroleum, involving smaller companies to help detect hydrogen for the hydrogen economy. These are not made with off-the-shelf components. We have a chicken and egg situation trying to create genuine quantum technologies and a manufacturing supply chain where a one- or two-person company does not know what to commit to making, to get all the way through to the end user. That for me, is where we are in a very exciting space. We are proving that these things are possible, getting the attention of multinationals and showing potential so that investors can believe this really is coming.

What is going to come as we develop these technologies and work out where the economic and social opportunities are for the UK? There is still a lot to be done, and it is a global race. 2025 is the UN's International Year of Quantum Science and Technology, and governments around the world are putting billions into the sector. There is also another £2.5 billion that we are expecting to come into the UK in the next 10 years. So we need to see an appropriate plan for that. We need to see things rolled out so that everyone around the world is influenced to create their own quantum cluster.

The Quantum Technologies Flagship wants Europe to be the 'quantum valley of the world'. Well, here in Scotland, we do not call them valleys.



Simon Andrews is Executive Director of Fraunhofer UK Research Ltd, which operates the UK's first Fraunhofer centre, Fraunhofer Centre Applied Photonics, CAP, works in very close partnership with the University of Strathclyde and is based in the Technology and Innovation Centre in Glasgow City Innovation District. He graduated from Strathclyde's Physics department in 1992, then spent 12 years in the medical device industry including time in a Strathclyde spin-out company. He later worked in Strathclyde's Institute of Photonics for seven years and was then part of the team establishing Fraunhofer CAP in 2012. Simon is also Chair of AIRTO, the UK's Association for Research And Technology Organisations and has other board roles with Technology Scotland, Glasgow Science Centre and the UK's Photonics Leadership Group.

More than 50% of the Innovate UK projects involve at least one Scottish partner.

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We call them glens. So our glen of quantum entanglement, has been named 'Glenlentanglement®'. We've been involved in quantum technologies for at least 10 years now and we have got some local companies involved to help build some momentum in that cluster. More than 50% of the Innovate UK projects involve at least one Scottish partner, such as Fraunhofer. We estimate that we are involved in about 30% of all Innovate UK work in quantum technologies, so we're in the right space, oiling the machine of getting this stuff out there. But we are not alone. This is collaborative work.

The growth of photonics

The photonics leadership group produces figures that show there are various regions around the UK where there is substantial employment and output and a rapidly growing photonics sector which is larger than pharmaceutical, larger than space, and growing faster than both. However, it is not often in the limelight because it lacks some of the larger companies. So the Scottish Photonics Cluster was primed to get involved. If you look at the makeup of the photonics industry in the UK, whether you are looking at engineering or manufacturing or other physics based sectors, there are very few large companies. However, the ones that do exist dominate the turnover of the UK. There is then a long tail of small and micro companies and a fair number of medium-sized companies. The number of medium-sized companies involved in these projects is quite surprisingly low and I think this points to where some of the opportunity is for the UK. It also shows that we are on a journey to maturing all of these technologies. I hope we have played a part in getting the smaller companies to meet the larger companies when otherwise they might not be able to demonstrate what is actually possible.

The next part – along with skills and funding – is providing opportunities for the smaller companies to scale up. We know that there are scale-up challenges in the UK, but I think there is a vacuum of Tier 2 companies that the multinationals normally buy their equipment from. This is moving so quickly from physics lab through to the real world that there are really exciting opportunities for small and micro companies to grow and dominate their sector, and buy and sell around the world. One of the difficulties is that we do not yet know what the 'engine' or 'gearbox' is supposed to look like yet. So we are back to the iterations that we have in engineering and development, and there is more to be done.

Clusters, Research and Technology Organisations (RTOs) and universities can have enormous impact, and we have seen that with academic hubs and the industrial strategy challenge fund. The quantum sector is very collaborative and, in the UK, it has been our great advantage in introduce everyone to each other, so we can have conversations like "What do you need?" and "What can you make?" I do believe there is a huge opportunity for growth for all of us. □

DOI: 10.53289/ZIU04182

2025 is the UN's International Year of Quantum Science and Technology, and governments around the world are putting billions into the sector.

Quantum successes and the next steps

Rachel Maze

SUMMARY

- The quantum programme has been going for about 10 years and has great partnerships across the people that make it up
- The quantum programme is the first in Europe, and third globally for the quality of research
- The quantum strategy (which supersedes the programme) is focused on several pillars including the continuation of world-leading research, scaling up and adoption.

The UK National Quantum Technologies Programme has been going for about 10 years now. It comes to a close this year, and over that period, we have spent about £1 billion across various activities, from funding the quantum hubs, which bring together industry and academia around technology development, to Doctoral Training Centre (DTC) activities. We also have the Quantum Technologies for Fundamental Physics Programme and activities across research innovation. As part of Innovate UK's Challenge Programme, we have funded about 180 companies and provided around £180 million in funding for projects mentioned in the previous article. Alongside this, we have key pieces of infrastructure, such as the National Quantum Computing Centre, which is due to open this year. This will really help to scale quantum computing and explore adoption and readiness within the programme. The quantum programme has been going now for a long time and has great partnerships across the people that make it up, which includes: the Defence Science and Technology Laboratory (DSTL), the National Physical Laboratory (NPL), the Department for Science, Innovation and Technology (DSIT), the Ministry of Defence and GCHQ.

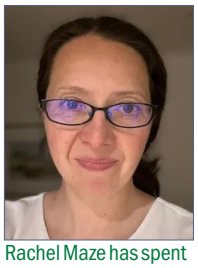
The quantum strategy and next steps

The programme has had great successes so far, including being first in Europe and third globally for the quality of research. We are also second in the world for the number of quantum companies, and second in attracting private investment into the country. We are also building on really broad industrial and academic capabilities across computing, communication, sensing, time and imaging, and we have a very vibrant supply chain in the UK. We knew that the programme was coming to an end in 2024, so towards the end of 2022, we started to plan for a new programme in Government and across our partners. We really started thinking about what fits around the programme, recognising global competition and growth that we were witnessing, and the need to maintain that global position that we have in the UK.

The quantum strategy is focused on a number of pillars. It builds on the success of the programme, but looks to fill gaps around commercialisation and scaling. The first pillar is to continue to fund world-leading science and develop the skill set. The second pillar is around addressing these scale-up challenges and helping businesses to grow. The third is around adoption and creating that pull and focus on societal benefits, and then the last pillar is on supporting innovation and the ethical use of technologies through international regulatory frameworks.

There are many potential applications for quantum technologies. They aren't just one technology. They are a suite of technologies that have many benefits and opportunities, and that in itself represents a challenge. What we try to focus on in Government is making sure that we have clear trajectories towards areas of high impact, and we did that through the development of five quantum missions. Towards the end of 2023, we published these missions, which were developed in collaboration with the community. They focus on key technological milestones, such as achieving scale in quantum computing or networked systems in the UK, as well as key application areas for sensing.

We are also looking at the value that quantum can bring to this government's missions. Be that economic growth, for example, where we think that quantum will play a really important role in achieving the outcomes in the growth mission. This government has signaled that it sees the importance of quantum and will continue to support it moving forwards. We will see what happens with this over the coming months. Quantum also has value for the other government missions – the NHS 'Fit for the Future' mission, the 'Take



Rachel Maze has spent more than 15 years within UK Government and Parliament developing and evaluating science and technology policy within the House of Lords, Defra's Chief Scientist's office, the Government Office for Science, and within the Technologies and Innovative Regulation Directorate in DSIT. Most recently she led the development of the UK Government's National Quantum Strategy.

The quantum strategy is focused on a number of pillars. It builds on the success of the programme but looks to fill gaps around commercialisation and scaling.

Back our Streets' mission and making Britain a 'Clean Energy Superpower'.

We have already committed to funding five new hubs that fit very well with the quantum missions, two of which are in Scotland. We have the quantum networks hub and one on position, navigation timing (PNT), led out of Edinburgh and Glasgow respectively. We also have sensing, imaging and timing led out of Birmingham, sensing for health led out of London, and quantum computing led out of Oxford. As with the last set of hubs, these will be partnerships, delivering a programme of work across a number of leading academic institutions across the UK. We've also established five new doctoral training centers (DCTs) and run competitions around networking and PNT, as well as European projects and the National Quantum Computing Centre, which is due to open shortly.

As you can imagine, we are in the midst of a spending review, where government will need to balance many priorities, so this is a big challenge that we are currently trying to navigate. This will look at what does one year (25/26) versus multi-year spending activity (26/27 onwards) look like for quantum alongside all other activities? We are also in the middle of thinking about the next steps for the Infrastructure Review. The Royal Academy of Engineering produced a very helpful report, which is really the start of the conversation, and we will be doing community engagement to better understand the crossover of those requirements for infrastructure across quantum, and also how it marries to the requirements for semiconductor, telecoms, AI or other critical technologies. We are also due to receive the Skills Task Forces report in the near future, which has been over a year's worth of work with a lot of people within the community who have started to get to grips with the skills needs beyond PhD. ☐

DOI: 10.53289/PDVL9923

The debate

After the presentations, the speakers engaged in a Q&A with the audience on issues including how to scale up manufacture, our capabilities in chip manufacture, and the UK's strategic approach to the sector.

Many demonstrations of quantum technologies have been no more than a 'heroic one-off or a heroic few-offs'. Until now, many quantum technology demos have been about whether or not the technology works. However, over the next few years, efforts must be made to scale up the manufacture of some of these technologies.

One major challenge is a common line of thinking that we have foundries among some compound semiconductors. What we really need to think about are the requirements for quantum, where these align with the capabilities and explore the divergence.

Several factors need to be considered when thinking about investments, such as a UK 'make versus buy' type investment in quantum technologies. To what extent do we think we are good at it? Also the strategic positions – is this something that we need to have control over for defence and security purposes? The UK needs to focus on one or two offerings. This is important for international collaboration. We need to have something on the table if we want to have access to other nations' technologies.

There are quantum products on the market but there is still a lot in the pipeline, so until we can find a solution as to what everyone needs and where those components and materials will come from, there is still a lot to work out.

An audience member noted the many commonalities between the Quantum Infrastructure and Semiconductor reviews, saying that as a country we should take notice of these. With other countries marching ahead with investments in their quantum technologies, what did panellists think were the timescales for the UK? One answer to this was that we should be looking at wins of value to different sectors now, and exploring those for the Spending Review. Otherwise, it is a work in progress.

The next step is surely recommendations and policies for quantum technologies. In the meantime, the Government Office for Science is looking at rolling out strategies that explore challenges at a granular level. For example, looking across quantum sensing and the cross-cutting technologies and capabilities.

What is the focus for the national content coming out of the UK as we build new devices and systems? Panellists responded with some examples and projects of technology developed and built in the UK, including some of the technology currently being deployed to monitor volcanic activity (which is supported by UKRI). The audience was assured that the supply chain for these technologies is very much a hot topic. ☐

LINKS

The online version of this section is available by scanning this QR code and includes links to featured research and reports.

CONTEXT

Professor Dame Angela McLean DBE FRS joined us in conversation with the Rt Hon Lord (David) Willetts, Chair of the Foundation for Science and Technology on Wednesday 9th October 2024. Professor McLean is the Government Chief Scientific Adviser, a role that she has held since April 2023. She is also Head of the Government Science and Engineering Profession.

Professor McLean and Lord Willetts explored a range of topics including the challenges of providing science advice, the role of science and engineering in the civil service and working with ministers and civil servants. This was followed by questions from the floor. The event can be seen at: **www.foundation.org.uk/Events/2024/In-Conversation-with-Professor-Dame-Angela-McLean**.

In conversation with Dame Professor Angela McLean

Lord Willetts: We really appreciate your coming along and joining us this evening. You've been Government Chief Scientific Adviser for over a year. What's your assessment of the role of government Chief Scientists, and how does it compare with what you were expecting?

Dame Angela: Well, it is definitely the best job in the world without any question. It is a wonderful mixture of quick-fire, "you are going to do three short meetings this morning" with an afternoon spent on something a bit longer. If I want to know more about something – particularly with good reason, I say to my lovely team in 'GO-Science', "I wonder if we should have a round table about that?" We do, and then a set of people from academia and industry and the relevant parts who really know about it, come in and answer our questions. It is like having a reverse tutorial with a bunch of profound experts. It is exactly what I think we really need to get some very expert advice down on paper and across to colleagues in Government that they need to know about. There are some exhausting round tables in the summer, when I sometimes literally find myself going and lying underneath a tree in St James's Park after they were over, just to let it sink in. So, it is a terrific job. It is more varied than I had understood.

Lord Willetts: Of course, you came to it from having been the chief science adviser in the MOD and you could argue that one of the big changes in Research and Development policy in the UK in the past ten or 15 years has been the rise of the security angle permeating so many decisions on science and technology, and a gradual recognition that just about everything is potentially dual use. Can you give me some comparisons to your defence background before and what extent to which you find yourself drawing on that with your new enhanced role?

Dame Angela: It is very useful to have had that time in defence. I thought I understood the civil service. I have done lots of advisory work as an external on science advisory councils and things like that. I'd spent days shadowing people in the civil service, but I had not ever worked in the civil service. I'll be honest with you, the culture shock was tremendous, moving to a full-time, four-day-a-week job in the Ministry of Defence, after being a full time academic. It was like moving to a foreign country and having to speak another language.

Lord Willetts: When you say a different language, what do you think is the difference between the civil service public policy language and the scientific, rigorous language of empiricism and mathematical models?

Dame Angela: I think the difference is highlighted by a meeting I had with other senior civil servants recently. Somebody started talking about a book she had found called *Radical Candor*. (I actually misheard her and thought it was called "*Radical Panda*"!) Anyhow, it is quite a thing for civil servants to be candid. I think civil servants are very honest and truthful, but let us face it, the entirety of the joke in the TV series *Yes, Minister* is about the gap between candour and honesty. Academics are very candid. Sometimes to the point that it can be a bit painful, but I think we academics are used to that. So that's the huge difference. I can see

Dame Professor Angela McLean is the Government Chief Scientific Adviser, a role that she has held since April 2023. She is also Head of the Government Science and Engineering Profession. She has had a distinguished career including serving as a fellow of All Souls College Oxford with a particular interest in mathematical modelling of biology. She was former Chief Science Adviser at the Ministry of Defence (MoD).

I can see myself slowly being hauled into the gravitational field of 'Thou shalt not say what one really thinks', but I hope I will not collapse into it.

myself slowly being hauled into the gravitational field of 'Thou shalt not say what one really thinks', but I am hoping that I will not collapse into it before I finish.

Lord Willetts: So, there are a variety of subtle ways of saying what you really think?

Dame Angela: I have a book. I wish I brought it with me. My first notebook when working at the MOD. I actually used to keep a list of them. The first one of course was "Consider it done". Do you know what Consider it done means? Consider it done is "Yes, you have told us, but we are never going to do that, and we are hoping you are going to figure out another way". There is also, "Thank you for that very full description". That means, "Oh my god, I thought you would never shut up". I must say that I actually refuse to speak that language and the one I really hate is, "I agree with everything that has been said", because to me, the implications of that are, "I have not really listened to what you said, because I do not care and now I am going to tell you what I think anyway". I think behind the politeness, there is a reticence for real debate that is unhelpful, but there is also this incredible importance of building consensus in order to deliver. That is really what the civil service is there for. If you spend all your life arguing about the details, you will not deliver anything.

Lord Willetts: That is the civil service but of course, you are also dealing with politicians from a wide range of backgrounds too, and you now have a science minister who was previously the Chief Scientist. How do you find engaging with ministers who have such a wide range of frameworks?

Dame Angela: Well, I like that challenge. I mean, I think in my heart I am really a university teacher. Nevertheless, I really relish the sort of challenge of trying to make it feel that anybody can ask any question. I think one of the things that is becoming a better habit of ours is to make time to talk to people one on one, so that they do not have to feel worried about what their colleagues think. I think it's a very strong story that Patrick (Sir Vallance-former GCSA) used to talk about going to see the (then) Prime Minister with a couple of scientists to talk about climate change, with nobody else in the room. A total safe space. I think we should do more with that.

Lord Willetts: We really got to know ministers and the political process through that intense crisis of Covid. In my experience, it is often when an unexpected event with significant scientific assessment needed, such as Fukushima or the Iceland volcano, when the chief scientist is summoned and suddenly it's their moment in cabinet. What are the challenges that you have faced at the more urgent end of the scale, when you've suddenly found yourself briefing ministers on an emergency?

Dame Angela: So, there are all the things that have not blown up where we have done some of the steps to being ready such as mpox. In this case, Chris Whitty and I were there and lots of people from the UK Health and Safety Authority. The process is, you go downstairs in a building, and you hand over all your technology and go through a special door and you are never allowed to mention the fact that this meeting existed. You then have a very sensible discussion about what you are going to do. Our job, in the case of mpox, is making clear to everybody that we already have mpox in this country called a Clade. Clade 2b is what is already here. Clade 1b is what we're worried about. We also explore why this new thing is a problem and then the operational stuff like how much vaccine should we buy? What's the right vaccine. And then, of course, the other thing I talk about that comes up with resilience is the UK Covid-19 inquiry.

Lord Willetts: The network of Chief Science Advisers is a great kind of cross governmental structure and when you are trying to get a message across government, getting all the chief scientists to understand, share and transmit it, it is very powerful.

Dame Angela: So, we meet every week. We actually genuinely like each other – it is one of the best groups of people I have ever worked with. I must say, I really appreciate the time I spend with the CSAs.

Lord Willetts: There are varying relationships with ministers. You can sense that with some CSA's, there are absolutely key policy advisers in the minister's office, all the time. For others, you are not quite so sure how strong the access is. How do you help out in those circumstances? Always

Dame Angela: Whenever new posts come up, I remind departments that their CSA ought to be advising their minister and not someone else. A powerful Chief Scientific Adviser is not always a blessing to a department, I think. And why is that?

Professor Dame Angela McClean: "A powerful Chief Scientific Adviser is not always a blessing to a department."

They ask awkward questions. They're not part of a network of career advancement. We are there to be awkward. One of the things we are there for is to defend the future. It is so hard to spend money on things that you know you are going to need in the future, and that is one of the reasons most CSAs have no operational responsibility. So, if you do not have to buy the mpox vaccine, it is easier to say, "No, I am going to invest in the new class of vaccines that is going to absolutely revolutionise the way we do vaccination in five to ten years' time". That is one of the reasons why it is important that the CSA should be external.

Lord Willetts: Does defending the future (which is a great way of putting it) include pressing for science in delicate public expansion negotiations?

Dame Angela: Very much. My job is to press for the science across negotiations and because I don't really have a budget, I am a trusted voice to say, "Here are some bits that fit together". I mean, mostly my voice at the moment is "don't cut the R&D budget". That would be a foolish move.

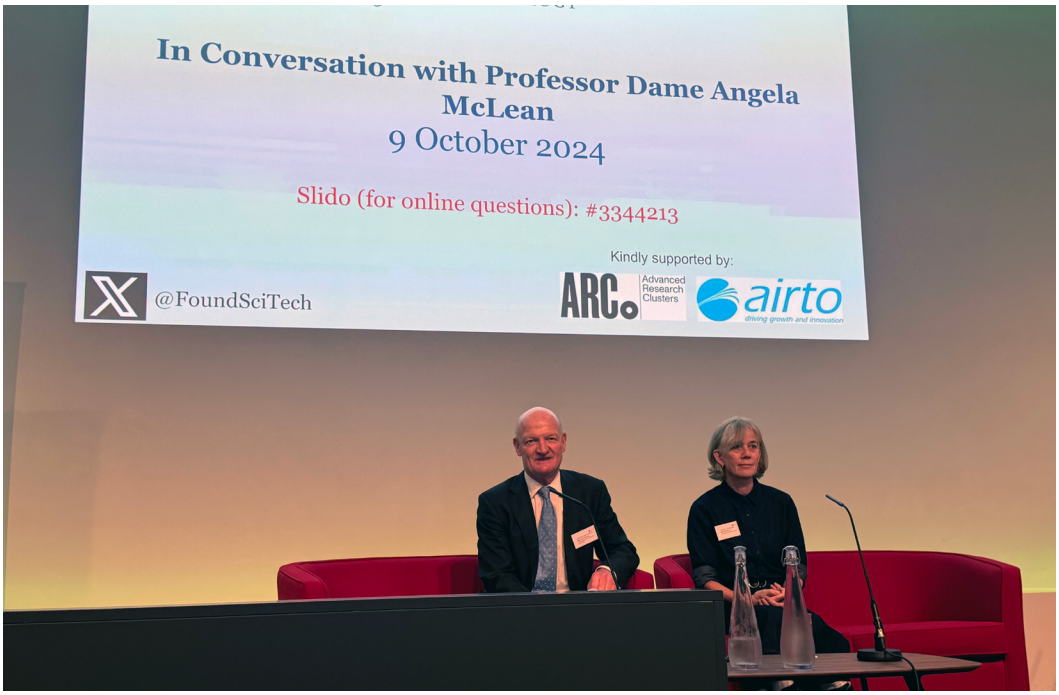
Lord Willetts: Within the network of chief scientists, there is not a particularly large cadre of social scientists. How do you decide on the balance of disciplines? How do you ensure that the social science needed to answer some of these questions is available alongside all the other forms of scientific expertise?

Dame Angela: So, I think I could probably name four of my CSAs who are social and behavioural scientists. (Which out of 20, is not bad). They organise themselves into a sort of special interest group and bring along other people from within the civil service – particularly those thinking about resilience. This is part of our continuous work to be ready in case SAGE gets called tomorrow. So that's always there. Quite a lot of our roundtables are social science because so many of the questions that government asks are social and behavioural science questions. For example, a lot of the work that we were doing over the course of the summer was around the situation with prisons, which eventually became very public. There was a lot of preparatory work based on the fact that the prisons were getting very, very full. Fundamentally, that work was behavioural science. I must say, I had not understood that there is not very much behavioural science in government.

Lord Willetts: What do you think levels of expertise in the civil service? Sir Patrick Vallance had (in the past), ambitions for patterns of recruitment, particularly trying to attract people from a scientific background into the general civil service. Is there more still to be done?

Dame Angela: There's lots more to be done. There is our sort of flagship recruitment process which is called the 'fast stream'. This does recruit some scientists. There is also a special thing called The

Professor Dame Angela McClean: "One of the things I find a little bit strange about the civil service is I don't see as much learning from each other as you do in academia."



Science and Engineering fast stream that has a lot to do with GO-Science and that is a great way of bringing in people, sometimes straight after a first degree, though many of them will have done a PhD or even a postdoc. However, this is ongoing work, and I often think about, how do we help the civil service itself become more scientific? We're working to make a programme to get people much later in their career to come and be civil servants. So, it is people who will come having done maybe ten to 15 years as a university academic, or at one of our own Public Sector Research Establishments or, in our dreams, in industry. This would mean that they bring that real depth of knowledge with them and then become a policy generalist. The power in the civil service lies in policy.

Lord Willetts: Do you think that there is a willingness to accept the limitations of information and analysis if you are functioning in Whitehall with the limitations of time? I sometimes say that often in Ggovernment, you're more like a GP than a hospital consultant – taking decisions with limited information and limited time. I think sometimes the cultural pressures are the scientists accepting that decisions have to be taken under those constraints. Can that cultural gap be bridged?

Dame Angela: Yes, by some people. Some people hate it, and some people revel in it, and there are quite a lot of secondment schemes. We would encourage most people to try it.

Lord Willetts: So, you are actively designing these type of career options and routes which will be public information and easily accessible and understood? Fantastic. We ought to focus briefly on some of the Government's specific priorities. And one of the messages that comes across very clearly is using science and tech to improve public services. There is a particular focus on AI and data. How do you think we are doing at harnessing science and tech to deliver better public services, even when they're operating under very serious resource constraints?

Dame Angela: I think learning from each other is a thing that we need to do more of. Coming from an academic background, it is one of the things I find a little bit strange about the civil service. I don't see as much learning from each other as you do in academia. I mean, let us face it, in academia, we have a whole system for nicking each other's ideas, but you have to do it with accreditation. Because they do not have accreditation in the civil service, there is not much motivation to have people take your ideas, which I think is a bit of a problem, actually. There is not a seminar series in the civil service for all the people who work on quantum, for example. Those people who do work on quantum and do know each other quite well, don't get together and say, "look, here is this amazing paper, what can we do with this?". That is a surprise to me, so I think we should do more of that. □

Please note: this is a shortened summary of a much longer discussion which can be viewed on the Foundation's 'Events' page. Please visit: https://www.foundation.org.uk/Events/2024/In-Conversation-with-Professor-Dame-Angela-McLean.

DOI: 10.53289/HXXI5173

CONTEXT

Evidence of a link between R&D and economic output in different geographical areas is clear. English regions are developing plans for economic development based on their own circumstances and the industries and skills in that area.

Around two-thirds of R&D is funded by industry and one-third from the public purse, and private investment often follows public. Public investment in R&D is primarily funded at a UK-wide level, with UK Research and Innovation (UKRI) being the primary funding agency. UKRI has traditionally had a mission to fund the best research, regardless of location, and that focus has contributed to an incredibly strong UK research sector which feeds into economic output – but with significant differences across different regions.

On Wednesday 23rd October 2024, in an event organised in collaboration with the University of Liverpool, we explored some of these issues. Professor Richard Jones from the University of Manchester prepared a short briefing note for this event and speakers included The Rt Hon the Lord Willetts FRS, Chair of The Foundation for Science and Technology; Professor Tim Jones, Vice-Chancellor at the University of Liverpool; Thomas O'Brien, Vice-Chair of Liverpool City Region's Innovation Zones Programme; Dr Lesley Thompson, Vice-President at Funders Global and Business Development at Elsevier and Dean Cook, Executive Director at Place, Innovate UK.

Region really does matter

Tim Jones

SUMMARY

- The research excellence of the country is internationally recognised, but we cannot carry on with the existing highly centralised funding model
- We have perpetuated a model where the parts of the country that have long benefited from significant levels of public sector R&D funding continue to get more
- The greatest distortion of public R&D funding is in the healthcare area, especially for infrastructure funding, which is heavily skewed toward London and the Greater Southeast. Place really does matter and populations which benefit from large amounts of health-related R&D generally have much better health outcomes
- We can raise the profile and value of existing schemes to encourage more devolved innovation funding into the regions. One obvious area is in capital investment and place-based schemes
- There is a financial viability gap for R&D infrastructure in the regions that does not exist in the South East. You need public sector funding to help plug that gap and make the private sector investment proposition work.

The short answer to the question of whether I think Science and Technology (S&T) budgets should be devolved to English regions is, yes. I will caveat that only to a limited extent. I don't believe, for example, that the whole of UKRI funding should be devolved to regions and I think the key question is how we best use current systems and structures to better devolve some of the research and development (R&D) and innovation funding and not create a whole set of new structures and complexities which will make it even more difficult to do the things that we want to do.

We all believe in the greater good of the country and the research excellence of the country is very strong. It is internationally recognised, and we have to make sure we protect that, but also we need to diversify that research excellence. What I do believe is that we cannot carry on with the existing model. It has failed. We have a highly centralised model and one of the most distorted economies in the developed world. The regions are underperforming economically compared to London and the Greater Southeast, and alongside that, we have major societal challenges in healthcare, education and so forth. I think those things are undoubtedly connected.

R&D funding

Several years ago, when I was a member of EPSRC Council, people told me repeatedly that it didn't matter where the research was done, because the whole country would benefit. However, I don't think we can say that is true. I don't think the current model we have works. We have perpetuated a model where the parts of the country that have long benefited from significant levels of public sector R&D funding continue to get more. Whereas those in the regions that traditionally

Professor Tim Jones took up the post as Vice-Chancellor of the University of Liverpool in January 2023. He moved from the University of Birmingham, where he was Provost from 2016. Previously, he held several senior leadership positions at the University of Warwick, including Pro-Vice-Chancellor for Science, Engineering and Medicine, and Pro-Vice-Chancellor for Research, Knowledge Transfer and Business Engagement. Professor Jones has undertaken several external roles connected with the research and innovation agenda, including being a board member of organisations such as the Engineering and Physical Sciences Research Council (EPSRC), the Manufacturing Technology Centre (MTC), the Welsh Science and Innovation Advisory Council, and the Alan Turing Institute.

The Sanger Institute in Cambridge received around £115 million in funding in 2022 – more than the whole of the north of England that year.


NBBJ

receive much less funding continue to receive less. Some recent figures shared by Professor Richard Jones at the University of Manchester show that the greater Southeast of the UK has 36% of the population but accounts for 55% of total R&D funding. If you look at UKRI funding specifically, the investment per person inside the greater Southeast was £170. The investment per person outside the Southeast was £87 and I think that distortion in R&D expenditure has been amplified by government decisions around major research infrastructure over the past few years and indeed, decades. Two notable examples are The Diamond Light Source, which was built in Oxfordshire at the expense of Daresbury in the Liverpool City region. The Crick Institute was founded in King's Cross London (not exactly a deprived part of the UK), and that has sucked huge amounts of biomedical research funding into the capital at the expense of the regions. Government has made some infrastructure investments outside of London and the Southeast, but I don't think anything has been of the scale of those two investments, and therefore the impact has been much more limited.

Healthcare inequalities

Perhaps the biggest distortion of all (and I thank my colleague, Professor Louise Kenny, for this information), is in clinical healthcare infrastructure funding. This was highlighted in a report published by the Northern Health Science Alliance (NHSA) – 'Analysis of the UK Clinical Research Landscape in 2022'.

The report showed that the Northern Combined Authorities, (i.e. the whole of the north of England) was awarded £49 million in healthcare infrastructure funding in 2022 to drive clinical research activity. However, there are individual buildings in London and the Southeast which receive more. For example, The Crick receives around £70 million, while the Sanger Institute in Cambridge received around £115 million. This is a very significant difference.

The statistic for spending on healthcare infrastructure in that year in the Liverpool City Region was £5.42 per person. For the population in Cambridgeshire, it was a factor of 30 more, at £160.84. Why does that matter? Well, healthcare R&D funding stimulates economic growth, as it does in all the sectors that we work in, but in healthcare, it matters because of health outcomes. All the evidence shows that the health outcomes for the population where healthcare research is carried out is significantly better by up to 30%. We have major healthcare problems in cities and regions like Liverpool and the rest of the North and the Midlands. We've amplified inequalities as well as the problems over economic growth. Place really does matter.

Appropriate levels of government R&D funding help retain highly skilled graduates, so they don't just move to London and the South East. It helps clustering of business and private sector investment, including foreign direct investment. It will increase the number of spin-outs and spin-in companies. It will help drive economic growth – one of the key missions of the new Government. It provides attractive job opportunities for local people and, in the specific case of healthcare funding, it should significantly improve health outcomes and reduce inequalities.

So how do we solve this? There is no simple answer, and I do not believe we can simply tear up UKRI and other R&D funding. We cannot channel all funding into particular regions, not least because I do not think the capacity and expertise within regions is actually commensurate with the

UNIVERSITY OF LIVERPOOL

The Materials Innovation Factory at the University of Liverpool was funded through the nationally competitive Research Partnership Investment Fund (RPIF) – but future RPIF schemes could put more focus on place.

work that would be required to deliver it. We also risk competition between regions and major duplication of effort, which would not help the nation. We all remember the days of the regional development agencies of the late 1990s and early 2000s. I worked in nanotechnology, and every region built a nanotechnology centre, which did not make sense.

However, there are things that could be done that build on previous and existing schemes. These could be raised in profile and value to encourage more devolved funding into the regions. I think one obvious area is capital investment. We have already talked about the impact capital investment has on R&D. Here at the University of Liverpool, The Materials Innovation Factory (MIF), which involves long-standing collaboration with Unilever, is a fabulous success story based on world-class research in materials chemistry, longstanding industrial collaboration and a history of delivery. The MIF facility was funded through the Government's Research Partnership Investment Fund (RPIF), a nationally competitive and not place-based scheme. It could be possible to put a place-based lens on future RPIF schemes to ensure that more of that funding goes into the regions and is aligned with the innovation priorities of those regions.

We also know that when private sector investment is required for capital funding – for example in buildings, space for incubation, innovation, laboratory space and expensive facilities – that's an expensive model. But it is much needed around the regions to promote spin-outs. There is also a financial viability gap in the regions that is less prevalent in the Southeast and makes private sector investment much more challenging. You need more public-sector funding to plug that gap and make the private sector investment proposition work. You can't charge the same rents for lab space in Liverpool, Newcastle and Leeds as you can in Oxford, Cambridge and London, but the building costs are similar. So there are ways that public sector funding help could address some of those challenges.

There are other existing, and successful, place-based innovation schemes that we need to expand and continue – for example Strength in Places, Innovation Zones and Investment Zones. More needs to be done to align with regional priorities and regional innovation plans.

Finally, could we do something around low TRL Research Council Funding without damaging the excellence of the UK's research base? I think the answer is yes and I am going to borrow an idea from my colleague here at Liverpool, Professor Matt Rosseinsky, If you sit on a Research Council panel, there may be 10 proposals deemed to be excellent and above the threshold for funding, but in reality, there is only enough funding for four of those proposals, so six get rejected. Now suppose all four of those were from London and the Southeast, and number five and six were from the North. What you could do is say, we will only fund two in London and the Southeast and will fund one in Newcastle and Liverpool. You then get a place-based lens within the final decision making, but you do ensure that the excellence threshold is met.

None of this is easy, but I will come back to how I started. We cannot continue as we are. We have one of the lowest growth rates of any economy in the world. We have one of the lowest productivity of any economy in the world. The current model is not helping that. So, change is needed. There is my provocation. □

DOI: 10.53289/LZJT9214

There is a will and there is a way

Thomas O'Brien

Thomas O'Brien is a professional economist and global development expert with over three decades of front-line experience. As Director of The World Bank, he supervised a $75 billion portfolio across Africa. At KPMG and HM Treasury, he led major regeneration programmes and national policy analysis. He is the Vice-Chair of the Liverpool City Region Innovation Zones Programme that incorporates Freeport and Investment area regeneration. He is also an honorary professorial fellow at the University of Manchester.

SUMMARY

- The Innovation Zones Programme in the Liverpool City Region means that when companies come to Liverpool, they get a good deal, including tax breaks, purpose-built facilities and skills support to supercharge their prospects
- The Liverpool city region has a rich economic history and modern assets of innovation but our economy needs to catch up with the South East, and we need to give residents the jobs and opportunities they deserve
- We have a stretch target that we can move towards allocating 5% of our economy's gross value added to research and development
- We argue strongly that there should be greater transparency in the allocation and spending of nationally supported R&D across regions, and more influential involvement of the regions in setting priorities and making decisions.

If you want to devolve money, what are you devolving into? What will make it worthwhile?

I am the Vice Chair of the Liverpool City Region Innovation Zones Programme, and along with the board, we work with the Metro Mayor, Steve Rotherham to help promote innovation and help create good jobs for communities right across the conurbation.

The Innovation Zones Programme is a new approach, and it is one of the largest regeneration initiatives in the UK. Bringing together two programmes with national recognition (Freeport, plus Investment Zone), our integrated programme combines capital funding from our colleagues in central government with valuable and significant tax incentives for businesses. When companies come to the Liverpool City Region or expand here, they get a compelling package that can supercharge their growth. We also have skills and innovation funding to make a more attractive package overall – drawing on national support from the "Freeport" initiative established by the UK Government a couple years ago, and from a similar national initiative called "Investment Zones".

We already have business parks and sites that are expanding or coming on stream, and they provide ripe locations for new and expanding companies to establish and grow. The sites are designed for the needs of key sectors which are targeted for our economy to grow. Life sciences is a prominent sector where Liverpool and its region have obvious world-class assets, including in a city centre location known as the Knowledge Quarter. We also have other sectors, particularly modern logistics and advanced manufacturing, where current assets are strong and ripe for expansion. For example, some of our investment is setting up a new business park in Parkside, St Helens, at the edge of the conurbation.

At the moment we are wrapping together site locations, financial incentives, and skills and innovation support which can be accessed by new investors and growing companies. This combined approach is entitled the Innovation Zones Programme, because it is innovation which is the element of the wider strategy for the economic future of Liverpool City region to be an innovation superpower. We already have many of the ingredients. For example, Unilever (one of our great companies in the locality), founded its first laboratory in the early 1900s in what is now the Liverpool City Region and it has 850 scientists here in the area. We also have our fine universities. The University of Liverpool has the Materials Chemistry Research, with 99% of it rated as world-leading or internationally excellent. There is also the Liverpool School of Topical Medicine (LSTM), which attracts very substantial research funding per academic employed, at a rate which compares favourably with other leading institutions, even Oxford.

It is clear that when it comes to innovation, the Liverpool City Region has got the history, it has productive assets (people, facilities, intellectual prowess and business entrepreneurship) that make innovation part of our DNA today, but what about tomorrow? Well our economy needs to catch up with the South East – to help drive national economic growth in a broader, more sustainable way, and importantly to give residents the jobs and opportunities they deserve.

We are striving for our stretch target for our economy to devote some 5% of gross value added to research and development. That is higher than the average UK performance and so is a heavy lift. Yet Metro Mayor Steve Rotherham has put it forward because we believe that this type of change is

needed to drive the economy for the benefit of those living in the region. What are some of the ways this will come into practice, including through the Liverpool City Region Innovation Zones Programme of which I am vice-chair?

One compelling opportunity is in important strands of the life sciences industry. It would be fantastic if the UK's preparedness to use vaccines and other therapeutics to take on the next pandemic was anchored here in Liverpool, using our strengths in research and development and in bio-manufacturing. This is why the Innovation Zones Programme is putting capital funding into infrastructure, including new high-tech commercial labs here in the Liverpool Knowledge Quarter, and at the Sci-Tech campus in Daresbury. We are also expanding partnerships with globally significant national companies that manufacture vaccines and other medical therapeutics.

Indeed more broadly, for the UK and its corporate base, almost 50% of trade with North America goes through Liverpool. That can grow substantially, but it would be better if it could be expanded and made more cost-effective, with greater digitisation of customs and the trade regime. That is the type of challenge that we are putting innovation funding into with Liverpool University and its consortium partners. Our local resources are limited, however, and this is why we come to the debate about how to get more devolution and a more equitable distribution of national R&D spending to the city-region level.

A case for devolved budgets

I left Liverpool in the early 1980s and this place was struggling then. The contrast with London was quite extreme. I worked overseas for nearly three decades and on my return I am really quite proud to see how Liverpool and its region have rebounded, re-organised and regained their civic pride. That is very encouraging, and we are moving forward at pace, but we know our competitors are not standing still. That is why we, as a national community across the country, have to tackle the issue of making national research and development investment more purposeful for growth in places where it is needed most. We need new and improved national policies and budgets that drive research and development in a better and more equitably targeted way across English regions. That change needs to happen quickly and decisively.

One way of doing it would be through integrating it within wider political moves for devolution to city regions (metropolitan combined authorities). Certainly, in the Liverpool City Region, that would play into a wider canvas of our enhanced capability to deploy combined local and national resources for locally determined economic and social needs. We have the Liverpool City Region Combined Authority that has been around for almost ten years now. The Combined Authority led by Metro Mayor Steve Rotherham has experienced staff, solid financial systems, and operational capacity to take charge of devolved R&D spending allocations. A change in the approach nationally does not have to move to a blank canvas – we have actually got the institutional and financial strength here in the Liverpool City Region to take this on without delay.

SCIENCE AND TECHNOLOGY FACILITIES COUNCIL (UK)

The Innovation Zones Programme is funding infrastructure including new high-tech commercial labs at the Sci-Tech campus in Daresbury.

Another important advantage of devolving national R&D to city regions is that we are much better placed to match up national programmes with other sources of finance that we already have, or that are coming on stream. Now, I recognise there are arguments in favour of elements of the existing centralised system, because some elements of policy are probably more sensibly set nationally rather than at the local level. However, my plea would be that there can be greater transparency in allocations and spending across regions, and more influential involvement of the regions in priority and decision-making.

We are keen to be involved in a constructive conversation on this and to change the status quo. There is a way to deliver it, whether it is the full-scale reform of devolution or a hybrid approach which combines national and devolved resources. There is a way to make a change so that Liverpool City Region and other places can have a fairer slice of the national R&D pie that we contribute towards. That will be a major step to ensure that the power of innovation, research and development can be better harnessed, as it was in the industrial mercantile age. That was a time when Liverpool and other northern cities flourished—and our future will see them flourish again. □

DOI: 10.53289/IAPB1995

The diversity of roles and experiences in R&I

Lesley Thompson

Lesley Thompson joined Elsevier in 2016 as Vice President of Academic & Government Relations for the UK. In 2023, she transitioned to a newly created role leading the company's global business development for Funders. Before joining Elsevier, Lesley spent 26 years at the Engineering and Physical Sciences Research Council (EPSRC).

I will share insights from my multifaceted career, drawing on the various roles I have held. I currently work for Elsevier, part of RELX, a FTSE 10 global company, and I also serve on the Keele University Council. Previously, I chaired the Oxfordshire LEP Innovation Board and worked at the EPSRC, providing me with a diverse range of perspectives. Additionally, I have personal ties to Liverpool, as my mother was born there.

While Elsevier is often recognized as a publisher, its parent company integrates leading content with data sets and advanced analytics to serve various sectors, particularly research and healthcare. In 2015, Elsevier conducted a global search to determine the best location for its Data Science Hub. After an extensive evaluation, London was selected, primarily due to its access to top talent, the attractiveness of the location, and its critical mass.

During my tenure at EPSRC, we frequently emphasized the importance of global companies establishing and investing in the UK. To encourage this (particularly in fields such as data science, AI and pharmaceuticals), sustained research investment is essential to maintain the UK's strengths and to develop a highly skilled workforce. Notable examples we cited included Microsoft Research in Cambridge and the Elsevier Data Science Hub in London, highlighting the interconnected nature of our global landscape.

SUMMARY

- The UK is not alone in exploring how investments in science and technology can drive regional economic growth. In the US, the NSF TIP Directorate has invested in technology and regional mapping to assess the impact of its investments down to congressional district level
- In the Netherlands, TU Eindhoven and Elsevier have developed a set of indicators to showcase the value and impact of a fourth-generation university, which is expanding influence globally
- Liverpool is not an island. Liverpool and Liverpool John Moores Universities actively engage in strong collaborations regionally, nationally, and internationally with other universities and corporate partners. These partnerships yield benefits for both the universities and their collaborators
- People are arguably the most significant output of universities. Cornell PhD alumni contribute to the prosperity of the entire USA. In Staffordshire, the robust partnerships that Keele University is forging with local further education providers are vital for the overall prosperity of the county
- Looking ahead, the UK must focus on building strong regional, national, and international collaborations and networks. Striking the right balance among these three areas, while maintaining excellence in research and technology will be critical for future success.

Global examples

In the USA, the CHIPS and Science Act of 2022 led to the creation of the National Science Foundation's Technology, Innovation, and Partnerships (TIP) Directorate. They approached us with a challenge: how to demonstrate the equitable distribution of their investments across various jurisdictions, including states, territories, and congressional districts. By focusing on promising key technologies, they aimed to achieve local economic benefits. This aligns with the comments made by other panellists regarding Liverpool and its region. Elsevier has developed a publicly accessible, interactive portal that allows users to search all NSF TIP investments at the congressional level and track their outputs, emphasising the importance of evidence-based approaches.

Another noteworthy example is Cornell University, which collaborated with us to assess the geographic impact of its PhD alumni. We examined five cohorts over 20 years from the Engineering, Agriculture, and Life Sciences faculties. Our research revealed that 18% of Cornell PhD graduates relocated to California, 25% remained in the New York region, while the rest dispersed across the USA. This demonstrates that Cornell PhDs have a significant impact nationwide, and I would love to map the influence of the alumni from UKRI's Centres for Doctoral Training (CDTs) in a similar manner.

Closer to home, about a year ago, the Technical University of Eindhoven approached Elsevier to explore the concept of a "fourth-generation university." This mission-driven model emphasizes both education and research, focusing on social value creation, transdisciplinary, and innovation spaces. TU Eindhoven is situated in the Brainport region of the Netherlands, a vital area for the Dutch economy. Our partnership has led to the exploration of ways to measure the characteristics and impacts of a "fourth-generation" university, and this work has expanded to include nine technical universities worldwide.

Liverpool's collaborative ecosystem

Liverpool is not an island; it thrives on collaboration. Liverpool University is well-networked and collaborates extensively, particularly with Manchester University, its strongest academic partner. While it plays a significant role in the region, the university's research output contributes to corporate–academic collaborations across the UK, exemplified by the spin-out company Oxford Nanopore from the University of Oxford.

Liverpool John Moores University also engages with corporations throughout England, including Unilever, Syngenta, and Liverpool and Manchester United football clubs. The local perspective on collaboration with Manchester United might spark debate, but the importance of research excellence remains clear. When examining the University of Liverpool's independent publications, the Field Weighted Citation Index (FWCI) stands at 1.2. This figure improves with national collaboration and increases nearly fourfold with corporate partnerships. This data indicates that corporate–academic and international collaborations enhance research quality, highlighting the need for a balanced approach when making regional research investments.

The true output of universities lies in their people and ideas, with people being the most vital component. In my roles in Oxfordshire and at Keele, I have observed a strong emphasis on social inclusion and community engagement, working to dispel the traditional "town and gown" divide. At Keele, we are actively building robust connections across the education supply chain, recognising their importance for the development of Staffordshire.

As we look to the future, it is essential to balance multiple objectives, including place, collaboration, skills development, and research excellence. Investing in excellence is crucial if we wish to remain globally competitive.

The post-COVID landscape has transformed the relationship between geography and employment, driven by advancements in technology. At Elsevier, we have adapted our geographical footprint, reducing the number of offices and enabling many of our teams to work from home. This shift raises important questions about the implications of changing work patterns for our place-based investments.

BART VAN OVERBEEKE

Elsevier has worked with the Technical University of Eindhoven to explore the concept of a "fourth-generation university", focusing on education and research as well as the creation of social value.

In my view, establishing strong networks and fostering co-creation at regional, national, and international levels is critical. Universities have become increasingly adept at this over time.

However, regional devolution is not uniform across the UK, which presents a significant challenge. While some areas may be well served, others are not. The lessons learned from the Regional Development Agencies and the Science and Innovation Audits conducted in 2016 reveal that, while regional strengths were documented, there was a lack of comparative analysis to assess performance nationally or internationally.

Finally, in these challenging fiscal times, we must carefully consider how to invest in ways that achieve multiple objectives while minimising bureaucracy.

My recommendation for the future is to prioritise networks and people in our investments. This idea is not new. As Oppenheimer famously said, "The best way to send information is to wrap it up in a person." To foster innovation and prosperity, we need strong regional, national, and international collaborations and networks. Moreover, the UK is not alone in this increased focus on place and economic growth; we are witnessing similar trends globally. □

DOI: 10.53289/SECX8824

The significance of place

Dean Cook

Dean Cook is Executive Director for Place and Global at Innovate UK. As part of the senior leadership team, Dean has responsibility for developing strategic relationships and action plans with local leadership and devolved authorities across the UK. His team of managers for the English Regions, Scotland, Wales and Northern Ireland work across the Innovate system to embed 'place' across Innovate UK's wider activities.

SUMMARY

- Innovate UK published a Plan for Action for UK Business Innovation (2021-25), which has a strong alignment with the aspirations of the industrial green paper
- Our national ecosystem is a super-cluster on the global stage so we must make sure that we are boosting all of the critical component parts and investing in our regional capabilities
- We need to make sure that there is a series of commitments to connect national to local. We cannot have a disconnect
- Innovate UK has put a lot of energy into connecting what we do nationally to what is happening locally, and driving local outcomes
- The new industrial strategy is a real opportunity to take advantage of the leadership capacity we have seen across the UK: metro mayors, devolved governments and wider ambitious local growth plans.

I am not going to take a position on devolution. This is because I work for Innovate UK, one of the nine councils of UK Research and Innovation (UKRI). We deliver to government policy, and it is for ministers and policymakers to decide on devolution priorities. However, I would say that the genie's out of the bag. The arguments have been successfully made that we have one of the most concentrated, centralised R&D systems in Europe and maybe we need to do something about that. For me, this is about exploring how we at Innovate UK as a national body and a national funder, support that agenda.

At Innovate UK we published a Plan for Action for Business Innovation (2021-25). At the top level we have got three major strategic priorities. They are the 'domains' that we support in terms of the sectors and the challenge areas which are Net Zero; health and life sciences (and agri-food); and digital and technologies. You will find a strong alignment there to the industrial green paper that has just been launched. There is 'place' – which is my leadership responsibility, and there are our 'products and services' – how we evolve the support we bring to all the brilliant businesses and all the brilliant innovators who are across the UK. Making sure we have that right customer journey, so we are giving the right support from start-up all the way through to the scale-up needs of those businesses. This is not just about what we do by ourselves. It is also how we work with other partners and other parts of Government.

Why am I passionate about place? I was born just outside Slough in the south of England, but as a young bioscientist working for what was then a government agency of the Ministry of Agriculture, Fisheries and Food (now Defra), I was relocated to North Yorkshire in the 1990s. It was also at a time we were coming out of recession with new government infrastructure projects helping reboot the construction sector and a great opportunity to build new headquarters and opportunities in the North of England. So that took me North just outside of York where I have been for the past 30 years. So the whole regional agenda really means something to me. I was relocated to be part of a bioscience cluster in North Yorkshire and given the opportunity to be part of, and contribute to growth in, that community. The whole essence of working in a cluster is that if my job goes today, there are other opportunities locally; it is a thriving ecosystem. This whole agenda really resonates with me. It is very personal.

As a geography, the UK is relatively small on the global stage. But our national ecosystem is a global cluster.

Going back to our plan for action and strategy, we are a very different organisation now from what we were three years ago, and very much different from 10 years ago. Just before I joined Innovate UK, there was a Government review. The review was extremely positive but it noted we were 'place blind'. I would like to think that we are not place blind anymore. In our plan for action, we laid down three priorities for what we are going to do, to advance our place agenda.

First, as a geography, the UK is relatively small on the global stage. But our national ecosystem is a global cluster. If you are operating in Silicon Valley and looking for opportunities in the UK, you are not looking at just, say, Liverpool City Region, you are looking at the whole of the UK. So it is incumbent as a national funder to look at our national ecosystem and make sure that we are boosting all the component parts, investing in our regional capabilities, and bringing it together as a coherent ecosystem that is globally competitive. This means that I work with my colleagues across those national domain teams to be thinking about place and not just driving the usual national competitions. We are committed to thinking about our national

programmes differently and connecting national to local. We cannot have a disconnect.

Thinking about the local opportunities to connect to, we now have investment zones and we have freeports. The much anticipated devolution bill is almost certainly likely to give greater local powers around areas such as Net Zero and the green economy and skills. How can we in the research and development system have any impact on place if we cannot connect to these things that will be happening locally?

At Innovate UK, we made a big commitment to put energy into connecting what we do nationally to what is happening locally, and to drive greater local outcomes. In 2020/21, about 55% of our funding went outside the Greater South East region, which was not bad considering about 45% of the research and development business, and of intensive business generally, sits outside the Greater South East. In the past couple of years, we have pushed that to 66% of our funding. That latter number hasn't been released yet, but has been validated, and shows a major shift of investment.

Deep local reach

Another reflection is that we are a national body, but we have got deep local reach. I spoke about the fact that I live and work in North Yorkshire. Most of our frontline innovation staff are field-based. We have got innovation experts all across the UK with a further 400 dedicated innovation and growth specialists locally embedded and operating as a regional resource, in partnership with both the university sector and local authorities. We have got a fantastic Catapult network. These are strategic assets set up deliberately within an innovation cluster geography and distributed all across the UK.

However, it is too easy to focus on just the funding or what we mobilise in terms of place programmes. While these place programmes offer major seed funding to build local capacity, we need to be much more ambitious than just thinking about local programme support. In addition to local capacity building, we need regions to be able to be nationally competitive, so that they can compete for a greater share of the national funding that is available.

That is how we have been using our targeted programmes and we have got a plethora of schemes reflecting the fact that all places are different. If you compare Liverpool City Region to North Yorkshire, they are very different – with different levels of business innovation maturity, different levels of capability within the combined authorities, and different university capabilities. We cannot just run the same programme in each place. So we have a range of tools, such as the Innovate UK Launchpads, which are deliberately targeted to stimulate SME capability in places that may be a little less mature, all the way through to the Innovation Accelerators, where we have got bigger, bolder pots of money to drive those more mature ecosystems.

INNOVATE UK

Innovate UK's Plan for Action for Business Innovation (2021-25) outlines a number of strategic themes and foundations that drive innovation success.

Going beyond the funding, what is really unique about the programmes is the way that we are starting to design them. Co-creation is the word I want you to take away. It is not about us as a national body implementing place-based programmes to a particular location. It is about working in partnership with local leadership to make sure that we understand the local needs and the local ambitions and work together to align and unlock them. That's the approach we took both with our 11 Launchpads and the three Innovation Accelerators in Greater Manchester, the West Midlands and Glasgow City Region.

We need a paradigm shift within the national R&D system. We need to make sure that when we are thinking forward to things like the new industrial strategy, we can harness the local growth plans coming through. How do we wire up those new national programmes so that they don't just deliver their outcome natiponally, but also drive the local economic growth that we're collectively looking for? In the Innovate UK local action plans we have launched, the first being here in Liverpool City Region, we worked together with local leadership to identify the strengths of the local area. We also highlighted where we are already making significant investment. Then we set out how we will work in partnership to further unlock those local opportunities. So far, we have eight action plans across the UK, including working with combined authorities and, in the case of Wales, working with the devolved Government.

I think the most important part of the levelling up white paper of 2022 when it comes to the R&D

place mission, is the new objective that UKRI was given to make place a strategic objective. For this to work its way through takes time – time to build local relationships, time to learn to do things differently and time to build trust. However, I am optimistic because I think we have built some deep and meaningful relationships, particularly in the past couple of years. I am excited about the prospect of a new industrial strategy because I believe this is a real opportunity to take advantage of the innovation leadership capacity we have seen across the UK, whether it be metro mayors, devolved governments, or other ambitious local growth plans, and an opportunity to harness 'big plays', such as investment zones. There is a real opportunity to make the totality greater than the sum of the parts. ❑

DOI: 10.53289/WTJV6352

The debate

After the presentations, the speakers joined a panel to answer questions from the audience on a variety of topics, including how funding is distributed, threats to the university sector and inclusion of rural areas.

The starkest difference in investment is in the bio-medical area.

There is a national opportunity to capitalise on globally leading knowledge assets and by doing that, we can be better partners with leading institutions in the South. There is more that UKRI can do to drive that.

The number of streams for funding for innovation is quite small. We should put more money into these funds, but whether this is viable, remains unknown. The advantage of devolution is that if you have a variety of pots of money, you can piece them together quickly and successfully at a local level. We need decisive change.

All of the UKRI Councils are distinctive, so the levers are different. There is a balance of funding going into different streams such as manufacturing which traditionally will go to places outside of the South-East. There is not a straightforward answer to the balance of funding but UKRI are trying to get better at this. The council is developing a toolkit to move the whole of the UKRI 'machine' so that funding is more evenly distributed.

From a business perspective, there is something to be said for sustainable funding over the longer term, to build ecosystems across the UK. With the UK economy in mind, building long-term relationships with strong institutions in the UK is preferable to a boom-and-bust approach.

When you look at the current threats to the university sector such as the decline in international students, the scale of what is needed will be a challenge and should concern the Government. Areas such as Liverpool are not asking for charity, they are asking for a fair share. They collaborate across the country and internationally but still need appropriate investment. The starkest difference is in the bio-medical area. A lot of money still goes into the Greater South-East in this space and there are knock-on effects based on decisions made a long time ago. The major centralised version is not serving everyone properly. Devolved funding comes with low risk and should be trialled.

All of this is down to people and people making things work. If we are collaborative instead of competitive, then devolved funding will work. The UK needs to spend more on skills and education, otherwise the agenda will fail.

Awareness of the 'place issue' has gradually increased within UKRI. Some of the programmes that we discuss today (such as The Catapults and The UK Launchpad) were instruments developed some time ago and can still be used as resources for funding to support this issue.

Should geographically close metropolitan areas such as Manchester and Liverpool receive separate funding or shared support? It was agreed that geopolitics should stay out of decision-making and that there are opportunities across regions and each area has strengths. There are obvious areas that they can partner on and if the two cities can get that right, it could be very powerful.

We do not have symmetric governments across the UK and we must make sure that rural communities are not left behind in this discussion. The Industrial Strategy should allow all regions to play their part, show sophistication and act with a consistent strategy to see what works and what does not. ❑

LINKS

The online version of this section is available by scanning this QR code and includes links to featured research and reports.

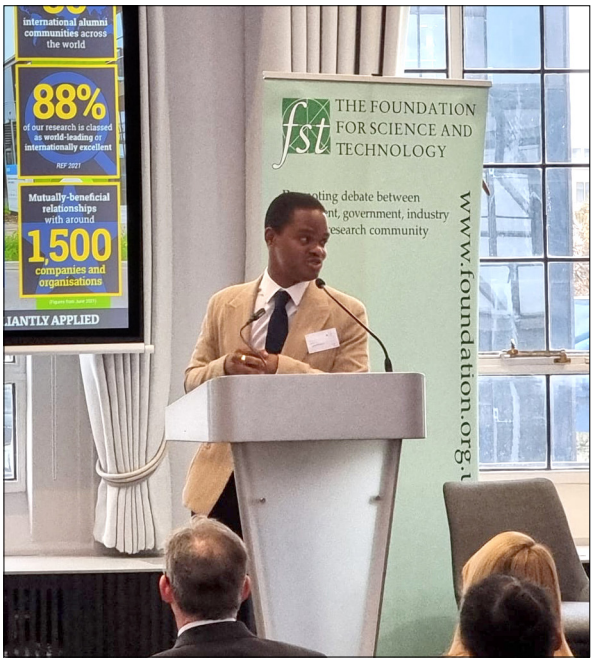
Careers and skills for global challenges

CONTEXT

On Friday 8th November 2024, the 2024 cohort of the Foundation for Science and Technology's Future Leaders gathered in Birmingham to discuss building careers and skills in science and technology to meet national and global challenges. The conference heard from speakers from academia, industry and policy, at a wide range of career stages and from diverse backgrounds. The day also included breakout sessions where participants came together to consider how academia and industry could work together with government to help achieve the new Labour government's five core missions.

Across the day, several common threads emerged and these are summarised below. View the recording of the conference at **www.foundation.org.uk/Events/2024/Building-Careers-and-Skills-in-Science-and-Technol**.

The discussions highlighted several recommendations for individuals, industry, academia, government and funders which could help improve the development of talent and skills; equality, diversity and inclusion in science; international collaboration and cross-sector engagement.



Leadership and career development

Jenny Hindson

Jenny Hindson is a marine climate change policy delivery manager for the Scottish Government. She worked as an oceanographer for many years, and then worked as a science adviser within central Scottish Government, covering a broad variety of topics to help best inform policy decision making within Scottish Government. She is now back in the Marine Directorate working in marine climate change policy, specifically considering the Maritime Just Transition. She is passionate about ensuring evidence is front and centre of policy decision-making.

While some people see career paths and the route to leadership as relatively linear, there is great value in following a less traditional path, developing skills and experiences in different sectors or roles, and taking them onto the next career move. These pathways can often involve stepping outside of one's comfort zone and embracing new challenges, and in doing so gaining a diversity of experience that could otherwise be missed, and can lead to fantastic leadership roles. Sarah Sharples, Chief Scientific Adviser at the Department of Transport, spoke at the conference on her route into this position from an undergraduate student in psychology into a professorship in engineering and into the CSA role, highlighting that a winding route into leadership is possible, and can be very beneficial.

The long game

Leadership skills often develop over time, and advancing these skills while on your career journey can build confidence, enabling individuals to apply and succeed in roles that go beyond their initial academic or professional training. □

RECOMMENDATIONS

For individuals

Value diverse opportunities that you are given, and do not shy away from stepping out of your comfort zone to develop new skills and broaden your experiences.

For many of us mentorship can be a hugely valuable aspect of our career journeys, with the power to inspire, influence and guide us on our way. For future generations of scientists, a mentor can provide access to information about job roles and organisations that are otherwise relatively hidden, and provide an informal network for opportunities, as well as advise and support on university or further training. Further along your career path a mentoring relationship can provide further inspiration and advice, supporting career advancement and helping with navigating challenges. For under-represented groups mentoring can be an invaluable source of information, build confidence and lead to finding a supportive network (see also the section on Diversity and Inclusion).

For academia, government and industry

Set up effective mentorship pathways, where being a mentor is viewed as a personal development opportunity, to encourage staff to provide mentorship to young people and encourage a propagation of skills throughout an organisation.

Skills development and talent acquisition

Fabrizio Ortu

The science and technology skills pipeline was a key topic of discussion across all sessions of the conference. One of the pillars of sustainable technological and economic growth is the identification of skills gaps in key industries, so that strategies can be put in place to support the science and technology sector at its core. The new mission-led approach of the UK Government heavily relies on the ability of the wider science and technology community to deliver on large infrastructure projects, thus requiring very close collaboration and mobility between sectors.

The Labour Government, in its 2024 election manifesto, committed to making the UK a clean energy superpower. This was one of five declared missions to rebuild Britain.

This was a key point of discussion in the Clean Energy Superpower breakout session, where participants discussed at length the delivery targets of the Government's related mission. Because of the scale of the challenge to increase our renewable energy production and energy storage capabilities, it is imperative that people coming out of their scientific training are equipped with the necessary technical skills, such as engineering, chemistry, software and programming skills.

Academic upgrade

Academia still plays a pivotal role in providing these tools to the private sector, but it can be slow to respond to industry skills demands. Often, this is the result of teaching practices and curricula being constrained by dated accreditations awarded by governing bodies that are not fully synchronised with critical workforce needs, and do not reflect strategic priorities for economic and industrial growth. Therefore, promoting a symbiotic relationship between academia and industry will go a long way to ensure that academic institutions are providing the skills needed by the workforce (a key message that emerged from the Growth breakout session). In turn, this will align teaching practices and outcomes with 'real world' industry demands. □

Dr Fabrizio Ortu is an Associate Professor of Chemistry and Sustainable Technology Lead at the University of Leicester. Dr Ortu has been involved in academic research for over 15 years, working on a number of projects covering quantum computing, nuclear materials and green chemistry. His main research passion is sustainable manufacturing, and his research team works on the development of new technologies that could reduce the carbon footprint of chemical processes, and break their reliance on critical materials and precious metals.

RECOMMENDATIONS

For academia, industry and Government

Establish a good synergy between private sector and academia, to ensure taught curricula across STEM are modernised to support critical workforce needs of the science and technology sector.

Another key component of the discussion across the sessions was the need to encourage mobility of talent across sectors, particularly between academia, industry and the Civil Service. Mobility must be considered a resource for science and innovation because of the scientific and societal added values it brings to the table, particularly with regards to widening opportunities for a skilled, resilient and diverse workforce. As discussed in the 'Breaking down barriers to opportunity' breakout session, effective mentoring of future generations of scientists can be a catalyst to breaking down barriers to STEM careers and boost mobility across sectors, also exemplified by some of the success stories discussed during the Conference (see Leadership and Career Development).

All these ingredients are essential to enrich the scientific community and equip our workforce with the necessary skills to deliver on Missions set by the UK Government.

Diversity and inclusion

Lauren Thomas-Seale

Dr Lauren Thomas-Seale is a senior lecturer in Engineering Design, a chartered engineer and strong advocate for diversity and inclusion. She leads a research group at the University of Birmingham which develops design methods for advanced manufacturing and transdisciplinary engineering, with applications in healthcare. She is passionate about increasing diversity in engineering, and inclusive processes are integral to her teaching and research. Dr Thomas-Seale aspires to create innovation and engineering design techniques, which leverage the diversity and agility of thought, which is present in inclusive teams, to ensure that the future of engineering is globally sustainable for everyone.

To ensure that the economic growth generated by the UK science and technology sector is socially inclusive and environmentally sustainable, it is imperative to ensure that the natural diversity of our society, i.e. the diversity of knowledge and thinking within innovation, is reflected through the workforce. As such, diversity and inclusion underpinned all the themes discussed during the conference. Whether explicit or implicit to the presentations and panels, the value of diversity and an inclusive approach was showcased. Further to this, the importance of an evidence-driven approach was emphasised. It was discussed that, as opposed to being purely altruistic, initiatives need to be driven by data to ensure that outcomes are efficient and effective.

Impactful innovation

The McKinsey reports (*Why diversity matters*, 2015; *Delivering through diversity*, 2018; *Diversity Wins*, 2020) are well-cited resources when making the quantitative and financial business case for diversity. It is frequently acknowledged that a diverse workforce brings different perspectives, creativity and problem-solving capacity, which is inclusive of the society which we endeavour to serve. Diversity drives impactful innovation. Yet almost 10 years after the 2015 McKinsey report was published, attracting, developing and retaining diversity in science and technology is still a widely unresolved challenge. While promoting inclusivity and accessibility is key to attracting diverse talent, inclusion itself is not enough. Where inclusion is about being given a seat at the table, belonging is a feeling which represents qualities such as being valued and welcomed into a community and being given the opportunity to thrive.

Recommendations for academia, government and industry: Emphasise an evidence-driven approach, as opposed to altruism, in diversity and inclusion initiatives. Consider incentives and initiatives that aim beyond inclusion and towards belonging.

The conference reflected on the value of a doctoral degree, the post-graduate research training that some scientists undertake. While the value of a PhD is often promoted through career trajectory and long-term salary, for many doctoral students, the value lies in career skills, and social and personal development. The often unspoken yet crucial fact is that PhDs are very hard. Current doctoral training requires high levels of resilience in a person as well as time – PhDs are essentially full-time jobs. They are particularly difficult to do if you are self-funded, have caring responsibilities or are the first in your family to go to university.

While it requires resilience to work in science and technology as a member of a marginalised group, additional socioeconomic challenges can make it even harder. Importantly, the term "resilience" itself was questioned, implying needless suffering in the pursuit of an academic career. Many science careers exist outside of academia, but post-graduate research students are not routinely exposed to, or trained for, them. □

RECOMMENDATIONS

For Government and academia

Review the environment in which PhDs are being completed, what professional (as well as technical) skills are being developed, and how this is developing the pipeline and shaping the science and technology workforce.

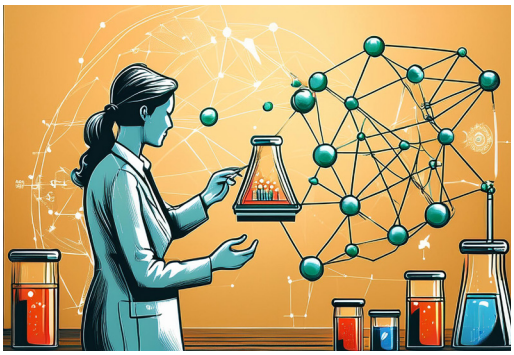
During the breakout sessions, mentorship was discussed as particularly useful for those from lower socioeconomic backgrounds who might not have existing connections in STEM, or networks. This is where sponsorship is also important. To sponsor means to elevate a person, to connect them to more opportunities and advance their career. The distinction between mentorship and sponsorship is important: sponsorship can be developed from a mentor-mentee relationship, but it requires the active choice to advocate for and advance that person.

For academia, Government and industry

Set up effective mentorship, sponsorship or equivalent schemes, to foster a sense of belonging for people from marginalised groups. Aiming for equity, by enabling them to access similar professional networks and career opportunities to those enjoyed by the dominant group.

Integration of science and policy

Myriam Telford



Research can play a critical role in shaping policy-making. Where strong relationships exist between the scientific community and policy-makers, this can ensure that policy decisions are informed by the latest scientific knowledge and, conversely, increase the impact of research by ensuring its rapid translation into practical application in policy.

For this reason, there are multiple formal structures in place across government to enable the integration of science and policy. Sarah Sharples, Chief Scientific Adviser at the Department for Transport, spoke at the conference on her role in facilitating relationships between her policy colleagues and scientific experts across a range of fields. As well as convening experts – both ongoing through the Science Advisory Councils and on an ad hoc basis for specific projects, Chief Scientific Advisers play a role in translating between the two communities. Similar convening structures exist across other aspects of the UK's policy-making, for example the Parliamentary Office of Science and Technology sources impartial scientific research for parliamentarians.

New ways of working

While these structures are an important step, they can often be complex for an external audience to navigate, especially when Government research priorities are rapidly changing. The creation of Government missions is encouraging new ways of working across departments. This has advantages in breaking down silos and pinpointing the key priorities of Government, but also may make it more challenging for the scientific community to identify the best entry route for sharing their expertise. □

Myriam Telford is Head of International Data and Analysis at UK Research and Innovation (UKRI). She has a decade's experience in research funding, much of which has been focused on working with global partners to enable international R&I collaboration. She is passionate about using data and evidence to understand the role of collaboration in modern research and innovation endeavours, reduce barriers to collaboration, and evidence the value of being globally engaged to address global challenges.

RECOMMENDATIONS

For Government

Increase awareness of the structures for integrating policy and science. Create a single entry point through which scientific experts can identify and respond to the research priorities of Government.

A further challenge in the integration of science and policy is the nature of Government work: often driven by a need to solve a specific task in a challenging timeframe. This reduces the time available to engage with external advice, increases the imperative for a simple, consensus-driven answer, and aligns poorly with academic funding, project and publication timelines. Some Government departments are setting up a 'Futures team' with a remit to explore long-term trends and engage with emerging thinking beyond an immediate policy need.

However, addressing this barrier also requires a cultural shift within academia. Further work is needed to ensure that academic incentives – including the Research Excellence Framework (REF) assessment, as well as career progression within institutions – recognise alternative routes to value creation from research beyond traditional outputs such as publication. Engaging with government also requires a new skillset: it may require researchers to look beyond their own area of specialism to represent cutting-edge knowledge from across their field, and it calls for the ability to communicate complex and nuanced information to a lay audience in a succinct way. And, sometimes, it requires a rethinking of what is impactful: in the words of Sarah Sharples, "Sometimes we want science to be reassuringly boring."

For academic institutions and funders

Review academic incentives to put greater emphasis on engagement with policy. Consider the skills development needs of academia at all levels of seniority to improve their confidence and ability to have policy impact.

In a world of rapid scientific and technological progress, policy-makers need access to cutting-edge research to support their decision-making. But, overcoming the natural silos between the scientific and policy-making communities requires cultural shifts on both sides.

Economic growth and the value of R&I

Christopher Pilgrim

Dr Christopher Pilgrim is in the Materials and Manufacturing team at Innovate UK Business Connect focussing on facilitating innovation towards resource and energy efficiency. Chris supports the Transforming Foundation Industries Challenge and other projects including AI applications in the materials value chain. His background is in materials and mechanical engineering. He completed an engineering doctorate with an Imperial College spin-out company looking into smart coating materials and measurement. Since then, he has worked in technical management roles to drive the development of the technology for commercial applications and then in quality assurance for a global aerospace manufacturer.

Economic growth is traditionally measured by Gross Domestic Product (GDP), but this narrow focus misses the broader factors that truly define a nation's well-being. Truly sustainable growth involves not only financial metrics but also elements such as health, education, and societal happiness. It also requires considering the consumption of resources and the long-term environmental impact. While research and innovation (R&I) can drive progress on these fronts, their benefits are often long-term, requiring patient investment. In times of financial strain, investment in R&I is often cut which can stifle economic recovery by limiting the pathways to future growth.

The contribution of science and technology to the economy is important but difficult to quantify and often under-estimated. In the breakout session on economic growth, much of the discussion related to the balance between funding R&I with clear return on investment versus allowing more emergent benefits. Taking a simple return on investment approach, fails to account for the less tangible, but highly impactful, contributions of scientific and technological advancements.

Take, for example, the development of the Covid-19 vaccines. Beyond their direct health benefits, the vaccines helped restore productivity, enabling economies to reopen and recover. Similarly, innovations such as fibre-optic cables, which were developed through basic research in the 1960s and 1970s, now form the backbone of global internet infrastructure. Despite their low-cost production, their impact on global connectivity – and, by extension, economic growth – is immense. This illustrates the need for a broader definition of economic value that includes long-term societal and technological benefits, rather than just immediate financial returns.

The rapid commoditisation of new technologies further complicates the economic impact of R&I. As technologies mature, their potential for driving economic growth diminishes unless supported by strong manufacturing capabilities and robust supply chains. This means the true value of R&I often lies not in the immediate commercial payoff but in the foundational changes it makes possible over time.

RECOMMENDATIONS

For Government and industry

Through the mission targeted at economic growth, consult on the agreed vision for growth. Develop the mechanisms which can realise growth against the agreed vision.

Similarly for industry, purpose-led businesses are more successful than the competition. Establishing and articulating a clear purpose will help drive growth, retain talent and increase impact.

The need for collaboration

The UK has made some of the most significant scientific and technological breakthroughs in history, yet the full economic impact of these innovations has often been distributed across multiple countries over many decades. As we enter an era marked by increasing international tensions and climate-related risks, international collaboration will be critical in translating world-leading research into tangible economic benefits for the UK. Opportunities for such collaboration were discussed in the final session of the conference.

Collaboration between academia and industry is also essential for the translation of research to innovation. Programmes like Knowledge Transfer Partnerships (KTPs) and industry-sponsored PhDs bridge the gap between academic research and real-world business needs, fostering a symbiotic relationship that benefits both sectors. Tax incentives, knowledge-sharing and other methods to encourage researchers to commercialise innovation will help drive economic opportunities.

As mentioned in the closing session of the conference, there is a clear ambition for economic growth in the UK but no collectively agreed purpose for this growth. As such, we have the mechanism but without the motivation. Falling between the US and EU, we need to have a clearer picture for the reason for growth which will in turn help define a more effective path forward. ❐

Innovation and emerging technologies

Sam Islam

The UK has a storied history of innovation within science, medicine and engineering ranging from Fleming's accidental discovery of penicillin to the development of the steam engine, which propagated the industrial revolution in the 1800s. As highlighted in the breakout panel 'An NHS fit for the future', the COVID-19 epidemic is a very recent example of how unexpected global challenges demonstrate the more disruptive pathway to innovation through the development of the COVID-19 vaccine.

Beyond the technological breakthroughs that have followed and will follow because of this achievement, the pandemic has also elicited some complex lessons learned regarding public health and emergency preparedness, which are finding application in other areas such as wastewater epidemiology. The pandemic has also helped to identify the broader healthcare challenges such as the need for data that more accurately reflects the diversity of the current population, and further opportunities growing within the personalised medicine space.

This echoes a key point noted within the 'Clean energy superpower' breakout panel where the topic of library and information sciences was discussed and the potential role that this field could play in enabling improvements in the standardization of taxonomies and ontologies across science and technology activities regardless of discipline. The specific role of digital archiving was also discussed to understand the importance of consolidating historical data with more recent data to aid ease of collective data retrieval and facilitate more innovation mining activities through minimising the risk of "reinventing the wheel."

In both breakout panels, it was noted that although there is collective understanding and recognition of the importance of being discipline-agnostic in addressing the key challenges outlined in the current government's mission-led strategy, in practice, current funding mechanisms for interdisciplinary, multidisciplinary, transdisciplinary and cross-disciplinary approaches differ considerably. This constrains opportunities to explore more uniquely lateral collaborations that could yield the scale of innovative breakthrough that is typically reserved for more unprecedented times.

Barriers to integration

Lack of appropriate funding can also create a barrier to supporting new technologies being integrated wholly into existing systems. This was discussed in the breakout panel 'An NHS fit for the future', where the initial cost of introducing new and more effective treatments needs to be balanced with the benefits of existing treatments that have already been proven in service. It was also noted in the 'Clean energy superpower' breakout panel that a key area for innovating within the clean energy space is addressing the challenges of scaling up existing solutions such as waste storage to accommodate the increasing uptake of small modular nuclear reactors in the UK. □

Sam Islam is a systems engineering consultant based at Energy Systems Catapult. Her key role is performing research and development activities and leading and providing technical expertise in the UK's journey to Net Zero for projects ranging from zero emissions shipping to sustainable cooling. She has over a decade of experience working in renewables, international development, offshore oil and gas and transport industries. She has worked on international assignments across Europe, Asia, the Middle East and Africa across both public and private sector organisations and businesses. She is a member of INCOSE UK and the IET and is passionate about inclusive innovation and ensuring the equitable development of solutions to address the climate crisis.

RECOMMENDATIONS

For funders

Consider creating funding mechanisms and processes that enable lateral collaborations and exploratory research and innovation.

Although mission driven collaboration has so far enabled the identification of such challenges, openness to supporting exploratory, "curiosity-driven" collaboration activities that do not have a deliverable defined from the outset could lead to the identification of brand-new research areas that would not ordinarily be elicited from existing research methodologies. This would require a different approach to funding and preliminary work to understand which subject matter areas are currently under-utilised within the given research space. This is reflective of a comment made in one of the breakout panels that topics such as the NHS and clean energy have a clear relationship with science and technology. However in missions such as crime and justice, the role of science and technology beyond obvious fields such as forensic medicine is less clear. Therefore the value and impact of innovating in these missions is less well defined.

Such open-ended collaboration needs to be paired with the presence of a diverse workforce and this must be achieved through proactive measures to improve access and inclusivity within training opportunities.

International collaboration

Geoffrey Neale

Dr Geoffrey Neale is a trailblazing researcher in the field of composite materials, focusing on making these materials structures stronger and smarter. Dr Neale is a Royal Academy of Engineering research fellow and lecturer at Cranfield University, whose work has pushed the boundaries of manufacturing multifunctional and innovative composite structures. He is passionate about making the world more inclusive, safer, and sustainable, by tying in his research to real-world applications.

Today's global socioeconomic climate is one in which international collaboration is ubiquitous and necessary to achieve efficient, sustainable, and impactful outcomes in the science and technology landscape. The UK is already considered a global leader in research, being at the cutting edge of most fields, but has national ambitions to take this to the next step and become a science superpower. We have been quick to recognise that open collaboration underpins our ability to achieve this superpower status and we aim to leverage our position of strength to expand our global impact. However, we live in a volatile world where many challenges are no longer confined to national borders and historical partnerships cannot always be relied upon. Simply put, addressing the barriers to widening international participation in our technological goals and those of our global community is of key importance.

Emphasising the importance of international collaboration in research is the first step. In the current spending review, UKRI will spend somewhere in the region of £4 billion on international collaborations, according to Professor Christopher Smith, UKRI International Champion and executive chair of AHRC. He noted that UKRI partnerships are highly concentrated in Europe but spread fairly well globally, though with a noticeable underrepresentation of collaborative activities in Africa, which is being addressed through exciting new initiatives.

Many universities are not just internationalising their research agenda, but are physically installing overseas campuses in emerging markets across the globe. Professor Marika Taylor, Pro Vice Chancellor and Head of College of Engineering and Physical Sciences at the University of Birmingham, explains that the benefits are twofold. Not only is it more cost-effective for these students and researchers to study or work in their own countries, but the physical presence of UK institutions facilitates a more direct link to local governments and industry. This fosters a strong international research and innovation ecosystem, driving up research quality and providing two-way access to the full research and innovation pipeline in both countries.

Open research principles like FAIR (Findability, Accessibility, Interoperability, and Reuse) underpin scientific rigour and allow for greater dissemination of research outcomes that allow the global community to adopt and build on our outcomes to the benefit of us all. This maximises the return on research expenditure and creates new opportunities for researchers in the UK to engage with a wider pool. Alex Hale, technology programme manager at the National Composites Centre explains that our R&D challenges are often tied to global challenges where the faster spread of new and emerging technologies can sometimes be plagued by barriers like knowledge access and freedom to collaborate. Export control regulations, although necessary and well-intentioned, can sometimes prove a hinderance to broadening our partnerships. Sometimes the innovations in these areas are extremely complex and judgements on whether export control regulations should apply is incredibly subtle, making it a challenge for these typically small teams that make these assessments.

There are inherent efficiencies gained from internationalisation of research efforts, where shared expenditure and resources help to reduce duplication of efforts and spending. This is especially poignant in large-scale projects where it may be difficult for one country or institution to dedicate sufficient resources. Crucially this also underpins integrity, reproducibility and public trust.

In a globally competitive market, talent acquisition is a continued challenge. There are large skills gaps in areas vital to our national interests, such as manufacturing, defence, and pharmaceuticals. If we are to attract the right talent to support UK ambitions, we must look outward to bolster our workforce and further develop sovereign capabilities. Then the risks associated with relying on limited reliable supply chains, that may in future become unreliable, can be more effectively mitigated. □

DOI: 10.53289/CIVM2963

LINKS

The online version of this section is available by scanning this QR code and includes links to featured research and reports.

RECOMMENDATIONS

For Government

Facilitate the freer movement of science and technology professionals, resources and funding in the areas that we can and must share with others for the global good. Encourage R&D solutions that have potential for a wider global impact, rather than more Western-centric positive outcomes. Consider the synergies between what researchers value in the discovery cycle and the social value of economic growth to clarify the purpose of increasing the research wealth of the nation so that the mechanisms better align with a clear motivation.

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The Foundation is grateful to these companies, departments, research bodies and charities for their significant support for the debate programme.

The Journal of The Foundation for Science and Technology

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