fst journal

The Journal of The Foundation for Science and Technology

Volume 22 Number 7 August 2020 www.foundation.org.uk

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

COUNCIL AND TRUSTEES

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

The Foundation for Science and Technology
22 Greencoat Place
London SW1P 1DX

Tel: 020 7321 2220
Email: **fstjournal@foundation.org.uk**

Editor Dr Dougal Goodman OBE FREng
Production Editor Simon Napper
Layout Simon Clarke

FST Journal was redesigned in 2015 by IOP Publishing's Design Studio, under the art direction of Andrew Giaquinto. IOP Publishing provides publications through which leading-edge scientific research is distributed worldwide and is central to the Institute of Physics, a not-for-profit society.

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

Neither the Foundation nor the Editor is responsible for the opinions of the contributors to *FST Journal*.

ISSN 1475-1704

Charity Number: 00274727 Company Number: 01327814

CONTENTS

fst journal

Volume 22 Number 7 August 2020

New Global Partnership on AI finds a home at the OECD

The OECD will host the Secretariat of the new Global Partnership on AI (GPAI), a coalition launched in mid-June that aims to ensure Artificial Intelligence is used responsibly, respecting human rights and democratic values.

The GPAI will bring together experts from industry, government, civil society and academia to conduct research and pilot projects on AI. Its objective, as set out by founding members the UK, Australia, Canada, the EU, France, Germany, India, Italy, Japan, Korea, Mexico, New Zealand, Singapore, Slovenia and the USA, is to bridge the gap between theory and practice on AI policy. An example would be looking at how AI could help societies respond to and recover from the Covid-19 crisis.

Basing its Secretariat at the OECD will allow the GPAI to create a strong link between international policy development and technical debate on AI, taking advantage of the OECD's expertise on AI policy and its leadership in setting out the first international standard for trustworthy AI – the OECD Principles on Artificial Intelligence. The OECD Principles formed the basis of the G20 Principles on AI endorsed at the Osaka Summit in June 2019.

www.oecd.org/going-digital/ai/oecd-to-host-secretariat-of-new-global-partnership-on-artificial-intelligence.htm

Joint statement from founding members:

www.gov.uk/government/publications/joint-statement-from-founding-members-of-the-global-partnership-on-artificial-intelligence

'Power of place' is central to R&D agenda

The Campaign for Science and Engineering (CaSE) has published a new report on how to maximise the local economic impacts of R&D investment and ensure the UK economy rebounds from the Covid-19 pandemic.

Designed to feed into the Government's 'levelling up' and R&D investment agenda, the CaSE report *The Power of Place* examines how to maximise the local economic impact of greater R&D intensity across the regions and nations of the UK.

The report makes a series of recommendations, including:

- Excellence cannot be grown from scratch: investment needs to be focussed on R&D excellence that already exists nationwide, whatever its size;
- Brand is important: regions should clarify their distinctive strengths and develop their pitch for national and overseas investment;
- The best examples of regional R&D growth have been driven by strong civic leaders.

The report's findings are based on views gathered from over 80 contributing organisations through an extensive consultation exercise across the UK, conducted over the last 18 months, including roundtables in Edinburgh, London, the West of England, the West Midlands, and the North East.

www.sciencecampaign.org.uk/static/uploaded/f68487de-0f87-44ce-bba06fc0882cc57c.pdf

IBM withdraws from facial recognition tech

In a letter to Congress on 8 June, IBM CEO Arvind Krishna outlined policy proposals to advance racial equality in the United States. He also shared, in the context of addressing responsible use of technology by law enforcement, that IBM has withdrawn its general-purpose facial recognition and analysis software products. In his letter, he said:

"IBM no longer offers general purpose IBM facial recognition or analysis software. IBM firmly opposes and will not condone uses of any technology, including facial recognition technology offered by other vendors, for mass surveillance, racial profiling, violations of basic human rights and freedoms, or any purpose which is not consistent with our values and Principles of Trust and Transparency. We believe now is the time to begin a national dialogue on whether and how facial recognition technology should be employed by domestic law enforcement agencies.

"Artificial Intelligence is a powerful tool that can help law enforcement keep citizens safe. But vendors and users of AI systems have a shared responsibility to ensure that AI is tested for bias, particularity when used in law enforcement, and that such bias testing is audited and reported."

See also pages 36-44 of this issue.

International policy shake-up sees FCO and DFID merger

The Prime Minister has announced that the Department for International Development (DFID) and the Foreign & Commonwealth Office (FCO) will merge, uniting development and diplomacy in one new department to bring together Britain's international activities.

Work has already begun on the merger. The new department – the Foreign, Commonwealth and Development Office – will be established in early September and will be led by the Foreign Secretary.

The Government said: "UK aid will be given new prominence within our ambitious international policy. The Foreign Secretary will be empowered to make decisions on aid spending in line with the UK's priorities overseas, harnessing the skills, expertise and evidence that have earned our reputation as a leader in the international development community."

The Prime Minister also announced that the UK's Trade Commissioners will come under the authority of UK Ambassadors overseas, in order to bring more coherence to the UK's international presence.

The objectives of the new overseas department will be shaped by the outcome of the Integrated Review, which is expected to conclude in the autumn, and is the biggest review of foreign, defence and development policy since the Cold War, says the Government.

The Foundation for Science and Technology has been taking a series of steps to address the challenges posed by the coronavirus pandemic, writes Gavin Costigan

Coronavirus and the Foundation

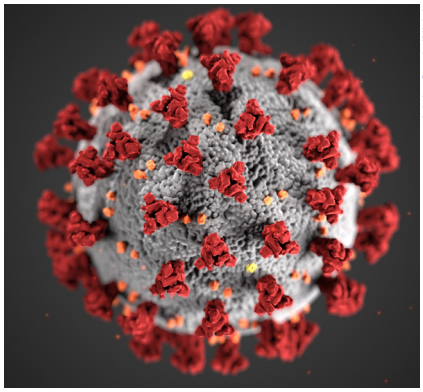
The Covid-19 pandemic has affected all parts of economy and society and the Foundation for Science and Technology has been no exception. An evening meeting at the Royal Society in March – ironically focussed on dealing with the pandemic – had to be cancelled as the country went into lockdown. With no clear endpoint in sight, and with most of our activities based on physical meetings, it was clear that alternative arrangements would have to be made.

It was fortuitous that the Foundation's new website had recently been launched with a range of new features including podcasts and video recordings of the speakers at the events held at the Royal Society.

The Foundation's major evening meetings were reorganised and re-scheduled to webinar format. These are now taking place with invited speakers, presentations and an audience of 150 – but all now linked through the Foundation's online Zoom platform. The audio files and presentations – as well as a meeting summary – are all posted on the FST website shortly after the event. Video interviews with the presenters and regular podcasts on topics of interest make the website a resource for the many issues involving policy making, science and technology.

A new initiative to introduce the Foundation to professionals in early- and mid-career positions – in government, academia and industry – had been launched in October. The Foundation Future Leaders programme was designed to allow young professionals to meet colleagues from other sectors of the economy, to discuss different approaches and ways of working – and to encourage networking the building of long-term professional relationships. These Future Leaders were also encouraged to take in the regular meetings of the Foundation.

Part of the programme included a visit to the Royal Society of Edinburgh and Strathclyde University at the end of March. This was quickly reorganised and participants were still able to speak to key personnel online. A series of other meetings have also taken place online. The final, one-day conference of this year's programme is also now being re-designed in an online format.



Adobe Stock / Nitish

An evening meeting at the Royal Society – ironically focussed on dealing with the pandemic – had to be rescheduled as the country went into lockdown.

The reaction from those on the programme has been generally very positive – indeed one member, who is involved in overseas science projects, has been able to join more of the meetings. We hope, nevertheless, that it will be possible to get everyone on the programme together before the end of the first year.

Our weekly podcasts have continued, and we have expanded our blog site. At the same time, the core services we deliver to learned and professional societies have continued via email and the ubiquitous Zoom, including the development of a new section on the Foundation's website for members to access guidance notes on governance issues.

The short-term future remains uncertain. We recognise that for many, a key benefit of Foundation meetings is networking, and we are committed to returning to physical meetings as soon as it is safe to do so. In the meantime, the Foundation is working online to ensure that it continues to fulfil its core mission of providing an impartial platform to debate policy issues with a science, research technology or innovation element.

Gavin Costigan is Chief Executive of the Foundation for Science and Technology.
Email: gavin.costigan@foundation.org.uk

PODCASTS AND BLOGS

One of the online developments on the FST website is the posting of weekly podcasts. These weekly one-to-one interviews allow an in-depth discussion of topics being explored in Foundation events. In addition, there are one-off discussions with senior figures across science, research, technology and innovation. The podcasts are available on the website but can also be accessed on the main podcast hosting platforms. Recent features include Member of the Shadow Cabinet Chi Onwurah MP on the relation between science and politics, Chair of the Commons BEIS Select Committee Darren Jones MP on business and coronavirus, and Peter Betts of Chatham House discussing COP26.

Another new feature of the website are the FST blogs. These are short, contributed pieces about topics of interest. Recent postings include: Patrick McHugh on intergenerational justice in the face of the coronavirus pandemic, Alana Cullen on a new 'sustainable normal' and Benjamin Lichman on full open-access scientific publishing.

All these and much more can be found on the FST website at: **www.foundation.org.uk**

A sustainable and inclusive future for all

Jim McDonald

Engineering matters. It underpins our daily lives, drives economic growth and helps ensure our readiness for the future. As we have seen in recent months, it also helps us to address major global challenges: engineers have been integral to the fight against COVID-19 around the world, from manufacturing ventilators to designing and building field hospitals in record time.

The Royal Academy of Engineering brings together the most talented and successful engineers from the UK and overseas. As the UK's National Academy for engineering and technology, we have a responsibility to provide progressive leadership for engineering and technology, stimulate innovation and enhance the positive impacts of engineering for wider society. Our Fellows are the lifeblood of the Academy and they inspire and influence every aspect of our work. I was privileged to be elected as President of the Academy last year and my first few months were spent listening to the views of Fellows across the country and from all fields of engineering, in order to inform a new strategy for the next five years.

Fiftieth anniversary

Our new programme of work will take us up to the 50th anniversary of the formation of the Fellowship of Engineering, which would become the Royal Academy of Engineering in 1993. Nearly half a century ago, it will not surprise you to know that the Fellowship of Engineering looked very different from our modern Academy. Conceived in the late 1960s, during the excitement of the Apollo programme and the buzz of Harold Wilson's 'white heat of technology', the Fellowship was eventually born in 1976, the year of Concorde's first commercial flight.

Thanks to the enthusiastic backing of HRH Prince Philip the Duke of Edinburgh who became its Senior Fellow, the new Fellowship met for the first time at Buckingham Palace, where 130 of the UK's finest engineers were enrolled: these were people who over the course of their careers had literally changed the world. They included the jet engine visionary Sir Frank Whittle and Sir Maurice Wilkes, father of the UK computer industry.

Since those early days, the Fellowship – and latterly the Academy – has taken every opportunity to champion excellence in all fields of engineering and honoured the UK's most distinguished engineers. Yet the challenges facing our nation, and humanity as a whole, have increased dramatically in complexity and urgency, so the role of our Academy and of engineers has evolved rapidly along with the pace of technological development.

In the past five years alone, we have seen three UK general elections, left the European Union and committed to achieve net-zero greenhouse gas emissions by 2050. The world has witnessed rapid digitalisation, a growing public appetite to tackle our unsustainable use of natural resources and to address inequalities in society, as well as confronting the emergence of new threats to stability and security.

Against this backdrop, and amid the current COVID-19 crisis, there has never been a more urgent need for engineering expertise to inform public debate and provide workable solutions to our shared challenges. It is fitting then that the Academy has set itself an ambitious goal for the next five years: to harness the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

This goal means that we will work towards a sustainable society where development meets the needs of the present without compromising the ability of future generations to meet their own needs. Engineers have a vital role to play in creating technologies, systems and solutions to address the climate crisis and support more sustainable use and management of natural resources. We will advance solutions to sustainability challenges, and enable engineers to engage effectively with policymakers, society at large and media on the UK's commitment to net-zero greenhouse gas emissions by 2050.

Three decades is a very short time to completely renew, upgrade, install and secure entire parts of the UK's national infrastructure: current projections suggest that the UK is not on track to meet its emissions targets. So, while we continue to tackle the pandemic, it is vital that we address the longer-term threat to humanity from climate change.

I am confident that we can learn from the rapid changes in behaviour and working practices – as

Professor Sir Jim McDonald FRSE FREng FInstP FIET is President of the Royal Academy of Engineering. He is also Principal and Vice-Chancellor of the University of Strathclyde, a post he has held since 2009. With the First Minister, he co-chairs the Scottish Government's Energy Advisory Board. He is Chairman of the Independent Glasgow Economic Leadership Board and chairs two of the pan-Scotland research pools in Energy and Engineering. He also chaired the Royal Academy of Engineering Research Committee for three years. He was awarded a knighthood for services to education, engineering and the economy in 2012.

The challenges facing our nation, and humanity as a whole, have increased dramatically in complexity and urgency, so the role of engineers has evolved rapidly.


Rolls-Royce PLC

By 2025 we are aiming to have enhanced the leadership capabilities of more than 7,500 engineers, and inspired 1 million young people to consider engineering careers.

well as the single-minded drive to develop solutions – in the face of the coronavirus, and so bring a similar level of collaboration and commitment to our common purpose of slashing carbon emissions.

Our new goal also means working to ensure that engineering contributes to an economy where prosperity is shared across all regions and groups in society. Engineers have an important role to play in translating advances in research into new products, services and technologies that improve our lives and generate jobs. An inclusive economy is also internationally competitive, as well as resilient to technological changes and future threats to public health, security, safety and stability. Resilience is a much discussed concept and engineers' expertise in systems thinking, problem-solving and innovating is vital to shaping a 'new normal' that is well-prepared for future shocks.

Three areas

Our work towards this ambitious vision will be concentrated in three areas: growing talent and developing skills for the future; driving innovation and building global partnerships; as well as influencing policy and engaging the public. We will build on some of the Academy's most successful and important work, from our Enterprise Hub (which supports exceptional engineering entrepreneurs and SME leaders with an unrivalled package of mentoring, funding and training) to the National Engineering Policy Centre (which brings together 43 professional engineering institutions, representing 450,000 engineers) to provide policymakers with a single route to advice from across the engineering profession.

We will broaden our engagement and scale our most effective activities to increase our impact. By 2025 we are aiming, for example, to have supported the founding and growth of at least 500 companies that will deliver benefits to society, enhanced the leadership capabilities of more than 7,500 engineers, and inspired 1 million young people – from all backgrounds – to consider engineering careers. Our effort will be international as well as domestic: we will support alliances that use engineering and technology to address global challenges in more than 40 countries across six continents.

We cannot, however, achieve this alone. A critical factor in our success will be collaboration. The Academy's Fellows, awardees, partners and supporters have always played an invaluable role in our efforts to advance engineering's contribution to society, and collaboration is enshrined in our values. The challenges engineers must solve cross disciplinary and geographic boundaries, and so the scope of our activities must too. We would invite anyone who shares our ambition to shape a sustainable society and an inclusive economy to engage with us and consider the role that engineers can play in shaping such a future.

At a time of global disruption and enormous uncertainty, it is an incredible privilege to lead an organisation that represents the collective expertise of exceptional engineers and innovators, and an absolute imperative to apply that expertise to the delivery of public benefit and a more inclusive and sustainable future. □

www.raeng.org.uk/publications/strategy-and-finance/strategy-2020-2025

RESILIENCE AND VULNERABILITIES

Understanding the supply chain vulnerabilities that emerged during lockdown will help us to prepare for future shocks, including a potential second wave of COVID-19, according to a National Engineering Policy Centre paper. The Centre is a partnership of 43 organisations, led by the Royal Academy of Engineering. Critical supply chains with immediate impacts on daily life demonstrated considerable resilience and adaptability during the disruption and the solutions adopted may also help address some of the key challenges in distributing a vaccine against the virus.

Supply chain challenges, lessons learned and opportunities looks at how UK supply chains were disrupted during the early stages of the COVID-19 pandemic and assesses the success of mitigation measures from procurement to logistics and skills in the food, electronics, telecommunications, transport and energy sectors. The results, including spotlights on each of these sectors in the report, are based on evidence gathered from 60 different organisations, ranging from large companies to SMEs and micro-organisations.

www.raeng.org.uk/Publications/Reports/Supply-chain-challenges,-lessons-learned-and-oppor

How can the UK ensure that its international research collaborations achieve maximum impact and deliver maximum benefit to the country and the economy in a post-Brexit world? This was the topic of a meeting of the Foundation for Science and Technology held on 26 February 2020 at the Royal Society.

Future frameworks for international collaboration

Adrian Smith and Graeme Reid

SUMMARY

- The Smith-Reid report was commissioned by the UK Science Minister in 2019. It provides advice on frameworks for international collaborations should the UK not associate with Horizon Europe
- EU funding covers about 3% of total UK expenditure on R&D but that figure masks specific concentrations
- Around 50% of UK business R&D comes from foreign-owned firms with growth from the wider world far exceeding that from the EU
- The UK needs to become more agile to grasp new opportunities for international R&D collaboration
- The first priority is to protect and stabilise existing capabilities.

In early 2019, facing uncertainty around the UK's future relationship with Europe, the then Science Minister Chris Skidmore commissioned independent advice on alternatives to association with the EU Horizon 2020 research and innovation programme. The resulting Smith-Reid report[1] made a series of recommendations for action in the event that the UK does not associate with Horizon Europe.

We made no assessment of whether the UK should associate with EU programmes. That was not part of our brief. We assumed the decision on association will be made at a senior political level, in the wider context of negotiations on the UK's future relationship with the EU. We submitted our report to the Science Minister in July 2019 and it was published by the Government later that year.

For several decades, the UK paid a subscription to the EU as part of our treaty commitment as a member state. That automatically conferred membership of the EU's research programmes and covered the cost of participation. Many of the choices and decisions associated with EU research and innovation were made in Brussels. Now that the UK has left the EU, any future financial contribution to EU programmes is in tension with other demands on public expenditure.

Historically, about 3% of total UK R&D investment came from the EU Framework programmes (Figure 1). That is a little less than the level in the EU as a whole. Given this small percentage, one might ask what all the fuss is about. However, that overall figure masks several specific funding patterns. In the Russell Group of universities, for example, over the past few years funding from European programmes has been over 10% of research income. In Wales, much of the R&D funding comes through EU structural investment funds. Some academic disciplines are more dependent on European funding than others – for archaeology and classics, over 30% of research income in the UK comes from the EU. Furthermore, participation in EU programmes bring intangible benefits such as access to people, networks and equipment that the financial picture alone does not reveal.

Of course, collaborations within EU programmes should be set in a global landscape. In 2017, over half the peer-reviewed publications by UK researchers had at least one non-UK co-author. The UK's top collaborative partner countries are largely unchanged over the last decade with the USA being by far the largest and five out of the top ten being outside the EU.

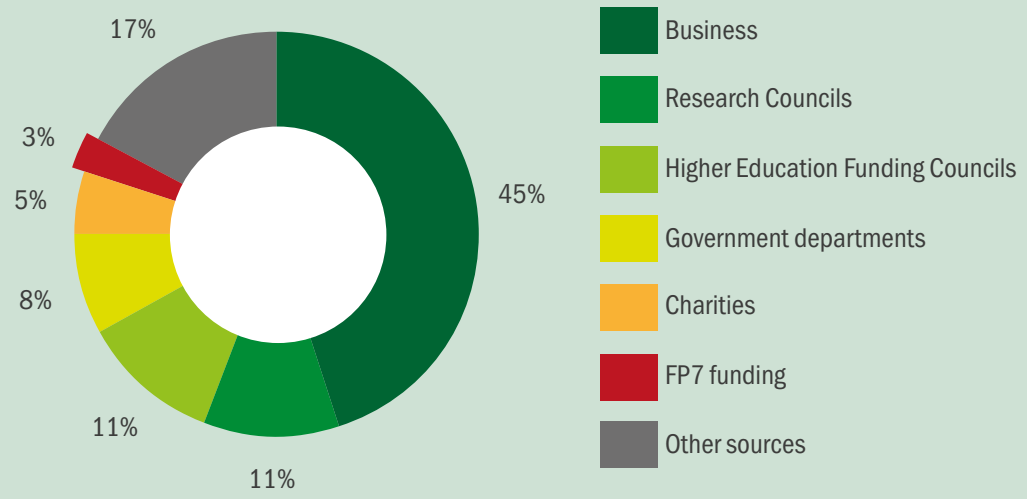
Businesses contribute around 65% of total R&D investment in the UK, similar to levels in the USA and Germany. However, around 50% of business R&D in this country comes from firms headquartered overseas – the highest level in the G7 group of nations (Figure 2). This foreign direct investment in UK R&D has increased by almost 70% over the last decade. Since 2007, investment by UK firms in R&D has hardly increased. Meanwhile, US and EU firms have increased their investments by significant amounts. But these changes are dwarfed by rises in R&D investment

Professor Sir Adrian Smith FRS is Director and Chief Executive of The Alan Turing Institute. He is also President-Elect of the Royal Society, a post he will take up in November 2020. His previous role was as Vice-Chancellor of the University of London. He was Director General, Knowledge and Innovation in BIS (now BEIS) between 2008-2012. He received a knighthood in the 2011 New Year Honours list.

Professor Graeme Reid FRSE is Chair of Science and Research Policy at University College London. He has spent much of his career at the interface between science and Government, having worked in the Business Department, the Cabinet Office and HM Treasury. Graeme was specialist advisor to the House of Lords Science and Technology Committee during their extensive inquiries into Brexit. He was a member of the Government's High Level Group on EU Exit, Universities, Research and Innovation.

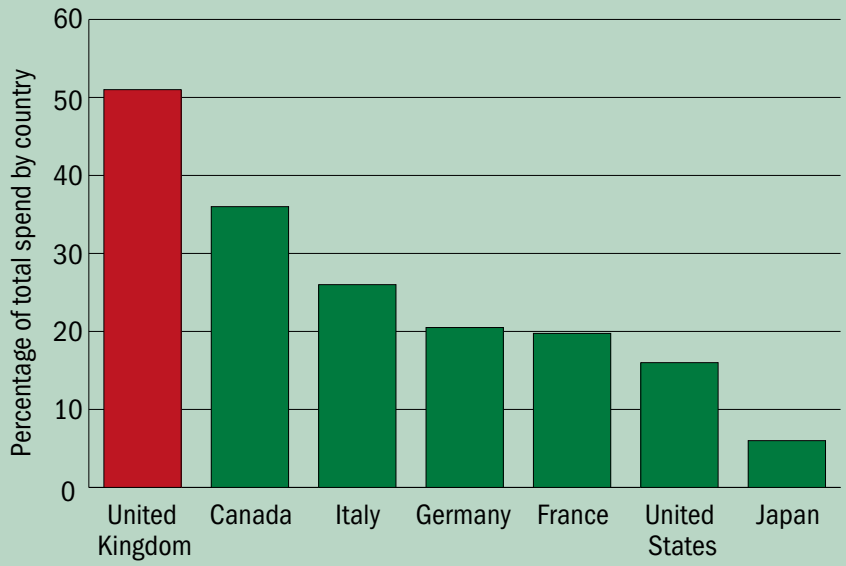
Data indicates the shape of R&D in this country and the wider international context in both the business and academic communities.

Figure 1. Sources of UK R&D funding (2007-13).



Source: The Royal Society

Figure 2. Percentages of R&D spend in the UK in 2015 by country.



Source: OECD, MSTI Database

into the UK from the rest of the world (Figure 3).

Those data indicate the shape of R&D in this country and the wider international context in both the business and academic communities.

UK research after leaving the EU

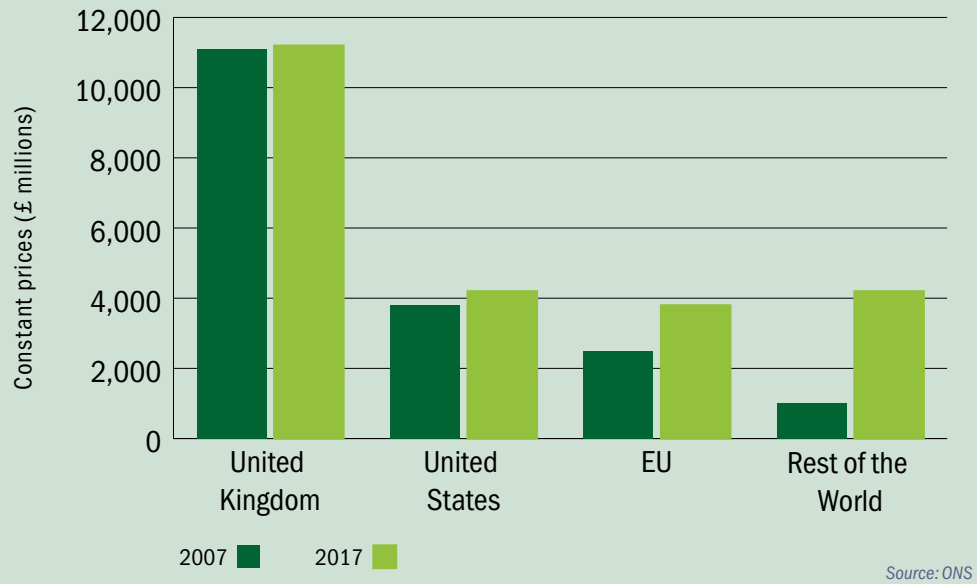
There is no point in deciding not to associate and then spending a sizeable sum of public money to disguise that decision.

If the UK Government decides not to associate with Horizon Europe because the terms of association do not provide sufficient benefit to the UK, then we are not convinced that a case can be made for replicating line-by-line EU research and innovation arrangements in the UK. There is no point in deciding not to associate and then spending a sizeable sum of public money to disguise that decision.

Instead, we recommended that the first priority should be to protect and stabilise the capabilities that have been acquired by this country over several decades of participation in EU programmes. Any temptation to seize exciting new international activities should be resisted until stabilisation is complete.

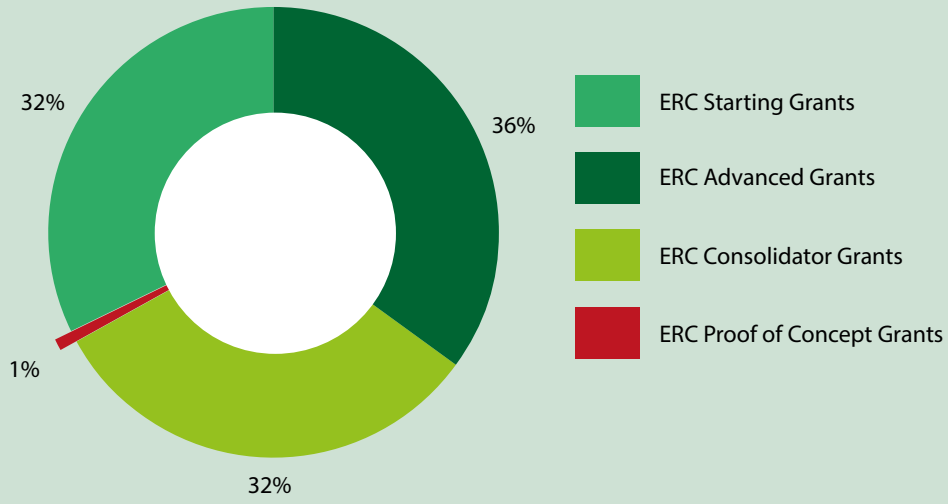
We then set out a framework for global collaboration. This framework provides an opportunity to pursue the 2.4% R&D agenda vigorously. In particular, we propose that the UK should aim to

Figure 3. Country of ownership of businesses performing R&D in the UK.



Source: ONS

Breakdown of European Research Council grants received by the UK 2015-2017.



Source: eCORDA, Royal Society

There is a clear mismatch between the amounts of money going into international collaboration and the visible level of activity.

attract even higher levels of business investment in R&D from around the world. To pursue this ambition, the report proposes a number of specific interventions.

This time of change provides an opportunity to address persistent disparities between different parts of the UK. Many governments have tried to address these but have never managed to overcome the economic and social differences between regions of this small island.

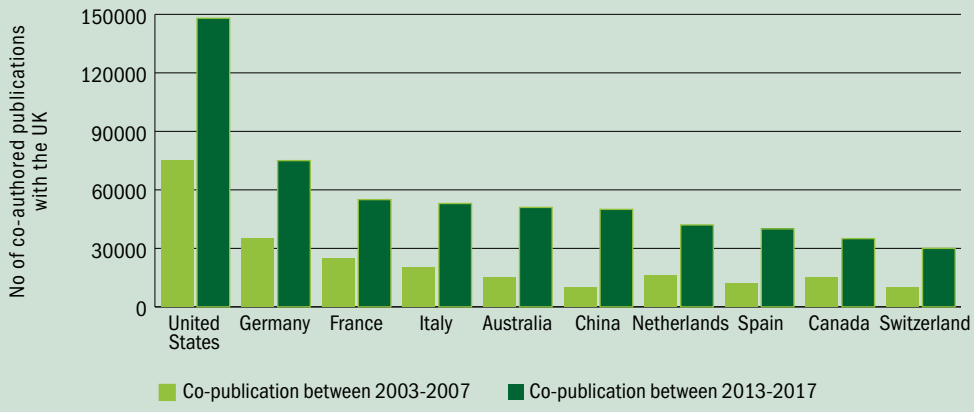
There is a clear mismatch between the amounts of money going into international collaboration and the visible level of activity. Far more research is being carried out internationally than can be accounted for by funding that is allocated explicitly to international programmes. This difference reveals, among other things, the scale of contribution that universities make to international activities, presumably from their QR block grants.

Unfortunately, these informal processes for supporting international work mean that money is often unavailable to seize opportunities that have been identified at political or scientific levels. The report recommends that there should be funding set aside for the express purpose of increasing the agility of the research base. This would allow

The first priority should be to protect and stabilise the capabilities that have been acquired by this country over several decades of participation in EU programmes.

The Smith-Reid report, *Changes and Choices,* **provides advice on frameworks for international collaborations should the UK not associate with Horizon Europe.**

Sources of UK R&D funding (2007-13).



Source: Elsevier Scival Database

researchers and politicians to grab fast-moving opportunities that will be lost if researchers must spend several months following the usual processes of grant applications and awards.

For far too long this country has had half an immigration policy. It has had a policy for regulating immigration into the country but the other half, attracting talent to the country, has been absent. The report recommends a Global Talent Strategy with a much closer alignment between immigration policy on the one hand and research and innovation policy on the other. We were pleased to see some of this thinking reflected in the recent announcement of the Government's Global Talent Visa.

The European Research Council

The European Research Council is an elegant design for research funding. The European Research Council is rightly held in high esteem. It is immensely popular in some parts of the community. Continued access will be more difficult without full association with Horizon Europe. Of course, it cannot be replicated outside the EU but the UK can learn from some of its strongest features – and optimise them around UK interests – given money, political will and patience.

The report recommends a 'Flagship Programme of Research Fellowships'. This proposal was arrived at by analysing the European Research Council machinery, taking those aspects that worked best and making each of them a little better!

The European Research Council is an elegant design for research funding. Continued access will be more difficult without full association.

Designing new funding arrangements is a complex process. We set out some core principles for funding international collaborations and then derive a number of options from them. Effective international collaboration in a post-Brexit world will require dedicated administrative machinery with a high level of expertise, not least working with immigration authorities, negotiating arrangements with funding agencies overseas, and agreeing access to international facilities. Options include the creation of a new international council within UKRI.

Unfinished business

There remain some items of unfinished business. First, how is the Government going to make decisions on our future participation in European programmes? What level of engagement will the research community have in these decisions? Will the evidence behind the decisions be made transparent?

The Treasury provided a funding guarantee in the event that the UK left the EU without a deal. As the UK has now left with a deal, the Treasury guarantee has lapsed. So where would money for a 'protect and stabilise' agenda come from?

Agility funding would have to be treated quite differently from the conventional protocols for awarding research grants. There would be public accountability, of course, but it would need a different governance model.

And finally, there are disciplines like archaeology and the classics, and there are regions of the UK, which all have an unusually high dependence on EU funding. What will the Government and UKRI do about these? There are domains within the research and innovation community that stand to lose not 3% of their research funding but something like 30%. Should they be given transitional support, or allowed to find their own place in the new world? □

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/844488/Changes_and_Choices.pdf

EU–UK academic collaboration – a European view

Günter Stock

SUMMARY

- Europe is taking on a leadership role in academic research
- The UK has particular strengths in collaborative research
- Continued freedom of movement needs to be taken seriously
- Action must be taken to bridge any gaps in the new relationship
- There are a number of bilateral and multinational options for ongoing engagement.

What impact will the UK's exit from the EU have strategically, but also at the level of projects, applications and people? To maintain its activity at the highest, strategic level is a genuine priority for the EU. A 2019 article in *Nature* entitled 'Europe, the Rule-Maker' argued that the growing European research agenda (through the Horizon programme, which is projected to spend €94 million over the coming years) has taken on a leadership role in global research.

This is true in terms of the contribution European scientists make, of the money being spent and in terms of the direction that European scientists and political agencies are giving to climate change, chemical regulation and data protection, for example.

While this has much to do with the European science agenda itself, it is also a result of the US administration's retreat from multilateral activity in these areas. Pascal Lamy, Chair of the High-Level Expert Group that evaluated the future of the framework programme in 2007 made clear that it was up to the EU to continuously invite the rest of the world to collaborate in research and innovation. Or as Carlos Moedas, the Former Commissioner for Research, put it: "To be open to the world is a wonderful mandate for the future in times of re-occurring nationalism and protectionism."

What a loss for the planning of new programmes, the research to be performed in new programmes and for the quality of what we are doing, if the UK absents itself from this activity. In continental Europe, we would feel the loss of the international networks that British scientists have, something European science does not have to the same degree. Our networks are there, of course, but not in the same way or with the historical dimension our British colleagues have through the Commonwealth.

I also feel that, especially in the field of 'big science', British scientists and British society have a greater appetite for risk. In the debate on stem cells, for example, British scientists took a more pragmatic approach, which in the end proved to be right. Think also of Louise Brown (the first child born through the use of IVF); think of Dolly the sheep.

The project level

Projects: Some 20% of Horizon 2020 projects and programmes are led by British scientists. In comparison, German scientists lead 11%. However, the number of applications to European programmes by British scientists has been decreasing since 2015 and there has also been a decrease in the money awarded to British scientists.

Collaborations: In 1998, 26% of all British published papers were the outcome of international collaboration. In 2008, just 10 years later, the figure had risen to 55% of all British publications. Germany is the prime European collaborator with British scientists.

People: Looking at the leading UK universities, such as Oxford and Cambridge, about 30% of the staff are non-British. Between 20-25% come from EU countries, but there is already an exodus – and some British scientists are seeking jobs on the continent as well.

If the UK is not to face a brain-drain in the years to come, it will need to attract and support new talent. Freedom of movement for scientists has to be taken very seriously. By the way, this is not a new challenge: as long ago as 1088, there was a Bologna declaration asking for free movement of scientists across Europe. What applies to scientists applies to students as well: the minimum requirement would be to continue the Erasmus programme. Students from continental Europe will lose access to British universities if steps are not taken.

Politicians should not underestimate the necessity to work in international teams, in

Professor Dr Dr hc Günter Stock is Chairman of the Einstein Foundation in Berlin. He served as President of the Berlin Brandenburg Academy of Sciences and Humanities from 2006 to 2015, and was President of the Union of the German Academies of Science and Humanities from 2008 to 2015. He was Vice-President and member of the Senate and Executive Committee of the Max Planck Society (MPG) until 2011 and Chair of the Jury of the Deutscher Zukunftspreis of the Federal President of Germany until 2012. He also served as President of the All European Academies (ALLEA) from 2012 to 2018 (Photo courtesy: Pablo Castagnola).

If the UK is not to face a brain-drain in the years to come, it will need to attract and support new talent.

However much is achieved through UK associate membership in future EU programmes, there will be a gap compared with today. What can be done to bridge that gap?

multi-disciplinary consortia, in order to address the great challenges ahead of us.

However much is achieved through UK associate membership in future EU programmes, there will be a gap compared with today. What can be done to bridge that gap?

Bilateral agreements between the UK and countries in Europe, like Germany, would be one option. Doctoral training programmes could be run between two universities – one in the UK, the other in Germany, for example. Graduate schools would be financed either by governments or perhaps by foundations.

The Einstein Foundation in Berlin has a programme of Visiting Fellows. So, a scientist who would like to work more closely with, say, a colleague from Cambridge, applies for extra funding from the Einstein Foundation. This allows the British academic to visit six times a year, using a laboratory in Berlin while there, and so facilitating a deeper, long-term relationship in science. Under the umbrella of this scholarship, students and post-docs can move backwards and forwards. It is a successful programme which could easily be replicated.

Joint colleges for advanced studies in particular disciplines would be another ideal instrument to maintain and deepen the relationships between continental Europe and British scientists.

We could also create more international research institutes, based in different countries of Europe. Different countries would contribute by becoming shareholders and by allowing scientists to work for a certain period in those labs.

As a German, I will end with a quote from Goethe: "Science and art belong to the whole world, and before them vanish the barriers of nationality." □

The value of international collaboration

Nancy Rothwell

Professor Dame Nancy Rothwell FRS is President and Vice-Chancellor of The University of Manchester. She joined the Victoria University of Manchester in 1987, became Professor of Physiology in 1994 and held an MRC Research Chair from 1998 to 2010. She was elected Fellow of the Royal Society in June 2004 and made Dame Commander of the Order of the British Empire in June 2005, in recognition of her services to science. She was the founding President of the Royal Society of Biology and has also served as a non-executive director of AstraZeneca. She is currently Co-chair of the Prime Minister's Council for Science and Technology.

An increasing proportion of our research – and not just science research – is international. Citations of outputs in almost every discipline are much higher with an international partner than if all the authors are UK-based.

It is important not to focus just on academic outputs: there has not been much debate about international collaboration within industries, between different industries and between academia and industry. The EU has been particularly successful in building partnerships between universities and industry.

Of course, much research is inherently international. To truly understand space weather, climate change or global disease, research has to be carried out by international teams and they have to be funded internationally.

There are also areas of research that the UK is very good at, but which are not just about the UK. A project in Manchester is bringing together engineers, social scientists, anthropologists, ecologists and geographers to look at the impact of dams in Africa, for example.

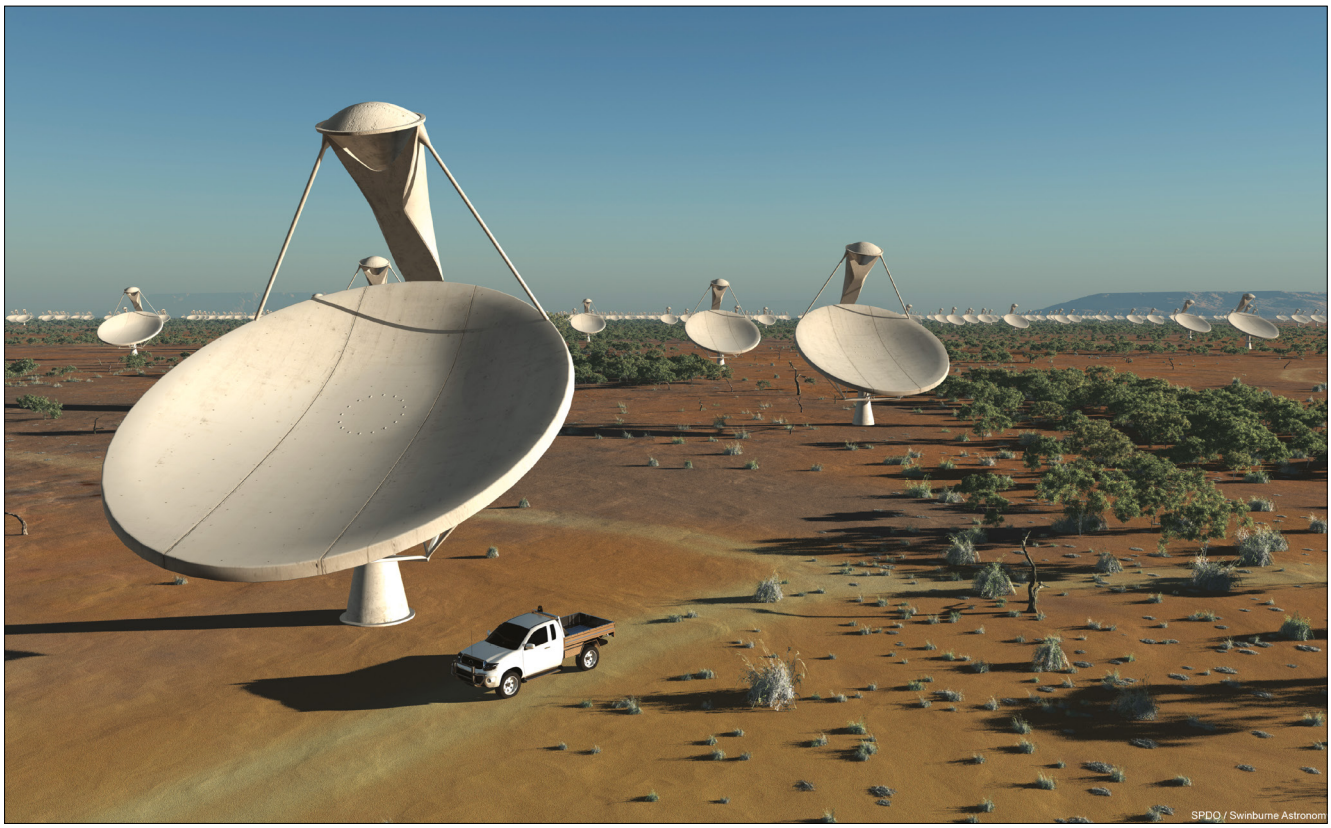
The really big international teams do tend to be in the sciences but we have to recognise the real importance of humanities and social sciences. The European Flagships are good examples.

SUMMARY

- Research is becoming increasingly international
- Some research cannot be successfully carried out on a national basis
- There is evidence that diverse teams achieve more
- International research projects can help to break down barriers
- There are new research opportunities in the wider world that the UK can grasp.

There is one focussing on Graphene which brings together numerous researchers and industries from across Europe into a big and long-term funding programme.

Another example involving big teams is clinical trials. The UK is not big enough to undertake all the clinical trials that we would wish to carry out – even those based on our own discoveries. This is particularly true with rare diseases. Why do these matter – after all, they are not common? All too often a rare disease will give us an insight into a common disease, so taking part in clinical trials is extremely important – and, of course, rare diseas-



Swinburne Astronomy Productions for SKA Project Development Office

es in total are a big problem.

Then of course there are the large-scale facilities, those things no country can really afford on its own. Some of these were established under international treaties and we will remain involved, such as the Large Hadron Collider and the Square Kilometre Array. The UK may have difficulty participating in some others, though.

Benefits of diversity

Many in the research community have benefitted from experience overseas as well as from having overseas visitors in their research groups. There is also a significant body of social science research which indicates that diversity *per se* has value: diverse teams often achieve much more.

Because research tends not to recognise political barriers, it can be a wonderful way to build bridges. The partners in the Sesame Synchrotron project in Jordan are Jordan, Bahrain, Egypt, Israel, the Palestinian Authority, Pakistan and Turkey. Where else would you imagine these countries coming together, collaboratively (with no knowledge or worry about their nationality or the political divide) to work on a single project? There are many more such examples of research spanning political divides.

There are three particular concerns I have about international research collaborations. I hope we can resolve them all. The first is the geopolitical aspect. Research collaboration must be built on trust but we are already seeing countries imposing restrictions and regulations on collaboration with certain other countries. That is something that is starting to impinge on international research.

Second – and hopefully a short term issue – is the spread of the coronavirus pandemic.

The final concern is that many researchers, and in particular young researchers, are increasingly unwilling to fly. This will become a major factor and we will have to find different ways of doing international research.

Looking further afield

Europe is an extremely important and physically close partner. Yet over the past year I have been to a number of countries, and the institutions I have visited have all suggested we look more closely at establishing partnerships with them. These countries included Canada, India, Hong Kong and Singapore. They are not suggesting the UK turn its back on Europe , but rather that we consider greater involvement with them as well.

Significant and perhaps painful change will happen, but there are also important new opportunities which we should not ignore. ❐

The UK will still participate in some large-scale facilities, such as the intergovernmental Square Kilometre Array project based in South Africa and Australia, but may have difficulty participating in some others.

Young researchers are increasingly unwilling to fly. This will become a major factor and we will have to find different ways of doing international research.

Full association with Horizon Europe is vital

Chris Skidmore

Chris Skidmore is MP for Kingswood. He was first elected in May 2010. He was Minister for Universities, Science, Research and Innovation jointly at the Department for Education and Department for Business, Energy and Industrial Strategy (BEIS) until February 2020. He has previously held posts as Minister of State at the Department for Health and Social Care, Parliamentary Secretary at the Cabinet Office and Parliamentary Private Secretary to the Chancellor of the Exchequer. He is a fellow of the Royal Historical Society and a fellow of the Society of Antiquaries.

SUMMARY

- International research offers huge opportunities to the UK
- Our research ecosystem depends upon international collaboration
- The UK's new relationship with the EU will be the most important determinant of the research landscape
- Full association in Horizon Europe is essential
- The public must be convinced of the value of close engagement in European research.

Change can be uncomfortable, unsettling. Yet embracing change and managing disruption is an essential part of our endeavour. Research and innovation by their very nature hold a looking glass to policy makers and governments, warning of the need for constant change if we are to adapt to the future.

When it comes to international research, there may be challenges but there are also huge opportunities for the UK over the next decade. Now is the moment to shape the change we want to see.

The global importance of the UK to the international research landscape is well known. With 0.9% of the world's population, we make up over 4% of its researchers, producing over 15% of the most highly-cited research papers. The UK's international research landscape has also been transformed in the past 10 years. Between 2007 and 2017, there was a 70% increase in foreign R&D investment in the UK, with a 22% increase in US expenditure, a 42% increase from the EU and 300% from other international countries. As a result, we have become the second most collaborative country among research-intensive nations, just behind France.

This success has been achieved by the careful creation of an international research community right here in the UK. Research is, and always will be, about people. One third of university staff are now from outside the UK, up from 28% in 2014-15. Over half of all UK peer-reviewed publications are co-authored by at least one international researcher.

Our research ecosystem depends upon our international collaborations, both here in the UK and across the world. Like innovation itself, these collaborations are complex, the product of decades of academic and business relationships layered upon each other: generations of effort have gone in to achieving them.

As Science Minister, I published not only the International Research and Innovation Strategy and commissioned the work that Sir Adrian Smith and Graeme Reid have undertaken, but also published the International Education Strategy. In announcing a £300 million initiative to double the number of maths PhDs over the next five years, I also lifted the 10% cap on international applications. I am very keen that a Research People Strategy will seek to develop the best working conditions for researchers in the UK, so that we can make the UK the most attractive place to come and achieve excellent research.

Visa reforms, including the Global Talent visa and the post-study work visa will play a part in attracting international researchers, just as further reforms will recognise mobility in producing research.

Our new partnership with the European Union will undeniably be the most important feature of the science and research landscape in the 2020s.

The future landscape

Our new partnership with the European Union will undeniably be the most important feature of the science and research landscape in the 2020s.

Encapsulated in the Withdrawal Agreement is, I believe, a common understanding among the UK and our European neighbours that we cannot risk breaking apart our European research partnerships. These are too precious, too valuable, too important. Research that is genuinely protecting and saving lives, and which is leading the fight against climate change, must not be gambled with.

The UK has been the second largest beneficiary of Horizon 2020, with 13,000 participations receiving nearly 14% of its total grants. Some 35% of the UK's total grants could not be accessed under third country status, which is why an association agreement is essential.

We must all continue to make the case to the public that this is of the utmost value to the taxpayer; that for every £1 spent on Horizon, the direct

and indirect economic benefits are multiplied. Our clinical trials in the NHS are reliant on continued collaboration in Horizon, with the UK having the third highest number of joint clinical trials with EU countries, and indeed the second highest for rare diseases and paediatrics.

This case must look forward to the opportunities it presents for this decade. Association agreements are readily possible, but we have an interest in agreeing an association as soon as possible. I believe that full association with Horizon Europe is essential.

So we need a campaign that will demonstrate to the public the true value of association with Horizon Europe, with universities, academies and, vitally, researchers themselves promoting the positive value of continuing European research partnerships. This campaign must also convince our European neighbours that, while we are no longer members of the EU, we place great importance on protecting our research partnerships. We must show them that this is at the core of our future relationship and our future priorities.

This is the year of decision, and it needs to be the correct decision, for the sake of British research and our international reputation. For too long, this has been a binary discussion between the UK Government and the European Commission. We need now to work together to highlight that it is in the British national interest to form an association agreement.

At the same time, we must also seek to extend our wider international partnerships and to create new opportunities as we seek to expand our global collaborations. One initiative must not exclude the other. We work and research under a single horizon: we have done so for decades, and we must do so in the decade to come. □

We need a campaign that will demonstrate to the public the true value of association with Horizon Europe.

The debate

Given that the detail of Horizon Europe could take until 2021 to emerge, a funding gap could yet emerge in the coming year even if the UK gains full association status. To align with the research grant cycle and Primary Investigators' pre-planning, decisions are needed urgently. However, a UK Government statement of intent to associate would go some way to smoothing planning.

There remain challenges in articulating the benefits of association, as the economic analysis struggles to reflect intangible benefits such as regulatory alignment. Judgements of this kind cannot be made on financial grounds alone.

Improved coordination across Government is needed to nurture global collaboration and present a coordinated front. The Government's administrative machinery should aim to coordinate several key interests; those of the Foreign and Commonwealth Office and the Department for International Trade in promoting the UK globally; the work of the Home Office in its responsibility for immigration; and the responsibility of the Department for Business, Energy and Industrial Strategy for setting the overarching science policy framework.

As well as funding research, it is important to consider continued support for innovation by SMEs that has been provided by the European Small and Medium Sized Enterprise Instrument. Many policy makers are unaware of the extent to which Innovate UK funding is combined with Horizon 2020 and other funds, in particular in the regions. Historically, the UK has focussed more on the research than on development. This balance should be redressed. Collaborative innovation with other countries is a way to leverage both trade deals and inward investment.

The importance of the Erasmus programme was highlighted: European students coming to British institutions bring enormous value to UK research. Yet, the UK receives many more Erasmus students than it sends internationally.

The coming year will be critical for the UK to protect and stabilise its present research capabilities, to prepare funding for Horizon Europe and, only then, on a firm base of strong international collaboration, to look with confidence to bold new projects. □

In the debate following the formal presentations, a number of topics were raised, including: forward planning; coordination across Government; and the Erasmus programme.

FURTHER INFORMATION

***Changes and Choices* – Advice of future frameworks for international collaboration on research and innovation, published November 2019, Report by Professor Sir Adrian Smith and Professor Graeme Reid.** https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/844488/Changes_and_Choices.pdf

The UK's approach to Negotiations with the EU, published February 2020 (Horizon Europe, Euratom, Copernicus and Erasmus mentioned page 23, paras 20-21). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/868874/The_Future_Relationship_with_the_EU.pdf

Electricity storage is important for a range of applications, from telecommunications, through electric vehicles to grid power management. Battery technologies are the subject of much research and development and were the subject of a meeting of the Foundation for Science and Technology on 16 October 2019.

Making better and better batteries

Clare Grey

Professor Clare Grey FRS is the Geoffrey Moorhouse-Gibson Professor of Chemistry at Cambridge University and a Fellow of Pembroke College Cambridge. She holds a Royal Society Professorship. Professor Grey is currently the director of the EPSRC Centre for Advanced Materials for Integrated Energy Systems (CAMIES) and is a member of the Expert Panel of the Faraday Institution. She is a foreign member of the American Academy of Arts & Sciences, and a Fellow of the Electrochemical Society and the International Society of Magnetic Resonance.

The energy density of lithium-ion batteries has increased due to new materials and better engineering, but the technology is approaching its theoretical limits.

Batteries are important for reducing carbon emissions and reducing pollution, but this must be done in a sustainable manner. While bodies like the Faraday Institution are focussing on the automotive sector, an even bigger challenge is to make an impact on grid storage, since with more and more renewables the grid becomes increasingly unstable.

While we do need to scale-up our current small batteries, simply making a fatter and thicker battery will not be successful because the ions cannot move fast enough to cover the longer distances they must travel.

The challenge is to make batteries cheaper, lasting for at least seven years in the case of electric vehicles and 20-40 years in the case of the grid. The automotive sector wants batteries that can respond very quickly (e.g. regenerative braking in a hybrid system) and achieve an energy density that suits all electric vehicles, while at the same time being cost-effective.

Theoretical limits

The lithium-ion battery was invented more than 25 years ago. Its energy density has increased due to new materials and better engineering. The price has consequently gone down by a factor of more than 10, but the technology is approaching its theoretical limits and new approaches are needed.

Why do batteries fail? The electrolyte is metastable, and when batteries are charged a passivating layer on the anode, in particular, is required to ensure stability. Heat a battery up by, for example, using a laptop on your lap, leaving your phone in the sun, or charging your EV battery too rapidly, and the materials will start to decompose – i.e. your battery will start to degrade.

Then there are cost considerations as well as issues concerning materials resources and capacity challenges. In a $LiCoO_2$ system, only 50-60% of the lithium can be extracted before it becomes too unstable causing degradation and safety issues. There is a lot of chemistry still to be done!

SUMMARY

- The challenge is to make batteries that are cheaper and last longer
- Understanding how batteries degrade may highlight ways to improve performance
- Big data and AI will help in the development of new technology
- To achieve a step change in technology, radical innovation is necessary
- A more comprehensive understanding – from the atomic level to full-scale – will open up new opportunities.

For electric vehicles, $LiCoO_2$ is expensive and there are a number of resource issues associated with the cobalt. $LiNiO_2$ is cheaper and allows high rates of charging but it too is unstable. To increase stability, aluminium (along with Co) has traditionally been added but that results in a decrease in capacity.

Using other materials such as lithium-nickel-manganese-cobalt-oxide batteries (NMCs) allows capacity to be increased, but again involves adding cobalt and thus more cost. Today there is a move to materials such as '811' (80% nickel, 10% cobalt and 10% manganese). While this is a good compromise in terms of cobalt use, it is more unstable because of the greater proportion of nickel. One current Faraday Institution project is concerned with understanding how these batteries degrade and then devising ways to mitigate that, enabling greater use of nickel and less of cobalt. Batteries that last longer are also, in the long term, cheaper.

Silicon can combine with more lithium ions per atom than carbon to give a higher energy density. The downside is that the material expands and contracts as the lithium ions go in and out. Battery materials that change size all the time are not ideal, although that itself is not the biggest

challenge – rather this expansion exposes fresh surfaces in this process which in turn react with the electrolyte. While car manufacturers are putting small amounts of silicon in the batteries, they are having to struggle with degradation issues.

Efforts to reduce cost include making cheaper materials and, for example, thicker electrodes. It may be possible to reduce the expense of the 'separators', i.e. the polymer films that physically separate the anode and cathode from each other and the packaging, but this all comes with a challenge. Moving ions through a thicker material takes longer which reduces the power of the system: one active area of research seeks to find ways to arrange the way the particles in a material are packed together to maximise porosity while also preserving energy density and so maximising vehicle range.

Importantly, we need to increase longevity, with reactions that do not cause degradation until year 7 or 10 of a battery designed for the grid. To do this in the timescales available to typical PhD students, we will increasingly use extremely accurate potentiostats to monitor the electrochemistry, coupled with big data and AI to help make predictions. And then, of course, this all has to be carried out in a sustainable way: battery production has an inherent carbon footprint, after all.

The production of lithium ion batteries has ramped up faster than most experts predicted. I personally think we have enough lithium in the world, that is not the challenge: sustainable mining and recycling are (in the end we need to reclaim the cobalt).

To achieve a step change, radical innovation is necessary – and that is needed now if 2050 targets are to be met. Could cheaper and more abundant materials be used for batteries? For the cathode, is it possible to move from lithium to materials made from sodium and then to magnesium? For the anode, are silicon and sulphur options? In principle, these offer higher energy density batteries. Sodium also allows manufacturers to move away from the use of copper as the current collector. However, sodium atoms are just that much bigger, so this metal brings a penalty in terms of energy density. Magnesium is a cheap element, but has a 2+ charge, which makes it difficult to move, difficult to pull out of solution.

The ultimate lithium battery will be lithium-air, in which oxygen is taken from the air. This would have the same theoretical and practical energy density as petrol (gasoline). However, the technology currently has many of the challenges of a fuel cell combined with many of the challenges of a battery. The lithium ions and the oxygen molecules have to react at an interface where the electrons are supplied to make a solid product that is then insulating. Remember, though, the issue is not just about removing the lithium ions from a material, when the battery is charged there has to be a way to get the electrons in and out, so if this material is an insulator, that becomes a challenge.

Solid-state batteries can be all ceramic or they can contain polymeric components, a sort of 'semi-solid-state'. One of the challenges with these systems is that if you have an all-ceramic system, in order for it to work the lithium ions have to move backwards and forwards between the cathode and anode, through a solid-state electrolyte (i.e. a solid with a crystal structure that allows the Li ions to move quickly in it). Each contact between ceramic particles has a 'grain boundary resistance', making it harder for the ions to move between the particles. As the Li ions are pulled out of one material and inserted into another, the particles expand and contract– and all of this has to happen and to work over many cycles without the particles and whole electrode structure cracking.

One avenue of research is examining redox flow batteries. This is a route that could represent the ultimate in battery technologies. The idea is to take a battery but not have all the oxidised/reduced materials in the same box or can, so to speak. The oxidised and reduced materials can be stored in separate tanks, and when you want electricity, you pump in the oxidised and reduced materials into the electrochemical cells and you get electrons out. Like a fuel cell, it must also be possible to operate reversibly, so we need to be able to reform the starting materials. It sounds amazing. However, there are challenges and currently these batteries are no cheaper than conventional lithium-ion technologies. But definitely an area to keep an eye on!

Looking forward

There is a need to understand better the way battery systems work: from the atomic level, to the electrode, the cell and then to the whole pack level. For example, nuclear magnetic resonance – the technique that my research group works on – permits us to look at the lithium ions to see what they get up to in-situ, while we cycle (charge and discharge) the battery. This provides unique insights into how things function, but also how they fail.

In the next five to 10 years, there will be new combinations of technologies and indeed new chemistries, coupled with increasingly responsive battery management systems. I would also hope that we will have enhanced sensors so that we can follow what is happening (and respond) in real time, in order to develop new strategies to mitigate battery degradation and keep those electric vehicles on the road for longer and longer times! □

We have enough lithium in the world, that is not the challenge: sustainable mining and recycling are (in the end we need to reclaim the cobalt).

To achieve a step change, radical innovation is necessary – and that is needed now if 2050 targets are to be met. Could cheaper and more abundant materials be used for batteries?

Building the industry of tomorrow

Ian Ellerington

Ian Ellerington is Head of Technology Transfer at the Faraday Institution. He joined after six years in central Government where he worked on designing and implementing innovation programmes in the energy sector. Ian is an engineer who graduated from University of Cambridge with an MEng in Manufacturing Engineering in 1993 and is now an experienced technical manager who has worked with small, medium and large corporates, academia and Government.

SUMMARY

- The automotive industry will not be able to meet future emissions requirements without switching to electric power
- Vehicles being designed today must be 'battery capable'
- Other sectors, from household appliances to the electricity grid, will all employ battery technology in the future
- The Faraday Institution is bringing together researchers, industry and the education sector
- Creating a battery industry in the UK will take at least a decade: it is a long-term project.

The Faraday Institution was set up as part of the Faraday Battery Challenge, one of the first wave of the Government's Industrial Strategy Challenge Fund projects. It has three elements, the first of which was the establishment of the Faraday Institution itself. Then there is the research and innovation programme to help small companies through collaborative research and development (run through Innovate UK). Finally, there is the UK Battery Industrialisation Centre, which includes elements of all of the technologies needed for a large-scale battery factory.

Together, that should be a compelling offer for anyone wanting to set up a battery industry in the UK. In addition, it will give us time to develop our own technologies to make the UK world-leading in this area.

The Foundation for Science and Technology held a meeting on batteries in 2009 – one of several where it has addressed this topic – when Professor Brian Collins, then Chief Scientific Adviser at the Department of Transport, and Neville Jackson of Ricardo, concluded that a mixture of technologies would need to be progressed because building an electric vehicle was likely to be too expensive for the foreseeable future. Costs would have to come down by a factor of about 10 to be competitive. It turns out they have now come down by about 90% (a factor of 10) and they are still coming down: they are expected to become even cheaper over the next few years.

Now, the UK has a large automotive industry which includes building engines. If the rest of the world is moving to electrification and batteries, this country needs to be there too. In fact, the automotive industry will have to change because future CO_2 emissions requirements cannot be met with any other technology. Vehicle life is around 15 years and it currently takes five years to design a new model, so vehicles that are still roadworthy in 20 years need to be designed with technologies which are available today.

If the rest of the world is moving to electrification and batteries, this country needs to be there too.

Thus, the next generation of vehicle has to be 'battery-capable'. If the UK is going to stay in the automotive industry, it must have access to batteries, which means a battery industry. We can either build them from scratch ourselves, or else attract overseas manufacturers into the country – or both.

It might seem surprising that electric vehicles can be cost-effective. Our research suggests that they will be cost-comparable with combustion-engine alternatives by 2025. Indeed, the European Battery Alliance predicts 2022! Even today, a BMW Mini has the same list price for petrol and battery versions.

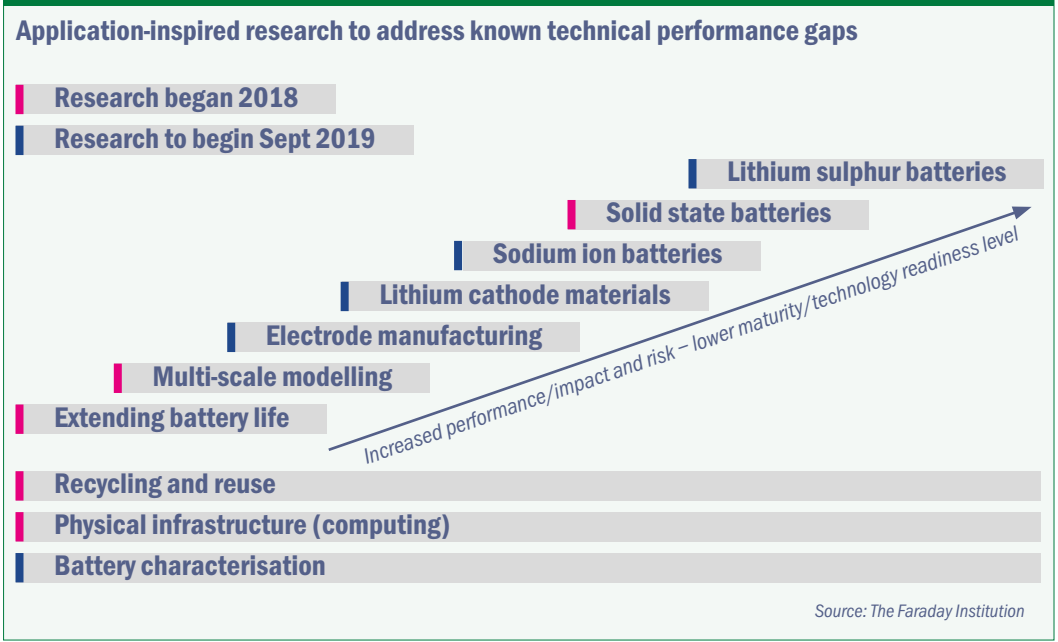
Batteries are not just important for the automotive sector. Dyson have stated they cannot envisage the next generation of vacuum cleaners with a cord, so I think we are going to see more and more items that move over to being cordless and running off batteries. Then of course there are opportunities for grid energy storage.

The research base

To build this industry securely, it is important to have a strong research base and that is where the Faraday Institution comes in. Our remit is 'application-inspired research', which is subtly different from typical Research Council work because we are not seeking pure knowledge in the hope of impact, we are seeking specific impact and creating a programme to deliver that.

Figure 1 illustrates a set of research programmes which we need to carry through. The first group is about understanding lithium-ion batteries. The next generation of vehicles is going to be designed with these because that is what is available now. Still using current technology, is there a smarter way to build batteries? Are there

Figure 1. Battery technology research programmes



different techniques to manufacture electrodes? Then what are the next-generation materials that can drive better performance, safety, energy-density and cost?

Looking to that next generation, sodium will be more readily available and cheaper than lithium while allowing other applications. It has to be recognised, though, that there is a debate about whether lower costs will really compensate for a potential drop in performance.

Some research is looking even further ahead, to solid-state batteries and lithium-sulphur batteries. These research projects are investigating the main challenges that are hindering commercialisation of these technologies.

Partnerships

We are working with 20 of the UK's best research teams across different universities and encouraging them to collaborate, pooling their combined knowledge to give the maximum opportunity for industrial success.

We have patent applications on battery recycling, on instrumentation techniques and one patent application for a new electrolyte material. All of these things have immediate application to some of the companies the Institution is working with.

As well as university partners, we have industrial partners – everything from small spin-outs to medium sized engineering companies like Williams and big motor manufacturers such as Nissan, Toyota and Jaguar Land Rover. Then there is the chemicals supply chain, which is one of the UK's strengths but is often forgotten. With these businesses, we are looking across our research programme and shaping some short-term focus projects to answer genuine problems or issues that they have.

Our entrepreneur fellowships are generating some really great ideas for the research programme. We are sponsoring individual researchers to investigate the feasibility of spin-out companies and helping to create them, by finding the right partners and investments in order for them to make maximum use of the research programme.

Now, the research and technical side is not sufficient to start an industry, so investment is also going into skills and education in order to deliver a pipeline from schools through to universities. That way, we will have the people we need to make it successful.

We are also looking at how the technologies that we are creating can be applied in other industries. We are researching insight reports on topics such as the size of the market for battery systems in emerging markets for micro-grids and using that as a springboard for some of the smaller companies to build systems.

The Faraday Programme is for the long term. To carry out the fundamental research, understand the opportunities, build the skills and build the industry itself, will require a decade at the minimum. UK researchers and innovators need this sustained opportunity in order to be successful and build an industry for tomorrow. □

We are working with 20 of the UK's best research teams across different universities and encouraging them to collaborate, pooling their combined knowledge to give the maximum opportunity for industrial success.

The research and technical side is not sufficient to start an industry, so investment is also going into skills and education to deliver a pipeline.

Scaling up new technologies

Christopher Lee

Dr Christopher Lee obtained his PhD at the University of Alberta in 2002 in Inorganic Chemistry, developing electrocatalysts for direct methanol fuel cells. He was a postdoctoral fellow at the University of Southampton (2002-2005) developing high-throughput methods for synthesis and screening of electrocatalysts for polymer electrolyte membrane fuel cells. He is currently a Technical Director at Ilika, responsible for the development of large format solid-state batteries. He is a member of The Electrochemical Society and of the American Chemical Society.

SUMMARY

- Ilika is developing the fundamental manufacturing processes for large format solid-state batteries
- Solid-state batteries are dense, compact energy stores made of solid materials
- Solid-state batteries are inherently safe and will not burn
- We want to take insights from micro-battery projects and apply them to larger formats
- A key challenge is to provide a transition between conventional lithium-ion battery manufacture and solid-state batteries.

Ilika started developing solid-state battery components and materials using its proprietary high-throughput platform in 2008. Over the past five years, that platform has been used to develop a production method for thin-film, solid-state batteries. These are very useful in biomedical devices and remote sensors, but they are too small to power a car.

So now we want to take that experience and build a solid-state battery, using production techniques that are more amenable to scale-up and that are more familiar to lithium-ion battery manufacturing.

Ilika has established a pre-pilot plant outside Southampton to develop the fundamental manufacturing processes for large format solid-state batteries. 'Large format' here means about the size of an A5 or an A6 piece of paper. Our objective is to become UK experts on manufacturing processes for solid-state batteries.

We think solid-state batteries have significant advantages. They are dense, compact energy stores, made only of solid materials. Essentially, these are the same as lithium-ion batteries but with the liquids and plastics taken out, and instead made with ceramic – something that is inherently safe and will not burn.

Range, safety, performance

The range, safety, efficiency and performance of a vehicle can all be increased because you can get up to 40% more energy into the same amount of mass, i.e. the amount of energy per unit of volume is higher, so cars can go further and weigh less, be more efficient and be more safe.

We see solid-state batteries as an enabling technology for the uptake of electric vehicles. The public have concerns about electric vehicles, in terms of range, safety, recharge time. Solid-state batteries do not contain flammable electrolytes, they are able to operate over a much wider temperature range and they are going to provide higher energy densities.

The technology is difficult. That is where the Government's support and academic expertise really come in.

However, we do not have them yet! The technology is difficult. That is where the Government's support and academic expertise really come in. The technical challenges involve understanding the characteristics of the materials. Do they have the right capacities? Do they have the right thermodynamic compatibilities? Do they have the right kinetics in terms of transporting lithium ions through the interfaces? If every battery has millions of grains of sand in it and lithium has to move from one grain to another, this is a torturous journey. In addition, when these substances expand and contract, stresses and strains build up. Above all, though, the batteries must not fall to pieces.

In particular, we are looking at making composite electrode structures that mitigate some of these effects. This is being taken forward within one large project, the Ilika Goliath Solid-state Battery programme which is supported partly by our commercial partners and partly by Government via the Faraday Battery Challenge. Our focus is to take formulations and chemistry that we have studied on the micro-battery scale and put them into larger format batteries.

Our Power Line project looks at aspects of power production and the materials supply chain, in the light of the chemistries that can be used to make solid electrolytes and necessary additives that are not readily available at large-scale. Standard cathodes, anodes, powders and the like are available, but not solid electrolytes yet. The focus of this project is for fast-charging and a user-friendly experience.

The Granite project is looking at the gap between solid-state battery manufacture and lithium-ion battery manufacture – and how to achieve a good transition between the two. Otherwise the industry will have to wait 10 years for existing lithium-ion facilities to expire. How can that transition be made as easy and straightforward as possible? ❐

Delivering maximum power with maximum energy

Rob Millar

SUMMARY

- Our goal is to create a battery with both high energy and very high power
- A hybrid module would be one way to achieve this
- Modelling helps in understanding cell performance
- Efficiency gains can be achieved through the use of innovative materials.

Williams is known to most people as a Formula One team. Less well-known is its technology commercialisation business. Williams F1 spends millions of pounds to send two cars around a track each year – we then apply the products of that investment across other industries.

In the high-performance hybrid and EV propulsion sector, our aim is to take a cell and turn it into a pack. So we look at the commercially-available cells, screen them to identify the best one for a given application and then seek to transform that into a module. A module is one of the sub-components of the pack and is the fundamental building block that every manufacturer uses. Then we have to transform multiple modules into a pack which can be used in different applications.

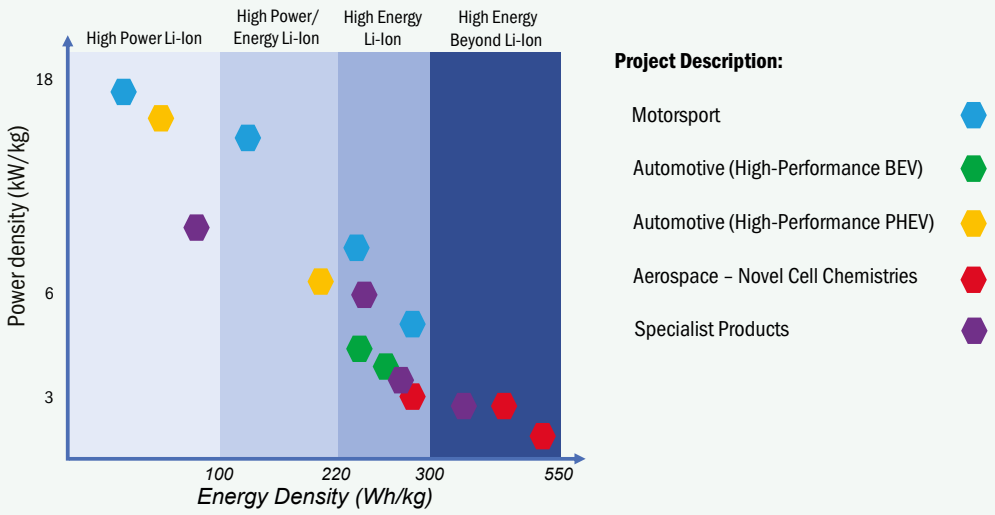
There are a huge number of different cells available today, each exhibiting specific characteristics in terms of power and energy. There are cells made specifically for motorsport, which are super-high in terms of the power capability (around 18kW/kg) but with very low energy density perhaps under 100Wh/kg. At the other end of the scale are high energy-capacity cells (around 280Wh/kg) which tend to have limited (less than 1kW/kg) power capability (see Figure 1).

Hybrid approach

The challenge is to create a battery with both very high energy and very high power. One possibility, which WAE has been pursuing, is a hybrid module. This uses two different types of cell – an energy cell and a power cell in combination, with a converter that shuttles power between the two. The concept is relatively simple but it has not been deliverable until fairly recently and even then

Rob Millar is the Head of Electrical at Williams Advanced Engineering (WAE), who provide world class technical innovation, engineering, testing, and manufacturing services to the motorsport, automotive, aerospace, defence and healthcare sectors. Rob became involved with vehicle electrification when in 2004 he founded his own company developing electronic systems for Modec, Tata and Daimler vehicles among others. He joined Williams in 2016 to head up the company's battery and electronics programmes.

Figure 1. Battery technologies.



Significant technology diversity within product portfolio

Source: Williams Advanced Engineering

The challenge is to create a battery with both very high energy and very high power.

Williams aims to create a battery with high power, high energy, and a high cell/module conversion ratio

only for quite specific applications. As higher capacity energy cells come to market, this kind of product will become much more feasible.

Another aspect concerns the algorithms we can apply in battery management. When I arrived at WAE, I inherited what looked like a totally crazy battery management system which had the highest-powered processor that I had ever seen in an automotive application. Yet we were making relatively little use of it.

We had the opportunity to work with people like Greg Offer at Imperial, taking the modelling capability that he was generating through the Faraday Institution and applying that to our management system – giving more power and more capability. Modelling cell performance closely helps us understand the cell's operating limits – and therefore the possibility to use more of the energy, do faster charging and generally, get better results.

The cutting edge

An important part of what we do relates to the a mechanical and thermal side of batteries, taking the available cells and combining them in the most efficient ways possible. Fundamentally, that is about taking the minimum number of ancillary materials that need to be added to the cells in order to create a module and then a pack. We achieve this through innovative techniques and new materials to deliver the most efficient module that we can from an energy and power-density perspective. This is at the cutting edge of battery development. ❐

The debate

In the debate following the presentations, participants raised points about recycling, decentralised electricity distribution, connection standards and the STEM talent pipeline.

Recycling is a major concern – this must be taken into account at design stage. Recycling facilities need to be created here in the UK if we are to avoid shipping material abroad. The recycling rate for traditional lead-acid batteries is around 99%, yet the figure for lithium-ion batteries is closer to 10%. The significant material challenges that still needed to be overcome with solid-state batteries and the challenges of scaling up the technology may mean that 2025 is too soon for them to be commercially viable.

Decentralised model

There is an urgent need to develop products that can be used by the national grid: these could make a more decentralised model of electricity distribution achievable. There may be some overlap with automotive use of batteries: consumers could use their car batteries to help power their homes while parked. An alternative strategy might favour having energy storage closer to the production of energy – this may be more feasible in the short term in terms of the costs of producing grid-scale storage. As there are likely to be a number of competing battery technologies, a universal connection standard will be necessary to ensure interoperability between different manufactures and technologies.

The USA is investing significant sums into research and there is more risk appetite there which allows for greater experimentation. The UK can also learn from other countries in the application of longer term investment. There is a need to expand and deepen the STEM talent pipeline for this new industry. The Faraday Institution has an important role in this area. ❐

FURTHER INFORMATION

Faraday Battery Challenge https://www.gov.uk/government/collections/faraday-battery-challenge-industrial-strategy-challenge-fund

Drone technology has come a long way in the past few years. But what more needs to be done – in technology and in regulation – to maximise its potential? This was the subject of a meeting of the Foundation for Science and Technology on 20 November 2019.

A technology with huge potential

Elaine Whyte

SUMMARY

- Drones could be worth £42 billion to the UK economy by 2030
- Societal acceptance is a key factor that is often overlooked
- Drones are used more and more in surveying and inspections
- Some form of traffic management for low-level airspace will be necessary
- To achieve widespread acceptance of this technology, there needs to be an expansion of regulation.

Drones are one more way to collect data and PwC is a company that works on data. We undertook an economic study in May 2018 and from that we predicted that by 2030 drones could be worth as much as £42 billion to the UK economy – that is nearly 2% of GDP, a substantial amount of money. However, in order to achieve that we believe there are three key areas that need to develop. We need to see: an expansion of regulation; an advance in technology; and, most importantly, societal acceptance.

Societal acceptance is a key factor that often gets overlooked. There is a regulator – the Civil Aviation Authority – and this helps to create the trust that is so necessary in order to develop this technology and use it across many commercial sectors.

Drones come in different shapes and sizes – and terminology. In the defence sector, these devices are called 'unmanned aerial vehicles' – something that transports a sensor of some description into a higher position than the eye can reach. That sensor is collecting data – it could be thermal-imaging data, it could be photographic data – indeed, many different types of sensors can be mounted on these devices. It collects the data which have to be sent back to a ground station where it can be analysed and interpreted. I will use the term 'drone' for the whole system.

The most mature industrial use of this technology is, I would suggest, in filming. In the *Blue Planet* TV series a couple of years ago, we were able to see creatures in their own environment, up-close, because the film crew had a drone. We, the viewers at home, gained insights we had not seen before.

That is, in its simplest form, the benefit of drones today – a different insight into something in our environment. And they can do this because they are quicker, cheaper and more accurate than existing methods.

Today, drones are being used more and more in surveying and inspection work. However, we are still a long way from a taxi service to hop from one urban city environment to another. Closer in time, they may soon be used as a delivery mechanism – Amazon predict this should be feasible within five years.

Social intrusion

At PwC we undertook a survey to see how ready people are to see drones flying around. They are quite noisy and there is a sense of intrusion when you see them. The results indicated that, when it comes to a 'risk-to-life' scenario such as a search-and-rescue situation, more than 80% of people are happy to see drones used. So there may be an increased uptake of this technology within the public services, including police and the fire-and-rescue services.

As a society, we do not yet seem ready for them to be used for packaged delivery. If, though, they could be used to deliver packaged medicines to somebody who is unable to go and collect their prescription, one can begin to see it as a technology that is being used for the good of society.

In 2018, a very complex series of experiments

Elaine Whyte is UK Drones Lead at PwC. A chartered engineer with 20 years of experience in the Royal Air Force, she has formed a drones specialist team. Elaine is advising clients on how to position and exploit this emerging technology to achieve a competitive advantage. Keen to develop drones as a 'Technology for Good', she aims to drive benefits for society and gain the support that is needed to put the UK at the leading edge of development.

If drones could be used to deliver packaged medicines one can begin to see it as a technology that is being used for the good of society.

Where drones are being used most effectively is by those with real, deep, sector knowledge who use them as one tool among the many they employ in their day-to-day work.

Shutterstock/Dmitry Kalinovsky

was conducted at Manchester Airport, which is a controlled airspace. In one of these, a drone was used to transport a commercial part from one side of the airport to the other. This sounds quite straightforward but the right controls have to be in place for it to happen safely. The benefit lies in being able to save an hour – the time needed to transport it by road around the site. Everyone benefits from reductions in aircraft delays in that kind of environment.

Network Rail has 12 or 13 trains that are sent out to inspect the tracks and predict where the next faults will be. They also have one manned helicopter that does the same. It is quite possible to foresee a future where a swarm of drones can go out to collect data and so prevent delays.

As a society, we can accept Network Rail using drones because they are being used in a controlled and benign environment. Equally, in the oil and gas sector, we do not see or hear them, so there is no intrusion from a privacy perspective.

Societal acceptance

When it comes to delivery, I think a lot needs to change to gain societal acceptance. Take regulation: at present the drone must be within visual line-of-sight of the operator. To fly beyond line-of-sight requires special authority from the CAA: for that the right safety case is needed. The regulator is there to protect the safety of the airspace – to protect our safety. From my background as a Safety and Airworthiness Engineer, that is the foremost consideration in the development of this technology.

Permission is only given in special cases. Yet for this technology to be used widely, some form of traffic management for lower parts of the airspace is needed. That is complicated: standards and regulations need to change and systems developed to support the new dispensation.

There are so many opportunities, in savings of time and energy as well as enhanced safety, through using drone technology rather than using traditional inspection methodologies (and our report predicted £16 billion of productivity savings). Yet to achieve these, we need to see the growth and expansion of regulation.

To successfully apply a drone technology in a particular sector, experience suggests that you need to have a familiarity with that sector first. Where I see drones being used most effectively in the surveying context is by people who were surveyors first and then picked up a drone and used it as a tool. While we are seeing more and more drone company start-ups, the real successes are being achieved by those with real, deep, sector knowledge who use drones as one more tool in addition to the other methods they employ in their day-to-day work. ❐

For this technology to be used widely, some form of traffic management for lower parts of the airspace is needed. Standards and regulations must change.

A means of exploring the most hazardous environments

Tom Scott

SUMMARY

- The nuclear site of Sellafield is an excellent place to demonstrate the benefits of drone technology for improving safety and reducing cost
- Drones and robots can repeat the same task exactly, time after time
- Drones can carry out inspections at height quickly, efficiently and at much lower cost than with human labour
- The ability to fly beyond line-of-sight will be increasingly important
- Drones are a great way to enthuse young people about science and engineering.

Drones represent, for the UK and globally, a huge economic opportunity. For the industries that I work in, there is an amazing opportunity for cost savings in inspection and surveying. As a nuclear materials specialist, drones and other types of robots allow me to collect sensory data from places that matter (invariably where there are radioactive hazards) and then to quantify that hazard and work out if the area is safe for a human being to enter. The drone can go into that location and I can stay at a safe distance!

Sellafield has a great deal of infrastructure on a very small area of land. It is high-risk infrastructure with very significant nuclear assets and nuclear materials. Much of its £2 billion annual running cost is dedicated to the safety measures that are needed to protect the people that work there. So what better place than Sellafield to demonstrate that drone technology can improve on safety and at the same time reduce costs?

I and my team were the first people to fly a drone on a UK nuclear site. We conducted 15 flights over a three-day period at Sellafield. We were given different parts of the site to try out the technology and we demonstrated, without any incidents, that we could not only record radiation data but we could give a pretty good indication as to what materials lay in which buildings.

Now, in the nuclear sector the potential value of developing robotic technologies is very significant, helping to deliver some of the cost savings that the industry has signed up to in its Sector Deal, notionally a 20% reduction in decommissioning costs by 2030. Robots remove the cost of placing a person in a dangerous environment and make the whole situation inherently safer. In addition, a robot is very good at repeating things again and again (and it does not need a break to eat or sleep), so productivity can go up.

A wide range of tasks

In fact, drones can be used to do a wide range of tasks. They can do roof inspections, for example: this may seem a simple operation but roof inspections are quite important. All in all, roof or building inspections have traditionally taken something like six months, with proper scaffolding and specially-trained operatives used to working at height. A drone on the other hand can complete the exercise in a morning, gathering the same quality of survey for a fraction of the cost and time.

Drones in an emergency response context are also potentially incredibly valuable. Put the kit in the back of a vehicle and it may be just a handful of minutes between parking that vehicle and having the drone in the air. It can be recording thermal imaging, radiation data, laser scanning; lots of different types of sensors recording different types of information and at very short notice. Many of these sensors can transfer data in real time, such that the operator or the ground crew has an amazing situational awareness, and that is really very important.

For radiological inspection, three things are very important. The first is repeatability: someone on the ground, asked to repeat a survey, will not walk exactly the same path they walked the first time. With a drone, though (and I have done this in Japan, many times on nuclear sites), just reload the previous mission specification and press 'go'. Within 1-2% positional error, the result is the same survey as last time. So you can compare apples with apples, as opposed to apples with pears.

Another reason for removing humans in radiation surveys is that a human is a walking bag of water. Now, water is really good at blocking radiation, so if there are different radiation sources, a human is going to block some of the radiation that would otherwise reach the detector, causing an

Professor Tom Scott is Royal Academy of Engineering Professor of Materials at the University of Bristol and Director of the South West Nuclear Hub. His research is based around ageing, corrosion and characterisation of radioactive materials in engineered and environmental systems. He is the academic lead for the Sellafield UK Centre of Expertise for Uranium and Reactive Metals. Work with Sellafield has resulted in the successful development and deployment of two novel radiation detection technologies in the past five years, including the Advanced Airborne Radiation Monitoring (AARM) system.

What better place than Sellafield to demonstrate that drone technology can improve on safety and at the same time reduce costs?

From our drone measurements we know that in the centre of the Red Forest near Chernobyl, a human might get a dose of radiation that could be lethal, even after just a couple of hours.

under-read. A drone is generally carbon fibre and aluminium which is very poor at blocking radiation. So there is much greater sensitivity and no human-induced error. In addition, humans do not have to enter a site of hazardous radiation.

To use the example of Chernobyl: in 1986, they did not have drone technology nor a means of real-time measurement and mapping of radiation. Instead, they used helicopters to fly from location to location and take point measurements and ground samples: they then interpolated the data to form a map which is very crude in terms of spatial resolution.

Today we can do it very differently. From our drone measurements we know that in the centre of the Red Forest near Chernobyl, a human might get a dose of radiation that could be lethal, even after just a handful of hours. So, drones can be used instead and, indeed, several types can be considered. A fixed wing machine can fly across large areas: if something of interest is indicated, a multi-rotor can go in flying lower and slower, covering a much smaller target area but providing a higher sensitivity and spatial resolution – the multi-rotors cannot fly as fast and or as long, so it is important to use the right tool for the right part of the job.

Looking forward

For the development of this technology, there will have to be a convergence between the technology itself, societal acceptance (people do not want to be overlooked by drones but they do want them to be used to save people's lives), and the evolution of regulation.

For many applications, a key factor is flying beyond line-of-sight. If the pilot cannot see a drone well enough to properly control it, then it should not be going that far in the first place. To fly beyond line of sight requires methods which allow the same degree of control, ensuring an awareness of potential nearby objects so that collisions can be avoided.

There will have to be a convergence between the technology itself, societal acceptance (people do not want to be overlooked by drones but they do want them to be used to save people's lives), and the evolution of regulation.

Some off-the-shelf drone systems have BVLOS (Beyond Visual Line Of Sight) technology built in. It is usually based on cameras or acoustic centres which are distributed around and underneath the machines so they can understand where they are relative to the ground and any nearby objects. They will also have built in software to automatically avoid objects that are in close proximity – it is very useful and still developing.

For flying around Chernobyl, because we were flying very close to the reactor building and the confinement structure, we had to calculate the kinetic energy each drone would have at full speed, to show that they would not damage the new safe confinement building in the case of impact. For every single flight, we had to phone into security before take-off, we had to phone the regulator as well, and as soon as we had landed we had to phone in again and let them know we had finished.

In late 2019, there was a breakthrough – the first BVLOS demonstration was carried out in Cumbria by Blue Bear (who work with the University of Bristol). However, while technically beyond the line of sight, there was still a safety pilot who was in line-of-sight and ready to take back control in case anything went wrong.

To realise the full value of drones, beyond-line-of-sight flying is needed. For that to happen, there must be, first, a proven detect-and-avoid system on board – and that must be approved specifically for the type of airspace, application and airframe. There is no point in having an avoidance system which is too heavy for the drone to carry!

The drone needs what the Civil Aviation Authority calls 'electronic conspicuity', essentially some kind of transponder device so that systems on the ground can understand where it is at any moment. That capability then offers the possibility of an air traffic management system.

Finally, the drone system must have very good communications with the people who are in charge of it, who are either operating or monitoring it. That could mean standard directional radio telemetry (standard radio control), but the development of 5G-enabled networks in all towns and cities across Britain could help unlock beyond-line-of-sight flying for activities such as deliveries. It is already possible to do this with satellites and satellite uplinks, but that is a relatively costly option.

I have two children who grew up with drones on the kitchen table and many kids receive small drones as presents today. I do a lot of outreach work with schools and drones are a great way to unlock a child's interest in engineering and science: it teaches everything from gravity to radiocommunication and batteries. Learning can be extended to understand different types of sensors that might go onto the drone and help understand global positioning. This is a really great way of enthusing children about science and engineering!

Drones represent a very significant opportunity for the UK. We are currently a world leader in this area and we should push to stay at the forefront of technology development. We do need to evolve regulation and legislation, but we need to do this sensibly with due consideration for the good and the bad. And we should not forget the benefits from young people having access to robot technologies: it is the engineers of tomorrow who will have to solve many of the environmental issues we have created for ourselves today. □

Getting the full picture

Pae Natwilai

SUMMARY

- Different data streams can now be overlaid and the results viewed in real-time
- Real-time mapping will allow dynamic adjustment of drone flights
- Multiple imaging and time-sequencing can be applied to inspections
- New technologies need to align to existing work patterns
- This type of technology can be used to both track and predict change.

I have a background in inspection and maintenance within the oil and gas industry. I would walk around sites, climbing stairs and taking photographs while carrying a hard drive full of different types of information (reports, x-rays, etc) all in order to understand the lifecycle of the structure. About five years ago, I realised I could replace my way of doing data capture by finding a way to control drones in the air.

But Trik, the company I founded, is not just about physically controlling drones: it is a suite of 3D analytic software for structural inspections. It enables data capture from drones and other devices followed by analysis and interpretation, mainly for survey and inspection situations.

In the past couple of years, the technology has been developing rapidly. Instead of collecting data, feeding it into a computer and waiting for the analysis to emerge after days or even weeks, cloud computing allows everything to be uploaded, processed at higher speeds and then streamed back down to the end-user.

Real-time streaming

It is now possible to have real-time streaming and, even from the other side of the world, see just what the drone is seeing. 3D modelling, 3D analytics, defect detection with machine learning, all can now be done in real time. Trik is a cloud-based platform where people feed data in from drones and are then able to analyse this for asset management or other data-analytic applications.

It can convert photographs from drones into a 3D model, but also combine this with other data types, so for example laser scans, photos taken with mobile phones, or a design drawing. Importantly, these multiple data sources can be overlaid on top of one another, because each type of information on its own is not as useful as when comparing it all together.

I expect that, in the near future, it will be possible to carry out real-time mapping while the drone is flying. The user will be able to see the 3D model being gradually generated, in real time, on their hand-held device. This is crucial because it will give a lot of flexibility. Seeing the result of the data analysis in real time allows the operator to vary the drone's flightpath to collect additional data to supplement those results as they appear.

One of the key problems I found when carrying out manual inspections was that when I had a set of photographs and I wanted to examine, say, one corner of a building, I would want to see all the photos of that aspect over the past 10 years. Yet that meant opening 20, 30, 40 folders and going through them one at a time (one large building may have 2,500 photos). However, all the close-up photos of the windows looked exactly the same, so it was almost impossible to tell where a particular photo came from. This is the common experience of people utilising this kind of data. So one of the features built into our system is the ability to click anywhere on the 3D image and see every single photograph, every single laser scan, every single piece of information for that point.

Reporting

Not only is it now possible to easily search through information, the same point can be examined through time (and projections made of the future as well). Yet it has been designed so that the analysis can be printed out on a typical 2D printer – no matter how fancy the technology is, users still want to print out a report and add a signature in order to get paid at the end of the day!

An important consideration for those of us who develop technology is to design it so that people do not need to change their working patterns immediately but can gradually adapt to new procedures over time. Keeping this in mind helps a lot of our clients to start utilising drones and 3D imaging technologies.

A drone can map a building, but equally it can map a whole town. Yet that generates a lot of data! We have a client who sends us 30TB of data on a

Pae Natwilai is an innovator and technologist in drone innovation and digital construction. As CEO and founder of Trik, she has developed and launched software that uses drone photography to create real-time 3D mapping of buildings and other architectural structures. The development of Trik began when Pae researched intuitive ways of controlling drones for her Master's project. She then struck on the business idea of using drones to inspect large structures, such as multi-storey buildings, bridges and oil rigs.

An important consideration for those of us who develop technology is to design it so that people do not need to change their working patterns immediately but can gradually adapt to new procedures over time.

With 5G arriving, many people are looking for a way to digitally map all their assets in order to optimise their equipment and roll-out.

survey. It is really difficult for a single computer to open the file, so we have to find a way to optimise it in order to dynamically see different resolutions on the go. In Google Maps, as you zoom in, more and more information is downloaded. Trik does something similar, but it also has to be enabled for all types of platform.

I come from Thailand, a developing country. I want to make something that people in my country can use without spending a fortune: the technology has to be optimised in order to create something that people can actually use.

We were recently awarded an Innovate UK grant from the Department for Transport to develop the system that people can access, not just through the web or a tablet, but also in a VR environment in real time. Right now, to stream the information through VR, it typically has to be downloaded first: so the data is never actually live.

By building in 3D AI functionality, defect detection and object recognition can also take place in real time, via live-feed video. People can use this to track progress and track change. So it can be linked to project management, to cost, or to any other forecast of resource. This kind of automated method will allow us to predict in the future where the project is going to be delayed and when that will happen – and offer the opportunity to prevent it.

This type of technology is not just relevant to buildings, but is being used in the rail industry, on bridge inspections, and more recently on power-transmission towers and mobile phone masts. With 5G arriving, many people – in the UK and abroad – are looking for a way to digitally map all their assets in order to optimise their equipment and roll-out. The opportunity for drone-based technology and digital data is massive, but we have to find ways to enable people to move easily from existing processes to these digital technologies. ❐

The debate

Discussion after the presentations included public acceptance, detection and countermeasures.

The public perception of drones is a major concern: the Gatwick incident of 2018, in particular, may have influenced public opinion of the technology. On the other hand, more positive news stories are appearing about drones and how they can benefit society.

Local authorities are becoming more accepting of drone technology. Furthermore, sales of recreational drones have increased in recent years, which may also be an indication of an increasingly positive public opinion of the technology.

The possibility of criminal uses of drone technology and the use of drone countermeasures was raised. A commonly cited example is the use of drones to deliver drugs into prisons. Yet, when a new technology emerges, there are always people who attempt to use it in a negative way. The first step to preventing a potential incident is to ensure drones can be tracked in the first place. This can be done using radio waves, radar or thermal imaging.

The development of countermeasures against drones has received funding in the past year. One of the most promising counter-drone technologies is a type of tight-band radio signal which disrupts the radio signal controlling the drone. However, this can only be used for radio-controlled drones.

Organisations should have risk assessments in place for drone incidents. A change in regulation to allow drones to fly beyond visual line of sight would be a key step forward, but advances in other technologies are also needed. For example, advances in battery technology and in sensor technology would make drones weigh less. Greater resilience to adverse weather would also increase the range of applications in which they can be deployed. ❐

FURTHER INFORMATION

Nesta: Flying high – shaping the future of drones in UK cities
https://media.nesta.org.uk/documents/Flying-High-full-report-and-appendices.pdf

Sellafield case study
www.gov.uk/government/case-studies/sellafield-remotely-operated-unmanned-aerial-vehicle-combined-with-radiation-mapping-software

Disruptive Change in Unmanned Aerial Systems, Nuclear Facilities, and Radiological Protection: A Review of US and French Developments
www.bnl.gov/isd/documents/94219.pdf

Trik http://gettrik.com

PwC: Skies without limits – the impact of drones on the UK economy
www.pwc.co.uk/issues/intelligent-digital/the-impact-of-drones-on-the-uk-economy.html

What are the best ways to use the data brought together by the NHS and how can value be extracted without compromising the rights of patients and the public? That was the subject under discussion at a meeting of the Foundation for Science and Technology held on 4 December 2019.

Making best use of NHS data

Saira Ghafur

SUMMARY

- Proper use of NHS data could have a significant effect on the quality of care
- A clear framework covering privacy, ethics and security is needed
- Gaining an appropriate financial return for the use of data depends on understanding its real worth
- Much of the NHS's data is fragmented, although it could possibly be linked together
- For the public to trust the NHS, it must operate transparently and respect people's privacy.

This meeting took place before the onset of the Covid-19 pandemic. There will be an update on this topic in the next issue of *FST Journal*.

The NHS in England collects a huge amount of data year-in, year-out. It holds one of the most comprehensive longitudinal patient datasets in the world. Properly utilised and connected, this data could have a significant effect on the quality and sustainability of care.

However, the NHS does not currently have the resources and skills to capture the full value of its data. It is investing significantly in strengthening its own capabilities, such as the NHS Digital Academy, while it is also relying increasingly on partnerships with industry to extract utility from its datasets.

Policy framework

For these efforts to be successful and acceptable to the public, they need to be governed by a clear framework that robustly addresses questions of privacy, ethics and security. The policy framework in the UK has been developing rapidly over the past year or so, and this includes the publication of the Code of Conduct for Data-Driven Health and Technology, the proposed launch of the Centre of Expertise by the Office of Life Sciences and also the creation of NHSX in July 2019.

Data science and opportunities in healthcare can pose pressing issues of equity, responsibility and human rights. The UK Data Service has outlined a set of ethical issues that are intrinsic to data sharing. These include privacy, informed consent, de-identification of data, inequality and research integrity. All of these issues are inter-connected and addressing each will help mitigate the others. Things like the *Data Protection Act* 2018, the *Human Rights Act* of 1998 and frameworks such as OECD Recommendation of the Council on AI are all there to protect personal data.

It is also important to think about the financial value of data-sharing. Although patient benefit is the key priority for the NHS and the main reason to share data with partners, this is not the only type of return that the NHS can gain. NHS data, like all public sector knowledge and assets, can also deliver a financial return, providing money for the taxpayer. There is a significant risk of negative public reaction if this is not taken into account; for example, if NHS data contributed to the production of a new digital technology and the NHS were not fully compensated or sufficiently recognised for its input. This can, in turn, undermine the public's trust in data-sharing.

Yet, gaining an appropriate financial return relies on an accurate valuation of the worth of the data. Unfortunately, it is very difficult to calculate this, which is a common problem for intangible assets such as data and information. Methods do exist which are used in other sectors, but they are not easy to apply to the NHS context. However, the UK Treasury has provided a useful reference point: they estimated the value of public sector assets at approximately £150 billion with a potential return of at least £5 billion per annum.

The first step in estimating the value of NHS data would be to calculate the total annual cost of creating, collecting, curating, maintaining and linking all of these systems that are related to the management of data. This is across a continuum, and this is from frontline data collection to the storage and linking of it at national level. This can amount to many millions of pounds per year and

Dr Saira Ghafur is the lead for digital health at the Institute of Global Health Innovation (IGHI), Imperial College. She also practises as a consultant in Respiratory Medicine at St Mary's Hospital, London. Dr Ghafur is leading the work on the value of the NHS data asset at IGHI. This involves working with partners from academia, governments, NHS and industry. Other programmes of work she leads include: cyber security for healthcare, AI and machine learning in low and middle income countries and a simulation-based testbed for digital health products.

Gaining an appropriate financial return relies on an accurate valuation of the worth of the data.

The number of people willing to share data with doctors remains high even though sharing with technology companies has very low approval.

one of the biggest costs is human capital – something that is largely unaccounted for. As an example, clinicians and other healthcare staff enter data directly into NHS healthcare records. While primarily for direct clinical care, this forms the basis of the datasets, so if this is not accounted for in the creation of the datasets then some of the value is missing.

Improving the data

Health and social care systems are, in the UK, moving towards electronic records, although there needs to be much more capital investment in both IT hardware and software to ensure machine-readable data is collected at source.

Systems and infrastructures have evolved across the NHS to varying degrees. There is a wide spectrum of data quality, of IT investment, timeliness of data, interoperability of data – and many different systems exist. Much of this NHS data is fragmented, although there is a possibility that it can be linked.

Then there is the issue of sharing data between the NHS and commercial partners. Several value-sharing mechanisms are available to the NHS; the right one will depend on the specific circumstances of any partnership. It is, however, critical that all relevant stakeholders and decision-makers in the NHS are aware of what those options are. For example, the NHS could be given free or discounted access to the products created from the data. In Moorfields' partnership with Deep Minds on retinal imaging, Moorfields has access to the clean data repository and has free access to the product for five years. However, there are questions about how equitable this may be for the rest of the NHS which has to pay for this product.

Other examples include receiving a one-off payment in exchange for data access, or a series of one-off payments based on regulatory or commercial milestones. Other options include royalty payments, a share of the resulting products, a share of the profits of the company commercialising the data or even a share in the equity of the company commercialising the data.

Who should receive the benefits of the data? Is it the individual NHS organisation which has actually collected and curated the data? Is it the NHS as a whole or should it be a separate body that has been set up by the NHS?

However, across the NHS generally, there are not enough people who would know which deal would be the most appropriate for any partnership. Selecting the most suitable option (or combination of options) will depend on a number of factors including: the quality of the data; the type of end product; the extent of the reliance on NHS data; the NHS's inventive contribution to the partnership; as well as the work and cost that the commercial partner has to invest to make the data useful (remember, we are not collecting machine-readable data at source, at present).

Several factors may limit NHS access to the most desirable options, for example, the quality of the data or the contribution of the NHS beyond the sharing of the data. Where the NHS contribution justifies it, a combination of sharing mechanisms is probably the most appropriate choice. This will ensure that the NHS receives both a certain return but also a share in the potential future market as well.

Sharing value

Who should receive the benefits of the data? Is it the individual NHS organisation which has actually collected and curated the data? Is it the NHS as a whole or should it be a separate body that has been set up by the NHS (the idea of a Sovereign Health Fund has been proposed and discussed in Parliament)? At the same time, it is vital not to create more inequalities.

Policy development in this area has the aim of ensuring that the NHS captures fair financial value from its data. Decision-support tools are being introduced for NHS organisations entering into these data-sharing partnerships.

Public support

Since the 2017 WannaCry cyber attack on the NHS and then the 2018 Facebook/Cambridge Analytica data scandal, the proportion of the public in favour of data-sharing with technology companies for research purposes has dropped. However, the number of people willing to share data with their healthcare providers, their doctors, remains high, even though sharing with technology companies, whether for health or commercial purposes, has very low approval ratings. In fact, people trust pharmaceutical companies more than technology companies.

For the public to trust the NHS, it must operate transparently. It must respect patients' privacy and comply with all data protection laws. This is an issue that will become more complex. As an example, a recent partnership was announced in the USA between Google and Ascension Health which involved the transfer of 50 million patient records – apparently without patient consent. This raises many ethical and regulatory questions.

Here in the UK, the NHS must prioritise the interests of patients and ensure, when sharing data, that we remain ever-mindful of ensuring privacy, ethics and security. ❑

Bringing all the data together

Caroline Cake

SUMMARY

- Accessing the breadth of health data for research and innovation can be very difficult
- Members of the public recognise the benefits of health data being used
- HDR UK has national research priorities, hubs and training in 31 locations across the UK
- The Health Data Research Alliance brings together the custodians of different health datasets
- The Innovation Gateway provides a single point of access to over 400 different health datasets for research and innovation.

Health Data Research UK was launched in 2018 and is the National Institute for health data science. It is developing partnerships across NHS, industry, academia and patients, and aims to provide safe and secure access to healthcare data. Funding comes from a range of organisations across the four home nations.

Our physical base is at the Wellcome Trust in London but we are, in fact, federated across the UK and HDR UK draws together a range of institutions and universities across the four countries.

We lead a four-year project within the Industrial Strategy called the Digital Innovation Hubs Programme. Over the past year, we have been talking to thousands of people in order to understand what people really want from health data research. A range of messages and concerns were expressed. The UK health service has fantastic data resources, but it is difficult to determine what exactly exists – there is a very fragmented landscape. Regardless of what is actually there, accessing it is hugely challenging. As a result, innovation and research is taking place outside the UK which could be carried out here.

One clear finding was that members of the public do see the value and benefit of health data being used, provided they know how it is being used and they can understand how it benefits the NHS.

We are working on a number of key features that people have said they want from health data. Researchers and innovators want longitudinal data, i.e. data over time. They also want multi-modal data covering different subjects and themes. However, this needs to be easy to access and use. It is no good for a researcher if data is not made available for many months after a request is made and then it is of insufficient quality to be of use.

One of the very first steps HDR UK took was to establish a public advisory panel: it demonstrates our emphasis on building real trust with our stakeholders. Yet it is only a starting point: our actions need to be driven by an understanding of how the public sees these issues.

Investing in science

We have identified six national priority areas where we believe we can demonstrate the value and benefit of doing large-scale health data research:

- Human phenome project
- Applied analytics
- Understanding the causes of disease
- Better, faster and more efficient clinical trials
- Improving public health
- Better care

The aim is to build a picture of the UK population over time, understanding the different factors that affect people's lives and coming to a more comprehensive understanding.

We are working with a wide range of organisations right across the UK, across many different universities but clustered around 31 locations, each of which has close working links with the NHS in its area.

We want to engage young people in what we are doing as well, creating career paths that they can tap into from an early age: in academic environments or the NHS, or industry. This is, after all, a new profession and we will need thousands of experts in this field.

We will create an infrastructure to bring together the disparate parts of this field in order that it can deliver advances that improve people's lives. One of the first initiatives is the establishment of the Health Data Research Alliance that brings together the different custodians of health data custodians.

Caroline Cake is Chief Operating Officer and Deputy Director, Health Data Research UK (HDR UK). She leads the strategic implementation and operational delivery of HDR's priorities. She coordinates collaboration between Government, the NHS, academia and industries across the UK. With more than 20 years of experience working in commercial organisations, Caroline joined Health Data Research UK from 2020 Delivery where she advised health organisations, universities and central Government departments on strategy, transformation, capability building, and delivery planning.

The UK health service has fantastic data resources, but it is difficult to determine what exactly exists – there is a very fragmented landscape.

The Health Data Research Innovation Gateway provides a common portal to UK health research data for accredited researchers and innovators.

The Alliance was established in 2019. It has nearly 30 members including national health bodies, individual NHS trusts, charities and research organisations. We want to build an alignment around data standards and quality. That allows members to make linkages between their different datasets and environments.

Then there are the health data research hubs. These will take the data that exists in fragmented environments and draw that together, curating, improving and enhancing it – providing value-added services around items such as clinical trials or evidence in the wider world.

A competition was launched as part of the Industrial Strategy in 2019. Over 160 organisations applied in different consortia, with different institutions working together to deliver a common goal. The seven initial hubs focus on a range of areas – some on diseases, respiratory health, cancer, eye disease and others on clinical trials and 'real world evidence'.

The final piece of the jigsaw is the Health Data Research Innovation Gateway (the Gateway). One of the real challenges is not knowing the breadth or depth of existing data sources. The Gateway provides a common portal to UK health research data for accredited researchers and innovators. This will be developed in two phases: phase one is focussed on 'minimum viable product'. The second phase will involve the creation of a technology partnership. □

Data as a means of enhancing public benefit

Natalie Banner

Dr Natalie Banner leads Understanding Patient Data (UPD), an independent initiative hosted at The Wellcome Trust in London. UPD works with patients, charities, researchers and health professionals to champion responsible uses of data, feeding into policy development, creating accessible resources and horizon scanning for emerging issues that may affect public confidence in the use of health data. Natalie formerly led Wellcome's policy work on GDPR and data protection, seeking to ensure UK legislation and regulation creates a supportive environment for health research using patient and health-related data.

SUMMARY

- There are many ways of assessing value
- Fundamentally, value is linked to the uses to which data is put
- The public want to see data used for public benefit
- There is a need for greater diversity in determining what constitutes public benefit
- The effective use of data is one tool in solving health challenges, not an end in itself.

The value of health data is more than just financial. It includes social, personal, and psychological benefits, both for individuals and communities, but also more abstract concepts – could better use of data increase dignity and care, for instance? Could it empower individuals to take more control of their own healthcare and their own conditions? Could more effective use of NHS data give clinicians more time for their patients, rather than for admin?

Yet value also has negative connotations. There are risks – potential harms – not least in relation to things like privacy breaches and misuse, but also through poorly-designed tools and algorithms. People can be excluded from data, or inappropriately targeted. Inaccuracies can lead to the development of guidance or guidelines that create issues for safety and so on.

Value has, therefore, both positive and negative aspects, but the notion of 'value' is fundamentally linked to the uses to which the data is put: we have to understand value as going beyond financial value alone.

Citizens' juries

So what are the purposes that patients and the public think matter? Importantly, people care about things that go beyond questions of privacy and data protection. A series of citizens' juries that UPD ran in conjunction with the Office for Life Sciences and NHS England explored this by asking what constitutes a 'fair partnership' when it comes to the use of NHS data.

These citizens' juries lasted 2.5 days each: they provided a comprehensive process to explore issues with members of the public, from a diversity of backgrounds and holding a range of views – some were positive about the potential for data use while others were sceptical. They were asked what a fair exchange of value would look like if NHS organisations allow commercial organisations, academics or charities access to the data

they hold. What should the NHS and patients get back for allowing access to data from patients or from hospital administration?

Unsurprisingly, the primary conclusion was the need for 'public benefit'. There has to be benefit for the NHS and patients, but that does not automatically exclude benefits to the other partners. Even if their data have been anonymised, people still care what happens to it. There is a strong, underlying wish to ensure benefits come back to patients and the NHS. This benefit should also be fairly distributed across the health and care system, and participants raised concerns that data could exacerbate health inequalities if only used to benefit some areas of communities and not others.

But who decides what counts as public benefit? Power and influence tend to accrue to those who already have power, which means that there is not the diversity of perspectives and views needed to question and challenge received notions of public benefit. What benefits some people may well disadvantage others. UPD is therefore particularly focussed on engagement with a wide range of audiences when it comes to the use of health data.

Promises

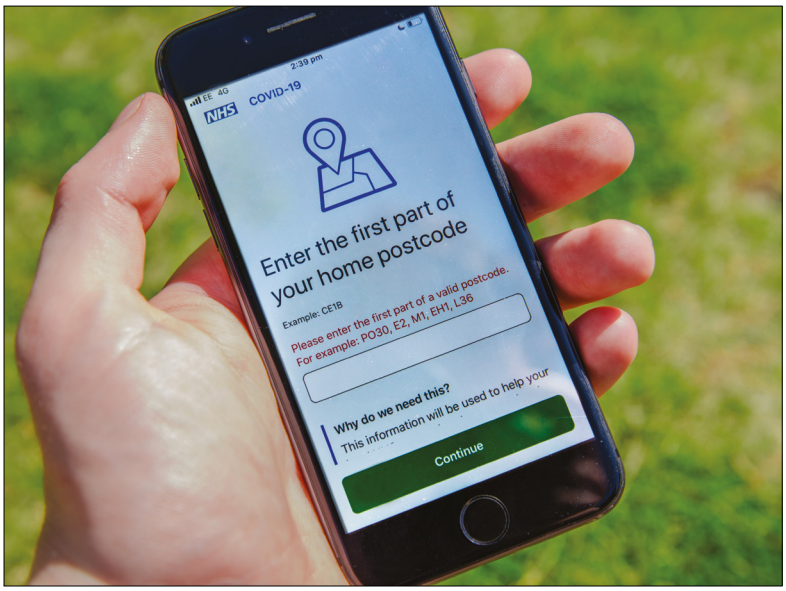
Public benefit must mean better outcomes for patients – but, interestingly, there was scepticism about the promises being made. Artificial Intelligence in particular has been heavily promoted as 'a revolution in healthcare' – but a somewhat sceptical public is yet to be convinced that benefits really are going to accrue. As research outcomes are intrinsically unpredictable, over-promising on benefits and outcomes can also be counter-productive.

Uses of data can create an illusion of objectivity when algorithms are developed or analyses performed. However, there are many assumptions, values and perspectives that go into the collection of data that are often invisible. It is only when the result is undesirable that questions are asked about how the decision was reached and whether there might be biases in the system. Take, for example, the recent furore over a credit card that appeared to discriminate against women applicants. It is worth noting that many women, as well as people of colour, have highlighted these kinds of risks before, repeatedly, but they have not been heard or their concerns highlighted.

Of course, the way questions are framed really matters. If we start with the idea that data is king, the data becomes key. Instead, we need to reframe the debate in terms of the challenges in our healthcare system that could be addressed or mitigated through the use of data.

If we start with the challenge or problem we are trying to address, the assumptions and value judgements that are informing decision-making and thinking are more likely to become apparent. Reframed in those terms, the real value of data can be seen: it is one more tool, a means to an end, not the end itself.

With greater clarity about the ends to be achieved, we will be in a much better position to work out where and how to use data … in a way that is ambitious, realistic and fundamentally trustworthy. □



Shutterstock/Ben Thornley

If we start with the idea that data is king, the data becomes key. Instead, we need to reframe the debate in terms of the challenges in our healthcare system that could be addressed through the use of data.

FURTHER INFORMATION

Department for Digital, Culture, Media and Sport Guidance: Data Ethics Framework www.gov.uk/government/publications/data-ethics-framework

Department of Health and Social Care Guidance: Code of conduct for data-driven health and care technology www.gov.uk/government/publications/code-of-conduct-for-data-driven-health-and-care-technology

Department of Health and Social Care Guidance: Creating the right framework to realise the benefits of health data www.gov.uk/government/publications/creating-the-right-framework-to-realise-the-benefits-of-health-data

Ghafur S *et al* (2020) NHS Data: Maximising its impact on the health and wealth of the United Kingdom https://spiral.imperial.ac.uk/handle/10044/1/76409

Health Data Research UK www.hdruk.ac.uk

Institute of Global Health Innovation
www.imperial.ac.uk/global-health-innovation

NHS Digital Transformation
www.longtermplan.nhs.uk/areas-of-work/digital-transformation

Working together to extract value from data

Nicole Mather

Dr Nicole Mather leads IBM's Life Sciences business in the UK, bringing together technology and digital capabilities to enable the transformation of the health and life sciences industries. IBM is engaged in health data programmes in the UK including 'DigiTrials', the Discover Now Real World Evidence Centre, and is working with HDR-UK to develop the Gateway portal to UK Health Data for Research. Nicole led for UK government on the development of the first Life Sciences Sector Deal, focusing on the creation of new UK industries in the UK such as genomics, digital health and early diagnosis.

SUMMARY

- NHS data is distributed over many different data sources
- Better use of datasets can help to identify which patients are suitable for which trials
- There are a range of different models for sharing – and gaining value from – NHS datasets
- 'Fair share' is a guiding principle for commercial agreements involved NHS data
- Much of the initial effort in a project has to be directed to making the data usable.

The Life Sciences Industrial Strategy and Sector Deal set out to grow new subsectors in the UK which could take advantage of our strong bioscience base, bring investment to this country, and generate benefit for UK patients. Initiatives included:

- genomics: extending the 100,000 genome programme to five million participants, delivering benefits to the NHS and enabling further research in the UK;
- early diagnosis: creating an 'accelerated detection of disease cohort' to help identify patients earlier;
- a digital health ecosystem: establishing the Health Data Research Alliance, setting national standards of interoperability where NHSX is playing a key role, and publishing a code of conduct for the fair use of data in the NHS.

It has long been argued that the NHS has the components to form a rich, longitudinal patient record, but this is distributed across many different data sources, whose data custodians have different governance processes and may not be well coordinated. There are primary and secondary data, there are genetic data such as that held by Genomics England, and indeed there are data that individuals have on their phones – so the data is held in a wide variety of places.

Different groups want to make use of this data. Patients, for example, care very much about their healthcare data, but many also have an interest from an ancestry point of view. Academia wants to carry out research. Providers want to provide more cost-effective healthcare pathways through personalising and tailoring treatment for patients – or instance, some oncology treatments might cause more harm than good in some individuals and that can be determined through genomics.

And then researchers in the biopharma sector are trying to understand disease and the progression of disease so as to better manage clinical trials and also understand the markets into which they want to sell.

To take one example, as part of the Health Data for Research programme, DigiTrials, a consortium of IBM, Microsoft, NHS Digital and Oxford University will enable researchers to use NHS data to shape and deliver clinical trials across the NHS. This builds on the Orion 4 trial paradigm, a large scale project which enabled patients across the whole of the UK to participate in trials, and benefit from cutting-edge medicines.

Finding out whether individuals are suitable patients for a particular trial is something that, in the past, has been difficult. A researcher would have to write to clinicians they already knew. Now, using the NHS digital dataset, there are ways proactively to find out if there are many patients with the required attributes in the UK before shaping the trial. Then, by identifying those patients, monitoring them and collecting information during trials, it may be possible to flex the trial's paradigm and answer clinical questions more rapidly.

Using the NHS digital dataset, there are ways to find out which patients have the required attributes for a clinical trial. Then, by collecting information during the trial, It may be possible to flex the trial's paradigm and answer clinical questions more rapidly.

Targeted trials

Another advantage, if the dataset is very rich, is that it may only be necessary to carry out a clinical trial on those identified patients and provide them with a product without needing a control or 'not treated' cohort, because that information can be found by creating a 'synthetic control' from patients in the dataset. In the USA, Roche has used this approach extensively: all the patients in a trial are treated, so there are no patients who are missing out and all are reporting back.

NHS data in the UK is quite unstructured and will need a great deal of curation, cleansing and standardisation to make it useful. In a number of locations, that work is already underway. There are a range of different organisations that might

wish to make use of NHS data – whether in academia, in pharmaceuticals or other areas. It is an interesting question as to what structures might be developed to bring them together.

Data-sharing agreements, licences, commercial agreements – all are in use across the NHS. An Office for Life Sciences study laid out a range of different potential approaches, a continuum from an open model where the data is given away for free to, at the other end, a very commercial approach where the NHS might retain the IP as products are developed by a consortium.

While there are different sorts of commercial models, it is notable that the Code of Conduct of the Department for Health and Social Care states that 'fair share' is a really important principle. This should be central to the approach of any organisation wanting to generate insights from NHS data: a fair share must go back to the NHS and to patients within the NHS.

In looking at the basic capabilities required to make use of this data, it needs suitable storage, it needs to be cleaned and curated – and then there needs to be the ability to analyse it in order to generate insights. So there are many different data sources to bring together. Curation is an extremely complex process because the data have to be annotated, aligned and integrated.

Now, if you reflect on the way a GP might make notes, they might put information in all sorts of different fields. It is therefore not a simple task to bring the data together in such a way that it is possible to interrogate the dataset. In my mind, it is a bit like painting – about 80% of the time is spent on preparation, all of which is unseen. People like to talk about using AI, algorithms and other tools to achieve insights, but much of the time and investment goes into that basic groundwork to make data useable in the first place.

The data is distributed across organisations and the way that consortia interact and share data is very important to enable progress, but this has to be done in a way that respects data security. If collaboration and partnership are key to these data-sharing opportunities, it is vital to identify at an early stage what the aims of the project are, what we are trying to do with the data and what the benefits to patients and the NHS will be. □

People like to talk about using AI, algorithms and other tools to achieve insights, but much of the time and investment goes into basic groundwork to make data useable in the first place.

The debate

The UK has an international reputation for a good regulatory environment that respects the rights and interests of the various players: that is a unique selling point.

The potential to track individuals through linked data and for insurers or employers to make decisions based on such information must be addressed. Risks of inappropriate use must be minimised by the governance frameworks that are developed.

Privacy and consent

It is imperative that the public understand what is happening with their data. The concepts of property and ownership are poor analogies in the case of data, as data can be licensed and copied – control and choice are limited once this happens. People do not read terms and conditions and data contains information not only about us as individuals but also others, e.g. through genetic data. Privacy should not become a luxury commodity. Yet, currently, patients often cannot even access their own data.

Recent legal changes in data protection and stories in the media have made people more aware of their data. It is crucial that the health data community protect the relationships of trust the public have with their GPs around their data use and that they work to enhance confidentiality.

There is an issue about who decides on the benefit-to-risk balance, as different people may choose different points on the spectrum. Feedback mechanisms must be in place so that, when errors in judgement and access to data do occur, measures are in place to ensure they are not repeated.

Patients themselves can play a critical role in improving front line data quality through highlighting inaccuracies in their own records. This could lead to enhanced patient safety. Stronger relationships could provide a powerful opportunity to improve front line decision making and engage patients more closely.

Inequality can have social causes not picked up by data. In Wales, there are initiatives to bring data together from different sources: education, social, environment as well as health. This could be used to address public health questions.

The narrative that is used around health data will be critical, as without patient permissions and engagement, none of the potential benefits will be possible. The opportunity costs and benefits must be clearly communicated to the public. Examples that demonstrate the human cost of not using the data effectively may also help to convince the public. □

In the debate that followed the formal presentations, a number of issues were raised, including: inappropriate use; public understanding; and the engagement patients in the process.

A joint meeting of the Foundation for Science and Technology with the Ada Lovelace Institute on 29 January 2020 examined both the technology and the ethics underlying the use of facial recognition techniques and other biometrics.

Issues of trustworthiness and legitimacy

Carly Kind

Carly Kind is the Director of the Ada Lovelace Institute, an independent research body and thinktank with a mission to ensure data and AI work for people and society. A human rights lawyer and leading authority on the intersection of technology policy and human rights, Carly has advised industry, Government and non-profit organisations on digital rights, privacy and data protection, and corporate accountability. She was formerly Legal Director of Privacy International, an NGO dedicated to promoting data rights and governance.

SUMMARY

- Facial recognition technology raises complex legal, technical and societal questions
- Social acceptability can depend on the use to which the technology is applied
- An 'all or nothing' approach to facial recognition is unhelpful. It is important to consider the use of the technology in particular use cases and by specific actors
- The technology must be both trustworthy and legitimate.

The Ada Lovelace Institute began working on biometrics in the summer of 2019. The combination of recent advances in machine vision and the proliferation of off-the-shelf image recognition products meant that facial recognition was suddenly seemingly everywhere – from the Hong Kong protests to police trials in Romford. There were stories of deployment by police in the USA, India and the UK, while there were facial recognition bans in Sweden and San Francisco. Legal challenges were brought here in the UK by Liberty and Big Brother Watch. There was increasing public concern – expressed in some countries by street demonstrations.

Facial recognition has emerged as the most visceral of the 'just over the horizon' AI technologies – only it is already here. It is a reminder of the urgent need to grapple with the complex legal, technical and societal questions that these types of technologies raise.

The 'spectre' of facial recognition and all it invokes has grabbed the public attention and concern, yet there are big differences between the facial recognition on an individual's smartphone and that being used by the police.

The use of facial recognition by Chinese authorities to detect and target Uighur populations is very different from Indian authorities' efforts to locate missing children, or UK attempts to identify individuals subject to outstanding warrants. It is one thing for supermarkets to use facial recognition to detect undesirable customers (as they are doing) and another for airports to use it to speed up check-in processes (which is also happening).

It is one thing for supermarkets to use facial recognition to detect undesirable customers and another for airports to use it to speed up check-in processes.

Those differences give rise to different emotional reactions – I may feel differently about using facial recognition to unlock my iPhone than to it being deployed on the CCTV system in my apartment building, for example.

The origin of a technology can be relevant, as can be seen in some of the media reporting about Chinese facial recognition technology. The future of the technology is also very important: it is not just about the purpose for which it is being used today, but also the uses to which it may be put in the future.

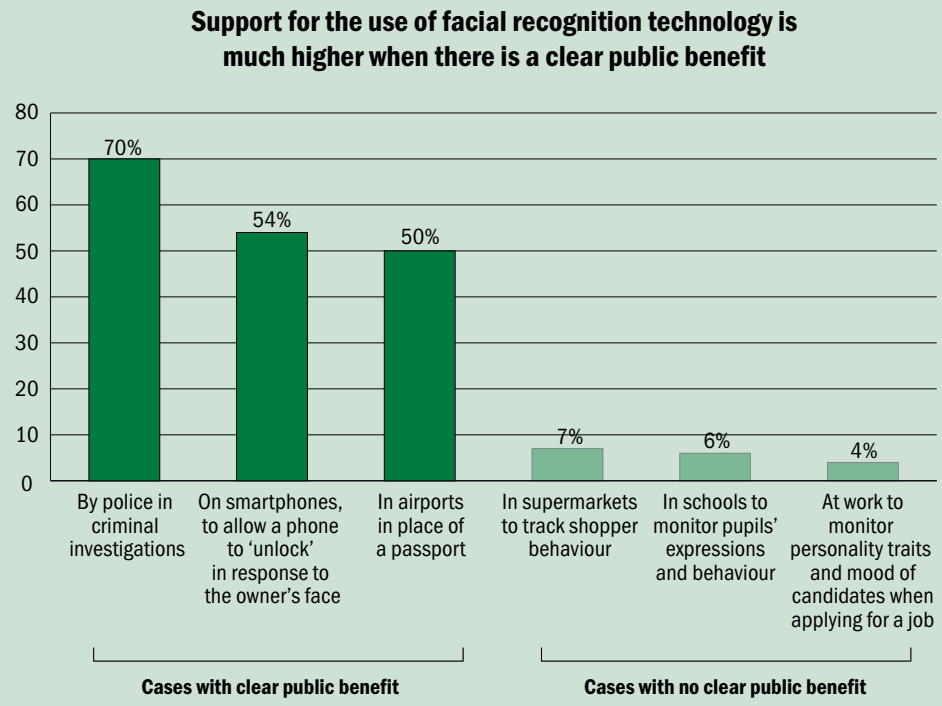
The context in which facial recognition is being used (i.e. by whom, for whom and overseen by whom) affects the way it is viewed. When the Institute undertook a public attitudes survey last year, there was quite a divergence in the levels of public confidence and comfort when facial recognition technology was used by public authorities compared with private organisations – and also where it was used in the public interest compared with applications of individual convenience or private sector benefit.

So each application involves a range of legal, technical and societal factors, each of which is relevant to the calculation of how invasive, beneficial, problematic or critical the technology might be.

It is therefore unhelpful when choices around facial recognition and other biometric technologies are framed in 'all or nothing' terms. Complete bans on the one hand or claims that nothing can be done to stop it on the other, are neither constructive nor appropriate. It also hampers individual agency when people are deprived of the choice to decide on the conditions when technology can be deployed.

Historically, technology has been developed and deployed to respond to a specific challenge or

Levels of public support for different facial recognition applications.



When the Institute undertook a public attitudes survey last year, there was quite a divergence in the levels of public confidence and comfort when facial recognition technology was used by public authorities compared with private organisations.

need: 'what can we do?' More recently, however, there has been an emerging consensus that the more appropriate question is: 'what should we do?' What should we do about facial recognition and other biometric technologies? Whose interest should prevail? How should it be used, if at all?

Technical concerns

Now, there is only one way to eat an elephant and that is one bite at a time. The first bite is to ask how good the technology itself actually is – does it work, is it reliable, is it biased?

Research by Joy Buolamwini and Timnit Gebru at MIT in 2017 first demonstrated that inaccuracies in facial recognition exist when attempting to recognise women and people of colour. A further study by the National Institute for Standards in Technology (NIST) in 2019 examined 189 facial recognition algorithms and found higher rates of false positives for Asian and African American faces than for Caucasian faces.

Independent observations of police trials in the UK by experts such as Professor Pete Fussey have revealed concerns about the accuracy of the technology being used. When the Metropolitan Police rolled out their live facial recognition policy at the beginning of January, it acknowledged that although their system displays no racial bias, it does display a gender bias.

While there are a number of technical concerns with facial recognition technology, it is improving year by year. We should continue to look for ways to continually verify its accuracy, but issues related to accuracy, bias, discrimination and false positives are only one piece of the puzzle.

There are also questions about its legality. Facial recognition must meet the requirements of current regulatory frameworks – including human rights. This poses a further issue regarding the adequacy of the current regulatory frameworks.

A further set of questions is concerned with efficacy and whether this technology delivers the outcomes intended. Is there demonstrable and independently verifiable evidence of efficacy? Are there other methods that are effective but less intrusive?

Then there is the concern about social impact. Will this cause harm or disadvantage to certain groups? Will its use affect decision-making and the allocation of public funds? Could it exacerbate historical and structural inequalities?

Those developing and deploying this technology must ensure it is legitimate and trustworthy, particularly by those groups who may be uniquely affected by it.

The widespread introduction of facial recognition may have long-term consequences by normalising surveillance and persistent identification.

Some of these issues will be addressed by on-going, independent research and others will be

Is there demonstrable and independently verifiable evidence of efficacy? Are there other methods that are effective but less intrusive?

The Institute is continuing to advocate for companies to voluntarily pause further deployment of facial recognition as consultation proceeds.

resolved by legal cases brought by campaigning organisations. The Ada Lovelace Institute is well-placed to help answer some of these questions as an independent organisation with a remit to bring together diverse voices.

We are responding to calls made by, among others, the House of Commons Science and Technology Committee by setting up an independent review to identify gaps in the legal system. This will be overseen by an advisory group comprised of experts in law, data protection, civil liberties, individual identity, policing, criminal justice and genomics.

A second initiative is the facilitation of public deliberation through a Citizens' Biometrics Council. This involves 60 members of the public – 30 from Bristol, 30 from Manchester – who have received a range of evidence from experts on issues related to biometrics technologies and have then been asked to deliberate on questions about trustworthiness, legitimacy and public interest.

Pause for reflection

The Institute is continuing to advocate for companies to voluntarily pause further deployment and sales of facial recognition as public consultation and regulatory processes proceed. As last year's survey demonstrated, there is support for further public consultation and further reflection on the regulatory framework in order to ensure adequate public legitimacy and trust in the deployment of this technology. □

Balancing a range of needs and requirements

James Dipple-Johnstone

James Dipple-Johnstone is the Deputy Commissioner (Operations) for the UK Information Commissioner's Office, providing executive oversight of the ICO's investigation, regulatory audit, complaints handling and appeals functions. He provides strategic leadership to the ICO's efforts towards global enforcement data sharing and cooperation including the Global Cross Border Enforcement Cooperation Agreement. Prior to joining the ICO, he served as Director of Investigation and Supervision for the Solicitors Regulatory Authority, the UK legal profession regulator.

As the UK's independent data protection authority, the Information Commissioner's Office (ICO) has been researching, investigating and observing the development of live facial recognition (LFR) technology.

The ICO concluded its first investigation into LFR – specifically, how police use LFR in public spaces – towards the end of 2019. We had examined the pilot systems in two police forces. The conclusion was that there needed to be improvements in how police authorised and deployed the technology if public confidence was to be maintained – which is at the heart of the UK policing approach. Our views were set out in the first ever formal Commissioner's Opinion for police forces to follow.The technology continues to advance and we have been conducting a series of investigations on the commercial applications of LFR. We are also looking very closely at the interactions between public and commercial uses of the technology and the datasets involved.

The issues we are considering are the same as those that our colleagues in privacy authorities around the world are grappling with. How we share that learning and find the synergies in our work has been part of our investigations.

When this technology processes personal biometric data identifying individuals, data protection law will of course apply. The ICO has been prioritising our interest towards those proposing to use the technology as a normal part of their business, or at scale. We also have to react to new and novel uses of the technology.

The ICO recognises the potential benefits in public safety and security that appropriately gov-

SUMMARY

- Live facial recognition (LFR) is a rapidly developing technology with applications in both public service and commercial areas
- Data protection law applies to the whole process of LFR - deployment, the compilation of watchlists, the processing of the biometric data right through to the retention and deletion of that data
- A balance has to be struck between the privacy that people rightly expect when about their daily lives and the surveillance technology the police need to effectively carry out their role
- Data protection laws should not be seen as a barrier to innovation
- Regulators are there to ensure that everyone working in this developing area is in full compliance with the law.

erned, regulated and deployed LFR could provide. However, there should be a balance between the privacy that people rightly expect as they go about their daily lives and the surveillance technology that the police need to effectively carry out their role.

To comply with the privacy rules, our view is that forces must provide sound evidence to show that the technology is strictly necessary, balanced and effective in each specific context in which it is deployed. This includes addressing the issue of bias as identified by researchers.

LFR is being used in commercial applications to improve customer service, make it easier to live our lives and to help businesses reduce operating costs. Yet it is possible to see the beginning of applications which track, and make decisions about, fellow citizens in commercial contexts such as recruitment or education – and sometimes this happens in a less than transparent manner. So the questions around fairness are a little different..

Would someone in a retail space expect the technology to be used there? Is it happening in a fair and appropriate manner? There are also questions about data-sharing – within the private sector, or where public information is shared with private sector organisations or indeed private sector technology is used for public duties.

LFR can help reduce queueing times, streamline authentication and authorisation or grant access to secure premises. However, from a regulatory point of view, these uses must meet basic privacy tests. They need to be proven to be lawful, necessary, justified, effective and proportionate if the technology is to enjoy public confidence.

We expect there to be rigorous Data Protection Impact Assessments (DPIAs) conducted prior to any processing, outlining how the processing adheres to the principles of data protection law and how a data protection by design approach is implemented.

Data protection should not be perceived as a barrier to the technology. As the Commissioner says: "We are not the Ministry of No." Data protection law in the UK was born in the 1970s out of the concern that the emerging potential of new technology might be lost if society did not have the confidence to embrace it. Digital privacy regulation has a crucial role, therefore, in assuring people that protections are in place while at the same time supporting innovation. That is especially true in the context of LFR.

At the heart of the Data Protection Act is the concept of 'privacy by design'. As with the processing of any personal or biometric data, there has to be a clear, lawful basis to demonstrate that the processing is fair, lawful and where appropriate, transparent. We expect rigorous data protection impact assessments to be conducted prior to any processing. These should outline how the processing adheres to the principles of data protection law and how data protection by design principles are being implemented. Where risks cannot be mitigated, the ICO should be consulted on the proposals in advance.

Police forces must provide sound evidence to show that the technology is strictly necessary, balanced and effective in each context in which it is deployed.

There is a tougher message, too: a range of enforcement and sanctioning powers can be used against those who fail to follow the law, ranging from warnings through to enforcement notices and, if necessary, financial penalties for serious or harmful deliberate contraventions.

We do, though, want to work with others to minimise regulatory burdens and to reflect different perspectives which we each bring.

Public opinion

We have been carrying out research into public attitudes. Over 80% of those surveyed indicated that they felt it was acceptable for the police to use LFR technology and three-quarters agreed it should be used on a permanent basis in areas of high crime. So there is a clear message for us as a regulator about the type of crime that it was being targeted at. However, in qualitative research, citizens explained that they only want facial recognition technology to be used when necessary and, importantly, they want to know when it is being used, with the opportunity both to object and to find out if their faces have been processed and stored.

In our recommendations to the two police forces involved, we said that sensitive processing must take place, whether an image yields a match to a person on a watch list or alternatively the biometric data of an unmatched person is subsequently deleted within a very short space of time.

Data protection law applies to the whole LFR process, from initial consideration about its necessity and the proportionality of its deployment, through the compilation of the watch list, to the processing of the data, its retention or deletion. Controllers must identify a basis in law for their actions.

Intelligence-led, narrowly focussed and specific deployments related to the prevention and

Data protection should not be perceived as a barrier to the technology. As the Commissioner says: "We are not the Ministry of No."

This technology has potentially significant privacy implications. The Government should introduce a binding code of practice as a matter of priority.

detection of serious and violent crime are more likely to meet the necessity and proportionality thresholds than more speculative uses.

This is an important new technology with potentially significant privacy implications for citizens. We have recommended that the Government introduce a statutory and binding code of practice as a matter of priority. The absence of such a code and accompanying national guidelines risk inconsistency of practice which in turn increases the risks of compliance failure and could undermine public confidence.

Live facial recognition technology remains a high priority for the ICO. Over the coming months, the focus will be on commercial applications. We are looking very closely at the manner and means by which seed lists are gathered, shared or sold and the justification for the processing of such images. In addition, we are examining the impact on individuals of such applications.

Resources and guidance

We are producing a range of resources to help organisations comply with the law and will be updating our existing guidance on the use of video surveillance technologies more broadly, including body-worn video, automatic number plate recognition and drones, to name but a few.

It is right that our public services should be able to innovate and use new technology to improve services and our lives, but regulators must ensure that everybody working in this area satisfies the full rigour of UK data protection law. ❑

Making sure biometric systems meet the needs of society

Carsten Maple

Professor Carsten Maple is Deputy Pro-Vice-Chancellor at the University of Warwick. He is the Principal Investigator of the NCSC-EPSRC Academic Centre of Excellence in Cyber Security Research at the University and Professor of Cyber Systems Engineering in WMG. He is also a co-investigator of the PETRAS National Centre of Excellence for IoT Systems Cybersecurity where he leads on Transport & Mobility and is a Fellow of the Alan Turing Institute. Carsten has extensive experience of institutional strategy development and interacting with external agencies.

SUMMARY

- Biometrics have been with us since the 19th century
- Facial recognition systems can be used for calculating numbers in crowds rather than identifying individuals
- There are a number of characteristics each system needs for it to be truly effective
- Public trust in biometrics is vital if the technology is to become an integral part of our economy
- This is a rapidly developing field.

It should be remembered that biometrics are not new at all. The use of biometrics to classify or identify people has been around for a long time. Alphonse Bertillon in the late 1800s developed 'anthropometry' as a tool for law enforcement. A police officer and researcher, he used five different measures to identify criminals: head length, head breadth, the length of the cubits between middle finger and elbow, foot and middle finger. It was useful although not very exact – but it was revolutionary.

Biometrics are used today for a number of reasons, but particularly for identification and authentication (i.e. whether someone has the right to access a service or an environment). It is also used to classify a type of person and that is quite different from merely identifying an individual. That depends on dataset size and which dataset is used – which can lead to the biases people have become aware of.

Facial recognition is very much in the news at present, but there are other biometrics: iris scans, palm vein, for example. The concern for many people is about being tracked and their data being used in ways they are not comfortable with.

It is also being used to detect people and crowds, so not identifying individuals but rather how many faces are in a certain crowd. When people talk about public facial recognition systems, we think about optical sensor cameras in Hong Kong or other places. Yet there are many different ways to gather biometrics.

For example, it may be necessary to know how many people there are in a crowd so that we can carry out emergency evacuation in smart cities. Such cases can be useful and do not involve identifying me as an individual, rather they use facial

recognition technology to recognise how many people are in a certain environment.

In other uses, people may accept facial recognition technology in order to access their phones. Drones are being trialled by the Red Cross in mountainous regions which are difficult to access in other ways. Animals can be identified and tracked by wildlife organisations: they may be very difficult for a human to spot, but machine vision can do it. We can agree that these types of application are important.

Operating requirements

When using biometrics to identify an individual, it is really important the assessment is unique. The biometric must be able to identify me and not confuse me with anybody else. The difficulties errors could cause are obvious.

The biometric used should also be 'universal'. Using a biometric such as a fingerprint is fine in most cases but what about people do not have a fingerprint because they are an amputee, or they have been working in a hard manual role for many years, for example?

The results of biometric scans should also have permanence, meaning they do not change over time. The data must be collectable. Certain biometrics are hard to collate and to store.

Then there is the overall performance of the product. It should be accurate and there are discussions going on about 'false rejection rates' and 'false acceptance rates'. How fast is it? That will depend upon the application, whether recognition needs to be live and immediate in order to access a service or if it is 'after the fact'. How robust is it? Can people fool a biometric system and can an attacker compromise it?

Often, a biometric that is collected may not quite match the stored record and so machine learning is needed in conjunction with the algorithm that sits behind the system. That is where some of the bias appears in recognising certain groups of people. It is important to ensure that the algorithms themselves are resilient and well-governed. While that is a different conversation, it overlaps with a discussion on the appropriate use of facial recognition when machine learning is used to correct for inexact matching – and there have been challenges on this.

Trustworthiness

Facial recognition is not just a technology, but rather a system of many parts housing some pretty important data. For the public to regard it as trustworthy, a number of features need to be apparent.

It needs to be secure. It needs to preserve an individual's privacy. When decisions are made based on biometrics, how transparent is that process? Is it reliable to the extent that if I am accepted once then I will be accepted a number of times and the system is predictable? Then, overall as a system, is it robust in all these different circumstances?

Using a biometric such as a fingerprint is fine in most cases but some people may not have a fingerprint because of accident or occupation.

Current research is working to strengthen trustworthiness. One area of work is concerned with secure systems development: on some smartphones, facial recognition is placed in a secure enclave so that is held more securely. These have good systems-access control systems which make sure unauthorised people cannot access them.

Privacy-enhancing technologies are very important. They offer a mechanism which, for example, perturbs the data a little so that the full data of a face is not stored, but there is sufficient to answer the question 'Does my face fit this authorisation?' Equally, data can be shared between datasets using secure, multi-party computation, without ever releasing the full data in each set.

New techniques for encrypting data are important and are being developed now.

There is a good deal work going on into making the complexities of AI explainable to the many groups with an interest in this technology.

We need to look at new systems for verification and to understand the threats to the successful development of this technology. ❐

Privacy-enhancing technologies can perturb the data a little so that the full data of a face is not stored, but there is sufficient for authorisation.

Creating an ethical and legal framework

Matthew Ryder

Matthew Ryder is a senior QC at Matrix Chambers, with well-established expertise in human rights, data and information, regulatory and criminal law including terrorism. He is leading an Independent Review of the Governance of Biometric Data, a flagship initiative of the Ada Lovelace Institute, which will analyse the existing regulatory landscape applicable to biometric data and prescribe modernisations and modifications. From 2016-2018, he was Deputy Mayor of London for Social Integration, leading several teams in the Mayor's work on diversity and social mobility including overseeing the work of the Mayor's data team.

SUMMARY

- Arguably as a result of a single legal case, the UK ended up with the largest DNA database in Europe
- Biometrics law is not concerned solely with chemical and DNA records
- Law and regulation have struggled to keep pace with the development of technology
- There is an increasing overlap between public and private collection and use of biometric data
- How far the regulator can control or limit enforcement agency behaviour is still open for debate.

As a junior barrister in 2002, I worked on a claim by a 12 year old boy – we shall call him 'S' – brought against South Yorkshire Police. A change in the law a few years earlier had resulted in a change of policy and South Yorkshire Police, like most police forces at that time, began retaining DNA samples indefinitely for everybody who was arrested, even children who were acquitted like S.

The policy had developed because of a horrible crime in which a 66 year old woman was raped. The DNA sample of the rapist had actually been retained when he was suspected of a burglary – a completely different crime. This sample should have been destroyed when he was acquitted of the burglary, but was not. Because of that breach of the law, he was convicted for the rape. It could be argued that this single, horrible crime led to a huge transformation in DNA policy.

In a short period of time, the UK had developed the largest DNA database in Europe – it included children, people who had never committed a crime but had just been arrested, and it had a disproportionately high representation of black and ethnic minority people. So S and another person brought a claim, challenging the policy about their biometrics.

Legal challenges

We challenged the policy in the High Court and failed, challenged it in the Court of Appeal and failed, challenged it in the House of Lords and failed. The House of Lords said collecting biometric data like that did not affect rights under Article 8 of the *Human Rights Act*. We were relying on a report by the Nuffield Foundation about biometric ethics and were trying to explain to their Lordships that biometric ethics was an important aspect of DNA data. We did not get very far.

But S took his case to the European Court of Human Rights and the UK government lost. It is worth noting that the ECHR did give significant weight to the Nuffield Foundation report on biometric ethics. However, it was not until 2012 that the law really changed with the *Protection of Freedoms Act* – 10 years after S started his claim in 2002. Now, during that time the technology had completely transformed, so by the time the 2012 Act came in, the world had changed again.

Partly due to the awareness that built up during the course of S's case, an understanding of biometrics and what it means to society has developed within the legal context. There is a better understanding of the need to regulate the use of fingerprints and DNA. Emerging forms of biometric data, such as when artificial intelligence analyses behaviour and creates data about an individual's behaviour, are also covered by the Act. Biometric data are not simply the chemicals in your body or the genetic material.

There is also increasing evidence that law enforcement and intelligence agencies are gaining access to private data sets. We have learnt, since the Edward Snowden revelations of 2013, how there is a relationship between those who gather data privately and those who need that data for law enforcement or intelligence purposes. That particular type of relationship remained secret for a long time, not being regulated until 2016 by the *Investigatory Powers Act*.

Not only did this country develop a permissive culture in allowing the DNA database to grow through its lack of legal regulation, but we have the most extensive CCTV coverage in Europe. It is important to recognise this existing permissive culture when thinking about the kind of law and regulation needed.

Law and regulation have struggled to keep pace. There is, finally, a new EU data regulation – GDPR – and a *Data Protection Act* that goes

Anna Bacciarelli/@a_bacci/Twitter

The Metropolitan Police decision to roll out live facial recognition indicates that the police are not bound to accept or follow the view of regulators.

with it. There is an Information Commissioner: the role goes back decades but was transformed at the turn of the century and has embraced the role of regulation over an expanding area of technology. It is an extensive brief, covering everything from Freedom of Information through to nuisance calls, AI and machine learning.

The 2012 Protection of Freedoms Act created a Biometrics Commissioner. That Commissioner is there to regulate DNA and fingerprints because of S's case. The role had less to do with the wider implications of biometric data and has had to adapt to embrace that wider area. There is now also a CCTV Commissioner.

Overlapping roles

These roles have emerged to cover different areas at different times and while they were not necessarily seen as overlapping, they do when it comes to issues like facial recognition. All of them have given their view of what they believe is needed for live facial recognition regulation.

It should be noted that the decision of the Metropolitan Police to roll out live facial recognition indicates that even though regulators have a view, the police are not bound to accept that view nor to follow it as a matter of strict law. The police will of course take account of it but are entitled to make their own interpretation. How far the regulator can control or limit their behaviour is still open for debate.

London does have the London Policing Ethics Panel (and some other forces have an equivalent organisation) which helps with some of these questions. During my time as Deputy Mayor, I sat in on one of those panels. They start from analogies from bioethics, but this is an emerging field in which the ethics panellists themselves are trying to understand the areas at the same time as the scientists and lawyers.

In May 2017, the Scottish Cabinet Secretary for Justice asked a leading criminal QC in Scotland, John Scott, to chair an advisory group to review the policy and law about the retention and use of custody images (there were at the time a number of legal challenges about this). It was a very forward-thinking move which was then broadened out to establish a human rights framework in the fast-moving area of biometrics.

The report was published in March 2019 and in May the Scottish Government published the Scottish Biometrics Commissioner's Bill, after consultation with the UK Biometrics Commissioner. It was attempting to establish what a modern Biometrics Commissioner's role would look like.

It is a good example of how independent review, government effort and meaningful collaboration can cover something more comprehensively and clearly than if a solution had just been imposed.

In my two years as Deputy Mayor I became aware how those working in local government do not have much time to think about how public services might best be delivered – sometimes other people need to do that. We hope that the Independent Review may help with that challenge. □

Independent review government effort and meaningful collaboration can cover something more comprehensively than an imposed solution.

The debate

The formal presentations were followed by a discussion in which a number of topics were raised, including: bias; holistic approaches; other biometrics; marginalised groups.

Data-driven and AI technologies are known to develop their own forms of bias (e.g. greater levels of inaccuracy with some groups of people, and more overt surveillance of some groups of people relative to others). When taken uncritically or adopted in combination with human bias, the technologies can exacerbate structural bias in society. Biometrics therefore need to be related to the world around it. Forensic science regulation is also important.

There are limits to what facial recognition technologies can do. Emotional recognition (as used in gaming apps) needs to be separated out from other forms of facial recognition technologies.

There needs to be a holistic or ecosystem approach, with legislation, evidence and consultation working hand in hand on an ongoing basis. This will ensure better collaboration between agencies and organisations (and between nations) and promote an understanding of facial recognition technologies within a broader remit of biometrics and identity.

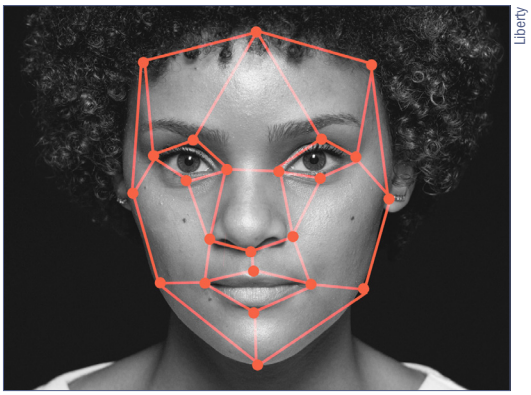
It is not only the face that marks our identity but also the ways we move. So we also need to consider how to protect or use those individual characteristics, such as gait recognition, rather than focusing exclusively on facial recognition technologies.

The public view is crucial for the sake of trust in the system. And in the public eye there is a profound difference between facial recognition technologies and biometrics used for protection and those that are used by the commercial sector for profit. The latter has a low level of public acceptance.

Environmental consequences should also be taken into account: data centres are an increasing source of carbon emissions – it was estimated that 14% of carbon emissions would be related to data technologies by 2040. Organisations need to work together to collect, share and store data in order to reduce this load.

We must not ignore what 'citizenship' means. It is not only UK nationals who need to be protected but also the many non-nationals whose fingerprints and photographs are taken by British authorities, and many of whom live in the UK. What are their rights?

The experience of specific, often marginalised groups (such as children, migrants, BAME and LGBTQ+) should be included in discussions about facial recognition technologies and biometrics. □



Liberty

FURTHER INFORMATION

European Data Protection Supervisor: Facial recognition – a solution in search of a problem?
https://edps.europa.eu/press-publications/press-news/blog/facial-recognition-solution-search-problem_en

Dotoeveryone: Responsible Facial Recognition Technologies
www.doteveryone.org.uk/wp-content/uploads/2019/06/Doteveryone-Perspective_Facial-Recognition-1.pdf

Fussey Peter and Murray D (2019) Independent Report on the London Metropolitan Police Service's Trial of Live Facial Recognition Technology. Project Report. University of Essex Human Rights Centre.
http://repository.essex.ac.uk/24946

ICO (2019) The use of live facial recognition technology by law enforcement in public places. https://ico.org.uk/media/about-the-ico/documents/2616184/live-frt-law-enforcement-opinion-20191031.pdf

New York Times: Wrongfully Accused by an Algorithm
www.nytimes.com/2020/06/24/technology/facial-recognition-arrest.html

MAJOR SUPPORTERS IN 2019/2020

A
Arts and Humanities Research Council, UKRI
Association for Innovation, Research and Technology Organisations (AIRTO)
AstraZeneca
Atkins Limited
AXA XL

B
Babcock International
Biochemical Society
Biotechnology and Biological Sciences Research Council, UKRI
BP International Ltd
BPE Solicitors LLP
BRE Group
British Academy
British Geological Survey
Brunel University London
BSI Group

C
Canterbury Christ Church University
Chartered Association of Building Engineers
Chartered Institute of Credit Management
Chartered Institute of Editing and Proofreading
Chartered Institute of Plumbing and Heating Engineering
Comino Foundation
Cranfield University

D
Defence and Security Accelerator
Defence Science and Technology Laboratory
Department of Health and Social Care

E
Economic and Social Research Council, UKRI
EIB Institute
Elsevier b.v.
Engineering and Physical Sciences Research Council, UKRI
ERA Foundation

G
GlaxoSmithKline
Genomics England

H
Haskel Family Foundation
Heads of University Centres of Biomedical Science (HUCBMS)
Health and Safety Executive
High Value Manufacturing Catapult

I
Imperial College London
Innovate UK, UKRI
Institute of Biomedical Science
Institute of Food Science and Technology
Institute of Materials, Minerals & Mining
Institute of Mathematics and its Applications
Institute of Quarrying
Institution of Chemical Engineers
Institution of Mechanical Engineers

J
Japan Society for the Promotion of Science
Jewellery Valuers Association
Johnson Matthey Plc

K
Keele University
King's College London
Knowledge Transfer Network Limited

L
Leiden University
London Mathematical Society

M
Make UK
McLaren Group Ltd
Medical Research Council, UKRI
Met Office

N
National Physical Laboratory
Natural Environment Research Council, UKRI
Natural History Museum
Nottingham Trent University
Nutrition Society

O
Open University

P
Palaeontological Association
Parliamentary and Scientific Committee
Peter Jost Memorial Foundation

Q
Queen's University Belfast

R
Recruitment and Employment Confederation
Research England, UKRI
Rolls-Royce
Royal Entomological Society
Royal Geographical Society (with the IBG)
Royal Society of Biology
Royal Society of Chemistry
Royal Society of Medicine

S
Science and Technology Facilities Council, UKRI
Society for Applied Microbiology
Society of Maritime Industries
Society of Operations Engineers
Sovcomflot (UK) Ltd

T
The Academy of Medical Sciences
The Foundation for Professionals in Services to Adolescents
The IET
The Lady Butterworth
The Medical Schools Council
The Nautical Institute
The Royal Academy of Engineering
The Royal Commission for the Exhibition of 1851
The Royal Society

U
UK Statistics Authority
University College London
University of Birmingham
University of Bristol
University of Dundee
University of East Anglia
University of Edinburgh
University of Glasgow
University of Hull
University of Kent
University of Leeds
University of Leicester
University of Nottingham
University of Plymouth
University of Reading
University of Sheffield
University of Southampton
University of Warwick
University of Westminster
University of York

W
Willis Towers Watson

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

The Foundation for Science and Technology
22 Greencoat Place
London SW1P 1DX

Telephone: 020 7321 2220
Email: fstjournal@foundation.org.uk

www.foundation.org.uk