fst journal

The Journal of The Foundation for Science and Technology

Volume 24 Number 1
August 2025

Space Science

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

Governing AI

Seeking a balance between strategy, governance and risk

Critical Minerals

Navigating a challenging geopolitical landscape

Industrial Strategy

How the UK can use science and technology to achieve growth

PLUS:

Guest editorial: Unlocking UK deep tech at scale, by Dom Falcão, Dr Claire Thorne, and Dr Thane Campbell, Deep Science Ventures

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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

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

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

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

The Foundation is strictly neutral and does not express an opinion on any policy question.

Information about supporting the work of the Foundation can be found at www.foundation.org.uk/About/Support-Us

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

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

Editor Gavin Costigan
Editorial Charlotte Raynsford
Layout Simon Clarke

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

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

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

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

CONTENTS

fst journal

Volume 24 Number 1 August 2025

LINKS

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

DOI: 10.53289/KSBV9046

Can social science and engineering decarbonise the built environment?

In May, the Foundation met at The Royal Society to explore how social science and engineering can contribute to solving one of the most challenging areas in the UK's Net Zero agenda – decarbonising the built environment. The UK is known for its older architecture, but retrofitting these properties is an issue, alongside making new-builds more sustainable. On the back of the Government's Warm Homes Plan, four experts spoke from across academia and Government, including: Professor Jennifer Schooling, Professor of Digital Innovation and Smart Places at Anglia Ruskin University; Helene Gosden, Associate Director and Retrofit at Scale Taskforce leader at Arup; Professor Chris Wise FREng, Senior Director, Expedition Engineering at the Useful Simple Trust and Professor Mari Martiskainen, Director of the Energy Demand Research Centre at the University of Sussex.

To further explore the theme of decarbonising the built environment, you can listen to our podcast episode with Antoinette Nothomb, co-founder of Cyanoskin – a start-up that has created a living carbon-capturing paint designed to absorb CO_2 from the exterior of buildings. You can also read this blog post from Dr Jill Zhao, Senior Lecturer in Architecture and Construction Technology at The University of the West of England, on making the decarbonising transition more efficient and resilient and keeping the everyday people involved at the forefront.

Future Leaders meet UK Parliamentarians

Walking in the footsteps of many famous decision-makers, this year's Foundation Future Leaders visited the UK Parliament in June. After a tour of the historic building, the cohort had a series of meetings to explore how Parliament seeks, receives and uses science. This included discussions with Dame Chi Onwurah MP, Chair of the Commons Science, Innovation and Technology Committee, and Viscount Stansgate, a member of the Lords Science and Technology Committee. They also met Oliver Bennett MBE, Head of the Parliamentary Office for Science and Technology, and staff from Parliamentary Select Committees.

Podcast makes top 60

The Foundation's podcast series has been ranked a 'Top Science Communications Podcast for 2025' by Million Podcasts. Guests come from research in areas such as climate monitoring, advanced materials and bio-engineering, and senior figures from organisations looking at issues of equity, gender and socio-economic gaps in STEM. Stream any episode free on Spotify, Apple Music, Amazon Music and the FST website.

R&D collaboration with African nations

To mark the final evening event of our busy spring/summer season, we posed the following question to a panel of expert speakers: How can R&D collaboration with Africa support an agenda for sustainable growth in the UK and beyond?

We were joined by Dr Rhona Mijumbi, Co-Director at The Center for Rapid Evidence Synthesis (ACRES), Makerere University and Head of the Policy Unit at the Malawi-Liverpool-Wellcome Programme; Professor Ambreena Manji, Dean of International for Africa, Cardiff University, and Professor Christopher Smith, Executive Chair of AHRC and UKRI International Champion,

alongside our chair Lord David Willetts. Together they discussed how UK R&D collaboration with African nations could support the UK growth agenda alongside meeting core in-country African development objectives. A lively and fruitful discussion followed. The whole event can be viewed again on the FST website.

Future Leaders alumni meet in Southampton

Six years' worth of Foundation Future Leaders gathered at Southampton University Campus in June for this year's Foundation Future Leaders Alumni in-person event.

Those attending were treated to a tour of the Optoelectronics Research Centre, the 'wind tunnel' and other engineering facilities. They also heard from Professor Mark Spearing and Professor Mark Hanson on university leadership and current issues in higher education and R&D and policy in healthcare.

The Future Leaders came together from across all cohorts dating back to 2019, comprising early-mid career professionals from research scientists to consultants and senior policy officers.

Discussing exascale computers in Scotland

In May, the Foundation went on the road to Edinburgh where we hosted a joint event with the University of Edinburgh on exascale computers. The audience helped us explore the implications of AI and future developments in quantum computing, and how the environmental impact of exascale computing can be reduced. We were delighted to be joined by expert speakers Professor Mark Wilkinson, Professor of Astrophysics at the University of Leicester; Professor Mark Parsons, EPCC Director and Dean of Research Computing at the College of Science & Engineering, University of Edinburgh, and Professor Katherine Royse, Director at Hartree Centre, STFC. You can rewatch the event on the FST website.

GUEST EDITORIAL

The UK has a scientific foundation that is second to none, with groundbreaking research and some of the best minds. The challenge we face is translating this research into globally competitive business. In this editorial, authors explore broadening definitions, filling gaps and unlocking potential.

Unlocking UK deeptech at scale

Dom Falcão, Claire Thorne and Thane Campbell

We all agree that the UK is a global beacon of scientific excellence. Our universities consistently rank among the world's best, producing groundbreaking research and the most brilliant minds. This scientific foundation is one of our nation's greatest assets, a wellspring from which we can draw solutions to humanity's most pressing challenges and drive economic growth. The question, then, is whether this scientific excellence alone is enough to translate into the real-world impact and scale that we urgently need.

For all our pride in UK science, a critical challenge remains: the struggle to translate this world-class discovery into globally competitive businesses that deliver tangible impact and scale – whether it is saving more lives, wielding geopolitical power or protecting national security – and inclusive growth. In the Industrial Strategy, the UK has laid out plans to invest 10% of its defence budget into novel technologies. Do we have the tools to develop those and secure scale-up investment? The assumption that we have cracked translation is a fundamental impediment to achieving our national ambitions, particularly in the realm of deeptech – the key to solving complex global problems.

At Deep Science Ventures (DSV), we are busy building the infrastructure, programmes, and companies that enable scientists to become VC-backed entrepreneurs and vice versa. Our focus on pre-identified opportunity areas actively de-risks the company founding process, with our companies facing an 82% survival rate, with none built in the last five years dying – a contrast to the 90% of deeptech companies that do not survive beyond five years. This not only leads to the creation of businesses that are designed to scale and thrive, for instance Mission Zero or Supercritical, but also strengthens the UK's reputation as a global science leader.

Listen to any keynote, participate in any roundtable and you would conclude that capital is all that UK deeptech needs. According to DSV calculations, we need to scale capital into UK deeptech by at least 50 times to meet our policy and economic goals. However, the pursuit of capital alone is naive; US ARPAs still lack technology commercialisation skills and UK startups feel that The British Business Bank does not conduct sufficient sector analysis. The UK needs a concurrent scaling and integration of the entire deeptech ecosystem: talent pathways (both new and existing), infrastructure to incubate nascent ventures, and an agile regulatory environment.

Our current talent pool is insufficient to meet the UK's R&D demands; we will need more than 382,000 researchers by 2027 just to sustain 2.4% R&D (The R&D Pipeline). The talent challenge is not just about volume. To achieve the extraordinary innovation results the UK desperately needs, we must think beyond traditional definitions of talent: cultivating a new type of talent, marrying scientific expertise with entrepreneurial drive to feed the appetite which will, in turn, scale the scalers.

The bottleneck: beyond discovery

The current trajectory, an organic, incremental evolution of the ecosystem, is inadequate. We risk falling short of our economic objectives, seeing our brightest talent drawn to more fertile entrepreneurial grounds abroad, and consequently losing our competitive edge as a global hub for innovation.

While we celebrate our science higher education system and the hungry talent it produces, the UK finds itself in a familiar cycle, generating knowledge but, retrospectively, failing to translate and scale solutions that break free from the lab and shape futures. Today, less than 0.5% of PhD students spin-out or licence their research findings (Beauhurst & RAEng Spotlight on Spinouts 2022).

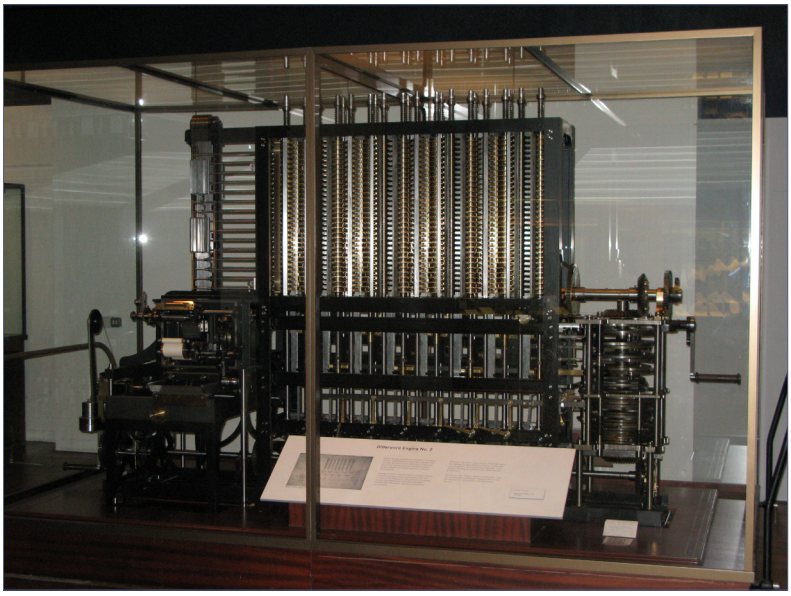
At the same time, deeptech has fallen out of favour. While artificial intelligence (AI) is, without question, a transformative enabler and infrastructure for research itself, without high quality data – which in turn requires an understanding of the underlying science to be created and the tooling and talent to produce it – we cannot fully harness emerging AI-in-science capabilities.

The current laser focus on AI, leads to a skewed, less vibrant landscape where an array of vital

Dominic Falcão and Mark Hammond co-founded DSV in 2016. Previously, they worked together to build Imperial College London's accelerator, the alumni of which have raised >£100m and include Puraffinity, Notpla, Sonalytic (acquired by Spotify) and Surreal Vision (acquired by Meta). Dom holds a degree from the University of York in Politics, Philosophy and Economics, focused on fundamental systemic drivers of wellbeing and fairness.

Dr Claire Thorne is adviser and venture partner at DSV, co-founding and now scaling the Venture Science Directorate (VSD). She serves on the Council of The Foundation for Science and Technology, is a member of the Sutton Trust's Tech Future Taskforce and techUK's TechSkills Advisory Board.

As dean of education at Deep Science Ventures, Dr Thane Campbell trains elite deeptech founders. He led the firm's evolution into a College delivering the world's first PhD in invention, spearheading partnerships with over 30 universities and national research assets, including NPL, The UK Catapult Network, The Max Planck and DLR.



GENI VIA WIKIMEDIA COMMONS CC BY-SA 4.0

DYSON

(Top) Charles Babbage's difference engine and (above) James Dyson's Dyson Institute: examples of British scientists who created inventions with purpose.

foundational, disruptive institutions and programmes struggle for attention and investment.

Reinventing the wheel: invention as discipline

To unlock the UK's deeptech potential, we need to fundamentally broaden our definition of 'scientist', rethink how we cultivate scientific leaders and intentionally, systematically build and scale ventures. This demands a paradigm shift: treating venture creation not as an accidental or serendipitous outcome of scientific discovery, but as a rigorous, teachable discipline in its own right, i.e., the science of building companies that scale: Venture Science. Following in the footsteps of great British scientists, who consistently created inventions with purpose, from Charles Babbage, to Hertha Ayrton, and Sir James Dyson.

What if we were to pivot from a pure "discovery mindset" to an "invention mindset," asking not just "what can we uncover?" but "what can we build, and how can we bring it to life at the biggest scale?" When we invent, we begin with a goal to solve a problem and are open to using any knowledge to find a solution. This is in effect, to apply an engineering mindset to science.

Venture creation is being re-imagined beyond traditional academic pursuits, beyond traditional academic walls, demanding a new kind of policy and infrastructure. The opportunity is truly UK-wide – not mapped to the geographies of traditional academic powerhouses.

Proven solutions to the UK's translation and scaling problem already exist. Many exciting organisations, such as SCVC, ConceptionX and DSV, are already established, delivering compelling impact while operating outside and in partnership with the traditional higher education institution (HEI) mould. These outliers often go under the radar, or are a challenge to support in a system designed centuries ago for a single type of organisation. These are not a threat to existing, successful talent pathways or HEIs but rather designed to be complementary, expanding our national capabilities – and must be championed.

A new approach to deeptech solutions

For a decade, DSV has honed an approach of systematically identifying high-impact problems ripe for deeptech solutions. Uncompromising, obsessively focusing on creating or combining IP to solve them, DSV has built more than 50 companies along the way, translating science into startup, scale-up and beyond. This methodology prioritises, backs and values the deliberate creation of solutions: an "invention mindset". This has been done in partnership with key UK institutions – such as the Net Zero Technology Centre since 2020, Innovate UK with whom we created a therapy for childhood cancer, and Agency of Advanced Research and Invention (ARIA) with whom we are developing a true entropy source. We understand the skills deficit behind the lack of UK scale-ups.

Venture as a discipline demands a new flavour of talent, thereby reinventing the traditional PhD. Re-imagine a doctoral programme designed not solely for academic publication, but for the systematic identification of critical global problems and – in direct response – the invention of novel, scalable solutions. It would involve attracting not only the best scientific minds, but also individuals with nascent commercial instincts, empowering them to intentionally translate that science into impactful ventures, from the outset.

DSV is pioneering this with its PhD in invention: the Venture Science Doctorate (VSD), seed-funded by Innovate UK and Schmidt Futures, among others. This three-year, fully-funded, sector-agnostic, global programme is a direct response to the translation challenge, explicitly embedding venture creation at the

GORODENKOFFSHUTTERSTOCK

heart of research. Unlike conventional doctoral studies, VSD candidates do not simply conduct research; they are trained as VC-backable, science entrepreneurs from day one.

They directly target critical, often overlooked problems within sectors like health, climate, agriculture and computation. The programme is set to train 1,000 venture scientists a year within ten years, and is currently fundraising for its third cohort. A proud home-grown initiative, developed by a UK-headquartered venture studio, it is now backed by SPRIN-D (Germany's Federal Agency for Breakthrough Innovation) – and is scaling in Germany.

NETZERO TECHNOLOGY CENTRE

DSV has partnered with organisations such as the Advanced Research + Invention Agency (ARIA) and the Net Zero Technology Centre to identify high-impact problems ripe for deeptech solutions.

Optimising for invention

The UK's ambition to be both a leading science and innovation powerhouse is within reach, but seizing this future demands more than wishful thinking; it demands new language, structures and mechanisms to back 'venture science' and a willingness to embrace radical new models of education and venture creation. We must collectively shift our mindset away from the passive hope that increased UK research and innovation funding and an increase in the same kind of innovation activities will automatically yield UK-grown, global deeptech companies.

Venture creation is not just the business of building companies – it is the business of education too, in order to train the builders and future scalers.

Currently, a critical gap exists: while research councils fund research and studentships, and Innovate UK backs innovation, there is no dedicated person, team, funding pot or organisation within the UK government or its agencies focused on venture creation itself. This 'no-man's land' overlooks a vital reality: startup creation disproportionately happens outside UK universities.

To fill this gap, we must cultivate the entire ecosystem to create and sustain a fertile UK ground for global scientific ventures to flourish economically. □

www.deepscienceventures.com

DOI: 10.53289/YFWS8960

GOVERNING AI FOR HUMANITY

CONTEXT

There have been several developments at both an international and UK level exploring how best we can govern and regulate AI, which is developing rapidly with exciting new opportunities but also potential threats emerging. In September 2024, the United Nations High Level Advisory Body on AI published its final report, *Governing AI for Humanity*. This notes the urgent need for global governance, and the current inequity in representation in such governance. It has several recommendations, including policy dialogue, capacity development, a global AI data framework and a global fund for AI. Delivering any of these recommendations requires global co-operation. In the UK, the government published its *AI Opportunities Action Plan* on 13 January 2025.

On Wednesday 29 January 2025, the Foundation for Science and Technology hosted an evening discussion at The Royal Society to explore what needs to happen at a global level, the UK's approach, domestically and internationally, and how we can maximise the benefits while minimising the risks. Our panel of expert speakers included Dr Douglas Gurr, Director of the Natural History Museum and Chair of The Alan Turing Institute; Professor Dame Wendy Hall DBE FRS FREng, Regius Professor of Computer Science at the University of Southampton, and Member of the UN High Level Advisory Board on AI; Adrian Joseph OBE, Board Member and AI Advisor (DirectLine Group, National Lottery, GOSH and NatWest) and former Chief Data and AI Officer at BT Group; and with Feryal Clark MP, Parliamentary Under-Secretary of State for AI and Digital Government, joining the panel for the discussion period.

A video recording, presentation slides and speaker audio from the event are available on the FST website at: **www.foundation.org.uk/Events/2025/Governing-AI-for-Humanity-What-is-needed-globally**

AI: How we got here

Wendy Hall

Dame Wendy Hall DBE FRS FREng is Regius Professor of Computer Science, Associate Vice President (International Engagement) and is Director of the Web Science Institute at the University of Southampton. She became a Dame Commander of the British Empire in the 2009 UK New Year's Honours list and is a Fellow of the Royal Society, the Royal Academy of Engineering and the ACM. Dame Wendy was co-Chair of the UK government's *AI Review*, which was published in October 2017, and a member of the AI Council. She is currently the co-Chair of the ACM Publications Board and Editor-in-Chief of Royal Society Open Science.

SUMMARY

- What we are witnessing now is not something entirely new, but rather a significant evolution in how AI is developing
- China has long been an active player in this domain, not just trying to catch up, and they have enacted several notable laws
- Generative AI does not present an immediate existential threat, although future advancements may require ongoing scrutiny
- A primary concern now lies in not just regulating AI, but also in the broader implications for the internet itself.

I do not have time to go through the full history of AI, but I will say that while many like to believe that AI's history began with Alan Turing's work in the UK in the 1950s, AI has gone through multiple reincarnations between then and where we are today. What we are witnessing now has not just emerged out of the blue, but is a profound tipping point in the evolution of AI and how it is perceived by society at large. In longer discussions, I touch on the AI winters – periods of stagnation, when AI failed to deliver on promised impact – but currently I feel like we are in an AI blazing summer and none of us knows how it is going to turn out.

National strategies

I first got involved in the sector when Jerome Pesenti and I were asked to undertake the UK review of AI by Theresa May and her Government in 2017. This was all about economic growth and job creation – words we hear a lot today. I then worked with Greg Clark, then Secretary of State for BEIS, as our review was incorporated into the Government's Industrial Strategy. The result was a billion-dollar investment in AI by the Government which included the establishment of the Office for AI and the AI Council, and led to the development of the UK's National Strategy for AI in 2021. Investment in AI then came through a series of successive Conservative Governments, including when Rishi Sunak was Chancellor. He authorised a considerable amount of funding for AI, and we were really on the front foot internationally.

Other countries began to follow our direction of travel and at the same time the regulation of AI started to appear in various national AI strategies. 2021 was when the EU started laying the groundwork for its AI Act, building on GDPR. China was, and has always been, in this game. It is important to note that it is not playing catch-up and that it has passed a lot of interesting laws to regulate AI, albeit having

a very different way of dealing with content.

Back in the UK, the Office for AI was overseeing the adoption of the National AI strategy and implementing the recommendations we made in the 2017 review. This was a pivotal moment, as the UK was one of the first nations to adopt a national AI strategy. The EU, meanwhile, was putting the finishing touches to its AI Act and trying to persuade the US to adopt it. That discussion is now history as the playing field has shifted quite dramatically. In November 2022, Sam Altman, Chief Executive of Open AI, very cleverly created a user-friendly interface to its large language model (LLM) GPT to create ChatGPT. Now anybody could interact with AI. All of a sudden, over Christmas 2022, everybody from Government ministers through to the media and the general public, was playing with Chat GPT without really understanding what they were doing, but it felt like they were talking to something intelligent because of the easy natural language interface and the answers in prose.

In March 2023, the UK published its well-intentioned pro-innovation AI regulation white paper, but it gained little attention. Perhaps it was not the right time to produce something like this during the ongoing debate around ChatGPT. We then swiftly moved into an era when everyone was talking about the risks of generative AI becoming an existential threat to humanity. Scientifically, generative AI is never going to be an existential threat in terms of going rogue. It could do that in the future as the technology evolves, so I applaud the work of the UK AI Safety Institute. However, I want them to look more broadly rather than narrowly at the US Generative AI models. I hope they are also looking at Chinese models.

Judgment day

The existential threat meme became very dominant in 2023. It was over hyped by the technology companies and picked up by the media in a way that was very scary for people. Geoffrey Hinton, the Nobel Prize winning computer scientist, said words to the effect of "I am leaving Google because it is all too dangerous". This is the man who invented it all. I really felt that this was not the right thing to say, but I think he was saying, "I want to be free to say what I want and I do not want to be constrained by being employed by one of the big tech companies." He has tempered his remarks since, and been a bit wiser about things. However, it was a statement that the media picked up on and which contributed to a dangerous rhetoric.

In October 2023, the UN AI advisory body on AI was set up. I was privileged to be a member. We had less than a year to produce a report about how the world should set up some form of global governance of AI. In November 2023 the UK hosted the first AI Safety Summit at Bletchley Park in association with then President Joe Biden, which included significant discussions with prominent tech leaders and companies heavily involved in the development of AI, including in China. Around the same time, China was actively launching its AI framework through the Belt and Road initiative, showcasing its growing influence in technology and AI development worldwide. The shift in global power dynamics is considerable, as China is providing funding and resources to assist other countries in their AI endeavours, outpacing Western efforts in some areas.

Just before the UK AI Safety Summit President Joe Biden announced his executive order calling for self-regulation by the big tech companies. While both countries appeared to work collaboratively, underlying disagreements persisted regarding AI governance strategies and tensions became clearer.

The UN HLAB on AI report *Governing AI for Humanity*, which I took part in, was released in September 2024 and was largely accepted by the UN General Assembly that month. If this is implemented it will lead to the formation of a global scientific panel aimed at establishing unified standards and policies for AI governance, similar to historical nuclear treaties. The report proposed the creation of a global AI capacity development network and an accompanying fund to support AI initiatives in developing regions, which are often referred to as the "Global South".

Meanwhile, the EU has announced funding for an AI research initiative akin to CERN, with the goal of fostering significant innovation in European AI capabilities. As 2025 began, the new UK Government released its AI Opportunities Action Plan highlighting key initiatives such as creating AI growth zones and an AI Energy Council to address the energy demands of AI technologies. Recently, however, political shifts have complicated the landscape, with expressions of concern over the potential revocation of Biden's executive order by President Trump and substantial investments from tech giants into AI development in the US with who knows what regard to the safety of the technology. Looking ahead, as we prepare for the next summit in France, my primary concern lies in not just regulating AI, but also in the broader implications for the Internet itself. If we do not approach these challenges responsibly, we risk turning the Internet into a dysfunctional space.

The future of the Internet and AI can either be a catastrophe or a significant advancement for us

The future of the Internet and AI can either be a catastrophe or a significant advancement.

– it is crucial that we engage thoughtfully in this discourse. Let us hope we can steer it in a positive direction.

As an aside: neither the US nor the UK signed the agreement that emerged from the Paris AI Summit in February 2025. We were told that the UK did not sign because the agreement did not say anything about safety and security. The next AI summit will be in February 2026 in New Delhi in India. □

DOI: 10.53289/PHXL1099

AI at the coalface

Douglas Gurr

Douglas Gurr is Director of the Natural History Museum. He is also Chair of the Alan Turing Institute and Interim Chair of the Competition and Markets Authority. Previously, he was Country Manager of Amazon UK and President of Amazon China. Earlier roles included the Civil Service, partner at McKinsey and Company, Director at Asda-Walmart, Founder CEO of internet start-up Blueheath, Chair of the British Heart Foundation and Chair of the Science Museum Group. He has a degree in Mathematics from the University of Cambridge and a PhD in Computing from the University of Edinburgh. He previously taught mathematics and computing at the University of Aarhus in Denmark.

SUMMARY

- By considering AI as part of an organisation's decision-making process, we can understand that decisions can be made by humans, randomly, or by machines
- AI's true value lies in its ability to speed up decision-making and improve granularity, transforming not only individual organisations, but also broader societal functions
- I believe that idea that AI poses an existential threat is overstated and diverts our attention from more immediate societal concerns
- However, we must consider who benefits from the value generated by AI systems
- It is crucial to recognise the accessibility of advanced technology to malicious actors

I am going to bring us down from global regulation to the practical realities of AI – what is really happening at the coalface. I will explore what AI is, how it creates value, what can go wrong, and how we might think about regulating it appropriately.

What is AI? Think of any organisation– whether it is a university, a commercial company, a charity, or even The Royal Society. You can view an organisation as a decision-making machine, making numerous decisions every day. Fundamentally, AI is just a sophisticated decision-making tool. It takes inputs, which we usually convert into numerical forms (bits and bytes), applies algorithms, and produces outputs. That is essentially its function: taking inputs and generating outputs. I often ask business leaders: How does AI actually create value? What can AI do to add value to your organisation, whether that is social, economic, or commercial?

By considering AI as part of an organisation's decision-making process, we can understand that decisions can be made by humans, randomly, or by machines. When discussing the value of AI, there is often a misconception. In any decision-making scenario, there are two key dimensions to consider: fidelity (the quality of decisions) and velocity (the speed of decisions). Many debates around automation and replacing human workers with AI assume that AI creates value by making better decisions. For example, we have AI systems that can analyse skin images to identify potential cancer better than even some expert oncologists. While that sounds promising, the real issue often is not whether AI improves decision quality; it is about how much faster decisions can be made.

We are talking about speed increases that can reach billions of times faster, creating significant value in many domains.

How AI can create value? Let me share three simple examples.

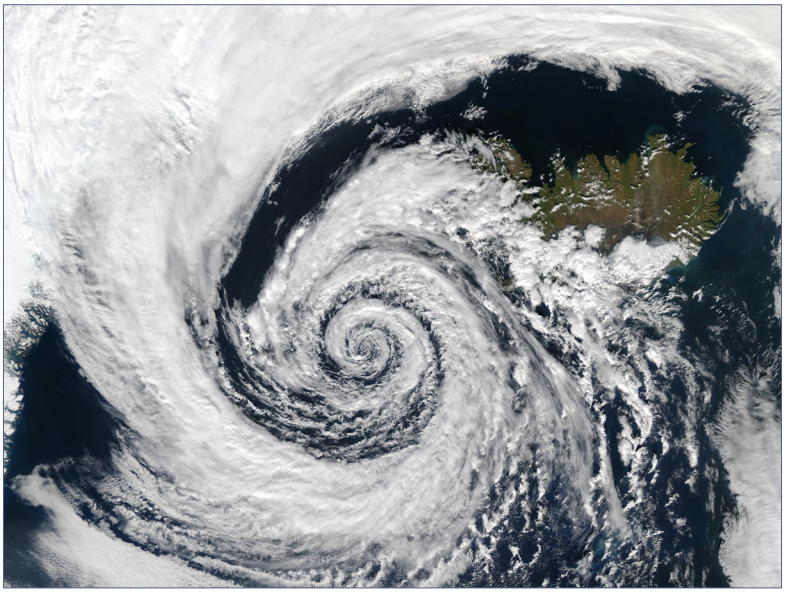
- Retinal eye scans: These scans can indicate serious health conditions like diabetes and cancer. However, there are not enough human experts to analyse the high volume of scans; only a small fraction get reviewed. If we use an AI algorithm to assess all those scans, even a minimally effective one could identify the small percentage that needs further examination. This could create immense value simply by increasing the speed of analysis.
- Weather forecasting: At the Alan Turing Institute, we have partnered with the Met Office to enhance weather predictions. Weather forecasting is complex; small changes in initial conditions can create vastly different outcomes. Traditional models, based on fluid dynamics, struggle with local accuracy. However, by using physics-constrained machine learning, we can gain better predictive capabilities, even in areas lacking data. In tests against existing supercomputers, we found that our models could match their accuracy while being a

million times cheaper and faster. This means that, for the first time, more people can access advanced forecasting powered by AI, which is a game-changer. These examples highlight how AI's true value lies in its ability to speed up decision-making and improve granularity, transforming not only individual organisations, but also broader societal functions.

- Analysing fossils: My day job involves overseeing the Natural History Museum, and one intriguing question we often encounter is: how do we date a dinosaur fossil? This question is vital for palaeontologists and anyone interested in deep time, yet it is surprisingly complex. Fossils are essentially just different types of stone, and they all look quite similar, which makes dating them over a span of 200 million years challenging. However, we can date fossils by collecting a small sample from the surrounding substrate–be it chalk or sandstone. This sample often contains nanofossils, like pollen and plankton, which serve as reliable indicators of time because they evolve and change over periods. With careful analysis, we can achieve good dating accuracy. To do this effectively requires a trained postdoc, whom we will call Tom. He needs to make around 2,000 observations, meaning he would spend about ten days looking through a microscope for hours at a time. Unsurprisingly, it is a monotonous job. To tackle this inefficiency, we decided to leverage AI by pairing Tom with one of our machine learning experts. They developed a straightforward model that analyses images of the samples. In just four to five weeks, they created a model with 98.5% accuracy that processes data 30,000 times faster than Tom can. Now, we are preparing to offer this as a commercial service at a competitive price.

AI threats

On a different note, I want to address a more pressing issue: the notion that AI poses an existential threat. I believe this idea is overstated and diverts our attention from more immediate societal concerns. For example, many organisations are now using machines to make decisions. Today, machines handle billions of tasks, such as credit checks, inventory management, and pricing. During my time at Amazon, we recognized the importance of understanding how to manage these machines effectively. While we have over a century of experience managing people, our understanding of machine management is still developing. Machines can fail due to poor data or outdated algorithms, leading to rapid, sometimes catastrophic outcomes. Unfortunately, many people who implement these systems lack the proper training to manage them effectively, which can be dangerous.



NASA/GSFC, MODIS RAPID RESPONSE TEAM, JACQUES DESCLOITRES

The Alan Turing Institute has partnered with the Met Office to enhance weather predictions.

Additionally, we must consider who benefits from the value generated by AI systems. In the UK, we have some of the world's most valuable datasets, often provided for free to businesses. While this might seem advantageous, it poses the question of whether taxpayers should subsidise these resources, especially when much of the value created does not benefit the UK. Trust also remains a significant concern in AI. We need to think critically about where and how to involve humans in decision-making processes. Even if machines perform better in certain areas, human oversight is sometimes necessary.

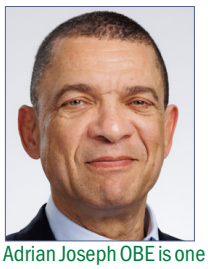
Lastly, I want to highlight a concern that keeps me up at night: the accessibility of advanced technology to malicious actors. During my time managing Amazon's operations in China, I saw how organised crime can exploit these capabilities. This risk is often overshadowed by concerns about state actors, but it is crucial to recognise this threat as we advance machine-learning technologies. In conclusion, regulating AI and related technologies is essential, but it presents considerable challenges. It requires a thoughtful approach that balances genuine societal concerns with the need to foster innovation. The region or country that successfully navigates this balance will likely attract significant investment and growth. Therefore, it is vital that we address these legitimate issues while maximising opportunities for innovation. □

The risk of how organised crime exploiting these capabilities is often overshadowed by concerns about state actors, but it is crucial to recognise this threat.

DOI: 10.53289/GMBU5116

Embracing AI without the risk

Adrian Joseph



Adrian Joseph OBE is one of the UK's leading applied data and AI-focused technologists with more than 25 years' experience in AI, big data, analytics and digital transformation. Currently, he is a Non-Executive Director at Direct Line Insurance Group, Allwyn Entertainment (UK National Lottery operator) and at Great Ormond Street Hospital for Children. He also sits on the Technology Advisory Board of NatWest Group. His advisory roles extend to the private equity sector and multiple AI-centric startups.

SUMMARY

- Once believing that governance slowed things down, my perspective shifted when I experienced firsthand the consequences of neglecting it
- It is our responsibility–whether as board members, policymakers, or leaders–to find the right balance between strategy, governance and risk, and resource allocation
- Boards often find themselves torn between two fears: the dread of a potential AI catastrophe and the anxiety of missing out and falling behind the competition
- Just as a Formula 1 car needs an expert driver, pit crew, spectator inputs and safety systems to go faster, AI requires regulations and safeguards to ensure both effective performance and safety.

I have had a complicated relationship with AI and data governance. At times, I felt almost allergic to it. Many individuals in governance roles seemed disconnected from the technology itself, its practical applications, and the real-world risks associated with it – risks were often presented to me in a disastrous way, without considering their probability or materiality, or they were purely theoretical. Instead of fostering innovation, governance often slowed things down with layers of bureaucracy, complexity, and red tape.

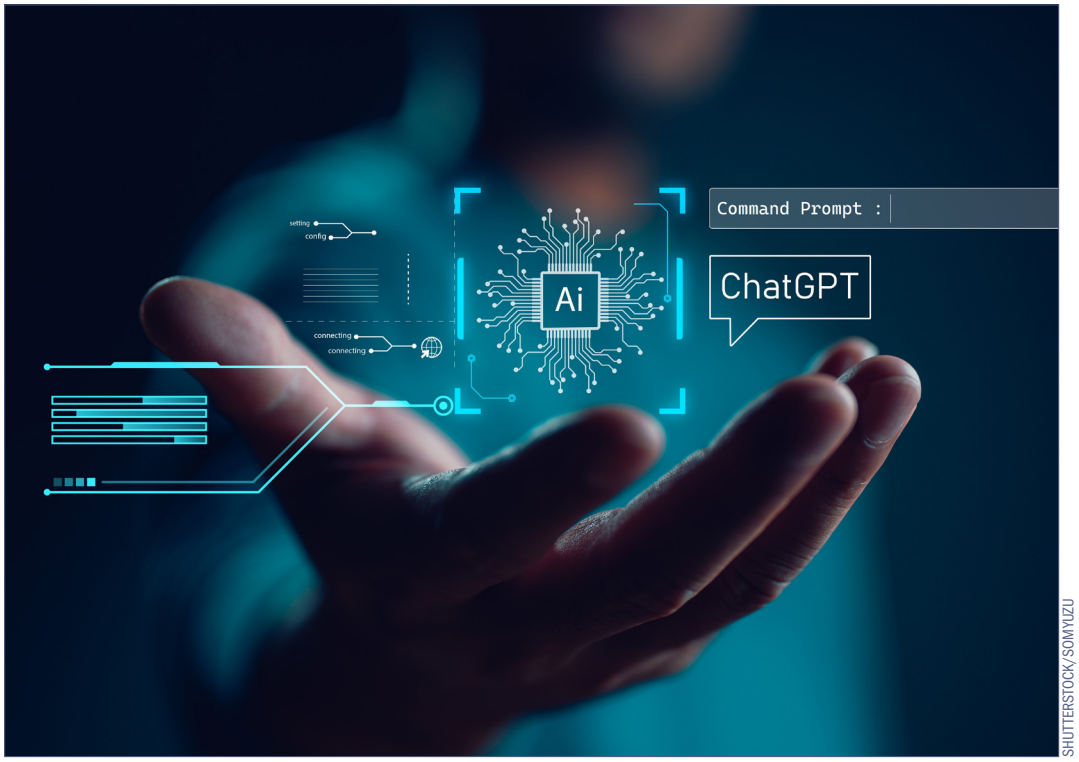
My perspective shifted when I experienced firsthand the consequences of neglecting AI governance. I was involved with a significant AI and data migration programme for a FTSE 100 company that was expected to deliver hundreds of millions of pounds in value over the medium term. We were making excellent progress until we hit a wall. During this transformation, we detected and self-reported a substantial cybersecurity risk that could have exposed the personal information of millions of customers. Fortunately, we caught it in time. However, we then faced the daunting task of standing in front of the board to explain that we needed to pause a major strategic programme for the company. You can imagine how well that went down. Despite the efforts of top-tier internal teams, highly paid consultants, and a leading cloud provider, our review uncovered several critical security risks along with several medium- to low-risk concerns. The outcome was a six-month delay in one of the company's top three strategic programmes.

This experience taught me something invaluable, which I observe in many boards I work with today. Boards often find themselves torn between two fears: the dread of a potential AI catastrophe and the anxiety of missing out and falling behind. They struggle with the dilemma of either letting the genie out of the bottle or trying to lock it away forever. It is our responsibility – whether as board members, policymakers, or leaders – to find the right balance between strategy, risk, and resource allocation.

AI as an accelerator, rather than a brake

So, how can we govern AI in a way that promotes innovation instead of hindering it? How can we ensure that AI acts as an accelerator rather than a brake? Here are five key areas where effective AI governance can make a difference:

1. Shape strategic direction: When done right, AI governance aligns with corporate values, regulatory requirements, and long-term strategic goals. It helps organisations to build ethical, compliant, and sustainable AI systems.
2. Empower responsible AI: Governance should focus on people, not just policies. Through training and education, good AI governance ensures employees understand how to use AI safely and responsibly, creating a culture of trust and ethical deployment.
3. Measure value and ROI: Well-implemented AI governance provides frameworks for tracking investments, measuring return on investment (ROI), and ensuring AI initiatives deliver tangible business and societal value. In many organisations I work with, we evaluate four key levers of value:
   - Revenue growth: Can we identify the best customers for our B2B teams through effective models, for example?
   - Efficiency improvements: Are we able to reduce costs, such as optimising field force teams, potentially cutting costs by 20% while also reducing CO_2 emissions?
   - Enhanced customer experience: Can AI connect the right customer with the



SHUTTERSTOCK/SOMYUZU

AI governance is not a set of bureaucratic roadblocks – it is the finely tuned safety and performance systems that allow us to go faster, safely.

right representative for better service and improved upselling opportunities?
- Risk mitigation and management: From fraud detection to quickly extracting contract obligations from extensive documents, good governance enhances risk management capabilities.

4. Drive adoption: Effective governance should provide a holistic view of AI activities across the organisation, reducing duplication, identifying opportunities, and accelerating adoption. It needs to be a coordinated effort rather than a series of fragmented experiments.
5. Enable smarter decisions: Good governance frameworks assist organisations in making informed buy vs. build decisions, assessing vendors, mitigating risks, and ensuring AI procurement aligns with evolving legal and ethical standards. At one organisation I worked with, we formed a cross-functional team to create a responsible AI framework, uniting policy, regulatory, and data protection teams to ensure our AI initiatives were fair, accountable, transparent, and focused on positive outcomes.

I am a bit of a speed geek, so let me put it this way: AI is like a Formula 1 McLaren. It delivers mind-blowing performance, but only when handled by a skilled driver like Lando Norris, supported by an expert pit crew and engineers at the factory. It needs powerful brakes, robust safety measures, and well-defined rules of the track. And crucially, it needs an engaged audience – public input to shape its future.

AI governance is not a set of bureaucratic roadblocks – it is the finely tuned safety and performance systems that allow us to go faster, with confidence, and with fewer crashes.

AI is not just another technological evolution; it is increasingly central to the future of economies and societies. I believe that our role is to create governance frameworks that do not just mitigate risk but actively drive responsible, value-driven AI adoption. We must build trust, transparency and capability – so that AI can serve as a force for good rather than a source of unintended consequences.

Let us not be paralysed by fear, nor reckless in our ambition. Instead, let us drive AI forward – safely, strategically, and at speed. ❐

DOI: 10.53289/YERS7658

MCLAREN

AI is like a Formula 1 McLaren: it delivers mind-blowing performance, but only when handled by a skilled driver, backed by an expert pit crew.

The debate

After the presentations, the speakers engaged in a Q&A with the audience on issues including the relationship between safety and opportunity, Data Trusts and the Chinese model of AI regulation

Following the presentations, the panel discussed a wide range of issues in response to questions from the in-person and online audience. Some of they key points raised are summarised below.

Under the previous government (in 2023), there was a lively debate on key issues for AI. The decision was taken that the number one issue was safety. More recently, the NHS has been in the spotlight. There is a surprising number of things you can do if you stay ahead of what is happening internationally. One audience member asked, what can we expect to see happening next?

The minister said that the Government believes safety and opportunities are not at odds. They are two sides of the same coin. You cannot make use of AI opportunities unless you have safety baked in from the beginning. We have the AI playbook which sets out steps for every department to go through when using AI in public services. There is also research going into societal harms with regards to AI. She said that the work we do with our academic sector is going to be key in making sure we keep a good understanding of upcoming threats and safety issues.

Existential threat

Another panelist commented that setting up the AI Safety Institute was a good initiative, but that it was too narrowly focused on the existential threat from foundation models. It needs to broaden out and start being part of the debate on things like responsibility frameworks. She said that the UK could drive this debate. Any new regulations need to consult scientists who can see what is coming down the pipeline.

In 2023, the UK published guidelines for the safe and ethical use of AI, which had to apply to every regulatory body. There is a lot there to build frameworks out from.

With regards to helping people to manage their data and privacy, the concept of 'Data Trusts' (managed by third parties who negotiate with companies on an individual's behalf) was advocated for by the panel. This could be done with healthcare data and, in particular, NHS data. However, this cannot be achieved without the idea of data trust and data stewardship.

Looking at the Chinese model of regulation of AI and the internet is interesting and useful. Exploring the concept of the 'four internets' – that there are in fact parallel versions of the internet to the standard US type model we see regularly in this country, and these are worth looking at with regards to how AI will operate in the future.

We should be mindful of how we regulate and put restraints on AI in the UK so as not to drive business elsewhere. We need to be more thoughtful about a wider set of skills needed for the development and training of AI. We should look at things holistically, particularly in terms of safety and open-source models. These can speed up development but are also very 'open' to bad actors. It is important to think carefully about the regulation of open-source models.

One panellist stated that one of the biggest existential risks for the UK is not adopting technology early enough and more money and opportunities going to big tech companies outside of the country. There is also an undercurrent feeling here in the UK that we spend a lot of time using AI that is developed overseas and that more should be developed here in the UK. However, investment is low. One factor is that venture capitalists (VCs) in the UK do not seem to understand science properly. The Government has started a programme that attempts to help VCs train and get a better understanding of STEM. There is also a view that the US company Palantir winning the contract for the NHS data framework was a missed opportunity for UK businesses. □

OXYMAN/WIKIMEDIA COMMONS

A US company winning the contract for the NHS data framework was a missed opportunity.

CONTEXT

Modern developments in electronics, batteries, electric vehicles and other technologies depend on certain critical minerals. There is a global race for these minerals as demand across the world rises, and the UK Government's Critical Minerals Strategy sets out how this country will ensure sufficient supply to meet UK needs going forward. Science and technology can make a major contribution to delivering the strategy, from more efficient extraction to effective and commercially viable recycling and new materials. This is leading to new commercial opportunities.

On Monday 24th February, the Foundation hosted a discussion event in collaboration with the Geological Society, and the Royal Society of Chemistry to discuss the UK strategy, and explore how science, technology and innovation can help deliver it. Expert speakers included: Professor Paul Monks, Chief Scientific Adviser at the Department of Energy Security and Net Zero; Dr Gavin Mudd, Director of the Critical Minerals Intelligence Centre at the British Geological Survey; Dr Sarah Gordon, Chief Executive Officer at Satarla , and Co-Director of the Rio Tinto Centre for Future Materials at Imperial College and Professor Emma Kendrick, Chair of Energy Materials at the School of Metallurgy and Materials, University of Birmingham.

A video recording, presentation slides and speaker audio from the event are available on the FST website at: **www.foundation.org.uk/Events/2025/Critical-Minerals-%E2%80%93-how-can-science-and-technology**

The key to a transitioning world

Paul Monks

SUMMARY

- It is important to understand what we mean by critical minerals and the implications of their extraction and use
- Critical minerals often have complex supply chains: mined in one country, refined in another, and packaged in a third
- The global geopolitical landscape has an impact on supply, as these minerals are sourced from different countries
- The UK's Critical Minerals Strategy emphasises the importance of accelerating growth in the UK's domestic markets and collaborating with international partners.

A conventional car contains around 1km of copper wire, while an electric car contains approximately 11km. This stark contrast highlights the significant differences in the technologies involved. We are also witnessing a transition toward various energy sources such as onshore and offshore wind, solar, nuclear, and natural gas. Notably, coal is no longer the incumbent technology in the UK, as we closed our last coal-fired power station on September 30th of last year. The chart on page 5 shows that there are significantly more critical minerals involved in the power production of these renewable technologies compared to conventional ones.

It is important to understand what we mean by "critical minerals" and the implications of their extraction and use. The global geopolitical landscape plays a significant role, as these minerals are sourced from various countries. Data from 2019 indicates a diverse range of mineral sources, each with differing production metrics and applications. However, it is inaccurate to view the story of critical minerals purely from the perspective of primary production. These minerals often have complex supply chains; they might be mined in one country, refined in another, and finally packaged and sold in yet another country. This movement highlights the importance of the value chain for these minerals. The extraction and refining processes for these minerals differ significantly from those for conventional energy sources like natural gas and oil. Additionally, the geographical distribution of these resources and their processing locations vary greatly across the globe. In response to this landscape, we produced the first UK Critical Minerals Strategy in 2022, acknowledging the need for resilience for the future. The strategy emphasises the importance of accelerating growth in the UK's domestic markets, collaborating with international partners, and enhancing international markets to promote responsible practices. To implement this strategy, we established a Critical Minerals Expert Committee and several initiatives to support these goals.

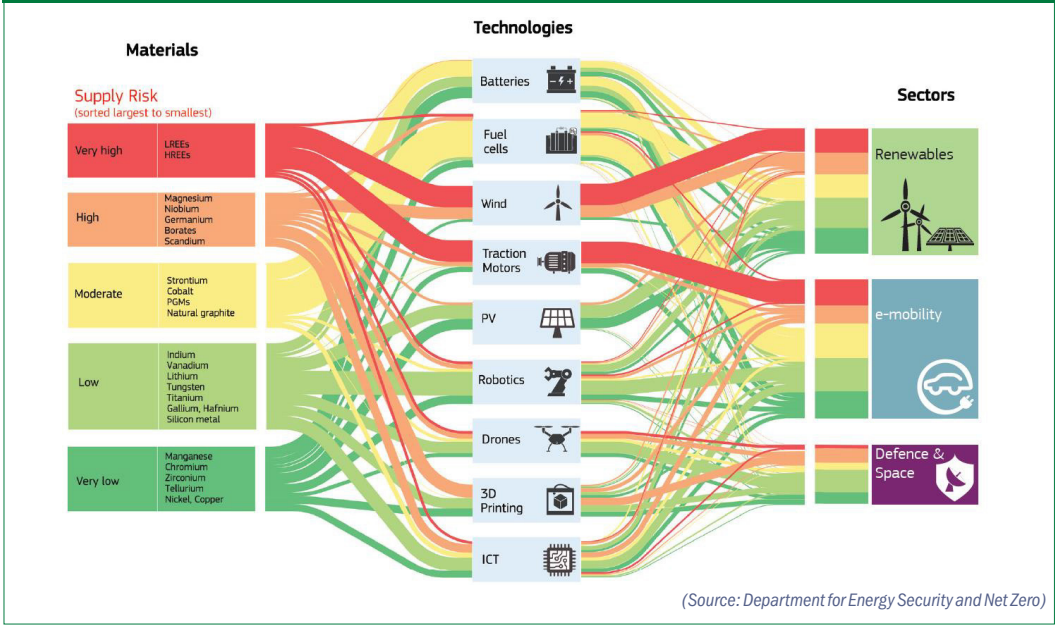
Markets

We must accelerate the growth of the UK's domestic markets and collaborate with international partners to enhance and make our international markets more responsible. During this process, we established two key initiatives: the

Professor Paul Monks CB is the Chief Scientific Adviser (CSA) for the Department for Energy Security and Net Zero (DESNZ). As CSA, he delivers independent and impartial science and engineering advice to ministers and policy makers across the department's policy and delivery portfolio and Clean Energy Superpower Mission. He also works closely with the Government CSA, the cross-government network of departmental CSAs, and the DESNZ Chief Analyst, to strengthen the links within and across departments, encouraging effective engagement and knowledge sharing, and to support delivery of a robust evidence base to underpin policy decisions. Prior to joining the department, he was Pro-Vice Chancellor and Head of the College of Science and Engineering at the University of Leicester, where he remains a Professor in Atmospheric Chemistry and Earth Observation Science.

There are significantly more critical minerals involved in the power production of renewable technologies compared to conventional ones.

Figure 1. Drivers of critical mineral demand



(Source: Department for Energy Security and Net Zero)

Critical Minerals Expert Committee, and the Critical Minerals Intelligence Centre. These committees are among the best I have worked with, as they comprise a diverse mix of academia, industry economists, producers, and midstream financiers. This diversity allows us to obtain a comprehensive understanding of the critical minerals sector and emphasises the UK's role as a hub for critical thinking on minerals. The Critical Minerals Intelligence Centre continuously monitors supply chains and projects future supply and demand.

A core aspect of our strategy focuses on economic vulnerability regarding the supply of minerals in the UK compared to global availability. Assessing criticality poses challenges, particularly in looking backward while also projecting forward. Currently, we are considering the assessment for late 2024, which expands from 18 or 20 to 34 minerals in our strategy, reflecting the evolving criticality of these materials and their applications within UK supply chains. Before we discuss upcoming changes to the strategy – typical of the government's approach – it is important to look at key components of the previous strategy. These include domestic production, skills development, research and development (R&D), and circular economy initiatives. While the UK has a limited supply of some minerals, we possess significant knowledge and skills, along with some of the world's top R&D in this area. We are focused on promoting circularity and diversifying supply chains by collaborating with UK companies operating overseas. Our diplomatic, trading, and development relationships have been effective – I have worked with our partners who are engaged with British industry in various supplier and processing countries. We also recognise the necessity of responsible operations, adhering to the highest environmental, social and governance (ESG) standards.

Moving forward

The sector has a checkered history regarding these issues, and consumers are increasingly demanding ethical practices. No one wants to see child labour involved in mining minerals for their vehicles. The London market is one of the largest mining finance markets globally, and we have achieved several successes.

Recently, the UK Government invested £28 million in Cornish Metals, while the UK Infrastructure Bank added approximately £24 million in equity investment to Cornish Lithium. New companies, such as Green Lithium in the North East, are emerging alongside established entities like Pensana and Rare Earths, which are involved in reprocessing rare earth magnets. Additionally, innovative firms like HyProMag is pioneering hydrogen recycling methods to recover rare earth magnets from computer disk drives.

While we have made significant strides in innovation and R&D, as demonstrated by projects like the CLIMATES initiative, which seeks to build a more sustainable supply chain in rare earths, we continue to invest heavily in this area. One of the UK's real strengths is its international partnerships. We are recognised as a fair broker in many discussions, and during my international missions, various countries express interest in accessing our skills and R&D capabilities. We

have established several bilateral agreements, and are actively engaged in multilateral initiatives. A notable example includes the Mineral Security Partnership, which is heavily led by the US, and we anticipate changes to this partnership as we proceed.

I have provided an overview of the importance of minerals in our changing world. As we work towards decarbonisation, these minerals become increasingly vital. They are globally mobile and extracted from the earth, but it is the midstream processes that facilitate their movement. We need a comprehensive strategy that incorporates all the elements shown on this screen to ensure safety, security, and economic growth in this sector. □

DOI: 10.53289/TERL8867

The risks and the impact

Gavin Mudd

SUMMARY

- The British Geological Survey assists the UK Government in achieving its goals regarding critical minerals
- Our technology and reliance on it are evolving rapidly. With this comes a need for more diverse range of metals, minerals, and materials
- We are primarily concerned about risk management – specifically, the risks of not having essential materials due to supply chain issues, conflict and other impacting factors
- While not all elements are labelled as critical, such as molybdenum and cadmium, they remain essential in various contexts and are monitored as part of forecast studies with regard to decarbonisation efforts
- The dominance of China in supply chains, particularly concerning EV batteries and electrolysers, illustrates a significant geopolitical challenge which needs careful addressing.

One of the first questions I often get is, "Why is Australia a mining powerhouse, and why would you come to the UK?" Well, I think the answer is clear: the opportunities here and the chance to contribute to the changes happening in the world are significant. As an import-dominant country, the UK needs to tackle problems like a more circular economy, planning for technological evolution and other issues. So, for me, this presents a great opportunity, and I am very happy to have the chance to join the British Geological Survey.

I want to discuss The UK 2024 Criticality Assessment, some of the issues we face, as well as share about the foresight work being led by my colleagues, Dr Evi Petavratzi and Dr Pierre Josso, among others. First, why do we exist? Our primary purpose is to assist the UK Government in achieving its goals regarding critical minerals. There is a recognition that critical minerals are not just important for clean energy; they affect every sector of the UK. I want to highlight that the last criticality assessment in 2021 only assessed 26 elements, mainly those related to decarbonisation and digital technologies. We have broadened our focus since then; our job is to look at everything associated with critical minerals, including understanding changes over time.

Risk management

We are primarily concerned about risk management – specifically, the risks of not having essential materials like niobium or lithium. Even helium falls into this category. We often grapple with the language we use, but we are fundamentally discussing risk management to ensure we understand the risks and can make informed decisions. Not only do we need a more diverse range of metals, minerals, and materials, but we also need more of them. Our technology is evolving rapidly. Often, the first thing we reach for today is a phone or perhaps a tablet, which shapes how we engage with the world. One interesting fact about mobile phones is that approximately 70% of the value within a smartphone stems from gold. This is what funds recycling efforts.

When considering circular economies and supply sources, there are many examples to examine. For instance, in the late 1970s and early 1980s, civil unrest in the Congo severely disrupted cobalt supply. As a result, the aerospace industry had to substitute cobalt with other alloys due to high costs. Once stability returned to the Congo, cobalt supply was restored over the years. More recently, the 2012 Marikana riots in South Africa raised concerns about the availability of platinum group

Dr Gavin Mudd has over 25 years experience researching the environmental and sustainability issues of modern mining. Starting from groundwater, his career has expanded to look at environmental impacts of mining, key sustainability trends, life cycle assessment, governance, regulation, global mineral resource assessments and critical minerals – Dr Mudd's experience includes how we mine and use almost the entire periodic table and is a world-renowned scholar in sustainable mining and critical minerals. Moving from academia in Australia, Dr Mudd joined the British Geological Survey in December 2023 as Director of the Critical Minerals Intelligence Centre.

MARCO VERCH CC-BY 2.0

Approximately 70% of the value within a smartphone stems from gold, which is what funds recycling efforts.

elements. Without these, vehicles that rely on them for catalytic converters and exhaust systems – no catalytic converters would lead to dramatic worsening of our air quality. Interestingly, despite the Marikana riots, the price of platinum remained stable, which highlights a common misconception: we often overestimate the impact of such events on prices. On the other hand, the rare earth crisis involving China and Japan in 2010 did lead to a significant spike in rare earth prices. We aim to integrate various examples like these to assess supply risk.

The specific methodologies we use are outlined in detail in our reports. As we worked through the criticality assessment, we have made some adjustments to our methodologies. First and foremost, we consider production: identifying the source countries of essential raw materials needed for the UK. We also analyse global trade and the largest net importers, as part of our comprehensive risk assessment.

We do not differentiate between the individual sectors unless we specifically state that we are analysing their uses and examining the gross value added. This is where we utilise economic data to assess, for example, how much steel is consumed in construction versus how much is used in the automotive industry. This helps us begin to understand and calculate various impacts.

The traditional approach involves assigning a minimum value for economic vulnerability and a minimum value for supply risk. For instance, in the 2021 assessment, tantalum and tin were deemed critical, whereas germanium and nickel were not. If we adopt a risk management approach, we find that a high consequence-low probability event is a medium risk, which is equivalent to a low consequence-high probability event (also a medium risk). In risk management, these should be treated the same. We have adjusted our methodology to determine what is critical more effectively by using this risk-based approach. Our analysis indicates that the overall risk associated with nickel is comparable to that of tantalum and germanium, suggesting a more nuanced approach is necessary.

What is critical – and what is not?

We expanded our scope from 26 elements in 2021 to 82 elements and minerals, including various industrial minerals like kaolin, which have low associated risk because the UK is a significant exporter. This positions these materials as non-critical for us. When comparing various elements, we can analyse their standing, including iron, nickel and copper. A common concern arises about copper, as it is used extensively in infrastructure, homes, phones, and increasingly in electric vehicles (EVs) and renewable energy technologies. Currently, copper is well supplied globally, which places it lower on the supply risk scale, despite its significant value. However, there are future concerns about copper's ability to meet the growing demands for net zero targets, which we consider a longer-term issue.

Our data crunching focuses on the period from 2018 to 2022. Interestingly, the EU's positioning for elements like iron, nickel, and copper is similar to the UK's. From a risk management perspective, even though iron is well supplied, it is still considered critical for the UK, indicating a notable difference from the EU's perspective. We also have a criticality plot illustrating the relationship between different technologies and the materials they rely on.

While not all elements are labelled as critical, such as molybdenum and cadmium, they remain essential in various contexts. In our ongoing efforts, we have initiated foresight studies that anticipate the next 25 years of decarbonisation technologies. The studies assess a range of renewable energy sources and electric vehicles. The accompanying graphic represents different elements needed by 2050, with larger bubbles indicating a greater total requirement and, consequently, more supply expansion needed. Conversely, smaller bubbles suggest lower risk. Our team at BGS, led by Dr Petavratzi and others, has examined scenarios from the National Grid regarding energy and the tracking of various elements over time in relation to technological evolution. When we analyse these results, we can see the dominance of China in supply chains, particularly concerning EV batteries and electrolysers. This illustrates one of the significant geopolitical challenges we are currently facing – how to effectively address these dynamics. □

DOI: 10.53289/MMGZ6251

Risks and rocks

Sarah Gordon

Sarah Gordon is the co-founder and CEO of Satarla sustainability and risk management, co-founder of the not-for-profit Responsible Raw Materials and production company Critical Productions. She has also recently been appointed as a Professor of Practice at Imperial College London.

SUMMARY

- We require a wide variety of materials for energy transition-related tech and for other essential items used in our daily lives. We must make decisions now on where our finite volume of materials will be sourced from and allocated to
- Science and technology is key to ensuring we maximise the use and value of materials we already have in circulation – for example through designing products for reuse rather than recycling or discarding as waste
- We may need to change our expectations and behaviours to use what is available to us – for example, cars that may not travel as far as we are used to on a single charge
- Mining of additional minerals and metals should be a last resort, but is currently neces-sary. The unlocking of natural resources should be a positive for the local community and economy, and business models should support this
- We should use transdisciplinary approaches to revolutionise how we extract the materials we need
- We cannot alter the physical rocks, but we can improve our understanding and interpretation of the data related to them.

The first-ever critical mineral strategy for the UK was only published in 2022. This was in part instigated by COP26, the major climate change summit held in Glasgow in 2021. Back in 2021, the connection between the world of rocks, minerals, metals, and the technology needed for the energy transition had not yet been widely recognised, especially here in the UK. However, one country had already made that connection – China. One of the reasons why China dominates this field is that they skilfully developed their minerals strategy over 40 years ago and executed it exceptionally well. This puts the rest of the world at a crossroads: do we play catch-up, or do we change the game?

How can science and technology support the UK's Critical Minerals Strategy?

I believe science, technology, innovation, and research and development can significantly influence the contents of our new Critical Minerals Strategy. One of the UK's many strengths is in science and technology, therefore we should be able to develop new designs for standard technology that currently wastes or uses excessive volumes of critical materials.

The future is where we begin to understand our needs: we require various materials for technologies related to the energy transition and for essential items like ventilators. We must make decisions now on where these materials will be allocated – whether they will be directed towards batteries and wind turbines or utilised in other areas. The reason materials are termed critical is that we need a wide array of them to sustain our lives. Moreover, as I highlight a major aspect of this discussion, it is important to note that we should not mine materials unless absolutely necessary. Most people perceive mining negatively, partly due to a lack of understanding regarding its processes. As someone who has lived and worked on many mine sites around the world – starting out as an exploration geologist – I can attest that mining often faces scrutiny. It is a perspective we need to address in our discussions today.

What can we change?

Regarding the future and the critical minerals we need, there is fundamentally one thing we (as humans) cannot change: the natural rocks themselves. They of course change over millenia, but no matter how hard we wish that we might be sitting on a resource of valuable materials, it is only there if the Earth's natural processes have put them there. The most important people in this room are the geologists! We cannot alter the physical rocks, but we can improve our understanding and interpretation of the data related to them. Regardless of our efforts or beliefs, the rocks themselves remain unchanged. This leads us to a critical discussion point: what do we need? This is where assessments come into play, albeit with a broad perspective that may need refining as we consider our future needs and priorities in mineral resources.

Recycling and changing behaviours

Currently, much of what we refer to as recycling is actually downcycling. For example, when we take a car, strip it down, and discard its components into the steel production process, we are not maximizing the value of those materials. I remember

We should respect and preserve valuable resources like copper rather than throw them away as scrap metal.

an event at the Institute of Physics a few years ago where I was shocked to learn that one of the least valuable types of steel, known as rebar, contains approximately 0.42% nickel and 0.31% copper. To put that into perspective, there are copper ore bodies being mined right now that have a grade (or concentration) of just 0.31%. From a geological standpoint, this seems irresponsible; we should respect and preserve valuable resources like copper rather than throw them away. The reason we do this is that the steel and scrap industry prioritises volume. They often do not or cannot take the time to figure out better ways to extract and utilize these materials. This creates a complex situation where science, metallurgy, economics, and market forces clash. It begs the question: how can we revolutionise our approaches and practices? While we can certainly change our behaviours, encouraging people to use less electricity is a significant challenge, especially as the world moves forward and seeks development. So, how do we make these necessary changes? The answers lie with everyone in this room. It is our expertise, imagination, and creativity that will drive progress. We also need to cultivate a willingness to challenge each other. I am sure we have individuals from various disciplines present here, and the real innovation often occurs when we step into that uncomfortable zone of unfamiliarity, where new ideas emerge. To harness this potential for innovation, we must encourage conversations across disciplines.

Ultimately, in addressing the critical minerals aspect of our examination question – how can science and technology support the UK's strategy? – we need to rethink our approach. Current material flows are constrained, so we must innovate to meet future demands. □

DOI: 10.53289/KHXC2741

Critical minerals and battery technology

Emma Kendrick

Emma Kendrick is Professor of Energy Materials, School of Metallurgy and Materials, University of Birmingham and co-lead of the Energy Materials Group (EMG). Her research focuses on the design and development of sustainable battery technologies and chemistries. Prior to academia, she led innovations in the battery industry, as Chief Technologist in Energy Storage at SHARP Laboratories of Europe Ltd (SLE) and as Lead Scientist of two lithium-ion battery SMEs, Fife Batteries Ltd and Surion Energy Ltd.

SUMMARY

- Classification of materials as "critical" varies by region
- In a battery, mixed lithium, manganese, cobalt and nickel oxides are carefully engineered and then formulated into an electrode coating onto metal foils.
- Most lithium mining occurs in Australia, and nearly all of it is shipped to China for processing. The lithium is then distributed worldwide
- Cobalt is typically a secondary element. Around 70% of the world's cobalt is sourced from the Democratic Republic of Congo (DRC), and most of it is shipped to China where the refining takes place before worldwide distribution
- To enhance sustainability, we could reduce the reliance on critical materials, explore the re-use of batteries and their components, and focus on recycling. One possibility is to increase the energy density of our devices.

I would like to present a case study focused on technology and the understanding of critical materials within that technology, specifically batteries. As a battery scientist, I aim to illustrate how innovations can impact the use of critical materials and how we might reduce the quantity of these materials in our battery technologies.

Battery science

Let us start by discussing the basic structure of a battery. For those who may not know, a battery consists of two main components: the anode and the cathode. The anode is typically made of graphite, which is classified as a critical material or mineral. The cathode, on the other hand, is commonly composed of a mixed metal oxide that includes lithium, nickel, cobalt, and manganese. It is important to note that the classification of these materials as "critical" varies by region. For example, in Europe, lithium, manganese, and cobalt are considered critical, while nickel is categorised as a strategic material due to its low supply chain risk. In a battery, these materials are carefully engineered and coated onto metals. The anode, made of graphite, is connected to a copper current collector, while the cathode, formed from mixed metal oxide, is attached to an aluminum current collector. These materials are precisely

CALISTEMON/WIKIMEDIA COMMONS

The open pit of the Greenbushes lithium mine in Western Australia. Australia accounts for more than half the world's lithium supply.

designed to create spherical particles that pack together efficiently, maximising energy storage in a small space while allowing enough space for electrolytes to flow. The electrolyte is responsible for transporting lithium ions between the anode and cathode. During battery operation, lithium ions move from the graphite anode to the cathode, while electrons flow through the external circuit.

Materials

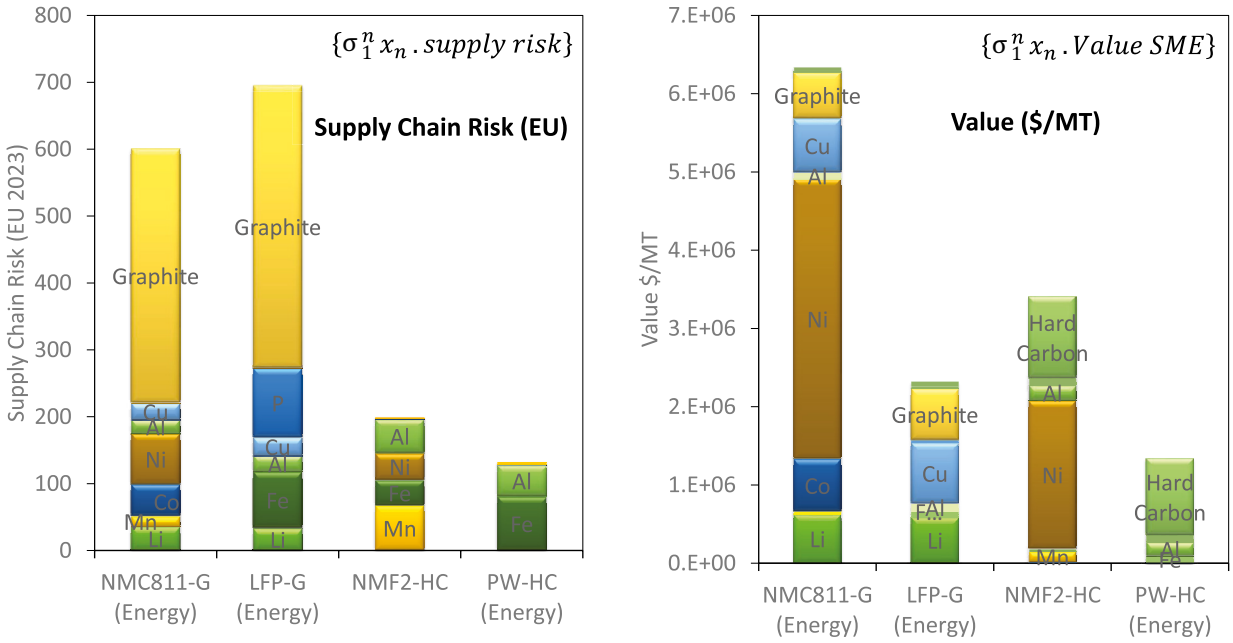
I will now focus on a case study involving specific materials. Firstly, lithium, particularly in the context of the European critical materials list, which has been established for some time. In 2024, we will begin analysing data from the recent UK critical materials and minerals list. Globally, two primary regions produce lithium. Australia accounts for over 50% of the world's lithium supply, while the remainder primarily comes from South America, specifically from salt flats or brines. In these regions, brines are pumped from salt lakes, allowing the water to evaporate, which leaves behind concentrated lithium deposits that are then exported and refined. Australia extracts lithium from a rock called spodumene. Most of the lithium mining occurs in Australia, and nearly all of it is shipped to China for processing. Once processed, the lithium is then distributed worldwide.

The story of cobalt, nickel, and copper is quite different. Cobalt is typically a secondary element obtained from various ores, such as copper or nickel ore. In fact, around 70% of the world's cobalt is sourced from the Democratic Republic of Congo (DRC), and most of it is shipped to China where the refining takes place before it reaches the rest of the world. When we discussed nickel as a strategic material, we noted that its supply chain risk is significantly lower. Europe has a considerable number of nickel refineries and some nickel and copper mines, which helps to mitigate the supply chain risks associated with these materials.

Sustainability

So, what can we do to enhance the sustainability of these technologies? One approach is to reduce the reliance on critical materials, explore the reuse of batteries and their components, and focus on recycling. This aligns with the well-known waste hierarchy for sustainability. To minimise material usage, we can first increase the energy density of our devices. By improving energy density, we require less material overall. Additionally, increasing the lifespan of battery technologies can play a crucial role in sustainability since longer-lasting materials mean a smaller initial value chain. To achieve this, battery manufacturing can incorporate substitutions. For instance, we can consider substituting lithium with sodium or cobalt with iron. Sodium is abundant, including sources like soda ash in the UK and seawater, which is globally available. However, substituting lithium with sodium comes with trade-offs; sodium is heavier and larger, which reduces the overall energy density and average voltage. On the other hand, iron is far

Figure 1. Supply chain risk



(STEPHENS, ISABELLA D. R. AND SLATER, PETER RAYMOND AND KENDRICK, EMMA, A PERSPECTIVE ON CELL BILL OF MATERIALS USING BATPAC.JPS, 2025, HTTPS://DOI.ORG/10.1016/J.JPOWSOUR.2025.236170)

Using this data we can begin to compare the quantities of materials used in these different technologies and how these impacts both the cost and the supply chain risk associated with these minerals.

more abundant and globally available compared to cobalt, and it is also significantly cheaper. In battery technology, substitutions can be made by replacing lithium with sodium and adjusting the electrolyte, as well as swapping graphite for hard carbon. Additionally, we can substitute copper for aluminum and replace cobalt with iron. Currently, there is a new battery technology being developed in China that focuses on these substitutions, particularly for use in lower-range vehicles.

Recycling in relation to batteries

If you take a Nissan LEAF battery cell and disassemble it to recover its materials, a typical method would involve shredding. This process essentially destroys the intricate engineering that went into creating the battery with its carefully crafted components. After shredding, the challenge is to reclaim and purify the resulting materials. If we could disassemble battery cells instead of shredding them, we could separate the materials with less waste, making the process potentially more economically viable. This raises an important question about innovation: can we design new battery technologies with disassembly in mind? By designing for easier disassembly, we can enhance material recovery while minimizing waste. When discussing substitution in battery technologies, we can compare different types of chemistries.

In Figure 1, I have examples of nickel manganese cobalt (NMC), lithium iron phosphate (LFP), and two types of sodium-ion technologies. We can begin to compare the quantities of materials used in these different technologies and how these impacts both the cost and the supply chain risk associated with these minerals. For instance, in lithium-ion technologies, graphite poses a significant supply chain risk, as 99.9% of battery-grade graphite comes from a single country: yes, that's China. Additionally, when we look at the value of materials, nickel, cobalt, and copper have the highest values. Therefore, there is a strong economic incentive to recycle these materials. On the other hand, if we consider lithium iron phosphate and some sodium-ion technologies, which contain lower-value components, we need to find a way to reclaim those materials as well. Ultimately, we must ask ourselves: what happens at the end of a battery's life? If there is no economically viable solution for recovering these materials, what will become of them? □

DOI: 10.53289/BJDE2755

Nissan LEAF batteries are typically shredded to recover the materials inside.

The debate

Following the presentations, the speakers at the event formed a panel and took questions from the audience. Some of the key points included social governance , ethical issues, bio-recycling and robotic disassembly

The first question from the audience was, how much does geopolitics play a part in thinking around mining of critical minerals? Panellists responded by saying that vulnerability (with regards to the availability of critical minerals), is a key aspect when thinking about gaining entry to a country which holds certain rocks. Geopolitics can provide a barrier to accessing some countries, but critical minerals can also provide an enabler. An example given by one panellist was about the rocks in Afghanistan and Iran which, so far, are not being looked at by many British companies but have potential, with 'risk appetite'.

We cannot change where the rocks are, but we can change which rocks we mine said another panellist. We can choose to mine in different places, but the question many experts are grappling with is: what are the market conditions to enable this? One enabling assessment criterion is the recycle input rate. Recycling is very important when looking at new minerals and rocks. If we can start doing more to recover the materials to recycle and reprocess them, that will improve where we stand on new rocks in 'new' locations.

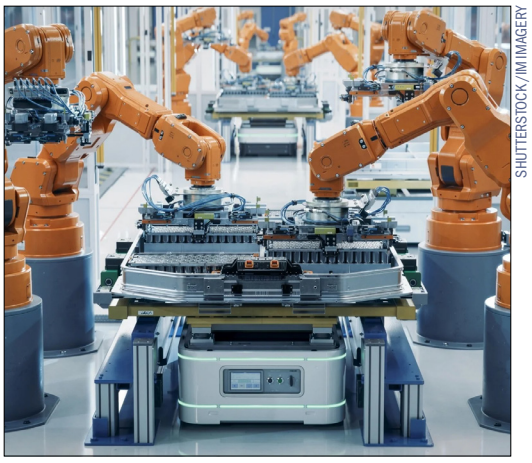
Are there any plausible biological processes that can help recycle or change existing components into valuable resources? One panellist said that there are a lot of smart people designing enzymes to break down plastics and change core elements. She said that the relevance of this work with regards to critical minerals is demonstrated in some work going on in Edinburgh where teams are looking at the extraction of metals from batteries using enzymes. There has got to be a better way to extract resources from batteries than to grind them down to 'black mass' and then try to repurpose, said another panellist.

Answering this, another panellist said that there is currently no economic way to disassemble batteries safely, and safety is important. Shredding is a safer process but if we could start looking at robotic disassembly for example, there would be no people involved. She went on to say that you could start separating all of the components of the cell (such as graphite) without impurities of other elements. This lack of impurities would be helpful in the manufacturing process later.

Innovation can play a big part in the future of a more circular critical minerals extraction process, but we should not be afraid of regulation, said the panel. The right regulation can enable some positive outcomes, especially with regards to recycling and extraction of critical minerals in a more circular fashion.

The Government representative on the panel said that one of the main jobs of the Government's Critical Minerals Strategy is to raise awareness of the problem, scale and levers that can be used. The simplification of ESG Standards (the set of criteria used to assess a company's performance in the areas of environmental, social, and governance factors) could be useful in addressing ethical issues around country conflict, which are associated with the mining of critical minerals. Battery passporting could also help address the ethical supply chain question. He said that we have a Corporate Governance Code which means that companies here in the UK are accountable, whether they are working regionally or in other countries. Governance is something that the UK can bring to the international table as a speciality.

A final question from the floor asked whether a mine can ever be a good partner for social mobility and biodiversity gain. One industry based panellist said that mining companies could "shoulder the responsibility" of bringing different communities together with regards to mining critical minerals. She said that there are some examples of companies doing this. It may not support profit straight away, but it can help support social and nature 'capital'. Science and technology can help change the way we mine – making it cleaner, more efficient and safer. □



SHUTTERSTOCK / IM IMAGERY

Robotic disassembly could be one way to safely extract resources from batteries.

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

The FST podcast invites senior figures across science, research, technology and innovation to take a deep dive into their field of expertise

www.foundation.org.uk/Podcasts

Services for Learned and Professional Societies

The Foundation assists a wide range of **learned and professional societies** with regulatory, administrative, governance and policy matters. This bespoke support is available to societies who are members of the Foundation.

- Bespoke support provided by the Foundation's Learned and Professional Societies Liaison Officer
- Access to almost 50 guidance notes on a variety of relevant topics, including data protection, professional discipline, conflicts of interest, Royal Charters and more
- A quarterly newsletter that covers relevant legislative and regulatory developments, news, events and consultations
- Access to the newsletter archive, dating back to 2001
- Invitations to Foundation for Science and Technology events throughout the year

www.foundation.org.uk/Learned-Societies

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

Wednesday 8th October 2025, 5:30pm
The Royal Society, London

In Conversation with Professor Dame Ottoline Leyser

In this event, Professor Dame Ottoline Leyser DBE FRS, the recently retired Chief Executiive of UKRI, will be in conversation with Rt Hon Lord (David) Willetts FRS, Chair of the Foundatiion for Science and Technology.

This wide-ranging conversation will explore topics across UK science and technology, both looking back at Dame Ottoline's tenure in UKRI and looking forward to the future.

There will also be an extended period to take questions from the audience.

CONTEXT

The UK science community have played a central role in space science missions over several decades, and the UK was a founder member of the European Space Agency (ESA), which celebrates its 50th anniversary in 2025. On Wednesday 30th April, the FST held a discussion event to explore what the scientific impact of the UK's leading role in space science missions over the last decades has been. The event also looked at how the UK's expertise in space science has fed through to its dynamic and growing space industry sector.

Our panel of expert speakers included Professor Carole Mundell, Director of Science at the European Space Agency and Head of the European Space Astronomy Centre; Professor Adam Amara, Chief Scientist at the UK Space Agency and Dr Tudor Williams, Chief Technology Officer at Filtronic.

A video recording, presentation slides and speaker audio from the event are available on the FST website at: **www.foundation.org.uk/Events/2025/How-can-space-science-missions-advance-science,-dr**

How Europe is pushing boundaries in space science

Carole Mundell

SUMMARY

- The ESA science programme aims to enable world leadership in cutting-edge science and technology, empowering its 23 member states to drive global and interdisciplinary space science initiatives
- The quest for breakthrough discoveries drives technological innovation and economic growth, while inspiring the next generation of thought leaders
- Despite challenging global circumstances in 2022, ESA's budget was increased by 17%, reflecting the importance of space to its member states governments
- Europe has many proud space science accomplishments including landing on Saturn's moon Titan – still the most distant ever landing made by humanity – and the Rosetta mission that landed humanity's first probe on a comet. Current missions span a wide array of scientific inquiries, from near-Earth heliophysics to the fundamental nature of spacetime
- ESA's zero debris charter and sustainability charter enshrines the agency's commitment to responsible space mission delivery from cradle to grave.

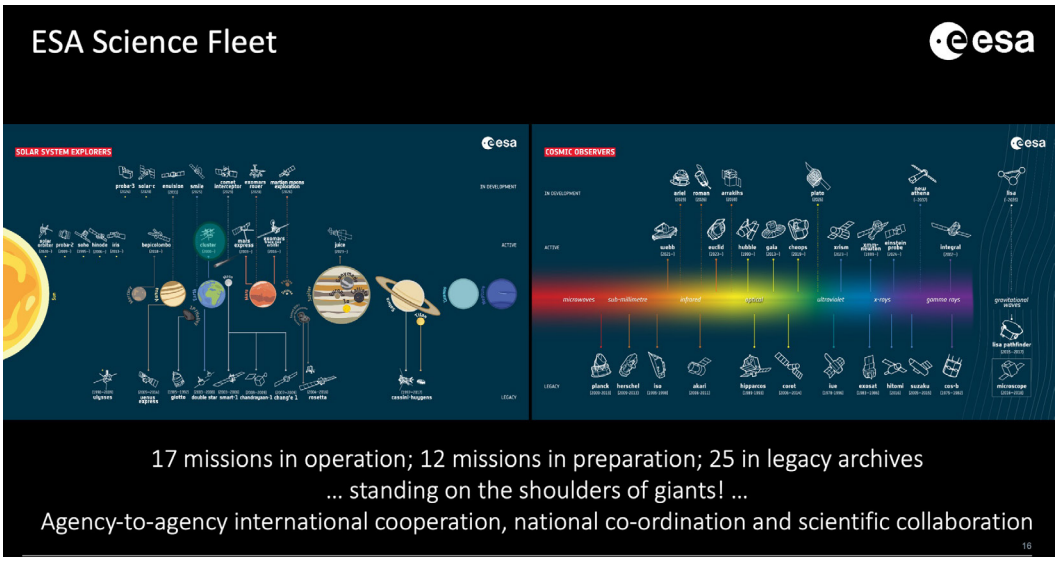
As the director of science at the European Space Agency (ESA) for the past two years, I have come to appreciate the diverse perspectives surrounding ESA's science programme. Often, when we think of science, we envision brilliant scientists in offices, and it begs the question: why do we need all this funding? I want to emphasise that it is not just about scientific inquiry but also about technology, engineering, and economic growth. Our programme is strictly designed to cost; we do not request open-ended funding from our ministers. Each mission within the science programme is crafted to be cost-effective, requiring us to operate at ruthless efficiency. This year marks a significant milestone for ESA for two reasons.

First, we are celebrating 50 years since the agency's founding; the UK is a founding member. 50 years ago, ESA emerged from the merger of the European Launcher Development Organisation and the European Space Research Organisation. The science programme serves as the backbone of our agency, and we aim to make it even stronger for the future. Additionally, we are welcoming Slovenia as a full member, bringing our total to 23 member states. Every three years, we gather our ministers to discuss funding for ESA. In 2022, despite challenging global circumstances—like the cost of living crisis and the Ukraine conflict—our member states increased the ESA budget by 17%. It is inspiring to see such commitment across political lines, that acknowledges the importance of space and power of working together across national borders for common interests.

A founding programme within the ESA portfolio, the science programme forms part of the mandatory programme for member states, ensuring their investment yields direct benefits and

Professor Carole Mundell is an internationally renowned scientist with extensive experience in inclusive leadership, operational management, strategy and international science policy development. She joins ESA from the University of Bath where she held the Hiroko Sherwin Chair in Extragalactic Astronomy, was founding Head of Astrophysics, and served as Head of the Department of Physics until becoming the first woman Chief Scientific Adviser at the UK's Foreign and Commonwealth Office in 2018 and first Chief International Science Envoy in the Foreign, Commonwealth and Development Office until 2021. She was elected President of the UK Science Council in 2021.

ESA's current missions span a wide array of scientific inquiries, from near-Earth heliophysics to the fundamental nature of spacetime.



member states industries and scientific communities can plan their activities over ths short, medium and long term. Co-ordinating the diverse ambitions, interests and capabilities of 23 countries is a challenge I relish! At its core, the goal of the science programme is to enable leadership in cutting-edge science and technology, empowering member states to drive global space science initiatives. One excellent example is our Euclid mission, which has garnered attention for its world-leading cosmological contributions.

Our missions

This scientific programme allows for long-term sustainability, with multi-year budgeting that benefits industry planning. Our long-term implementation strategy has evolved through a bottom-up process from the scientific community, shaping missions that are competitively proposed and selected. In turn, European industrial competitiveness is crucial for the implementation of these iconic missions and for delivery value for money to member state taxpayers.

To give you a sense of what Europe is capable of, look at our accomplishments over the past two decades, such as the incredible landing on Saturn's moon Titan and the Rosetta mission that landed on a comet. These successes illustrate Europe's growing capabilities in space science and exploration. We are continually innovating, with a focus on efficiency and effectiveness in our missions – underpinned by scientific excellence – exemplified by our upcoming projects such as those aimed to launch in 2028. Our current missions span a wide array of scientific inquiries, from near-Earth heliophysics to the fundamental nature of spacetime itself. This year, the ESA Director General will present his new budget proposal to our member states and their ministers will gather in Bremen, Germany in November to agree on our level of resources for the coming three years. In this, our 50th Anniversary, it is clear that Europe through ESA leads the world in fundamental 'big' science and there is a clear imperative for a stable and healthy budget to ensure sustained global leadership in the coming years: without investing in technological advancements now, we risk a gap in our mission capabilities and loss of scientific talent and engineering/technology industrial competitiveness.

In addition to drawing together our 23 ESA member states in scientific collaboration on missions that no single country could achieve alone, the excellence of the ESA Science programme has long been a vehicle for international collaboration with other leading space agencies such as NASA and the Japanese Space Agency (JAXA). We each have our unique areas of leadership and strategic alignment across our missions enables us to do even more to foster innovation, economic growth, peaceful dialogue and cultural understanding.

The Sun

We have a long history of studying our closest star – the Sun. Flying at the moment, very close to the Sun is our wonderful Solar Orbiter mission. All of our missions operate in the most extreme conditions: deep space, hot and cold temperatures, magnetic fields, particle fluxes and radiation. Solar Orbiter is delivering a range of scientific 'firsts' – with exquisite resolution, the Sun's surface is being imaged in great detail and we have real-time measurements of the hot plasma dynamics, magnetic fields, rotation and radiation. Deeping our understanding of the Sun is critical in todays' modern technological era in order to help our colleagues in planetary defence and space safety protect space and ground-based assets when the Sun is most active, and to understand its impact on the Earth even when it is in its less active phases.

But perhaps the most important capability of Solar Orbiter will come soon when we start to manoeuvre the spacecraft out of the plane of the Solar System in which the Earth orbits the Sun. We will gather humanity's first ever view of the poles of the Sun. This will be a triumph of spacecraft flight dynamics from our ESA missions operations colleagues – and an ambition of US and Chinese scientists, who would like future Solar missions from their own space agencies to also have this capability.

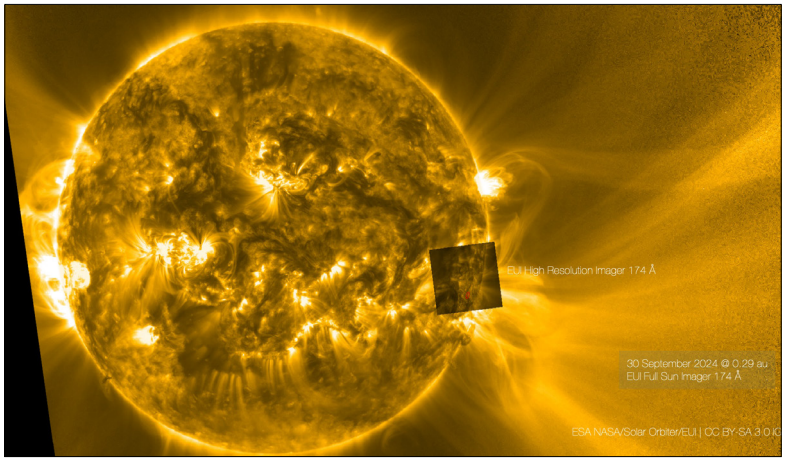
Venus, Jupiter's moons, Mercury and beyond

In order to change the trajectory of Solar Orbiter, we used gravitational slingshots around Venus to change its speed and orbital plane. We never miss an opportunity for extra science and so we used the Venus flyby to gathered valuable data about the planet. These data are a small taste of what will be possible with our upcoming Envision mission to Venus in 2031, which will study the planet from its upper atmosphere to its core, exploring a very hostile environment that has temperatures of 420 degrees Celsius and about 1000 atmospheres of pressure and answering why our sister planet is so different from the Earth.

To give you an example of the extreme conditions we work in, there is the BepiColombo mission we are running with JAXA, the second and most complex mission ever to orbit Mercury. In the background of one slide, you can see Mercury passing the limb of the sun, which truly illustrates its harsh operating environment. We are facing engineering challenges with power transfer from solar panels, but we are overcoming them with clever methods and gravitational assists. We will settle into orbit around Mercury in 2026 to release two probes. Even with just 30 minutes of flyby data, we have mapped Mercury's magnetic fields and captured the first thermal mid-infrared photographs of its surface.

Looking now to the outer Solar System, we launched a new mission in 2023 called JUICE – Jupiter Icy Moons Explorer. This mission aims to determine whether Jupiter's icy moons could be habitable for life. While we will not land, we believe there might be salty liquid oceans beneath their icy crusts. We are using gravity assists to reach our destination, having already conducted a flyby between the Earth and Moon, gathering significant scientific data along the way.

Now, bringing everything together, we hope to secure funding for a future flagship mission that will fly to Saturn, tour its icy moons and land humanity's first-ever astro-biology laboratory on a distant planetary body. The target destination will be the surface of Saturn's moon Enceladus.



Soon we will gather humanity's first ever view of the poles of the Sun. For ESA, this will be a triumph of spacecraft flight dynamics.

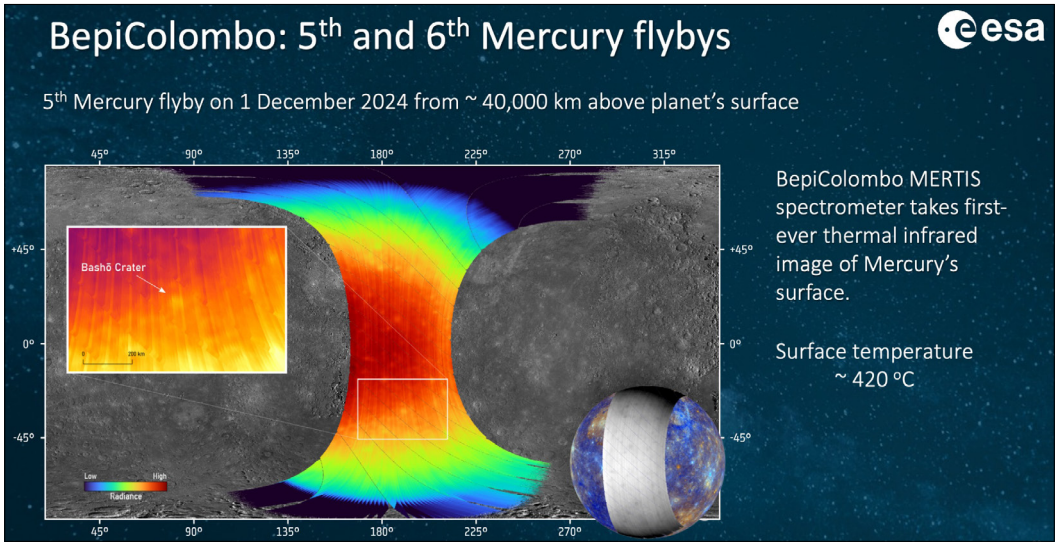
Scientists believe that Enceladus is the most likely location in the Solar System for detecting signs of life beyond Earth. And the race is on. We already have a cosmic deadline for landing – 2052, when the south pole of Enceladus is illuminated by the Sun and planetary alignments are optimal.

This may sound far in the future, but we must launch the mission in 2043, and so all of the technology for this exciting and ambitious mission must be developed ready to begin building the mission by 2034. We need a modest budget increase this year to put that technology development on a firm footing and grow the capabilities in our member states industries. One of the biggest challenges will be power for the lander. We have a strict mass limit, so innovative instruments must developed – miniaturised, but highly sensitive and robust. We need a very special battery to power the laboratory on the surface and all of the operations at Saturn will be autonomous and intelligent because real-time operational communications are impossible so far from Earth.

We won't just limit ourselves to our Solar System; we are also extending our search for habitable exoplanets. Although we cannot travel to planets in distant solar systems, our Plato and Ariel missions will gather the light from distant planets and their host stars, seeking Earth-like planets around Sun-like stars and studying the atmospheric chemistry of thousands of distant worlds. Detecting signs of life in our Solar System will be profound. Discovering signs of life beyond will be transformative and answer one of humanity's biggest questions – are we alone?

The Lisa mission, which was endorsed for implementation on the same day in 2024 as our Envision mission, will together see an investment of 2.6 billion euros into our member states industrial and scientific ecosystem. LISA – the Laser Interferometer Space Antenna – is actually three identifical spacecraft that will fly in convoy in an Earth-Sun orbit to form humanity's first space-based gravitational wave interferometer. The

With just 30 minutes of flyby data, BepiColombo has mapped Mercury's magnetic fields and captured the first thermal mid-infrared photographs of its surface.



technology and precision engineering required to realise this mission is exceptional. The three spacecraft will fly in a triangular configuration, each separated by 2.5 million kilometres and aligned by lasers to within the size of an atom's core. As ripples in spacetime caused by catastrophic cosmic events such as the violent merger of supermassive black holes reach LISA, the minute disturbance in the positions of the spacecraft – and therefore the distance between them – will be measured and scientists will probe the fabric of spacetime directly. These ripples – named gravitational waves – were predicted from Einstein's General Theory of Relativity and were proven to exist in 2015 when the first gravitational waves from the merger of two small black holes were detected by the ground-based LIGO interferometer. LISA will open a new window on the dark gravitational universe and push the frontiers of our understanding of the laws of physics.

LISA builds on a long history of European leadership in precision space-science missions. This year sees the culmination of the Gaia mission – our billion-star mapper which over its 11.5 year lifetime has revolutionised our understanding of the formation and evolution of our home galaxy, the Milky Way. This mission has also transformed the way we serve science: the Gaia consortium of over 400 scientists working to analyse the data has enabled unexpected discoveries across astrophysics. The study of more than 150,000 asteroids in our Solar System and the discovery that 350 of them have little moons of their own. The discovery of hidden black holes in our own Milky Way galaxy that are 10, 20 and 30 times more massive than our Sun, whose formation mechanisms are yet to be understood and whose precursors will likely act as cosmic calibrators for our LISA space system. Being able to precisely measure tiny wobbles in the trajectories of billions of stars is a new way to discover hidden cosmic objects.

ESA has a strong pedigree in space navigation. Standing on the shoulders of giants, Gaia epitomises an even longer history of using the night sky for navigation, from Hipparchus in 150 BC, to scientists like Flamsteed and Brahe where improvements in precision of a factor of 1,000 were achieved over 2,000 years – painstaking work and impressive and important advances of the day. In contrast, the leap into space has yielded a 10,000-fold increase in navigation precision within just 25 years!

Long-term planning and an inspirational future

In this short talk, I can barely scratch the surface of the array of novel and ground-breaking technologies we create with our member states, building missions to tight budgetary constraints and stringent delivery schedules. But I hope I have given you a flavour of European ambition, capability and the translation of wonder into real-world impact.

While we often must invent novel and innovative technologies to deliver the scientific goals of our ESA missions, we also work hard to enable technology transfer to industries beyond space. The 'molecular sniffers' on board Rosetta's Philae lander are now used in the perfume industry; the accelerometers developed by the UK for our Plato and ExoMars missions are useful in a wide range of transport systems and perhaps in the future in automous vehicles.

Our space science strategy and rolling business plan for the coming ESA Ministerial Conferences in 2025, 2028, and 2031, emphasises long-term sustainable planning, business growth and globally leading break-through science.

And we look forward to continuing to deliver to our member states and international partners for the next exciting 50 years and beyond. □

DOI: 10.53289/YDTP1864

Government-funded space science is remarkable

Adam Amara

SUMMARY

- The space sector is a vibrant community and one that is open to fresh ideas
- Government-funded space science often embraces risks, strive for the seemingly impossible and tackle challenges that are difficult to measure or quantify
- We need to do a better job of showcasing the work of the UK Space Agency
- We are at an inflection point in the space sector and one of the most pressing challenges we need to address is the skills gap
- 'Euclid' is set to make significant strides in our understanding of dark energy and is an excellent example of a mission done well, that catches the public's attention.

Professor Amara believes that space has become an integral part of our culture. He has collaborated with dedicated civil servants who are working to implement outstanding programmes, and with strong leadership in Europe to coordinate our efforts. He says that one of the most rewarding aspects is how receptive the space sector is to fresh ideas.

When discussing science and exploration programmes, he says that there is something remarkable about government-funded space science. These projects often strive for the seemingly impossible, tackling challenges that are difficult to measure or quantify, with risks that might feel overwhelming. By embracing these risks, we can achieve groundbreaking discoveries and foster innovation, which, can then be commercialised by the industry to enhance efficiency. Indeed, space science is at the forefront of innovation. Professor Amara says that, while NASA often steals the spotlight, the amazing work here in the UK also deserves recognition. However, we need to do a better job of showcasing our achievements. A successful science programme opens pathways for new discoveries and Euclid is on track to do this, alongside many other missions. If executed effectively, these programmes can inspire and engage the public.

Bringing the public along

Interestingly, while only a small percentage – about 8% – is dedicated to the science component, it is often the science that captures public interest and imagination more than other aspects of the programme. Professor Amara says that this underscores how a well-conceived space initiative can both unlock cosmic mysteries and drive economic progress. At its core, a successful programme pioneers new findings. However, given the scale of these initiatives, we must ensure that we take the public along for the journey, engaging their imagination with significant, relatable questions. From a UK standpoint, it is vital that we leverage our existing strengths to establish ourselves as leaders in future missions, while also utilising this participation to cultivate new capabilities. In the UK, our involvement in these science programmes has significantly spurred technological advancement. It is crucial to recognise that the innovators behind these technologies are our neighbours; they are part of our culture and ecosystem, not just distant experts working for NASA. Professor Amara stresses that we need to communicate this narrative more effectively.

A UK inflection point

The space sector is a massive, ever-growing field expected to reach a trillion dollars by 2030. In the UK, we have consistently seen growth of about 8% across all relevant metrics – be it revenue, job creation, or number of firms – regardless of wider economic fluctuations. We are facing an inflection point. The pressing question is how committed we are to the future of our space sector. One of the most pressing challenges we need to address is the skills gap. Many companies voice this problem and it is puzzling because so many children are fascinated by space and dinosaurs. So how did we miss the mark? Professor Amara says that educators and career advisors are often surprised to learn about the innovative work happening right in their communities, as they tend to assume it is all happening with experts in the US.

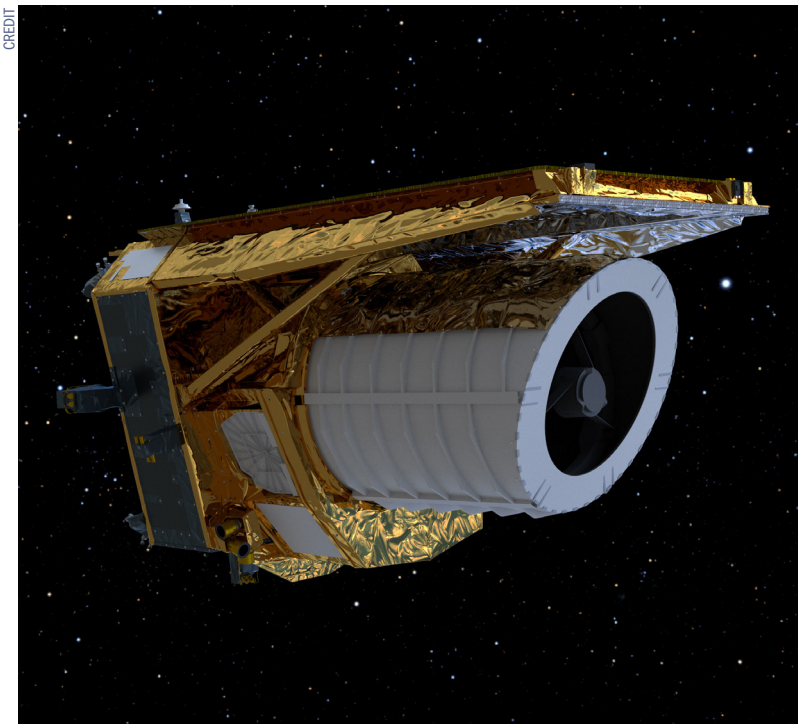
Focusing on the astrophysics of the universe, the UK has pioneered imaging technology. The detectors that flew with ESA's Gaia mission, the biggest digital camera ever launched into space,

Adam Amara is Professor of Cosmology at the University of Surrey and Chief Scientist at the UK Space Agency. His research explores the fundamental nature of the Universe, with particular focus on dark energy, dark matter and cosmology. He has made major contributions to a range of large international science missions, combining academic expertise with industry collaboration.

NOTE

This is a summary of Professor Amara's talk and, as such, is written in the third person.

CREDIT



An artist impression of ESA's Euclid mission in space.

were built here in the UK and led us to Euclid, which produces the most precise wide-field images out there, also a result of UK technology. Through earlier missions like Planck and Herschel, Professor Amara says that we developed sensors that measure minute temperature changes, which has allowed us to create thermal imaging cameras that are among the best in the world. Additionally, advancements in cryogenics, drag-free flight technology, and laser Lidar have all been driven by British innovation. While we have world-leading scientists across various domains, such as Jupiter, Mars, galaxies, the Milky Way and dark energy, one of our challenges lies in our ability to collaborate effectively. We must align our efforts and build a united front to enhance the incredible science we conduct.

Professor Amara says that industry also faces issues, including low production volumes of highly complex hardware, making it difficult for companies to invest in commercially viable innovation. Funding cycles that have gaps can create a feast-or-famine scenario, affecting some companies' stability. It is crucial to address these challenges.

Skills and retention

There are straightforward measures we could implement regarding skills and retention, as well as tackling financial pressures and the fragmentation of our ecosystem. Professor Carole Mundell has led significant work on ESA's long-term implementation plan, which aims to create a more stable programme landscape with a variety of missions, enabling more participants in the space race.

Better engagement between academia and industry is essential, even though ESA has traditionally positioned itself between scientists and industrial studies. Other countries supplement their ESA efforts with additional programmes, a practice the UK has struggled with in the past. However, the UK Space Agency is taking steps in this direction by initiating new bilateral programmes. Early engagement in missions is vital. If we wait until a mission is ESA-adopted, it becomes challenging to lead, even with skilled scientists and engineers, as projects are usually in their mature stages by then.

Professor Amara looks at the case study of Euclid. One of the key takeaways from this project is the importance of early engagement. At that time, the UK was not particularly strong in this area, so the team ventured to France for initial studies, which ultimately positioned them advantageously. The Euclid team were able to shape the mission concept from the outset, securing leadership and establishing technology transfer. Initially, Euclid was going to be a small mission led by a single country, but it became a groundbreaking mission that could succeed under the ESA's Cosmic Vision programme.

Another lesson learned was the necessity of being bold and audacious. Although it was believed that only the US could lead dark energy missions, the UK Space Agency set out to change that perception and successfully designed a remarkable dark energy mission. They leveraged existing achievements, specifically the expertise built through the Gaia project, and combined that with a strong knowledge of weak gravitational lensing to push the boundaries of European space science.

Euclid is set to make significant strides in our understanding of dark energy, with a target to measure the equation of state parameter with 2% precision. This ambitious goal involves thousands of scientists and engineers over a span of a decade and promises to shed light on the universe's expansion and its cosmic origins.

In conclusion, Professor Amara says that a successful experiment must pioneer discoveries, and Euclid meets that criterion. It captures the public's imagination and leverages our existing capabilities, while also creating future strengths in data management and processing, an area we need to develop further. It is crucial for the space agency to support the transfer of innovation, especially regarding data, to ensure our academic work translates effectively into industry applications and benefits broader society. □

DOI: 10.53289/OGTH4499

Breaking into the space industry as a business

Tudor Williams

SUMMARY

- When I joined Filtronic three and a half years ago, we had limited presence in the space sector. Now, that area has become core to our business
- Filtronic's partnership with Space X marks our significant entry into the space industry
- To stay competitive in the comms market, we have had to carve out a niche
- ESA funding has been transformational, allowing us to build new capabilities and explore new markets
- Science programmes provide the guidance we need and the opportunity to explore what we may be selling in five or 10 years.

I wanted to share some insights about Filtronic's journey into the SatCom market, which has been quite an adventure for us. Although we are relatively new, we have seen rapid growth in this area. For many companies outside the space industry, figuring out how to break in can be intimidating. It seems like a significant leap, and I will outline our experiences as we navigate through it, emphasising what our company stands for and our trajectory. I will also reflect on how science and business can shape the future of electronics.

Growth

We focus on design and manufacturing RF and microwave subsystems for payload and ground systems, as well as Aerospace and Defence applications. These components facilitate the communication links – typically high-frequency data connections – between satellites and the ground. Our company has been a leader in the RF and microwave domain for over 40 years, originally starting at Leeds University with a focus on filters. While our roots are in telecoms and defence, when I joined the company three-and-a-half years ago, we had limited presence in the space sector. Now, that area has become core to our business. When I joined, our revenue was around £16 million annually, which grew to £25.4 million last year, with estimates suggesting around £55 million this year. This rapid growth has included expanding our team from 110 to 180 employees over the last year, particularly increasing our engineering team from 30 to 80, which is quite a challenge in the UK job market.

We operate from the north-east of England, where we have a factory. We also have satellite operations around the UK to attract top talent to enhance our design capabilities. In terms of our growth journey, we are relocating to a new head office in NETPark, Sedgefield, County Durham. We will be moving into a larger facility that is twice the size of our current space, with six times the manufacturing space, which will significantly boost our manufacturing capacity.

Space X

Our growth has been driven by the emerging "new space" market, where there is a shift from complex geosynchronous satellites to large Low Earth Orbit (LEO) constellations of thousands of satellites. Companies like SpaceX have revolutionised this space, emphasising the importance of cost-effective solutions that have a lifespan of seven to 10 years. Our partnership with Space X marks our significant entry into the space industry. Announced in April last year, this collaboration focuses on the ground segment, which is generally more accessible than payload systems. SpaceX is known for being highly vertically integrated, producing many components in-house. Thus, our partnership is quite unique and indicates the value Space X sees in our offerings. Our journey continues to evolve, and we are excited about the future.

A small SME with core capabilities

At Filtronic, we have some core capabilities here in the UK, operating as an SME that competes with the best in the world at what we do. Our leading performance in millimetre wave solutions speaks volumes about our expertise. We work at very high frequencies, and coming from a communications background has pushed us to always be at the forefront of technology. To stay competitive in the comms market, especially in the UK, we must carve out a niche, as a lot of similar work is done elsewhere, particularly in Asia, where costs are lower.

Over the last 10 to 15 years, we have made significant advancements in developing high-

Dr Tudor Williams is a strategist in the fields of space, communications, semiconductors, and defence. He currently serves as the Chief Technology Officer at Filtronic, where he collaborates closely with business development and engineering teams to shape the company's technical strategy and roadmaps. In this role, he also manages industry and academic partnerships and secures funding for strategic roadmap projects. Dr. Williams holds a Master of Engineering (MEng) in Electronics and Communications Engineering from Swansea University and a PhD in RF/Microwave Engineering from Cardiff University.

CREDIT

Filtronic's partnership with SpaceX marks the company's significant entry into the space industry.

frequency links, such as the E-band products we provide to SpaceX, which operates at 81-86 GHz. Manufacturing and designing these components are a challenge, as many can make a few units, but scaling production is incredibly difficult. Mike Nichols at SpaceX has praised us as a strong partner, noting our ability to keep pace with their rapid development. Growing our team from about 30 to 80 people in such a short time has been impressive, enabling us to maintain our engineering capabilities alongside SpaceX. Looking forward, after our work with SpaceX has laid a solid foundation for revenue growth, we aim to expand our offerings to other satellite companies and constellations.

Sector support

Diversification is crucial, and thanks to the support of the UK Space Agency and the European Space Agency (ESA) through the ARTES programme, we are developing new hardware for payloads. Without this support, we might not have been able to take the investment risks necessary for this project.

The ESA funding has been transformational, allowing us to build new capabilities and explore new markets. This funding is not just financial; it comes with a dedicated team of engineers from ESA, assisting us in developing our capabilities and skills, making us a true space company. On our side, we are developing payload modules that facilitate high-frequency data links from satellites to the ground at Ka and Q/V-band frequencies, allowing for substantial data transmission.

R&D roadmap

Our R&D roadmap is full, highlighting our rising profile since our association with SpaceX. As we grow our team, we are also exploring ways to diversify, particularly moving down in frequency, which reflects new market opportunities in both commercial and military satellite communications. We are attentive to the growing UK military satellite capabilities and feel well-equipped to participate in that sector, leveraging both our engineering and manufacturing skills.

In addition, we are partners in the ViaSat D2D programme, looking to facilitate direct satellite communications with mobile phones. This project leverages cutting-edge technology, and I am excited about our involvement. While we have not yet ventured into science missions, we are eager to participate. These initiatives offer insights into long-term technological investments that are often difficult for commercial enterprises to pursue, as they focus on immediate needs.

Science programmes provide the guidance we need and the opportunity to explore what we may be selling in five or 10 years. By engaging with these programmes, we can build product foundations for future commercial and defence markets, turning visionary ideas into revenue streams. The feedback from the UK Space Agency's research informs us on the technological landscape, helping us align our efforts with industry demands. □

DOI: 10.53289/VGWY1226

The debate

After the presentations, the speakers joined a panel to answer questions from the audience on a variety of topics, including encouraging young people into STEM, fragmention within the sector and sustainability.

The first question from the audience concerned the skills gap. How do we encourage more young people into STEM and importantly, help to maintain interest through secondary school and beyond? A panellist said that we could do better by 'training the trainers' – talking to and engaging teachers and educators to help them to understand the application side of STEM and pass this on to young people. Another panellist said that there is something in the 'prestige' of the STEM sector that is attractive. Visibility of industry is important. Can young people image themselves in these jobs? The gender pay gap does not help, and we are losing a huge pool of talent because of this. Visibility of women in the sector here in the UK is key to encourage more young women to come into the sector. There are lots of jobs that will "pay the mortgage" in the space sector, but we need to do more to communicate this to families. The other aspect of the skills gap is lack of experience. There is not enough people who have "touched hardware" or have engineering experience to employ. We need to create programmes that build experience, not just classrooms for theory.

Fragmentation

Another question to the panel was how wider public bodies could support academia and government to connect lots of the good work going on in a seemingly fragmented ecosystem, with the wider public. One panellist said that we need to change our communications mentality around science. He said that we live in a peer-reviewed world, but that we should place more value on going out into the world and communicating the science to everyday people, not just other scientists. Another panellist challenged this point saying that she felt that the UK had a strong science communication culture but connecting the UK's space-science ecosystem to start-ups and capital needed developing.

With regards to getting more young people into STEM, FST Chair Lord Willetts chimed in to say that the early specialisation in the UK's education system was a "big problem". He said that we are expecting 14- and 15-year-olds to make decisions on their professional life and we need to change our culture around this. In the US system, the biggest single group of applicants for university courses are "not yet decided". They spend their first year of university trying out a range of different subjects and choosing a major after that. That then changes the culture of explanation. The academics will pitch their subjects to their students, bringing STEM subjects to light and engaging students with their expertise.

INSTAGRAM.COM/KATYPERRY

Katie Perry's mission to space has been controversial, but has got people talking about space.

Controversy

Katie Perry's mission to space came up briefly and panellists said that it has caused a lot of controversy but that it has got people talking about space which is positive.

A question around connecting sustainability issues on earth with space missions was answered by the panellist representing the European Space Agency (ESA) as Director of Science there. She said that ESA have a very strong Earth Observation Programme which is world leading for Europe, they are also looking at sustainability of the space environment. She said that space is becoming crowded and that Spectrum and Low Earth Orbit is contested. ESA has a voluntary Zero Debris Charter, which companies and countries can sign up to. It is a value proposition that can't be policed, but ESA hopes that by behaving in the right way, it will mobilise public support to make sure that everybody also behaves well in space. Concern was voiced around recent announcements of cuts to NASA programmes dealing with climate science and climate monitoring. There was support for David Attenborough's comment on one of his recent documentaries about the Earth, which said that to bring everybody together in thinking about our planet in a sustainable way, we must first view it from space. ❐

CONTEXT

On 14th October 2024, the UK Government published a Green Paper entitled Invest 2035: the UK's modern industrial strategy. The Green Paper outlines the initial proposals from the new UK Government on developing an industrial strategy to help deliver economic growth. It sets out eight growth-driving sectors, discusses skills, and notes the importance of research, development and innovation, among many other aspects. The Green Paper asks several questions, and the Government sought responses to these by way of a consultation.

On Monday 2nd December 2024, the Foundation held an evening discussion at The Royal Society to explore how science and technology can contribute to the industrial strategy, and provide a useful input to the Government as it develops its thinking. Speakers at this event included Dr Julia Sutcliffe, Chief Scientific Adviser at the Department for Business and Trade, Professor Mariana Mazzucato, Professor in the Economics of Innovation and Public Value at the University College London, Dr Peter Waggett, UK Director of Strategic Relationships at IBM Research Europe and the Rt Hon Greg Clark, Executive Chair of Warwick Innovation District, and former Secretary of State for Business, Energy & Industrial Strategy.

Note: The UK Government published its new Industrial Strategy on 23rd June 2025. You can view it here.

A video recording, presentation slides and speaker audio from the event are available on the FST website at: **www.foundation.org.uk/Events/2024/How-can-science-and-technology-contribute-to-the-U**

Two perspectives on industrial strategy

Julia Sutcliffe

Professor Julia Sutcliffe was appointed Chief Scientific Adviser at the Department for Business and Trade in February 2023. Julia is responsible for providing expert, independent advice to Ministers and policy teams, and for developing the department's system for accessing and using science and engineering evidence. She works with the cross-government network of departmental Chief Scientific Advisers and the Government Office for Science to resolve cross-cutting issues and maximise cross-governmental insights. Julia holds an Honorary Professorship at the University of Manchester in computer science, is a Chartered Engineer, and a Fellow of the Royal Academy of Engineering and the Royal Aeronautical Society.

SUMMARY

- For businesses to turn a profit, they must innovate and the role of science and technology is vital. However, converting that technology into trade is extremely challenging
- Without an aligned ecosystem, innovation cannot thrive
- Growth is the number one mission of this government, and a modern industrial strategy is central to this mission.

I would like to present two perspectives that I hope will complement those of my fellow speakers. The first is that of an end user, drawing from my extensive experience in industry where I have felt the implications of an industrial strategy. The second is that of an insider, as a civil servant in the Department of Business and Trade, which co-leads the UK's Industrial Strategy with the Treasury. This gives me an insider's view.

The first perspective

Prior to my role in Government, I was the Chief Technologist at BAE Systems' Air Sector, where I spent around 25 years in the technology-intensive aerospace, defence, and security sectors. During this time, I worked both domestically and internationally, collaborating with companies of all sizes, academics and entrepreneurs. It may seem obvious, but for businesses to turn a profit and stay ahead, they must innovate, transforming ideas and technology into tradable outcomes – competitive products and services. Whether it is developing robotics for human-machine teaming in a digitised factory,or applying new materials to reduce the carbon footprint of aircraft, the role of science and technology is vital. However, converting that technology into trade is extremely challenging.

Many factors must align. Technology must be ready at the right time, and we know that different technologies mature at varying rates. Consider the rapid refresh rate of phone handset technology compared to the long development cycle of quantum sensing for brain imaging. Development cycles, service lifetimes, and business models all differ significantly and require careful planning and agility.

Moreover, the right skills must be available – not just technical skills, but also those that help businesses deliver programmes, scale operations, raise finance, and manage risk. Without a comprehensive skill set, innovation cannot thrive. Additionally, the necessary infrastructure – physical, digital and data infrastructure – is crucial for connecting the ecosystem and enabling development, testing, qualification, and certification. Without

Business face consistent challenges, whether establishing floating offshore wind capabilities, such as the 2.3 MW Hywind, or developing a supply chain for semiconductors used in batteries for electric vehicles.

this infrastructure, innovation struggles to flourish, and products cannot reach the marketplace.

Regulation is another factor. We expect innovative, disruptive technology to challenge established practices. Therefore, it is crucial for regulators to be part of the innovation journey and to have the incentives that allow them to support growth. Access to finance is essential at every stage of the innovation process, whether for large corporations or university spinouts. Innovators need access to capital throughout their development journey – from lower technology readiness levels to higher, more complex stages, and into the marketplace.

Competition for market access and market share is a vital part of business strategy. Successfully delivering competitive products to the right market at the right time is critical. Often, the domestic market may not be sufficient, necessitating access to international markets. These challenges are consistent, whether establishing floating offshore wind capabilities or developing a supply chain for semiconductors used in batteries for electric vehicles. Overcoming these hurdles requires a unified vision and coordinated resources among Government, industry, and academia. Targeted investments can accelerate collaboration, drive onshore innovation, and create self-sustaining ecosystems. This fosters the exchange of ideas across different sectors and builds enduring expertise through the people, businesses, institutions, and communities developed over time. This demonstrates the potential of a well-conceived industrial strategy.

When I joined the department two years ago, my first question to the Permanent Secretary was whether we would create an industrial strategy; I was pleased to find that my wish had come true.

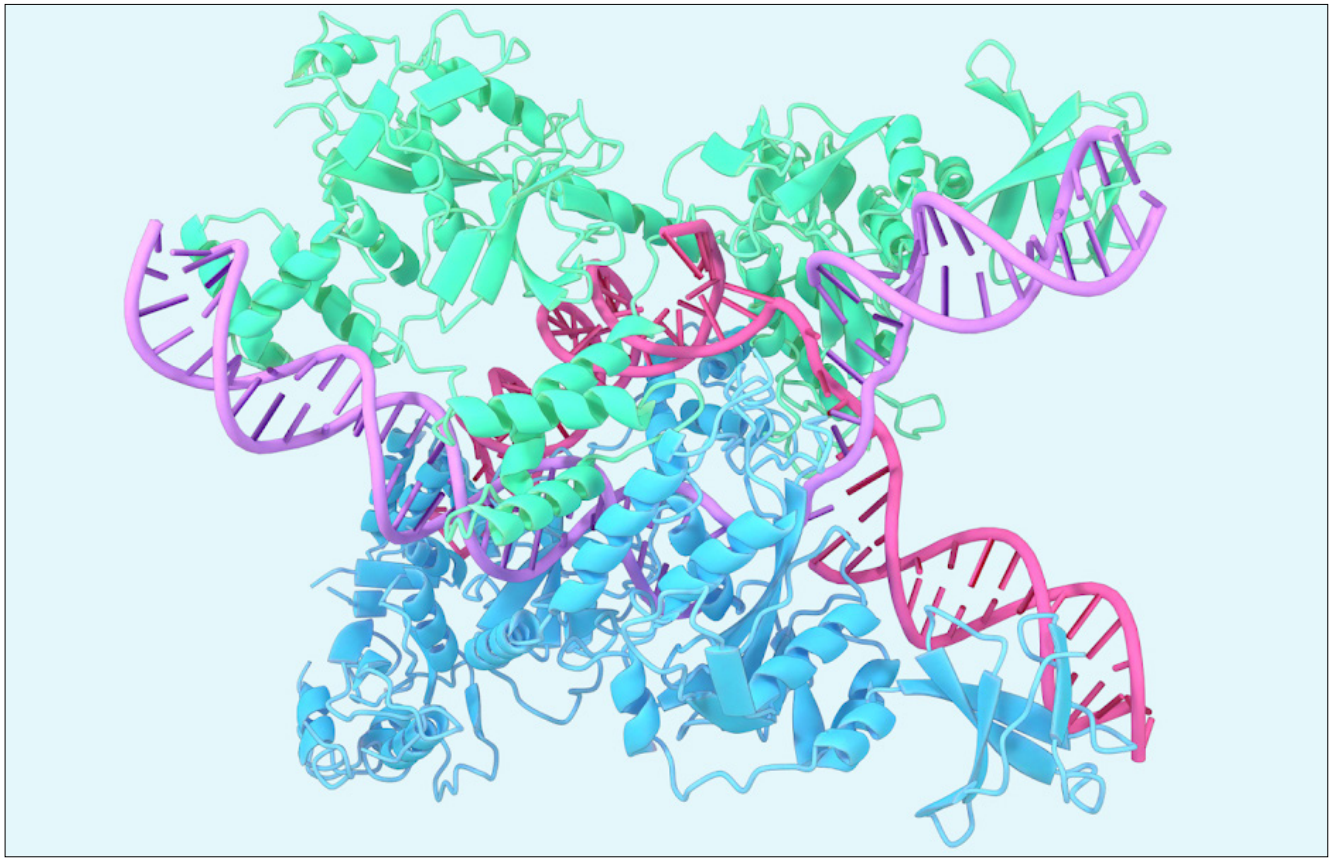
The second perspective

From my role on the inside I can say that growth is the number one mission of this Government. A modern industrial strategy is central to this mission. Our Green Paper outlines this vision for a modern industrial strategy and aims to invest in a 10-year plan that provides the certainty and stability businesses need to invest.

We all recognise that the current context is challenging. In the 20 years leading to the global financial crisis, productivity grew by around 2% per year. In the (nearly) 20 years since, however, it has grown by less than 1%, which has resulted in significant challenges. Yet the opportunity to build on our strengths is substantial. The UK possesses high-quality research capabilities, innovative firms, a favorable global trade outlook, trusted regulatory frameworks, and a highly skilled workforce.

Our goal is to support the adaptation and growth of the UK's already successful services and manufacturing sectors while seizing opportunities to lead in emerging sectors that create high-quality, well-paid jobs and shape sustainable growth. We are committed to supporting net-zero initiatives,

GOOGLE DEEPMIND



AlphaFold, developed by Google DeepMind, predicts a protein's 3D structure from its amino acid sequence. The latest freely available database release contains over 200 million entries.

regional growth, and economic sustainability.

Policy will be guided by long-term stability and the strategic coordination of efforts. Our commitment to free and fair trade, alongside an improved investor journey, will involve collaboration with local and regional leaders, devolved governments, and businesses. Science and technology will be crucial in driving growth across growth driving sectors.

Growth driving sectors

Our industrial strategy will channel support to eight key growth-driving sectors – those in which the UK excels today and will excel tomorrow. These are:

1. **Digital and Technologies:** Our strong foundations enable a technology ecosystem valued at over a trillion dollars, ensuring we develop and grow new businesses while underpinning innovation in existing sectors.
2. **Advanced Manufacturing:** This sector accounts for nearly half of the UK's private sector R&D investment, generating over $200 billion annually.
3. **Life Sciences:** With around 7,000 businesses generating over £100 billion in turnover, advancements in AI technology such as AlphaFold showcase the innovation potential in this field.
4. **Defence Industry:** Supporting over half a million jobs, this sector applies advanced technologies that often benefit other areas of the economy.
5. **Clean Energy Industries:** The transition will involve significant investments in new technologies, projected to create over a trillion pounds in opportunities by 2030.
6. **Financial Services:** As a global financial centre, our potential for exports is enhanced by technological advancements in areas such as FinTech.
7. **Creative Industries:** The UK ranks as the third-largest exporter of creative services globally, increasingly influenced by technology.
8. **Business and Professional Services:** Contributing £174 billion in exports in 2023, this diverse sector presents vast opportunities for growth.

To maximize these opportunities, we need an integrated approach where academia, industry, and regulators work together to stimulate growth and remove barriers.

Thank you to all who engaged in the green paper consultation. Our teams are diligently working on synthesising the feedback as we build the foundations for businesses, innovators, and individuals to thrive in this exciting time. It is a privilege to be part of this journey. □

DOI: 10.53289/GKZJ6150

What we can learn from our journeys to the Moon

Mariana Mazzucato

SUMMARY

- The UK's new Industrial Strategy is a step forward in tackling the UK's central issue of a low-investment economy. However, growth is the result of a well-structured mission-oriented industrial strategy, rather than a mission in itself
- Tackling some of our greatest challenges requires a genuinely cross-sectoral approach to industrial strategy. Instead of only focusing on winning sectors, mission-oriented industrial strategy focuses on bold, societal challenges that require innovation and investment across multiple sectors
- Bottom-up experimentation across various sectors is essential in addressing challenges, from tackling our climate, water, and biodiversity crises to making progress on health and digital inequities
- Public-private partnerships should be genuinely symbiotic rather than parasitic, akin to a mutualistic relationship in nature with clear conditionalities that share both risk and reward.

My aim of founding the UCL Institute for Innovation and Public Purpose in 2018 was to bring public purpose back to the centre of our thinking about economic growth, which has not only a rate but a direction. At IIPP we seek to leverage our expertise across multiple areas – industrial strategy, innovation policy, and financial policy – to consider how they can be shaped to tackle significant societal problems. Addressing these problems requires an economy-wide, inter-sectoral approach that necessitates inter-ministerial coordination.

In 2018, we collaborated with David Willetts on the development of a mission-oriented industrial strategy for the UK, through the creation of the UCL Commission for Mission-Oriented Innovation and Industrial Strategy (MOIIS). The question was how to transform an already ambitious strategy, which Greg Clark, had inherited from Vince Cable during David Cameron's coalition government, into something more effective and implementable.

The request was to transform the prior vertical approach – which often involved a random list of sectors that lobbied their way to the top – into one focused on the specific problems that many sectors can collectively address. This meant moving away from a sector-based approach – where we could list sectors like aerospace, automotive, finance, the creative industry, and life sciences – to a challenge-based approach that requires innovation and investment across various sectors. This does not mean we ignored the sectors, but we used specific challenges to ensure investment in them was outcome-oriented and aligned to the overarching goal.

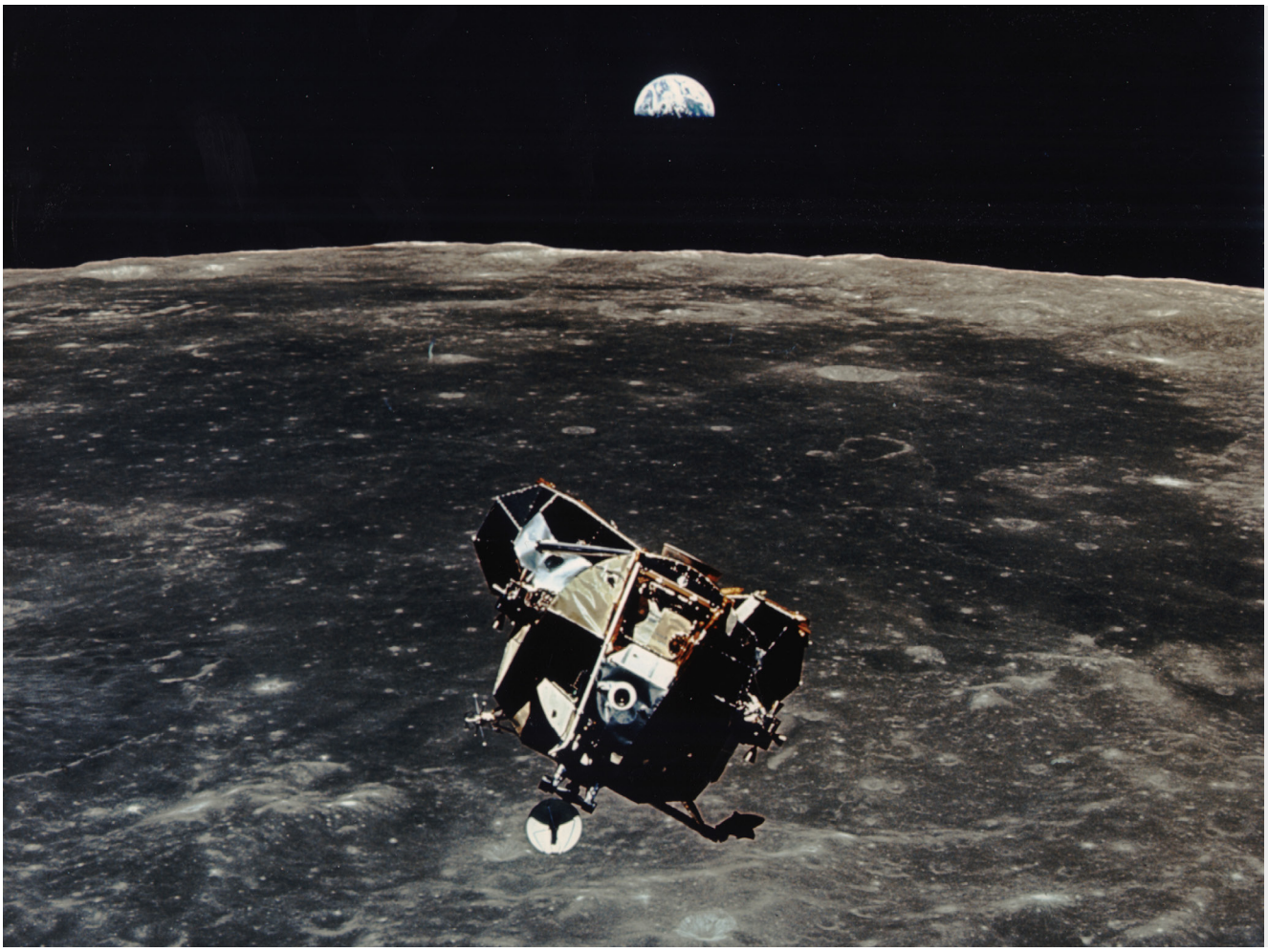
Building blocks

The new Industrial Strategy has returned to a sectoral approach and has selected eight priority sectors rather than asking what we would need from each sector to achieve such goals. The Clean Energy sector plan in the UK's new Industrial Strategy is a step towards this, as it is aligned with the Clean Energy Superpower mission and looks to embed net zero across the entirety of the strategy. However, we still need the foundational building blocks like investment in basic research and development, centres like the Fraunhofer Institute, where science and industry can connect, a skilled workforce, a robust visa system, regulatory policies, and so on.

The reason I wrote *Mission Economy: a moonshot guide to changing capitalism* was to illustrate how we achieved the Moon landing. The challenge was the space race against the Soviet Union's Sputnik, but the ultimate mission was to land on the Moon and return safely within a short timeframe. This required contributions from numerous sectors – not just aerospace. Considerations like how astronauts would eat, use the restroom, and what they would wear involved cross-sectoral innovation spanning nutrition, materials, electronics, and software.

Interestingly, this also required a transformation in government operations. A vital step was changing procurement practices from a cost-plus model to challenge-oriented procurement, which incentivises innovation and investment. This bottom-up experimentation across various sectors is

Mariana Mazzucato is Professor in the Economics of Innovation and Public Value at University College London, where she is Founding Director of the UCL Institute for Innovation & Public Purpose. She advises policymakers around the world on innovation-led inclusive and sustainable growth. Her roles have included Chair of the World Health Organization's Council on the Economics of Health for All, Co-Chair of the Global Commission on the Economics of Water, and Special Adviser to South Africa's G20 Presidency. Her highly acclaimed books include The Entrepreneurial State, The Value of Everything, Mission Economy, and The Big Con.



CREDIT

A giant leap for mankind: genuine mutualistic partnerships facilitated our journey to the Moon.

essential in addressing goals such as achieving net-zero emissions, tackling health-related challenges, and reducing the digital divide.

While it is commendable that Keir Starmer has reintegrated the idea of missions into our conversation, the fundamental point is that growth itself should not be a mission. Rather, growth is the result of an effective mission-oriented industrial strategy. This is because missions demand substantial cross-sectoral investment. Currently, the UK ranks 28th in the OECD for business investment and last among G7 countries for public investment. Had we invested even half as much as the average OECD country over the past two decades, we would have allocated an additional £500 billion. The Industrial Strategy recognises this, and the UK Government has committed £115 billion to increase capital spending, and it is focused on increasing investment from both the public and private sectors.

Business investment is absolutely critical, but relying on so-called business-friendly policies often leads only to tax incentives that boost profits without necessarily increasing actual investment. The current UK Industrial Strategy is focused on promoting the UK as a home for investment through reduction in regulations and so-called 'red tape', rather than leveraging investment through clear mission-aligned policies that signal the priorities of the Government and opening of market opportunities that align with this mission.

In consequence, we miss opportunities for additionality – investments that would not have occurred otherwise. The structural challenges we face, regarding productivity, stem from insufficient investment. So, how do we foster dynamic public-private partnerships? I often refer to them as symbiotic partnerships, drawing on biological terminology. For example, a partnership ecosystem can be predatory, parasitic, or symbiotic; our goal is to build genuine mutualistic partnerships akin to those that facilitated our journey to the Moon. While I appreciate the push towards a mission-oriented approach, I urge us to move beyond mere slogans. Let us leverage this opportunity to transform our industrial strategy, ensuring that growth becomes the outcome.

We need to rethink our understanding of the economy and where value originates. If the state is to take on an entrepreneurial role, we must recognize that value is collectively created, shifting our focus from merely fixing markets to shaping them. A major challenge is that we cannot achieve this if we continue outsourcing civil service functions to

consulting firms like Deloitte. Spending £1 million a day on a test and trace system highlights the lack of investment in our digital governance – a critical area, especially during the COVID-19 pandemic.

At IIPP, we aim to centre strategies like the Net Zero Mission within economic growth discussions. This requires rethinking procurement practices, distinguishing between outcomes-oriented and cost-plus methods, which can foster collaborative intelligence between public and private sectors. Additionally, we must reevaluate intellectual property rights, as the current system allows for overly broad patents that hinder innovation. These rights, granted by the state, should facilitate progress rather than create barriers.

Our work in the London Borough of Camden illustrates the power of participatory strategies, where local citizens engaged in developing a local mission-oriented procurement strategy. Rebuilding trust in the policy-making process is essential for addressing everyday challenges. Countries like the UK can turn significant issues such as climate change and water scarcity into national priorities requiring innovation and investment, thereby turning their commitments to the Sustainable Development Goals (SDGs) into reality.

The Apollo programme serves as a model: beating the Russians was the challenge, while the mission of reaching the Moon required collaboration and grassroots experimentation. By shifting from cost-plus procurement to mission-oriented contracts, NASA achieved remarkable innovations, emphasising the balance between strong direction and bottom-up experimentation vital for future success.

Interdisciplinary approaches

Addressing a big issue such as climate change requires an all-of-government approach, much like the multi-sector effort to reach the Moon. This challenge is not the sole responsibility of the Department of Energy; rather, it demands an inter-ministerial, mission-oriented strategy. The German public bank KfW exemplifies this. Germany's Energiewende Policy has created public funds that require companies in sectors like steel to meet innovation targets to receive loans. This approach has fostered the production of green steel by encouraging practices such as repurposing, reusing, and recycling throughout the production process.

There is significant potential in these initiatives. In Sweden, the goal of creating a fossil-free welfare state extends to school meals, which must be healthy, tasty, and sustainable. This necessitates innovative collaboration between the Departments of Education and Health and the food supply chain. Moreover, we collaborated with Gina Raimondo, the former US Secretary of Commerce, on the CHIPS and Science Act, exploring how grants and subsidies can effectively steer growth in the semiconductor industry. These efforts require us to normalise ambitious goals for societal betterment.

Addressing a big issue such as climate change requires an all-of-government approach, much like the multi-sector effort to reach the Moon.

Boosting semiconductor production

The CHIPS Act, which allocated nearly $400 billion for semiconductor companies, aimed to ensure better worker pay, as many employees were not earning a living wage, and required the use of energy-efficient supply chains. A key condition was that profits generated must be reinvested back into the businesses instead of being distributed as dividends or used for share buybacks. In fact, over $7 trillion has been spent by large US corporations on buybacks, boosting stock prices and executive pay.

The UK has some interesting examples of conditional public investment, particularly at the city level, with initiatives like Camden's green agenda. Residents debated what "green" means for their community, leading to food banks being turned into cooperatives that empower individuals and promote dignity. Public sector capabilities are essential for these initiatives to succeed, highlighting the importance of cross-ministerial coordination. NASA learned this after the Apollo 1 fire, realising that communication was vital for progress. They restructured to ensure constant communication among project teams.

Overall, mission-oriented policies have many myths surrounding them. Our recent report on global insights reveals what works and what does not. While growth is not the main objective, it can result from substantial public and private investments focused on addressing significant societal challenges. The lessons from our journey to the Moon remain as relevant today as they were 50 years ago: ambitious missions require both strong direction and bottom-up experimentation, symbiotic partnerships between public and private sectors, and the courage to embrace uncertainty in pursuit of transformational change. By applying these principles to today's greatest challenges – from the climate crisis to health inequities – we can build economies that work for people and planet alike. □

DOI: 10.53289/GMJX9407

Industrial adoption of new technologies

Peter Waggett

Dr Peter Waggett is IBM's Research Director in the UK. His research interests include the processes around the industrial adoption of novel and disruptive technologies. His current portfolio of projects include the Hartree National Centre for Digital Innovation. The HNCDI is a joint research project between the UK's Science and Technology Facilities Council and IBM. HNCDI provides free training and proof of concept solutions to UK Industry to enable them to understand how industrial competitiveness can be improved through the application of the latest digital technologies.

SUMMARY

- The scientific method remains our best framework for discovery, even in complex scenarios
- The real world is based on quantum principles. We need to utilise the same tools and techniques to explore it and facilitate progress
- The goal of the Hartree National Centre for Digital Innovation is to create a platform for UK public- and private-sector researchers to adopt new technologies to make major improvements to their industrial competitiveness.

I want to discuss the importance of industrial adoption of novel and disruptive technologies as both a standalone field and as an enabling one for the UK. I will outline some of the problems and challenges we face. Finally, I will present the Hartree Centre as an opportunity to explore how we can assist UK industries with real-world challenges.

The critical question we need to consider is how science and technology can help us. Most discussions on growth focus on the economy, often highlighting growth rates of just a fraction of a percent or so. Our challenge has been to explore how we can achieve significant improvements – essentially, how we can reduce cost and time scales by a order of magnitude at least. To do this we need substantial step changes in various areas. The COVID-19 pandemic prompted us to urgently address pressing problems, and while we navigated that crisis, we continued facing ongoing challenges, particularly concerning climate change.

In the face of these challenges, I firmly believe that the scientific method remains our best framework for discovery, even in complex scenarios. Historically, we have seen improvements in life expectancy, GDP per capita, and population growth, even as we tackled significant challenges like the Spanish flu and other crises.

In discussing these trends, I want to highlight the evolution of the scientific method to incorporate all of the tools we have available as technologists. I anticipate backlash, especially from traditional big data technologists. My view is that we are at a critical juncture. We can no longer rely solely on big data approaches – processing more and more data with diminishing returns is clearly unsustainable. Instead, we must adopt a more intelligent approach and be selective in our processing through "accelerated discovery". Essentially, this involves making progress through a cycle of hypothesis, testing, reporting, and feedback using AI and quantum processing to guide which processing we do. The challenge we have set for ourselves, which also underpins our work at Hartree, revolves around the question: What happens if…?

We must use utilise all available technology to address the speed-up of the scientific method. For example, it is important to recognise that, as researchers, it is not possible to keep up with every single publication in a field of knowledge unaided. The volume of data is simply overwhelming for individuals to process effectively. Therefore, can we employ AI-powered deep-search techniques to delve into the data, understand the context, discern the relevance of information, and ensure that we avoid repeating past mistakes and answer our research questions more quickly?

Quantum computing

We at IBM are actively working to develop these capabilities, supported by significant advancements in the hardware and processing we develop and use. Quantum computing technology, in particular, is gaining momentum and presents exciting opportunities. If we think about it, the real-world problems we face are often based on quantum principles and we need to utilise the same tools and techniques to explore it and facilitate progress. This does not mean that traditional high-performance computers will become obsolete; they remain a vital part of the approach. Instead, we are exploring different dimensions to address additional use cases through specialised AI and quantum processing.

You might wonder why this approach is challenging. One part of the answer lies in the work of Geoffrey Moore (for example: *Crossing the Chasm*). He pointed out that the model outlined in traditional marketing and technology textbooks that claims technology adoption follows a

BART VAN OVERBEEKE

One of the key goals at Hartree National Centre for Digital Innovation is to bridge the gap between innovators and businesses.

bell curve for its progress, breaks down with high-technology items.

There is often a significant gap between innovators and businesses that he christened the "Chasm". Technologists understand the technology, while business professionals understand the market, but they often fail to communicate effectively. This disconnect leads to missed opportunities and faltering adoption.

Multidisciplinary approach

One of our key goals at Hartree National Centre for Digital Innovation is to bridge this gap. We assemble multidisciplinary teams that can tackle these challenges in a manner that allows both sides to recognise the benefits and close the Chasm. Business professionals need to grasp how technology can enhance their operations, while technologists must understand what makes their innovations appealing to businesses. Creating teams that can communicate with each other across these divides is essential. This mission of accelerating the adoption of new technologies is what attracted IBM to collaborate in this space in the UK.

The Hartree National Centre for Digital Innovation (HNCDI) project is particularly impressive, with no equivalent existing globally. I feel privileged to share our work with my colleagues in the countries where we have IBM research labs, encouraging them to see what we are accomplishing in the UK and how it can inspire their efforts.

The premise of the HNCDI initiative is based on collaboration between IBM and the Science and Technology Facilities Council (STFC) (which manages the UK involvement in projects like the Large Hadron Collider at CERN and the Diamond Light Source). We need this collaboration to create a symbiotic partnership that benefits both public and private sector researchers.

This programme has been immensely rewarding. The decision-making process is collaborative, with STFC and IBM jointly sitting on a management board that selects projects based on their potential impact on UK industry. The teams consist of participants from industrial, academic, and public sectors, creating a truly joint initiative. We aim to unite the best of all research worlds to provide a robust platform for UK industry to take advantage of.

Our approach is centred around a series of programmes. One programme, called EXPLAIN, is designed to deliver high-quality training and education for both technologists and managers at no cost to the attendees.

The EXPLORE programme allows industrial partners in the UK to approach us with industrial challenges they face. We break down these challenges into a proof of concept, which includes both technical aspects and a business template to help partners understand how to implement the results of our work in their business for the UK's competitive advantage. Participation in the EXPLORE programme is offered at no cost to

partners, although they must cover their own costs and usually provide data to the project. Our goal is to remove entry barriers for partner companies wanting to engage with AI technologies.

Partners are also supported in the EXCELERATE workstream to exploit the results of the EXPLORE programme and to embed it into their enterprise. This support can come in a number of different forms that span from simple consultancy support to full-scale implementation activities (under different costing models).

Finally, our Emerging Technology programme focuses on future-proofing solutions, ensuring they remain relevant as technology evolves. This is particularly relevant to our work in quantum computing technology. □

DOI: 10.53289/HDLE5015

An integrative approach is paramount

Greg Clark

The Rt Hon Greg Clark is Executive Chair of the University of Warwick's Innovation District (and Chair of WMG - the Warwick Manufacturing Group). Greg served for 19 years as a Member of Parliament, before stepping down in 2024. He was a senior minister for nearly 10 years, including serving in the UK Cabinet as Secretary of State for Business, Energy and Industrial Strategy, Secretary of State for Communities and Local Government, Minister for Science and Universities, and previously as Minister for Cities and Financial Secretary to the Treasury. In the last Parliament Greg was elected by the whole House of Commons to serve as Chair of the cross-party Science, Innovation and Technology Select Committee.

SUMMARY

- In a world characterised by change, it is crucial for the Government and the country to be clear and explicit about their intentions
- Instead of adopting a "Year Zero" approach, the current Government is building on our previous efforts
- A strategy should also serve as a means to integrate various strands and policies within the Government, aligning different perspectives on the future.

I would like to make three observations regarding the Government's new approach to industrial strategy and briefly highlight five challenges that I believe need to be addressed.

First, it is beneficial to have an industrial strategy. Back when David Willetts, Professor Mariana Mazzucato and I, along with many others, were working on the 2017 strategy, we had hoped it would be established for the long term. Despite our efforts to embed it, that did not happen. Therefore, it is fortunate that we can convene now in the context of a new industrial strategy.

This is not merely a formality; I believe that in a world characterised by change – where international competition and cooperation coexist – it is crucial for the Government and the country to be clear and explicit about their intentions. We cannot expect people to read our minds. Articulating our strategy allows others to understand our direction and assists us in refining our own policies, investments, and priorities. Some members of my party, the Conservative Party, have expressed scepticism about industrial strategy, arguing that it is not something a Conservative government should pursue.

I find this perspective rather puzzling, given that the party prides itself on being in tune with business. I can easily envision a scenario in which a chief executive addresses shareholders at an annual general meeting and, when asked about the company's future and plans for prosperity, responds with, "We have not really thought about it; we will just play it by ear." I do not believe that such an inadequate response would be well-received. Similarly, any government adopting a comparable attitude should not expect a favorable reaction from the electorate. Thus, it is advantageous that an industrial strategy is back on the agenda.

Second, it is reassuring that there is an intention for this strategy to endure in the long term. While it may require adjustments over time, the Government's commitment to establishing an Industrial Strategy Council on a statutory footing means that it cannot be easily dismantled, unlike the council I previously set up and persuaded Andy Candi to chair, which was abolished by one of my Conservative successors shortly after its introduction. This seriousness of purpose, aimed at ensuring the strategy endures, is commendable. Third, I recognise and appreciate that the Government has sensibly drawn upon the work we did together in this room, where many have contributed valuable time and thought. People from various sectors, including businesses, universities, research institutions, trade unions, and local authorities, have significantly contributed to this effort. Instead of adopting a "Year Zero" approach, which is often the case with new governments – where previous work is

dismissed – the current Government is building on our previous efforts. Jonathan Reynolds, the Secretary of State, has commendably referenced our work on multiple occasions, explicitly stating that it will be utilised moving forward. The green paper presented, clearly acknowledges and draws from our previous contributions. I would like to celebrate the way the Government intends to approach industrial strategy and emphasise the challenges that we, as a community committed to its success, need to address.

Integrative approach

Many of the points I will discuss have already been touched upon by my colleagues, which is not surprising and, in fact, is a positive development. The first key aspect is that our strategy needs to be integrative. When most people think of a strategy, they typically view it as a plan for the future, which it certainly is. However, I believe there is another important interpretation of the term "strategy." It can serve as a means to integrate various strands and policies within the Government, aligning different perspectives on the future. This integrative approach is crucial to ensure that all policies point in the same direction and do not contradict or undermine each other.

As several speakers have noted, Government tends to be organised into departmental silos, which can operate like separate baronies. These departments may pursue policies that are not aligned and can sometimes be incompatible. When I served as Secretary of State for Business, Energy, and Industrial Strategy, I had a substantial portfolio to manage. However, the title did not encompass a vital aspect: science, innovation, and technology, including the research budget, which also fell under my department's responsibilities.

Many of the tools and policy instruments for industrial strategy were consolidated in one department. Yet there have been changes to the machinery of government that have led to the creation of the Department for Business and Trade, incorporating trade but separating energy into another department. The Department for Energy and Net Zero, along with science, innovation, and technology, were also moved to different departments. While I understand the rationale behind this focus, the fragmentation that has occurred makes it more critical than ever to pursue an integrative approach within government. I hope that this will be the guiding principle for the Government moving forward.

Consider the example of the future of mobility, which includes electric vehicles and autonomous vehicles. This area clearly involves the Department for Business and Trade, but it also requires collaboration with the Department for Transport regarding energy, as well as the Department for Energy and Net Zero. Innovation will involve the Department for Science and Technology, and likely other departments, including the Treasury concerning operational matters like charging points. Additionally, the Ministry of Housing, Communities and Local Government will be relevant. With so many interconnected aspects, it is vital to recognise that we cannot send innovative businesses on a wild goose chase through Whitehall, knocking on multiple doors and expecting them to compete effectively on the global stage. Therefore, an integrative approach is paramount.

With so many interconnected aspects, we cannot send innovative businesses on a wild goose chase through Whitehall, knocking on multiple doors. An integrative approach is paramount.

What to do about resource

The second challenge we face is the reality of limited financial resources. Recently, we had the budget announcement, and David Willetts, during his time as Minister for Universities and Science, made notable efforts to protect the science budget even amid austerity measures. As a result of a persuasive industrial strategy, I was able to secure what was then the largest percentage increase in the science budget, raising it from £9 billion to £12 billion annually. After my tenure, it increased further, from £12 billion to £20 billion per year. Thus, we have seen a rising public sector investment in science.

The research and development budget is a topic of interest, but I find it hard to believe we will see significant increases. While I would be delighted if that were the case, I think we should manage our expectations regarding new funding. The additional resources we have had in the past helped us establish initiatives like the Industrial Strategy Challenge Fund, which supported many significant missions. These funds did not require reallocating existing resources; they were genuinely new money. Moving forward, however, I believe securing such additional funds will be more challenging. One idea I have is to leverage other tools that the Government possesses, particularly regarding the regulatory environment. The Government has proposed establishing a new Office of Regulatory Innovation, which could provide valuable opportunities that we may not have fully considered in the 2017 Industrial Strategy. We should explore how innovative regulation can effectively address the country's challenges and support various industries.

Another crucial point is that delivery will be vital for any newly elected government. The Labour manifesto prominently featured the word "change." Such a bold slogan demands tangible results, and voters will certainly ask what has changed come the next election. Although we may feel like we are at the start of a new parliament, these processes evolve

If there is an opportunity for growth in an area that lacks capacity, the Government should partner with local authorities, roll up its sleeves, and offer assistance.

rapidly. Without a fixed-term parliament, there is always a chance of an election within a few years – potentially as early as May 2028. This reality leaves us with limited time to make impactful changes.

Reflecting on my nine years as a minister working in various government roles, I have learned that effective governance often relies on partnerships. Whitehall departments typically do not operate in isolation; they engage in collaborations with businesses, local councils, mayoral authorities, and academic institutions. The fourth challenge I see for the Government is addressing "levelling up" – ensuring prosperity across the entire country. This has been a significant focus for me, particularly during my ministerial career, in which I worked extensively to create mayoral authorities and decentralise power to them. My advice would be for the Government to take a more active role in these regions. If there is an opportunity for growth in an area that lacks capacity, the Government should partner with local authorities, roll up its sleeves, and offer assistance. Finally, one of the enduring challenges is maintaining and strengthening excellence in science, research, and technology while ensuring equitable benefits from public investments and policies across the country. I believe the partnership approach has considerable merit and will be crucial in meeting these challenges. ❐

DOI: 10.53289/XCJC2235

The debate

After the presentations, the speakers joined a panel to answer questions from the audience on a variety of topics, including developing markets for technology, support for specific sectors and long-term focus

Following the presentations, the speakers at the event formed a panel and took questions from the audience. Some of the key points raised are shown below.

One question noted that in the UK, we see a lot of support for research and development, a lot of support for startups and exporting, but very little support for getting traction in our own markets for technology, and went on to ask whether it was now the time (within this current generation of industrial strategy), to be more proactive in the co-creation of markets and adopt technologies as we create them? In response, the panel mentioned various initiatives in the USA looking at outcomes-orientated innovation and procurement and suggested that the UK should be clearer on matching its investment to its missions. Particularly where money is tight, opportunities exist in regulation and procurement. Productivity performance in the UK has been sluggish – new technology can help drive improvements, but so can a dissemination and wider adoption of existing technologies. In some cases the technology is the easy bit, and issues around IP are much more problematic.

The panel were asked about whether the government, through the Industrial Strategy, should support specific industry sectors, with the example of the automotive industry given. In response, the panel noted the strengths of the UK car industry, and argued that while the Industrial Strategy should not be used to save an industrial sector, it should look at where the UK has strengths and there is also demand. The UK's innovation budget should then be utilised to help focus on how we can keep them. For example, the Faraday Institution was created to support our research in battery technology, feeding directly into electric vehicle manufacturing. However, there is the danger of Government being "captured" by certain sectors and introducing poor regulation as a result of lobbying. Some previous R&D tax incentives have increased profits but not increased investment. It is best for companies to invest and to innovate and do what they would not have done otherwise, and then the Government can help them if they are willing. The UK should move away from picking winners and instead pick the willing.

It is important to understand how the UK is different from other countries. We do not have patient, long-term finance, we have short-term finance. Catapult centres spend 10 times less than the German Fraunhofer Institutes, and Brexit has lost the UK some market opportunities. But we can learn lessons from others. Denmark is the number one provider of high-tech green digital services to China, which came about through demand-side policies, coupled with the Danish push to make Copenhagen the greenest city in Europe. That created a market to allow small tech start-ups to thrive.

It is important that the UK has "staying power" – clarity of purpose and focus for the long term. This will allow the UK to build on the foundations of the academic sector and create whole new industrial sectors such as floating offshore wind and large scale, complex, integrated systems. ❐

Forthcoming and recent events

Presentations and audio recordings from all meetings of the Foundation for Science and Technology are available at: **www.foundation.org.uk**

In Conversation with Professor Dame Ottoline Leyser
Wednesday 8th October 2025
The Royal Society

FST discussion event
Wednesday 22 October 2025
Belfast

The UK Life Sciences Strategy
Wednesday 12 November 2025
London

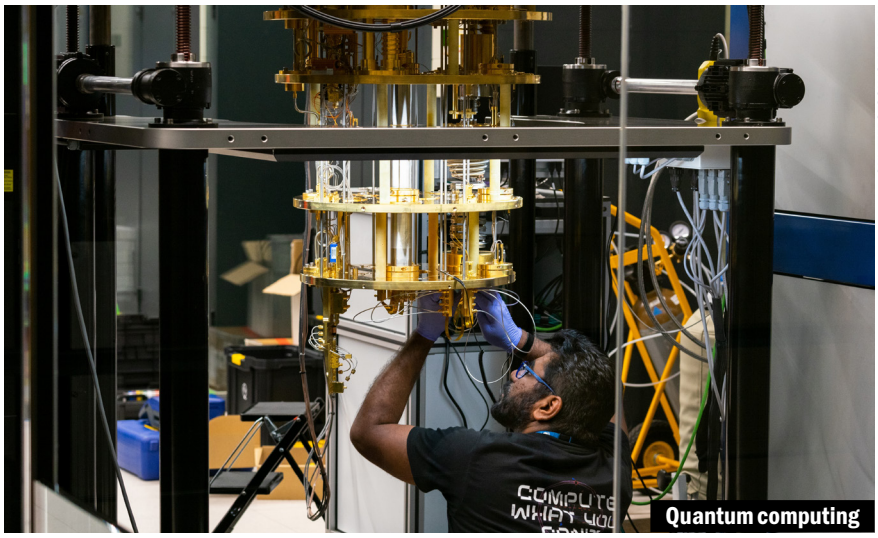
The Foundation Future Leaders Conference
Wednesday 19 November 2025
Liverpool University

Decarbonising the built environment and delivering the Warm Homes Plan – the role of social science and engineering
Wednesday 21st May 2025
The Royal Society, London
Professor Paul Monks, Chief Scientific Adviser at the Department of Energy Security and Net Zero [Chair]
Professor Jennifer Schooling, Professor of Digital Innovation and Smart Places at Anglia Ruskin University
Helene Gosden, Associate Director at Retrofit at Scale Taskforce Leader, Arup
Professor Chris Wise FREng, Senior Director of Expedition Engineering and the Useful Simple Trust
Professor Mari Martiskainen, Director of the Energy Demand Research Centre at the University of Sussex

Exascale computing for research and the implications of quantum computing, AI and Net Zero
Thursday 29th May
The University of Edinburgh
Professor Mark Wilkinson, Professor of Theoretical Astrophysics and Director of the DiRAC High Performance Computing Facility at the University of Leicester
Professor Mark Parsons, EPCC Director and Dean of Research Computing at the College of Science & Engineering, University of Edinburgh
Professor Katherine Royse, Director of the Hartree Centre, STFC

How can R&D collaboration with Africa support an agenda for sustainable growth in the UK and beyond?
Wednesday 11th June 2025
The Royal Society, London
Dr Rhona Mijumbi, Co-Director at The Center for Rapid Evidence Synthesis (ACRES), Makerere University and Head of the Policy Unit at the Malawi-Liverpool-Wellcome Programme at the Liverpool School of Tropical Medicine
Professor Ambreena Manji, Dean of International for Africa at Cardiff University, and former director of the British Academy's British Institute in East Africa
Professor Christopher Smith, Executive Chair of AHRC and UKRI International Champion


STURTISTOCK
Warm Homes Plan


SHUTTERSTOCK/GERMANRU
Quantum computing


SHUTTERSTOCK/VIC JOSH
R&D collaboration with Africa

Past events

Exascale computing for research and the implications of quantum computing, AI and Net Zero

May 29, 2025

Professor Mark Wilkinson, Professor of Theoretical Astrophysics and Director of the DiRAC High Performance Computing Facility, University of Leicester
Professor Mark Parsons, EPCC Director and Dean of Research Computing, College of Science & Engineering, University of Edinburgh
Professor Katherine Royse, Director, Hartree Centre, STFC

Decarbonising the built environment and delivering the Warm Homes Plan - the role of social science and engineering

May 21, 2025

Professor Jennifer Schooling, Professor of Digital Innovation and Smart Places, Anglia Ruskin University
Helene Gosden, Associate Director, Retrofit at Scale Taskforce Leader, Arup
Professor Chris Wise FREng, Senior Director, Expedition Engineering and the Useful Simple Trust
Professor Mari Martiskainen, Director, Energy Demand Research Centre, University of Sussex

How can space science missions advance science, drive innovation and create a vibrant UK space industry?

April 30, 2025

Professor Carole Mundell, Director of Science at the European Space Agency and Head of the European Space Astronomy Centre
Professor Adam Amara, Chief Scientist, UK Space Agency
Dr Tudor Williams, Chief Technology Officer, Filtronic

Critical Minerals – how can science and technology help deliver the UK Strategy?

February 24, 2025

Professor Paul Monks, Chief Scientific Adviser, Department of Energy Security and Net Zero
Dr Gavin Mudd, Director, Critical Minerals Intelligence Centre , British Geological Survey
Dr Sarah Gordon, Chief Executive Officer, Satarla , and Co-Director of the Rio Tinto Centre for Future Materials, Imperial College
Professor Emma Kendrick, Chair of Energy Materials, School of Metallurgy and Materials, University of Birmingham

Governing AI for Humanity – what is needed globally and in the UK?

January 29, 2025

Feryal Clark MP, Parliamentary Under-Secretary of State for AI and Digital Government, Department for Science, Innovation and Technology
Dr Douglas Gurr, Director of the Natural History Museum and Chair of The Alan Turing Institute
Professor Dame Wendy Hall DBE FRS FREng, Regius Professor of Computer Science, University of Southampton, and Member of the UN High Level Advisory Board on AI
Adrian Joseph OBE, Board Member and AI Advisor (DirectLine Group, National Lottery, GOSH and Natwest), former Chief Data and AI Officer BT Group

How can science and technology contribute to the UK's Industrial Strategy?

December 2, 2024

Dr Julia Sutcliffe, Chief Scientific Adviser, Department for Business and Trade
Professor Mariana Mazzucato, Professor in the Economics of Innovation and Public Value, University College London
Dr Peter Waggett, UK Director of Strategic Relationships, IBM Research Europe, IBM UK
Rt Hon Greg Clark, Executive Chair, Warwick Innovation District, and former Secretary of State for Business, Energy & Industrial Strategy

Building Careers and Skills in Science and Technology for National and Global Challenges

November 8, 2024

Professor Sarah Sharples, Chief Scientific Adviser, Department of Transport
Dr Stephen Hendry, Programme Manager Socioeconomic Inclusion, Royal Society of Chemistry
Dannielle Croucher, Policy Lead for Skills and Talent, National Centre for Universities and Business
Dr Billy Bryan, Evaluation and Research Leader, RAND Europe
Professor Christopher Smith, UKRI International Champion and Executive Chair of AHRC
Professor Marika Taylor, Pro Vice Chancellor and Head of College of Engineering and Physical Sciences, University of Birmingham
Alex Hale, Technology Programme Manager, National Composites Centre
Dr Geoffrey Neale, Royal Academy of Engineering Research Fellow and Lecturer, Cranfield University

Should R&D policies and budgets be devolved to English Regions?

October 23, 2024

Professor Tim Jones, Vice-Chancellor, University of Liverpool
Thomas O'Brien, Vice-Chair, Liverpool City Region's Innovation Zones Program
Dr Lesley Thompson, Vice-President Funders Global; Business Development, Elsevier
Dean Cook, Executive Director – Place, Innovate UK, UKRI

In Conversation with Professor Dame Angela McLean

October 9, 2024

Professor Dame Angela McLean DBE FRS, Government Chief Scientific Advisor
The Rt Hon the Lord Willetts FRS, Chair, The Foundation for Science and Technology

Quantum Technologies – from research to reality

September 24, 2024

Dr Dame Frances Saunders, Chair of the Royal Academy of Engineering's Quantum Infrastructure Review 2024
Professor Melissa Mather, Professor of Quantum Sensing and Engineering and Royal Academy of Engineering Chair in Emerging Technologies, University of Nottingham
Simon Andrews, Executive Director, Fraunhofer Research UK Ltd
Rachel Maze, Head of Quantum Technologies Policy, Department of Science, Innovation and Technology

Safeguarding trust in science – the role of research integrity

July 9, 2024

Professor Rachael Gooberman-Hill, Co-Chair, UK Committee on Research Integrity
Professor Andrew George, Co-Chair, UK Committee on Research Integrity
Cathy Alexander, Deputy Director for Science & Innovation, Systems & Capability, Government Office for Science
Professor Christopher Smith, Executive Chair, Arts & Humanities Research Council
Sarah Jenkins, Senior Director, Research Integrity & Publishing Ethics Centre of Expertise, Elsevier

A Roundatable on critical technologies

July 8, 2024

MAJOR SUPPORTERS IN 2024/2025

A
Advanced Research Clusters
Arts and Humanities Research Council, UKRI
Association for Innovation, Research and Technology Organisations (AIRTO)
AstraZeneca
AWE

B
Biotechnology and Biological Sciences Research Council, UKRI
British Geological Survey
Brunel University London
BSI Group

C
Chartered Institute of Credit Management
Comino Foundation
Cranfield University

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

E
Economic and Social Research Council, UKRI
Elsevier b.v.
Engineering and Physical Sciences Research Council, UKRI

H
Health and Safety Executive
High Value Manufacturing Catapult

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

K
King's College London

M
Matrix - The Northern Ireland Science Industry Panel
Medical Research Council, UKRI
Met Office

N
National Centre for Universities and Business
National Physical Laboratory
Natural Environment Research Council, UKRI
Nottingham Trent University

P
Parliamentary and Scientific Committee

Q
Queen's University Belfast

R
Research England, UKRI
Rolls-Royce
Royal Society of Biology
Royal Society of Chemistry
Royal Statistical Society

S
Science and Technology Facilities Council, UKRI
Society of Operations Engineers

T
The Academy of Medical Sciences
The Royal Academy of Engineering
The Royal Commission for the Exhibition of 1851
The Royal Society

U
Ulster University
University College London
University of Bath, Institute for Policy Research
University of Birmingham
University of Dundee
University of East Anglia
University of Edinburgh
University of Exeter
University of Glasgow
University of Hull
University of Keele
University of Leeds
University of Leicester
University of Nottingham
University of Reading
University of Sheffield
University of Southampton
University of Westminster

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: communications@foundation.org.uk

www.foundation.org.uk