

# fst *journal*

The Journal of The Foundation for Science and Technology

Volume 22 Number 6 January 2020 [www.foundation.org.uk](http://www.foundation.org.uk)

---

## Editorial

**Sir Ian Boyd:** Science and Government – the benefits and costs of greater integration

---

## Are there two cultures today?

**Chris Skidmore MP:** Revisiting the ‘Two Cultures’ debate today

**Sir Venki Ramakrishnan:** Building bridges across a range of divides

**Professor Helen Small:** Snow versus Leavis, 60 years on

**Professor Jane Macnaughton:** The need for transdisciplinary research

**Dr Sarah Main:** The wider world

---

## Reforming the UK tertiary education system

**Philip Augar:** A new dispensation for Higher and Further Education

**Professor Julia Buckingham:** At the heart of the economy

**Stella Mbubaegbu:** A new age of Further Education

---

## Solving the productivity conundrum

**Professor Jennifer Rubin:** What tools and levers can we use?

**Paul Johnson:** Productivity in the aftermath of the financial crisis

**Robert Jenrick MP:** Improving productivity across the UK

---

## A strategy for the maritime sector

**Roger Hargreaves:** A place in the front rank

**Sarah Kenny:** Collaboration is the key to future success

**Professor Ed Hill:** Drawing in support from the wider economy

**Professor Susan Gourvenec:** A critical role

**Liz English:** The benefits of a long-term vision

---

## The future of aviation

**Professor Iain Gray:** 2050 is just around the corner

**Simon Burr:** Designing the next generation of aircraft – today

**Martin Rolfe:** Building smart motorways in the sky

## COUNCIL AND TRUSTEES



### VICE-PRESIDENTS

The Earl of Selborne GBE FRS  
Dr Dougal Goodman OBE FREng

### COUNCIL AND TRUSTEE BOARD

#### Chair

The Rt Hon the Lord Willetts\* FRS

#### Deputy Chair

The Baroness O'Neill of Bengarve\* CH CBE FBA FRS FMedSci

#### President, The Royal Society

Sir Venki Ramakrishnan PRS FMedSci

#### President, Royal Academy of Engineering

Sir Jim McDonald FRSE FREng FIET

#### President, British Academy

Sir David Cannadine PBA

#### President, The Academy of Medical Sciences

Professor Sir Robert Lechler PMedSci

#### President, The Royal Society of Edinburgh

Dame Anne Glover DBE CBE FRSE FRS

#### President, The Learned Society of Wales

Sir Emyr Jones Parry GCMG FInstP PLSW

#### Chair, EngineeringUK

Malcolm Brinded CBE FREng

#### President, The Science Council

Professor Sir Keith Burnett CBE FRS

#### Executive Chair, Engineering and Physical Sciences Research Council, UKRI

Professor Dame Lynn Gladden DBE FRS FREng

#### Executive Chair, Economic and Social Research Council, UKRI

Professor Jennifer Rubin

#### Executive Chair, Research England, UKRI

David Sweeney

#### Executive Chair, Arts and Humanities Research Council, UKRI

Professor Andrew Thompson

#### Executive Chair, Science and Technology Facilities Council, UKRI

Professor Mark Thomson

#### Executive Chair, Medical Research Council, UKRI

Professor Fiona Watt FRS FMedSci

#### Executive Chair, Biotechnology and Biological Sciences Research Council, UKRI

Professor Melanie Welham

#### Executive Chair, Natural Environment Research Council, UKRI

Professor Sir Duncan Wingham

#### Interim Executive Chair, Innovate UK, UKRI

Dr Ian Campbell

#### Chair, Steering Board, UK Space Agency

Dr Sally Howes OBE

### CHIEF EXECUTIVE

Gavin Costigan

Professor Polina Bayvel CBE FRS FREng

Sir John Beddington CMG FRS FRSE HonFREng

Mr Justice Birss

Sir Drummond Bone FRSE

Professor Sir Leszek Borysiewicz FRS FRCP FMedSci FLSW DL

The Lord Broers FRS FREng HonFMedSci

Sir Donald Brydon\* CBE

Sir Anthony Cleaver HonFREng

Sir Gordon Duff FRCP FRCPE FMedSci FRSE

Dr Paul Golby CBE FREng

The Lord Haskel\*

Professor The Lord Hennessy of Nympsfield FBA

Dr Julian Huppert

Professor Sir David King ScD FRS HonFREng

The Lord Krebs Kt FRS FMedSci Hon DSc

The Rt Hon Sir Norman Lamb

Professor The Lord Mair CBE FRS FREng

Dr Sarah Main\*

Dr Julie Maxton\* CBE

Stephen Metcalfe MP

Jonathan Neale

The Rt Hon the Baroness Neville-Jones DCMG

Sir Paul Nurse FRS FMedSci HonFREng

Chi Onwurah\* MP

The Lord Oxburgh KBE FRS HonFREng

The Lord Rees of Ludlow OM Kt FRS

The Baroness Sharp of Guildford

Dr Hayaatun Sillem\* CBE FIET

Professor Sir Adrian Smith FRS

Phil Smith CBE

Professor Sir Michael Sterling FREng

Sir Hugh Taylor KCB

The Lord Trees HonFRSE

The Baroness Wilcox

Sir Peter Williams CBE FRS FREng

The Lord Willis of Knaresborough

#### Honorary Treasurer

John Neilson\*

#### Honorary Secretary

Patrick McHugh\*

\*Trustee Board Member

### The Foundation for Science and Technology

22 Greencoat Place  
London SW1P 1DX

Tel: 020 7321 2220

Email: [fstjournal@foundation.org.uk](mailto:fstjournal@foundation.org.uk)

**Editor** Dr Dougal Goodman OBE FREng

**Production Editor** Simon Napper

**Layout** Simon Clarke

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

*FST Journal* publishes summaries of all the talks given at its meetings. Full audio recordings are available at [www.foundation.org.uk](http://www.foundation.org.uk)

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



©2020 The Foundation for Science and Technology  
ISSN 1475-1704

Charity Number: 00274727 Company Number: 01327814

# fst *journal*

Volume 22 Number 6 January 2020



## THE COUNCIL AND TRUSTEES OF THE FOUNDATION

Inside front cover

### UPDATE

- The future of international collaboration • Protecting against space weather • 2  
Taking account of natural capital • Hackitt is new adviser on building safety

### FUTURE LEADERS

- Foundation launches Future Leaders programme 3

### EDITORIAL

- Science and Government: the benefits and costs of greater integration **Sir Ian Boyd** 4

### ARE THERE TWO CULTURES TODAY?

- Revisiting the 'Two Cultures' debate today **Chris Skidmore MP** 6  
Building bridges across a range of divides **Sir Venki Ramakrishnan** 8  
Snow versus Leavis, 60 years on **Professor Helen Small** 10  
The need for transdisciplinary research **Professor Jane Macnaughton** 12  
The wider world **Dr Sarah Main** 13

### REFORMING THE UK TERTIARY EDUCATION SYSTEM

- A new dispensation for Higher and Further Education **Philip Augar** 15  
At the heart of the economy **Professor Julia Buckingham** 17  
A new age of Further Education **Stella Mbubaegbu** 20

### SOLVING THE PRODUCTIVITY CONUNDRUM

- What tools and levers can we use? **Professor Jennifer Rubin** 22  
Productivity in the aftermath of the financial crisis **Paul Johnson** 24  
Improving productivity across the UK **Robert Jenrick MP** 27

### A STRATEGY FOR THE MARITIME SECTOR

- A place in the front rank **Roger Hargreaves** 30  
Collaboration is the key to future success **Sarah Kenny** 32  
Drawing in support from the wider economy **Professor Ed Hill** 34  
A critical role **Professor Susan Gourvenec** 37  
The benefits of a long-term vision **Liz English** 37

### THE FUTURE OF AVIATION

- 2050 is just around the corner **Professor Iain Gray** 39  
Designing the next generation of aircraft – today **Simon Burr** 41  
Smart motorways in the sky **Martin Rolfe** 42

## Protecting against space weather

British satellites will be better protected through a £20 million investment to predict severe space weather events. Space weather, such as flares or winds from the Sun's surface or geomagnetic storms, can damage satellites, and cause disruption to power, air transportation and communications systems, such as GPS and mobile phone networks.

The boost nearly quadruples investment from Government into research that can improve systems at the Met Office Space Weather Operations Centre.

This new fund, delivered through the UKRI Strategic Priorities Fund, will be used to look closely at space weather innovation, measurement, modelling and risk assessment. By predicting when and where space weather events take place, the Met Office can issue warnings and advice that will allow operators to take necessary action, such as manoeuvring satellites and isolating parts of the power network to ensure the least amount of disruption possible.

The UK will also be able to share forecasts with other space weather centres around the world, including the US Space Weather Prediction Centre.

## Hackitt is new adviser on building safety

Dame Judith Hackitt has been appointed Government adviser to provide independent advice on the establishment of a new Building Safety Regulator. She led the Independent Review of Building Regulations and Fire Safety (see *FST Journal* 22-3) following the Grenfell Tower disaster. The Government committed to take forward all of her recommendations and go further, by forming a new national Building Safety Regulator.

The Regulator will oversee the design and management of buildings, with a strong focus on ensuring the new regime for higher-risk buildings is enforced effectively and robustly. It will also have the power to apply criminal sanctions to building owners who do not obey the new regime.

## The future of international collaboration

International collaborations are fundamental to the UK maintaining its position in global science. These partnerships are helping to tackle global challenges like climate change, life-threatening diseases, and the world's ageing society, as well as advancing technologies like Artificial Intelligence (AI) that could transform whole industries.

An independent report on this topic, by Professor Sir Adrian Smith and Professor Graeme Reid, sets out the new opportunities for the UK to extend its international collaborations.

The report includes a range of principles and ideas, setting out potential opportunities for the UK to extend its international collaborations globally and strengthen current partnerships, including options in the event the UK does not stay fully part of European funding programmes.

This includes options for:

- protecting and enhancing the UK's science, research and innovation base, including through building R&D capacity across the UK;
- increasing the agility of research funding to react to new and unexpected international opportunities;
- achieving the Government's commitment to increase research and development (R&D) investment to at least 2.4% of GDP by 2027 including attracting foreign direct investment to the UK;
- developing a Global Talent Strategy to attract and retain a wide range of scientific talent in the UK.

The Government has also announced that it will consider associating to Horizon Europe, the EU's future science, research and innovation programme.

<http://bit.ly/future-frameworks>

## Taking account of natural capital

There is an increasingly urgent need for decision-making by businesses and policy makers to take account of natural assets, such as clean air and water, crop pollination, and flood regulation. This so-called Natural Capital approach is necessary to ensure businesses' long-term viability as well as the protection and restoration of the environment.

A series of reports have been published by the Valuing Nature Programme covering three business sectors – built-infrastructure, land management and insurance/financial services – all of which substantially depend upon, and have significant impacts on, natural resources in the UK and beyond.

The three sector reports identify existing Natural Capital approaches being taken by businesses, barriers preventing businesses adopting a Natural Capital approach, and key research and innovation (R&I) needs to support further uptake.

A fourth report highlights commonalities and differences in R&I needs between the built-infrastructure, land management and insurance/financial services sectors. These needs include:

- increasing business-relevant research into natural assets;

- developing datasets, frameworks, standards, models, metrics and other tools to integrate natural assets in business decision-making;
- new pilot projects to enable the creation of business models and solutions to protect and restore natural assets;
- research and innovation to help stimulate investment in natural assets and develop new markets;
- assessing risk and resilience in relation to natural assets;
- creation of specialist training programmes and knowledge exchange.

The report proposes options to meet the identified R&I needs, including a substantial hub, which would coordinate and accelerate UK investment in business-relevant R&I and also promote knowledge exchange.

Partners in the Valuing Nature Programme, funded by UKRI and Government, say change is required to reverse the catastrophic decline of nature recently highlighted by the IPBES Global Assessment and to comply with recent UK Government policy such as the 2050 net zero target for greenhouse gas emissions and the 25 Year Environment Plan.

<http://bit.ly/business-round-tables>

# FUTURE LEADERS

A new initiative by the Foundation for Science and Technology brings together early- and mid-career professionals from Government, academia and business.

## Foundation launches Future Leaders programme

The Foundation for Science and Technology provides an impartial platform for consideration of policy issues that have a science, technology or medical element. Those taking part in Foundation meetings come predominantly from a policy, academic or industry background. Helping professionals from different parts of the economy to share insights and understand different priorities and viewpoints is a fundamental part of FST's work.

Traditionally, audiences at meetings have tended to be senior people close to the decision-making process in their respective disciplines. Yet, the need to understand different perspectives and apply them in multi-disciplinary environments is important in a wide variety of contexts.

So, the Foundation has launched an initiative to bring that cross-disciplinary approach to early- and mid-career professionals in Government, Parliament, academia and industry. The Foundation Future Leaders programme is giving a group of 30, drawn equally from these four sectors, the opportunity to share experiences and insights with others at a similar stage of career development.

The programme offers participants a series of opportunities to look at the way in which science and innovation benefits and services the wider UK economy. By sharing these experiences with colleagues from industry, the research community, Parliament or Government, they will learn to understand different approaches and methods. It is hoped that the networking will also stand them in good stead as their careers develop and help them to build enduring links across different fields.

They will be a regular presence at Foundation meetings, bringing their own insights – and questions – to the events.



**The Chair of the Foundation, Lord Willetts, speaking with members of the Foundation Future Leaders programme.**

**The programme offers participants a series of opportunities to look at the way in which science and innovation benefits and services the wider UK economy.**

The inaugural meeting of this year's scheme included a tour of Parliament and an introduction to science in Government, with presentations to the group from the Parliamentary Office of Science and Technology (POST) and the Lords Select Committee on Science and Technology. The Chair of the Foundation, Lord Willetts, also spoke to the group and answered questions about his time as Science Minister.

The second meeting provided an opportunity to get beyond the world of Whitehall and London with a visit to

Harwell, one of the UK's foremost science parks. Tours of the Diamond Light Source, the Satellite Applications Catapult, the MRC's Mary Lyon Centre and also the Culham Science Centre demonstrated the way in which the research community is engaging with industry and business to drive forward the UK's knowledge-driven economy.

Further visits will be taking place in the New Year, culminating in a conference for 200 early- and mid-career professionals in the early summer.

Gavin Costigan, Chief Executive of the Foundation, explained the reasoning behind the programme. "We aim to help these future leaders of our economy gain a better grasp of the interplay between Government, Parliament, research and industry. That will enable them to maximise a whole range of opportunities over the coming years and help stimulate the UK economy, identify impact from research and develop better policy." □

# Science and Government: the benefits and costs of greater integration

Ian Boyd



Professor Sir Ian Boyd is the former Chief Scientific Adviser at Defra (2012-2019) and is now at the University of St Andrews. He is a marine and polar scientist, but since working in Government has developed an interest in the ways in which scientific information is used in decision making. He is also interested in promoting quality and trust in scientific information and is Chair of the UK Research Integrity Office.

The pages of *FST Journal* illustrate the contribution that science and technology make to society, and also how this progresses through communication and debate. Research and innovation are seen to generate public good and are most commonly associated with helping to drive economic performance and social change. Yet science can perform more functions for Government than just the delivery of these goods. Science is a system of thinking about problem-solving which Government can sometimes appear reluctant to embrace.

The instrumentalist view might be that science is a functional component of Government, a service, like a navy or a health service, to be used when needed and sustained but otherwise ignored. Certainly, I think this is a common view within Government of the function of science. The question about who decides when the services provided by science should be used and in what circumstances is rarely surfaced. Chief Scientific Advisers (CSAs) exist to help raise awareness that science exists to help, but this does not guarantee that those who could call on the services of science will ever do so.

### Under-representation

This attitude leads to under-utilisation and under-representation of science in both the political and bureaucratic sectors of Government. In 2019, only one MP (0.15%) had a science PhD. Given that perhaps a little over 0.5% of the UK population has a science PhD, this seems like a shockingly low level of science representation, especially since the UK has the objective of spending 2.4% of GDP on research. It has been an uphill struggle to get some Departments to understand what science can do for them and to appoint a CSA. Even incumbent CSAs sometimes struggle to get traction. Government

and science often do not appear to mix well.

This immiscibility deprives Government of a diversity of thinking to solve difficult problems and it deprives science of a broader perspective on how it can be made useful. This divide is perhaps reflective of cultural differences between science and the rest of society, but are those cultural differences amplified for convenience? Vested interests have little incentive to promote a process of telling truth to power (which is often the message coming from science) when the truth is likely to challenge those very interests.

### Tension

In a recent editorial in this journal, Dougal Goodman expressed this tension as the divide between analytically- and emotionally-based thinking, where the scientists represented the analytical end of this spectrum while policy makers and politicians (and also those running corporate organisations) were at the emotional end. This is certainly one way of looking at the problem through a sociological lens, but science has an important contribution to make from analysis through to emotion. It has broad equivalence to the spectrum that spans from certainty to uncertainty. Science tests our understanding of how the world functions by challenging it with measured reality. This parameterises uncertainty which contributes to emotionally-based assessments of risk in decision-making. By this definition, policy making, from the ministerial committee to the corporate board room, is itself an exercise in scientific exploration.

Science can bring a different kind of discourse to Government. It can broaden perspectives and present different solutions. Government still suffers from what C. P. Snow referred to as the 'two cultures'. Snow recognised a divide between a humanities-based, normative type of thinking, which tended to dominate within Government, and science which tended to be radical and to promote change.

Government still operates under the principle that change is good so long as it is the right kind of

Even incumbent Chief Scientific Advisers sometimes struggle to get traction. Government and science often do not appear to mix well.

change. As a result, it has a remarkable capacity for hysteresis in the presence of pressure to change. Even if the British Civil Service now recognises the need for greater intellectual diversity in Government and is gradually breaking out of its narrow foundations, the old culture dies hard.

Nevertheless, change has happened and one of the greatest of these has occurred in the past 20 years, as economics has begun to control decision making in Government. This has replaced normative ethical foundations rooted in duty and obligation with consequentialist ethics.

As a result, analytical economics dominates policy making in Government. The Treasury 'Green Book' sets out the rules of decision making and, perhaps by accident but more likely by design, places consequentialism at the heart of the philosophy of Government. It is, for example, what creates or reinforces the hegemony of GDP which is arguably the *ultima Thule* for the reductionist objectives of consequentialism.

The options emerging from economic analysis are usually built on models of how these economists think the world works. Inevitably, the models incorporate the morals and educational background of those who create them, arguably placing strategic power in the recesses of a small number of academic organisations, those which train most of our economists.

### Rationality

Science can also help to bring greater rationality to decision-making but the case of the rise of economics shows that there is a downside and needs careful implementation. Experience from the application of analytical economics shows that it is the outcome of the benefit-cost analysis, rather than the analysis itself, which becomes a point of political debate. HS2 and the expansion of Heathrow are cases in point. Debates on policies are therefore often based on the deeply flawed belief that the benefit-cost analysis is correct.

Science would take a very different view. The scientific lens sees most analytical economics as unvalidated prediction because the models are very rarely ever challenged by having to be fitted to how the world really works and they rarely properly include uncertainty. As a result, fine margins in the benefit-cost ratios can dictate large swings in the options given to Ministers. When seen through a scientific lens, the uncertainties in the model structure, model assumptions and lack of fitting of the models to data, can mean the options being recommended are not significantly different from each other. Yet this is not the story being told to Ministers or the public. An unjustified

Government still operates under the principle that change is good so long as it is the right kind of change. As a result, it has a remarkable capacity for hysteresis in the presence of pressure to change.

veneer of rationality means trust can be undermined and this has perhaps emerged in the role which economics had in the debates about the exit of the UK from the EU.

Greater integration of science can ensure a better balance between the normative and the utilitarian poles of Government decision-making. Following the example of economics, social research has attempted to make its presence felt in order to shift this balance. Enthusiastic pragmatist principles have recently guided a 'what works' agenda in Government social research. It was the pragmatist philosopher William James who said that truth is what works, but even as he and the other pragmatist philosophers noted, what works in one place or time does not always work in others.

Over-promising has been a characteristic of the experience to date of bringing greater rationality to decision-making in Government. Enthusiasm for evidence-based policymaking needs to be tempered against the problems of delivering this ideal. The calls from those who are most vocal in its promotion are normally really promoting their own brand of evidence rather than the principles under which evidence will be constructed and used. A lot more work is needed to get this right.

### A challenge

A change towards greater integration will be a challenge to science itself, which has often revelled in being the unruly child sitting outside the tent of policy. The kind of maturity this is likely to demand will be reflected in accountability. With power comes accountability, something the field of economics is perhaps only now beginning to understand in the aftermath of its complex role in the vote for the UK to leave the EU.

The very least that a greater presence of science can do in Government is to create a more honest picture of uncertainty and risk. With honesty comes trust: trust in Government and in the political process is presently at an all-time low. William James also said that truth is agreement between our ideas and reality. Without truth, trust is ephemeral. The process of getting to truth is science. □

The very least that a greater presence of science can do in Government is to create a more honest picture of uncertainty and risk.

# TWO CULTURES

On the 60th anniversary of C.P. Snow's famous 'Two Cultures' lecture, the Foundation for Science and Technology held a meeting on 24 April 2019 to examine whether his views are valid today.

## Revisiting the 'Two Cultures' debate today

Chris Skidmore



Chris Skidmore MP FRHistS FSA FRSA is Minister of State for Universities, Science, Research and Innovation. He has also served as Minister of State at the Department of Health and Social Care and Parliamentary Secretary at the Cabinet Office. Chris Skidmore was elected Conservative MP for Kingswood in May 2010. He is a Fellow of the Royal Historical Society and a Fellow of the Society of Antiquaries.

The interweaving of Sciences with Arts is crucial for meeting the huge environmental, social and technological challenges we face today.

Before becoming a politician, I was a Tudor historian and the Arts and Humanities have completely shaped my view and understanding of the world. Being able to bridge the divide between the Arts and the Sciences has been one of my ambitions as Minister for Universities and Science. It is tremendously exciting to witness what can be achieved when they combine.

Re-reading C.P. Snow's Rede Lectures on the 'Two Cultures', he outlined three inter-related concerns. His focus on the education system (in particular his pioneering approach to international comparisons), his desire to secure the UK's position in a changing world and his dedication to meeting challenges faced by humanity as a whole – these are as relevant today as they were then.

### Different barriers and boundaries

There are different barriers and boundaries to be overcome in the Higher Education system today if the UK is to meet the needs of the present day. Removing the constraints created by the core structure, lifting barriers to participation, breaking down the worrying division between town and gown – these are the new fronts that will shape the future of education.

Since 1959 when Snow was writing, there have been significant improvements: around 50% of the UK population goes into Higher Education today, compared to just 5% of young people back then. The gap between Arts and Sciences is also blurring.

In March 2011, Steve Jobs launched the iPad 2 saying: "Technology alone is not enough. It is technology married with liberal arts married with humanities that yields the results that make our hearts sing." He was right. It is never just the tech that make Apple's products so popular, allowing them to shape consumer behaviour. It is also the design, the user interface, the understanding of how people relate to their devices. As Snow said, when he lamented that division between the Arts and the Sciences: "The clashing point of two subjects, two disciplines and two cultures, of two galaxies, so far as that goes, ought to produce creative chances."

### SUMMARY

- C.P. Snow's concern was how the education system could adapt to the needs of the present and the future
- There are similar but different barriers to be addressed today
- Multi-disciplinary approaches are becoming more common
- Businesses – and students themselves – want more flexible models for learning
- Universities have a crucial civic role in their communities.

It is no wonder, then, that we are increasingly seeing a multi-disciplinary approach across business. In fact, whole industries rely on that fusion for their success. Video game companies, for example, employ coders and computer specialists, but also psychologists and anthropologists, musicians, artists and storytellers.

In universities, too, we are seeing Arts and Science convergence. In 2012, UCL launched a BASc degree where students study for a joint liberal arts and science degree. The Royal College of Arts describes itself as 'evolving into a university focussed on science, technology, engineering, art and mathematics'. In September 2020, the first undergraduates will take their places in the new London Interdisciplinary School, with degrees organised around complex problems, rather than subject disciplines.

The interweaving of Sciences with Arts is crucial for meeting the huge environmental, social and technological challenges we face today – just as Snow felt this to be necessary for the UK in the world of 1959. As the world decarbonises, as industrial societies age, as the AI revolution unfolds, we in Britain need to be at the fore, but will need the Arts and Sciences to work together more closely than ever before in order to achieve this.

We need to work across disciplines to ensure the

effective development and deployment of Artificial Intelligence. That is why the Centre for Data Ethics and Innovation which advises Government boasts members such as Lord Robert Winston, the Bishop of Oxford and Professor Luciano Floridi. The Centre for AI and Music at Queen Mary is one of 16 centres for cultural training set up to explore AI, with computer scientists and machine-learning specialists working alongside creative companies and major arts venues.

### The future

There are other barriers that affect the future of our education system. The question has to be asked about the continued usefulness of the traditional 3-year degree. New models are needed that respond to today's economy and accommodate the needs of industry, workers and students. That requires flexible, portable learning combined with on-the-ground experience.

These new fronts are comparable with Snow's battle for an education system that would meet the needs of the future, as he saw it then. Snow never offered an analysis of how to bridge the gap between the two cultures, but we need to ensure that we can indeed do that.

In Snow's world, his concern was for the 18 year olds, but ours cannot be just for the students starting Higher Education. The Government has a target of 2.4% of GDP going to R&D by 2027: by that date, 60% of the workforce will already have achieved a first degree, so the challenge will be to retrain existing workers within the framework of the Higher Education system.

So, we hope to introduce accelerated two-year degree programmes to allow students (maybe mature learners) to complete a degree course in two-thirds of the normal time. This is an attractive prospect for businesses upskilling staff, or adults returning to education.

The Government is looking for ways to support more flexible models of learning. The demand from students and business for industry experience is changing too, with more and more institutions offering free apprenticeships and industry placements as standard. Universities like Aston are embracing four-year models which give students a placement year – valuable industry experience and workplace skills as well as contacts they might not otherwise have gained.

In his lectures, Snow talks of 'pure versus applied sciences': it really struck me how he highlighted the value of the engineer as opposed to the pure scientist. Today, we might be more likely to talk about applied vocational careers. Industry experience is so valuable for students from less-privileged backgrounds (those who do not

have social capital or the family networks to give them an advantage in the job market).

Snow's lectures are permeated by his own personal experiences, particularly fascinating anecdotes about his grandfather, a signal engineer. Snow seems to understand inter-generational divides. He tells how his great-grandfather came from 'the darkness of history' as an agricultural labourer and he understood the limitations of ambitions that can permeate through generations. While I do not quite share Snow's optimism that we can instantly end the rich/poor divide, still we recognise that while the context may have changed, these issues are still there and we must not take our foot off the accelerator in seeking to solve them.

### The civic role of universities

Universities play a vital function in society, not only enriching lives, addressing the challenges facing humanity and educating the workforce of tomorrow, but also in serving their localities. Universities are crucibles of their local communities: they raise aspirations and provide opportunities that would not otherwise exist. They are magnets for local business and industry and can completely transform and regenerate urban areas.

Sadly, over recent years, we have seen another iteration of the two cultures theme: the rise of a crude 'Them and Us' mentality, with the public rejecting the experts and with those who have not experienced university themselves unable to see any benefit, direct or indirect. This is the new frontier that we need to address.

Greater effort is needed to banish that false divide between the academic sphere and the outside world. In my own field of historical study, public history has undergone a rapid transformation in being able to communicate the value of historical analysis to wider audiences. As Science Minister, I have seen how issues such as climate change and other pressing concerns are opening up a previously-hidden world of ecology and environmental science to a wider public. Tremendous efforts are being made to raise awareness of the civic benefits that universities and academic life bring. The Made at Uni campaign of Universities UK is doing a fantastic job of explaining how university researchers have pioneered many of the innovations we take for granted.

And likewise, the UPP Foundation Civic University Commission Report illuminated ways in which universities contribute to their local regions.

Although we are increasingly bringing the Arts and Sciences together in ways Snow never imagined 60 years ago, there are new divisions to be overcome, and new fronts to Snow's fight for an education system that responds to the needs of today. □

The question has to be asked about the continued usefulness of the traditional 3-year degree. New models are needed that accommodate the needs of industry, workers and students.

Although we are increasingly bringing the Arts and Sciences together in ways Snow never imagined 60 years ago, there are new divisions to be overcome.

# Building bridges across a range of divides

Venki Ramakrishnan



Sir Venki Ramakrishnan is a Group Leader at the Medical Research Council Laboratory of Molecular Biology (LMB) in Cambridge and President of the Royal Society. He grew up in India but moved to the USA at the age of 19 in 1971. He took up his present post in Cambridge in 1999. He is a member of the European Molecular Biology Organisation (EMBO), the US National Academy of Sciences, Leopoldina (the German Academy of Sciences) and a Foreign Member of the Indian National Science Academy. He shared the Nobel Prize for chemistry in 2009.

A chasm has always existed in which science as a whole is on one side of the divide. This concerns the difference between rational, empirically-based ways of knowing and other ways based on emotion, faith or moral values.

C. P. Snow has a particular resonance in English culture, but it is worth taking a critical look at his words on the 60th anniversary of his lecture. I did not know him at all until I read his introduction to *A Mathematician's Apology* by G. H. Hardy. Hardy was known to every Indian science student because it was he who plucked the self-taught mathematical genius Srinivasa Ramanujan out of obscurity and brought him to Cambridge.

I could not think of anyone more different from Hardy in some ways, even though the two appear to have been good friends. Snow was what I would call a London man, someone interested in the corridors of power, whereas Hardy was a stereotypical shy, reserved Cambridge academic, much more interested in getting to the bottom of things than being on top of things (to paraphrase Donald Knuth).

The main thrust of Snow's Two Cultures essay is the seemingly unbridgeable chasm between the Arts and Humanities on the one hand, and the Sciences on the other. Each, on his analysis, is not only ignorant of the achievements of the other, but unable to even comprehend their language.

Snow complained in particular of the asymmetry regarding the social acceptability of ignorance in the two spheres. He pointed out that, although it was considered perfectly acceptable for someone in the Humanities not to have heard of the Second Law of Thermodynamics, "not to have read *War and Peace*, *La Cousine Bette* and *La Chartreuse de Parme* is not to be educated."

I am afraid that the Tolstoy novel has remained on my 'list of books to read' for the past 40-50 years. I do not know the other two.

In an earlier discussion of the Two Cultures, Peter Lachmann, a former Biological Secretary and Vice President of the Royal Society, notes: "Snow says very little about historians or social scientists or economists; and music and the performing arts also do not figure among his humanities scholars. Scientific culture is, in an analogous way, restricted almost entirely to physics and the biological sciences are largely ignored. He regards ignorance of the Yang and Lee experiment of 1957 showing 'contradiction of parity' as culpable but makes no mention of Watson and Crick's 1953 paper on the structure of DNA which did so much

## SUMMARY

- The accuracy of Snow's analysis has been questioned
- There is unquestionably a chasm between empirically-based knowledge and that based on emotion, faith and values
- Arguments cannot be made on cold empirical logic alone
- Bridging the gap between scientists and non-scientists is ever more important
- We must reconsider the appropriateness of our narrow secondary education system.

to fire the revolution in molecular biology, the implications of which have spread across – and beyond – the two cultures into the consciousness of the general public." So it is not clear that Snow's comments were valid even when he made them.

The real problem is that knowledge has become highly compartmentalised. Science now is so technical that it is not understandable even to other scientists outside a narrow field.

Similarly, it is not clear to me that a playwright or an artist will understand deconstructionist theory in literary criticism or how historians go about reaching their conclusions. The chasm is not just between two cultures but between the many individual branches of knowledge.

## A different chasm

There is a different chasm that has always existed, one in which science as a whole is on one side of the divide. This concerns the difference between rational, empirically-based ways of knowing and other ways based on emotion, faith or moral values. The Enlightenment and the development of the modern scientific method have driven an unparalleled growth of knowledge about nature in the past few centuries. At its heart is a reliance on reproducible and demonstrable empirical evidence above all else. The Royal Society's motto, *nullius in verba* – 'on nobody's word' – epitomises this.

However, there is a resentment of the influence of science and technology on society and academia today, a resentment too of the arrogance of

scientists who consider themselves to be the sole bearers of truth.

### A hierarchy of arrogance

Such arrogance is not, though, just one of scientists towards non-scientists. Even among scientists, there is a hierarchy. There is a famous XKCD cartoon called Purity (Figure 1) which describes a reverse hierarchy, from sociology, through psychology, biology, chemistry and physics to mathematics. Yet, those in the so-called 'pure sciences' are slowly realising that they do not have all the answers and their methods are not always useful for studying problems at different levels of complexity and scale. It is futile to try to understand the brain by solving Schrödinger's equations for all the atoms in it.

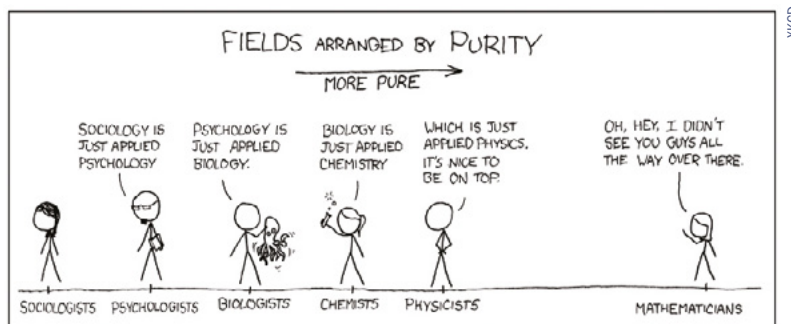
Reacting to the power and arrogance of scientists can lead some in the humanities to question the objectivity of science and the truths revealed by it. Carried to its logical extreme, everything is stated to be a result of cultural bias and there is no objective truth. This is clearly nonsense. Nobody can doubt that quantum mechanics and nuclear physics – both based on quite abstract and non-intuitive concepts – led to nuclear weapons. Or that the theory of relativity allowed accurate geolocation in our smartphones. The laws of physics apply equally in India where I grew up as they do in Cambridge where I now live, although culturally they are far apart.

### The emotional factor

Scientists should take note, though, that while we think of ourselves as objective and rational guardians of the truth, science itself demonstrates that (under a thin veneer of rationality) we are all, scientists and non-scientists alike, highly emotional beings. Daniel Kahneman's book, *Thinking, Fast and Slow*, sets out many examples of how humans instinctively act in one way when rational thought would argue otherwise.

If we scientists do not acknowledge our emotional selves, we risk not being able to convince society about crucial issues. Social scientists and psychologists – those in the so-called 'soft sciences' – understand this and are playing an important role in shaping knowledge and policy. Literature, art and music approach reality in a different way from scientists and can reveal fundamental truths about ourselves by appealing to our underlying emotional and moral selves.

Given our nature, arguments cannot be made on cold empirical logic alone. For example, despite scientific evidence to the contrary, there is a persistent belief that homeopathy is beneficial and that vaccination or GM crops are dangerous. One side



appeals to evidence and data based on statistics and randomised controls. The other plays on our instinctive fears about anything that is new and perceived as 'unnatural'. A recent political example of this could be seen in the referendum debate.

Bridging the gap between scientists and non-scientists is ever more important. First, science is a public (and publicly-funded) enterprise, so everyone has a stake in it. Second, we live in an increasingly technological world, in which decisions will be made by governments, corporations and other entities that affect us all. It is important for the public to participate intelligently in debates about key issues.

### Alternative approaches

If scientists want to bridge this chasm, we have to shed some of our arrogance and recognise that Humanities and the Arts offer an alternative way of approaching and describing things that may resonate better with people. This does not mean compromising on evidence-based analysis. Rather, it involves an acknowledgement that our emotional insights are just as real and well-established as our other evidence and they need to be included in any analysis of how to move forward.

We in science need to understand there are other ways of approaching ideas and knowledge. Equally, those in Humanities and the Arts owe it to themselves to become familiar with some of the basic concepts of science.

In that regard, we need to ask whether our current approach of segregating students at a very early age is sensible. The British educational system is one of the narrowest in the world, with the average number of A-levels being taken just 2.7. Countries that formerly used the British system have abandoned it.

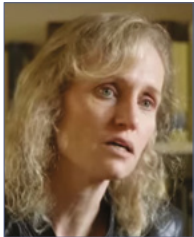
To bridge the chasm between the various strands of culture and knowledge, we must broaden our educational system and educate future generations in both the Humanities and Sciences through secondary school. Otherwise, we will perpetuate the chasm and future generations of Britons will thereby be worse off and poorly-equipped to face the 21st century. □

**Figure 1. Even among scientists there is a hierarchy: 'Purity' from XKCD.**

While we think of ourselves as objective, science itself demonstrates that (under a thin veneer of rationality) we are all, scientists and non-scientists alike, highly emotional.

# Snow versus Leavis, 60 years on

Helen Small



Professor Helen Small is Merton Professor of English Language and Literature at the University of Oxford. She has wide interests in the connections between literature and philosophy (especially moral philosophy). Her book *The Value of the Humanities* is a critical account of the arguments standardly employed to defend the public value of the Humanities. Its discussion of the distinctiveness of scholarly practices in the Humanities includes an in-depth consideration of the Two Cultures debate.

One possible sign of cultural difference is that humanities scholars tend not to think of Snow's lecture in isolation but as 'the Snow-Leavis conflict'. Two-culture arguments are, by their nature, polemical, such as Matthew Arnold v T. H. Huxley; Snow v Leavis; Alan Sokal v the editors of *Social Text* – and, long before any of these, the Battle of the Ancients and Moderns with the old rivalries of *ars* and *scientia*.

The debates walk a thin line between plain statement and over-statement. Even set within a long genre, Snow v Leavis stands out for the sheer animus injected from the humanities side. For Snow, the scientific culture is distinctively "intensive, rigorous, ... constantly in action", "exacting in its requirements for objectivity and reasoned argument". It is "optimistic" about "progress", however pessimistic the scientist in his individual character may be. His aim is to counter a bias against science institutionalised, he thought, with the help of politically too-influential literary men. Complacent in their no-longer-earned cultural authority, they tend to pessimism and to conservatism, in certain prominent cases even to fascism. His long goal is to give future governments access to new technologies in the fight against world poverty.

For Leavis, in fierce reaction, Snow's view of the modern world is deadening, vulgar, and dangerously self-aggrandising. If we want an understanding of what it would mean for individual lives to be "filled with satisfaction and significance" in anything beyond the basic material sense of satisfaction, we must turn to "the great novelists and poets" to enliven our individual sensibilities.

The easy explanation for the hardening and sharpening of two cultures conflicts between the end of the nineteenth century and the start of the 1960s would be the growing institutional power of science. But the easy explanation is inadequate. It is far from obvious that the enhanced institutional standing of the sciences should produce greater animus against the humanities. Benign condescension, perhaps? Why not mutual respect?

Leavis owed a lot to Arnold's sense of culture as self-perfection, and the pursuit of the "best that has been thought and said", but he owed as much

## SUMMARY

- For Snow, the scientific culture is distinctively "intensive, rigorous, ... constantly in action"
- For Leavis, the question that should concern the university (and society more generally) is: "What, ultimately, do we live by?"
- There remains a public appetite for understanding intellectual endeavour as a field of combat
- Neither science nor humanities alone can explain, or 'read', the primary forces of human identity
- The welfare advances brought by technology and medicine will not guarantee happiness.

to Arnold's definition of criticism as an exercise of freedom. Culture (the intellectual culture fostered by the university, and the wider public culture) seemed to him in imminent danger from philistines of Snow's ilk. Leavis's contributions to the debate are galvanised by a visceral loathing of the kind of public intellectualism represented by Snow, seen as a poster-boy for the "publicity-created culture" of metropolitan London: lazily journalistic, complacent in its Establishment credentials, in and out of the BBC on a daily basis, all over the *New Statesman* and the Sunday papers.

As to content, the grounds of Leavis's disagreement were fundamental: the question that should concern the university (and society more generally) is not 'How are we to improve the general social condition', but 'What, ultimately, do we live by?' It followed, for him, that there is only limited value in quantitative reasoning.

Leavis upholds a vision of the university as something quite unlike Snow's place of research, assisting the advancement of global wellbeing. For Leavis the university is, or should be, "a centre of consciousness for the community", a "third realm" neither professional (as a laboratory is professional) nor merely private and personal.

## The Robbins report

As important to Leavis was the appearance, four years after Snow's lecture, of the Robbins Report with its recommendations for expansion of the higher education system to meet 'the needs of the economy'. It seemed to Leavis grimly symptomatic of the state of higher education and politics alike

For Snow, the scientific culture is objective and reasoned. For Leavis, Snow's view of the modern world is deadening, vulgar, and self-aggrandising.

that Robbins so unhesitatingly accepted Snow's account of the two cultures. Leavis's self-appointed task was to dislodge that obviousness: to expose, behind the complacent diagnostic clichés, a failure to grapple with the 'rootedness' of intelligence in experience, and with it the need of a creative response to 'the new challenges of time'.

Much of the best critical literature on 'The Two Cultures' after Snow and Leavis has focussed on loosening the 'two', either working to flesh out a more serviceable model of three cultures (to include the social sciences) or stressing an underlying cultural unity to all our intellectual endeavours. Snow was at least alert to objections on this score. Not far into 'The Two Cultures' he confesses his unease that he is over-simplifying: "The number two is a very dangerous number ... I have thought for a long time about going in for further refinements: but in the end I have decided against. I was searching for something a little more than a dashing metaphor, a good deal less than a cultural map, and subtilising any more would bring more disadvantages than it's worth."

I take it that what Snow grasps at by 'more than a metaphor' is an assertion that his description can claim some degree of reality, or realism. Clearly, the word 'culture' could be taken in two senses: the personal sense of 'intellectual development, development of the mind', and the anthropologists' sense. It is this second sense that is losing the critical work.

The argument by way of 'cultural' differentiation is only quasi-anthropological, rather than one that would pass muster with a Department of Anthropology. Snow's description is not empirically grounded beyond his own broadbrush observations and a bit of circulating anecdote. This was, for Leavis, a matter of strenuous objection: "There is no evidence ..."

### Psychological development

However imperfectly worded, the claim is that educational specialisation has an effect on the psychological development of individuals. 'Two cultures' claims are typically no more than gestural about the nature and extent of that effect.

This is, as might be expected, a particularly tricky area for the social sciences. Tony Becher and Paul Trowler carve a fairly representative middle path through the difficulties in *Academic Tribes and Territories: Intellectual Enquiry and the Culture of Disciplines* (2001), when they observe that a constructivist will see training in the academic disciplines as induction into "a particular 'way of being'; a personal and professional identity, a set of values, attitudes, taken-for-granted knowledge, and recurrent practices. Some room

However imperfectly worded, the claim is that educational specialisation has an effect on the psychological development of individuals.

should be allowed for the "creative power of individuals"; on the other hand, that power should not be "overstressed".

So, observing how a humanities professor, a social scientist and a scientist speak and act at a cross-disciplinary seminar may not tell you anything about the inner psychological states of the individuals concerned, but it will certainly tell you a great deal about respective conventions of intellectual behaviour, something about respective values and a lot about strategic interests.

The difficult question, for all of us, especially as we try to construct meaningful conversations across the divisions of the university, is how much such patterned divergences say about core values. To put the point in the most general terms: conditions of competition often reduce the disciplines to their most extreme typologies; conditions of cooperation make for less predictable behaviour.

### Dispiriting

The most dispiriting aspect of the 'two cultures' argument, as Snow and Leavis bequeathed it to us, is the extent to which it tells us that there remains a public appetite for understanding intellectual endeavour as a field of combat, and thus for seeing representatives of different disciplines in public conflict with one other. The most enlightening point is the extent to which we can see that the grounds of opposition have altered.

If one were re-scripting 'The Two Cultures?' to fit today's academic and political circumstances, there would be less talk of disciplines and much more about methods. At the core of our disagreements (whether they arise under conditions of competition or duress) is the difference not in value but in explanatory scope, and thus meaning, attached to quantitative and qualitative reasoning.

I am on Leavis's terrain in making this observation, but I cannot go along with him in his apparent refusal to grant that a quantitative approach to human welfare has 'any' real truth to offer us. Almost all our disciplines practise both, but there is not enough systematic encouragement to incorporate the two methods into cogent pieces of thinking which are alive to the limita-

The most dispiriting aspect is the extent to which there is a public appetite for understanding intellectual endeavour as a field of combat.

### The disagreement between Snow and Leavis over how far the general tendency of human civilisation is toward progress has resonance today.

tions of rhetoric and the limitations of numbers (as well as the value of both).

Then, Leavis's claim that literature has supreme authority to speak about the ultimate ends of life is far less likely to get a hearing now. Thinking about one's ultimate ends may be essential at critical points in one's life, but it is palpably not the only purpose (and often not the most germane one) of the university in any of its departments.

Education has near goals as well as end goals, some of them appropriately modest: improving knowledge and understanding of particular objects, problems, methods. So does research. It is much less clear now than in Leavis's day (and it was far from clear to everyone then) that literature is the place to which the culture turns first in search of truths about life.

General culture has substantially shifted its attention from the written word to the image. Take away the exclusive claim for the literary and

replace it with a claim for critical attention to the cultures in which all human experience takes shape and acquires meaning and there is a form of advocacy for the humanities that can attract more confidence. This must be especially so in a context where digital media and AI are rapidly changing the world we inhabit and the forms of work it will admit.

Science alone cannot or will not explain, or 'read', the primary forces of human identity and the ties that bind and sometimes break. Neither can the humanities alone.

The disagreement between Snow and Leavis over how far the general tendency of human civilisation is toward progress has resonance today. Snow's claim was that the applied sciences gave human beings the power to do 'simple and manifest good' on a very large scale. Leavis's counter-claim was in effect that 'good' is never simple, and the welfare fixes of technology and medicine will not suffice for happiness. Our domestic politics of late has given us ample cause to reflect that, though our language has evolved, this is not a difference in perspective that we can reason away. It is, crucially, a difference with which we have to learn to live and work. □

# The need for transdisciplinary research



Jane Macnaughton, Professor of Medical Humanities in the Department of Anthropology, Durham University, joined the panel after the formal presentations.

I initially took an arts/humanities degree and but then switched to medicine and took a PhD in Philosophy to understand medical practice better. Today I am proudly an interdisciplinary researcher in medical humanities. At Durham, my university, we highlight the importance of knowledge and methodologies across the disciplines – arts, humanities, social science, as well as clinical science – for working out the best ways of improving health. We meet in research groups to enable different disciplines to coalesce around a single subject matter.

The Academy of Medical Sciences report *Improving the Health of the Public in 2040* looks at approaches to public health improvement and explicitly calls for 'transdisciplinary research' including the Arts and Humanities because of the 'breadth and complexity' of public health drivers – such as social and cultural, environmental and health inequalities issues. But this report also recognises that we do not have a research workforce fit for purpose. It calls for capacity building of

researchers who are skilled in this work, suggesting a need to change our educational system.

CP Snow says that the lack of cross-cultural literacy impoverishes us because we are unable to take an informed interest in many aspects of our world. My experience of working in interdisciplinary projects has made me aware of the power of critical disciplines. Humanities and social science disciplines are predicated on the need to critically appraise, to lay open the flaws of an argument or approach, but without accepting responsibility for proposing an alternative. I have sometimes thought of this as 'carping from the sidelines'. It can create a damaging 'them and us' culture. So, in my field, we are committed to suggesting alternative ways forward as well.

In contrast, it is also important to recognise the power of expert knowledge, based on scientific facts and clinical experience. This can be very alluring in its certainties and potentially very dominating where people do not usually deal in such certainties.



**Crossing the divide: addressing the challenges of interdisciplinary work is difficult but it can be achieved through humility and good relationships.**

Methodologically, interdisciplinary work can be challenging. There is a need to balance complex reality against the need for simplicity. We all enjoy the rich cross-disciplinary conversations in our research groups, but converting these into hypotheses that might form the basis of study design is much more difficult.

Addressing the challenges of interdisciplinary work is difficult but it can be achieved through humility – involving a willingness to share and listen and learn from others – and through good relationships well facilitated. Good interdisciplinary work also depends on

excellent disciplinary scholars whose handle on their own field is deep, but who have minds allowing an openness of challenge or the possibility for thinking differently about the tenets they hold so securely. This means they can challenge thinking in other disciplines than their own but also that they can go back to their own areas with new insights that will change thinking that has been accepted as dogma.

Interdisciplinary work is key to addressing new challenges in our world – but also has the potential to revitalise and renew our established disciplines, keeping them alive. □

## The wider world

The Social Market Foundation published a study which calculates there will be 142,000 new jobs related to science, technology, engineering and mathematics by 2023. They identified emergent roles for science in professional services, such as architecture and law, in addition to roles in the scientific world. These will require a mix of skills from Snow's two cultures.

As Director of the Campaign for Science and Engineering, I am asked about the specific value of a scientific education. I might say something about the value of research, analysis, critical thinking, logic, argument but then I know my historian friends would rightly claim that they learn and value these skills as well. Perhaps there is something unique in quantitative, controlled experimentation. But if you think of experimentation as exploration, curiosity, discovery and

application of rational thought, then perhaps the two cultures have a lot in common.

The original debate 60 years ago focussed on the academic world with very little consideration of the research world – scientific or otherwise – outside of this sphere. Similarly, there is little consideration of industry as a centre of research itself. One of the things Snow missed was the rise of corporations as leading centres of research that are capable of stimulating workforce demand, educational change and improved productivity.

Snow argued for the importance to industrialisation of growing the numbers of trained scientists and engineers across the world. Numbers have indeed grown: between five and ten-fold for the UK, USA and Russia, and exponentially in China and India. However, as Snow points out, in the UK we tend to cut our talent pool in half



Dr Sarah Main, Executive Director, Campaign for Science and Engineering (CaSE), also joined the panel.

through cultural expectation and norms. One third of Russian graduate engineers in 1959 were women and we cannot even claim that proportion of women in engineering in the UK today.

For me the challenges that Snow was talking about – and that we are still faced with – absolute-

ly require working across disciplines within the sciences and outside of the sciences. Our major concerns and challenges all involve, to some extent, people. There will always be an interaction between what we can learn and how people may respond to it. □

# The debate

In the debate following the presentations, participants raised points about the reform of the English education system, introducing greater breadth to studies and financial aspects of the decision.

There are formidable political difficulties in securing support in Parliament to reform GCSEs and A Levels: this may therefore not be feasible in the short term. Past attempts at reform in this area have not succeeded. More promising might be to encourage universities to deliver greater breadth in provision.

Scotland has historically done better than England in providing more breadth in 16-18 education. In England any discussion would have to involve universities as their entrance requirements heavily influence 16-18 provision. In the leading universities, admissions are frequently handled by academic departments rather than centrally, so widespread support for reform would be needed for change to be successful. The international success of leading UK universities contributes to their being reluctant to change their specific admission requirements.

An alternative present-day Two Cultures could be the perceived divide between haves and have-nots. Some universities are providing first degree provision which is more attractive to diverse communities, with Foundation years making a contribution. However, it has to be recognised that the current pattern of 'early-depth' suits the Treasury: public expenditure is lower if many first degrees are completed by 21, instead of the longer periods common in the USA and Europe. Reform of UK Higher Education finance, to reduce the burden on the public purse, may be needed before increasing breadth of study can be implemented.

The introduction of AS Levels in 2000 had produced some helpful breadth to English post-16 provision, and Cambridge's support for AS Levels – when the Government more recently turned away from them – has been helpful.

The rigid separation between academic and technical qualifications at 16-18 is also problematic. Given the depth of research endeavour currently, arguably there may now be closer to 200 cultures than two. The bulk of major issues faced by Government Departments need social science as well as science to resolve them. □

## FURTHER INFORMATION

**Becher A and Trowler P (2001) *Academic Tribes and Territories: Intellectual Enquiry and the Culture of Disciplines*. OUP.** [www.amazon.co.uk/Academic-tribes-territories-Intellectual-Disciplines/dp/0335206271](http://www.amazon.co.uk/Academic-tribes-territories-Intellectual-Disciplines/dp/0335206271)

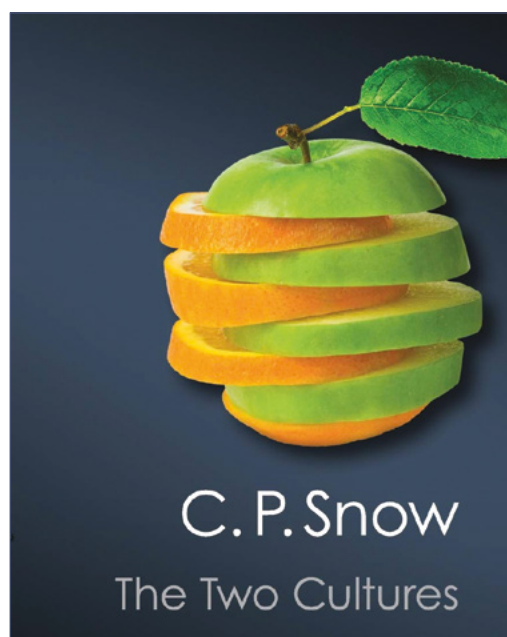
**Made at UNI** <https://madeatuni.org.uk>

**The Rede Lecture 1959 C.P. Snow**  
[www.s-f-walker.org.uk/pubsebooks/2cultures/Rede-lecture-2-cultures.pdf](http://www.s-f-walker.org.uk/pubsebooks/2cultures/Rede-lecture-2-cultures.pdf)

**The Two Cultures C.P. Snow Cambridge University Press**  
[www.cambridge.org/gb/academic/subjects/philosophy/philosophy-general-interest/two-cultures-1](http://www.cambridge.org/gb/academic/subjects/philosophy/philosophy-general-interest/two-cultures-1)

**Truly Civic: Strengthening the connection between universities and their places. UPP Foundation.**  
<https://upp-foundation.org/wp-content/uploads/2019/02/Civic-University-Commission-Final-Report.pdf>

**Two Cultures? Canto Classics F.R. Leavis Contributor: Stefan Collini The significance of C.P. Snow**  
[www.amazon.co.uk/Two-Cultures-Canto-Classics-Leavis-ebook/dp/B00FF6QBCK](http://www.amazon.co.uk/Two-Cultures-Canto-Classics-Leavis-ebook/dp/B00FF6QBCK)



# EDUCATION REFORM

A report from an independent panel that reviewed post-18 education and funding was the focus of a meeting of the Foundation held on 3 June 2019.

## A new dispensation for Higher and Further Education

Philip Augar

### SUMMARY

- The UK has a skills gap, particularly in science and technology
- In principle, increasing HE tuition fees in 2012 was the right thing to do
- The change produced significant distortions in university spending by subject
- Of an £8 billion subsidy in 2018, STEM subjects received much less than half
- Changes are needed to the Higher Education resource allocation.

At the beginning of a 15-month journey, the review panel considered how the current system of post-18 education lines up with the country's economic needs.

The Government's Industrial Strategy says: "By 2030 we want the UK to be the most innovative country in the world: a home to the most dynamic businesses at the cutting edge of new technologies and processes." So, how are we doing?

In the panel's judgment, the answer is mixed. There is excellent work going on in universities as reflected in the sector's pre-eminence in research rankings and citations, as well as the close collaboration with industry in universities such as Sheffield, Warwick and many more. Yet both employers and expert academics stated that this country has a skills gap, particularly in science and technology.

The Industrial Strategy says that "40% of employers reported a shortage of STEM graduates as being a key barrier in recruiting appropriate staff. Jobs in science, research, engineering and technology are expected to rise at double the rate of other occupations between now and 2023 and the majority of jobs on the Home Office Shortage Occupation List are in either STEM-related roles or industries."

Below graduate level, the situation is also pressing. The objective of the Industrial Strategy is

admirable: "Technical excellence has historically not been valued as highly as academic success and standards have been lower. We want our technical education system to be as prestigious as higher education in this country and for it to rival the best systems in the world."

Again, there is excellent work going on at specific institutions, but the country is a long way short of the objective. There are only 190,000 people studying at level 4/5 compared to 1.14 million degree students. In addition, relatively few of these higher technical students are found in STEM-related areas. As the then Prime Minister Theresa May noted when she launched the post-18 report at the end of May, 20% of 25 year-olds in Germany hold a higher technical qualification – the figure in the UK is just 4%.

Many of the proposals from the review panel relate to the reforming and refunding of technical and vocational education built around a stronger network of FE colleges, as well as a new suite of employer-focussed higher technical qualifications and opportunities and incentives for universities to widen their offer at this level.

### Higher Education

In terms of Higher Education and the place of science and technology, the panel started by examining the principle of the income-contingent loan system. This shares the cost of provision between the state – in the form of loan write-off – and the student. When it was introduced 20 years ago, it became the means of expanding HE. The panel believes that the principle of sharing this cost between public and private beneficiaries is correct.

Next we progressed to examining the fee structure, starting with the trebling of tuition fees in 2012. Again, it was felt that in principle this was the right thing to have done, correcting a long period of under-investment in HE. But this big increase had consequences for the different teaching bands.

For the lowest cost subjects, the new fee cap was higher than the old 'fee plus grant' payment, so these subjects would not get any grant under the



Philip Augar is an author and former investment banker. With a PhD in History, he has been speaking, writing and broadcasting about the challenges of modern capitalism and banking for 20 years. He contributes to the *Financial Times* and other publications and appears regularly on BBC radio and television. He has held a number of advisory and non-executive roles in the public and private sectors and chaired the panel reviewing post-18 education for the UK Government in 2018-19.

There is excellent work going on in universities. Yet both employers and expert academics say the UK has a skills gap, particularly in science and technology.

It was expected that universities would price at below the cap to reflect the cost of provision; in fact nearly all went straight to the maximum fee level.

**Table 1. Change in funding per student. (Source: IFS)**

	Course price group				
	A	B	C1	C2	D
Share of students	2%	20%	18%	28%	33%
<b>Funding under 2011-12 system</b>					
HEFCE funding	14,543	5,337	3,736	3,736	2,536
Fees	3,681	3,681	3,681	3,681	3,681
Total	18,224	9,018	7,417	7,417	6,217
<b>Funding in 2016-17 under new system</b>					
HEFCE funding	10,180	1,527	255	0	0
Fees	9,162	9,162	9,162	9,162	9,162
Total	19,342	10,689	9,417	9,162	9,162
<b>Change in funding</b>	<b>+6%</b>	<b>+19%</b>	<b>+27%</b>	<b>+24%</b>	<b>+47%</b>

new arrangements. Higher cost subjects got the trebled fee, but it was still a smaller grant than under the old scheme.

It was expected that universities would price at below the cap to reflect the cost of provision; in fact nearly all went straight to the maximum fee level.

The consequences, according to IFS analysis, was that between 2011-12 and 2016-17 the lowest cost band D subjects received a 47% increase in income compared to a 6% increase for the highest band A subject, Clinical Medicine (see Table 1).

This produced significant distortions in university spending by subject. Looking at the change in income by subject per student over these years, the greatest increases were seen in education (41.1%), architecture (39.7%) and sports science (33.9%). The bottom six, by contrast, were: veterinary science (6.2%), physics (6.4%), chemical engineering (8.7%), clinical medicine (8.8%), general engineering (13.8%) and biosciences (14.1%).

For STEM subjects, the consequences of this reallocation of resources were profound. In responding to a call for evidence, the Russell Group said: "Strategically-important, high-cost subjects remain under-funded with an estimated £90 million deficit across Russell Group universities in England for undergraduates in subjects in bands A and B (clinical and laboratory-based subjects). This is an area where the system could be refined to support innovative delivery of research-intensive STEM subjects which are critical to meeting the future skills needs of the UK."

Another question was how the resource allocation lined up with Industrial Strategy priorities. Does the taxpayer subsidy from the expected student loan write-off reflect the Government's stat-

ed strategic objectives? The evidence shows some resemblance to the Industrial Strategy but mathematics and computer science, as well as engineering still fall in the bottom half of the list.

Taking the funding per student and multiplying by the number of students gives the total taxpayer subsidy per subject. Of the £8 billion subsidy last year, STEM subjects received much less than half.

The panel concluded that, in a system the cost of which would soon rise to £14 billion on ONS estimates, some changes are needed to resource allocation. Options included differential fees, but these could reinforce already flawed incentives. The student fee could be kept at £9,250 with a negative teaching grant: this was rejected on the grounds that it would still leave too many students paying more than what a KPMG analysis said was the reasonable cost of provision.

The final recommendations of the review in regard to Higher Education included:

- A fee cap of £7,500 by 2021-22.
- Government should replace in full the lost fee income by increasing the teaching grant, leaving the average unit of funding unchanged at sector level in cash terms.
- The fee cap should be frozen until 2022-23 and then increased in line with inflation.
- The grant should reflect cost and social and economic value to state and student.
- High quality, specialist institutions should if necessary be protected.

The lower fee would create the headroom to enable greater differences of funding between subjects which could then be aligned with the country's economic needs. □

A fee cap would create the headroom to enable greater differences of funding between subjects which could then be aligned with the country's economic needs.

# At the heart of the economy

Julia Buckingham

## SUMMARY

- A joined-up approach to post-18 education, encompassing both Higher and Further Education, is needed
- Any income lost to the universities needs to be reimbursed in full
- The interface between research and education at our universities is crucial
- The post-18 system should be progressive and support social mobility
- Foundation years provide a valuable pathway into Higher Education and are a true aid to social mobility.

When Theresa May announced her review of post-18 education and funding in February 2018, universities saw an opportunity to ensure that Higher and Further Education were properly supported and made accessible to all post-18 year-olds whatever their background. Indeed, the review demonstrates a joined-up approach to the many different components of our tertiary education system.

There are several key tests that the review's recommendations must meet in order to maintain quality, access and choice, while ensuring that the post-18 system can meet current and future skills needs. In addition, there must be sufficient support for the growing numbers of people who want to access Higher Education in the coming years.

These tests cover some critical themes. Will the recommendations:

- improve access to Higher Education;
- plug the nation's skills gaps and help to drive an increase in productivity;
- improve the quality of higher-level education;
- increase the positive impact that universities and colleges have on their local communities and more broadly – nationally and globally;
- help current and future students make informed choices about higher level study?

Importantly, will they support student mobility across all four nations of the UK by enabling students to study wherever they choose – whether Southampton, Sunderland, Swansea or Stirling?

## The universities

The recommendations represent a mixed bag for Higher Education. There are some clear positives but also some major areas of concern.

First among those is the proposed cut in tuition fees, or university fees as I would prefer to call them, from £9,250 per year to £7,500. This may initially appeal to students, but analysis by Universities UK indicates a £1.8 billion reduction in funding for universities. Unless this is made up in full by Government, universities would need to make some very difficult decisions. These decisions would, inevitably, impact on students, on staff and on local communities – as well as the sector's ability to maintain the UK's position as a global leader in Higher Education.

The review's recommendation that the income lost to universities by a cut in tuition fees should be made up in full by the Government is welcome. In the current political and fiscal climate, though, this is a big ask and a very significant risk.

The panel has effectively recognised that the average unit of resource – i.e. the investment needed to fund each student – is the minimum cost of educating a student. Yet will the Government recognise this too, and commit the full replacement funding in a forthcoming spending review?

Will the Treasury guarantee that the funding shortfall is covered in the long-term and will it include grant funding to support the expected growth in student numbers in coming years? If not, then it is difficult to see how tuition fees can be cut without causing serious damage to our students' interests and to the sector more broadly. The richness of the student experience would suffer with increased class sizes, pared-back learning resources, as well as reduced investment in staff, infrastructure and support services, such as those for mental health.

## Practical subjects

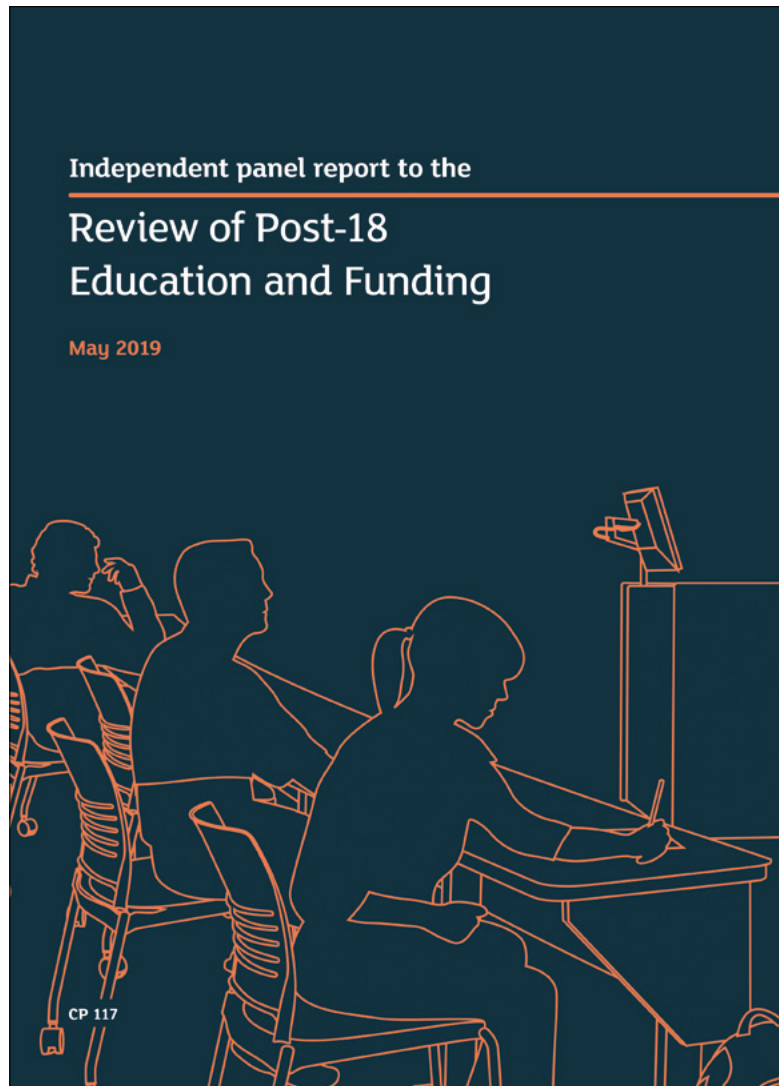
The teaching of practical subjects – engineering, natural sciences, medical and health sciences, design, technology, creative arts – will suffer if funding is cut. If universities cannot afford to invest in equipment, consumables, staff or infrastructure, then the quality of provision will be impaired.

While the report acknowledges that the UK



Professor Julia Buckingham is Vice-Chancellor and President of Brunel University London. She was awarded a CBE in 2018 for services to Biology and Education. She is currently President-elect and Treasurer of Universities UK, a Director of Imperial College Health Partners and of the National Centre for Universities and Business, a member of the All-Party Parliamentary University Group Council and Chair of The Concordat Strategy Group, supporting the career development of researchers, and the Athena SWAN Review Steering Group.

Unless the proposed cut in tuition fees is made up in full by Government, universities would need to make some very difficult decisions.



**The review's recommendation that the income lost to universities by a cut in tuition fees should be made up in full by the Government is a significant risk.**

Higher Education sector has an outstanding reputation for research, it says little about the critical interface between research and education – something I regard as a hallmark of a UK university education.

Exposing students to research and introducing them to researcher skills is a core part of a university education. It takes students to the cutting edge of their field, opens their minds and sharpens their thinking. It helps them develop and apply critical and analytical skills, to interrogate and challenge the evidence base, to develop logical evidence-based arguments and to solve problems etc.

These are the intellectual skills that so many employers are looking for in graduates and they are delivered through countless courses, not just the STEM subjects but also the in arts, humanities

and social sciences. Research-led education is also key to developing the pipeline of future researchers needed to deliver the Government's aim of increasing investment in R&D to 2.4% GDP by 2027.

The damage cuts would bring to our educational offering would also impact on the global reputation of UK Higher Education – at a time when global competition is increasing. We welcome the commitment in the Government's new International Education Strategy to grow international student numbers to 600,000 by 2030. We must protect the quality of our offering if we are to succeed.

### **Inclusion and mobility**

The post-18 system should be progressive and support social mobility. The current system is not perfect but, as noted in the report, it is progressive and access and participation have improved.

In 2017, 18-year-olds from the most disadvantaged areas in England were 82% more likely to enter Higher Education than in 2006. Universities have invested substantially to support students in their transition into university and taken significant steps to improve retention and successful progression towards rewarding graduate-level positions.

Living costs are a very significant worry, particularly for those who come from disadvantaged homes and from care, who need to borrow more money than their better-off peers to fund their time at university. These students often combine full-time study with long hours in paid jobs to make ends meet. That puts them under huge pressure with little opportunity to relax or to engage with the broader experience that university offers. The sector has long been calling for the reintroduction of means-tested maintenance grants to support disadvantaged students – we very much welcome the report's recommendation on this.

While we also welcome the proposed reduction in the interest rate on loans while students are studying, there is concern that other recommendations on loan repayment are regressive, including extending the loan write off from 30 to 40 years.

Cutting fees does not mean all graduates will have more money in their pockets or pay less for their courses in the long term. The Government's own analysis shows that higher earners will be the winners, while someone on average earnings, such as a nurse or teacher, will pay back £12,000 more than under the current system.

### **The numbers game**

The report steers clear of restricting student numbers or recommending a minimum entry require-

**Cutting fees does not mean all graduates will have more money in their pockets or pay less for their courses in the long-term.**



**The report challenges the sector to deal with courses which have poor retention, poor graduate employability and poor long-term earning outcomes.**

ment – at least for the short term. This would have reduced opportunities for those who have the potential to benefit from Higher Education but have lower attainment (many of whom come from more disadvantaged backgrounds). However, there is a suggestion that measures to limit student numbers may be imposed in the medium term.

The report challenges the sector to deal with courses which have poor retention, poor graduate employability and poor long-term earning outcomes. While poor quality courses cannot be defended, tackling the issues involved is not simple. It is important to rebalance the narrative on Higher Education with its prevailing focus on graduate salaries, which can be misleading, against the broader social and culture value it brings to society.

## **Flexibility**

The increased focus on encouraging more flexible learning is welcome, to ensure the most diverse range of learners can benefit from Higher and Further Education. The proposed introduction of a lifelong learning allowance would go some way to addressing calls to create more opportunities. With rapidly changing workforce needs, this could enable more people 'to learn while they earn', accessing education in a way that suits individual circumstances at all stages of a career.

However, we must understand more fully the implications of the four-year timeframe proposed for the lifelong learning allowance; how it will impact on social mobility and the disadvantaged

and what it means for Masters and Doctoral study.

There is particular concern about the proposed removal of loan support for Foundation years: these provide a valuable pathway into Higher Education. I believe they are a true aid to social mobility. They enable students who have not had a good experience at school to make up for lost ground and to adapt to university culture before joining the main degree stream.

Any reform must not restrict the ability of students to select the right course at the university that is right for them, wherever it may be in the UK. The Higher Education system has enabled students from all four nations to study in any part of the UK regardless of their domicile at the time of application. The review risks disrupting cross-border flows and may result in unintended consequences for student choice across all four nations. The UK Government must take time to consider its responsibilities to students and universities across the whole of the UK, not just those in England.

Universities must be at the heart of efforts to boost productivity and growth, to bring prosperity to all regions of the UK, to drive innovation and to deliver high-quality research that changes lives. Any review must acknowledge and respond to these broader challenges. □

**Encouraging more flexible learning is welcome to ensure that the most diverse range of learners can benefit from Higher and Further Education.**

# A new age of Further Education

**Stella Mbubaegbu**



Stella Mbubaegbu CBE is Principal & Chief Executive, Highbury College, Portsmouth. She was awarded a CBE by her Majesty the Queen in 2008 for her services to further education. Stella is a Fellow of the Institute of Directors, the Royal Society of Arts, the NEF Institute of Innovation and Knowledge Exchange and the City & Guilds of London Institute (FCGI), as well as a Companion of the Chartered Management Institute (CCMI) and the South East Region's WorldSkills UK Ambassador.

In Portsmouth we have very few adults who are qualified to Levels 3, 4 and 5. A significant proportion are in low-paying jobs. Over 25% of young people are living in poverty. Surely we can do better!

Further Education colleges did not know what to expect from this review, but there is now a sense of excitement about the recommendations in the final report.

Half of young people today go to university: we teach the 'other' 50% and, as the review panel noted, there is a real issue to be addressed here in terms of fairness and equity. It is desperately unfair that some young people have a huge slice of the education cake, while others get a sliver.

The panel talks about rebuilding FE so that a technical or vocational education can address the country's skills gap – a gap that is now widely acknowledged. They describe a way of doing this in very simple, understandable terms. I hope that, once and for all, we can move forward and that we no longer hear about the 'Cinderella sector'.

We need a sense of equity for FE and, indeed, for all of us as a society. We do not expect a 'happy-ever-after' fairy story. We all have to work to bring about change – so no Prince Charming, no fairy godmothers, just a fair solution.

The Government refers to the colleges as engines of social mobility and economic prosperity, delivering the Industrial Strategy. The reality is that they are under-valued and under-funded. There is now an opportunity to put right the errors of the past. The excellent recommendations of this review must be taken forward.

Further Education colleges form a very diverse sector. They originally focussed on vocational training – a pre-entry to employment. Colleges also provided opportunities to retrain, re-skill and up-skill.

Yet the sector has now acquired a general education mandate, dealing with failures in the education system. We have been referred to as 'the adaptive layer of the education system'. We are rightly proud of the work we do in terms of being inclusive, but there does need to be a rebalancing. There needs to be a clear focus for Further Education. The Institute of Fiscal Studies says that we are in 'a near-permanent state of revolution in FE' – always changing, always adapting. We have become providers of everything to everyone.

We need to build a national network of collaborative FE colleges, the key word being 'collaborative'. We need to stop competing among ourselves and work together with a clear focus on Levels 3, 4 and 5 (where over recent years there has been a fall

## SUMMARY

- We need to move beyond the 'Cinderella sector' image of Further Education
- Further Education is a very diverse sector
- Colleges are engines of social mobility and inclusion
- To move forward, we need to work together: FE, HE and employers
- The vision is for a 'Camelot Age' of lifelong learning where all can take part.

in numbers of young people studying).

We do work very closely with our local employers and are therefore engines of economic growth, social mobility and inclusion as well as community learning. Yet many colleges exist in survival mode, current funding bringing unintended consequences by focussing on low-value qualifications which do not need expensive equipment.

## Flexible funding

In Portsmouth, my home city, we have very few adults who are qualified to Levels 3, 4 and 5. A significant proportion are in low-paying jobs. Over 25% of young people are living in poverty. Surely we can do better! Funding must be increased and it must become more flexible. We have the most complex financial regulation in the world. The panel sees a quick win here and, indeed, our funding body says it is able, if so instructed, to change things quite quickly.

When you compare our colleges with those in America, Canada or Germany, it is interesting that the same multinationals operating in the UK are happy to contribute generously over there in terms of equipment that they want future staff trained on. Consolidation and specialisation are absolutely key for this sector. Working in partnership with universities we can ensure that the total cake is shared equitably.

College staff are 'dual-professionals'. That is the nature of what we offer. Our engineering lecturer, for example, would be a qualified engineer who has worked in industry and has then trained to teach. Our construction workers, plumbers, those in the built-environment, all are dual-pro-

professionals who teach as well. However, it is very tough to recruit the right people and pay them competitive rates to deliver up to date vocational skills, so we must have adequate investment. It is not a matter of asking for favours: we are asking for fair funding which gives us the wherewithal to pay our staff well.

A protected title for colleges would recognise what colleges do. People often say ‘well what do you do?’ We tell them we do entry level provision, Maths and English, Higher National Diplomas, we have a focus on STEM, but then we do remedial work as well. That is not the way to run a railroad! If people do not recognise the brand, then they will not really value the technical, professional skills and training on offer – which the country so desperately needs.

How can we move forward? Well, we need to work together, working with employers and working with universities. It is absolutely vital to break down the false dichotomy between FE and HE. There are huge opportunities to work together in a locality. I can see this working in my own area with the University of Portsmouth looking at how the colleges in that city, both the FE college and the 6th Form college, together with the University Technical College that the University backs, and also other institutions, can work together to deliver a world-class education.

I would like to see a new narrative that is not about Cinderellas. I hope we can look forward to a ‘Camelot Age’ of lifelong learning where all can participate and all can win, a time when all are collaborating and working together. □

It is very tough to recruit the right people and pay them competitive rates to deliver up to date vocational skills, so we must have adequate investment.

## The debate

One major problem is that Further Education funding is capped. There is little point in discussing entitlement to education if the places are not there. The proposal in the review for uncapped access to courses at Levels 2 and 3 is welcome, but this will not resolve the bigger issue.

If accepted, the review’s proposals will lead to Treasury providing some funding of HE. This is likely to result in a return to controls on numbers entering this sector as funding will be restricted. In addition, greater financial support for FE could impact on the money available for research in HE.

Teaching and research are closely linked in universities with staff normally carrying out both roles. If money is reduced, then staff are likely to be required to spend more time teaching, allowing less capacity for research. Universities point out that they already make a significant loss on their research activities and a cut in funding could reduce this further.

It is unfortunate that the media and the public in general refer to ‘tuition fees’ when these should more accurately be described as ‘university fees’. There is a great deal of cross-subsidy of different activities within universities and it is very difficult to apportion exactly the funding for each.

While everyone understands the status of a university, there is no such ‘protected title’ in FE. A college can be a school, a private provider or a Further Education institution. Colleges do not confer their own awards but rather run courses for other awarding bodies (such as universities). Having a recognisable and well-understood title for FE

institutions would help.

Tertiary education needs to be seen as a single ecosystem, not as separate silos. This report does have that overarching approach to the sector. And there is much that FE and HE can do together – there are many examples across the country. The fundamental problem is that there is not enough money in the system as a whole. So the question may come down to whether, in order to properly finance FE, it is acceptable to take some away from HE. That may be the acid test of our willingness for reform.

In the media coverage of this report, all the focus was on HE. Those in the HE world need to help make the case for FE so that a united voice can be heard. □

In the debate that followed the main presentations, a number of topics were raised, including: funding caps; the balance between research and teaching in Higher Education; ‘protected titles’ in Further Education; and the need to view tertiary education as an integrated whole.

## FURTHER INFORMATION

### Post-18 review of education and funding: independent panel report

[www.gov.uk/government/publications/post-18-review-of-education-and-funding-independent-panel-report](http://www.gov.uk/government/publications/post-18-review-of-education-and-funding-independent-panel-report)

### Robbins report on Higher Education, 1963.

[www.educationengland.org.uk/documents/robbins/robbins1963.html](http://www.educationengland.org.uk/documents/robbins/robbins1963.html)

### Department for Education Review of Post-18 Education and Funding Terms of Reference

<https://dera.ioe.ac.uk/31239/>

### House of Commons Library Summary of potential impact of reforms to HE

**Funding** <http://researchbriefings.files.parliament.uk/documents/CBP-8490/Summary-of-potential-impacts.pdf>

# IMPROVING PRODUCTIVITY

Productivity in the UK remains a challenge with the economy lagging behind competitors on this metric. The issue was debated at a meeting of the Foundation for Science and Technology on 19 June 2019.

## What tools and levers can we use to boost productivity?

Jennifer Rubin



Professor Jennifer Rubin is the Executive Chair of the Economic and Social Research Council (ESRC), the UK's largest funder of social science. She is UK Research and Innovation's (UKRI) Champion for Equality, Diversity and Inclusion and leads on the Healthy Ageing and Next Generation Services streams of the Industrial Strategy Challenge Fund. She is a member of the UK's Industrial Strategy Council and NATO's taskforce on ethnic intolerance in the military. Professor Rubin is Professor of Public Policy at King's College London and former Director of its Policy Institute.

While there are different ways of measuring productivity, all of them indicate that the UK is under-performing and all of them show major variations across the economy.

During my professional life I have had the opportunity to work with academics and policy makers, with professional practitioner communities, with the third sector and with business. Looking at problems from different perspectives often opens up new insights, allowing problems to be tackled more effectively and sustainably.

The lack of growth in productivity since 2007 is one of the major economic challenges facing the UK. It cuts across all sectors of the economy and each sector will need to be involved in findings ways to improve it. Given the complexity of the problem and its economic importance, this is an area where high-quality research can provide important insights and help drive improved outcomes.

Broadly speaking, productivity is a term that captures how much is produced with a given amount of input. These inputs can be things like hours of work or amounts of machinery. High productivity economies produce a lot of output with relatively little input. Productivity is typically understood in terms of ratios of inputs to outputs, with output per hour being one widely-used measure of labour productivity.

It is well known that the UK has a productivity problem. This is regularly remarked upon in the media; and is also a serious concern to policy makers, businesses and academics. The UK's low productivity has important consequences for wage growth and living standards. As John Van Reenen put it, productivity determines "the size of the pie we have to distribute and do things with our public services and more". The gap between our trajectory before 2007 and our current situation caused the Chief Economist at the Department for Business, Energy and Industrial Strategy (BEIS) to describe it as "our £300 billion problem".

While it is widely accepted that there is a problem, there is less consensus about its causes or what to do about it. This is a very complex problem and there are many inter-related issues that need to be explored. Even things that may seem simple (like measuring productivity) are more

### SUMMARY

- The lack of productivity growth in the UK since 2007 is one of our major economic challenges
- Low productivity in the UK is an issue affecting every sector of the UK economy
- Social science research is helping us understand and address the UK's productivity challenge.

complex than they first appear. It could be that we are counting the wrong things. For example, it recently became apparent that the UK included days when people were not working in its productivity calculations, whereas other countries did not. Having corrected for this, we now appear to be more productive than Italy and are under-performing less relative to others.

Similarly, our measurements may be missing important changes in the economy. For example, technological developments change how we do things but these changes are not always well-captured by our traditional measures. Day-to-day banking, for example, used to take many hours, with considerable time spent processing cheques and cash at bank tills. Today, many transactions can be carried out on a phone or an app. The impact of these kinds of changes can be difficult to measure for a firm, let alone an entire economy. Likewise, changes in economic activity may influence productivity, but they can have negative effects on the environment or on people's lives. These costs need to be captured in our new productivity measures.

Unfortunately, while there are different ways of measuring productivity, all of them indicate that the UK is under-performing, and all of them show major variations across the economy. There are many proposed reasons for this, some of which may help to explain the slowdown in productivity growth (such as the time it takes for organisations to adapt to new technology) and some may help explain our relative under-performance compared to other countries.

For example, an important driver of productivity growth is innovation. This raises questions about whether UK firms are investing enough in R&D and whether we are too slow taking up new technologies and improvements. If these are the main problems, new questions arise about what causes them: does our education system adequately support an economy that has changed dramatically and is now over 80% services? Similarly, recent research suggests wellbeing has a causal effect on productivity, with stress, anxiety and depression now accounting for more than half of all lost working days. Are there, too, problems with the way UK firms are managed?

### The role of research

Addressing these kinds of issues is exactly what the Economic and Social Research Council (ESRC) was established to do. In 1965, the Heyworth Committee convinced the then Education Secretary, Sir Anthony Crosland, that social sciences could help understand and address the major societal challenges that industry and policy makers were interested in. To do this well would, however, require the establishment of a new public funding body that would be responsible for everything from training researchers, developing methods and supporting a range of disciplines, to funding and coordinating fields of study.

More than 50 years later, Government Departments are publishing research questions they think will be of use in their areas, in order to inform policy, improve the effectiveness of services and improve outcomes for the wider public. These ‘areas of research interest’ or ‘ARIs’ help policy makers communicate their needs to researchers within Government and academia. It turns out that most of these questions relate to people and their behaviour and are, therefore, questions for social science.

In terms of productivity, BEIS is interested in research to better understand “what drives differences in productivity growth within and across UK sectors and regions, and how this compares internationally ... Through research we want to deepen our understanding of this area and what can be done to improve outcomes.” The Department for Education seeks to understand “How do skills needs in the national and local economy and qualifications of our labour force match up?” Similarly, the Department for Work and Pensions is looking at “the different ways to define and measure labour market progression and sustainable work”.

ESRC and UKRI are funding research in a wide range of related areas. Our research portfolio has a big emphasis on addressing important societal challenges. It includes research on: how people can

reduce their energy consumption (which will be vital to hit our zero-carbon target); the role of mainstream and social media in countering extremism; and understanding the drivers of lifestyle diseases, such as obesity. Research on topics such as these is helping us improve public services and enhance outcomes for people, communities and businesses.

But we can do more. Improving how data is used in policy analysis has enormous potential to help improve understanding of, and suggest how to address, the UK’s productivity puzzles. Given this potential, ESRC is partnering with the Office for National Statistics to securely bring together administrative data from across Departments. When these datasets are linked together and anonymised to maintain privacy, they will allow researchers to explore important policy questions on a scale that was not previously possible.

The Government has brought together a group of senior people from business, academia and civil society in the Industrial Strategy Council. It is tasked with developing metrics to assess the contribution of the Industrial Strategy to UK productivity and economic growth.

This will require expertise, insight and intelligence from academic research, from policy makers and business, and it will work across disciplines and sectors. It is an independent body that will advise on policy as issues and address gaps in our understanding of how to improve productivity.

So, by better understanding and measuring productivity, new ways can be found to improve it. This then links to good jobs and a wider spread of benefits, both geographically and in other ways. There is much to be done.

The relatively low levels of UK productivity compared to similar nations, and the slowdown in productivity growth since 2007, make improving productivity one of the most important economic challenges facing the UK. Understanding what the causes are, and then understanding what to do about it, are clearly not going to be easy tasks that will have simple answers. There are potentially very difficult measurement problems, and problems caused by a lack of high-quality data.

However, investment in research by UKRI and ESRC, the clarification of key problems by Government Departments in their ARIs, investments in developing new linked data, as well as improved coordination by the Industrial Strategy Council, are going a substantial way towards addressing them. The UK’s productivity challenge involves a range of complex, interconnected problems that interact in different ways and in different places. They are now being tackled in a much more coordinated way, but given the scale of the problems, a lot remains to be done. □

While it is widely accepted there is a problem, there is less consensus about its causes or what to do about it.

By better understanding and measuring productivity, new ways can be found to improve it. This then links to good jobs and a wider spread of benefits, both geographically and in other ways.

# Productivity in the aftermath of the financial crisis

Paul Johnson



Paul Johnson CBE has been Director of the Institute for Fiscal Studies since January 2011. He is also a visiting professor in the Economics Department at UCL. He is currently a member of the UK Climate Change Committee, and of the Banking Standards Board. Previous roles have included time as chief economist at the Department for Education and as director of public spending at HM Treasury, where he also served as deputy head of the government economic service. He has also worked at Frontier Economics and at the Financial Standards Authority.

Productivity rose pretty steadily for 40 years, right up to the financial crisis, and has flatlined since. There is no doubt at all that things have been going not well since 2010: the corroborating evidence is that median earnings have not risen since 2008 (earnings and productivity are well-correlated).

Now, nobody saw this coming, neither the Office for Budgetary Responsibility (OBR), nor the Bank of England, nor any other major forecaster (see Figure 1). This slowdown was absolutely not predicted. Essentially all the forecasts assumed that, after a period of flatness, the economy would return to the pre-crisis trend – and this simply has not happened.

This probably says quite a lot about how much we actually do not know and how much we still need to understand about what is going on here. It is, however, related to all sorts of things. So, we have the lowest interest rates since the Bank of England was founded in the 1690s. We have had the lowest productivity growth in a century. We have the lowest earnings growth in at least a century and a half.

This is new. What is happening in the economy has not happened for many generations. It is undoubtedly related to very low interest rates, to very low earnings growth and the other unusual things happening in the economy. But the complete failure not just to predict the crisis but also to predict what happened afterwards, does present a case for chastisement!

The slowdown has been worse in the UK than elsewhere. Yet, just at the point when the crisis broke, measured productivity in the UK had essentially caught up with the G7 average. We have fallen a long way behind since then. Productivity has slowed down everywhere, but it has slowed down a lot more in the UK than in a lot of other countries.

There is a good news story here: employment has been doing particularly well in the UK. To some extent this is because low-productivity people are being brought into the labour market. This

## SUMMARY

- After steadily increasing for 40 years, productivity has flatlined since the financial crisis
- Productivity growth depends primarily on resource allocation and technology growth
- Business investment has significantly reduced
- Political uncertainty has real economic effects, most directly on business investment
- The increase in small businesses has not positively contributed to productivity.

does mean that the productivity of those in work will have fallen, but that is by no means everything that is going on.

## Productivity growth

I believe that, in the end, there are only two things that really matter for productivity growth. One is the way resources are allocated – is this being done in the most efficient way? So, for example, there is evidence of some misallocation of capital in the aftermath of the recession. Very low interest rates meant that some firms remained using capital who were very inefficient. There was some labour-hoarding going on as well. So, in the immediate post-recession period there was clearly some mis-allocation of the capital.

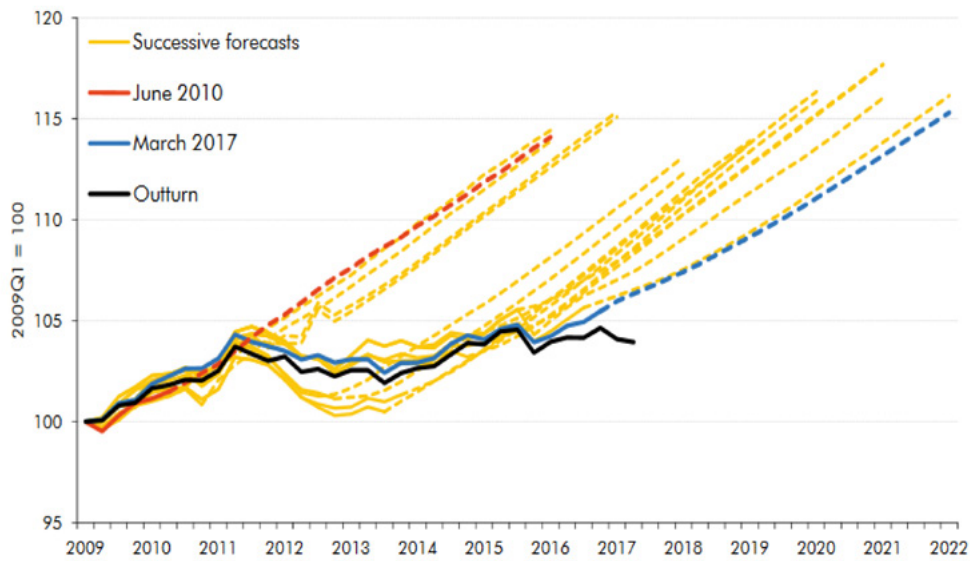
Another kind of misallocation occurs when people with particular kinds of education are working in a firm where they were less-productive than if they were working somewhere else. This is a geographical issue if people are working in firms because they cannot travel from one place to the next. The gender pay gap has a similar effect. It is clear from the data that women, after they have children, significantly reduce their commuting times: that reduction is very closely correlated with the reduction in pay relative to men. If women do not have the opportunity to travel into the centre of town for highly-productive work, they get paid less and end up working in less-productive sectors.

So this misallocation issue is very important as a social issue as well as a productivity issue.

The second way of promoting productivity is

Misallocation of capital is very important as a social issue as well as a productivity issue.

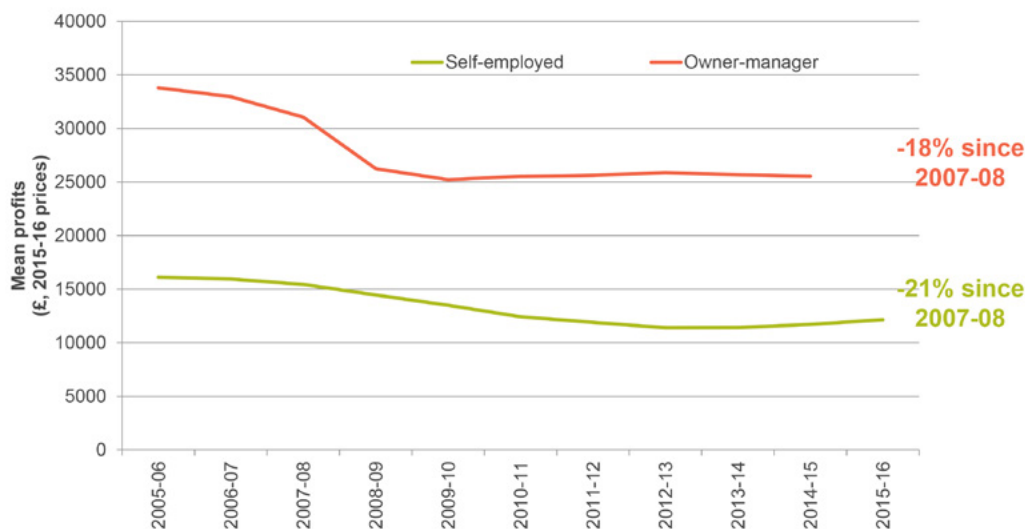
**Figure 1. Forecasts for increases in economic productivity have been inaccurate.**



Source: Institute for Fiscal Studies

All the forecasts assumed that, after a period of flatness, the economy would return to the pre-crisis trend. This simply has not happened (figure 1). Nor has the surge in the number of small businesses and sole traders create greater productivity (figure 2).

**Figure 2. Average profits for small businesses are lower than before the financial crisis.**



Source: Institute for Fiscal Studies

through technological progress. For decades, productivity growth ran at 2% per year. This was achieved by getting better at capital, better at technological progress, people being better educated and so on. This not automatic, though, as has become clear. It means investing – in education, in transport (so that people can get around the country), in housing and all those things that clearly matter for progress. In fact, over the past 10 years, there have been very large reductions in business investment.

Crucially for policy, it is not that firms cut their investment by a bit, rather that many firms

stopped investing completely. If all firms were changing their investment strategies a little, then incentives in the tax system might make a big difference. However, if firms are curtailing investment altogether then marginal changes to taxes are unlikely to have a big impact.

In fact, in policy terms, there are some initiatives that could be made which would be good for productivity and yet, for perfectly good reasons, they are not implemented. In general, roads are not built through places where people do not want them. Yet, better road connections would be good for productivity and building more houses

Some initiatives could be made which would be good for productivity – and yet are not implemented. In general, roads are not built through places where people do not want them.

Artist's impression of the plan for the third runway expansion at Heathrow airport



in London and the South East would be good for productivity. Building a third runway at Heathrow without huge delay would be good for productivity. So there are a number of things that would be good for productivity but we do decide as a country not to do them.

Then there are areas where we struggle: particularly in education, particularly with regard to vocational and technical education, where there are labour shortages and the UK is way behind most of its European competitors. Indeed, funding for Further Education has dramatically reduced over the past 30 years compared with schools and Higher Education. Philip Augar said in his recent report on post-18 education (see pages 15-21 of this issue) he was shocked to find there are actually fewer 18 year olds in education now than 20 or 30 years ago. There have been big increases in universities, but the rest of the system has just fallen apart. That is clearly a really important area if we are to improve productivity.

### Business investment

One of the most important drivers for productivity is what businesses are doing, not just what Government is doing. Comparing business investment in the aftermath of the last three recessions – 1979, 1990 and 2008 – is instructive. After the first two, it bumbled along for a period and then took off strongly. Pre-2016, the Bank of England and others were forecasting a similar big upswing in business investment – but it did not happen. In contrast, it has flatlined: there has been no increase in investment in the past three years and that is almost certainly directly associated with the uncertainty since the Brexit vote.

The whole world was struggling with investment in the period up to 2015 and the UK was not

dissimilar to the rest of the world. Since then, we have fallen behind the rest of the G7.

Political uncertainty has real economic effects, most directly on business investment. Economists and social scientists do not give enough weight to the relationship between political institutions and living standards, productivity and so on. In fact, we know that stable, well-working, effective institutions are probably, in the long run, one of the most important things in determining how business thrive and how living standards thrive – that is why capitalist western democracies have done so well relative to many other parts of the world. This point is absolutely crucial.

Many businesses in the UK say that Brexit is one of their top sources of uncertainty. Worryingly, the most productive firms are the ones who expect Brexit to have the biggest impact on sales.

### Small businesses

The Industrial Strategy argues that the surge in the number of small businesses, sole traders and company-owners/managers (i.e. people who have incorporated) will be good for productivity in the long run. This group accounts for about 15% of the labour market, so it is important to stress that employees are still by far and away the biggest part of the market.

Now, is that really creating greater productivity? I am afraid the data suggests not (see Figure 2). The net income of these people has gone down significantly over this period. The figures indicate that, on average, these very small businesses are doing worse now than a decade ago. There is nothing wrong with being self-employed or company-owners/managers, but at the moment they are one element of what is pushing down measured productivity. □

Many businesses in the UK say that Brexit is one of their top sources of uncertainty. Worryingly, the most productive firms are the ones who expect Brexit to have the biggest impact on sales.

# Improving productivity across the UK

Robert Jenrick

## SUMMARY

- The UK's productivity growth over the past decade has been lower than our competitors
- Raising productivity is the only sustainable way to raise living standards
- This country needs to reform – and invest in – vocational technical education
- Improvements to local issues such as transport can make a significant contribution to productivity
- We need to focus on increasing productivity in all the regions of the UK.

In the decade before the financial crisis unfolded in 2008, productivity growth in the UK was around 2%, but since then it has averaged just 0.2%. This has affected wages, which in real terms are still about £8 a week lower than a decade ago.

It is not unusual to see sluggish growth after periods of very significant disruption, but the length and the persistence of this sustained slowdown in productivity is almost without precedent. Our productivity growth has also been weaker than most of our major competitors.

This country has traded some productivity growth for another distinguishing characteristic of the past decade – historically very high levels of employment (and very low levels of unemployment). This has an importance beyond economics, in terms of the dignity and self-respect of individuals in families and communities.

Nonetheless, raising productivity is the only sustainable way to raise living standards, preserve our prosperity and build a more united country and society.

## Measuring productivity

For decades, statisticians have measured productivity essentially by taking GDP as a measure of output and dividing it by the amount of inputs – dividing GDP by the number of hours worked to calculate labour productivity or by the amount of investment in employment for total productivity.

Yet what we mean by 'productivity' is being fundamentally challenged by the digital revolution –

largely because so many new services are free.

For example, thanks to the internet, I can book my holidays from my home. I get more choice, better value for money and can do it from the comfort of the armchair. However, because no high street travel agent is involved and therefore no travel agent's fee is due, measured GDP falls – and so does the measure of productivity.

The fuel that powers the digital economy is data, but unlike normal goods and services, data can be replicated for free. It is vital to get an accurate measure of its economic impact. In 2016, the Treasury commissioned the Bean Report and used its recommendations to advise the ONS on how to adapt to some of the challenges.

Yet, however we refine the measurement, there remains a problem with productivity. If it were true that we were just underestimating our productivity, then one would expect a correlation between the size of digital economies around the world and how much productivity has tailed off – there is no such relationship.

## Addressing the productivity challenge

There are a number of ways to address this challenge and we have policy levers at our disposal, although we have discovered in recent years that there are no easy or quick fixes.

Persistent capital under-investment by businesses remains a challenge and that is despite this Government, and the Coalition before it, taking a number of steps to address it. Corporation taxes are now among the lowest of any major economy. R&D tax credits have been increased. There has been increasing public investment in science and innovation. The Budget reduced corporation tax again while raising the annual investment allowance from £200,000 to £1 million a year.

Yet there has to be a question over the impact of these policies. Barely 10% of small and medium sized businesses were even using the £200,000 allowance in the first place.

SMEs, particularly family businesses, are often less well-managed in this country than in others such as Germany and the USA. The Government has invested money in more networking opportunities, in better management education and in ways to increase and encourage greater uptake of



Robert Jenrick MP was Exchequer Secretary, HM Treasury, when this meeting took place. He has since been appointed Secretary of State for Housing, Communities and Local Government. On 1 August, he also became Ministerial champion for the Midlands Engine. He was elected Conservative MP for Newark in June 2014. Prior to joining Parliament, he had a successful business career, latterly as International Managing Director of the art business, Christie's.

What we mean by 'productivity' is being fundamentally challenged by the digital revolution – largely because so many new services are free.

Birmingham's productivity is a third lower than it should be, in large part because of poor transport.

technology. There are initiatives to encourage the adoption of digital technology by SMEs in order to improve productivity, such as helping a small business to use cloud computing, the internet or social media.

### Further Education

This country needs to reform – and invest in – vocational technical education. There is a consensus on this across British politics. The introduction of T Levels represents the biggest change to the secondary education system in this country since the advent of A Levels: these will be piloted from September 2020 and then scaled up across the country. There will also be a continued emphasis on apprenticeships.

Digital skills are beginning to permeate the curriculum, such as introducing coding in primary schools.

Then there is the challenge of retraining, particularly for those who find their working lives disrupted by technological change. The Government's National Retraining Scheme, in partnership with the CBI and the TUC, will be piloting a number of approaches.

### A regional issue

Looking at productivity statistics for the various regions, London is of course way out in front. It is the home for star businesses and is one of the great cities of the world. It attracts successful graduates and highly skilled workers. It is a truly global city. It is exposed to new ways of doing things from other countries and brilliant young people want to build their lives here.

The average worker in the Capital produces a third more per hour than the average for the UK. As a share of the workforce, twice as many people work in professional, scientific or technical roles than in any other major UK city. In places like Bradford and Birmingham, productivity is very significantly lower.

We cannot replicate London in the rest of the country. As a Midlander representing a small town near Nottinghamshire, I think we should look to the best performing places outside of London – like Bristol and Aberdeen – and examine what they have in common. They have links to good universities, to science and R&D, they have

deep pools of talent and, most importantly, they tend to be places where people want to live and where graduates and highly-skilled people want to build a life.

### Transport

These are the sorts of thing that sometimes get overlooked in the grand debates and the attraction of grand projects. Housing, of course is part of the challenge – and that is not just a London problem – but another is local transport. The journey into work each day really affects everyone's lives, yet British cities lag behind our continental neighbours in terms of local public transport connections. Leeds is the biggest city in Europe without a mass transit system. The two most congested commuter lines in the country are train routes into Manchester. Birmingham has a metro with just one line, whereas Lyon, a city half the size, has four.

That means that people in the city have to rely on slow buses which get stuck in traffic. Buses are themselves in decline in the countryside. This creates barriers to people commuting in from the suburbs. A study from City Metric shows that Birmingham's productivity is a third lower than a city of its size should be. In large part, that is because of its poor transport network.

Projects for commuter line improvement and local roads generally have a much higher return on investment than long distance routes and grand projects – that was why the Government, a couple of years ago, created the £2.5 billion Transforming Cities programme for inter-city and regional transport. The roadbuilding budget for the period commencing in 2020 will be at the highest level since the 1970s, almost £30 billion over five years. This type of investment is critical to boosting our productivity.

When the Government set aside £400 million for dealing with potholes, it was treated a bit snobbishly by commentators, but was hugely welcomed by anyone who actually has to use the roads. When I created a £150 million fund for tackling small pinch-points like a congested roundabout, a bridge or a flyover in need of repair, it was a struggle to persuade others of its relevance, perhaps because it was so mundane. Yet we know these are the sorts of projects that will make a real difference to productivity and to people's lives.

Politicians need to get out of Westminster and understand what is actually holding people back in their daily lives. They must set their sights beyond the Capital to the regions of the UK and measure success by levelling those up, by doing small things that, in aggregate, make a huge impact on the productivity of the country. □

Digital skills are starting to permeate the curriculum, such as introducing coding in primary schools.

# The debate

The debate that took place following the main presentations touched upon, among other topics: the impact of R&D; management practices and training; and the environment.

**I**ronically, R&D can in fact reduce productivity levels by making products more efficient and cheaper. That kind of anomaly needs to be addressed when considering the best means of measuring productivity.

While a great deal of research is devoted to improving technologies, much less is focussed on the psychology and behaviours of employees – and the training that managers need in order to run their teams better. Effective management is a key part of improving productivity, yet in a recent survey, only 25% of managers taking part had received any training on this subject and even fewer had any interest in further training.

The quality of British management has been an issue. How businesses treat their workers has an impact on success – if staff feel engaged, they will be more productive.

## The low-pay cushion

The 2010s are very different from the 1980s. In those earlier days, the economy recovered with very fast earnings growth for a large percentage of the population but with high unemployment as well. By contrast, today there is low earnings growth but high levels of employment. One result is that some sectors have been able to defer investment in new technology through reliance on lower-skilled – and lower-paid – workers.

It should be remembered that wage levels do not always reflect the value of the work being carried out – the care industry is a case in point. Social value should be included somehow in measuring productivity rather

than just economic return.

The Industrial Strategy is finalising a number of sector deals to incentivise different parts of the economy. The recent Construction Industry sector deal aims to help the sector move to productivity levels similar to those in manufacturing but that will need stability and business confidence – which are hard to come by at present.

People will be happier and more productive if they like and value the environment where they live. So one challenge facing Government, both central and local, is how to make more of our towns and cities more attractive places to live. □



Laura Jean King/WorldSkills UK (CC BY 2.0)

**Social care is one industry where wage levels do not reflect the value of the work carried out.**

## FURTHER INFORMATION

### The UK's Industrial Strategy

[www.gov.uk/government/topical-events/the-uks-industrial-strategy](http://www.gov.uk/government/topical-events/the-uks-industrial-strategy)

### Independent Review of UK Economic Statistics (the Bean Report)

[www.gov.uk/government/publications/independent-review-of-uk-economic-statistics-final-report](http://www.gov.uk/government/publications/independent-review-of-uk-economic-statistics-final-report)

### Construction sector deal

[www.gov.uk/government/publications/construction-sector-deal](http://www.gov.uk/government/publications/construction-sector-deal)

### ESRC, The Social Sciences Archive

<https://esrc.ukri.org/files/about-us/the-social-sciences-archive>

Effective management is a key part of improving productivity, yet in a recent survey, only 25% of managers taking part had received any training on this subject.

# MARITIME STRATEGY

The Government's strategy for the future of the British maritime sector was debated at a meeting of the Foundation for Science and Technology on 6 March 2019.

## A place in the front rank

**Roger Hargreaves**



Roger Hargreaves OBE is Director of Maritime at the Department for Transport. Prior to taking up his current role, Roger was responsible for securing the legislation and other powers necessary to allow the construction of High Speed 2. Roger's previous civil service roles include Programme Director at the Office for Renewable Energy Deployment in the Department for Energy and Climate Change, National Project Director for a major emergency services project at the Department for Communities and Local Government, as well as a series of posts at the Cabinet Office in the national security field.

When I took up this role two years ago, the most significant surprise was that we did not have a plan. I have always been firmly of the view that you need a plan in life for almost everything that you do. Maritime did not have one, despite the sector being so obviously critical to the economy and to the life of the nation.

I have worked in a number of infrastructure areas and all these had long-range forecasts and a really clear sense of what the Government was trying to achieve. Other sectors have benefitted from a clear and strong partnership between Government and the private sector together with a clear, long-range vision for what the country is trying to achieve. I concluded that maritime could really benefit from that – and Ministers agreed.

It was also clear that doing nothing was not an option because the cold, hard truth about UK Maritime is that it has experienced a relatively steady 100 years of decline. Today, the UK is facing some very significant challenges.

### Shifting eastward

Trade is growing, global population is growing and that drives maritime activity. However, there is also a dramatic, relentless shift eastwards in the global economy while climate change presents new challenges. In addition, the emergence of new technologies has the potential to fundamentally affect how the sector works.

When the Maritime 2050 strategy was published, the aim was to set out a strong, long-range vision, one that was both a conceptual, intellectual framework and also a route map. It is constructed around a number of themes (Table 1) and contains concrete proposals for delivering the kind of changes that we want.

The strategy is grounded in partnerships. During the course of a year thousands of people were asked for their thoughts. That was an extremely interesting process because the maritime sector

### SUMMARY

- The UK's maritime sector needs a long-term strategy
- Trade and population growth are driving global maritime activity
- The UK must represent a premium brand in a global economy
- Science and technology are fundamental to the UK's maritime future
- The Government is determined to maintain the UK's place in the front rank of maritime nations.

is far less used to dealing with Government than other infrastructure sectors that are more dependent on Government funding or have had a closer relationship with Government over time.

My last job was in rail where the world is full of people with bright ideas about the rail sector. There is an almost endless supply of people who are thinking deep thoughts. So here we convened an expert panel – people who were known to be thinkers about the maritime sector or who are on the edges of the sector but were engaged in thinking about public policy. That injected a fresh sense of challenge into the process.

### Core values

The strategy sets out some core values. One is the idea that the UK must represent a premium brand in a global economy, rather than trying to compete endlessly – and potentially fruitlessly – on price.

It outlines the balance between security, prosperity and sustainability. There are some maritime powers across the world who abandon one or two of these in pursuit of the other. However, for the UK, in line with our public policies, sustainability, prosperity and security go hand in hand.

Another core value is the partnership with industry, because this is fundamentally a sector driven by private concerns. While the Government might have had a really active role in our maritime life in a previous age, any vestige of such intervention fell away a couple of generations ago.

**There is a balance between security, prosperity and sustainability. Some maritime powers abandon one or two in pursuit of the other. Not the UK.**

So today, we are keen to facilitate a partnership between Government and industry.

The strategy also provides a route map, a way forward, with short-, medium- and long-term recommendations. The short-term recommendations are being pursued now and over the next five years as an immediate plan of action.

The medium-term recommendations set out our expectations of what we think the UK maritime sector should be trying to achieve, while the longer-term ambitions frame the direction of travel.

### Science, technology and innovation

The UK's maritime story is fundamentally intertwined with the UK's progress as a technological, innovative power, and vice versa. Navies are much more complicated things to deliver than armies, so a huge industrial hinterland was needed. The UK's naval and maritime power amplified its industrial power and vice versa.

Science and technology are also fundamental components of the UK's maritime future. Looking at the UK's strengths, its competitive advantage lies in areas like thought leadership and its research base. Clusters of activity around key ports and universities mean that businesses and people still look to the UK as a powerhouse of science and technology.

For many people, shipping is the heartbeat of maritime and will frame what the future looks like. So the strategy talks about the future of shipping and the ways in which it might develop. We discuss the creation of test beds, as well as regulatory environments which allow people more autonomy. The UK has to be an environment in which different kinds of technology can flourish.

### Ports and infrastructure

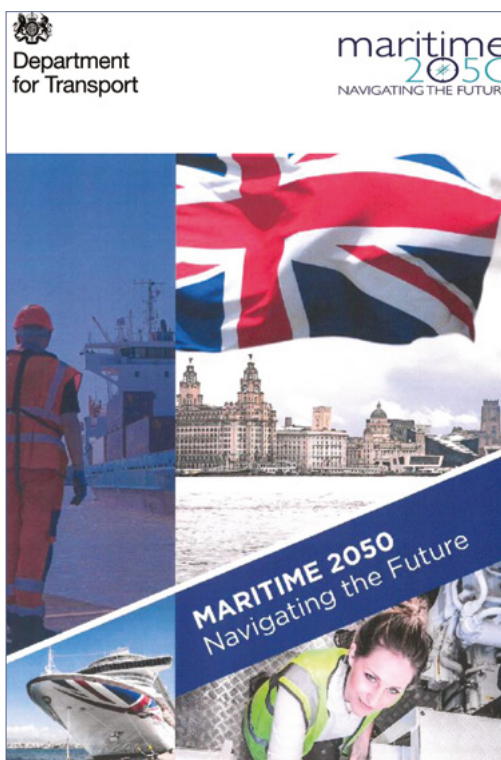
The strategy says a great deal about ports, infrastructure and associated technology. Ports today are part of an end-to-end process: people care less about the ship that their goods are on, or the port that they go through, and more that they get from A to B in a seamless way. Shipping companies and port operators have a sense that the future involves making the most of assets through the use of big data, on one level a slightly more remote relationship but on the other hand a more controlling and well-understood relationship with those assets.

The Government must allow that to develop but also provide funding or support for those people at the cutting edge. Looking around the world at our competitors, this is what they are doing, yet we think we can take this even further and faster in the UK.

Over time the value of a square mile of sea has

**Table 1. The central themes of the Maritime 2050 strategy**

- Competitive advantage – making the UK a place to do business.
- Infrastructure – our ports and their connectivity.
- People – helping us to maintain our position in the global economy.
- Trade – the lifeblood of the maritime sector.
- Security – giving us the freedom to trade.
- Environment and technology – both potentially major disruptors to the sector.



**The strategy has a strong, long-range vision – a conceptual framework and also a route map.**

gone up and up. The sea can be exploited in different ways: underneath the sea bed, there is oil and gas industry, there are resources to be mapped and mined. There is a whole world to be explored there and technology will play a vital role in this. These new areas of innovation and activity will change and expand the maritime sector.

We pursued this strategy because we were convinced that doing nothing was not an option. The intention is to move from a world where we do not have a strategy to one where we do. It represents a really big step forward.

The Government is determined to maintain the UK's place in the front rank of maritime nations and to retain the UK's leading place in technology in the world of maritime. □

**The UK's maritime story is fundamentally intertwined with the UK's progress as a technological, innovative power, and vice versa.**

# Collaboration is the key to future success

**Sarah Kenny**



Sarah Kenny OBE is Chief Executive of BMT, which specialises in defence and security, specialist ship design and surveys, critical infrastructure, and environmental modelling. A marine environmental scientist by background, Sarah has worked in marine and maritime science and technology businesses throughout her career. She is Vice Chair of Maritime UK, a member of the UK Defence Innovation External Advisory Panel, the UK Department for Transport Maritime 2050 Expert Panel, and the UK Maritime Enterprise Working Group. Sarah is a member of the board of the National Oceanography Centre, an Honorary Officer of the Royal Navy, and an Honorary member of the Royal Corps of Naval Constructors.

For a sector which collectively contributes £40 billion to the UK economy and employs around 1 million people – and with 95% of the UK's trade conducted by sea – our contribution has not been well-understood. So, the Maritime 2050 strategy is a huge opportunity.

It is especially noteworthy because it indicates that the UK is taking a leading role in maritime science, technology and innovation. There is a necessary and major focus on how the UK will achieve and sustain a competitive advantage through the smart exploitation of technology, human capital and, most importantly, how it will accelerate progress and improve the chances of success through partnerships between Government and industry.

As an island nation with a long seafaring tradition, Britain has a rich maritime heritage with particularly impressive achievements in technology and innovation. These include the first iron-clad warships, steamships, hovercraft and hydrofoils. Innovation is often conflated with technology, but of course it is much broader than that.

For example, the UK has an excellent reputation in the development of safe maritime operations. Our influence is evident in maritime regulation around the world today, such as the load line to indicate the safe loading level of ships, created by the British MP Samuel Plimsoll in the late 19th Century. Our model for the Marine Accident Investigation Branch, established during the 1980s, has been adopted in many other countries since.

## An international sector

The maritime sector is, and has always been, international. We are influenced by geopolitical events and trends and have historically anticipated and responded through commercial and business models. However, the rate of change is increasing exponentially.

We are seeing the impact of dynamic and rapidly-changing trade policies such as Brexit, America First and the Chinese Belt and Road. While

We are seeing the impact of dynamic and rapidly-changing trade policies such as Brexit, America First and the Chinese Belt and Road.

## SUMMARY

- Britain has a rich maritime heritage with impressive achievements in technology and innovation
- The maritime sector is, and has always been, international
- The UK can gain a strategic edge through the well-considered integration of people and technology
- The sector is being challenged to reduce carbon emissions by 50% by 2050
- A maritime research and innovation hub is being established to bring together public and private sector initiatives.

that creates uncertainty, we have to respond and adapt through improved investment, innovation and, importantly, collaboration. This can only be truly enabled by business leaders adapting to more flexible, agile business models in consort with governmental and other stakeholders.

In its report *The Ocean Economy in 2030* the Organisation for Economic Cooperation and Development predicts that ocean industries can double their contribution to global value creation by 2030. Like many analysts and commentators, the OECD anticipates that the future will see increased demand for shipping, shipbuilding, marine equipment and related services. So the opportunity is both exciting and compelling.

However, the adoption and integration of advanced technology, coupled with flexible, collaborative business models, will be essential in order to take full advantage.

The maritime sector is in many ways ill-prepared for the disruption that is unfolding before us. Smart ships will exploit intelligent systems using lightly-manned, semi-autonomous and in time fully-autonomous capabilities. They will operate seamlessly with interconnected ports which use digitally-tagged containers, autonomous trucks and remotely-operated cranes to drive up efficiency and productivity.

Logistics and asset data from disparate sources will employ technologies such as block chain to

quickly, securely and accurately connect owners, operators, hauliers, traders, insurers, supply chains and consumers with real-time information about their product or assets.

Fully realised, these technologies will create an innovative, connected, trading ecosystem, transforming our maritime sector. Greatly-enhanced speed and productivity in shipping and port operations could change the types and volumes of goods and services which are currently traded by sea. The adoption of technology-enabled security enhancements might influence customer and supply chain choice as to where trade takes place, in a world where cyber and piracy threats challenge traditional trade routes and practices.

### A strategic edge

There is an opportunity to gain a strategic edge through the well-considered integration of people and technology. This will need a highly-trained, motivated and committed workforce or we simply will not achieve the competitive edge we seek. In the competition for available talent, we must 'up' the image of this sector so that we literally do not miss the boat.

The Government estimates that the value of the global ocean economy will be \$3 trillion by 2030. Much of this growth will come from the exploitation of the maritime environment in new and exciting ways – such as advanced aquaculture and seabed mining.

Maritime 2050 commits the UK to charting its own seabed. This currently uncharted frontier offers great potential for British industry, necessitating closer collaboration and knowledge-sharing between industry, Government and academia.

Regarding autonomy and digitisation, the UK is already a leader in the design and manufacture of small-scale autonomous vehicles as well as autonomous command-and-control.

Through Maritime 2050, Government and industry will deliver flagship projects to develop technological proofs-of-concept and provide demonstration-of-use cases for smart shipping. The UK is also leading the debate on maritime autonomy. Maritime 2050 recommends the establishment of a new, adaptive international regulatory framework for autonomous vessels.

This builds on the work of the Maritime UK Autonomous Systems Regulatory Group which hosted an international conference in 2019. Maritime 2050 will also see Government and industry working together to achieve the first multi-modal autonomous freight movement through a UK port, making digitised ports and shipping a reality.



### Climate change

The International Maritime Organisation (IMO) has set the sector a challenge to reduce carbon emissions by 50% by 2050. To do so, shipowners, manufacturers, providers and technologists will have to innovate and collaborate in areas such as vessel efficiency, propulsion and energy management, drawing upon other sectors which have already worked on these technologies. Many of these advances will come from small- and medium-sized enterprises (SMEs).

For the past few years, significant effort has been expended by industry and academia, supported by Government, in establishing a maritime research and innovation hub MarRI-UK. This is an open consortium pooling collective investment in maritime sector innovation.

The consortium is looking for a range of partners in maritime research and innovation. We aim to create both critical mass and a regional spread to prioritise resources so that the maritime sector can achieve the 2050 vision. It will provide much-needed coordination and collaboration across our diverse industry, but this is not about bricks and mortar. MarRI-UK will be a hybrid, a physical and virtual collaboration environment, encompassing a range of centres – many of which already exist – to develop a research and innovation programme driven by industry need.

To make this work, for everyone's benefit, we must build a culture of collaboration (which is not traditional in this sector). That requires change. We have made real progress, but there is so much more to do.

To close I will quote Darwin: "It is not the strongest of the species that survives, nor the most intelligent, it is the one that is the most adaptable to change." □

**The maritime research and innovation hub MarRI-UK is an open consortium pooling collective investment in maritime sector innovation.**

**We must build a culture of collaboration (which is not traditional in this sector) to make this work.**

# Drawing in support from the wider economy

Ed Hill



Professor Ed Hill OBE is Chief Executive of the UK's National Oceanography Centre, a post he has held since 2010. He currently heads the UK Delegation to the Intergovernmental Oceanographic Commission of UNESCO, is chair of the National Partnership for Ocean Prediction and serves on scientific advisory boards for oceanographic institutions in China and Japan. He was appointed OBE in 2010 for services to environmental sciences.

The ocean economy consists of three vital elements. The first is the ocean-based industries themselves. These are hugely dependent upon, and interact with, the second element – the ocean environment and ecosystems. The third factor is the way in which the ocean is governed and regulated at international, regional and national levels. R&D and innovation are vital to informing all three dimensions of the ocean economy.

The maritime sector is actually a subset of the broader ocean economy (see Table 1), but it is a very diverse sector covering the five main pillars of that economy – everything from low- and medium-tech to high-tech manufacturing or other forms of production, knowledge-based services and other marine services.

The ocean economy itself has three other significant features. First, it is explicitly defined by the environment in which it operates – the marine environment. It is impacted by the sea: much of it is based on marine resources or draws resources from the sea. In turn, it also impacts the ocean environment and, crucially, as the 2015 WWF report *Reviving the Ocean Economy* demonstrates, it is all underpinned by a vast, natural capital of marine ecosystems worth about \$24 trillion dollars, delivering direct economic benefit of about \$2.5 trillion a year, 70% of which depends on the health of the ocean environment.

The second feature is that the ocean economy is fundamentally a knowledge-based economy. We think of Captain James Cook as a sailor and an explorer. Yet Cook was a Fellow of the Royal Society and in modern terms might be described as a 'pioneer of marine geo-spatial information of very high accuracy and quality'. Finally, it is characterised by interconnectedness e.g. the ocean environment and global trade that uses the sea.

The Maritime 2050 strategy sits within the context of larger UK ambitions for R&D – the Industrial Strategy, published in 2017, the 25-year Environment Plan and UK's Research and Innovation Prospectus.

The ocean economy is fundamentally a knowledge-based economy. Captain James Cook was a Fellow of the Royal Society.

## SUMMARY

- The maritime sector is part of the broader ocean economy
- R&D and innovation are vital to this sector, which needs to make better use of the UK's science, technology and engineering base
- To achieve the 3% Government longer-term ambition, there is scope for stimulating increased R&D intensity
- There is a need to import R&D from adjacent sectors
- Mapping of the ocean floor represents a major opportunity and symbol of ambition.

There has been recent thinking about the oceans from the OECD which forecast the ocean economy will double from \$1.5 trillion to \$3 trillion per year from 2015 to 2030. They have also been the subject of a major Government Office for Science Foresight Report about R&D in the marine environment. The International Ocean Strategy is expected to be published imminently.

## R&D and innovation

Maritime 2050 talks about the role of innovation in achieving the high-level vision, though interestingly does not identify innovation as a core value. Of the 185 recommendations, about 30 explicitly relate to research and innovation, while it is implicit in others (e.g. green shipping). There is emphasis given to: improving the ties between Government, industry and academia; thought-leadership in the sector; support for maritime innovation, creating a very attractive regime for testing autonomous systems; a maritime innovation hub in a UK port; and mapping the seabed. The strategy also talks of creating an analogue of the Aerospace Technology Institute, while the skills section discusses the need to bring STEM skills to the forefront.

While the strategy highlights that this is an innovative sector, it might be better characterised as one where there are hotspots and highlights, but one in which R&D intensity is not as high as in other areas (pharmaceuticals, aerospace). We

<b>Table 1. The Marine &amp; Maritime Sector as a subset of the Ocean Economy</b>	
<b>Ocean Economy - £47 billion GVA (2.7% of UK Gross Value Added)</b>	
<b>Marine &amp; Maritime - £14.5 billion GVA</b>	
<i>Low-Medium Tech Manufacturing</i>	
Seafood processing	Shipbuilding
	Boatbuilding
<i>Medium-High Tech Manufacturing</i>	
Marine Biotechnology Products	Marine Engineering
	Marine Scientific Equipment
<i>Other Production</i>	
Offshore oil & gas	Marine renewables
Fishing	
Aquaculture	
Deep sea mining	
Offshore construction	
Subsea cables	
<i>Knowledge Services</i>	
R&D	Maritime business services
Ocean education	Public marine science and technology
	R&D
	Marine-related education
	Marine technical consulting
	Marine and maritime education
<i>Other services</i>	
Marine and coastal tourism	Ports
Royal Navy	Border Agency
Marine & Coastguard Agency	Recreational marine activities
General lighthouse authorities	Support for offshore oil & gas
	Support for marine mining
	Support for offshore engineering
	Support for offshore engineering

The OECD forecasts that the ocean economy will double from \$1.5 trillion to \$3 trillion per year from 2015 to 2030.

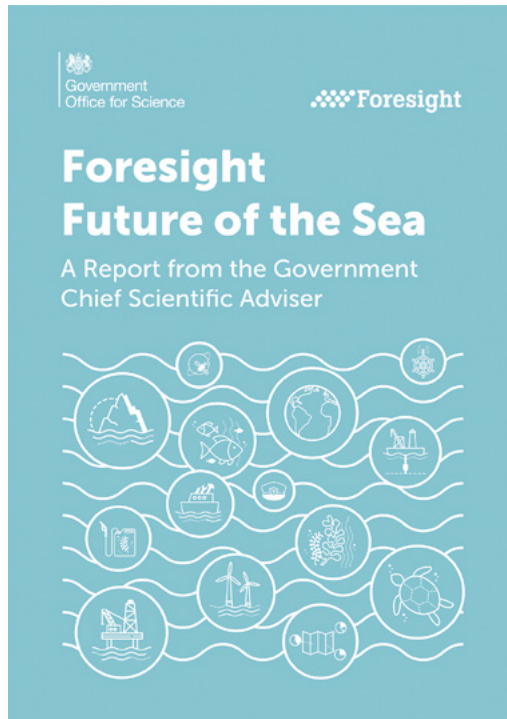
might speculate why this is. For example, there have been transformative innovations in maritime which have not been R&D led – containerisation is a classic example. Maritime is also highly service-orientated and the service sector of the economy is not noted for R&D-led innovation. One big component of maritime is the leisure industry – once again not noted for being R&D-intense. Shipbuilding and boatbuilding are classified in the public accounts as ‘low- to medium-tech manufacturing’, a perception not entirely justified if advanced warships and the world’s most advanced polar research ship, built by Cammell Laird in Birkenhead, are taken into account. Perhaps perceptions are influenced by there being fewer visible icons of innovation. There does not seem to be a good quantitative picture of present R&D intensity in the maritime sector and this should be addressed.

R&D investment plays different roles at different stages of the business cycles of maritime industries. It provides evidence needed to: establish the potential and regulatory framework for emerging new industries (e.g. seabed mining); help early stage industries develop technologies and knowledge of marine conditions (e.g. marine renewables); and assist mature industries sustain productivity, change, adapt and diversify (e.g. oil & gas).

On top of business cycle aspects, consumer interest and the need for a social licence may come into play and R&D may be important for public confidence.

**There have been transformative innovations in maritime which have not been R&D led – containerisation is a classic example.**

**The Foresight Future of the Sea Report recommended focussing on common research infrastructure and skills needs, and making better use of the UK's science, technology and engineering base.**



A major plank of the UK Industrial Strategy is the target for the UK to achieve 2.4% of GDP R&D intensity. The largest increase in R&D spend will come from business R&D, including inward investment. The marine and maritime sectors warrant particular interest from Government as a promising target for public R&D spend to stimulate business investment. This is because maritime, first, has major growth potential and, second, is not already near saturation in terms of R&D intensity. Maritime will need help to import R&D from adjacent sectors and then translate and develop it within the sector.

The Foresight *Future of the Sea Report*, published in 2018, identified a number of structural issues with marine and maritime in the UK, including the need for very long-term approaches as well as the global nature of the sector. One of the key recommendations was to address insufficient join-up between the diverse parts of the marine economy by, first, focussing on common research infrastructure and skills needs as well as, second, making better use of the UK's science, technology and engineering base.

Thought-leadership is highlighted in the Maritime 2050 strategy. The maritime sector needs an image 'makeover' – it is generally perceived as invisible, low-tech and dirty. It needs to develop and better project icons of vision, ambi-

tion and innovation. What is the maritime equivalent of a Formula 1 car or the Mars Rover? Is it the super yacht, Americas Cup boats or the next generation of deep ocean exploration vehicles?

One area where technological innovation is starting to transform marine activities is the rise of autonomy and robotics. Measuring the ocean with ships takes years in which to collect and process the data. However, autonomous vehicles sitting in the ocean, returning continuous, real-time data, are fast becoming the norm. Frontier technologies developed for ocean exploration and continuous ocean observations are being adopted for other maritime operations. These can drive out high ship costs and are better suited to 'dull, dirty or dangerous' tasks. While technology is transforming the sector, innovation in the business models to exploit them is lagging (e.g. those supporting sustained ocean observations and monitoring).

### Mapping

Mapping the ocean floor, also identified in Maritime 2050, provides an opportunity to create an important global, digital, data infrastructure: in parts of the ocean the only information dates from Cook and his contemporaries in the 18th Century, while for 85% of the ocean we have no directly measured information at all. To measure the ocean at 350m resolution and 5km depth (involving some 270 exabytes of data) would take one ship 1,000 years and cost \$3 billion – the cost of the Cassini mission to Saturn. But it is scalable and can be accelerated with autonomous technologies. When the UK leaves the EU, it should consider joining the Atlantic Ocean Research Alliance (AORA) and become a partner in its own right, alongside the EU, USA and Canada. This includes a joint endeavour to map the whole of the North Atlantic Ocean.

Drawing on the Foresight Future of the Sea report, it is important to:

- find common research needs across the whole ocean economy;
- better understand the nature of R&D intensity in the sector;
- determine what a 3% of GDP R&D target actually means for the sector;
- define relevant research needs;
- influence major funders such as UKRI and Maritime UK.

The marine and maritime sector is strategically important for the UK and has many natural advantages and major growth opportunities. It is a sector worthy of the growing attention it is starting to receive – and an obvious target for stimulating expansion of R&D intensity. □

**The maritime sector needs an image 'makeover' – it needs to develop and better project icons of vision, ambition and innovation.**

# A critical role

To paraphrase Darwin, it is those species that collaborate rather than compete that thrive.

Government needs to recognise and reward collaboration so that national interest can take precedence over self-interest. Business leaders must become more adaptable and versatile, with flexible business models that enable new ways of operating.

The MarRI-UK consortium enables collaborative endeavours to be greater than the sum of the parts. Over the past few years a consortium approach – whether it was known by that name or not – has been central to a number of initiatives. Now, there is a need for that energy and commitment to be brought together in an action plan that can be realised by a ‘coalition of the willing’.

Academia has a critical role in providing the next generation of maritime leaders and the research that underpins the next generation of science, technology and innovation. It is surprising and disappointing how often, in the Maritime 2050 Strategy and the Science and Technology Autonomy Route Map, collaboration between Government and industry is discussed without reference to academia. The role of academia must be visible as part of the collaborative nexus with Government and industry to realise the ambitions of Maritime 2050.

There has been some discussion about the need

to build humans/systems partnerships – and the role of science and technology in taking the workforce out of risky and dirty environments. It is clear that the aspirations of Maritime 2050 Strategy can only be realised through investment in people and, of course, the application of science, technology and innovation will be driven by people. Investment must be made not only in the people already in the maritime sector but also in order to attract those who have not yet selected a professional path.

The strategy and the route map set out a range of ideas and aspirations, and it is important that the activities that go forward are prioritised and coordinated efficiently to ensure they have impact.

In the UK we have great opportunities to train the new generation of maritime leaders to develop new technologies with which to navigate the UK through this fourth industrial revolution.

We have a great maritime history, established industry, as well as demonstrated examples that shine light on cross-sector collaboration, but competitor nations do too and so the bold and aspirational ambitions of the Maritime 2050 Strategy must be supported by real investment. This is in the hands of several Government departments (not just Transport), together with the Research Councils and some of the Learned Societies. □



Professor Susan Gourvenec, Deputy Director, Southampton Marine & Maritime Institute, University of Southampton, responded to the formal presentations.

# Benefits of a long-term vision

From an industry perspective, a long-term vision and plan for the maritime sector is hugely beneficial. Having a positive policy position can do a great deal to enable growth and investment – inward investment.

People are, at the end of the day, going to be the enablers for change in our industry. Within the ports industry and certainly within ABP, we have a highly-skilled and committed workforce. Attracting new people to the industry is an issue, though. The main problem is the lack of visibility: young people do not really learn about ports, or the broader maritime industry, at school.

Making sure that, through schools and colleges, there is a very broad understanding of what the industry can offer will be hugely important. We are large employers of engineers and of really skilled people, but young people are just not aware of that.

In my job I look at innovation and research. It is sometimes hard to understand what research is

being undertaken across the entire field of academia so one task for Government is to help ensure that research is coordinated around the burning needs of industry (and not just autonomous vehicles). There are pressing common issues across the industry about safety for example. There are still too many serious accidents and this is something we should address as a sector.

We are, as an industry, used to adapting to change – bigger ship sizes, different cargoes, etc. Some of our revenue streams within ABP are cargoes that require very specialist handling facilities that did not exist five years ago, let alone 10. So we are used to adapting, but there are some harder nuts to crack, especially around safety, air quality, etc, that we need to work on collectively.

Industry is a key part of the solution to the issues facing the maritime sector, especially around the sustainable development challenges that are facing the nation as a whole. □



Liz English, Group Development Manager, Associated British Ports (ABP), also gave a response to the presentations.

# The debate

In the debate following the formal presentations, issues such as leadership, collaboration, skills and climate change were raised.

There is a need for leadership in the sector – it presents itself as extremely diverse and spends too much time and energy competing within itself. As a result, for example, Intellectual Property is being squandered. Other sectors have developed effective leadership models and the maritime sector should do the same. This will enable better working with Government, academia and internationally (including with the EU post-Brexit). It will also help ensure a joined-up approach to regulation, digitisation and data, and to seizing opportunities such as those from seabed mapping while minimising free-riding. Ultimately, it will enable better

marketing of the sector in the UK and overseas.

It is important for maritime to build more collaboration (in particular technology collaboration) with related sectors, and to influence parts of Government outside the Department for Transport. It is not generally realised in Whitehall that UK aviation is smaller than UK maritime. Nor is the sector sufficiently prominent in Ministers' minds when considering regional and political issues. The UK's competitive position will be improved if it can find ways to fund engagement in international collaborations such as AORA – this challenge should be addressed by Government, UKRI and the sector.

It is not realistic to predict today the skills that will be needed in 2050. However, the Maritime Skills Commission could review skills needs every five years and make recommendations. It will be important to promote maritime careers more effectively. Part of this challenge concerns making ports more attractive places to live, ensuring good onshore infrastructure (e.g. electrification, transport) and integration with local economic strategies.

One option for better engaging the public may be through environmental issues associated with the oceans (e.g. plastics, healthy food). The other side of that coin is the need to ensure a social licence for maritime activities such as seabed mining and arctic activities.

The ambition to reduce maritime carbon emissions by 50% by 2050 may be insufficient to deliver the Paris commitments. Carbon-free vessels will be needed long before then. One option may be a carbon price or levy. □

The ocean economy also impacts the ocean environment – as the 2015 WWF report *Reviving the Ocean Economy* demonstrates, it is all underpinned by a vast, natural capital of marine ecosystems.



## FURTHER INFORMATION

### Maritime 2050 – Navigating the Future. Department for Transport

[https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/772805/maritime-2050-executive-summary.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/772805/maritime-2050-executive-summary.pdf)

### Technology and Innovation in UK Maritime: The case of Autonomy. Department for Transport

[https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/773219/technology-innovation-route-map.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/773219/technology-innovation-route-map.pdf)

### Reviving the ocean economy. WWF

[https://d2ouvy59p0dg6k.cloudfront.net/downloads/reviving\\_ocean\\_economy\\_report\\_hi\\_res.pdf](https://d2ouvy59p0dg6k.cloudfront.net/downloads/reviving_ocean_economy_report_hi_res.pdf)

### Foresight: Future of the Sea. Government Office for Science

[https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/706956/foresight-future-of-the-sea-report.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/706956/foresight-future-of-the-sea-report.pdf)

The launch of Aviation 2050, the Government's strategy for the future of aviation, was the focus for a meeting of the Foundation held at the Royal Society on 17 July 2019.

## 2050 is just around the corner for the aviation sector

Iain Gray

### SUMMARY

- Aviation is a long-term business and needs to look more than just 30 years ahead
- Zero-carbon is a key priority for the aviation industry worldwide
- Aviation is one part of a much wider integrated transport picture
- Greater collaboration between academia, industry and Government is crucial to realise the potential opportunities
- The UK needs to move more quickly and with greater ambition if it is to maintain its place in global aviation.

There is amazing research and technology development taking place in our aviation businesses, in our research technology organisations and across the university network. The establishment of organisations like the Aerospace Technology Institute combined with UKRI funding is making a real difference.

However, I want to look specifically at the Government's proposals for the future of UK aviation. My questions are whether it is ambitious enough, whether it is sufficiently joined up and is it being implemented fast enough?

Aviation is a long-term business. In 2019, we have been celebrating 50 years since the first flight of Concorde. It is 50 years since man first set foot on the Moon. In June, we celebrated 50 years since the formation of Airbus and August marks 100 years since the formation of what is now British Airways.

So, in aerospace terms, 2050 is just around the corner, a heartbeat away. To meet the challenges of 2050, the industry has to move fast and act now. At the 2019 Paris Air Show, sustainability was a central theme with all the main players recognising that new technologies and operational procedures must become more environmentally-friendly. Indeed, seven of the world's major aviation manufacturers issued a joint statement,

committing to reduce CO<sub>2</sub> emissions to half of 2005 levels by 2050 and to limit net growth in emissions by 2020. In conversations with the CTO of Airbus, for example, she described her top three priorities as being "zero carbon, zero carbon and zero carbon".

Academia needs to fully support Government and industry in achieving these 2050 objectives. However, I believe we need to be much more forward-thinking and set out our long-term vision in research for the next 50 years and beyond. And we need to start preparing for it now. Tomorrow's world will be very different – a world where we have depleted today's energy resources, where we communicate with each other in new ways and where people's concept of travel will be hugely different.

### A technology revolution

There is a great deal of discussion about a forthcoming technology revolution in aerospace – new materials, greater use of autonomous systems, electrification powering our aerospace platforms – this could be quite transformational. In order to get the maximum out of these developments, we need to see them in the context of the challenges the world faces.

I recently had the great privilege to go to Washington to attend, as part of a DIT-led UK mission, the 3rd Uber Elevate Conference. It was all very glitzy but there was a company vision of bringing together air vehicle developers, regulators and infrastructure developers to create an ecosystem for 3D ride-sharing, building on existing 2D, ground-based Uber taxis, but extending into the air!

The scale of the vision was outstanding. It was supported by US senators, by government departments, by NASA – companies from all over the globe were dancing to Uber's tune! It struck me that something similar is needed in the UK – a big-pic-



Professor Iain Gray CBE FREng FRSE is Director of Aerospace at Cranfield University, responsible for all aspects of learning, executive education and research in Aerospace for the University and for developing the Aerospace Strategy across the University Group. Prior to this, he spent seven years as the Chief Executive of Innovate UK. Before that, he was Managing Director and General Manager of Airbus UK, whose Bristol operation he joined when it was still part of British Aerospace.

The industry has to move fast and act now. The CTO of Airbus described her top three priorities as being "zero carbon, zero carbon and zero carbon".



**A prototype electric passenger aircraft, the Eviation Alice, on display at the Paris Air Show in 2019. The aircraft has had a reported 150 orders, despite the fact that the aircraft's first flight is not until later in 2020.**

ture vision. The problem is that there is no-one pulling all the world-leading technology developers together into a single, focussed effort here.

UKRI's Future Flight Challenge is a four-year, £125 million Industrial Strategy Challenge Fund (ISCF) programme. It is exactly the right thing to be doing, bringing people together from across the ecosystem and giving industry and academia the opportunity to come together and create a vision for the future. However, I fear it might be too slow, too short on ambition. Where we maybe had a lead in this area two years ago, others are catching up very quickly.

The Aviation 2050 vision acknowledges the various challenges but does not offer a strategy for delivering it. The Industrial Strategy goes further than we have seen in the past, but how does the Aerospace Sector Deal sit with Aviation 2050? How does Aviation 2050 sit with Defra's Environment Plan? Different Government Departments need to work together in a way they have never done before.

It is often said that the environment is a key priority and yet in Defra's 25-year Environment Plan there is no mention of 'aerospace', 'aviation' or 'airport'. Policy has to be much better integrated.

## The wider picture

Aviation is about to go through a transformational change in aircraft design and operating concepts but, more than ever, the different players need to be working together: developing new platforms

alongside new infrastructure, finding new digital communications solutions, tackling new regulatory issues that address these technologies.

More importantly, aviation does not stand alone. It is an important part of an integrated transport vision across cities and regions. I believe the UK needs a Centre of Aviation Research and Development to support the Government's aim of maintaining its place in the world's aerospace and aviation business rankings. Cranfield offers a unique environment to do that and bring those interconnected capabilities together. It is the only university in the world with its own airport, runway, aircraft, pilots and, uniquely, its own air navigation service provider.

Technology development will be central to any integrated transport system but new infrastructure, business processes and regulations are also crucial. New zero-emissions technologies, whether they be electric or hydrogen-powered or biofuels-driven, all depend upon new infrastructure sitting alongside these technology developments.

Improving interoperability between the many existing – and future – systems is one of the priorities for Cranfield. Data-sharing, with secure flows of information, will be key to this and we are pleased to have had the support of Research England, with companies like Thales and Saab, at our Digital Aviation Systems Research and Technology Centre (DARTEC).

The UK Aerospace Research Consortium is a national consortium of leading aerospace universities which can provide the global aerospace community with a central point of engagement to the UK's top research capabilities.

## Joined-up working

There is much being done by universities. There is much being done by business. But there is so much more that must be done by joining up universities, business and Government if we are going to realise the significant societal and economic benefits achievable. That will, however, involve collaboration on a scale not seen before, which needs to start now and quickly.

To create our vision for the industry in 2050, we must look beyond that date, envisaging what the future might look like and starting to prepare for that now.

We must take opportunities like the Future Flight Challenge but we need to move more quickly and with greater ambition. Zero-carbon must remain a key priority and must be extended into infrastructure and the regulatory environment.

If we can do all of that then I believe we will see the economic, environmental and social benefits we all aspire to. □

**Aviation is about to go through a transformational change in aircraft design and operating concepts. The different players need to be working together.**

# Designing the next generation of aircraft – today

Simon Burr

## SUMMARY

- Aviation brings economic and social benefits
- The sector is growing at between 4-5% per year
- Decisions made and aircraft built in the next few years may still be in operation in 2050
- The sector has been challenged to meet demanding environmental targets
- Electrification could introduce radical change to the aviation industry.

Aviation is a large sector in terms of its sheer size and its contribution to global economics. It is impressive how many jobs are supported and the quantity of goods transported. Talking to a customer of ours – Finnair – I was surprised at the sort of things, like fish, being transported between Finland and Japan. Lobsters are regularly taken from Boston to Qatar. People go to their local restaurants and eat fine foods brought from across the globe by aircraft.

I have a strong belief in the value of aviation for bringing people together, breaking down barriers, repairing cultural misunderstandings, which means there is less likely to be conflict. We can see there are problems with societies which are isolated around the world. So there is a social benefit.

Jet fuel today largely comes from fossil fuels, so for us the challenge is sustainability. I am privileged to look after and direct the resources of nearly 10,000 engineers and we cannot attract young people into this industry unless they believe it is sustainable and it has a purpose.

There is a large growth in aviation of around 4-5% per year and existing aircraft will need replacing over time. That is a good thing in many ways because a new aircraft brought into service is more economic, uses less fuel, is less noisy, etc. Now, the aircraft engines we are delivering today are likely to be in service for 25 years. So some of the engines being built over the next few years may well still be in service in 2050: tomorrow is being created today.

Aviation accounts for about 2% of global carbon emissions, but that proportion is growing, so we have to address that. Rolls-Royce has many other interests and these can be brought to bear

on this problem. For example, our experience in electrification is one area where we believe we can make significant changes in aviation. We are successfully doing this in other transport environments, such as trains. We are introducing hybrid trains which can pull out of the station and run for several miles on batteries before the diesel system cuts in. It is quieter and is a way of avoiding massive investment in electrification. UK Rail and Irish Rail have ordered these train sets.

We are investing in hybridisation of gas turbines, etc. In future, yachts and other ships will come into harbour on electric systems which will be quiet and silent, giving efficiency gains as well as noise and other environmental pollution reductions.

Rolls-Royce also has a very strong belief in small, modular nuclear reactors. We have taken our experience on submarines and, using a more production-line approach, can build lots of the same model, rather than each power station being unique. Scale matters: shrink the product down and it can plug into the existing systems, becoming more cost-effective.

We are trying to introduce different aspects of our energy-related experience into aviation.

We have challenges: the EU Flightpath 2050 targets on noise and emissions reductions, as well as the Air Transport Action Group (ATAG) targets. The academic world and Government have also set some very ambitious targets.

We have made great progress. Aircraft have got a lot quieter – not just engines, but airframes, flaps and other things. They also produce much less carbon dioxide. There is, of course, much more to do. Look at the aggressiveness and the ambition of the targets we have been set and they have to be realised, otherwise the sector will not be sustainable.

When I started with Rolls-Royce only 9% of the long-haul market was powered by our engines: now it is about 50%. Long-haul is a major contributor to emissions and a challenge on sustainability.

Our plan has three main elements:

- The first is to evolve the gas turbine. A 1% improvement in efficiency in an aero engine will cost hundreds of millions of pounds and take four or five years. Gas turbine technology is already a very mature technology so taking out one percent here and there is very difficult.



Simon Burr MBE is Engineering & Technology Director, Civil Aerospace, at Rolls-Royce. He has 28 years' experience in the aerospace industry, with roles at Rolls-Royce, Goodrich Engine Control and Lucas Aerospace. He has a degree in Mechanical Engineering, is a Chartered Engineer and a Fellow of the Royal Aeronautical Society. He was appointed MBE for Services to the Aerospace Industry in the UK in 2009.

Aircraft have got a lot quieter – not just engines, but airframes, flaps and other things. They also produce much less carbon dioxide. There is, of course, much more to do.

There is no point driving up the price of wheat and causing food shortages around the world, so these sustainable fuels must not compete with food crops.

- Yet we continue to invest because there is much enhancement to come as we change the architecture of engines.
- A big prize is sustainable aviation fuel that does not compete with food stocks. There is no point driving up the price of wheat and causing food shortages around the world, so these sustainable fuels must not compete with food crops.
- Finally, we are investigating radical alternatives such as electrification. This is a very, very exciting area. We are working with universities like Cranfield to bring this topic to life.

On large engines there are architectural and material changes, bringing improvements in thermal efficiency and propulsion efficiency. We have just tested the world's most powerful aerospace gearbox – over 70,000 horsepower. We are pushing science to the limit.

Then there is the potential of electrification. With advances in battery technology and related systems, we believe electricity could give aircraft a range of 200+ miles. My ambition, before I retire, is to make sure Rolls-Royce can provide a propulsion system available to the public which is pure

electric – and that is closer than many people think.

We expect a revolution in regional flight, allowing it to compete with high speed rail, road freight and so on. An aircraft where the propulsion is distributed around the aircraft is inherently quieter, so there is no need to worry about night-time curfews. Vertical flight is also possible and then there is no need for massive infrastructure. Using hybrid power together with a gas turbine and jet fuel results in a different type of aircraft which enables different economics.

It would be great to run engines on purely sustainable fuel, but there are some technical challenges around elastomers and so on. Modern aircraft can use the new fuels, but older aircraft incorporate natural rubbers and nitriles. Of course, people want one fuel to cover everything but to take advantage of these developments may require a different point of view.

The future is about much more than just the aircraft itself. Take taxiing – release the brake and a large aircraft will accelerate to 60 knots, that is how much residual thrust is being wasted. So the challenge is to examine not just the propulsion system and the aeroplane, but everything that goes along with it in order to deliver a sustainable future. □

# Smart motorways in the sky

**Martin Rolfe**



Martin Rolfe was appointed Chief Executive Officer of NATS in May 2015 and is responsible for the UK's continuous air traffic operations. He joined NATS as Managing Director, Operations, in March 2012. Martin has worked in air traffic management for 18 years, leading large multinational teams across Europe, the USA, the Commonwealth of Independent States and the Far East, with customers including air navigation service providers, central government departments and military organisations.

People do not think of the space above us as being part of an infrastructure, effectively a network of roads in the sky. Aviation matters to us as a nation, but the question then becomes 'What next?' It will become more complicated, would be my prediction – at least from an air traffic perspective. There will be many more types of vehicle with a different range of users. There is the advent of drones. Then there will be space planes if the desire for the UK to develop a space hub comes to fruition.

The electrification of aircraft offers a huge opportunity in terms of noise reduction and the ability to change the way we use airspace, but again it adds a certain amount of uncertainty – they will probably not fly at the same speeds, they will not fly in the same way. With everybody sharing the same airspace, it will become much more complicated and we will need to rely more on emerging technology to help resolve the challenges this presents.

The challenges facing air traffic systems are threefold: they need to be safe, they need to be

## SUMMARY

- Air traffic in the UK is growing and the current system is approaching its limit of capacity
- Satellite tracking now means that the positions of all aircraft in the sky are known
- Technology is helping to optimise air traffic movements especially at airports on take-off and landing
- Fuel efficiency is increasing and noise levels are falling
- The airspace system in the UK is being redesigned to make it fit for the next 50 years.

optimised and they need to be sustainable. The first priority is for aircraft operation to be safe, so that everybody can fly around the world and in the UK without problems. Flying needs to be safe, but it needs to be optimised. In the UK, there are around 2.6 million aircraft movements a year. The difficulty lies, not in keeping them apart, but

getting them to where they need to be on time and without flying them round and round in circles. The solutions then have to be sustainable.

### Safety

Obviously, we need to know where everyone is. Now, over the major oceans of the world, nobody has known exactly where they are. The North Atlantic is the busiest ocean in terms of air traffic with about 2,000 flights a day traversing UK North Atlantic airspace. We rely on position updates from aircraft every 15 minutes and we meter aircraft onto the oceanic airspace. They are about 60 miles apart and never catch each other up because they all fly at the same speed, at the right levels and everything is very strictly controlled.

That, though, is inefficient. A 60-mile separation restricts the number of aircraft on what is a very large body of water. Since radar is not available over the ocean, it has been very difficult to track the aircraft individually.

That all changed a few months ago when a new satellite-based system went live. This piggybacks on the Iridium satellite system, using 66 orbiting satellites and picking up the transponder signal from each aircraft as well as the GPS position. From those satellites, the position of every aircraft can be tracked every 5-8 seconds.

That is a massive change. It means the separation between aircraft can be brought down from 60 miles to about 17. This could probably go down to 12 miles because we know precisely where everyone is. Aircraft can be allowed to climb and if they want to travel slightly faster that can be permitted. So savings in fuel and time, as well as improvements in safety, all result from what is actually a relatively straightforward application of science and technology.

This is a worldwide solution and in areas like Africa, where there is a real issue about security of assets on the ground, a space-based set of data which is secure by design can now be used. That also means there will be no more situations like the MH370 flight which disappeared in the Indian Ocean a few years ago.

To quote from someone else in the industry: "If it doesn't have feathers, we want to know where it is" – that is a very apt summary. We want to know where every single aircraft is, where every single air vehicle is, the drones, the space planes, etc, because only then can we make progress on safety.

### Optimisation

Moving on to optimisation, necessity is the mother of invention and innovation. The UK has been blessed, I would argue, by not having enough runways. That has given us the opportunity to

We want to know where every single aircraft is, where every single air vehicle is – because only then can we make progress on safety.

innovate in a way no other country has had to.

To maximise runway occupancy, it is not sufficient merely to set a distance and speed in the air between aircraft that are landing, because when they are flying into a headwind, they take longer to cover the distance, which wastes time before they get onto the ground. Optimising distances to take into account windspeeds saves, on average, 17 seconds per aircraft at Heathrow. That is 100,000 minutes of delay eliminated per year. This approach is now being extended to different classes of aircraft. A bigger aircraft disturbs the air more than a smaller, so different separation distances can be introduced.

Another example is the use of machine learning. One system being trialled at Heathrow uses cameras out on the airfield and on the tower to determine to a single pixel, when an aircraft is 77cm from the runway midpoint. Why 77cm? That is when it is safe to let another aircraft land or take off. A human controller takes an extra 3-4 seconds to recognise that point, so the tools and the science are allowing us to make the most of what we already have.

### Sustainability

The focus on sustainability is, first, to get net-zero carbon. In and around London, airspace is largely full under current modes of operation. It has grown organically since the 1950s. Air traffic control was then operated by experienced people – pilots and air traffic controllers using pencils and rulers and maps. We are well past that. The system is approaching its limit. We have, effectively, a network of B-roads in the sky – we need to turn them into smart motorways.

There is technology on modern aircraft to help do that. The aircraft know where they are, to within a half a metre (in the 1950s, it was more like a mile). That can deliver a much more sustainable set of routes. These can be more fuel-efficient – so continuous ascent and descent. It reduces the need for stacks. It will allow much greater use of air space by other users, like drones or general aviation.

Advances in technology will also deliver more connectivity. A redesign of the air space will have

In the 1950s, air traffic control was operated by pilots and air traffic controllers using pencils and rulers and maps. We are well past that.

to happen when a third runway is built at Heathrow, but it needs to happen anyway to support the growing air space plans for the next 20 or 30 years.

The biggest challenges to growth are noise and the need to consult effectively with people under the flightpaths. Noise has dropped by half over the past 20 years or so. However, consult people on the ground about where they would like aircraft flying and the answer is still 'nowhere near me'.

So there is a massive challenge in trying to design a system that can cope with the level of capacity this country needs and consult success-

fully on those plans. There is a question here about making the system as sustainable as possible, but also as noise-friendly as possible. How can everybody have a share in this exercise when the aircraft have to go somewhere?

We are already embarking on consultation about the redesign. We will have to consult with 35 million people who are flown over. There is no easy answer. Yet, the UK deserves an air space system for the next 50 years that is as capable as the one we have had before: it is time to bring that one into being. □

# The debate

In the debate that followed the main presentations a number of topics were raised, including: gender balance; wider engagement with Whitehall and with other industries; regional transport strategies; and sustainability.

The ratio between male and female engineers and technicians by 2050 was raised. While all agreed that it should ideally be 50:50, it was noted that action needs to be taken now if that is to be achieved. However, organisations large and small are setting targets in this area and change is happening.

The aviation sector has not had sufficient engagement with Government Departments other than BEIS. However, the Future of Flight Challenge is now bringing a focus to activities across the industry and will attempt to bring Departments closer together on this issue.

A strategy for regional transport – taking people from city to city – is needed as we shape the

future of this industry. Innovations, including vertical take-off, lower noise levels and hybrid-electric power, will enable aviation to be brought into the centre of cities and offer savings on infrastructure costs.

Common standards are vital if the industry is to move ahead together. Working with other industries will allow incorporation of advances made elsewhere. For example, the automotive sector is making progress on batteries and power conversion which might be applicable to aviation.

## Focus on the journey

It is important not to focus just on the end-point of the transformation process. Totally-electric solutions are unlikely ever to provide a complete solution for long-haul flights. Yet just achieving low-noise electric travel for the initial/final mile or so around an airport would allow many more planes to access these locations.

The future of aviation needs to be seen in the context of a more integrated, efficient transport system. The time taken to get to an airport can often be much longer than the time spent in the air flying to another part of the country.

Sustainability means more than zero-carbon. It means zero-waste, much more recycling and a move towards a circular economy. Manufacturers are already addressing these issues but more needs to be done.

Among the newer technologies vying for air-space are drones. How can these be integrated into our future air traffic systems?

A move towards electric-powered aviation will mean more demand on the power supply systems of the country. However, it is expected that take-up will occur first in the regional airports which gives an opportunity for decentralisation of supply. □

## FURTHER INFORMATION

### Aviation 2050: the future of UK aviation

[www.gov.uk/government/consultations/aviation-2050-the-future-of-uk-aviation](http://www.gov.uk/government/consultations/aviation-2050-the-future-of-uk-aviation)

### The Future Flight Challenge

<https://industrialstrategy.blog.gov.uk/tag/future-flight-challenge>

**Combat air strategy** [www.gov.uk/government/publications/combat-air-strategy-an-ambitious-vision-for-the-future](http://www.gov.uk/government/publications/combat-air-strategy-an-ambitious-vision-for-the-future)

### 25 year environment plan

[www.gov.uk/government/publications/25-year-environment-plan](http://www.gov.uk/government/publications/25-year-environment-plan)

### Flightpath 2050: Europe's vision for aviation

<https://ec.europa.eu/transport/sites/transport/files/modes/air/doc/flightpath2050.pdf>

**Air Transport Action Group** <https://www.atag.org>

---

## MAJOR SUPPORTERS IN 2019/2020

### A

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

### B

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

### C

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

### D

Defence and Security Accelerator  
Defence Science and Technology  
Laboratory  
Department for Environment, Food and  
Rural Affairs  
Department of Health and Social Care

### E

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

### G

GlaxoSmithKline

### H

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

### I

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

### J

Japan Society for the Promotion of Science  
Jisc  
Johnson Matthey Plc

### K

Keele University  
King's College London  
Kingston Smith  
Knowledge Transfer Network Limited

### L

Leiden University  
Lloyd's of London  
London Mathematical Society  
Luminance Technologies Ltd

### M

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

### N

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

### O

Open University

### P

Palaeontological Association  
Parliamentary and Scientific Committee  
Peter Jost Memorial Foundation

### Q

Queen's University Belfast

### R

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

Royal Society of Chemistry

### S

Science and Technology Facilities Council,  
UKRI  
Shell  
Society for Applied Microbiology  
Society for Editors and Proofreaders  
Society of Maritime Industries  
Society of Operations Engineers  
Sovcomflot (UK) Ltd  
SPTS Technologies

### T

The Academy of Medical Sciences  
The Alan Turing Institute  
The Foundation for Professionals in  
Services to Adolescents  
The Geological Society  
The IET  
The Lady Butterworth  
The Medical Schools Council  
The Nautical Institute  
The Royal Academy of Engineering  
The Royal Commission for the Exhibition of  
1851  
The Royal Society  
The Society of Maritime Industries  
The Wellcome Trust

### U

UK Innovation & Science Seedfund  
UK Statistics Authority  
University College London  
University of Birmingham  
University of Chichester  
University of Dundee  
University of East Anglia  
University of Edinburgh  
University of Glasgow  
University of Hull  
University of Kent  
University of Leeds  
University of Leicester  
University of Nottingham  
University of Plymouth  
University of Reading  
University of Sheffield  
University of Southampton  
University of Warwick  
University of Westminster  
University of York

### W

Welsh Government  
Willis Towers Watson

# The Journal of The Foundation for Science and Technology

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

**Telephone:** 020 7321 2220

**Email:** [fstjournal@foundation.org.uk](mailto:fstjournal@foundation.org.uk)

[www.foundation.org.uk](http://www.foundation.org.uk)

