The Parliamentary and Scientific Committee

The Journal of the Parliamentary and Scientific Committee

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AUTUMN 2014

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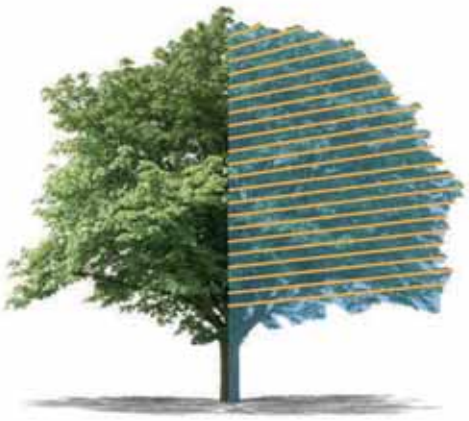

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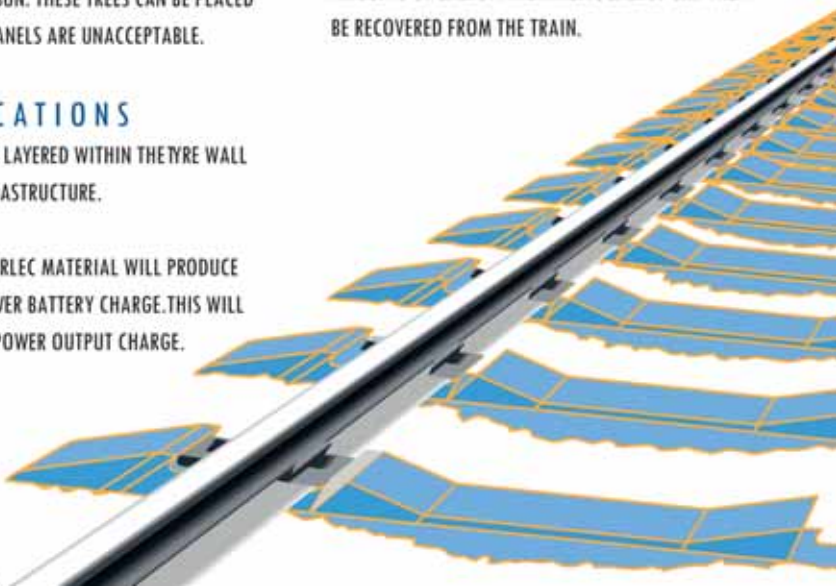

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Andrew Miller MP
Chairman, Parliamentary and Scientific Committee

There is good news, and there is other news.

At last the longest electoral campaign in British history is over. It has taken three years for Scotland to declare its intentions. Gratifyingly, it broke all records for turnout, so by any standards it was a democratic decision.

Already there has been comment on how the science community in Scotland should access funds from a further devolved Scottish Parliament with tax raising powers. My answer is that it is a matter for the Scottish science community who will quite rightly want to access funds from Holyrood whilst at the same time maintaining the strength of the UK position, especially in the international arena.

Scotland's intellectual history and scientific achievements are without parallel for such a small country – think Watt, Macadam, Dunlop, Kelvin, Simpson, Lister, Fleming, Baird, Bell – and that is only 150 years worth. Our daily lives would have been greatly impoverished without their inventions. Remind me what Texas, or even Massachussetts, produced during this period! Andrew Carnegie, for a time the world's richest man, was part of the Scottish diaspora.

More recently, its intellectual capacity has shown itself in Scotland's share of UK Government (including the Wellcome Trust) research grants. 8% of the UK population received 15% of UK funding.

We were delighted to note the wonderfully generous gift from David Harding to the Science Museum to promote Mathematics.

Science, Engineering and Technology (SET) for Britain only just got in ahead of him by admitting Mathematics to the competition for the first time in 2014! In this new era of devolution could I also encourage benefactors to think of the Museum of Science & Industry in Manchester and elsewhere in the UK?

Many organisations depend on enthusiastic volunteers to support their work. The P&SC has been fortunate to have had Robert Freer as one of its staunch members for nearly 20 years.

Robert was a Chartered Engineer, and used his contacts to help the P&SC, enormously. He always had ideas both for Discussion topics, as well as articles for Science in Parliament.

He came from a generation which might have used the epithet "a good egg". He certainly was one. He died suddenly on 11th August.

We shall miss him.

Frogs produce many millions of potential offspring. The P&SC which was itself born only 75 years ago, has now spawned 610 All-Party Parliamentary Groups. We are therefore celebrating both our longevity and our fecundity with a party at Buckingham Palace on 11th November. The Duke of Edinburgh, who has been an Honorary Member for more than 50 years, was our President in 1989, and has addressed our Annual Lunch on no less than three occasions, has kindly agreed to host it.

Finally, to my astonishment, in the same issue of the Evening Standard which announced the Science Museum gift, there was a powerful plea from Rosamund Urwin for more MPs to know and understand science. Of course I and the P&SC totally endorse this, but she used the phrase "anti science bias", which misrepresents the issue. MPs are NOT anti science. They are overwhelmed with data input, and science is often difficult to understand – even if you have a relevant degree. The ball is in the scientists' court – to make it intelligible to intelligent, committed colleagues. My reply was heavily edited by the newspaper. I am very proud to chair an organisation which has played a major role in this. Long may it continue!

SCIENCE IN PARLIAMENT
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The Journal of the Parliamentary and Scientific Committee.
The Committee is an Associate Parliamentary Group of members of both Houses of Parliament and British members of the European Parliament, representatives of scientific and technical institutions, industrial organisations and universities.

Science in Parliament has two main objectives:

1. to inform the scientific and industrial communities of activities within Parliament of a scientific nature and of the progress of relevant legislation;
2. to keep Members of Parliament abreast of scientific affairs.

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The covers of this issue are sponsored by National Physical Laboratory, the University of Bolton, the University of Nottingham and the British Society for Antimicrobial Chemotherapy.

THE RISE OF SCIENTIFIC COMPUTING – A UK SUCCESS STORY

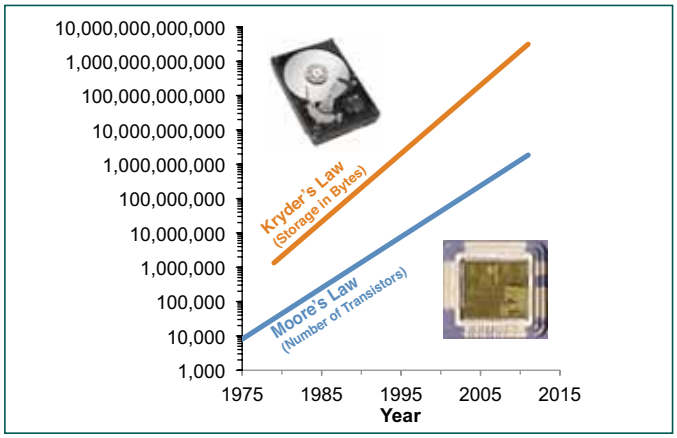
Professor Robin Grimes
Foreign and Commonwealth Office
Chief Scientific Adviser

THEY JUST GET QUICKER AND QUICKER

Computer based, attention-diverting technologies, improve year on year. This is facilitated by a steady increase in 'computer power'. When and why that increase will end has been discussed endlessly for years, but the computers don't listen and continue to advance. Furthermore, that growth is not linear. There are various measures for the increase in computer performance. Two often quoted 'laws' are due to Moore and Kryder (actually neither are true laws but empirical observations). Both express improvement in terms of a doubling of performance over a time period. This doubles even quicker, every 13 months, or by a factor of a thousand after roughly 11 years. In my 30 years as a computational scientist, the capability of computers to deliver results has increased by a million, but for storing those results, by a factor of two hundred million! What have been the consequences of this explosion in capability and how has the UK exploited it?

THE AGES OF COMPUTING

1943 to 1970. The world's first programmable electronic digital computers were designed and built at Bletchley Park. Despite rapid improvements in performance, computers throughout this period were used as little more than automated slide rules. They did, however, allow theorists to turn their equations into self-contained computer code (programs) that released numbers to be translated into simple graphs and diagrams for publication. UK scientists were quick to realise the potential benefits and the University of Manchester became an early international centre of excellence. Since the equations purported to describe the way nature behaved, predicting things we could observe experimentally provided an acid test for the validity of those equations. Simulations were often most useful when the prediction did not match experiment because it implied that nature behaved differently to how we thought, which led to better understanding.



A comparison of Moore's Law with Kryder's Law

Moore's Law counts the number of transistors on an integrated circuit – roughly, the more transistors, the more work that can be done. This number has doubled every 18 months, or by a factor of a thousand after 15 years. Kryder's Law considers the density of hard drives which equates to available data storage capacity.

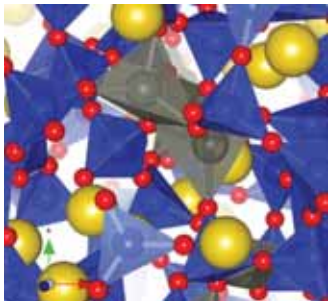
From **1970 to 1985**, more generic computer codes emerged where the given code could tackle a range of problems for the user community. For example, in the UK, codes were devised for biological systems such as protein interactions, for representing the laminar flow of liquids and gases for chemical engineering applications, and for predicting the outcome of collisions – from cars to atoms. Much of the pioneering work was carried out by Harwell Laboratory near Oxford as part of its atomic energy mission, where access to Cray supercomputers enabled simulations to be carried out which had more scientific impact.

1985 to 2000 saw greater access to high end computer power, which meant much larger systems could be commonly tackled. The range of tractable physical and biological science problems also increased. Social scientists and economists also began to take advantage.

Now behaviours could be investigated that were beyond usual experimental techniques – for example, sub-atomic lengths, or on timescales of electrons transferring across simple molecules. During this time computer graphics started to become common. Post analysis of results now allowed secondary codes to draw the diagrams – essential given the larger data sets. It also allowed us to peek into time and length scales beyond routine observation. Experimental data was also being translated into graphics using computers, thereby providing high level understanding of measurements.

Since **2000**, computer simulation has really been a mainstream research tool. Increasing access to ever more powerful computational facilities is too tempting even for the most ardent experimentalist – especially in the UK, the majority of science and engineering students use some form of simulation tools to aid their research.

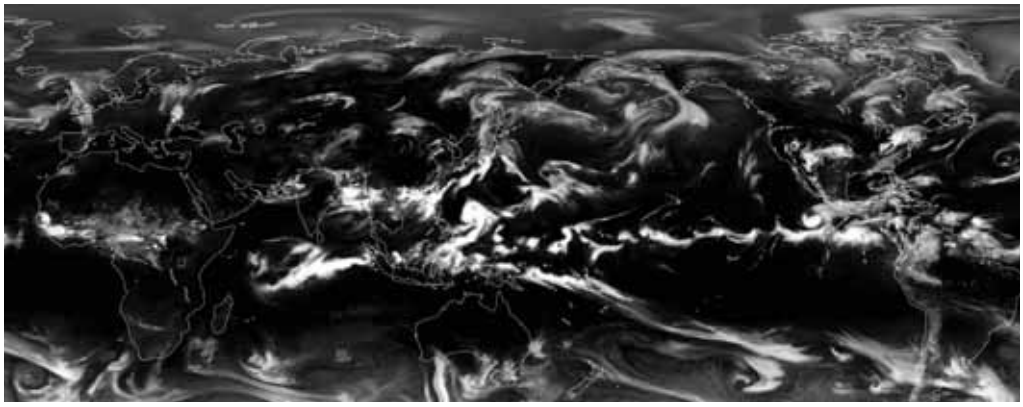
System sizes are much larger with a commensurate prediction of complex behaviour. This has delivered dramatic improvements in our understanding of physical systems. Prior to this we analysed systems that behaved in ways we expected. Now the codes and associated analysis tools were able to sift through data and simulate complex systems, such as the Earth's climate, by solving mathematical equations based on fundamental scientific properties, to reveal the consequences of this complexity and identify unanticipated behaviour. For example, simulating the turbulent flow of gases and liquids over many length scales enables us to predict weather patterns with kilometre precision. The UK Met Office is a world leader in developing and applying these types of simulations but it requires a world class computing resource which can complete more than 1000 trillion calculations a second. We also maintained our world leading capability for predicting atomic scale systems – where graphics display millions of atoms engaged in fascinating and complicated gyrations, as shown below.



Simulation of a zinc sodium silicate glass

UK prosperity benefited with many companies delivering simulation tools and analysis solutions to industries across the globe. Students also gained valuable skills that they took to related industries, especially the financial sector.

Most recently we have been occupied with the further democratisation of simulation. Now anyone can have a sufficiently powerful personal computer (PC) on their desk to carry out useful, if not cutting-edge, simulations. The UK is a leader in mobile computing with companies such as ARM and Imagination Technologies designing scalable semiconductor systems which provide opportunities to carry out simulations in different ways. The propensity to use simulation tools continues to grow. From the design of a next generation Formula 1 car to a new pharmaceutical, each begins with a foundation in simulation. Simulation is also a common tool for social scientists.



Met Office Climate Model simulation at 12km (credit: courtesy of Met Office)

Looking forward, how different will those scientific simulations be to what came before? For a start, programs will act more autonomously, waiting for particular events or a stimulus before performing a simulation to compare with an observation. Already, enormous volumes of data are mined and selected using autonomous processes. Since programs are much more easily connected, the code itself will increasingly decide the next step. This adds to the complexity of the modelled systems and therefore the thirst for more computer power. One way to address that is by distributing tasks between machines using parallel computing protocols. This has been with us for quite a long time but parallel computing has been for the aficionado. We are currently developing codes that can do the heavy lifting for us, optimising the parallelisation on the fly.

The future of scientific computing is being supported though the Big data and energy-efficient computing initiative, one of the Eight Great Technologies. This will help the UK to maintain our lead and benefit from the decades of sustained academic activity. Amazingly, around 90% of all electronic data has been created in the last two years. The FCO is engaged with the burgeoning data science community's development of big data analysis tools and is working to embed the use of digital tools across every element of foreign policy work. The joint FCO-BIS Science and Innovation Network is busy helping to maintain the UK's high global profile, ensuring that UK scientists gain access to the best international networks.

Finally, I have no doubt that new generations of students will find new ways to use simulation to make exciting discoveries and in so doing will create new tools for industry and even new industries. This requires us to renew our digital resources and invest in the training of those new simulation scientists. Fortunately, the resource continues to evolve. The prediction of a plateau in computing performance is not supported by the observations – computers continue to get brighter and, unlike most of us, their memories are improving.

TRUSTED TIME

NPL*Time*®

Leon Lobo
Strategic Business Development Manager at the UK's National Physical Laboratory

To a greater extent than ever before, modern society is dependent on the accurate measurement of time. While most of us rarely deal with anything smaller than fractions of a second, critical elements of the UK's infrastructure require accuracy to the sixth decimal place.

Front cover photograph:
Strontium ion optical clock
©National Physical Laboratory

As the UK's National Measurement Institute, the National Physical Laboratory (NPL) has been responsible for maintaining the country's time scale for more than four decades. The NPL time scale, called UTC(NPL), is used as the basis for time all across the UK and contributes to the international time scale, Coordinated Universal Time (UTC). We contribute to UTC formulation with 7 atomic clocks – 4 hydrogen masers and 3 caesium clocks. In addition, our caesium fountain, CsF2, accurate to 1s in 158M years, ensures that the duration of the second in the international timescale is correct.

In addition to managing the nation's time scale, NPL also has the remit to distribute it to the UK. The NPL time scale has been disseminated over radio waves, via dial-in, across the internet and through satellites, and NPL is now launching a service to provide connectivity over optical fibre.

This new service, called NPL*Time*®, delivers a precise time signal directly traceable to UTC and certified via a more resilient system than ever before. Currently, most people get their time via satellites such as the GPS constellation. These systems not only have their own intrinsic inaccuracies, but are also extremely vulnerable to interference. Malicious as well as inadvertent disruption has damaged GPS connections in the past, as have aspects of cosmic weather such as solar storms and flares.

The transmission of NPL*Time*® via fibre makes it impervious to attacks such as these, and generally much more difficult to disrupt. The network is also equipped with a highly accurate back-up signal, provided by another of our caesium clocks located in Docklands. Should a fibre go down, this system will provide the capability for over a month.

A further weakness inherent in current systems is that at any given moment, those consuming time via different sources may well be recording entirely different times. This lack of a common accurate clock in different locations is similar to the problem we had before Greenwich Mean Time was adopted across the country. These disparities, of the order of microseconds, can have dramatic consequences in areas where synchronicity is important.

... a unified time signal will be of tremendous benefit ...

NPL*Time*® allows consumers to make use of a reliable signal while feeling confident that all their peers are using it as well. A centuries-old dream will finally be realised – everybody will be on the same time. This common clock is particularly important in the Financial Sector where trading now occurs in the millions of trades per second.

TRADING TIME

Inaccuracies of the order of microseconds may seem insignificant in daily life, but in the high-frequency world of financial trading even the tiniest of delays can cost millions of pounds. It is truly remarkable that in such a high-stakes environment, there is no common clock across different markets. This makes transactions across locations and stock exchanges almost impossible to audit and any wrongdoing difficult to detect.

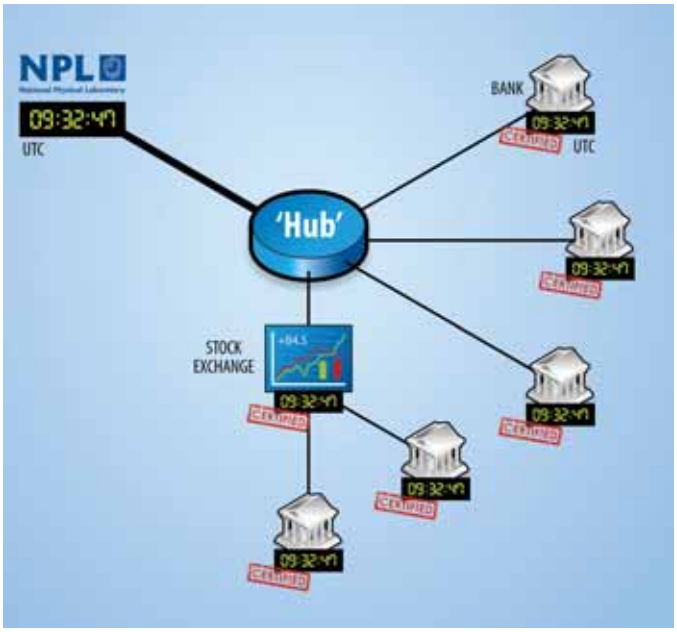
One particularly widespread effect is the so-called negative delta, which occurs if data leaving one location for another is marked by the receiving system as having arrived at an earlier time than was noted at the point of departure. Needless to say, this further complicates forensic analyses and necessitates complex adjustment systems to correct disparities. The NPL*Time*® system takes away from the user the need to manage or correct the signal they receive, providing a trusted time with synchronisation at the microsecond level.

Such a solution would be long overdue. On 3rd June 2013, Thomson Reuters released the day's manufacturing data 15 milliseconds earlier than expected, resulting in $28 million worth of trades for those quick enough to exploit the gap. Two months later, the German derivatives exchange Eurex was forced to shut down for an hour after experiencing "an incorrect time synchronisation within the system".

Fortunately, the use of fibre connections across the financial sector means that the new signal could be implemented

with very little difficulty. NPL has signed distribution agreements with trading technology company Intergence and TMX Atrium, the low latency infrastructure arm of TMX, the Canadian stock exchange.

As our data management systems make the transition to digital, having all systems running on the same clock will allow each to be connected to every other. In the NHS, for example, this will allow for increased



Through these, NPL provides users with a trusted timestamp, regardless of how many locations the trades cross.

Widespread adoption may be accelerated by the keenness of regulatory bodies to implement absolute traceability of time to UTC, as guaranteed by NPL in the UK. The European Securities and Markets Authority is considering regulations which would constrain trading firms to microsecond accuracy, while both the SEC and the FCA are currently debating the problem in the United States.

WIDER APPLICATIONS

In addition to the need for NPL*Time*® in the financial sector, the system is equipped to provide support across a wide range of other industries. From telecommunications networks to energy providers, and from media outlets to the NHS, the ability to have a unified time signal will be of tremendous benefit.

reliability in the capturing and transferring of individual patient details, as well as in the sharing of so-called big data.

While microsecond accuracy may be less important in an institution such as the NHS, having a trusted time source is extremely important. A 2012 survey conducted at four prestigious American hospitals found that only 3% of 1,700 devices checked were accurate to within three seconds. The average error was an astonishing 24 minutes. Interoperability of systems, accuracy of Electronic Health Records and legal liability, billing systems and financial implications, as well as accurate elapsed time measurement using multiple systems, are all dependent on trusted traceable timestamps.

When you don't have confidence in your time, you no longer have a reference. This is particularly important when the timing system is used for the validation of data, which places the institution's integrity on the line. Conflicting signals could lead to automated time stamps being out by hours or even days – substantial inaccuracies in the analysis of patient data. With the assistance of NPL, everything inside our hospitals would run on the same time – from the computers powering the data processing system to the clocks ticking away on the walls.

CRITICAL INFRASTRUCTURE TIME

Another key area where reliability of the time signal must be prioritised above all else is the UK's national infrastructure. Covering transportation, government services and security, these represent systems essential for the functioning of the country.

Currently, most of these vital institutions still get their times from GPS or other GNSS satellites. Not only are these signals inherently vulnerable to attack, but as a recent report by the Royal Academy of Engineering pointed out, such an outage would be more damaging for those who depend on satellites for timing than those who use them for navigation.

... everything inside our hospitals would run on the same time ...

Part of the problem is that GPS signals are very weak, reaching Earth with roughly the same intensity as light from a lamppost placed on the moon. This means that any signal produced in the same frequency band will easily drown them out, a disruptive technique known as jamming. Portable jammers, while illegal to use in this country, are simple devices that create broadband noise in the GPS frequency range. Even though the power output is only milliwatts, this is more than enough to drown out the microwatt-level GPS signal for an entire city block. Jamming of this kind is rarely used maliciously, with most disruptions occurring inadvertently by vehicle tracking systems being disrupted by individuals eager to prevent their employers knowing their exact locations.

More dangerous still is GPS spoofing, which occurs when the signal is effectively hijacked and replaced by one giving false information. Nowadays, specialist software and hardware exist that allow a user to receive the GPS signal and rebroadcast it with greater power, so that any receiver will automatically latch on to it. If the time reading is then changed slowly enough to override the systems' internal safety checks, the signal can be temporarily pulled away and then corrected with no-one being any the wiser.

While a few high-profile jamming and spoofing cases make it to the headlines, what is more worrying is the number kept under wraps in order to maintain public confidence in the system. The advantage of the NPL*Time*® fibre network is that it gives complete independence from GPS, allowing the country to operate regardless of natural or man-made disruptions.

NPL is currently forming a consortium of critical national infrastructure users who could benefit from such an alternative solution in order to see it delivered as a capability.

NPL*Time*® offers a trusted time, certified at the end user, to be consumed with the confidence that it is fully traceable to the international timescale (UTC) and delivered by the National Physical Laboratory, an organisation with a heritage in time.

IN THE ABSENCE OF ALTERNATIVES – addressing the dual challenges of antimicrobial resistance and the failing antibiotic pipeline

Tracey Guise
CEO, British Society for Antimicrobial Chemotherapy

Laura JV Piddock
Director, Antibiotic Action and Professor of Microbiology, University of Birmingham

Few of us alive today in high income countries can remember living without the unprecedented health benefits that antibiotics bring. In 1928, Sir Alexander Fleming's discovery of the antibacterial powers of *Penicillium* mould changed the face of human medicine. Within a few decades healthcare progressed more in the presence of these "wonder drugs" than in the two millennia prior to their discovery.

Antibiotics are now the mainstay of human health. They are lifesaving, life enhancing and life extending. Without them medicine as most of us know it would not exist. As consumers we have high expectations for our health and wellbeing, including treatment of infections allowing survival to adulthood and old age. They provide life extending treatments for those with chronic conditions such as cystic fibrosis, cancer chemotherapy regimens, organ transplant and joint replacement surgeries. In high income countries people expect to receive these treatments when required, and without exception, and this is an aspiration for everyone across the globe. Without effective antibiotics a simple scratch can prove fatal. It was therefore unthinkable that antibiotics would become ineffective, and yet this is the unprecedented health crisis we face. It is the dual crisis of antibiotic resistance and a depleted antibiotic discovery and development pipeline. It poses a crisis to human health as critical as the AIDS pandemic in the 1980s and 1990s. It is not a pending crisis – it is already here.

... Antibiotics are now the mainstay ... of human health

Physicians and scientists have been warning of the relentless rise in the numbers of antibiotic resistant bacteria for over 25 years. Between 1998 and mid-2013 over 90 enquiries, reports and recommendations, including some by the World Health Organisation, were published. These were laudably received, but political will to act has been lacking, and the public has remained largely unaware of the problem. However, one sector was listening, taking note and taking action. The pharmaceutical industry was acutely aware that antimicrobial resistance seriously reduced the life-span of the antibiotics they developed. Coupled with the requirement to work within an increasingly complex, and in turn expensive, regulatory environment the development of antibiotics became a high-risk activity with diminished returns to shareholders. The effect has been tragic. The number of companies has diminished mainly due to mergers. Those producing new antibiotics have declined dramatically, and consequently so has the number of new antibiotics reaching the market. Only two systemic antibacterial agents were approved for use in humans from 2008-2012 compared to sixteen from 1983-1987. Those that have reached the patient have been predominantly active against Gram-positive bacteria such as MRSA, and this trend continues today. This is of critical concern when faced with the continued emergence of new types of resistance in Gram-negative bacteria including *Escherichia coli* and *Klebsiella pneumoniae*,

... relentless rise in the numbers of antibiotic resistant bacteria ...

for which there are few – and sometimes no – effective treatments. In April 2014 The World Health Organisation published its first report on antimicrobial resistance, indicating how widespread the problem is.

Until recently there was little evidence of progress or the necessary political impetus to bring about change. It is difficult to imagine how loud the outcry might be if there were so few new cancer treatments, yet the size of the antibiotic arsenal available to defeat a growing number of multidrug-resistant bacterial infections is small. Learned societies and organisations have worked tirelessly to influence those in the research, political, economic and public arenas through education and continued pressure for action. The Alliance for Prudent Antibiotic Use, CDDEP and the Pew Trust in the US, ReAct and Antibiotic Action in Europe are a few of the influential organisations providing resource. All are aware of the task ahead but hope that their messages are being heard.

... magnitude of the burden of antibiotic resistance ...

There are signs that the landscape is at last changing with professional interest and campaign action helping accelerate change. The Transatlantic Taskforce on Antimicrobial Resistance (TATFAR) was established by US Presidential declaration in 2009 and issued its first report in September 2012, identifying the need for intensified cooperation between the USA and the EU. The same month saw the USA Food and Drug Administration announce the formation of a task force to support development of the Antibacterial Drug Development Task Force (ADDTF). This will assist in revising guidance related to antibacterial drug development, as required by the Generating Antibiotic Incentives Now (GAIN) and Food and Drug Administration Safety and Innovation Act (FDASIA). The European Medicines Agency has been reviewing the requirements for clinical trials of antibacterial treatments. The World Economic Forum Global Risks Report 2013 and 2014 recognised the magnitude of the burden of antibiotic resistance by its inclusion on the risks register. In India publication of the Chennai Declaration led to changes in Indian law aimed at ending the sale of over the counter antibiotics. The EU Innovative Medicines Initiative will soon announce the award of a multi-million grant 'Driving re-investment in R&D and responsible use of antibiotics'.

Recent political focus and activity has been especially high in the United Kingdom. The All Party Parliamentary Group on Antibiotics, chaired by Jamie Reed MP, Shadow Minister for Health, was established in June 2013 to ensure antibiotics remain high on the political agenda. 2013 saw publication of the UK Government's 5-year strategy on antimicrobial resistance. July 2014 was a landmark month: the House of Commons Science and Technology Select Committee reported on the findings of its inquiry into antimicrobial resistance; antibiotics won public support, and was voted the winning topic of the £10 million Longitude Prize; on 7 July the Prime Minister declared the need for urgent action and announced the launch of a Commission on Antibiotic Resistance.

Interest is now high across international medical, scientific and political arenas. The next steps must be to go beyond public statements and reports and take action. Governments must respond as they have to other public health crises such as Alzheimer's and obesity, and identify properly funded mechanisms that will further the scientific base for understanding the biology, clinical and societal impact of antibiotic resistance. Academic and small and medium-sized enterprises (SMEs) need to be enabled to work together and with Pharma to capitalise on their abilities, and accelerate discovery of new ways to prevent and treat bacterial infections. Regulators and economists must work together across international boundaries to examine and safely redefine the regulatory and financial models that govern the development and marketing of antibacterial agents to facilitate a return to this market.

... Governments must respond ...

Lastly, it is imperative that all stakeholders – professional, political, public, industrial – have a clear understanding of the importance of ensuring antibiotics are used appropriately, and with the respect they deserve. Antibiotics are used in many settings. Discouraging use other than to treat infection is essential. Education on appropriate use will include instruction on curtailment of use where there is no bacterial infection and restricting the purchase of antibiotics by the general public. This is widespread in some countries. Learned societies must work to ensure that prescribing of antimicrobial agents is included in the training and education of all who may prescribe these drugs. To assist in this process the British Society for Antimicrobial Chemotherapy is working with colleagues to develop a Massive Open Online Course (MOOC) on Antimicrobial Stewardship.

The road ahead is challenging, but there are opportunities aplenty. Henry Kissinger said *"the absence of alternatives clears the mind marvellously"*. We must now be bold enough to invest in the infrastructure and innovation needed to protect and replenish the antibiotic 'treasure trove'. Governments and funders must put their money where the problem is. Regulators must protect public health while offering innovative frameworks. Reimbursement models for antibacterial treatments must be redefined. Most importantly, there needs to be an acknowledgment by all stakeholders, politicians, scientists, funders, healthcare professionals and the general public, of the crossroad at which we stand.

... funders must put their money where the problem is ...

Note: Extracts from this article were published online by CNN News in August 2014.

GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

Professor Bruce Yardley
Chief Geologist, Radioactive Waste Management Limited

Disposing of the radioactive waste products from nuclear sites is one of the most difficult challenges for society in the 21st century. Internationally, it is now accepted that burying radioactive waste deep underground in a Geological Disposal Facility (GDF) is the safest way to achieve this. There are guidelines drawn up by the IAEA, and several countries already have advanced plans. In the UK, a range of alternatives were evaluated by the independent expert Committee on Radioactive Waste Management (CoRWM) whose 2006 report favoured geological disposal.

In a GDF, the waste is contained within engineered barriers but the surrounding rocks provide an essential further barrier to prevent radioactive materials (radionuclides) escaping to the surface. The site must have suitable geology to fulfil this role. Past UK governments have been criticised for placing insufficient emphasis on geology, so I was delighted to be appointed as Chief Geologist to a new NDA company, Radioactive Waste Management Limited, responsible for planning a GDF. In July DECC published a White Paper: "Implementing Geological Disposal", which provides the policy framework.

Radioactive waste comes from various sources, including electricity generation and medical applications, and is in a variety of solid forms which place different constraints on disposal. The White Paper identifies a total of 650000m^3 of waste for geological disposal; this includes existing wastes, spent fuel (SF), uranium and plutonium and materials from planned new build. SF and High Level Waste (HLW) will account for over 99% of the radioactivity at the anticipated opening of the GDF in 2040, but will occupy less than 15% of the packaged volume. The most radioactive isotopes decay very rapidly, as illustrated in Figure 1: our existing HLW will have lost 97% of its activity by 2200. Remaining uranium and Intermediate Level Waste (ILW) make up the great bulk of the packaged volume. Being less active, they remain radioactive for longer; after one hundred thousand years, the repository will have radioactivity comparable to a natural uranium orebody.

The objective of geological disposal is to separate effectively radioactive materials from the surface. The rocks that host a GDF must provide a stable environment for construction of tunnels and vaults, and also not contain potential future mineral resources. The rock must restrict or prevent the flow of groundwater through the GDF once it has been sealed, minimizing the risk that radionuclides could be taken up into solution and transported to the surface. Understanding groundwater at a site is vital.

Fluids such as water, brine, oil and gas occur in rocks in two distinct ways: they may occupy pores spread throughout the rock, or they may occur in cracks. Many sedimentary rocks are porous. In some, such as sandstone (Figure 2), pores are commonly well-connected and fluid moves through them easily making the rock permeable. In others, such as clays, pores are extremely small and fluids cannot move between them. These rocks are impermeable even if they have high porosity. Crystalline igneous and metamorphic rocks have very low porosity but can hold water in spaced cracks (Figure 3). Permeability values measured in the field are always higher than those measured on small laboratory specimens without the cracks. The permeability of fractured rocks depends very much on how open fractures are at depth and how well they interconnect. Having cracks does not ensure high permeability.

Despite the importance of permeability for groundwater flow, the wider geological context also matters. Even if rocks are permeable, water only flows if there is a driving force. In the UK it is unusual for fresh, potable groundwater to extend more than a few hundred metres below the surface. Deeper rocks generally contain dense saline water which does not mix with overlying fresh water and is probably very old (>10000 years) (Figure 4). Irrespective of rock types, the presence of old, dense, stagnant

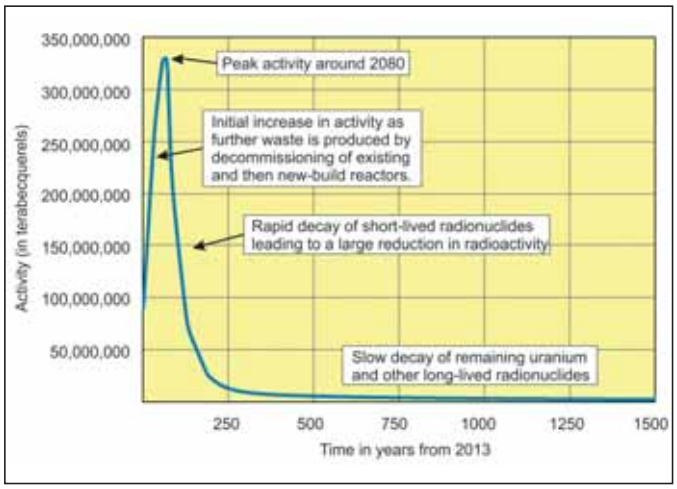


Figure 1: The decline in activity of the UK's total derived inventory of radioactive materials through time, from the date of the latest compilation (2013). This includes spent fuel from existing and planned new-build reactors.

groundwater at depth is a sign that radionuclides from a GDF will not be readily transported back to the surface, even over geological timescales, whereas if the groundwater is potable and young, there will be concerns that this could happen.

Internationally, three types of geological setting have been proposed as hosts for a GDF. Much early effort went into designing repositories in salt deposits. This is because salt provides an effective radiation shield, is impermeable to water and slowly flows underground, so that the cavities created to build the repository will naturally infill. The facility in New Mexico is hosted in salt. Other countries, including France and Switzerland, are planning to build their GDFs in clay or mudrock. Clays are impermeable and so provide a very effective natural barrier to the migration of radionuclides. Furthermore clays absorb many types of radionuclide from solution and so further retard their spread. Like salt, clays are weak and will flow, thus self-sealing cavities. Sweden and Finland are constructing repositories in strong granitic rocks with low permeability. The rock provides strength and facilitates construction and operation, while clay packing can be used to further isolate canisters of HLW or SF. The possibility of groundwater flow along fractures requires careful site selection but deep groundwaters in strong rocks are often distinct from shallow ones (Figure 4). Another option for a GDF constructed in strong rocks is a site where the GDF host rock is overlain by impermeable rocks such as clays.

Over the next few years, RWM will be screening the geology of England, Wales and Northern Ireland and, after public engagement and independent oversight, will publish the available information about geological properties that influence the suitability of rocks to host a GDF. What these precise properties are will be a matter for much discussion over the coming months, and only then will regional geology be evaluated. With geological guidance in place, communities throughout the UK will be invited to consider hosting a GDF, provided their geological setting offers good prospects.

For simplicity, unsaturated rocks close to the surface are not shown. On the left, fractures in crystalline basement rock retain stagnant saline waters at depth (dark blue) but have been flushed by fresh water (light blue) at shallower levels. They are overlain by a range of sedimentary rock types. While the coarser sediments contain freshwater in their pores, the clays retain old saline pore waters except near their margins. A similar range of rocks is shown on the right, but in a different sequence and no basement is present. Again, deep rocks retain old pore waters.

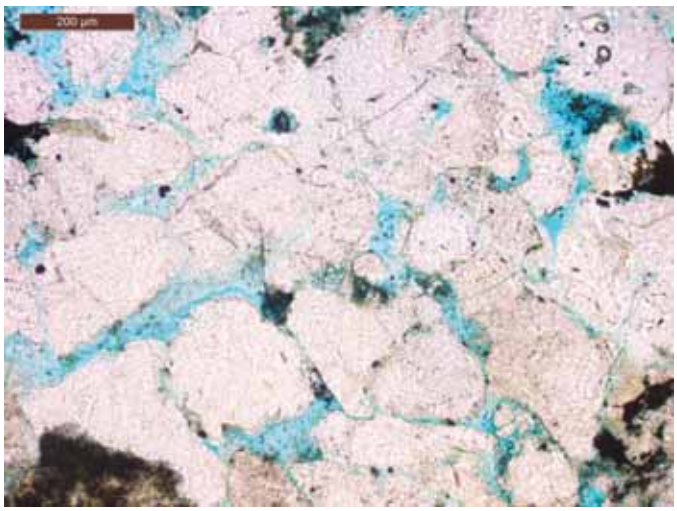


Figure 2: Photomicrograph of a typical reservoir sandstone that has been impregnated with a coloured resin so that the pore space, where water will reside below the water table, appears blue, and sand grains are mostly colourless. The field of view is about 1mm across.

Figure 3: Outcrop of hard, impermeable crystalline rock cut by discrete cracks that will permit water to move through them at depth.

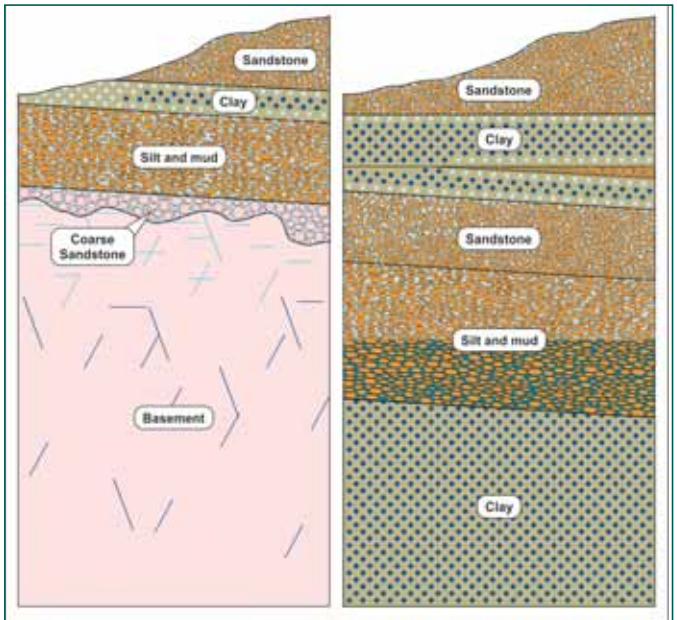


Figure 4: Examples of how groundwaters might be distributed through saturated rocks at depth in two idealised geological settings, represented by schematic geological cross sections. For simplicity, unsaturated rocks close to the surface are not shown. On the left, fractures in crystalline basement rock retain stagnant saline waters at depth (dark blue) but have been flushed by fresh water (light blue) at shallower levels. They are overlain by a range of sedimentary rock types. While the coarser sediments contain freshwater in their pores, the clays retain old saline pore waters except near their margins. A similar range of rocks is shown on the right, but in a different sequence and no basement is present. Again, deep rocks retain old pore waters.

BUILDING A STAR ON EARTH:
promising progress on the path to clean and plentiful energy from nuclear fusion

Dr A E Turrell
EPSRC Doctoral Prize Fellow
Imperial College London

What problem do you most hope scientists will solve in the coming years? Prof Stephen Hawking, when asked this question, said nuclear fusion[1]. Scientists, politicians, and even dictators[2], have long sought the 'holy grail' of energy production – to replicate how the Sun produces energy here on Earth. In recent years, astonishing progress in our understanding of just how to do that has been made.

Nuclear fusion is the cousin of nuclear fission, but where fission involves the splitting of heavy atoms, such as Uranium, fusion is the combining of light atoms, such as hydrogen, into heavier atoms. The new heavier atoms are just a fraction lighter than their constituent parts were, with the difference in mass being released as energy according to physics' most famous equation, $E = mc^2$. It is this process that powers all stars in the Universe and, indirectly, most life on Earth.

Construction of the US National Ignition Facility.

Why should we pour resources into replicating this process on Earth? The goal, it must be said, is not just to fuse two atoms – that has been done many times – but to produce a net gain in energy from fusion reactions; an entirely new power source. Given that much of what makes life pleasant in the modern world is reliant on the consumption of energy, and that the advantages of fusion energy are hard to underestimate, this is an important goal.

David MacKay, Chief Scientific Adviser to the Department of Energy and Climate Change, estimates that the supply of fuel for the most simple fusion reaction would last a world population of 6 billion for more than a million years[3]. Not only is there a supply well beyond the fossil fuel horizon of 100-150 years[4], but the fuel for fusion is found in seawater, meaning that energy security would never again be an issue. This would solve two serious geopolitical problems; that of countries using their fossil fuels to achieve political objectives, and that of terrorist organisations who have captured fossil fuels exploiting them to fund their activities, a situation most recently and tragically demonstrated by the rise of ISIS[5].

The greatest problems with fossil fuels, which currently account for 87% of world primary energy consumption, are their negative externalities. The most widely known is global warming due to gases released by the burning of fossil fuels. The 2013 Inter-governmental Panel on Climate Change report is

clear, and uses what is, for scientists, very strong language [6]:

"It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century."

Climate change is certainly happening, and its effects are causing suffering now. The World Health Organisation estimates

One of the two huge laser bays.

that around 120,000 deaths worldwide were caused by climate change in 2004 [7]. Fusion produces no CO_2 and its main by-product, Helium, is in short supply. Fossil fuels also produce air pollution, which was linked to more than 28,000 deaths in the UK in 2010 according to Public Health England [8] with a significant proportion coming from energy generation [9]. Surprisingly, Westminster, and Kensington and Chelsea, have the joint highest number of attributable deaths due to air pollution of anywhere in Great Britain. Fusion produces no air pollution.

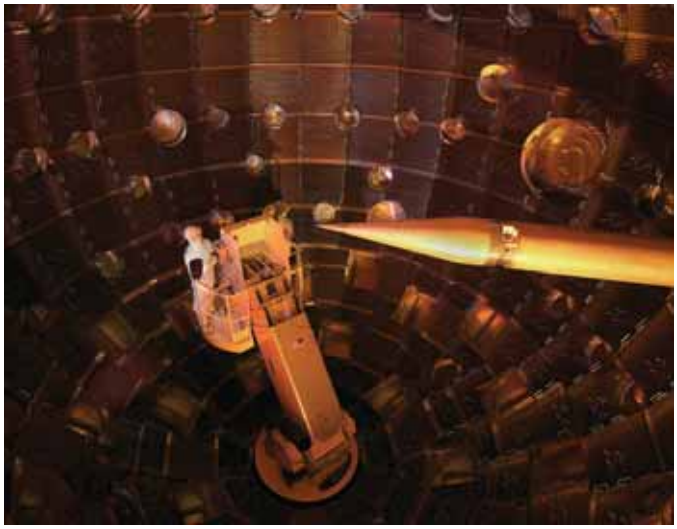
The word nuclear often unfairly prompts concerns over safety. Today's fission power plants give an insight into how safe a fusion plant would be. Fission has a reputation for being dangerous, but several reputable studies have concluded that it is far safer than fossil fuel plants, and even safer than most renewables [10,11,12]. Fusion would be similar but with two extremely important differences – there is no chance of a meltdown at a fusion power plant, and the radioactive waste produced by a fusion plant would be both short-lived and low-level, becoming safe after around 100 years as opposed to thousands of years. Another important difference with fission is that the components needed to ignite nuclear weapons have no place at all in current fusion reactors, as Uranium is not required for their operation.

One of the criticisms that can be levelled at fusion is that we will have no need of it because renewables could supply all of our energy needs using currently available technology. However, realistic assessments of UK renewables do not predict more than 10-15% of our energy needs being met by them, they are land intensive, do not provide a consistent supply, and may be more effective if located in other countries. In truth a mix of energy supplies will, as now, be the most useful strategy.

Given the enthusiasm of scientists, and the potential benefits, why haven't we achieved fusion yet, and what progress has been made? To bring star power to Earth will undoubtedly be one of the most important breakthroughs in human technology there will ever be. Fusion fuel has the highest energy per unit mass of any fuel available in the Universe (a single kilogram of it releases the same amount of energy as burning 12 million kg of coal), and is the most common fuel in the Universe, so it will surely be an important primary energy source for humanity in the future. However, it was only in 1920 that scientists realised that fusion reactions powered the Sun. Controlled fusion experiments began in the 1940s and 50s and it quickly became clear that the challenges of containing the state of matter of which stars are composed, plasma, at the millions of degrees C° and densities up to ten times that of lead which are required for fusion reactions would require leaps in technology, and multiple generations. Just as it took thousands of years for the full power of coal to be exploited in the industrial revolution, and decades of refinement thereafter [12,13], the much more complex process of fusion has necessarily involved considerable time and effort to understand.

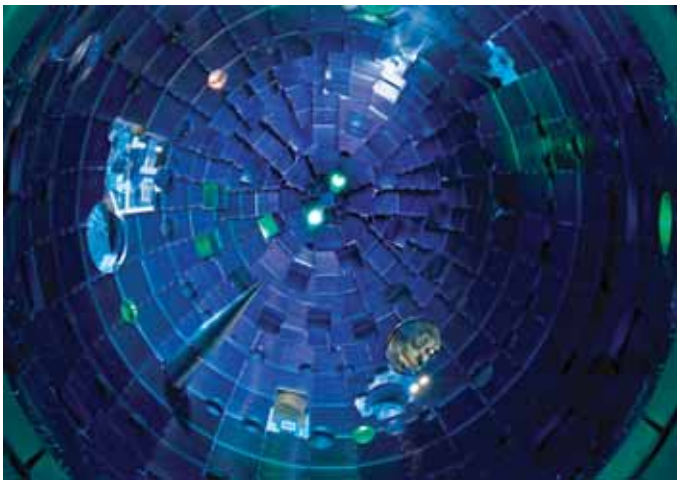
In the nine decades since fusion reactions were discovered, two methods for containment of the hot fuel have been devised – one using magnetic fields, the other using high power laser beams. Neither method has yet managed to achieve a net gain in energy but there are reasons to be positive about both. In the UK, the Joint European Torus used magnetic confinement of fuel to produce 65% of the power it consumed to operate, coming close to the magic 100% demonstration of technical feasibility. It is hoped that its successor, ITER, currently under construction in France, will be capable of reaching that goal in 2027 [14].

Laser fusion published its most successful result in 30 years of research in January 2014, in which the energy released by fusion reactions exceeded that put into the last stage of the compression of the fuel [15]. Though this result only represents an overall gain of around 1%, it is the first laser fusion experiment in which the fusion fuel was partially 'ignited'.



Scientists working inside the National Ignition Facility's target chamber. The fuel capsule, which is just millimetres in size but capable of releasing the equivalent energy of around 50kg of TNT, sits at the end of the long arm.

Full ignition would result in a gain well over 100%, so the excitement in the field is genuine. Laser fusion is a batch process, not unlike a petrol engine, in which a spark (provided by the laser) causes the fuel capsule, about the size of the pupil in your eye, to ignite and thereafter 'burn'. Burn means that self-sustaining fusion reactions propagate throughout the fuel, releasing energy. The machine responsible for the breakthrough is the National Ignition Facility (NIF), which is based at the US Lawrence Livermore National Laboratory. It has increased the energy produced from its experiments by orders of magnitude since opening in 2009.



Inside the National Ignition Facility's target chamber

Those in the laser fusion community are convinced that a machine with enough laser energy delivered to the fuel could cause a successful implosion of the capsule and high gain, and current work to improve gain is focused on how the energy is delivered. Their confidence is partly due to the pioneering work on fusion implosions by UK scientists Steven Rose and Peter Roberts in the 1980s [16].

Though much of this work, and the subsequent work led by US scientists, remains classified, a report on the US programme states that their experiments [17]

"...demonstrated excellent performance, putting to rest fundamental questions about the basic feasibility of achieving high gain."

In principle, the US National Ignition Facility has enough laser energy to get ignition, and is certainly making promising progress toward that goal, but other countries are fast catching up. France has almost finished its own reactor, Laser MégaJoule, while Russia and China have announced plans to build their own machines.

Though there is no ignition scale laser fusion experiment based in the UK, research councils have funded collaborative theoretical and computational work between UK and US scientists, and a US-UK memorandum of understanding was signed by the Minister, David Willetts, in 2011 [18]. There are currently only a handful of scientists directly involved in laser fusion in the UK, but relevant work has been conducted in the UK for many years. To capitalise on the early lead which the UK took in the field, and to take advantage of the close ties the UK has with the US programme, more UK scientists are desperately needed. The UK undoubtedly punches above its weight, particularly in the theoretical and computational challenges of laser fusion, but those competencies are threatened by the much larger, better resourced, teams of scientists that are operating in the US.

If the National Ignition Facility can achieve its goal with a significant contribution from UK scientists, then the UK will be uniquely placed to assist, or even construct, the next iteration of plant; a laser fusion reactor which would deliver power to the national grid.

Fusion is an important goal for humanity, and one in which the UK's scientists and engineers could play a large role. In the process of achieving ambitious goals where the nature of research makes outcomes and time scales uncertain, it is important to ask two questions. Is progress being made? And is the goal worth achieving? In the case of fusion energy, the answer to both of those questions is most emphatically 'yes'.

The small gold cylinder, just 8.4mm long, which holds the fuel capsule

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WORLD-CLASS SMART MATERIAL - BORN IN BOLTON

Daniel Keating
Managing Director, FibrLec Limited
www.fibrlec.co.uk

FibrLec Limited was established in 2013 to develop and commercialise flexible smart materials. These are based on applications in energy regeneration and renewable energy. They have spun out of recent breakthroughs at the University of Bolton. This has led to hybrid energy conversion systems driven by piezoelectric and photovoltaic materials and arranged in fibre, film and 3-D structures.

The multi-award winning team is led by Professor Elias Siores BSc, MSc, Dip Ed, MBA, PhD, CEng. FibrLec Limited has world exclusive licences of all related international patents.

FROM TYRES TO TREES, YACHTS TO TRAINS

The technology has reached exploitable commercial standing with huge potential applications. This stretches from energy parks to marine vessels, automotive parts, aerospace, military, construction and city-regeneration, wearable textiles, sports and outdoor lifestyle and biomedical devices. These materials exhibit flexibility, durability and recyclability, at a very low production cost.

FibrLec material can be layered within the wall of a tyre. Four such tyres will produce enough energy to power vehicle batteries, improving MPG and power output charge. Synthetic trees made with FibrLec will allow the capture of wind, rain and sun. Trees could be placed in areas where solar panels are unacceptable. The material can be deposited into building facades to harvest energy which can then be transferred to the building's electrical infrastructure. It can be woven to any size or shape, allowing it to combine with existing materials. FibrLec could be used in the sails of a yacht to harvest energy from the wind, rain and sun. Transferring this energy to the yacht's power sources allows the removal of heavy conventional batteries. FibrLec can be integrated into composite railway sleepers to recover large amounts of energy. The energy generated by people walking can be captured by integrating the materials into carpets. It has significant additional attributes. Once the material is placed onto an object or over an area, it reflects radar, making the material radar passive.

INDIVIDUAL ENERGY

You may soon be buying and wearing clothes containing FibrLec. There has been much coverage in recent years about the potential for apparel to incorporate smart technologies. FibrLec has some exciting applications here; the material can line the woven structure of clothing to allow 'wearable chargeables'. A jogger using the materials in shoes can recharge an iPhone in 60 paces.

MEDICAL AND BIOMEDICAL APPLICATIONS

Medical applications are another significant growth area. The reflection of radar and harmful rays means the material can be used to cover healthy areas of the body not subject to treatments. Its use in a pacemaker can allow constant charging, so that the patient does not require further surgery for battery replacement.

UK SUCCESS STORY

Our headquarters is on the University of Bolton campus. We are establishing manufacturing plants overseas and investing in international R&D collaborations to ensure that the technology remains competitive, and in the vanguard of UK materials innovation.

THE UNIVERSITY OF BOLTON

The University of Bolton has an illustrious background in engineering and smart materials. The Institute for Materials Research and Innovation is internationally renowned for its applied materials science and engineering applications. It has developed novel, smart and multifunctional materials (fibres, fabrics, films, foams and particles) at nano and micro levels. It also excels in the associated processing technologies.

This year is a celebration for the University as it looks back at its origins as the Bolton Mechanics' Institute 190 years ago. Research into the next generation of piezoelectric and organic photovoltaic fibres is already under way at the University. This includes designer materials modelling and experimentation, targeting improved energy conversion properties and enhanced power outputs. The success of FibrLec and the commercialisation of the University's research will support scholarships and bursaries for a number of students studying science, technology, engineering or mathematics (STEM) subjects. This will enable the next generation of innovators to make their mark.

Nottingham and Leicester Universities combine to develop 'intelligent mobility' across the UK's transport systems

Professor Sarah Sharples
Human Factors Research Group,
the University of Nottingham

From the start of the Industrial Revolution to the early part of the 20th Century, the UK's transport systems were transformed. New roads, canals and railways were built and vast numbers of goods and people were able to move at speeds hitherto unthinkable. The reduction in the time involved in moving people to their work and the speed with which products could reach their markets drove economic growth and increased wealth.

Today, the volume of traffic on our roads is more than 10 times greater than in 1949 and our railways carry more passengers than at any time since the First World War. The result has been steadily increasing congestion.

The government is committed to invest heavily in infrastructure through schemes such as Crossrail and High Speed 2. There is also a realisation that unlike during the days of the industrial revolution, there is now also an opportunity to use data to develop smart networks which connect vehicles, infrastructure and passengers in a way which was unimaginable a few years ago.

To explore these opportunities, the Transport Systems Catapult (TSC) was established by the UK's innovation agency, the Technology Strategy Board, to become the technology and innovation centre for 'Intelligent Mobility'. In simple terms, Intelligent Mobility is the optimised movement of people and goods; an emerging market which some experts estimate will be worth £900bn globally by 2025.

The TSC helps UK businesses develop solutions to public transport and freight needs. It harnesses emerging technologies to improve the movement of people and goods around the country by providing a network of expertise to help transform ideas into products and services. It will test the latest theories on how transport systems interact and function against real-world examples.

The TSC is one of a new network of technology and innovation centres established by the Technology Strategy Board as a long-term investment in the UK's economic capability. The Catapults aim to use cutting-edge research to help businesses compete in global markets tomorrow by transforming ideas into high value products and services.

Earlier this summer, fourteen universities were selected to support the TSC through the University Partner Programme. The programme was launched in order to promote collaboration with businesses and focus on the development of products and solutions in the field of Intelligent Mobility.

Two of the universities taking part in the University Partner Programme are our own, the University of Nottingham and also the University of Leicester.

A graphic representation of the weight of traffic in and around London

Our two universities have come together to form the Impetus Partnership. The Impetus Partnership will focus specifically on three elements – the journey experience, intelligent infrastructure and future transport systems. Together we will be drawing on the academic expertise of colleagues across our universities, including those in other catapult centres such as Connected Digital Economy and Satellite Applications, with whom we have close links.

The Impetus Partnership will also be helping businesses of all sizes and from all sectors to get involved with the work of the Transport Systems Catapult, by running events where they can learn about the latest developments, meet academic staff involved in the various research areas and find out how to access funding to develop new technologies and applications.

In addition, some of our leading researchers will also spend time at the Transport Systems Catapult's world-class 36,000 sq ft "Imovation" Centre (which combines Intelligent Mobility and innovation) in Milton Keynes, where they will work alongside other academics and industry experts from across the UK to help develop solutions to the ten main challenges identified by the TSC, namely:

1. **Improving the traveller experience at transport modal changes** – making journeys easier and ensuring smooth transition from one type of transport to another.

2. **Minimising the impact of disruption through the use of adjacent transport networks** – making passengers aware of

The Transport Systems Catapult aims to better use data to optimise the movement of people and goods

immediate alternatives when there is disruption.

3. Incentivising the provision of a seamless journey through modal changes – improving the design and management of transport interchanges so that they are easier to navigate and more pleasant to use.

4. Providing personalised, contextualised and trusted information which improves the traveller experience – taking advantage of increasingly sophisticated technology to help people plan and undertake their journeys.

5. Developing insights from transport system information to improve the performance of the network – transport systems generate huge amounts of data but very little is used to its maximum potential.

6. Offering end-to-end mobility as a service – to develop a global intelligent mobility market in which the UK is a world leader. Fundamental to this is a clear understanding and support for a traveller's whole-journey requirements, from departure point to destination.

7. Integrating quality-of-life and city-economy benefits into transport decisions – to help enable the decision-making process to consider the wider impacts and benefits of transport systems on individuals, communities, organisations and businesses.

8. Enabling the whole-journey accessibility of transport systems – ensuring that all travellers are able to make the journey of their choice, wherever possible.

9. Taking a systems approach to investment and policy in transport infrastructure – the transport sector works across a number of different areas in an inefficient and uncoordinated manner. A systems approach, where we can identify opportunities for effective collaboration, is key to delivering a better transport system overall.

10. Delivering seamless freight – encouraging freight-specific innovation and supporting effective, seamless, journeys for goods as well as for people.

A practical example of a solution aimed at the first objective of 'Improving the traveller experience at modal changes' can be seen in one of the demonstrations on display at the "Imovation" centre. A computer model visualises the stress levels of people travelling in and out of a train station, depending on the level of crowding. Various scenarios can be modelled to assess the impact which entrance closures at the station could have on the mood of the people in the area. Such data and models might be used to test layouts of future transport hubs to ensure they are built in the best way possible both socially and efficiently.

An early concept design of the driverless pods being trialled in Milton Keynes next year

The man at the helm of the new Transport Systems Catapult also has a wealth of experience in the rail industry as well as the automotive and transport engineering sectors. Before taking up the role of Chief Executive, Steve Yianni worked as Technical Director of Network Rail, where he played a key role in delivering the industry rail technical strategy.

Work with the TSC will also investigate the potential of new technologies in rail, road, aviation and water based transport modes. One project already under way by the TSC which could benefit road users is the Low Carbon Urban Transport Zone (LUTZ). This demonstrates the potential of driverless cars, cloud-enabled mobility and transport on-demand services. A research vehicle, 'the pod' is being developed which can be used to trial new technologies.

Another major project is in the aviation sector. The Departure Planning Information programme (DPI), is aimed at connecting a large number of UK airports into the European Network Manager to share information. DPI is an airport's ability to share real time data about when aircraft plan to push back, and the time they are likely to take-off. This will improve information about demand, capacity and traffic flows. It will help integration with other transport modes such as trains and buses as well as reducing stacking time, CO_2 emissions and delays.

Even factors such as the impact of weather are being explored by research groups linked to the Catapult. 'Instant Weather' provides access to localised weather on a short timescale, helping councils and businesses to manage better problems such as disruptions, routing and impacts on infrastructure.

Transport Systems Catapult's Chief Executive Steve Yianni (right) shows an interactive table top "demonstrator" of Manchester City Centre's transport network to Business Secretary, Vince Cable.

For more information about the Transport Systems Catapult and to find out how to get involved, visit ts.catapult.org.uk

For details about the work of The University of Nottingham and the University of Leicester's 'Impetus Partnership' contact Professor Sarah Sharples on 0115 95 14196 or email sarah.sharples@nottingham.ac.uk

New Study shows Britain's Technology and Innovation Sector has thrived during the recession!

Professor Richard Brook, President of AIRTO (the Association of Innovation, Research and Technology Organisations) discusses a new study by Oxford Economics and the importance of the sector.

Autumn 2014 has been a busy time for thinking about innovation policy, with the review of the Government's Science and Innovation Strategy in the run up to the Autumn Statement, the publication of the Hauser Review of Catapult Centres and Labour's work on its Science and Innovation policy emanating from a recent Green paper. Furthermore, an independent research study from Oxford Economics is highlighting the economic contribution of the sector and its impact on UK plc.

It may be helpful to say what we mean by INNOVATION. It is the translation of new ideas into successful products (and services). Innovate UK (formerly the Technology Strategy Board) defines innovation as "the successful exploitation of new ideas – because it drives economic growth". The new Oxford Economics study shows that Britain has a large and thriving technology and innovation sector contributing significantly to national capabilities and economic growth. The sector's business is centred on provision of specialist skills, facilities and knowledge to carry through the introduction of technology related innovations into commercial business and public service.

... a large and thriving technology and innovation sector….over 40,000, scientists, engineers and technical staff ...

The organisations that populate this sector include Catapult Centres, other independent Research and Technology Organisations (RTOs) and many of the Government's Public Sector Research Establishments (PSREs), as well as specialist private companies providing services in this area and university enterprise departments. Many are members of AIRTO.

Findings of the Oxford Economics study reinforce the scale of the sector's work and its potential to continue growing its contribution to the economy and public services. AIRTO's 50 plus members alone employ over 40,000 scientists, engineers and technical staff, comparable in size to approximately twenty research intensive universities. They have a combined annual turnover in excess of £5.5 billion, considerably larger than Germany's Fraunhofer Institutes. Other highlights show that through the recession, since the last survey in 2008, organisations in the sector have grown by an average of 2.5% per annum; their historically high level of productivity has been maintained and has even increased slightly. Furthermore, the sector's organisations are playing an increasingly important role in stimulating innovation, in fostering co-location on their campuses and in training postgraduates, much of the latter in conjunction with universities.

Why the Technology and Innovation Sector is so important.

The UK has superb research in its universities but, as noted recently by David Willetts MP, there is "no policy to move funding away from fundamental and curiosity-driven research. The impact agenda is about getting researchers to think about the potential implications of their research, not to get them to study something else." (Science in Parliament Vol 71 No 2 pp 27). This reflects a long standing policy.

Who is looking after the more immediate applied research, innovation support and technology application needs of businesses and public services? While some companies can take care of this for themselves and some university researchers are motivated by this type of work, most specialist scientific support and technical assistance for business and public services comes from the technology and innovation sector. This is critically important. Research has shown that innovative developments for most businesses originate within their supply chains. The capacity to turn such innovations into wealth and social benefit therefore relies on specialist support from the technology and innovation sector. It is unfortunate that until recently the sector's role has been poorly recognised in science and technology policy. Prior to the introduction of the Catapult Centres, we have to go back several decades to find programmes designed to support the activities of the sector on any appreciable scale. And yet, as the recent introduction of the Catapult Centres, historical precedent and experience abroad shows, an element of Government intervention is essential for the inception, progression and

renewal of a nation's capacity to apply new technology.

It is the role of the technology and innovation sector to pull through new technology into everyday use. This includes the fruits of fundamental and curiosity driven research in academia. The sector comprises the professional organisations and companies which supply the essential specialist services required to realise such innovations as successful value adding products, services or processes in the commercial marketplace or public service. There is a strong emphasis on the practicalities of implementation. As an example, AIRTO's members provide access to essential skills, experience, facilities, development capacity and training, [provision of specialist skills, facilities and knowledge] frequently culminating in proving compliance with regulation and standards and demonstrating performance at scale and the benefits to end users. They add value, bringing to bear the necessary combination of professional attitude and approach, skill set, experience and specialist facilities which they specialise in providing. Such work is part of the progressive risk reduction that has to take place between TRLs 3 and 7 on the Technology Readiness Level scale, whether the original idea and technological innovation came from a business or from academic research.

... provision of specialist skills, facilities and knowledge ...

Client needs for these services vary by sector and according to circumstance. Consequently the various organisations that comprise the Innovation Sector specialise in different types of work and different areas of application. Some serve specific industries (eg automotive). Others provide expertise in particular technologies (eg composite materials), others tackle multidisciplinary challenges (Catapult Centres for example) and some provide support for business processes (planning, staff development, risk and project management) in the particular context of innovation. Their work is undertaken for clients responding to the introduction of new products to market pull, competitive pressures and evolving regulation and also for those exploiting research to create new offerings and markets for their technology. Most members have varying degrees of interaction with both private and public sectors. The type of involvement varies from member to member according to need, circumstance and how they are financed.

AIRTO is the membership network for these organisations. It helps members to stimulate innovation, develop and exchange knowledge and best practice and foster connections between business, academia, finance and Government.

Why Government's role is important and what it can do to drive British-led innovation

As Britain emerges from recession it stands to gain a global competitive advantage by building on the current strength of the technology and innovation sector. It needs to continue to increase the level of innovation in business and public services.

Everyone recognises the risks in carrying through innovation programmes. Working in the innovation sector where new technologies are continually being introduced requires partnership between public and private sectors to share risk and increase confidence for investors. The challenge for Government is to mitigate those risks and support take up of innovative developments to the point where private finance has the confidence to take over. Spanning the TRL gap (or 'valley of death') from a policy perspective is therefore a matter of creating an appropriate and well-balanced 'public/private partnership'. In this context, for the sector to function efficiently and maximise contribution to the UK's continued growth, three things are needed from Government:

... important role in stimulating innovation ...

1. Assistance with replenishing physical and intellectual capital as established technologies are transferred to industry and new leading edge technologies move ahead. Without renewal of capital facilities and associated skills in the TRL 3 to TRL 7 domain (beyond the capital resources required by universities for their research), it will not be possible for the UK to exploit fully its investment in research. Industry will be disadvantaged in its ability to develop, test and demonstrate competitive, innovative products, services and technologies.

2. Leverage via public sector procurement to pull through innovative products and services into everyday use. Providing purchasing contracts, to innovative SMEs in particular, will help to raise the level of private investment in R&D and thereby increase SMEs' resources for growth and job creation. The Small Business Research Initiative (SBRI) could be used more extensively, from procuring research through to the supply of demonstrators and prototypes. R&D tax credits will further incentivise innovation and should be widely available, but they are not a substitute for procurement initiatives as they do not provide such a direct underpinning for investment decisions.

3. Continued focus on skills that strengthen innovation capabilities. This means ensuring that the UK has a strong and abundant mix of multi-talented people. Particularly interesting for AIRTO members are the skills needed for commercialisation of research. There is a shortage of people with these skills, including vitally important 'soft/people skills', to deal with this important challenge. Government could inspire STEM-related career aspirations in young people by raising the profile of PSREs and other non-university research and innovation establishments and their role in the economy. Promotion of Government owned and Government supported research and technology organisations as potentially rewarding career paths would be highly beneficial.

For further information:

For further details or to receive a copy of the forthcoming Oxford Economics report please contact enquiries@airto.co.uk; +44 (0)208 943 6600.

RADIOTHERAPY – THE STATE OF THE NATION

As cancer treatment becomes more complex, how can we provide a 'World Class Radiotherapy Service'?

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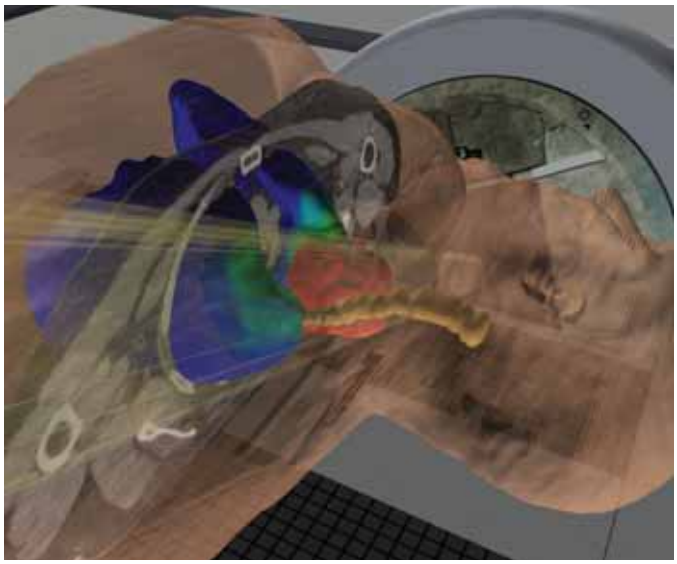
Since the discovery of radium by Pierre and Marie Curie, radiation has been used to treat cancer. Treatment has evolved from the use of radioactive metals closely applied to a cancer to using sophisticated computer controlled machines that deliver megavoltage radiation beams while rotating around a patient.

Radiotherapy can be used with 'palliative' intent, to relieve symptoms or pain or with 'curative' intent. When used curatively, it may be part of a multi-modality strategy, eg following breast conserving surgery or as sole treatment, eg where radiotherapy of the larynx allows retention of speech, which has obvious quality of life benefits. Radiotherapy is also often combined with chemotherapy. This improves the cancers' sensitivity to radiation, improving treatment efficacy and therefore cure rates.

The majority of radiotherapy in the UK is delivered using Linacs, machines that produce high energy X-ray or electron radiation 'beams'. Electrons are used to treat targets closer to the skin while X-rays can deliver dose to the deeper diseased organs (eg prostate). A single X-ray beam can be used, however, for deeper 'targets' two or more beams are generally used in order to reduce the dose to the healthy organs and tissues that lie between the skin and the 'target'. This strategy reduces the 'collateral damage' to the tissues lying close to the target.

The aim of curative radiotherapy is to attain the highest radiation 'dose' possible at the target whilst delivering the lowest 'dose' possible to surrounding un-diseased tissues. This is achieved using a 'conformal approach' where radiation-attenuating devices shield the un-diseased tissues. This approach reduces the side effects associated with radiotherapy.



Intensity modulated radiotherapy (IMRT) is a more sophisticated method of conformal therapy and is so effective that it now allows 'escalated' doses to be delivered. It maintains healthy tissues below any trigger doses for side effects. This increases the probability of controlling the disease, while keeping the risk of side effects low. By allowing greater shielding of normal tissue, side-effects are lowered, for example by decreasing the dose to the parotid gland in head and neck IMRT, the dry mouth side effect traditionally associated with radiotherapy was reduced.

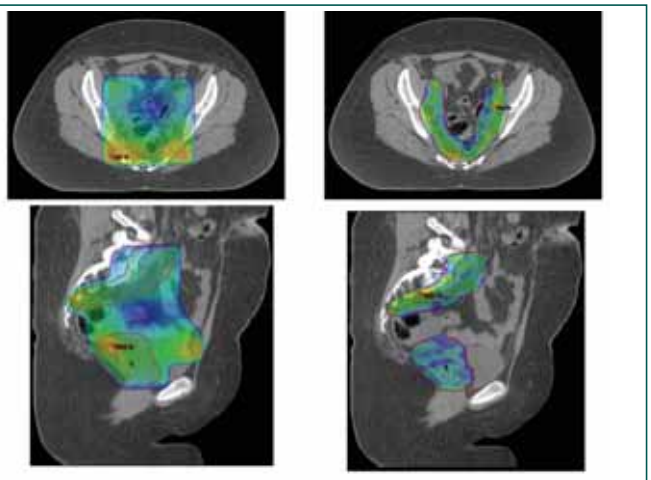
When delivering radiotherapy, accuracy is very important and breathing, cardiac motion and other natural processes can cause issues. Motion out of the treatment beams will reduce effectiveness and for other tissues movement will increase the risk of side effects. Treatment machines typically have X-ray imaging attachments to ensure that the target is accurately irradiated by the beams.

So called Image Guided Radiotherapy (IGRT) and IMRT are now common place and are considered the standard for prostate, head and neck cancers.

THE STATE OF THE NATION

Under the leadership of Professor Sir Mike Richards, the work of the National Radiotherapy Advisory Group (NRAG) and its operational committee, the National Radiotherapy Implementation Group (NRIG), roll-out of these techniques was implemented. In the UK there was a slower uptake of advanced radiotherapy techniques than in North America and other European countries. In 2012 work was undertaken to identify barriers to progress. Lack of specialist computer systems/licences, training of staff and staffing deficits were cited. Following this the Radiotherapy Innovation Fund (RIF) was announced by David Cameron to address such issues. Departments would commit to implementing IMRT to an agreed level of approximately 25% of those treated to 'curative intent'.

Departments were directed to submit short business cases and project plans, for subsequent rapid implementation and these were peer reviewed to extract a picture of requirements. A unique 'confirm and challenge' process followed. Each department presented their plans to a panel of experts. Plans were refined and advice was provided to less experienced departments. The final step required a prioritisation and revision with achievable milestones. Having received this revised intelligence and commitment from each department the leadership of NRIG was able to go back to ministers to argue that a fund of £23m would achieve the desired 'universal' goal. This enhanced level of funding was granted and Trust Chief Executives were informed of their funding in December 2012.



The images show a pelvic radiotherapy target on a CT scan, defined by the volume enclosed by the red line, we aim to have as little dose as possible to the area outside the red line. On the left images show the area irradiated by conformal radiotherapy and on the right the images show the area spared irradiation by IMRT

THE CHALLENGE

The vision of NRAG/NRIG was to ensure England had a 'World Class Radiotherapy Service'. The RIF programme was a great success in improving radiotherapy provision in England. It equalised the national 'contemporary' baseline. Ever-evolving technology means that challenges remain in keeping radiotherapy techniques current. One of the authors starts public lectures with the statement that in radiotherapy "We are techno-junkies" then follows up with "Actually, we are improvement junkies".

Wider implementation of imaging technology will improve the delivery of highly precise radiotherapy. MRI and PET imaging provide information about the functional state of tumours and may allow more aggressive treatment of cancer when a particularly persistent or radiotherapy insensitive tumour is detected. This could mean that diseases that traditionally responded poorly could be more effectively treated or patients for whom elongated and aggressive treatment was not appropriate might receive gentler options. In conjunction with other medical developments, such as genetic screening, this could allow personalised medicine in radiotherapy.

The majority of contemporary machines have imaging capabilities that allow the progress of the treatment to be assessed over the course of its delivery. This means that Adaptive Therapy, where adjustments are made to ensure everything 'stays on track', is now being investigated in a few centres.

A recent radiotherapy development known as Stereotactic Ablative Radiotherapy (SABR) is currently being offered in England for lung treatments. It has the potential for a broad range of both lung patients and those with other cancers (liver and spine for example). SABR utilises the IMRT and IGRT technologies described above, but is novel in that the treatments are given over a few days rather than protracted over a number of weeks which clearly provides a socio-economic benefit to patients. The treatment is considered more aggressive and potentially has a greater clinical effect.

CHALLENGES OF RADIOTHERAPY

One of the key issues and challenges for the continued advancement of provision of a world class radiotherapy service is that of funding. The current reimbursement system is 'tariff-based' and there is some compensation for different levels of treatment complexity but it is largely out-dated in its assumptions. No reimbursement mechanism exists for advanced imaging (such as MRI or PET) for radiotherapy treatment design, meaning imaging needs funding from a single payment that already carries the burden of several highly complex process steps including CT imaging. This restricts the purchase of dedicated scanners or the use of existing ones in the hospital. SABR treatments are often reimbursed as a simple multiple of the 'treatment days' delivered, meaning a department may lose up to 90% of the income per patient if it uses this new (desirable) technique.

Funding from Radiotherapy activity tends to be absorbed into Trust accounts and the departments themselves do not have access to the income. Business cases for new or even replacement equipment become long drawn-out processes that often fail or are dramatically cut back within the wider Trust 'Capital plan'. Whilst the radiotherapy community must exist within economic realities, the advancement of clinical services is often stifled due to outdated financial models. It is recognised by most that sensible revenue funding could promote a more sustainable service that relies less on 'frequent rescue' payments and more on business principles.

The radiotherapy community in England remains dedicated towards improving the care of our patients and striving for the provision of a sustainable 'World Class Service' of which England can be proud.

DID WE REALISE OUR POTENTIAL?
Celebrating 20 years of the mission led Research Councils

Meeting of the Parliamentary and Scientific Committee on Tuesday 17th June

Professor David Lane
Director, Ocean Systems Laboratory,
Heriot-Watt University

Have the mission led Research Councils realised their potential? Before I try and answer this, I'd like to invite you to reflect a little about purpose, not only for the Research Councils but also for yourselves as individuals, and on the nature of leadership that brings about change.

Why is it that you do what you do – as researchers, as leaders, as administrators, and why is it the Research Councils do what they do? To quote the Pythons, why is it that you get up half an hour before you went to bed, to finish that proposal, catch that early flight or prepare that lecture? It's not getting the money – that's just a result, available from pretty much any job. And I don't mean WHAT is it that you do – the day to day tasks that take up your time – filling in forms, sitting in meetings, or HOW is it that you do it – reading papers, synthesizing ideas, designing experiments. I mean WHY do you do it? And beyond that, WHY do you choose to follow the leaders that inspire you and guide you?

Some of you may recall that August last year saw the 50th anniversary of Martin Luther King's Washington DC speech where he proclaimed 'I have a dream'. Notice he said 'I have a dream' and not 'I have a plan'! The Dream is the thing that inspires us and unites us, and that effective leaders like Dr King capture, so that we all think, act and communicate in the same way. To quote Simon Sinek's 2009 TED Talk, "People don't buy WHAT you do, they buy WHY you do it". People are inspired by what great leaders believe, even though ultimately they do it for themselves.

... inspired by what great leaders believe ...

We live in an era of unprecedented disruption. The current churn rate of companies entering and leaving the S&P500 means that by 2027, 75% will have changed. In 2011 Kodak was replaced by a cloud computing firm and the New York Times was replaced by Netflix. On average, glaciers have thinned by over 10 metres since 1980, and the concentration of CO_2 has increased from 280 to 380 parts per million since the pre-industrial era. Wealth and population are concentrating in cities, with middle classes booming in the BRIC countries and squeezed in the West. Here in the UK, we are privileged to live in one of the wealthiest, most cultured and most organised countries in the world, with great institutions to guide us, and great people to inspire us. So my 'Why', my 'Dream' is clear – I want to keep it that way – I want disruption to work in our favour so that we capture the value from change to the benefit of Us. I want to be part of the Next Wave, not the Last Wave, so that Britain is not only Great, (to quote the strapline on the Government's Industrial Strategy) but will continue to be Great. I believe this so much, that I wrote it into the headline on my Linked In page. I went with my 'Why' and not my 'What', because it's who I am.

... riding this wave of disruption ...

Innovation is at the heart of riding this wave of disruption. It will create the new generations of products, services, and businesses that will make Britain productive and competitive internationally, help us monitor and intervene for our environment, make our cities function effectively. It's important to distinguish this Innovation from the Invention that precedes it. *Invention* for me is largely what we do here through the Research Councils, and is the process of turning money into ideas. Innovation, on the other hand, is largely what happens afterwards, and is the process of turning these ideas back into money again, but with a significantly larger transfer function! I like the strapline over the entrance to iRobot's headquarters in Boston – 'Make Money, Have Fun'. They know their Why! And the EPSRC too – 'Pioneering Research and Skills'. 'The Heart of Discovery and Innovation'. But what I'd really like is this innovation money to be sticky money – I'd like it to stick in the UK, I'd like it to stick to companies, universities and the Research Councils, and I think it's OK if some of it actually sticks to all of us as individuals too!

So how do we make Innovation happen from Invention? Well, there's no formula, and certainly no gantt chart, but there are lessons learned from exemplars that are working. For example, the autonomous car is coming, development programs are up and running in BMW, Audi and Google, and soon there will be demonstration vehicles driving around Milton Keynes as part of the LUTZ project, derived from EPSRC funded R&D at Oxford. However, this innovation really started at the break of dawn on March 13, 2004, when 15 vehicles left a starting gate in the desert outside of Barstow, California as part of a DARPA grand challenge. The goal was to autonomously navigate 142 miles across the desert to Primm, Nevada. None finished the course, and the top scoring vehicle travelled a nerve racking 7.5 miles! Not deterred, the teams came back in subsequent years, using competition to continually improve, and even raise the bar into urban environments. Similarly, autonomous underwater vehicles are now searching for the MH370 wreckage at 5000m depth in the Pacific, and Subsea7 in Aberdeen are now operating commercially the world's first Autonomous Inspection Vehicle in deep-water oilfields, based on EPSRC funded research spun out from Heriot-Watt. These also started life as freely-flooding prototypes in various AUVFests of the 1990s and 2000s. What both of these disruptive innovations have in common is the dream – I Have a Dream, not I Have A Plan. The key to reaching a tipping point where corporate interest takes over from public investment is the compelling demonstration, supported by the community, covered by media, embraced by the public, that captures the imaginations of business and market leaders, and from which a compelling disruption can flow. And one thing is sure – if we in the UK don't do it, somebody else will. So we have to compete to survive.

... The key to reaching a tipping point ...

Last year the Government launched its Industrial Strategy, and the Minister for Universities and Science launched the 8 (now 9) Great Technologies to spearhead the technology push from invention to innovation. In parallel, BIS, EPSRC and TSB have set up an unprecedented set of organisations and instruments to stimulate the innovation ecosystem, following reports from Hauser, Dyson, Witty and others. Leadership councils, special interest groups, catapults, catalysts, innovation and knowledge centres, knowledge transfer networks and more are the result. Inside the EPSRC alone, change has been everywhere. 113 CDT's have achieved impressive financial leverage and focus training around cohorts, creativity and innovation. We have impact acceleration accounts, public engagement, we write about pathways to impact and national importance in our proposals, and of course we have the REF. For the grey hairs amongst us, it's worth thinking back to how things were in 1994 – the uproar and controversy that surrounded the idea that research should have relevance to beneficiaries, and the new tick box on the reviewers' form. So as a nation we are taking the translation of invention into innovation seriously, but have we realised our potential?

Certainly there are stellar examples of success – LEDs from research into gallium nitride research, telecommunications from fibre optic research, and of course ARM. In the media, Marcus du Sautoy, Jim Al-Khallili and even Brian Cox. And the headline coverage of the Astra Zeneca takeover by Pfizer demonstrates the extent to which science and innovation are seen to be important in national life. Many more academics and their PhD students are having a go, offering themselves into CTO and engineering roles in spin outs, recognising that effective technology transfer is about the movement of people, not just licences.

... juggernaut of culture change is rolling ...

So we have made great strides, and the juggernaut of culture change is rolling. No longer is it the case that our Researchers are from Venus and Industrialists are from Mars. The UK continues to punch above its weight in scientific output, citations and international collaboration, second only to the US, partly thanks to ring fenced Government funding and FEC on grants. But set against my 'Why', we haven't yet realised our potential. Where are our Googles, Facebooks, Apples and Amazons? Even Estonia managed to produce Skype! And why are there so few with a research and innovation background in this weekend's Sunday Times Rich List – including me? It only takes a mere £85M to make it into one of the top 1,000!

Government and its agencies have created a stimulating and richly supported environment to promote UK invention and innovation. Ultimately, whether or not the Research Councils and the TSB realise their potential, is actually up to Us – the recipients of their support. Do we treat it as a form of public subsidy for our lifestyles and our businesses, or do we think of it as an investment to be nurtured, from which great things might flourish, that will keep Britain ahead in a disruptive and globalised world?

So I leave you with one challenge, to help us realise our potential. Can you write down your 'Why'? Not your 'What' or your 'How', but your 'Why'. And can you write it in one sentence that you can say in the lift or to your teams. Effective leaders start with 'Why'.

DID WE REALISE OUR POTENTIAL?
Celebrating 20 years of the mission led Research Councils

Sir Nigel Shadbolt
Professor of Artificial Intelligence
Web and Internet Science Group
Electronics and Computer Science
University of Southampton

We live in an age of rapid change. This is particularly so in science and technology where the rates of change in many areas are exponential. Over the past 50 years the computing power on a specific area of material has doubled roughly every two years – following what has come to be known as Moore's Law. When Moore wrote his 1965 paper he only had four data points – the earliest in 1962 – but the line he drew through them leads to the present we are now in. In 1972 the Intel 8008 microprocessor had 3500 transistors forty years later the Intel Ivy Bridge processor contains 1.4 billion.

These rates of change apply at every level in computing – not just to how many components we can fit on a chip or the minimum feature sizes used to build the chips in our computers and electronic devices, they apply to the speed of a microprocessor, they apply to the amount of information we can store in our memory technology.

... Computational tools and methods have refashioned science ...

This computational power has underpinned much other progress in STEM – whether it is proteomics or synthetic chemistry, astronomy or cryptography.

Computational tools and methods have refashioned science and technology. The digital ecosystem that has emerged has shaped the way research is conducted. The collection, analysis, interpretation and publication of scientific results is mediated by the Internet and World Wide Web, a social network of scientists collaborate and compete through their agency.

It is increasingly apparent that the problems we face nationally and internationally, locally and globally demand innovation, co-ordination and collaboration. This will be a defining characteristic of STEM research as we move further into the 21st Century. The Research Councils have been important in supporting and promoting this transformation in the nature of STEM – as the world has become a mixed reality of the digital and the physical.

Twenty years on from the ROPA report we can say that UK Research is World Class. Evidence can be provided from numerous sources but one recent BIS 2013 report[1] shows that the UK with just 0.9% global population and 3.2% of research expenditure is responsible for 4.1% of the world's researchers, 9.5% of downloads and 15.9% of the world's most highly-cited articles.

The ubiquity of data about STEM on the Web enables us to be much more precise about the impact of the investments the Research Councils make. Whether it is value for money, citation rates or international benchmarks.

... much more precise about the impact of the investments ...

The mission driven characterisation of our Research Councils has enabled a rational structure for funding research to emerge. This has helped promote collaboration and coordination. The challenge is around the right balance of investments. Are we able to be as agile as we need when the pace of innovation is accelerating?

Notwithstanding this challenge of balance and agility the Research Councils must take a significant part of the credit for our international performance.

But there are other reasons why our STEM landscape is in reasonable shape. Learned Societies and Professional Bodies have also become more mission driven. They have become more collaborative as they recognise the interdisciplinary challenge of many of the problems confronting us. For example, the Royal Society and the Royal Academy of Engineering do significant work together.

Another reason that the Research Councils have been successful is that STEM is seen to be indispensable to the security and the economic and social well-being of the country.

One of the notable features of the past two decades has been the continuity of the Ministerial appointments that oversee STEM and Research Council supported R&D. Two incumbents between them held the office for 12 years (David Sainsbury 1998-2006, David Willets 2010-14). The

commitment of these Ministers from across the political divide did much to secure the funding of STEM as well as associated R&D within Government.

We now have a network of Chief Scientific Advisers, across Departments of Government and across the devolved Administrations; there are Horizon Scanning and Foresight activities within a Government office of Science and a Chief Scientific Adviser, providing advice at the highest level. A number of Select and other Committees focus on S&T within Parliament. This has both raised the profile of STEM but also helped furnish policies with real evidence bases.

... interdisciplinary challenge of many of the problems ...

The health of STEM in the UK might be regarded as surprising given our relative under-investment in it. The facts are bald and striking. The most recent global comparative data from UNESCO 2008-10 [2] indicates that the UK invests 1.7% of GDP in S&T research. This is against a G20 average of 2.04%; it certainly contrasts with the aspiring knowledge economy that is South Korea which invests 3.7% of GDP.

If we take public funding of R&D the position is even starker. The G8 average is .79% of GDP – in the UK it is .57% – hardly an inspiring level of investment given the inspirational work that gets done.

Whilst we certainly punch above our weight in terms of the impact of the work funded by the Research Councils the UK as a whole still fails to exploit the fruits of its S&T at scale. The recent REF (Research Excellence Framework) exercise supervised by HEFCE is furnishing ample numbers of impact case studies that represent diverse forms of exploitation from the research done in UK Universities [3]. But the overall problem remains one of scaling. We are very successful at generating innovative start-ups that invariably are acquired by foreign companies. We produce too few global brands from our world-class research. The reasons for this are well rehearsed and being currently reviewed again by the Information Economy Council [4]. But we do not appear to have the investment infrastructure, incentivisation, inclination or culture to successfully scale our innovation.

A noteworthy development over the last twenty years has been the extent of citizen level engagement with science and technology. There has always been an aspiration that STEM subjects should better engage with the general public. The development of the Internet and World Wide Web over the past two decades has provided a dramatic new means by which individuals can participate directly, as never before, in the process of discovery, analysis and innovation.

... much wider participation in the knowledge economy ...

As of July 2014 members of the public had contributed hundreds of millions of classifications to the citizen science astronomy site Galaxy Zoo. Beginning in 2007 astronomers at the University of Oxford had built a site that enabled people to quickly learn the task of classifying images of galaxies. The first project comprised a data set made up of a million galaxies imaged by the Sloan Digital Sky Survey – far more images than the handful of professional astronomers could deal with. Within 24 hours of launch the site was achieving 70,000 classifications an hour. More than 50 million classifications were received by the project during its first year, contributed by more than 150,000 people and resulting in many scientific insights.

... citizen level engagement with sciences ...

From 2009 as the UK Government began to make more of its non-personal public data openly available a broad range of community based groups have taken the data and built innovative applications using it. Individuals, groups, public bodies, private corporations large and small have benefited from the availability of data at scale on the Web. News businesses, new applications and new services have been built using this new data resource. Moreover, the skills needed to exploit this new abundant resource are being fostered, in part, by the development of computing learning platforms such as the UK's Raspberry Pi.

... punch above our weight ...

When Tim Berners-Lee famously tweeted at the opening of the London Olympics that "this is for everyone" – it spoke to new possibilities and new realities – realising our potential through much wider participation in the knowledge economy.

Whilst these are positive developments there are very real challenges confronting research and development in our Institutions of Higher Education. As a consequence there are real challenges facing our Research Councils if they are to continue to be successful.

The funding of UK HE is being radically rebalanced. Universities are increasingly dependent on the money received from teaching. In general research loses money. Even on the full economic cost model that Research Councils use to fund Universities only 75% of costs are recovered. Increasing numbers of Research Council initiatives require Universities to match fund or else make substantial contributions towards the cost of doing research. Universities must often find 50% of major equipment costs. These are real and material concerns – the system is under stress. For all our success in realising our potential we need a secure and well-funded R&D capability if it is to continue into the future.

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2 http://data.uis.unesco.org/

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DID WE REALISE OUR POTENTIAL?
Celebrating 20 years of the mission led Research Councils

SYNTHETIC BIOLOGY: writing the future with biomolecules

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Director, BrisSynBio: a BBSRC/EPSRC-funded Synthetic Biology Research Centre

Summary: Synthetic biology is an emerging field that aims to make the engineering of biology easier, more reliable and more predictable. It combines understanding and methods from the biological and physical sciences with engineering principles and approaches. It is a truly multidisciplinary endeavour that requires input from experimental scientists, theoreticians, engineers and social scientists to succeed. If it takes root, the promises are considerable, and synthetic biology will have an impact on how we think about basic research in the biological sciences through to how we exploit it in the biotech, pharma and agrichem sectors. Through coordinated efforts from government, the Research Councils, industry and the academic research community over the past 7 years, the UK has built an extremely strong base for synthetic-biology research. This is largely founded in the universities and basic-research facilities, but there are strong links with industry. The challenges ahead are to grow this base to deliver high-quality basic science, which, in turn, will lead to applications underpinning UK SMEs and industry.

Synthetic biology is beginning to mean a lot of different things to many different people. Therefore, for clarity: in my view, synthetic biology simply aims to make the engineering of biologically inspired systems more predictable and more useful. Ideally, it involves the development and combination of experimental components and methods (some people call these biobricks) with mathematical and computational modelling to deliver solutions to biological problems. These could include different approaches in fundamental science, such as exploring simplified chemical systems that mimic biological molecules, cells and functions; or improvements on how we produce drugs, biofuels and foodstuffs in bacteria, yeasts and plants more efficiently.

I say "ideally" because the current vision for synthetic biology involves applying concepts such as *abstraction, modularisation,* and *standardisation* to biology. However, synthetic biology is still in its infancy and biologists do not fully agree on what the *standards* should be; or understand what can be *abstracted* from biology; or even know with certainty whether or not biological systems really are *modular* allowing them to be chopped and changed at will. As a result, it is not possible to say where this new field is heading, or what approaches will succeed ultimately. One thing is clear, however: the synthetic-biology wagon is rolling, it is picking up steam, and it will change the way that we think about biology and how we exploit it. The UK must be part of these developments; indeed, we must help lead and shape them both nationally and internationally.

... The UK has an extremely strong base for synthetic-biology research ...

Broadly speaking, there are four approaches to synthetic biology: first, one might consider a top-down approach that I refer to as Genome Engineering, and others call Synthetic Genomics. It is now possible to synthesise chemically and stitch together large pieces of DNA of the size of whole chromosomes, or even small genomes from natural organisms. The advantage of doing this rather than using traditional DNA manipulations is that in this process unwanted DNA can be excised, and new genes with specific uses can be incorporated. The resulting synthetic DNA can be 'booted up' inside living cells, and selected genes used. This approach is championed by George Church, J Craig Venter and others in the USA. Notable UK activity is from Imperial College who contribute to the Yeast 2.0 project.

In a second approach, which I call Biomolecular Engineering and is also known as Metabolic Engineering, useful genes, or even whole pathways of genes, are cloned from one organism into more tractable hosts, usually bacteria or yeasts. Here the aim is to get the best of both worlds and produce functional

molecules, such as biofuels, fine chemicals or pharmaceuticals, cheaply in bulk and in organisms that are easy to grow. One of the world leaders here is Jay Keasling at Berkeley. The UK has considerable strength in this area both in academe and industry, and particularly in enzyme engineering.

The third approach is Biomolecular Design. It is distinct from those described above in that the molecular targets are created *de novo*. As such, this approach is more basic, higher risk and further from applications than the first two approaches. That said, if we do manage to make stable and functional proteins or other biomolecules to order, it would place us in a strong position to engineer known or novel proteins for useful purposes, a principle at the very heart of synthetic biology. The UK is strong in this area with a good base of young and established academic research groups, including experts at the University of Bristol.

The final approach, Protocell Construction, is very much at the basic-science end of synthetic biology. Little research in this area can currently claim to be geared to foreseeable applications. Its aim is to produce entities that mimic the properties and behaviours of biological cells, but without using any of the natural building blocks, eg DNA, lipids, proteins.

... One ambition is to build synthetic cells ...

The ambition is to build synthetic cells in order to understand the rudiments and origins of natural cellular systems. The UK has growing activity in this area.

I will now describe what my group at Bristol does. Although DNA is the ultimate programming language of biology, we do not work at that level yet. We design and engineer protein molecules. This is because proteins are the workhorses of biology: they provide much of the structural scaffolding found within and outside cells; they help store, transfer and translate the genetic information in biology by interacting with, manipulating and controlling DNA and RNA molecules; and they provide biology's catalysts, making sure that reactions that convert one type of energy or molecule into another happen at the right time, in the correct place, and at a useful speed. In short, proteins do pretty much everything in biology apart from storing and passing on the genetic information.

In these respects, engineering protein molecules would seem an eminently sensible place to begin in synthetic biology. However, this turns out to be difficult: unlike the relatively straightforward codes that link the linear chemistry of DNA and RNA molecules to their structures and functions, we do not have similar instructions for how to write functional pieces of proteins. This is because protein functions are much more varied and complicated than those for DNA and RNA. It gets worse: in many cases, and unlike mutations in DNA and RNA, we cannot easily predict how changes in protein chemistry might affect the protein's shape, stability and function. This is precisely why the more-traditional synthetic biologists (sensibly) choose to engineer DNA and the genes that encode natural proteins, rather than starting from scratch and inventing new genes and new proteins; it is these natural genes and gene products that synthetic biologists often refer to as biobricks.

By analysing natural proteins, my group is learning some of the "rules" by which they are put together and function. We then apply these rules to engineer existing natural proteins to alter their functions, and also to create completely new proteins *de novo*. Protein structures and functions that we are targeting include: channel-forming structures that can span membranes to communicate between cells and sense the environment; fibrous proteins that can be induced to form gels to support the growth of human cells and tissue for use in regenerative medicine; and large cage-like assemblies of small protein modules, which might be used to deliver drugs to specific cells in the body.

... New genes with specific uses can be incorporated into biological systems ...

... Synthetic biologists will be creating new biomolecules, which may create public unease ...

I close with two further topics with national and global impacts: the first is about funding; and the other relates to topics such as public perception, regulation and responsible innovation around synthetic biology.

Regarding funding, the UK leads the way. This began with the RCUK's establishment of 7 Synthetic Biology Networks in 2007, which started to mobilise the research community. In 2012 a small group, established by David Willetts MP, published the Synthetic Biology Roadmap for the UK. Key recommendations of this were the creation of an Innovation Knowledge Centre, Centres for Doctoral Training, Research Centres, and Centres for DNA Synthesis. Over the past two years, and with Research Council, Government and industrial funding all of these have been achieved. These foundations still need to be supported with responsive-mode funds, seedcorn investment for spinning out applications and so on. However, the key message is that this is an extremely strong and healthy start for UK synthetic biology, which is unparalleled anywhere in the world.

My final thought might be seen as a word of warning. We have to tread carefully, and to be seen to be doing so, as we step into this new territory. Synthetic biologists will be creating new biomolecules; they will be questioning what life is; and they will develop capabilities to engineer living cells and organisms beyond those currently possible, or even currently imaginable. All of this makes lay people, pressure groups, regulators and even some scientists feel uneasy. We must tackle this head-on, through informed and open discussions with all parties. Above all, we must illustrate the benefits of synthetic biology while being cognisant of the concerns of others. My own views on this align with many more-eminent synthetic biologists: that is, we are likely to pass more opportunities over by not venturing into synthetic biology, than we are to risk harm to our planet and the future of the human race by embracing it. We must do synthetic biology, we must do it well and responsibly, and we in the UK must take the lead on this.

BUILDING ASPIRATION AND RECOGNISING INSPIRATION IN UK SCIENCE AND ENGINEERING

Whether it is a teacher, work colleague, relative or friend, we have all come across people who have been a source of inspiration, either in our careers or personal life. They may have provided guidance and helped to build our confidence over a long period of time, or they may simply have come up with an invaluable piece of advice that stays with us throughout our lives.

During the past year the Engineering and Physical Sciences Research Council (EPSRC) has been running a campaign that recognises scientists and engineers who are inspiring others. The initiative also provides the ideal

RISE Leader

Professor Kevin Shakesheff, University of Nottingham

Champion

Professor Jeremy Farrar, Director, Wellcome Trust

Rising Star

Dr Marianne Ellis, University of Bath

RISE Leader

Professor Lee Cronin, University of Glasgow

Champion

Dave Allen, Head GSK Respiratory Therapy Unit

Rising Star

Dr Oren Scherman, University of Cambridge

RISE Leader

Professor Jim Al-Khalili, University of Surrey

Champion

Liam Byrne, MP Shadow Minister for Universities, Science and Skills

Rising Star

Dr Radu Sporea, University of Surrey

RISE Leader

Professor Rachel Williams, University of Liverpool

Champion

Sir Mark Walport, Government Chief Scientific Adviser

Rising Star

Dr Paolo Paoletti, University of Liverpool

RISE Leader

Professor Jenny Nelson, Imperial College London

Champion

Zac Goldsmith, MP

Rising Star

Dr Piers Barnes, Imperial College London

environment for fostering the ambition, innovation and adventure of people who are in the early stages of their careers.

It not only benefits the individuals involved, but also scientific and technological endeavour in the UK and beyond.

RISE (Recognising Inspirational Scientists and Engineers) was set up in November 2013 as part of plans to mark the twentieth anniversary of EPSRC in 2014. The initiative, in partnership with the Royal Academy of Engineering, is part of the 'Engineering for Growth' campaign.

It also links to EPSRC's track record of supporting high calibre academics from the early stages of their careers. Many of these have gone on to become inspirational leaders in research and public engagement.

This building of aspiration and recognition of inspiration is also highlighted in one of EPSRC's strategic priorities which focuses on leadership and creates an environment that supports

... mutually beneficial learning process ...

"Ten of our outstanding Scientists and Engineers, RISE Leaders, have nominated rising stars whom they feel will lead internationally excellent research in the future," explains the Chief Executive of EPSRC, Professor Philip Nelson. "Our RISE Leaders are paired with RISE Champions who are senior people from industry, business, government and the media. A mutually beneficial learning process is taking place."

researchers throughout their careers.

The independent panel that selected the RISE Leaders was chaired by Professor David Delpy and consisted of Philip Greenish, Imran Khan, Sarah Main, Sir Richard Brook and Harold Poor. Nominations for the RISE Leaders came from more than thirty universities, industries and learned societies. Criteria included leadership, engagement, influence and impact.

The names of those selected reads like a 'Who's Who' of science and technology expertise. They would also make fascinating dinner guests particularly if the topic of conversation turned to *how should we be tackling some of the major challenges we are facing in the world today?*

RISE Leaders include Professors Jim Al-Khalili, Sadie Creese, Harald Haas, Lee Cronin and Rachel Williams. Research areas cover cybersecurity, ageing and chronic disease, using visible light to access the internet and regenerative medicine. Add to that their immense drive, ability to communicate and charisma, an essential ingredient for

RISE Leader

Professor Sadie Creese, University of Oxford

Champion

James Quinault, Cabinet Office, Director OCSIA (Office of Cyber Security and Information Assurance)

Rising Star

Dr Jason Nurse, University of Oxford

RISE Leader

Professor Steve Haake, Sheffield Hallam University

Champion

Sir John Armitt, Chairman of the Council of the City and Guilds of London Institute

Rising Star

Dr Jon Wheat, Sheffield Hallam University

RISE Leader

Professor Harald Haas, University of Edinburgh

Champion

Jonathan Legh-Smith, Head of Partnerships and Strategic Research, BT

Rising Star

Dr Lev Sarkisov, University of Edinburgh

RISE Leader

Professor Jeremy O'Brien, University of Bristol

Champion

Danny Finkelstein, Associate Editor, The Times

Rising Star

Peter Shadbolt, University of Bristol (on secondment to Imperial college London)

RISE Leader

Professor Rodrigo Quian Quiroga, University of Leicester

Champion

Professor John Perkins, BIS CSA

Rising Star

Dr Hernan Rey, University of Leicester

enthusing others, and you have ten people who will inspire and motivate. Their wealth of experience not only extends to their nominated rising stars but also the RISE Champions with whom they have been paired.

In putting forward names of potential rising stars the RISE Leaders were asked to nominate someone they consider to be a future world-class talent. They might have the skills, for instance, to invent a device that will change the way we live and work, to save thousands of lives or millions of pounds or to advance our understanding of the universe.

At the University of Leicester is RISE Leader, Professor Rodrigo Quian Quiroga who is Director of the Centre for Systems Neuroscience. He is improving understanding of how the brain works, particularly how we form memories and how we can develop engineering tools to understand the complex data that comes from brain signals. His work is providing insight into areas such as epileptic seizures and Alzheimer's disease.

His nominated Rising Star is Dr Herman Rey, Lecturer in Systems Neuroscience, also based at the University of Leicester. Rodrigo has been paired with Professor John Perkins CBE, Chief Scientific Adviser at the Department for Business, Innovation and Skills (BIS).

"My responsibilities in BIS are to ensure that the scientific evidence informing policy is fit for purpose", says Professor Perkins. "Rodrigo recognises that what he is doing has potentially a large impact. Thinking about ways of moving that agenda forward is a very exciting thing to be involved in. This is a way of enhancing the networks around some of the excellent science that is going on in the UK."

"As scientists in our labs, doing our research we don't always know the right people to help take our work on to the next level," says Professor Quian Quiroga, "being able to talk directly to John offers a source of invaluable advice."

... ten people who will inspire and motivate ...

... the right people to help take our work on to the next level ...

This is echoed by the Rising Star whom Professor Quian Quiroga has nominated, Dr Herman Rey, who said, "Our field of research has some interesting potential applications for the future." "John brings guidance on the different approaches."

Another rising star is Dr Marianne Ellis, Senior Lecturer in Biochemical Engineering at the University of Bath. "I was nominated by Professore Kevin Shakesheff from the University of Nottingham. Having recognition from somebody like Kevin is very humbling. It is acknowledging my potential. I will use it to build confidence and promote our field and bring to people what it can mean for the future."

Professor Shakesheff works in the area of tissue engineering. His nomination form for Dr Ellis stated that "Marianne's work has the potential to provide answers across the wide arena of 'health and well-being' where tissue engineering can be applied. This includes regenerative medicine and cell therapies, in-vitro models for drug discovery and toxicology testing, bio-artificial organs and cultured meat. Marianne's work takes the science of cell therapies into the clinic." Professor Shakesheff has been paired with clinical scientist Jeremy Farrar, the Director of the Wellcome Trust.

When it comes to engaging the public with the wonders of science and engineering research, Professor Jim Al-Khalili, based at the University of Surrey, has captured the imagination of many people from all walks of life, and inspired many in his own research area of theoretical physics. His long list of television and radio credits includes *The Life Scientific* on BBC Radio 4 and *Shock and Awe: The Story of Electricity* on BBC 4.

... captured the imagination of many people ...

Professor Al-Khalili nominated Dr Radu Sporea, also at Surrey, who specialises in power-efficient, cost-effective large-area electronics in organic and inorganic semiconductor technologies.

"Although Public Engagement and popularising of Science and Engineering are something that we do very well in the UK, a lot of these rising stars are deeply into their research", says Professor Al-Khalili, "so they don't have the time to look around, stick their head up and spread the word, but this gives them an opportunity to show off just how great innovation, engineering, technology and science is in this country."

Professor Al-Khalili has been paired with Liam Byrne, Shadow Minister for Universities, Science and Skills. As well as the immediate opportunities this initiative provides it is hoped that there will be long-term benefits: "If you look at the range of people, the champions that we are linked up with it's fantastic," says Professor Al-Khalili. "I think it is going to spread the word about the importance of science and engineering in a way that we won't fully appreciate until some way down the line."

The idea that the beneficial links formed will continue to reap rewards into the future resonates with the Chief Executive of EPSRC, Philip Nelson: "I've seen so many times that the really outstanding work is inspired by one or two critical people. It is those people that lead that make things happen."

For more information and a full list of names of all of those involved in the RISE campaign visit http://www.epsrc.ac.uk/rise/

PARLIAMENTARY LINKS DAY 2014
Science and Public Trust

The Attlee Suite was once again filled to capacity with MPs, Peers, scientists and engineers– standing room only from the start – for this year's Parliamentary Links Day at the House of Commons on the theme of *Science and Public Trust.*

> ***"The Society is to be congratulated for its initiative and leadership in organising today's event on behalf of the wider science and engineering community"***
>
> Rt Hon John Bercow MP
> Speaker of the House of Commons

There was a stellar array of speakers and for connoisseurs of *Twitter* this year's #LinksDay2014 was *trending* by 11.30am – a new record!

The Speaker of the House Rt Hon John Bercow MP – a steadfast supporter of science – launched the event as he has done throughout this Parliament.

He also included a poignant dedication to the work and scientific interests of the former MP Rt Hon Tony Benn who died in March and who had been a longstanding supporter of Links Day since its beginning.

Links Day remains the largest science event of its kind on the annual Parliamentary calendar and is sponsored on a tripartite basis by Andrew Miller MP, Stephen Metcalfe MP and Dr Julian Huppert MP. Organised by the Society of Biology on behalf of the science and engineering community Links Day promotes links and understanding between the worlds of Science, Parliament and Government.

This year's format included a mixture of keynote speeches and panel discussions. The speakers explored the importance of effectively engaging UK citizens with science and policy.

The two panels were made up of science journalists, academics and scientific organisations. They discussed the need for a stronger engagement with the public on scientific issues, and stressed the value of a strong connection between both Parliament and the Sciences in all capacities to advance policy making.

Discussion ranged around trust between scientists and politicians, scientists and the public and politicians and the public. There was agreement that trust is a two-way thing and that there is a need for all sides to engage honestly, moving from 'telling' to 'discussing' issues.

In his Keynote address Sir Mark Walport, the Government's Chief Scientific Adviser, discussed the planned development of a fast stream

specifically aimed at Science and Engineering Civil servants in order to bridge the gap for the scientists of the future, as well as the importance of the social sciences in relation to policy issues. He encouraged the room to engage with policy at local and national levels to continue integrating science effectively.

The two Panels were chaired by Stephen Metcalfe MP and Dr Julian Huppert MP.

The contributors on Julian Huppert's Panel included Nicola

Gulley (the Editorial Director of IOP Publishing), Mark Henderson (Head of Communications at the Wellcome Trust), Terry Lyons (Council for the Mathematical Sciences) and James Wilsdon (from the Science Policy Research Unit at the University of Sussex).

The contributors on Stephen Metcalfe's Panel were Fiona Fox (Director of the Science Media Centre), Pallab Ghosh (BBC Science Correspondent), Sarah Main (Director of the Campaign for Science and Engineering), Martin Pickersgill (Royal Society of Edinburgh), and Chris Tyler (Director of the Parliamentary Office of Science and Technology).

The Panel debates at the event (and across Twitter) were lively question and answer sessions that addressed topics such as the lack of funding organisations for post-graduate training, increasing productivity, global collaborations, inspiring young minds and most importantly constantly and consistently engaging with the public.

The political contributions to Links Day were made by Rt Hon Liam Byrne MP, Shadow Minister for Universities, Science & Skills and by Paul Uppal MP, PPS to the Minister of Universities and Science, who spoke at lunch as Rt Hon David Willetts MP was unavoidably absent on official business overseas. Mr Uppal pointed to the strong support that had been given to science by the Government over the years since 2010.

Liam Byrne launched the Labour Party's new Green Paper on science policy *Agenda 2030: One Nation Labour's Plan for Science and Innovation* and set out fresh House of Commons library research revealing the state of Britain's knowledge economy – including the falling Government and business investment in R&D and the falling number of people working in 'scientific research and development'– and argued that urgent change was needed to create a high-skilled workforce, stronger universities and a better environment for R&D investment. He added that after the consultation process a detailed White Paper on Labour's science policy would be published later in the year.

> ***"I am glad to support Parliamentary Links Day and I congratulate the Society of Biology on its continuing efforts to bring science into Parliament."***
>
> Rt Hon David Cameron MP
> Prime Minister

Sir Paul Nurse, President of the Royal Society, gave the closing Keynote Address and highlighted two aspects of trust in science . The first was what is it about science which means that it should be trusted? And the second was which scientists and scientific organisations should be trusted to give good advice about science to society and its democratic institutions?

Sir Paul argued that Science should be trusted because "it can generate reliable knowledge about the natural world and ourselves." This is because of the way that Science is done and because Science has a number of attributes not all unique to Science, but when put together make it a reliable and self-correcting process of generating knowledge.

> ***"This House congratulates the Society of Biology and… welcomes the Society's continuing commitment to serve the public interest by improving the access of all hon. Members to scientific information and a better understanding of science."***
>
> Early Day Motion 145
> Tabled 19 June 2014

He ended with a memorable plea. "Better discussion and engagement about science with the public will lead to more trust in science, and in my view this will be increasingly important for a healthy democracy. There is a job here for both parliamentarians and scientists, which is why Parliamentary Links Days such as this are so important."

The text of Sir Paul's Keynote Address is available at http://blogs.royalsociety.org/in-verba/2014/06/26/paul-nurse-speaks-on-trust-in-science/

"Parliament needs a working dialogue with the scientific community and I know that the Society of Biology and other societies work tirelessly to provide MPs with access to information and advice.

Rt Hon Ed Miliband MP
Leader of the Opposition

BSI Resources Parliamentary Links - British Society for Immunology
The Society of Biology demonstrated its heft in bringing together a heavyweight set of panellists and speakers for this latest Parliamentary Links Day

Pallab Ghosh ***@BBCPallab***
Speaker praises late Tony Benn's passion for science great impersonation of him #linksday2014

Wellcome Education ***@WTeducation***
Wellcome trust monitor data shows the public does trust scientists, much more than politicians http://wellcome.ac.uk/monitor ***@markgfh #linksday2014***

Dr Suze Kundu ***@FunSizeSuze***
If we want to understand public engagement, we need social science. YES! Complimentary.

Not a competition. ***@uksciencechief #Links Day 2014***

SciTechCom ***@CommonsSTC*** ***@uksciencechief*** *calls for more scientists and engineers to stand for parliament. Any volunteers?* ***#linksday2014*** ***#scipolicy***

Society of Biology ***@Society_Biology***
Events like ***#LinksDay2014*** *make a huge impact on MPs says* ***@liambyrnemp***

Society of Biology ***@Society_Biology*** ***@drsarahmain from*** ***@sciencecampaign*** *explains the importance of respecting that MPs are busy and using time with them wisely.* ***#linksday2014***

SciTechCom @CommonsSTC ***@SteveMetcalfeMP:*** *if you don't like something, tell us!* ***@sciencecampaign*** *raised issue of practical science, we responded.* ***#linksday2014***

SciTechCom ***@CommonsSTC***
For all those inspired to engage with parliament, keep an eye on our website for some announcements over the next week or two. ***#linksday2014***

A LEVELS – ARE THEY FIT FOR PURPOSE?

Meeting of the Parliamentary and Scientific Committee on Tuesday 15th July

Dr Michelle Meadows
Director of Research and Evaluation, Ofqual

It is worth asking first, what are A levels for? If you were to ask a sample of employers, university admissions tutors, teachers, pupils and parents you would hear many different but overlapping views. This is a problem. If a qualification tries to meet too many needs; if it lacks a clear purpose; it can fail to meet any of those needs.

A Levels have three primary purposes:

- **A Levels define and assesses the knowledge, skills and understanding needed to progress to undergraduate study**
- **A Levels provide a robust and internationally comparable post-16 academic course of study**
- **A Levels permit universities to identify learners' level of attainment**

But A Levels also have two secondary purposes:

- **A Levels provide a basis for school and college accountability measures**
- **A Levels provide a benchmark of academic ability for employers**

There are various methods by which Ofqual and other stakeholders assess the extent to which A Levels fulfil these purposes. One measure is public confidence. Ofqual conducts an annual survey and interviews with users of A level, including teachers, Higher Education Institutions (HEIs) representatives, employers and parents.

These data are from 2013. Confidence amongst HE and the teaching profession is high but it is noticeable that confidence amongst employers is significantly lower than in other groups. It is worth remembering that meeting the needs of employers is a 'secondary' purpose of the A level. A single qualification is unlikely to meet different needs to the same extent. Perhaps other ways of meeting employers' needs must be found? It is likely that employers require more than a benchmark of academic ability – measures of team working skills for example.

In fulfilling its purpose, the A level is not static. It is under constant review and frequently reformed. Setting aside the current reforms, significant changes have been made during the past 14 years. Before 2000 some modular A Levels existed (in particular in science) but in 2000 there was wholesale modularisation and the introduction of the AS qualification which students could undertake at the end of the first year.

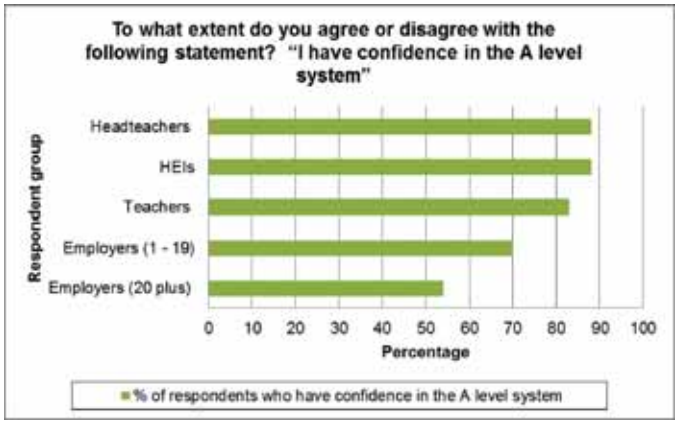
... A single qualification is unlikely to meet different needs ...

Modularity meant that some assessment could be taken every 6 months rather than all at the end of the 2 year course. Most A Levels were split into 6 modules. It was intended that this would motivate students and provide continual feedback. It quickly became clear that for most subjects, splitting into 6 assessments was too granular.

There was concern that this was affecting students' ability to develop in-depth knowledge and to draw links across subjects. In 2008, in most subjects, assessment was restructured into 4 modules but not in sciences or Maths. In science the 6 module structure suited the need for practical assessment.

At the same time more challenging assessment styles were included in the second year modules. Assessment which would require students to draw together knowledge from across the subject was introduced. The intention was to provide differentiation between students at the top end. A new grade was introduced to help universities select the very best – the A*. This was awarded for the first time in 2010.

However, these changes were insufficient to allay concerns over modular testing, and the sense that A Levels were not doing all they should to prepare students for undergraduate study.



Research conducted by Ofqual in 2012 involved interviewing HE representatives, employers and teachers. Some HE stakeholders argued that students on this diet did not develop a broad overview of a subject; that they lacked real understanding, and could not draw material together from across a subject. They complained that students lacked independent study and critical thinking skills.

They also felt that a re-sitting culture had developed. There was concern that this might have inflated grades, that students expected to have another go, and that getting a grade through repeated re-sitting was undermining that grade's value. Research based on one exam board's data from 2012 showed that 43% of A level candidates re-sat at least one of their modules, with almost a quarter re-sitting two or more modules. The strongest candidates, achieving the best grades, tended to re-sit the fewest modules.

Cambridge Assessment consulted 633 university lecturers. Over half of respondents thought that undergraduates were under-prepared for degree level study. They identified weakness in academic writing, self-directed study and independent inquiry, critical thinking skills, and depth of subject knowledge. Universities were putting on additional support classes for new students.

... Current assessments are open to malpractice...

What is being done to respond to these concerns? A Levels are being reformed from September 2015. In the meantime opportunities to sit modules have been removed. Exams can now only be sat in the summer. Effectively the AS and A level have become linear qualifications. More time will be available for teaching, and opportunities for re-sitting are much reduced.

The A level specifications from September 2015 are now being considered for Ofqual accreditation. All exams will be taken at the end of a two year course of study. This will support students in having a subject overview. Less time will be spent on assessment and more on teaching. Ofqual is scrutinising assessments to ensure they are not unduly predictable and that they will challenge the most able. We will only include teacher assessment where it is impossible to assess skills, knowledge or understanding validly without it. Where we can find methods of assessment that do not place pressure on teacher assessment, we have done so.

Overall the standard of the A level has not changed. We did not believe that there was a sufficient case to recalibrate the A level standard, as opposed to GCSE. The AS qualification still exists but its grading is decoupled from the A level – it will be a standalone qualification.

HE representatives have been involved in deciding the subject content for the new A Levels. They will be involved in reviewing the outcomes of the first awards.

There have of course been changes related to science A Levels. Some of these have been positively received. The maths content has been standardised across exam boards. Each science subject has a separate annex to the content setting out the maths that students will be required to master to at least level 2 (higher tier GCSE). This has been set at 10% for biology and psychology, 20% for chemistry and 40% for physics.

... a re-sitting culture had developed ...

Other changes have been controversial, in particular, the separate endorsement of practical skills. Students must carry out a minimum of 12 practical activities, which will be specified by exam boards. These will be assessed separately as pass or fail, rather than aggregated into the overall A level grade. Written exams will include questions (15%) set in the context of the specified or other practical activities. Students will only be able to do well on these questions if they have conducted a range of practical activities.

The separate endorsement of practical skills was a response to evidence of the current arrangements for assessing practical skills. The current assessments are predictable and have narrowed teaching. This is because the content of current tests is constrained by the limited time available for them to be completed; exam boards have to let schools know what's in assessments in advance so they can ensure they have the right equipment; and some schools only focus on teaching the skills they know students need to pass an assessment, rather than a broad range.

Most students get similar results, bunched around the top of the scale. This makes it difficult to differentiate students and grade boundaries. This makes for unreliable grading.

The marks do not reflect students' overall ability. They often get much better results in practical tests than written exams. Current assessments are open to malpractice. Different schools (and different students in the same school) might take the same assessments at different times. Schools get instructions for assessments in advance – this means some students and/or teachers might share information. Social media has exacerbated this problem. The way practical assessments are marked does not give evidence of the assessment of practical skills to check the marks teachers give students.

Stakeholders are concerned that this change will downgrade the importance of practical skills, meaning they are no longer taught within schools and colleges. The changes are intended to support the teaching of practical skills by removing them from the pressures of school performance measures.

This autumn the exam boards are trialling assessment methods and will be collaborating to ensure that a large sample of schools are visited each year to ensure that practicals are being conducted to an acceptable standard. They will be scrutinising student logbooks, talking to students and to teachers.

Ofqual will be conducting research to assess how well these arrangements are working and their impact on teaching and learning. We will also be talking to Ofsted about how to collaborate with exam boards to ensure these reforms have their intended impact. For science A Levels to be fit for purpose they must support good teaching and learning practical skills.

A LEVELS: Rearrange the deckchairs again or time for radical change?

Ian Haines
Executive Secretary, UK Deans of Science and Emeritus Professor, London Metropolitan University

LESSONS FROM HISTORY

Concerns over the state of school examinations have been a matter of debate for many years. A levels have been subjected to a two pronged attack over perceived grade inflation and questioning of the extent to which they prepare students for their future, whether this is for further study, usually in higher education, or directly into employment. In addition to the rhetoric in the popular press suggesting the annual grade inflation bore little relationship to the level of knowledge and understanding of students, there have been several studies that quantitatively indicated this. Two such STEM-related investigations that covered chemistry and mathematics are worth mentioning here.

In chemistry, the Royal Society of Chemistry carried out surveys[1] of entrants to about 40 Chemistry Departments. The study used the same standard test to measure the skills and knowledge of the core chemistry syllabus over the period between 1989 and 1996. Figure 1 compares the mean scores gained by candidates with the grade they obtained in A level chemistry. Over the period studied at all grade points there was a decline in percentage scores of at least one A level grade with those for B and C grades in 1989 having declined by over two grade points by 1996. The mathematics and engineering communities have had similar concerns. A mainly qualitative report[2] suggested problems of falling abilities of students with A level mathematics and the Engineering Council[3] showed comparable declines in mathematical skills in the 1990s to those observed for chemistry. These relatively historical reports are mentioned here simply to emphasise how long quantified evidence of problems with A levels has existed.

THE PRESENT AND FUTURE

Following many reviews, reports, workshops and conferences, too numerous to discuss here, the Secretary of State decided in 2012 to require Ofqual to 'consult' widely on A (and AS) qualifications. The consultation[4] was based on the importance of their use for entry to university, emphasising the need for increased rigour in the design and assessment of the curriculum, removal of the modular system with examinations only at the end of the course and non-exam assessment only allowed where this was absolutely necessary (as is the case of practical work in science). Much of what was suggested was broadly welcomed in principle by the STEM community, though many wondered why there was no serious questioning of why, after so many previous changes in A levels had failed to deliver better outcomes, he had not taken the opportunity to propose much more radical change. Of course, the consultation that followed contained questions that already assumed that A (and probably AS) level qualifications would remain.

... not taken the opportunity to propose much more radical change ...

Ofqual has published[5] the results of their consultation, confirming most of the previously announced reforms with some additional conditions. These included the requirement that A and AS levels will be separate and freestanding and although AS may be taught

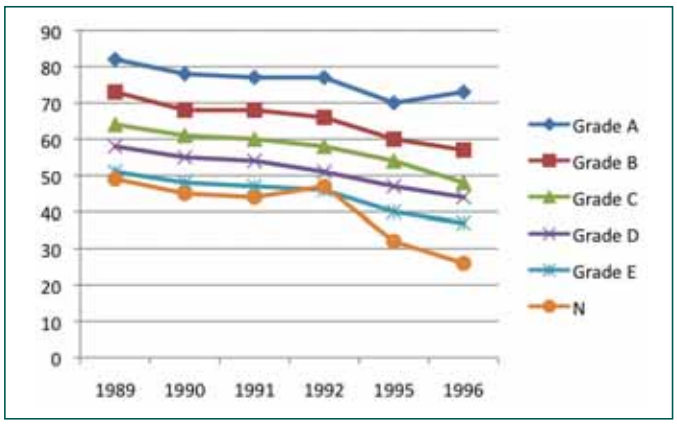


Figure 1 Mean scores in test versus A level grade of first year chemistry students

alongside A levels both will be assessed separately by written examinations at the end of the course. Each science A level will contain a minimum of 12 practical activities with at least 15% of written examinations consisting of questions that assess the 'theory and application of practical experimentation'. However, the practical skills will also be assessed and awarded a pass/fail grade, which will be reported separately from the written examination grade. It is this decision that is of particular concern for STEM subjects. Strangely, AS programmes in science will be assessed by written examination only.

Practical skills are as integral to science as they are to art and design. Decoupling of the reporting of practical skills at A level is an error of judgment by Ofqual. It is likely to give the wrong message about the importance of science practical skills to pupils, teachers, parents and school managers. There must be some concern as to how seriously the schools will take the need for resourcing and teaching practical skills if they are to be assessed purely by a pass/fail, 'tick the box' process. No matter how carefully the assessment criteria are defined, there will be a gradual move towards the 'bog standard pass'.

If we are to continue to have A and AS levels it is essential that manipulative skills and students' ability to plan, design, conduct and observe practical exercises, including fieldwork. They need to evaluate and explain the results obtained from their own work. This must be tested and graded beyond a simple pass/fail. The assessment of such skills should be integrated into the single overall grade awarded.

But surely it is time to stop fiddling with A levels and take the opportunity to think more radically.

TIME FOR RADICAL CHANGE? – SOME CASUAL EMPIRICISM

During the late 1980s and early 1990s Irish universities failed to keep up with the increasing demand for undergraduate places. I spent a number of years visiting Ireland to recruit Irish students to my university. The vast majority of students I met were far more articulate, confident and mathematically, and often scientifically, more advanced than many of their UK counterparts, in spite of the fact that they were studying a wider range of subjects than the typical three A levels. At the same time, some casual empiricism suggested that Scottish school leavers, who had also followed the broader Scottish Higher Certificate curriculum and were a year younger than A level school leavers, also appeared to be more intellectually prepared for higher education.

Region	Percentage of graduates in workforce
Inner London	60
Outer London	45
Scotland	41
South East	40
South West	37
East of England	36
Wales	33
North West	33
Yorkshire and the Humber	32
East Midlands	31
West Midlands	30
North East	29

Table 1 Percentage of working age population with a graduate qualification

It may be connected with these observations that Scotland has the third highest percentage of the working age population (defined as 21–64 for men and 21–59 for women) in possession of a degree level qualification[6] (Table 1). Also, although the PISA tables have some flaws and are intended to measure the effect of earlier schooling, 15 year-olds in the Republic of Ireland and Scotland generally outperform[7] those in England, Northern Ireland and Wales (Table 2).

Relative position	MATHS	SCIENCE	READING
1st	Rep of Ireland	Rep of Ireland	Rep of Ireland
2nd	Scotland	England	Scotland
3rd	England	Scotland	England
4th	Northern Ireland	Northern Ireland	Northern Ireland
5th	Wales	Wales	Wales

Table 2 Relative positions in PISA test 2012

... the wrong message about the importance of science practical skills ...

THE FUTURE. WHY A LEVELS?

The observations above indicate the clear advantages of a broad 14-19 education, which England, Northern Ireland and Wales would do well to copy in some form, whether this is simply a Baccalaureate or some other qualification. It would be better to make a decision about this now and not wait for the Baccalaureate to creep in over a period of years.

Why, ten years after the Tomlinson report[8], which was overwhelmingly supported by the STEM community, proposed a broader 14 to 19 curriculum are politicians and Ofqual still rearranging the deckchairs instead of facing the fact the A levels have had their day? The Government has handed over control of interest rates to the unelected Monetary Policy Committee and given regulation and control of the financial services industry to the independent Prudential Regulation Authority and Financial Conduct Authority. How long do we have to wait to have an independent STEM Education Authority (with representation from the major scientific and educational bodies, employers groups, teachers, trades unions, etc) with a remit to design, develop, introduce and oversee a more appropriate education system for the UK?

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VIEWS FROM ACROSS THE SECTOR

Dr Sarah Main
Director, Campaign for Science and Engineering

The Campaign for Science and Engineering represents a broad membership of organisations in the science and engineering sector.

Our membership consists of around a thousand individuals and about a hundred organisations. Over half of the organisations are universities, spanning the range from research-intensive universities to 'access universities' who are interested in getting people via non-traditional routes into higher education. About a third of our members are learned professional societies. We have about 20 companies as members.

PRACTICALS ARE ESSENTIAL TO A LEVEL SCIENCES

NEEDS OF INDUSTRY

The subject area which has given rise to the most vehement responses from our membership is that of practicals.

All the industrial members of CaSE desperately want to be able to recruit people with practical skills across a broad range of jobs: from technical, to graduate and postgraduate levels.

It is so difficult to recruit people with the correct skills that they recruit from overseas. This leads them to talk about our migration policy and how it may better fit their needs. Jaguar Land Rover say that they are 'exporting GDP' because they have to recruit so much from overseas.

For undergraduate teaching, it is now so costly in terms of capital and teaching time that many universities are moving towards computer simulation in place of practical courses. The number of graduates coming through UK universities with hands-on skills is diminishing.

You may think that technician level skills do not directly impinge on A levels. However, there is an ageing demographic of technicians, and the pipeline of technicians is going to run out as they retire. It is important to consider the experience that is given to students throughout their school life because they may become the technicians of the future. They are as important as are graduates.

ENTHUSING YOUNG PEOPLE

There have been many studies by learned and professional societies, which seek to quantify the skills that the UK will need in the near future.

The Institution of Engineering and Technology says that we need to double the number of engineering graduates by 2020. *The STEM Human Capital Crunch* by the Social Market Foundation estimates that the skills shortage in science and engineering is 40,000 graduates per year. There is a movement to interest a more diverse range of people interested in science, technology, engineering and maths (STEM) subjects in order to provide the skills required in industry and academia. This movement seeks to broaden the appeal of science and engineering and increase the diversity of practitioners.

Several studies address how this might be achieved. For example, see Ofsted's 2013 report, *Maintaining Curiosity: a survey into science education in schools* and the Wellcome Trust's 2014 tool, *Questions for Governors.*

COST AND RESOURCES

It seems intuitive that practical experience in school is both motivating and a good learning tool. The Government introduced the Your Life campaign in June 2014. This recognises that we need more people with these skills.

In the week that this was introduced, with the aim of increasing by 50% the number of people taking maths and physics to A level, Ofqual announced the changes to practical assessment.

The changes being proposed may hinder the Your Life campaign. Schools are driven by league tables and performance measures, including A level grades. The Ofqual proposal includes taking practical assessment out of A level grades and awarding a separate pass or fail mark. Many schools are tight on time, resources and space. CaSE members are concerned that those schools might be motivated to use their limited resources to do well in A level grades, which are measured in league tables, directing resources away from practical skills, which are not.

The worst-case scenario is that Ofqual's proposed changes to science A level practicals will cause damage. Schools with ample resource will provide a rich practical experience of their own volition, and those schools with limited resources are less likely to provide this. This disadvantages those who are already worse off. We need to prevent the worst manifestation of this, which would be that science laboratories are turned into classrooms, easing pressure on school places at the expense of practical experiences because they are no longer included in A level grades.

EVERYONE NEEDS SOME SCIENCE AND MATHS SKILLS

A move towards maths and science education for everybody

up to the age of eighteen has been proposed. There is recognition that it is important for young people to acquire a range of skills across the disciplines, not only for university, but for employment. David Willetts, the former Universities and Science Minister, has championed this idea, saying that we as a country will do well if people enter into the workplace with a broad range of skills. The idea that all students should study maths in some format to the age of 18 is gaining traction. It would be worthwhile broadening the discussion to include science.

A levels are not everything. There is a move to ensure students have a breadth of education after the age of 16; and there are alternative paths to A levels. The boundaries between further education, higher education and life-long learning are increasingly blurred. To widen access into traditional higher education there must be many routes. Some of our university members are proud to facilitate alternative pathways.

THREE PRACTICAL IDEAS FOR THE NEXT TERM OF PARLIAMENT

CaSE will put forward three ideas before the next election.

Teaching science

In 2010, the Royal Society reported that only 6,000 science specialists were distributed over 17,000 maintained primary schools in England *(State of the nation report on 5-19 science and mathematics education)*. In 2013, a Wellcome Trust study showed that only around 5% of primary teachers had a science-related degree *(Building Expertise)*. Due to the scale of the gap, while seeking to increase the number of science graduates training as primary school teachers, it is essential that teachers without existing science specialism are trained as science subject leaders.

CaSE recommends that by the end of the next Parliament, every primary school should have a nominated science subject leader. (S)he does not have to be a science graduate but would be a contact person who would undertake Continuing Professional Development (CPD) to enhance their understanding of science and methods of teaching science in a primary school. They would be a link to the local community and would communicate with local businesses and colleges to bring an up-to-date experience of what science and engineering means in the area for that primary school. Having one in every school will foster connections which may not normally occur in every school. This would improve the perception of science and engineering at an early age.

The National Science Learning Centres do great work in this field. Their courses of professional development cost roughly £3,000 each. CaSE would like to see stable funding for eligible teachers to access CPD at these Centres.

CaSE wants to see science CPD become a normal part of a teaching career, so that teachers can update their experience of modern science and engineering. This needs to be accessible, through a Government commitment to funding, and school commitment to give teachers time to partake.

Studies show how children, particularly girls, respond well to the confidence of their teacher in their subject. Girls seem to be more likely to progress onto the next stage of science education if they have a confident teacher who has a higher qualification in the subject. Subject-specific CPD may encourage students to progress into further study. It can also build realistic and modern expectations of a career in science and engineering with teachers, students and parents.

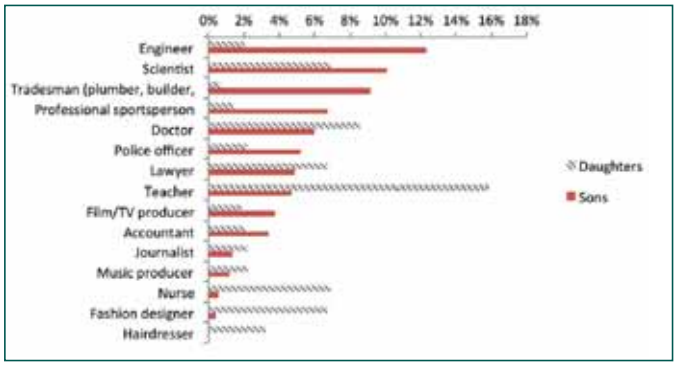
Parents' responses to the question, "What type of job would you most like your child to pursue when they finish their education?" show gender bias (from CaSE report *Improving Diversity in STEM*). CaSE believes that subject-specific CPD will help equip teachers better to convey the opportunities available to all through studying science and engineering subjects.

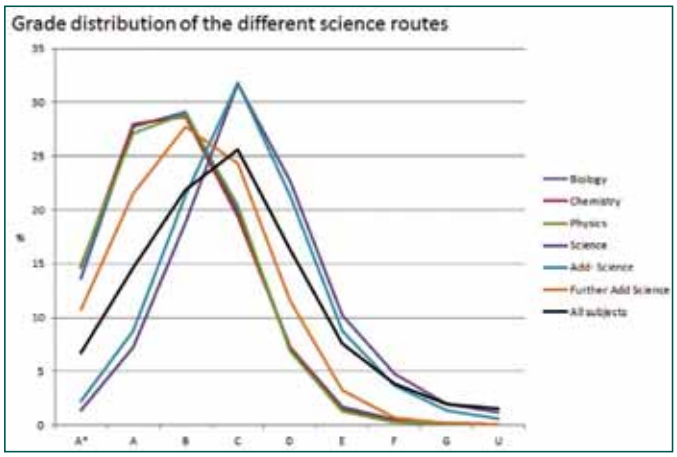
Practical science

All students should have practical experience at GCSE, AS and A level. Although we are talking about A levels, the issue about practicals also applies to GCSE and AS levels. The teaching and assessment of practical skills does not just mean written assessment, but an assessment of practical skills.

Studying science

All students should be able to study biology, chemistry and physics up to sixteen, and all should have the opportunity to study triple science up to GCSE level. The 2014 GCSE results suggest that students who take the triple science route achieve higher grades. We are told anecdotally that the triple science route is sometimes offered selectively to higher achieving students. CaSE would like all students to be offered the opportunity to study all three sciences at GCSE.





N.B. 'Science' – single award; 'Add- Science' is Additional Science – double award; 'Further Add Science' is Further Additional Science – triple award.

A robot walks into a bar…

The central photograph of a joke-telling robot that can tailor its repartee while performing a stand-up comedy routine was the overall winner in a national science photography competition organised by the Engineering and Physical Sciences Research Council (EPSRC) earlier this year.

The photograph, by Toby Harris, a PhD student at Queen Mary University of London's Cognitive Science Research Group, stole the show ahead of many other stunning pictures, featuring research in action, which were entered into EPSRC's inaugural 2013–2014 Science Photo Competition.

Open to all EPSRC-supported researchers and doctoral students, the competition attracted nearly 300 entries, and provided the opportunity for some of the UK's finest scientists and engineers to share their research through pictures. The results, we think you will agree, are truly impressive.

Not only are the 15 winning entries stunning images in their own right, they help to reflect the breadth of EPSRC's portfolio, which ranges from information technology to structural engineering, chemical biology to high performance computing, and mathematics to materials science.

All fifteen winning images will be exhibited in Room U, Portcullis House, 11.30–14.30, Wednesday 19 November 2014. Contact Sarah.Crew @epsrc.ac.uk if you would like to be sent further details. They can also be found online along with details of the current competition at http://www.epsrc.ac.uk/newsevents/events/photocomp2014/

ABOUT EPSRC

The Engineering and Physical Sciences Research Council (EPSRC) is the UK's main agency for funding research in engineering and the physical sciences.

EPSRC invests around £800 million a year in research and postgraduate training to help the nation handle the next generation of technological change.

The areas covered range from information technology to structural engineering, and mathematics to materials science. This research forms the basis for future economic development in the UK and improvements for everyone's health, lifestyle and culture.

EPSRC is committed to excellence and impact, supporting a research base and skills portfolio that meets key challenges of the 21st century, such as supporting an ageing population and meeting the need for sustainable energy.

EPSRC works alongside the other UK Research Councils, which work collectively on issues of common concern via Research Councils UK (RCUK).

LONGITUDE PRIZE 2014

Setting sail on a journey to solve one of the greatest challenges of our time.

Joshua Ryan-Saha
Longitude Prize at Nesta

This autumn the Longitude Prize 2014 will open for entries and the criteria outlining what competitors will need to do to win the prize will be published. From this moment on anyone, anywhere can take part and have the chance to win the multimillion pound prize fund.

Getting to this point has been an exciting journey. From the Prize's formation to its launch there has been a tremendous amount of interest and excitement from the public and we have received amazing support from our partners Innovate UK (the new name for the Technology Strategy Board), the BBC, the National Maritime Museum, and the Science Museum.

Most people already know the story of John Harrison – the Yorkshire clockmaker who, against the odds, developed the method to measure longitude at sea. By doing so he changed the future of Great Britain and the world. Inspired by this story, Longitude Prize 2014 was launched to coincide with the 300th anniversary of the Longitude Act.

In the early 18th century Britain was a great seafaring nation. However, its position and ambition was being challenged. Ships couldn't accurately measure their location and often got lost, resulting in shipwrecks and loss of life.

In 1714 the government came up with a prize to solve this problem. It offered £20,000 for a solution which could find longitude to within half a degree (equivalent to two minutes of time), and the Board of Longitude was set up to assess submissions to the prize and offer rewards. These experts included the Astronomer Royal at Greenwich and some of the best scientific, maritime and political minds of the age.

With life-changing rewards on offer, the challenge became the talk of London's thriving coffee houses. The Board received more than a few weird and wonderful suggestions and the phrase 'finding the longitude' became a byword for the mad pursuits of fools and lunatics. People believed that the problem simply could not be solved.

... may not have come to light within the traditional funding system ...

Of course it was eventually solved, but the answer came from an unexpected source with an unexpected method: John Harrison and his marine chronometer, the first seafaring clock. Harrison's chronometer solution led to accurate and safer navigation that ultimately enabled open global trade.

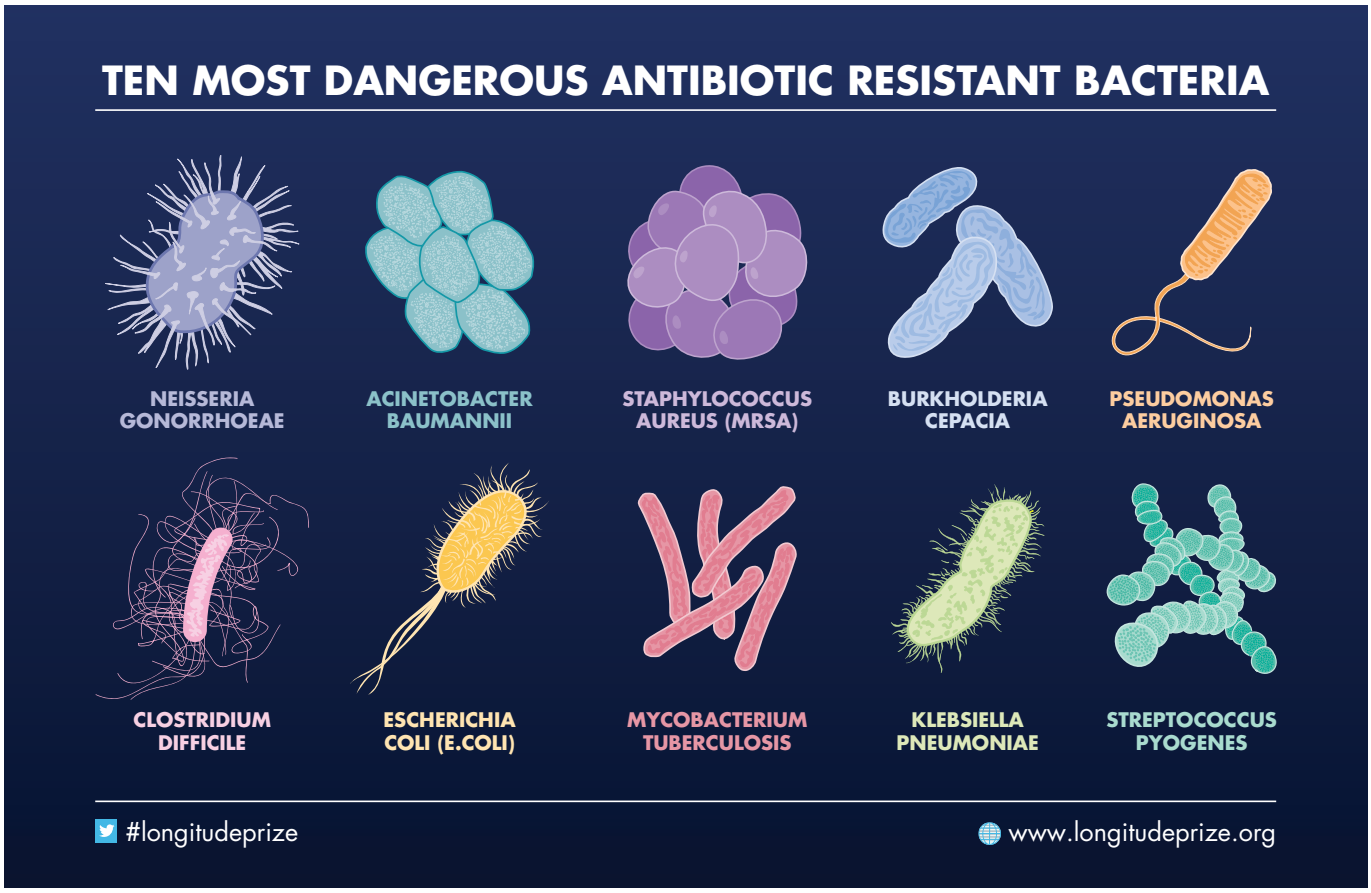
Fast forward 300 years and we now face a range of different issues that are equally significant and problematic. Selecting the challenges for the Longitude Prize 2014 was no easy feat. It began in the summer of 2013 with a round table consultation with over 40 of the country's leading scientists, engineers, and politicians at Number 10 Downing Street. Ideas were discussed under broad themes and the group identified a number of global challenges suitable for the new Longitude Prize.

These initial ideas were subjected to multiple rounds of critical analysis and deliberation with the public and over 100 scientists and academics across a variety of disciplines. From these rounds of research and refinement and with the support of the Longitude Committee at every stage, Nesta developed six challenges and they were put forward to the public to vote earlier this year.

THE SIX CHALLENGES WERE:

Flight – How can we fly without damaging the environment?

If aircraft carbon emissions continue to rise they could contribute up to 15 per cent of global warming from human activities within 50 years. This needs to be addressed in order to slow down climate change and its detrimental effects. The challenge was to design and build an aeroplane that is as close to zero carbon as possible and capable of flying from London to Edinburgh, at a



comparable speed to today's aircraft.

Food – How can we ensure everyone has nutritious, sustainable food?

One in eight people worldwide does not get enough food to live a healthy life. With a growing population and limited resources, providing everybody with nutritious, sustainable food is one of the biggest problems ever faced. The challenge was to invent the next big food innovation, to ensure a future where everyone has enough nutritious, affordable and environmentally sustainable food.

Antibiotics – How can we prevent the rise of resistance to antibiotics?

The development of antibiotics has added an average of 20 years to our life, yet the rise of antimicrobial resistance is threatening to make them ineffective. This poses a significant risk as common infections become untreatable. The challenge was to create an affordable, accurate, rapid, and easy-to-use test for bacterial infections that will allow health professionals worldwide to administer the right antibiotics at the right time.

Paralysis – How can we restore movement to those with paralysis?

In the UK, a person is paralysed every eight hours. Paralysis can emerge from a number of different injuries, conditions and disorders and the effects can be devastating. Every day can be demanding when mobility, bowel control, sexual function and respiration are lost or impaired. The challenge was to invent a solution that gives paralysed people close to the same freedom of movement that most of us enjoy.

Water – How can we ensure everyone can have access to safe and clean water?

Water is becoming an increasingly scarce resource. Forty-four per cent of the world's population and 28 per cent of the world's agriculture are in regions of the world where water is scarce. The challenge was to alleviate the growing pressure on the planet's fresh water by creating a cheap, environmentally sustainable desalination technology.

Dementia – How can we help people with dementia to live independently for longer?

It is likely that 135 million people will suffer from dementia by 2050. This will mean a huge personal and financial cost to society. With no cure, we need to find ways to support a person's dignity, physical and emotional wellbeing. The challenge was to develop intelligent, affordable technologies that could revolutionise care for people with dementia, enabling them to live independent lives.

At the end of June 2014, the British public chose antibiotics to be the focus of the Longitude Prize. Over the summer we have been consulting with scientists, academics and experts to define the criteria that will explain what competitors will need to do win the prize.

We hope that teams and individuals from a range of backgrounds will compete; after all, what makes challenges like the Longitude Prize unique is that they are open to anyone. They reward people who solve a pre-defined problem. They encourage and solicit entries from a broad, and possibly unlikely, range of sources that can pursue the development of ideas which may not have come to light within the traditional funding system.

Everyone has a chance to be involved in solving one of today's greatest challenges. If you want to find out more please go to www.longitudeprize.org.

HOUSE OF LORDS SCIENCE AND TECHNOLOGY SELECT COMMITTEE

The members of the Committee (appointed 12 June 2014) are Lord Dixon-Smith, Baroness Hilton of Eggardon, Lord Hennessy of Nympsfield, Lord O'Neill of Clackmannan, Baroness Manningham-Buller, Lord Patel, Lord Peston, Lord Rees of Ludlow, Viscount Ridley, the Earl of Selborne (Chairman), Baroness Sharp of Guildford, Lord Wade of Chorlton, Lord Willis of Knaresborough and Lord Winston.

Lord Krebs' term as Chairman (limited to three sessions) concluded at the end of the 2013-14 session. He has been replaced by the Earl of Selborne.

Resilience of Electricity Infrastructure

In July, the Committee launched an inquiry into the resilience of electricity infrastructure. Responses to the Call for Evidence were invited by late September. The inquiry will focus on the resilience of the UK's electricity infrastructure to peaks in demand and sudden shocks. It is interested both in the short term (to 2020) and in the medium term (to 2030) as electricity generation is decarbonised. Oral evidence will be taken until the end of the year. A report will be made in early 2015.

2025: Priorities for Scientific Research

In July 2014, the Committee conducted an inquiry into the key challenges that the Government's forthcoming *Science and Innovation Strategy* should tackle and the UK's priorities for scientific research. No report was produced but evidence was taken in public. Transcripts were published and brought to the Government's attention.

Behaviour Change

In May and June 2014, the Committee took oral evidence to follow up its 2011 report into behaviour change and assess what progress has been made. This focused on the two case studies that the Committee had investigated in its original inquiry: modal shift in transport and obesity. The Committee wrote to the Minister for Government Policy, Rt Hon Oliver Letwin MP, in July, making a number of observations and posing a series of questions, and received a reply.

International STEM students

In January 2014, the Committee launched a follow up inquiry to its 2012 report on higher education in science, technology, engineering and mathematics (STEM). The inquiry focused on the effect on international STEM students of immigration policy. Forty or so written submissions were received, seven oral evidence sessions were held, and a report published on 11 April 2014. A Government response was received in July.

Waste and the bioeconomy

The Committee launched an inquiry into waste and the bioeconomy in July 2013. The Call for Evidence closed on 27 September. This inquiry collected evidence on the technology to use bio-waste and waste gases to generate high-value products. It aimed to assess the potential for this technology to enable bio-waste and waste gas to replace current feedstocks, and the contribution this could make to a bioeconomy. Oral evidence sessions were held across autumn 2013 and early 2014. The Committee published its report on 6 March 2014. A Government response was received in early June.

Scientific infrastructure

The Committee launched an inquiry into scientific infrastructure in May 2013. The call for evidence closed on 22 June. Oral evidence was taken across June and July on large and medium-sized scientific infrastructure with a focus on: future needs and strategic planning, funding and governance arrangements, international partnerships and partnerships with industry. The Committee published its report on 21 November 2013. A Government response was received in February 2014 and a debate held on 13 May 2014.

Regenerative medicine

The Committee launched an inquiry into regenerative medicine in June 2012. A group from the Committee visited the California Institute for Regenerative Medicine. Oral evidence was taken from October to March 2013. The Committee reported on 1 July 2013 and a Government response was received on 1 October. A debate was held on 13 March 2014.

Nuclear follow-up

In July 2013, the Committee undertook an evidence session with Professor David Mackay, Chief Scientific Adviser at the Department of Energy & Climate Change, to follow up on its November 2011 report, *Nuclear research and development capabilities*. A further session was held with the Minister for Energy, Rt Hon Michael Fallon MP, on 10 December 2013. In July 2014, the Committee took oral evidence from Dame Sue Ion, Chair, Nuclear Innovation and Research Advisory Board (NIRAB).

FURTHER INFORMATION

The reports, Government responses, written and oral evidence to the Committee's inquiries mentioned above, as well as the Calls for Evidence and other documents can be found on the Committee's website. Further information about the work of the Committee can be obtained from Chris Clarke, Committee Clerk, clarkechr@parliament.uk or 020 7219 4963. The Committee Office email address is hlscience@parliament.uk.

HOUSE OF COMMONS SELECT COMMITTEE ON SCIENCE AND TECHNOLOGY

The Science and Technology Committee is established under Standing Order No 152, and charged with the scrutiny of the expenditure, administration and policy of the Government Office for Science, a semi-autonomous organisation based within the Department for Business, Innovation and Skills.

The current members of the Science and Technology Committee are:
Jim Dowd (Labour, Lewisham West and Penge), David Heath (Liberal Democrat, Somerton and Frome), Stephen Metcalfe (Conservative, South Basildon and East Thurrock), Andrew Miller (Labour, Ellesmere Port and Neston), Stephen Mosley (Conservative, City of Chester), Pamela Nash (Labour, Airdrie and Shotts), Sarah Newton (Conservative, Truro and Falmouth), Graham Stringer (Labour, Blackley and Broughton) and David Tredinnick (Bosworth).

Andrew Miller was elected Chair of the Committee on 9 June 2010. The remaining Members were appointed to the Committee on 12 July 2010. Caroline Dinenage, Gareth Johnson, Sarah Newton and Hywel Williams were appointed to the Committee on 27 February 2012 in the place of Gavin Barwell, Gregg McClymont, Stephen McPartland and David Morris. Jim Dowd was appointed to the Committee on 11 June 2012 in the place of Jonathan Reynolds. David Morris was re-appointed to the Committee on 3 December 2012 in the place of Gareth Johnson. David Tredinnick was appointed to the Committee on 4 February in place of Caroline Dinenage. David Heath was appointed to the Committee on 25 November 2013 in place of Roger Williams. Hywel Williams resigned from the Committee on 23 April 2014. David Morris resigned from the Committee on 5 September 2014.

CURRENT INQUIRIES

All evidence (written and oral) is on the Committee's website.

Climate: public understanding and its policy implications

The Committee held evidence sessions on Wednesday 19 June, Wednesday 26 June, Wednesday 17 July, Monday 9 September, Wednesday 11 September, Wednesday 9 October and Wednesday 6 November 2013.

A Report was published on 2 April 2014. The Government's response was published on 23 June 2014.

Government Horizon Scanning

The Committee held evidence sessions on Wednesday 23 October, Wednesday 27 November and Wednesday 4 December 2013.

A Report was published on 4 May 2014. The Government's response was published on 22 July 2014.

Antimicrobial resistance

The Committee held evidence sessions on Wednesday 18 December 2013, Wednesday 8 January, Wednesday 29 January, Wednesday 26 February and Wednesday 12 March 2014.

A report was published on 7 July 2014. The Committee is waiting for a response from the Government.

Blood, tissue and organ screening

The Committee held evidence sessions on Wednesday 5 February, Wednesday 5 March, Wednesday 26 March, Monday 28 April and Wednesday 30 April 2014.

A report was published on 24 July 2014. The Committee is waiting for a response from the Government.

National health-screening programmes

On Wednesday 7 May 2014 the Committee took evidence from Professor Jane Wardle, Academy of Medical Sciences, Jessica Kirby, Cancer Research UK and Dr Sian Taylor-Phillips, Warwick Medical School.

On Wednesday 11 June 2014 the Committee took evidence from Robert Meadowcroft, Muscular Dystrophy Campaign, Professor Michael Baum, Advocates for Honesty and Transparency in Breast Screening and Steve Hannigan, Children living with inherited metabolic diseases (Climb); Síle Lane, Sense About Science, Dr Margaret McCartney and Dr John Middleton, UK Faculty of Public Health.

On Wednesday 25 June 2014 the Committee took evidence from Dr Hilary Burton, PHG Foundation, Professor Ian Cree, Warwick Medical School representing the Early Cancer Detection Consortium, Professor Ian Jacobs, PROMISE 2016, Owen Sharp, Prostate Cancer UK; Dr Kevin Dunbar, National Chlamydia Screening Programme, Dr Sharon Hillier, Public Health Wales, Dr Anne Mackie, UK National Screening Committee, Jamie Waterall, Public Health England.

On Wednesday 9 July 2014 the Committee took evidence from Jane Ellison MP, Parliamentary Under Secretary of State for Public Health, Department of Health and Professor David Walker, Deputy Chief Medical Officer for England.

A report is being prepared.

Practical science in schools

The Committee discussed the proposals from Ofqual to change the practical assessment of science at A level.

On Monday 12 May 2014 the Committee took evidence from Professor Julia Buckingham, SCORE, Dr Sarah Main, Campaign for Science and Engineering, Professor Ian Haines, UK Deans of Science and Malcolm Trobe, Association of School and College Leaders; Dennis Opposs, Ofqual, Glenys Stacey, Ofqual and Janet Holloway, Ofqual; and Elizabeth Truss MP, Parliamentary Under-Secretary of State for Education and Childcare.

The Committee again discussed the proposals from Ofqual to change the practical assessment of science at A level.

On Wednesday 3 September 2014 the Committee took evidence from Janet Holloway, Ofqual, Dr Steven Evans, OCR, Darren Northcott, National Association of Schoolmasters and Union of Women Teachers, Professor Iain Haines, Deans of Science, Nicole Morgan, Royal Society of Chemistry on behalf of SCORE, Steve Jones, CLEAPPS; Michelle Meadows, Ofqual, Stella Paes, AQA, Max Hyde, National Union of Teachers, Elizabeth Swinbank, York University, Ginny Page, the Gatsby Charitable Foundation, Peter Mayhew-Smith, Association of Colleges, Richard Needham, Association for Science Education; Dennis Opposs, Ofqual,

Kaisra Khan, Voice, Professor Peter Main, Institute of Physics, Hilary Leevers, Wellcome Trust, David Britz Colwill, Sixth Form Colleges Association, Helen Thorne, UCAS; Glenys Stacey, Chief Regulator, Ofqual, Liane Adams, WJEC Eduqas, Philip Britton, Headmasters and Headmistresses Conference, Rachel Lambert-Forsyth, Society of Biology, Sir John Holman, CST, Jill Stokoe, Association of Teachers and Lecturers, Sarah Main, CaSE.

Social media data and real-time analytics

On Wednesday 18 June the Committee took evidence from Sureyya Cansoy, techUK, James Petter, EMC, Carl Miller, Centre for the Analysis of Social Media, Demos, Euan Adie, Altmetric.com, Digital Science; Professor John Preston, University of East London, Professor Mick Yates, University of Leeds, Dr Ella McPherson, University of Cambridge.

On Monday 23 June the Committee took evidence from Professor Derek McAuley, University of Nottingham, Professor David De Roure, ESRC, Professor Sir Nigel Shadbolt, Web Science Trust and the Engineering and Physical Sciences Research Council project SOCIAM; Professor Liesbet van Zoonen, Loughborough University, Professor David Robertson, University of Edinburgh representing the UK Computing Research Committee, Dr Mathieu d'Aquin, Open University, Emma Carr, Big Brother Watch.

On Wednesday 2 July the Committee took evidence from Steve Wood, Information Commissioner's Office, Dr Mark Elliot, University of Manchester, Dr Kevin Macnish, University of Leeds; Ed Vaizey, Parliamentary Under Secretary of State for Culture, Communications and Creative Industries, Department for Culture, Media and Sport.

A report is being prepared.

Current and future uses of biometric data and technologies

The closing date for written evidence was Friday 26 September 2014.

Genetically modified foods and application of the precautionary principle in Europe

The Committee's first evidence session is scheduled for Wednesday 15 October 2014.

Mitochondrial donation

The Committee will hold a one-off evidence session to discuss the scientific evidence on mitochondrial donation on Wednesday 22 October 2014.

REPORTS AND GOVERNMENT RESPONSES

The following reports have been published:

Government horizon scanning, HC 703

Ensuring access to working antimicrobials, HC509

After the storm? UK blood safety and the risk of variant Creutzfeldt-Jakob Disease, HC 327

The following Responses have been received from Government:

'Communicating climate science', the Committee's Eighth Report of Session 2013–14

'Government horizon scanning', the Committee's Ninth Report of Session 2013–14

FURTHER INFORMATION

Further information about the Science and Technology Committee can be obtained from the Clerk of the Committee, Stephen McGinness, or from the Senior Committee Assistant, Darren Hackett, on 020 7219 2792/2793 respectively; or by writing to: The Clerk of the Committee, Science and Technology Committee, House of Commons, 7 Millbank, London SW1P 3JA. Enquiries can also be e-mailed to scitechcom@parliament.uk. Anyone wishing to be included on the Committee's mailing list should contact the staff of the Committee. Anyone wishing to submit evidence to the Committee is strongly recommended to obtain a copy of the guidance note first. Guidance on the submission of evidence can be found at www.parliament.uk/commons/selcom/witguide.htm. The Committee has a website, www.parliament.uk/science, where recent publications, terms of reference for inquiries and press notices are available.

PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (POST)

RECENT POST PUBLICATIONS

Ancient Woodlands

June 2014 POSTnote 465

Ancient woodlands are irreplaceable features of our landscapes that can be high in biodiversity or cultural value. This summarises the challenges of conserving the biodiversity and cultural heritage of these sites to provide social and economic benefits, while still meeting the development needs of society.

Reducing Emissions from Deforestation

August 2014 POSTnote 466

The UNFCCC REDD+ scheme aims to promote sustainable forest management in developing countries to reduce carbon dioxide emissions. Developed countries are expected to provide approximately $20bn per year from 2020. This summarises the extent to which REDD+ could contribute to meeting international targets, challenges to its implementation and technologies for tracking its performance.

Childhood Allergies

July 2014 POSTnote 467

In the UK, 40-50% of children have at least one diagnosed allergy. The increased prevalence of allergies affects children's quality of life and puts pressure on health services. This discusses the causes and extent of allergic disease in childhood, examines the links between allergy, genetics and the environment, and summarises current research.

Big Data Overview

July 2014 POSTnote 468

'Big data' are data on a scale, or of a complexity, that makes it challenging to use. This examines definitions of big data, how it is managed, used and regulated, and the consequent public concerns. It sets the scene for a series of briefings exploring how data are increasingly used.

Big Data and Business

July 2014 POSTnote 469

Easier access to computing power and new analysis methods are enabling the use of big data by businesses, changing the way they operate and communicate with their customers. This examines the applications of big data by UK companies, highlighting the opportunities offered. It also considers the challenges that businesses and regulators face.

Big Data, Crime and Security

July 2014 POSTnote 470

Recent advances in analysing large and complex data offer opportunities and challenges for police and security agencies. This examines the use of such data in three key areas: crime prevention, crime detection and national security. It also covers regulatory issues and public perception about privacy, civil liberties and social benefits.

Smart Metering of Energy and Water

July 2014 POSTnote 471

Smart meters record energy and water usage and improve how this is relayed to consumer and suppliers. The Government plans to roll-out smart meters for electricity and gas to all households in Great Britain by the end of 2020. This examines the potential benefits and risks associated with smart metering of both water and energy.

Big and Open Data in Transport

July 2014 POSTnote 472

New ways to collect, manage and analyse vast quantities of data present opportunities to provide a more efficient transport system. This note examines factors affecting the growth of big data in transport and applications, focusing on road and public transport. It explores challenges to opening up, collecting, disseminating and using big data, and to sharing data whilst protecting users' privacy.

Biobanks

July 2014 POSTnote 473

Biobanks are repositories of biological samples, physical measurements. They correlate behavioural data for research, clinical practice or public health monitoring. Most biobanks are established to investigate the common determinants of mortality and morbidity. This updates POSTnote 180 and summarises biobank activity in the UK and the legal, ethical and practical issues.

Big Data and Public Health

July 2014 POSTnote 474

Patient health records and other large scale medical and administrative datasets are increasingly being considered as a valuable tool for the study and improvement of health. This examines the sources of data, their current and potential uses for health improvement, and the legal and practical issues raised by data use for public health or research purposes.

Alternative Currencies

August 2014 POSTnote 475

Alternative currencies are types of money or exchange that can be used instead of and alongside national currency. A number are used in the UK today. This outlines the different types and aims of these currencies. It also sets out how they are being used, and highlights regulatory and policy challenges regarding consumer protection, financial crime, taxation and benefits.

Environmental Citizen Science

August 2014 POSTnote 476

Environmental citizen science traditionally involves the public submitting sightings of wildlife to NGOs or record centres. Emerging technologies have recently broadened its use to all kinds of environmental data. This POSTnote summarises different types of citizen science projects, policy-relevant applications and the benefits and challenges of volunteer collected data.

Phosphate Resources

August 2014 POSTnote 477

World food security is dependent on phosphate fertilisers manufactured from finite deposits of phosphate ore. The majority of reserves are restricted to a limited number of countries, raising geopolitical risks. This POSTnote describes the uses of phosphate and summarises ways in which dependence on mineral reserves could be reduced.

CURRENT WORK

Biological Sciences – Minimum Age of Responsibility, GM Crops, Parity of Esteem between Physical and Mental Health

Environment and Energy – Short Lived Climate Pollutants, Biodiversity Auditing, Energy Storage, Floodplain Management, Reducing Greenhouse Gas Emissions from Agricultural Crops, GM Insects.

Physical sciences and IT – Unmanned Aerial Vehicles, Science Practicals in Schools, Broadband Internet Access, Innovation and the Future of the UK Economy.

Social Sciences – Palliative and end of life care.

CONFERENCES AND SEMINARS

Big Data Research Exhibition

On July 15th, POST hosted an interactive exhibition showcasing the latest developments in UK big data research. The term 'big data' typically describes large or complex datasets that cannot readily be stored and analysed using conventional computers and databases. This reception was produced in collaboration with Research Councils UK (RCUK) and included presentations from Adam Afriyie MP, Chair of POST; Francis Maude MP, Minister for the Cabinet Office; and Prof Rick Rylance, Chair of Research Councils UK. Following the talks, attendees explored exhibits on major UK big data projects and spoke to leading researchers about their work.

Science and Technology in Parliament

On 6th October, POST hosted a seminar on Science and Technology in Parliament. This event provided students from Science Communication Masters courses with an overview of the ways in which science and technology are used and communicated in Parliament. There were presentations from Chris Tyler, Director, POST; Sarah Hartwell-Naguib, Head of science and environment section, House of Commons Library; Christopher Clarke, Clerk of the House of Lords Science and Technology Committee and Stephen McGinness, Clerk of the House of Commons Science and Technology Committee, who all then joined a panel discussion.

STAFF, FELLOWS AND INTERNS AT POST

Fellows

Adriana De Palma, Natural History Museum, Biotechnology and Biological Sciences Research Council

Dr Anusha Panjwani, Pirbright Institute and Harvard University

Dr Chris Millard, Queen Mary, University of London, Wellcome Trust

Clare Wenham, University of Aberystwyth, Nuffield Council on Bioethics

Daniel Rathbone, Imperial College London, Engineering and Physical Sciences Research Council

Elizabeth Duxbury, University of East Anglia, Biotechnology and Biological Sciences Research Council

Helen Brewer, Rothamstead Research Centre, Biotechnology and Biological Sciences Research Council

Ian Keyte, University of Birmingham, Royal Society of Chemistry

Kimberley Pyle, University of Cardiff, Natural Environment Research Council

Lucy Anderson, University of Leeds, Biotechnology and Biological Sciences Research Council

Maria Thorpe, University of Manchester, Engineering and Physical Sciences Research Council

Mark Richardson, University of Reading, Natural Environment Research Council

Oscar Branson, University of Cambridge, Natural Environment Research Council

Paul Gilbert, University of Sussex, Economic and Social Research Council

Rachel Stocker, University of Durham, British Psychological Society

Rosalind Davies, University of Birmingham, Engineering and Physical Sciences Research Council

Rosanna Greenop, University of Southampton, Natural Environment Research Council

Stephen Hanley, University of Leeds, Economic and Social Research Council

Tom Ashfold, University of Oxford, Economic and Social Research Council

Interns

Dr Laura Childs, Imperial College Science Communication MSc

INTERNATIONAL ACTIVITIES

On September 10th-12th Dr Aaron Goater attended a PACITA conference in Prague to discuss 'Communication and Impact Strategies' with colleagues from the European Parliamentary Technology Assessment network.

Dr Chris Tyler, Director of POST, spoke at the inaugural international 'Science Advice in Governments' conference in Auckland. Organised by Sir Peter Gluckman, Chief Scientific Adviser to the Prime Minister of New Zealand, the conference brought together science advisers from over 60 countries. Dr Tyler highlighted the importance of legislatures in modern democracies, and argued that for science advice in governments to be most effective, attention must also be given to the need for quality scientific advice in parliaments.

Side meetings included focus on capacity building for scientific advice. In these meetings, Dr Tyler presented POST's work in African Parliaments, its UK Parliamentary Fellowship Programme, and training and induction programmes for parliamentary staff and new MPs.

HOUSE OF COMMONS LIBRARY SCIENCE AND ENVIRONMENT SECTION

Scientists and other staff in the Science and Environment Section provide confidential, bespoke briefing to Members and their offices on a daily basis. They also provide support to Commons Select Committees, and produce longer notes and research papers which can be accessed on line at http://www.parliament.uk/topics/topical-issues.htm

Summaries of recently updated briefings are opposite.

For further information contact:
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RECENT PUBLICATIONS

Assisted Suicide

SN04857

Under the Suicide Act 1961 it is an offence for one person to assist encourage or assist the suicide (or attempted suicide) of another. Suicide or attempted suicide are not in themselves criminal offences.

There have been several legal cases regarding the offence of assisted suicide, particularly in the context of disabled or terminally ill people who are unable to end their lives without assistance from family or friends. A recent Supreme Court judgement took the view that Parliament was the appropriate forum for considering changes to the law on this particular issue.

The House of Lords is considering the Assisted Dying Bill, a Private Member's Bill introduced by Lord Falconer of Thoroton. The Bill aims to enable competent adults who are terminally ill to request assistance with ending their life. There was consensus among those who spoke in the Second Reading debate – whether for or against the Bill – that Parliament needed properly to address the issue following the Supreme Court's judgment in Nicklinson and that the Bill should proceed to Committee for detailed consideration. The Bill was given its Second Reading without division. The Government has indicated that it considers this issue to be a matter of individual conscience.

Household Safety (Carbon Monoxide Detectors) Bill

SN06975

On 12 June 2014 Andrew Bingham secured fourteenth place in the Private Members' Bill ballot. He presented the *Household Safety (Carbon Monoxide Detectors) Bill* on 2 July; the debate on Second Reading was adjourned on 12 September.

The Bill would introduce a requirement that a functioning carbon monoxide detector must be installed in all newly built and all rented residential properties. This note provides information on the Bill's provisions and summarises the content of the Bill.

Infrastructure Bill: Planning Provisions

SN06909

The Queen's Speech on 4 June 2014 announced that an Infrastructure Bill would be introduced in the 2014-15 Parliamentary session. The Infrastructure Bill, HL Bill 2, was first introduced in the House of Lords. The committee stage started on 3 July and will continue on 14 October. This note explains the planning provisions in the Bill.

The Bill covers many areas, including: proposals to turn the Highways Agency into a Government-owned company; giving communities the right to buy a stake in a local renewable electricity scheme; and increasing the powers of the Land Registry. A number of planning reforms will increase efficiency in the planning system by:

- making changes to the procedures in the Planning Act 2008 for handling minor changes to existing development consent orders (DCOs) for nationally significant infrastructure projects (NSIPs). It would also simplify the processes for making significant changes;
- allowing the examining authority, (a panel of planning inspectors who consider DCO applications), to be appointed earlier on in the process, immediately after an application has been accepted;
- allowing the examining authority panel to comprise only two inspectors; and
- allowing certain types of planning conditions to be regarded as discharged if a local planning authority has not notified the applicant of their decision within a set time period.

This note focuses only on the planning-related provisions in the Bill. These provisions make amendments to the Planning Act 2008 and the Town and Country Planning Act 1990. The territorial extent has the same extent as the legislation to which it relates.

Common Agricultural Policy Reforms 2014-2020: Implementation Decisions in the UK

SN06929

Common Agricultural Policy reforms for 2014-2020 are now being implemented across the European Union. There is a considerable amount of flexibility for each Member State to implement the reforms in the way that best suits their own farming systems. The UK Government secured agreement that the devolved administrations should also have this flexibility. This means that a variety of implementation decisions have now been made or are being consulted upon across the UK.

This note was expedited for Estimates Day (7 July 2014) and currently concentrates on English decisions but provides comparisons with the devolved administrations. The paper will be further developed to provide a broader UK overview and further stakeholder comment on Library Research Paper 13/64 CAP implementation 2014-2020 in the UK and in Ireland (November 2013).

Carbon capture and storage
SN05086

This note has been updated following the publication of the Energy and Climate Change Committee's report on carbon capture and storage (CCS). CCS is a potential way of 'decarbonising' electricity generation, through capturing and storing the carbon dioxide (CO_2) produced. As a form of 'low-carbon' generation under the current Energy Bill, CCS would allow the continued burning of fossil fuels. However, the 'emissions performance standard' introduced by the Bill also allows unabated gas to 2045; some feel this is not set low enough to incentivise CCS.

CCS generation is not yet proven on a large scale, and nor is storage long-term, despite a series of UK Government and EU initiatives aimed at incentivising its development. In March 2013 Peterhead (Aberdeenshire) and the White Rose Project (Yorkshire) were named as the two preferred bidders in the latest UK CCS Commercialisation Programme Competition.

Badger Culling: Controlled Shooting Pilots
SN06837

This note has been updated to reflect the Government's publication of the Expert Panel's report and its response and future strategy (3 April 2014). The Secretary of State announced that the current two culls would be continued with amendments to improve effectiveness in the proportion of badgers killed, and the time taken for shot badgers to die. Further proposed culls would not be initiated until the methodology to improve this was in place. In July 2014 the Badger Trust was given leave for Judicial Review of the decision to continue the two pilots without independent monitoring.

ACTIVITIES

Since July the Section has produced debate packs, containing briefing and supporting press and parliamentary material, for debates on: CAP reform implementation; Public consent for local plans; Energy prices; Mitochondrial replacement techniques; Sale of puppies & kittens; Carbon tax and energy-intensive industries; Food fraud; and Research funding for and awareness of pancreatic cancer.

In September the Section welcomed Wendy Carr, a fellow from the Parliamentary Office of Science and Technology (POST), to begin a three month placement. Wendy is undertaking a PhD in pharmaceutical plant cleaning at Newcastle University. She will be researching Food Waste, as well as helping to answer Member enquiries.

The Section has continued its outreach to the academic world. Professor Tadj Oreszczyn, Director UCL Energy Institute and Professor of Energy and Environment, came to Parliament to give an overview of UCL Energy Institute's research programme and important results to date to specialists in the Library and also from Committees and POST.

Assistant Library Clerk, David Hirst, attended the POST and Research Councils UK (RCUK) interactive exhibition about the latest developments in UK Big Data research and met researchers using Met Office supercomputers to investigate meteorological phenomena (including extreme weather such as hurricanes) and historians who are data-mining archival texts.

Enquiry Executive, Jim Camp, attended a 'State of UK Nature' conference in September. Sir David Attenborough highlighted the decline of 60% native species in the UK. There were policy announcements from the Deputy Prime Minister which included a commitment to the full opening of the coastal path by 2020.

Team members posted blogs on the Library's 'Second Reading' blog, including on fracking and rural broadband. Library Clerk Oliver Bennett, currently on secondment in Burma, posted a blog about his experience advising on the establishment of a Burmese Parliamentary Research Service.

SELECTED DEBATES

Listed opposite (grouped by subject area) is a selection of Debates on matters of scientific interest which took place in the House of Commons, House of Lords or Westminster Hall between 26th June and 12th September 2014.

A full digest of debates and PQs on scientific issues during the 2013/14 and to date in the 2014/15 sessions of Parliament can be found at http://www.scienceinparliament.org.uk/publications/uk-digests/

AGRICULTURE AND FOOD

Agriculture and Food Industry	24.7.14	HoL 1340	Lord Plumb
Food Fraud	8.9.14	HoC 698	Roger Williams

HEALTH

Assisted Dying Bill - Second Reading	18.7.14	HoL 775	Lord Falconer of Thoroton
Clinical Technology Appraisals (NICE)	1.9.14	HoC 137	Eric Ollerenshaw
Global Health (Research and Development)	8.7.14	HoC 33WH	Andrew George
Medical Innovation Bill - Second Reading	27.6.14	HoL 1449	Lord Saatchi
Mitochondrial Replacement (Public Safety)	1.9.14	HoC 93	Fiona Bruce

TELECOMMUNICATIONS

Superfast Broadband (Urban Areas)	9.9.14	HoC 265WH	Mark Field

EDUCATION AND SKILLS

Adult Learning	3.9.14	HoC 111WH	Meg Hillier
Apprenticeships	26.6.14	HoL GC176	Lord Cormack
Skills and Training Facilities	1.7.14	HoC 183WH	Stephen McPartland
Technical and Vocational Education	9.7.14	HoC 356	Tristram Hunt
Ofsted (14 to 17-year-olds)	16.7.14	HoC 257WH	Graham Allen
Schools: Careers Guidance	23.7.14	HoL GC478	Baroness Sharp of Guildford

Science Directory

Research Councils UK

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Each year the Research Councils invest around £3 billion in research covering the full spectrum of academic disciplines from the medical and biological sciences to astronomy, physics, chemistry and engineering, social sciences, economics, environmental sciences and the arts and humanities.

Research Councils UK is the strategic partnerships of the seven Research Councils. It aims to:

- increase the collective visibility, leadership and influence of the Research Councils for the benefit of the UK;
- lead in shaping the overall portfolio of research funded by the Research Councils to maximise the excellence and impact of UK research, and help to ensure that the UK gets the best value for money from its investment;
- ensure joined-up operations between the Research Councils to achieve its goals and improve services to the communities it sponsors and works with.

Biotechnology and Biological Sciences Research Council (BBSRC)

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BBSRC invests in world-class bioscience research, innovation and training on behalf of the UK public. Our aim is to further scientific knowledge to promote economic growth, wealth and job creation and to improve quality of life in the UK and beyond. BBSRC research is helping society to meet major challenges, including food security, green energy and healthier lifespans and underpins important UK economic sectors, such as farming, food, industrial biotechnology and pharmaceuticals.

Economic and Social Research Council

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The ESRC is the UK's largest organisation for funding research on economic and social issues and is committed to supporting the very best research with wide-ranging impact. Social science contributes to greater knowledge and understanding of the many challenges our society faces today and by ensuring that ESRC-funded research makes the biggest possible impact, our research shapes public policies and makes business, voluntary bodies and other organisations more effective, as well as shaping wider society. We also develop and train the UK's future social scientists.

EPSRC

Pioneering research and skills

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EPSRC is the UK's main agency for funding research and training in engineering and physical sciences, investing around £800m a year in research and postgraduate training, to help the nation handle the next generation of technological change.

The areas covered range from information technology to structural engineering, and mathematics to materials science. This research forms the basis for future economic development in the UK and improvements for everyone's health, lifestyle and culture. EPSRC works alongside other Research Councils with responsibility for other areas of research.

Medical Research Council

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Over the past century, the MRC has been at the forefront of scientific discovery to improve human health. Founded in 1913 to tackle tuberculosis, the MRC now invests taxpayers' money in the highest quality medical research across every area of health. Twenty-nine MRC-funded researchers have won Nobel prizes in a wide range of disciplines, and MRC scientists have been behind such diverse discoveries as vitamins, the structure of DNA and the link between smoking and cancer, as well as achievements such as pioneering the use of randomised controlled trials, the invention of MRI scanning, and the development of therapeutic antibodies. We also work closely with the UK's Health Departments, the NHS, medical research charities and industry to ensure our research achieves maximum impact as well as being of excellent scientific quality.

Natural Environment Research Council

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NERC is the UK's leading public funder of environmental science. We invest £330 million each year in cutting-edge research, postgraduate training and innovation in universities and research centres.

Our scientists study the physical, chemical and biological processes on which our planet and life itself depends – from pole to pole, from the deep Earth and oceans to the atmosphere and space.

We partner with business, government, the public and the wider research community to shape the environmental research and innovation agenda. Our science provides knowledge, skills and technology that deliver sustainable economic growth and public wellbeing.

Science & Technology Facilities Council

Contact: Natalie Bealing
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The Science and Technology Facilities Council is one of Europe's largest multidisciplinary research organisations supporting scientists and engineers world-wide. The Research Council operates world-class, large-scale research facilities and provides strategic advice to the UK Government on their development. The STFC partners in two of the UK's Science and Innovation Campuses. It also manages international research projects in support of a broad cross-section of the UK research community, particularly in the fields of astronomy, nuclear physics and particle physics. The Council directs, co-ordinates and funds research, education and training.

Alzheimer's Research UK

Defeating Dementia

Contact: Dr Matt Norton
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Website:
http://www.alzheimersresearchuk.org/

Alzheimer's Research UK is the UK's leading dementia research charity. Currently, we support 130 projects worth over £21.5m. As research specialists, we fund pioneering research at leading universities across the UK and the globe with the aim of defeating dementia. Our expertise helps bring together leading dementia scientists to share ideas and understanding.

We work with people with dementia to reflect their concerns and firmly believe that science holds the key to defeating dementia.

Association of the British Pharmaceutical Industry

abpi

Bringing medicines to life

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Website: www.abpi.org.uk

The ABPI is the voice of the innovative pharmaceutical industry, working with Government, regulators and other stakeholders to promote a receptive environment for a strong and progressive industry in the UK, one capable of providing the best medicines to patients.

The ABPI's mission is to represent the pharmaceutical industry operating in the UK in a way that:

- assures patient access to the best available medicine;
- creates a favourable political and economic environment;
- encourages innovative research and development;
- affords fair commercial returns

AIRTO

airto

making innovation happen

Contact: Professor Richard Brook OBE FREng
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Website: www.airto.co.uk

AIRTO – Association of Innovation, Research & Technology Organisations – is the foremost membership body for organisations operating in the UK's innovation, research and technology sector. AIRTO's members deliver vital innovation and knowledge transfer services which include applied and collaborative R&D, (frequently in conjunction with universities), consultancy, technology validation and testing, incubation of commercialisation opportunities and early stage financing. AIRTO members have a combined turnover of over £5.5bn from clients both at home and outside the UK, and employ over 40,000 scientists, technologists and engineers.

AMPS

AMPS

The Association of Management and Professional Staffs.

Contact:
Tony Harding
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Website: www.amps-tradeunion.com

We are a Trades Union for Management and Professional Staff working in the pharmaceutical, chemical and allied industries.

We also have a section for Professional Divers working globally. We represent a broad base of both office and field based staff and use our influence to improve working conditions on behalf of our members.

We are experts in performance based and field related issues and are affiliated to our counterparts in EU Professional Management Unions.

Biochemical Society

Advancing Molecular Bioscience

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The Biochemical Society exists for the advancement of the molecular and cellular biosciences, both as an academic discipline and to promote its impact on areas of science including biotechnology, agriculture, and medicine. We achieve our mission though our publications and journals, scientific meetings, educational activities, policy work, awards and grants to scientists and students. The Biochemical Society is the largest discipline-based learned society in the biosciences with 6800 members.

The British Ecological Society

British Ecological Society

The British Ecological Society
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Ecology into Policy Blog
http://britishecologicalsociety.org/blog/
Twitter: @BESPolicy

The British Ecological Society's mission is to advance ecology and make it count. The Society has nearly 6,000 members worldwide. The BES publishes five internationally renowned scientific journals and organises the largest scientific meeting for ecologists in Europe. Through its grants, the BES also supports ecologists in developing countries and the provision of fieldwork in schools. The BES informs and advises Parliament and Government on ecological issues and welcomes requests for assistance from parliamentarians.

British In Vitro Diagnostics Association (BIVDA)

BIVDA

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www.bivda.co.uk

BIVDA is the UK industry association representing companies who manufacture and/or distribute the diagnostics tests and equipment to diagnose, monitor and manage disease largely through the NHS pathology services. Increasingly diagnostics are used outside the laboratory in community settings and also to identify those patients who would benefit from specific drug treatment particularly for cancer.

British Nutrition Foundation

BRITISH Nutrition FOUNDATION

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Email: postbox@nutrition.org.uk

Websites: www.nutrition.org.uk
www.foodafactoflife.org.uk

The British Nutrition Foundation (BNF) was established over 40 years ago and exists to deliver authoritative, evidence-based information on food and nutrition in the context of health and lifestyle. The Foundation's work is conducted and communicated through a unique blend of nutrition science, education and media activities.

BRITISH PHARMACOLOGICAL SOCIETY

BPS

Today's science, tomorrow's medicines

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The British Pharmacological Society is the primary UK learned society concerned with research into drugs and the way they work. Our 3000+ members work in academia, industry, regulatory agencies and the health services, and many are medically qualified. We cover the whole spectrum of pharmacology, including laboratory, clinical, and toxicological aspects. Enquiries about the discovery, development and application of drugs are welcome.

The British Psychological Society

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The British Psychological Society is an organisation of over 48,000 members governed by Royal Charter. It maintains the Register of Chartered Psychologists, publishes books, 11 primary science Journals and organises conferences. Requests for information about psychology and psychologists from parliamentarians are very welcome.

The British Society for Antimicrobial Chemotherapy

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www.bsac.org.uk | www.antibiotic-action.com
www.e-opat.com | www.nas-pps.com
|www.appg-on-antibiotics.com
www.bsacsurv.org

The BSAC is an inter-professional organisation with over forty years of experience and achievement in antibiotic education, research and leadership. The Society has an active international membership and:

- Is dedicated to saving lives through the effective use and development of antibiotics, now and in the future.
- Communicates effectively about antibiotics and antibiotic usage via workshops, professional guidelines and its own high impact international journal, the Journal of Antimicrobial Chemotherapy.
- Is home to the UK-led global initiative Antibiotic Action
- Serves as secretariat to the All Party Parliamentary Group on Antibiotics

British Society for immunology

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The BSI is one of the oldest, largest and most active immunology societies in the world. We have over 4,000 members who work in all areas of immunology, including research and clinical practice.

The BSI runs major scientific meetings, education programmes and events for all ages. We disseminate top quality scientific research through our journals and meetings and we are committed to bringing the wonders and achievements of immunology to as many audiences as possible.

Brunel University London

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Brunel University London is a leading international university which addresses the challenges facing society through ground-breaking applied research and educational programmes.

Our students are taught and prepared for their future careers in a supportive culture of excellence, enterprise and innovation. Our work changes the lives of people around the world bringing economic, social and cultural benefits.

We are committed to providing an intellectual environment that stretches our students and staff to ensure we are able to solve the challenges of society today.

Cavendish Laboratory

UNIVERSITY OF CAMBRIDGE

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The Cavendish Laboratory houses the Department of Physics of the University of Cambridge.

The research programme covers the breadth of contemporary physics

Extreme Universe: Astrophysics, cosmology and high energy physics

Quantum Universe: Cold atoms, condensed matter theory, scientific computing, quantum matter and semiconductor physics

Materials Universe: Optoelectronics, nanophotonics, detector physics, thin film magnetism, surface physics and the Winton programme for the physics of sustainability

Biological Universe: Physics of medicine, biological systems and soft matter

The Laboratory has world-wide collaborations with other universities and industry

Chartered Institute of Patent Attorneys

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Website: www.cipa.org.uk

Members of CIPA practise in intellectual property, especially patents, trade marks, designs, and copyright, either in private partnerships or industrial companies. It advises government and international circles on policy issues and provides information services, promoting the benefits to UK industry of obtaining IP protection, and to overseas industry of using British attorneys to obtain international protection.

Clifton Scientific Trust

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Science for Citizenship and Employability, Science for Life, Science for Real

We build grass-roots partnerships between school and the wider world of professional science and its applications

- for young people of all ages and abilities
- experiencing science as a creative, questioning, human activity
- bringing school science added meaning and notivation, from primary to post-16
- locally, nationally, internationally (currently between Britain and Japan; also the Ukraine)

Clifton Scientific Trust Ltd is registered charity 1086933

The Council for the Mathematical Sciences

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The Council for the Mathematical Sciences is an authoritative and objective body that works to develop, influence and respond to UK policy issues affecting mathematical sciences in higher education and research, and therefore the UK economy and society by:

- providing expert advice;
- engaging with government, funding agencies and other decision makers;
- raising public awareness; and
- facilitating communication between the mathematical sciences community and other stakeholders

Eli Lilly and Company Ltd

Lilly
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Lilly UK is the UK affiliate of a major American pharmaceutical manufacturer, Eli Lilly and Company of Indianapolis. This affiliate is one of the UK's top pharmaceutical companies with significant investment in science and technology including a neuroscience research and development centre and bulk biotechnology manufacturing operations.

Lilly medicines treat schizophrenia, diabetes, cancer, osteoporosis, attention deficit hyperactivity disorder, erectile dysfunction, depression, bipolar disorder, heart disease and many other diseases.

Energy Institute

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The Energy Institute (EI) is the chartered professional body for the energy sector, supporting over 19,000 individuals and 250 companies worldwide. The EI provides learning and networking opportunities, professional recognition and technical and scientific knowledge resources on energy in all its forms and applications.

The EI's purpose is to develop and disseminate knowledge, skills and good practice towards a safe, secure and sustainable energy system. It addresses the depth and breadth of the energy sector and informs policy by providing a platform for debate and scientifically-sound information.

A registered charity, the EI serves society with independence, professionalism and a wealth of expertise in all energy matters.

EngineeringUK

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EngineeringUK is an independent organisation that promotes the vital role of engineers, engineering and technology in our society. EngineeringUK partners business and industry, Government and the wider science and technology community: producing evidence on the state of engineering; sharing knowledge within engineering, and inspiring young people to choose a career in engineering, matching employers' demand for skills.

The Food & Environment Research Agency

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The Food and Environment Research Agency's overarching purpose is to support and develop a sustainable food chain, and a healthy natural environment.

Our role within that is to provide robust evidence, rigorous analysis and professional advice to Government, international organisations and the private sector.

GAMBICA Association Ltd

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GAMBICA Association is the UK trade association for instrumentation, control, automation and laboratory technology. The association seeks to promote the successful development of the industry and assist its member companies through a broad range of services, including technical policy and standards, commercial issues, market data and export services.

The Geological Society

The Geological Society
serving science & profession

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The Geological Society is the national learned and professional body for Earth sciences, with 11,000 Fellows (members) worldwide. The Fellowship encompasses those working in industry, academia and government, with a wide range of perspectives and views on policy-relevant science, and the Society is a leading communicator of this science to government bodies and other non-technical audiences.

Glass and Glazing Federation

GGF
Glass and Glazing Federation

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The GGF is the main representative organisation for companies involved in all aspects of the manufacture of flat glass and products and services for all types of glazing, in commercial and domestic sectors.

Members include companies that manufacture and install energy efficient windows, in homes and commercial buildings, the performance glass used in every type of building from houses to high-rise tower blocks and the components that are used to manufacture every type of glazing.

Institute of Food Science + Technology

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IFST is the independent qualifying body for food professionals in Europe. Membership is drawn from all over the world from backgrounds including industry, universities, government, research and development and food law enforcement.

IFST's activities focus on disseminating knowledge relating to food science and technology and promoting its application. Another important element of our work is to promote and uphold standards amongst food professionals.

Institute of Marine Engineering, Science and Technology (IMarEST)

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Established in London in 1889, the IMarEST is a leading international membership body and learned society for marine professionals, with over 15,000 members worldwide. The IMarEST has an extensive marine network of 50 international branches, affiliations with major marine societies around the world, representation on the key marine technical committees and non-governmental status at the International Maritime Organization (IMO) as well as other intergovernmental organisations.

Institute of Measurement and Control

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Reg Charity number: 269815

The Institute of Measurement and Control provides a forum for personal contact amongst practiioners, publishes learned papers and is a professional examining and qualifying organisation able to confer the titles EurIng, CEng, IEng, EngTech; Companies and Universities may apply to become Companions. Headquartered in London, the Institute has a strong regional base with 15 UK, 1 Hong Kong and 1 Malaysia Local Section, a bilateral agreement with the China Instrument Society and other major international links.

IOP Institute of Physics

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The Institute of Physics is a leading scientific society. We are a charitable organisation with a worldwide membership of more than 50,000, working together to advance physics education, research and application.

We engage with policymakers and the general public to develop awareness and understanding of the value of physics and, through IOP Publishing, we are world leaders in professional scientific communications.

In September 2013, we launched our first fundraising campaign. Our campaign, Opportunity Physics, offers you the chance to support the work that we do.

Visit us at www.iop.org, follow us @physicsnews

Institute of Physics and Engineering in Medicine

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IPEM is a registered, incorporated charity for the advancement, in the public interest, of physics and engineering applied to medicine and biology. It accredits medical physicists, clinical engineers and clinical technologists through its membership register, organises training and CPD for them, and provides opportunities for the dissemination of knowledge through publications and scientific meetings. IPEM is licensed by the Science Council to award CSci, RSci and RSciTech, and by the Engineering Council to award CEng, IEng and EngTech.

IChemE ADVANCING CHEMICAL ENGINEERING WORLDWIDE

The Institution of Chemical Engineers

With over 38,000 members in 120 countries, IChemE is the global membership organisation for chemical engineers. A not for profit organisation, we serve the public interest by building and sustaining an active professional community and promoting the development, understanding and application of chemical engineering worldwide.

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Kuala Lumpur | London | Melbourne | Rugby | Singapore | Wellington

Institution of Civil Engineers

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Representing over 80,000 professional civil engineers around the world, ICE actively contributes to the development of public policy at all levels of government in areas concerning infrastructure, engineering and our quality of life.

Established in 1818, ICE is recognised worldwide for its excellence as a centre of learning, as a qualifying body and as a public voice for the profession. Our members design, build and maintain the infrastructure that keeps our country running.

Under our Royal Charter, we have a duty to provide independent, expert advice on infrastructure issues for the benefit of the public and to serve wider society. We are seen by Parliament and industry alike as the authoritative voice of infrastructure.

Institution of Engineering Designers

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The only professional membership body solely for those working in engineering and technological product design. Engineering Council and Chartered Environmentalist registration for suitably qualified members. Membership includes experts on a wide range of engineering and product design disciplines, all of whom practise, manage or educate in design.

IET The Institution of Engineering and Technology

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The IET is a world leading professional organisation, sharing and advancing knowledge to promote science, engineering and technology across the world. Dating back to 1871, the IET has 150,000 members in 127 countries with offices in Europe, North America, and Asia-Pacific.

Institution of Mechanical Engineers

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The Institution provides politicians and civil servants with information, expertise and advice on a diverse range of subjects, focusing on manufacturing, energy, environment, transport and education policy. We regularly publish policy statements and host political briefings and policy events to establish a working relationship between the engineering profession and parliament.

LGC

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LGC is an international science-based company and market leader in the provision of analytical, forensic and diagnostic services and reference standards to customers in the public and private sectors.

Under the Government Chemist function, LGC fulfils specific statutory duties as the referee analyst and provides advice for Government and the wider analytical community on the implications of analytical chemistry for matters of policy, standards and regulation. LGC is also the UK's designated National Measurement Institute for chemical and biochemical analysis.

With headquarters in Teddington, South West London, LGC has 36 laboratories and centres across Europe and at sites in China, Brazil, India, South Africa and the US.

The Linnean Society of London

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The Linnean Society of London is a professional learned body which promotes natural history in all its branches, and was founded in 1788. The Society is particularly active in the areas of biodiversity, conservation and sustainability, supporting its mission through organising open scientific meetings and publishing peer-reviewed journals, as well as undertaking educational initiatives. The Society's Fellows have a considerable range of biological expertise that can be harnessed to inform and advise on scientific and public policy issues.

A Forum for Natural History

L'ORÉAL UK AND IRELAND

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L'Oréal employs more than 4,000 researchers world-wide and dedicates over €850 million each year to research and innovation in the field of healthy skin and hair. The company supports women in science research through the L'Oréal UNESCO For Women In Science Programme and engages young people with science through the L'Oréal Young Scientist Centre at the Royal Institution. L'Oréal also collaborates with a vast number of institutions in the UK and globally.

Marine Biological Association

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Since 1884 the Marine Biological Association has been delivering its mission *'to promote scientific research into all aspects of life in the sea, including the environment on which it depends, and to disseminate to the public the knowledge gained.'* The MBA represents its members in providing a clear independent voice to government on behalf of the marine biological community. It also has an extensive research programme and a long history as an expert provider of advice for the benefit of policy makers and wider society.

Met Office

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The Met Office doesn't just forecast the weather on television. Our forecasts and warnings protect UK communities and infrastructure from severe weather and environmental hazards every day – they save lives and money. Our Climate Programme delivers evidence to underpin Government policy. Our Mobile Meteorological Unit supports the Armed Forces around the world. We build capacity overseas in support of international development. All of this built on world-class environmental science.

National Physical Laboratory

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The National Physical Laboratory (NPL) is the United Kingdom's national measurement institute, an internationally respected and independent centre of excellence in research, development and knowledge transfer in measurement and materials science. For more than a century, NPL has developed and maintained the nation's primary measurement standards - the heart of an infrastructure designed to ensure accuracy, consistency and innovation in physical measurement.

Natural History Museum

The Science of Nature

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We maintain and develop the collections we care for and use them to promote the discovery, understanding, responsible use and enjoyment of the natural world.

We are part of the UK's science base as a major science infrastructure which is used by our scientists and others from across the UK and the globe working together to enhance knowledge on the diversity of the natural world.

Our value to society is vested in our research responses to challenges facing the natural world today, in engaging our visitors in the science of nature, in inspiring and training the next generation of scientists and in being a major cultural tourist destination.

NEF: The Innovation Institute

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The Innovation Institute aims to drive innovation and growth in science, technology and engineering to achieve growth, prosperity and wellbeing in the UK. Our partners, clients and stakeholders include:

- Businesses
- Education providers
- Government bodies

New Engineering Foundation, our charitable arm, focusses on SciTech skills development. NEF work in vocational training and further education is supported by a Panel drawn from key industries.

Our Institute of Innovation and Knowledge Exchange is a professional body and a "do tank", led by the Innovation Council to support the role of innovation in society.

Nesta

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Nesta is the UK's innovation foundation with a mission to help people and organisations bring great ideas to life. We do this by providing investments and grants and mobilising research, networks and skills.

Nesta doesn't work alone. We rely on the strength of the partnerships we form with other innovators, community organisations, educators and investors too.

We are an independent charity and our work is enabled by an endowment from the National Lottery.

Nesta is a registered charity in England and Wales with a company number 7706036 and charity number 1144091. Registered as a charity in Scotland number SC042833. Registered office: 1 Plough Place, London, EC4A 1DE.

www.nesta.org.uk

THE UNIVERSITY OF NORTHAMPTON

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The University of Northampton is a Top 50 UK University*. We are committed to science education through initial teacher training, a STEM Ambassador network which works within the community and teaching and research to doctoral level. We are only UK University with Ashoka U 'Changemaker Campus' status recognising our commitment to social innovation and entrepreneurship.

(*Guardian University Guide 2015)

The University of Nottingham

UNITED KINGDOM • CHINA • MALAYSIA

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With 43,000 students and campuses in Nottingham, China and Malaysia, The University of Nottingham is 'the nearest Britain has to a truly global university.' With more than 90 per cent of all research of international quality according to the most recent Research Assessment Exercise, the University is ranked in the World's Top 75 universities by the QS World University Rankings.

PHARMAQ Ltd

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PHARMAQ is the only global pharmaceutical company with a primary focus on aquaculture. Our mission is to provide environmentally sound, safe and efficacious health products to the global aquaculture industry through targeted research and the commitment of dedicated people. We have a product portfolio that includes over 20 fish vaccines along with specialist feed additives, anaesthetics, antibiotics, sea lice treatments and biocide disinfectants. Through our sister company, PHARMAQ Analytiq, we also offer a range of diagnostics services that can be used to help safeguard fish welfare and improve productivity.

The Physiological Society

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Physiology is the science of how molecules, cells and organs work in the body. Representing over 3000 life scientists, The Physiological Society supports scientific research through its grants schemes, conferences and its three open access journals.

The Society also supports the teaching of physiology in schools and universities, and works to promote an understanding of physiology amongst policy-makers and the general public.

Prospect

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Prospect is an independent, thriving and forward-looking trade union with 117,000 members across the private and public sectors and a diverse range of occupations. We represent scientists, technologists and other professions in the civil service, research councils and private sector.

Prospect's collective voice champions the interests of the engineering and scientific community to key opinion-formers and policy makers. With negotiating rights with over 300 employers, we seek to secure a better life at work by putting members' pay, conditions and careers first.

ROYAL ACADEMY OF ENGINEERING

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As the UK's national academy for engineering, we bring together the most successful and talented engineers for a shared purpose: to advance and promote excellence in engineering. We have four strategic challenges: drive faster and more balanced economic growth; foster better education and skills; lead the profession; and promote engineering at the heart of society.

Royal Botanic Gardens, Kew

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RBG Kew is a centre of global scientific expertise in plant and fungal diversity, conservation, and sustainable use, housed in two world-class gardens. Kew is a non-departmental public body with exempt charitable status and receives approximately half its funding from government through Defra. The key strategic priorities of Kew's science programme are to:

- understand and conserve biodiversity
- accelerate discovery and global access to plant and fungal diversity information
- map and prioritise species and habitats most at risk
- promote sustainable local use of plants and fungi
- collect and store seed from 25% of plant species through the Millennium Seed Bank Partnership
- restore and repair habitats
- inspire interest in plant and fungal science and conservation

Kew's mission is to inspire and deliver science-based plant conservation worldwide, enhancing the quality of life.

The Royal Institution Science Lives Here

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www.richannel.org
Twitter: ri_science

The Royal Institution (Ri) has been at the forefront of public engagement with science for over 200 years and our purpose is to encourage people to think further about the wonders of science. We run public events and the famous CHRISTMAS LECTURES®, a national programme of Masterclasses for young people in mathematics, engineering and computer science, educational activities at the L'Oréal Young Scientist Centre and policy discussions with science students. And through the Ri Channel we share the stories behind cutting-edge science with people around the world.

The Royal Society

THE ROYAL SOCIETY

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The Royal Society is the UK academy of science comprising 1400 outstanding individuals representing the sciences, engineering and medicine. It has had a hand in some of the most innovative and life-changing discoveries in scientific history. Through its Fellowship and permanent staff, it seeks to ensure that its contribution to shaping the future of science in the UK and beyond has a deep and enduring impact.

ROYAL SOCIETY OF CHEMISTRY

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The Royal Society of Chemistry is the world's leading chemistry community, advancing excellence in the chemical sciences. With 48,000 members and a knowledge business that spans the globe, we are the UK's professional body for chemical scientists; a not-for-profit organisation with 170 years of history and an international vision of the future. We promote, support and celebrate chemistry. We work to shape the future of the chemical sciences – for the benefit of science and humanity.

Society for Applied Microbiology

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*Sf*AM is a UK organization, serving microbiologists internationally. It works to advance, for the benefit of the public, the science of microbiology in its application to the environment, human and animal health, agriculture, and industry. With Wiley-Blackwell, *Sf*AM publishes five internationally acclaimed journals. Value for money and a modern, innovative and progressive outlook are its core principles. A friendly society, *Sf*AM values integrity, honesty, and respect, and seeks to promote excellence and professionalism and to inspire young microbiologists.

Society for General Microbiology

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The Society for General Microbiology is the largest learned microbiological society in Europe with a worldwide membership based in universities, industry, hospitals, research institutes and schools. The Society publishes key academic journals, organises international scientific conferences and provides an international forum for communication among microbiologists. The Society promotes the understanding of microbiology to a diverse range of stakeholders, including policy-makers, students, teachers, journalists and the wider public, through a comprehensive framework of communication activities and resources.

Society of Biology

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The Society of Biology is a single unified voice, representing a diverse membership of individuals, learned societies and other organisations. We are committed to ensuring that we provide Government and other policy makers – including funders of biological education and research – with a distinct point of access to authoritative, independent, and evidence-based opinion, representative of the widest range of bioscience disciplines. Our vision is of a world that understands the true value of biology and how it can contribute to improving life for all.

SCI

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SCI is an inclusive, multi-disciplinary forum connecting scientists and business people to advance the commercial application of chemistry and related sciences for public benefit. SCI is open to all to join and share information, ideas, innovations and research. Members can network with specialists from sectors as diverse as food and bio-renewables, water, waste and environment, energy, materials, manufacturing and health.

Society of Cosmetic Scientists

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Website: www.scs.org.uk

Advancing the science of cosmetics is the primary objective of the SCS. Cosmetic science covers a wide range of disciplines from organic and physical chemistry to biology and photo-biology, dermatology, microbiology, physical sciences and psychology.

Members are scientists and the SCS helps them progress their careers and the science of cosmetics ethically and responsibly. Services include publications, educational courses and scientific meetings.

Society of Maritime Industries

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The Society of Maritime Industries is the voice of the UK's maritime engineering and business sector promoting and supporting companies which design, build, refit and modernise ships, and supply equipment and services for all types of commercial and naval ships, ports and terminals infrastructure, offshore oil & gas, maritime security & safety, marine science and technology and marine renewable energy.

STEMNET

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Website: www.stemnet.org.uk

STEMNET is an independent charity which enables young people to meet inspiring role models, understand real world applications of STEM and experience practical activities that bring learning and career opportunities to life. We do this through three core programmes:

- STEM Ambassadors - We run the UK network of STEM Ambassadors: over 27,000 inspiring volunteers
- STEM Clubs Programme - We provide free, expert advice and support to all schools which have set up or plan to develop a STEM Club
- Schools' STEM Advisory Network (SSAN) - We deliver free impartial advice to teachers and use our business links and partnerships to enhance the STEM curriculum in secondary schools in the UK

Universities Federation for Animal Welfare

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Website: www.ufaw.org.uk
Registered in England Charity No: 207996

UFAW, the international animal welfare science society, is an independent scientific and educational charity. It works to improve animal lives by:

- supporting animal welfare research
- educating and raising awareness of welfare issues in the UK and overseas
- producing the quarterly scientific journal Animal Welfare and other high-quality publications on animal care and welfare
- providing advice to government departments and other concerned bodies.

The Welding Institute

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The Welding Institute is the leading institution providing engineering solutions and knowledge transfer in all aspects of manufacturing, fabrication and whole-life integrity management.

Industrial membership provides access to innovative problem-solving from one of the world's foremost independent research and technology organisations.

Non-Corporate services include membership and registration, education, training and certification for internationally recognised professional development and personnel competence assurance.

TWI provides Members and stakeholders with authoritative and impartial expert advice, knowhow and safety assurance through engineering, materials and joining technologies.

SCIENCE DIARY

British Science Association 2014 Sir Walter Bodmer Award

Dr Anne-Maria Brennan has been awarded the British Science Association 2014 Sir Walter Bodmer Award. Dr Brennan, Principal Lecturer in Bioscience and Forensic Biology at London South Bank University, and representative of the Foundation for Science, Technology and Civilisation, was this year's winner of the award because of her passion and commitment to the work of the Association and her work in the area of the public engagement with science. She is seen here receiving the award from Sir Walter Bodmer at the recent British Science Festival.

THE PARLIAMENTARY AND SCIENTIFIC COMMITTEE

Tel: 020 7222 7085
annabel.lloyd@parliament.uk

Tuesday 21 October 17.30
Does The UK have the Infrastructure it needs?
Speakers: Nick Baveystock, Director General, Institution of Civil Engineers, Charlotte Holloway, Head of Policy, techUK

Monday 3 November 13.00-15.00
with EngineeringUK
Big Bang @ Parliament

Tuesday 11 November
75th Anniversary Reception at Buckingham Palace

Tuesday 18 November 08.30
Energy Storage

Wednesday 26 November
Annual Luncheon

Tuesday 9 December 17.30
Dementia

THE ROYAL SOCIETY

The Royal Society hosts a series of free events, including evening lectures and conferences, covering the whole breadth of science, engineering and technology for public, policy and scientific audiences.

Details of all events can be found at www.royalsociety.org/events

THE ROYAL INSTITUTION

Details of future events can be found at www.rigb.org

Booking is essential. For more information and to book visit www.rigb.org

There is a charge for tickets. Members go free.

PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY

For details of events organised by POST visit

http://www.parliament.uk/mps-lords-and-offices/offices/bicameral/post/post-events/

THE INSTITUTION OF MECHANICAL ENGINEERS

For details of events visit: www.imeche.org/events

THE LINNEAN SOCIETY OF LONDON

For details visit: www.linnean.org

More information on P&SC members' events can be found at: www.scienceinparliament.org.uk/members-news

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Clinical Virology Network

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Infection Prevention Society

Welsh Microbiological Association

The Children's HIV Association

British HIV Association

British Society for Medical Mycology

British Paediatric Allergy, Immunology & Infection Group

Central Sterilising Club

Public Health Medicine Environmental Group

Royal Society for Public Health

The Royal Society of Tropical Medicine and Hygiene

The Royal Pharmaceutical Society

The British Society for Antimicrobial Chemotherapy

www.bsac.org

ANTIBIOTIC ACTION

www.antibiotic-action.com

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