Shaping the Future

30 years of science and engineering

CaSE
Campaign for Science and Engineering

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Foreword

Dr Sarah Main
Executive Director
Campaign for Science and Engineering

I believe that science, politics and society are intertwined. I admit, I didn't feel the hand of politics in my work at the bench when I was a cancer researcher, but I noticed its effects. What a scientist will devote their life to, what a person believes is worth their support, and what a politician will stand and speak for all has an effect on what gets done.

The Campaign for Science and Engineering provides a voice for science in politics. In celebrating our 30th anniversary, I want to think about the role of science and engineering in society over the next 30 years and ask what questions that raises for us as a scientific community, a Government and a society today.

The authors of these articles have all tackled the opportunities and challenges ahead, the progress we might reasonably expect, and the implications for us today.

I thank all the authors for rising to this challenge and I hope the broad spectrum of views offered raises questions in your mind and prompts a few conversations.

A word from our sponsor

Ron Mobed
Chief Executive of Elsevier

I'm proud to be a part of CaSE's 30th anniversary celebrations. It's an organization that has campaigned for three decades to drive better funding, better policies, and greater diversity for STEM. It's an organization that drives innovation. As an engineer, I've seen first-hand the power of innovation to transform industries, countries, and people's lives.

The UK has a vital role to play in driving innovation in the global research landscape. It is, for example, one of the most productive countries in the world relative to its R&D spend. CaSE's has helped create the environment that allows that to happen. As we face technological changes and shifting political landscapes, the benefits of an organization that places science and engineering high on the political agenda, and makes the case for the transformative qualities of innovation, are clearer than ever. CaSE has helped drive 30 years of STEM excellence in the UK. We will all need them to drive 30 more.

Cooperation; the answer to the perfect landing on Mars

Dr Ellen Stofan
NASA Chief Scientist

Over the next several decades, space agencies from around the world will focus on how to use technology to answer fundamental questions such as: How did the universe form? How do the planets of our solar system help us to better understand processes at work on Earth? And – are we alone?

One of the most important areas for which the global space community is using technology is Earth Science. Working together, we are using space observations to better understand how our climate is changing. Over the next several decades we will use these data to make countries more resilient to the effects of climate change. This matters, because we know that Earth's changing climate will continue to affect our planet, even as we reduce our carbon emissions. Information is power, so we're helping countries to adapt agriculture practices to changing weather and climate patterns, plan for rising sea levels and increased storm surge, and prepare and recover from extreme weather events.

At NASA, we are expanding our reach and working with local and regional leaders to improve awareness, increase understanding, and provide access to climate data so that resilience planning can begin at local levels. We are also involving the general public. Our longstanding open data policy, for example, provides access to NASA's extensive collection of Earth observation data.

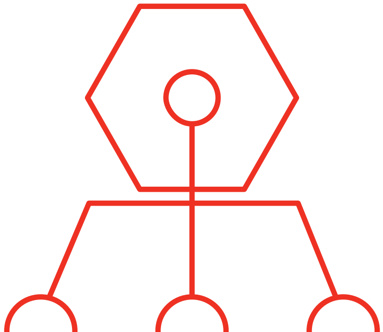
In the United States, we are on a journey to Mars that will send human beings to the Red Planet in the 2030s. Since the launch of our Viking missions in 1975, NASA has been sending orbiters and landers to study Mars – often in partnership with space agencies from around the world – discovering that Mars once had conditions that would have been suitable for the evolution of life. The robotic explorers have laid a great foundation; now it's time to extend our human presence into the solar system to explore Mars and look for evidence of past life.

Learning about Mars can teach us about life elsewhere in the cosmos, about how life began on Earth, and the very nature of life itself. Sending humans to Mars is also an investment in the global economy, as we push technology to turn science fiction into science fact.

Sending humans to Mars is not easy. However, with the right partnerships and a continual emphasis on innovation and technology development, it is achievable. As an international community, we are utilizing the International Space Station to conduct microgravity research for testing of new life support and crew systems, advanced habitat modules, and other technology needed for this long journey. Simultaneously, development is underway for our transportation to the Red Planet. The Space Launch System will be the most powerful rocket in the world, and the Orion crewed spacecraft is being designed with long-duration spaceflight at the forefront. We will go to Mars as an international space community, utilizing public-private partnerships, because no one country can achieve such an audacious goal alone.

An overarching theme for science and technology for the next several decades is cooperation – nations from around the world tapping into one another's talents to push the boundaries of science and technology. To do this as a global community, we need to have a diverse team of scientists and engineers from all of our population.

The first crew that lands on Mars will represent the best talents of Earth – women and men who are ready to boldly explore a new frontier.



DNAvigate a hitchhiker’s guide to DNA

Hayley Andrews
Biology Teacher at
the Judd School, Kent

In 1665, Robert Hooke first coined the term ‘cell’ in his world changing publication ‘Micrographia’. It was nearly three hundred years later when Watson and Crick discovered the structure of DNA. Then within only twenty-five years, we were able to cut DNA out of a mammalian cell and insert it into a bacterium, ultimately revolutionising the treatment of diabetes. This was only the beginning. By the turn of the last century, science continued to accelerate; we had mapped the entire human genome and I was about to have my fourth child.

The latter two events are significantly linked for me; by the time I had decided my brood were old enough for me to go back to work (starting teacher training) I was entering a world where these Nobel-winning bacterial experiments were now happening in A-level classrooms, and suddenly the subject I knew and loved had left me just a little behind.

Not one to be put off, I went on a course to upgrade my subject knowledge and began to realise that if this area of science had accelerated away from me – a biologist, it must be baffling to the general public. I could also see how important to our lives the advancements in this field were and that everyone should be informed enough to have an opinion on it.

Another revelation was that A-level specifications were not keeping up with exponential developments in biotechnology, and that areas I knew would be of interest to my very-able students didn't get a mention! I was concerned that students might be setting out on career paths completely unaware of blossoming new areas and unprepared to approach them. And yet the students at my school were lucky because we already had amazing biotech equipment.

And so DNAvigate was born. This was the project proposed to the Rolls-Royce Science Prize (RRSP) competition whereby local schools and the general public were invited into our labs for the evening to time travel through a series of ten stations, each depicting a pivotal part of DNA history with a practical activity (from Hooke, through Darwin, Mendel, Franklin, Jefferies and up to the future). Our Year 13 students became the teachers and were able to break away from the constraints of their A level course.

Our hard work paid off, and we won, and now we have seen the future. A future which heavily features synthetic biology, an emergent field which could well hold the answers to many of the world's problems, including disease, climate change and food/fuel shortages. Through the project we became aware of the international competition in this field, iGEM (the international Genetically Engineered Machine). iGEM started as a collegiate competition 12 years ago and came down to high school level 5 years ago but there are presently no UK (school) entries.

We need to be in the game; and so the next phase commences. I am heading off to Boston to judge at this years' iGEM Jamboree and on my return, the Judd School will begin readying a team for next year. Continuing the altruistic nature of DNAvigate and very much in the spirit of iGEM, we aim to make the path smoother for other UK schools to follow.

Lord Willetts
Chair of the British Science Association

The role of science and engineering in shaping the future

I congratulate the campaign of science and engineering on everything it has achieved since its foundation thirty years ago. That was a low point for British science, since when there has been a transformation. There is far greater recognition than there was then of the fundamental importance of science. Science and engineering is of course worthwhile in its own right but it is of growing economic significance too. And whilst budgets could always be bigger there is welcome understanding across Whitehall and Westminster and more widely of the importance of backing science.

What are the challenges of the next thirty years? First of course is Brexit. The messy process of disengaging from the EU, and creating a new relationship with it, is going to take years if not decades. This is the biggest single worry facing British science today and the challenge is to keep us part of the networks which link scientists across national boundaries. That means trying to remain within Horizon 2020 and its successors. It means ensuring there is continuing ease of movement for researchers across European boundaries.
It also means it is ever more important that Britain continues to play a leading role in the range of inter-governmental organisations responsible for science and technology.
I boosted our commitment to the European Space Agency, which provided Tim Peake with his mission and now has

a base in Harwell: next we should extend our role even further. The European Molecular Biology Laboratory has the excellent European Bioinformatics Institute at Hinxton outside Cambridge: could that be enhanced? We should make the most of the opportunity of leading the Square Kilometer Array project. Other such opportunities will doubtless come up over the years ahead: we must always be ready to seize them.

The pessimists fear that Brexit, combined with the rise of China, could mean that after decades of advance we will see this year as a turning point with relative decline from now on. But that is not inevitable. Just as this campaign brought hope thirty years ago it can do so again now. We still have the advantages of rigorous, transparent and meritocratic science in an open society. We have unprecedented levels of popular engagement in citizen science. Young researchers appreciate the opportunity to develop their own research programmes without having to wait for decades as the under-study to an all-powerful professor. These are all advantages which can be harnessed. It should lead us to work even harder to remain internationally engaged and to provide opportunities for talented younger researchers.

Brexit must also not divert us from a second, equally significant, long-term challenge. This is the difficulty of incorporating new science and technology into society in ways that do not undermine our values. This is where engineering and technology, the application of science, encounter the Humanities. As we look to the programming of robotic systems, or our ability to manipulate our own genes and to engineer new organisms, there is a danger that science is once more seen as a threat to human values. We can avoid this danger, but it will take hard work. The campaign for science and technology is most effective when it recognises that science and technology do not have all the answers and must be placed at the service of humanity. Just because something is technically possible does not mean it should be done. It makes it as important as ever to bridge the gap between what CP Snow called the two cultures.

There are other challenges too. The non-reproducibility of results is a growing issue in the sciences. We still need to go further in shifting attitudes towards welcoming diversity in staff as a source of strength. But I am always impressed by the resourcefulness and verve of our community of scientists and engineers and believe that they can rise to these challenges. And I hope they can do so knowing that they have the support and good will of policy-makers in Westminster and Whitehall.

Understanding the future: is public perception and comprehension keeping pace with science?

Quentin Cooper
Communicator and presenter

Happy 30th CaSE. It's not much of an age, yet in that time think how much of the fabric of our everyday lives has been replaced and rewoven. It's almost harder to point to what hasn't changed than what has. Science, technology and engineering – we'll call it science and engineering to keep CaSE happy – have driven the bulk of those changes. But even as we're all swept along in this endless revolution, how much of a shift has there been in attitudes to science and engineering: in general awareness and appreciation of all that's been achieved?

As researchers themselves are fond of saying in their papers, "the findings are inconclusive". Usually before adding, in a thinly disguised attempt to solicit additional funding, "further research is necessary". So let's examine the data and see if we are making quantum leaps in the right direction. Although only fair to mention that whereas the media, politicians and other technobabblers use "quantum leaps" to mean something big and purposeful, for physicists – who coined the term – they are something infinitesimally tiny and random.

Certainly there are positive signs. The quantity and quality of science programmes on TV and radio is far greater than it was even a couple of decades ago. And the roster of television science faces who look more or less like television science faces always have looked (Robert Winston, Michael Mosley, Mark Miodownik et al.) have been enhanced by others who are equally capable but confound those old stereotypes (Alice Roberts, Jim Al Khalili, Hannah Fry etc.), trading in a little of the grey hair and gravitas of their predecessors for snazzier wardrobes and unalloyed joy at tangling with what makes our universe tick.

Just as significantly – in terms of reaching mainstream audiences – there are also familiar figures like Richard Hammond, James May and Heston Blumenthal making programmes which contain a fair amount of scientific details and ideas but which avoid being boxed and labelled as “about science”. In crude terms, the positive is that viewers get informed and entertained, the negative is that many will not register it as being scientific unless it gets baffling or boring so any negative attitudes towards science are likely to remain unchanged. It’s one of the challenges across all media that audiences find a huge range of scientific stories and issues engaging and engrossing only so long as they don’t think of them as such. They like what science covers, they dislike science on the cover.

That said, there is no danger of media science disappearing into a black hole. There will always be room for stories about dinosaurs, cavemen, space exploration, amazing new gadgets, grotesque medical conditions and the other aspects of science that are conceptually straightforward with little need for explanation and lots of opportunities for pictures. Is that enough though? Go back to those monumental changes science and engineering have made to our lives and lifestyles in the 30 years since CaSE started campaigning. Around the clock and across all sorts of different fields, science is constantly nudging us into the future – adding to and altering our thinking about every aspect of existence from sub-atomic particles to solving the energy crisis, from brewing better beer to building better mousetraps. If we lack the basic knowledge to relate to those advances then they are shifting us into a future we increasingly feel unable to comprehend or control. Good science journalism enables us to bridge that gap. So does CaSE making their case. Neither can transform everyone into instant experts or even guarantee any more than rudimentary understanding – but both can stretch imaginations, help limit fear and distrust, and allow individuals and society to make more informed decisions about what we want, and don’t want, from science over the next 30 years and beyond.

Engineering our future: creating a world that works for everyone

Doug Harper
Chief Executive of Engineers without Borders UK

Close your eyes for a moment and think about the first ninety minutes after you wake up each day. You may be woken by the alarm on your smartphone, switch on your bedside lamp, listen to the news on the radio or watch it on tv. Perhaps catch up with your emails and social media. Then you might boil some water for a cup of coffee before leaving home to get to school, work or university by car, bus, bike or train.

Each of these activities relies on engineering. Electronic engineers have designed the hardware inside your phone, lamp, radio, tv and kettle. Software engineers have written the programs to make them work. Civil engineers have designed the pipework and water treatment plants that deliver drinkable water to your tap. Mechanical engineers have designed the engines and moving parts in your car or bike. Structural engineers have made sure that your house won't fall down during the night. Engineering is already all around us.

If we think more broadly, and consider the wider challenges facing society today, such as the effects of climate change, urbanisation, population growth and resource depletion, there is no political issue or policy decision that will not rely on the creative logic and technical capacity of an engineer to implement it. When we consider how engineering might shape our collective future we actually face a stark reality – our collective future relies on the proper application of engineering.

We live in a world which, for many, provides a better lifestyle than at any point in history. However, around 1 in 7 of our global community wake up each day with no reliable access to electricity, safe water to drink, or proper sanitation. As the world's population expands, and the UN projects that by 2050 we will have to make space for an additional 2.2 billion people, these challenges will affect many more of us. We will need to come up with increasingly intelligent and ingenious ways to make the only planet we have work for everyone. Engineers will be fundamental to our response.

And yet the engineering profession faces many challenges. There is a chronic shortage of people choosing engineering careers and, for those that do, they enter a community where diversity is poor. Women account for, at most, 9% of engineering and technology employees and 94% of engineers working in the UK are white. There is also a disconnect between what the public perceives engineering to be – 'building and fixing things' – compared to its true potential for creativity, innovation and social good.

Identifying solutions to these challenges is straightforward. Firstly, we need an engineering profession that represents society. That means inspiring more women and more people from diverse backgrounds to choose a career in engineering. Secondly, we need to challenge the wider perception of engineering and create a strong connection between the realities of an engineering career and the key motivational factors of those entering the workplace which, for 60% of millennials, includes believing in the purpose of their work.

Implementing these solutions is more difficult but engaging young people is essential. Young people should not only be our greatest motivation for pursuing a dream of a better future but also key to making it happen.

Whether you're reading this as an engineer, or a scientist, or a parent, grandparent, godparent, brother, sister, or friend, remember tomorrow, during those first ninety minutes after you wake up, how much we rely on engineers. Remember too, those of us without electricity, water, and homes and how much we all need engineers. Finally, remember that engineering isn't just about 'building and fixing' things but about creating a world that works for everyone. And then go and tell someone younger than you about all of this and encourage them to become an engineer.

In 1986…

0

websites online (1 in 1991)

18 years old

average life expectancy with cystic fibrosis (1980s)

1

female physics professor in the UK

7%

ten year survival rate for leukaemia (1971)

$4300

cost of a laptop

$3000

cost per kilobase of DNA sequence

UK gross domestic R&D expenditure

2.03%

of GDP

In 2016...

1,085,635,766

websites online

41 years old

average life expectancy
with cystic fibrosis

90

female physics professors in the UK

46%

ten year survival
rate for leukaemia
(2010–11)

$500

cost of a laptop

$1

cost per kilobase
of DNA sequence

UK gross domestic
R&D expenditure

1.67%

of GDP (2014)

Professor Anthony Finkelstein CBE FREng
Chief Scientific Advisor for National Security to HM Government

Science and technology in security and defence

There are people who want to hurt us: to kill and maim in the name of perverted ideologies. There are organised groups and hostile nation states, with contempt for our democratic processes and systems of laws, who threaten our security, and those of our allies. Though we would wish otherwise, these threats are unlikely to abate, although their form changes in ways that are difficult to predict. They are part of our future. Science and engineering have a critical role to play in mitigating threats and in protecting us from harm. They contribute to our ability actively to defend ourselves and to prevail in a conflict.

Much conflict is now what is known as 'asymmetric'. The adversaries possess an advantage in tactical flexibility and the ability to undertake actions that we would not contemplate for political and ethical reasons. We possess the ability to harness resources, economic and technological, beyond their reach. The balance of these two countervailing factors determines the outcome of the conflict. To date, our access to better science and engineering, confers a significant strategic advantage.

We cannot however rely upon this situation persisting. Our adversaries also have access to advanced science and engineering. There is less dependence on expensive facilities, information and software for analysis are widely accessible, components are sourced from global supply chains or can be locally synthesised. Formerly, the advanced capabilities of Governments and a sophisticated network of suppliers, supported by major investment, were necessary to deliver security and defence systems. Adversaries are however, increasingly able to leverage a multi-billion dollar commercial research and development base to secure capabilities hitherto beyond their reach. The challenge is thus, to ensure that science and engineering remains an advantage to the security and defence of the UK and its allies.

Meeting the challenge will necessitate methodological changes in security and defence science but also developing a sophisticated agenda. The science and engineering that will be critical covers a wide range: materials science, electronics, computing, chemistry and physics, are prominent amongst them. It is risky to call any to special attention, nevertheless I will tentatively identify some key areas, recognising that they reflect my biases.

Networked computing systems constitute an important domain in which threats are made manifest and act as a vector by which threats are communicated and amplified. We must be able to defend the software and computing infrastructure on which we depend and we must be able to respond proportionately to the threats posed to it. This requires significant advances in computer science and software engineering.

The ability to analyse and to make predictions based on 'big' data is a critical tool for identifying threats and threat actors. It is also, of course, itself a threat when deployed against us. This is the domain of the nascent discipline of data science. We are only at the early stages of this endeavour.

Behavioural science is 'coming of age'. The ability to harness the insights from psychology and neuroscience to decision making is developing with great rapidity. Behavioural insight and the methods of behaviour change have great promise for application in security and defence.

Novel sensors based on advances in quantum technologies have widespread potential. These are in their theoretical and experimental infancy however, we may be nearing early 'proofs of concept' in a number of areas with significant opportunities for use in security and defence settings.

In the final analysis, of course, the greatest contribution science and engineering can make to our security and defence are the values of openness, the pursuit of truth and the community of scholarship and learning.

The importance of diversity for innovation

Professor Dame Athene Donald
Professor of Experimental Physics and Master of Churchill College, Cambridge University

The UK is a world leader in science and innovation. This must mean that we are good at finding the 'best' people to put in the jobs that matter, doesn't it? Wrong. We don't necessarily manage that at all well. The diversity of our workforce does not reflect the make-up of our population. Potential stars are being squeezed out for reasons not necessarily connected with their abilities.

It starts at school. Whereas only around 25% of students taking psychology A level are boys, for physics the proportions are reversed, and computing sees a staggering 90% of the A level entrants being male. Whatever you may believe about whether girls 'like' physics less than boys, the fact that far more girls are likely to progress to physics A level if they come from a girls-only school suggests to me that the issues reside as much in a particular's school ethos as in the girls themselves.

The problems are not of course just restricted to gender. The differences in attainment at university for BME's (Black and minority ethnics) are well-attested, with (crudely and ignoring the differences between the different ethnic groups) more than a 15% gap in the numbers obtaining a 'top' degree, namely a 1st or 2.1, compared with white students with knock on effects to future employment prospects.

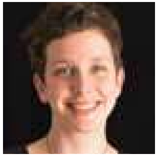
At least these problems are now recognized and spoken about. The Athena Swan scheme now has significant traction and a Race Equality Charter is now in its early stages. But such schemes are only part of the solution. Every organisation has to do some soul-searching, look at its own culture and implicit assumptions, and work out appropriate actions to facilitate culture change. Monitoring statistics is all very well, but too often one hears the whine that there simply weren't any women/BMEs qualified for a particular role when the reality is they were knocked out at the longlisting stage due to unconscious bias. People's unconscious biases are incredibly strong if subtle – try the tests at Project Implicit if you don't believe this about yourself – and it is an ongoing battle to ensure these do not win out at recruitment.

So far you could say that all I've written is simply based on the moral imperative of equality – which I would say should be sufficient. But, it is worth noting that diversity really pays off in a fairly literal sense. All the business studies demonstrate that diverse boards and diverse teams make better decisions and lead to higher profits and greater innovation. Although I am not aware of similar studies being done simply within the scientific sector, it is hard to see why this would not be equally the case.

Finally, ignoring gender effects in research can be costly and even fatal. In medicine in particular, carrying out all drug trials on male subjects has masked issues with the responses of women; clinical guidelines for recognizing heart attacks, based on how they present in males, has led to women suffering from heart attacks being sent home because their clinical symptoms do not match; and for many years all research on car safety was done using a standard (US) male dummy, thereby ignoring the fact that women – let alone children – are lighter and shorter on average.

We are progressing, but not nearly fast enough, in recognizing that diversity matters, that people are different but talent is not restricted to the white male. We have a long way to go, but we have at least progressed from overt discrimination to more subtle unconscious forms of disadvantage. Let us hope when CaSE celebrates its next 30 years an article such as this is completely redundant.

One climate data point



Dr Tamsin Edwards
Lecturer in Environmental Sciences
at the Open University

Thirty years is a single data point, for a climate scientist. Such is the challenge we face, scientists searching for slowly-shifting patterns and making them meaningful to an impatient world.

Perhaps it helps to think at climate timescales. Four data points ago, in 1896, Svante Arrenhius made the first global warming predictions. Atmospheric CO2 concentrations were 295 parts per million (ppm). Three data points ago, while Alfred Wegener presented his controversial theory of continental drift, they were 305 ppm. Around two data points ago, in 1957, Charles Keeling began directly measuring CO2 concentrations and discovered an unexpectedly rapid rise. 315 ppm.

One data point ago, as CaSE began, a Republican senator stated: "There is a very real possibility that man – through ignorance or indifference, or both – is irreversibly altering the ability of our atmosphere to perform basic life support functions for the planet." A bigger jump, 347 ppm, and a few years later the Intergovernmental Panel on Climate Change (IPCC) published its first report. We are now preparing the sixth, CO2 levels are the highest in three million years, and the world has warmed by 1 degree Celsius.

One data point from now, in 2046, scientists predict warming will be around 1.5 to 2 degrees Celsius, and that if all emissions stopped we would still have up to a 1 in 3 chance of exceeding 2 degrees. We can no longer claim ignorance or indifference.

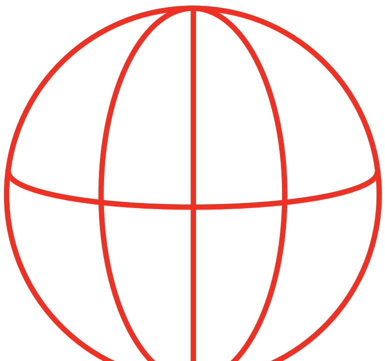
How can we make a future we want? Globally: support for a wide range of science and engineering to predict future climate, help vulnerable people and species to adapt, and expand the toolkit of solutions. In the UK, strong action to protect science from the risks of leaving the EU. My most rewarding and long-lasting collaborations result from a 24 institution EU project ice2sea, and younger researchers might not lead or even see such barrier-free multinational research. More optimistically, I look forward to results from the new interdisciplinary UK Global Challenges Research fund focusing on problems facing developing countries.

Some solutions may be less obvious. We must escape filter bubbles. We rely on algorithms and social connections to navigate the oceans of information. Unchecked – whether climate concerned or unconcerned – this can further entrench our views. This will only worsen in the future, unless we actively look beyond our cultural groups.

As a society, we should educate our children in critical thinking, computing and statistics, so they can filter information themselves. Climate changes are statistical patterns in big data and predictions of risk. We need to show girls, in particular, that their coding can change the world. Helping the planet's future can also help theirs.

We should hold our media accountable, not only when they minimise climate risks but exaggerate them too. At the same time we should make it unacceptable for publicly-funded science and data to stay behind paywalls and firewalls. Climate scientists have seen huge damage done by real or perceived gatekeeping of information, and huge benefits from increased scrutiny and openness.

But facts are not solutions. Facts are the raw clay with which dialogue and consensus-building can start to shape action plans. We should recognise the value of getting people in the same room over online discussions, of humility and openness over dogma and outrage. Perhaps most of all, we should seek diversity. It should no longer be acceptable to ask only western white men onto scientific panels and into decision-making rooms. Innovation flourishes from diverse ideas, and Climate change affects the most vulnerable in society, so their views should be sought. This is the only hope for finding better ways to live on the planet that we can all agree on.



From the underground, up. Engineering our future cities

Roma Agrawal
Structural Engineer

In 1800, 3% of the world's population lived in urban areas, by 1950 this had increased to 30%. In the last few years, for the very first time in recorded history, the majority of us live in cities. By 2030, the world is projected to have 41 mega-cities with 10 million inhabitants or more.

As a structural engineer, I design buildings and bridges and am responsible for ensuring the safety and comfort of the people that live and work in them. But a successful structure is one that works for its users and makes sense in the landscape of 2050 just as much as 2016.

Whereas now, we are used to a bird's eye (or google maps) views of our city showing clear outlines of buildings intersected by ribbons of train lines and roads, I believe the future city will be far more complex and challenging to map. We will increasingly think of our cities as three dimensional, less like a flat pancake and more like a multi-tiered cake. I see us moving roads and services further down underground, creating more space at ground level for parks and pedestrianised squares. Buildings will get taller, and increasingly incorporate activities at higher levels we currently see mostly at ground level e.g. shops, restaurants, car parks. We may see multiple layers of transport / connectivity corridors weaving between and even through our future buildings.

And some of this has already begun. In the last few years, I have worked on three projects in central London which entail creating space where we previously thought there was none – over and around pre-existing rail tracks and tunnels. This model brings its challenges – trains shake everything around them as they thunder past. There is even the risk that a derailment could generate a collision with the structure above, and threaten people's safety.

To stop someone's tea from rattling when a train runs past, we have learned how to 'isolate' the skeleton of a building from the ground. Large, robust rubber pads sitting between the foundations and columns act as a buffer, absorbing the vibrations and minimising the amount of force that travels into the building from movement of trains underneath. It sounds counter-intuitive to use a material like rubber to separate large pieces of steel or concrete, but this is proven method and it works.

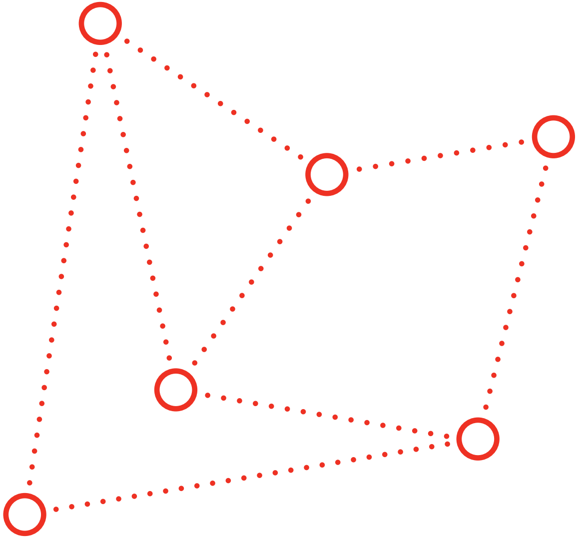
In designing buildings that sail above train tracks, we are becoming savvy with scenarios. If a train derails and hits a column, we make sure that the building stands strong even with a column missing – by giving the loads somewhere else to travel through its skeleton. Computing power allows us to test multiple permutations of impact and create a resilient structure with in-built redundancies. And as materials become stronger, trains lighter, and computer software ever smarter, I can see this evolving until not just train lines but stations become fully integrated within high-rise towers at different levels of our layered cities.

Clever engineering and construction techniques have also allowed us to respect our past as we race ahead with our future. Cities like London have hundreds of centuries-old buildings which give them character and continuity. In many cases, the buildings are no longer fit for purpose, with safety concerns such as tight headroom, poor insulation and no lifts. We can preserve the essence of these buildings by ripping out the skeleton but keeping their skin intact. London has many such examples of old distinguished buildings, with spacious atriums, modern glass interior courtyards and efficient technology driven heat and lift systems.

Britain's unique combination of architectural heritage and modern technology means we can use exciting engineering to allow our cities to be preserved and evolve. By modernising the old, and creating more intricate layers, we can accommodate growing urban populations. Alongside our rapid advances in technology we need our planning laws, transport policy and zoning regulations to evolve to a new reality. Where engineering leads, government will need to keep up.

Future Trends

Ron Mobed
Chief Executive
of Elsevier



Over the course of the next three decades, science and engineering will be defined by the expansion of technology-enabled collaborative networks, and the explosion in the availability of new sources of data.

We consistently hear from researchers that their work is becoming increasingly data centric, and that the sheer volume of data and connections present formidable challenges. Researchers, government bodies and other decision makers are already under increasing pressure to draw from a wider body of knowledge, and to use it to produce better outcomes, faster and at lower cost. That pressure will continue to grow, as will the huge amount of information available.

What will transform science, both in the research lab, and at a government and investment level, will be the technology that turns that data into meaningful insights and actionable information, and which provides professionals with the assurance of authoritativeness. A large volume of highly complex data sets are of little value without the technology to make it useful or the tools for turning it into meaningful insights and applications. Nor is it of any value if the user cannot rely on its sources or accuracy. Professionals need to know, with confidence what is truly authoritative, where it originated, and whether it is truly relevant.

Through the interaction of machine learning and big data technologies, researchers and governments can already draw specific insights from the vast corpus of scientific knowledge that inform which decisions to take, where to invest, what to research, and who to collaborate with.

That will increasingly become the case in the coming years. The data these technologies draw from will increase in depth and breadth, and the insights they provide will be backed by an evidence base far greater than any one person could manage themselves.

These technologies will lead to the emergence of a global knowledge ecosystem, and as that grows more open, it will become the most potent source for growing new ideas. 'Knowledge centres' as they now exist – clusters of expertise around a geographic location – will fade in prominence. Instead, we will see the continued emergence of knowledge networks, as researchers create their own groups to selectively interact, collaborate and lead across disciplines and geographies. We're already seeing examples of this in areas such as cancer research, where cross discipline groups formed on research networks like Mendeley, have brought engineering expertise to bear on medical research.

This knowledge ecosystem will present myriad opportunities for the scientific community, but it's an essential development, as much as an exciting one. Without it, the sheer amount of data and connections available for researchers will prove impossible to navigate. With it, the possibilities of the accumulated knowledge of the scientific community can be brought to bear on the challenges facing humankind, in a way that has never before been possible.

Shaping the Future of Science

CaSE 30th Anniversary Event

Monday 14th November 2016
Beveridge Hall, Senate House,
University of London

To celebrate its 30th anniversary year, CaSE brought together a broad range of perspectives looking ahead to the role of science and engineering over the next 30 years and asking what we can do now to make that future a reality that we want.

The evening featured a panel discussion with contributions from:

Professor Lynn Rothschild Adjunct Professor of Molecular Biology, Cell Biology and Biochemistry, Brown University

Phil Smith Chairman, Cisco UK and Ireland

Professor Jonathan Haskel Professor of Economics, Imperial College London

Dr Adam Kucharski Assistant Professor, London School of Hygiene & Tropical Medicine

Katie Ward Author of 'Girl Reading'

Followed by:

Professor Jim Al-Khalili Professor of Theoretical Physics, University of Surrey, 'in-conversation' with

Professor Brian Cox Advanced Fellow of Particle Physics, University of Manchester, and

Jo Johnson MP Universities, Science, Research and Innovation Minister

They were joined by a sell-out audience of leaders from scientific organisations in industry, academia, and public life.

This event was made possible by:

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About CaSE
1986 – 2016

The Campaign for Science and Engineering (CaSE) is the leading independent advocacy organisation for science and engineering in the UK. Our mission is to raise the political profile of science and engineering and campaign for policies and investment that support a thriving sector.

CaSE was founded as Save British Science in January 1986. The organisation started out when 1,500 scientists banded together to pay for an advert in The Times, calling on the Prime Minister, Margaret Thatcher to 'Save British Science'. We changed our name to the Campaign for Science and Engineering in 2005.

CaSE has an outstanding record over the last 30 years of campaigning for better policies and investment for science and engineering. CaSE's reputation is built on independent, authoritative analysis. Our robust evidence is relied upon by senior politicians and civil servants as the definitive voice of a wide science and engineering community.

As a charity CaSE receives no government funding. Instead we are entirely funded by our membership of 800 individuals and 100 organisations including businesses, universities, learned and professional organisations, and research charities.

For further details about CaSE and its work go to
www.sciencecampaign.org.uk

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Campaign for Science & Engineering
Gordon House
29 Gordon Square
London, WC1H 0PP

www.sciencecampaign.org.uk
@sciencecampaign