I am also an engineer, and of course, maths is at the heart of engineering. In my own career at Airbus, the importance of mathematics in delivering safer, quieter and cleaner aircraft, was vital to me every day. When we were faced with the challenge of trying to understand a landing gear failure, for example, it was important it is that children are taught programming and know that this is an important skill (alongside art) for the digital arts.

Most people don’t know you can’t make a modern animation software developed for the aerospace industry was being used to solve the problem – identifying stress concentrations, through complex grid analysis, that were not picked up earlier, and (more importantly) pointing to geometry solutions that were not identified by the traditional designers. I had always been aware of the mathematicians behind stress and fatigue analysis, but it was in solving problems like this that I was first convinced of the need for business to involve experts in applied mathematics early in the industrial problem-solving process.

But the real eye-opener for me came in my first few months at the Technology Strategy Board, during a couple of familiarisation visits to organisations that we work with. The first was to Glasgow University, to meet with some of their healthcare research staff, and see the outcomes of their projects. I met with one of the clinicians from Glasgow Royal Infirmary, who had received a grant to look at the cause of strokes (Scotland’s leading cause of disability), and in particular the role of the carotid arteries. He presented to me some of the work they were doing on fluid flows – contrasting it with aerodynamic predictions of the turbulent flow of an Airbus A380 in a wind tunnel – and he showed me how they were using ultrasound to detect the embolic signals coming from the carotid arteries going into the brain. This was aerospace maths capability being applied in the life sciences.

The second visit was to Lloyds of London. Lloyds is the world-leading insurance market, and it is increasingly reliant on high-performance computational fluid mechanics to advance the understanding and management of risk. Aerodynamics prediction software developed for the aerospace industry was being used to build this capability.

Celia Hoyles chaired an IMA session: ‘Why Does Mathematics Matter? the Case of the Digital Arts’ [6] that emphasised how important it is that children are taught programming and know that this is an important skill (alongside art) for the digital arts. Most people don’t know you can’t make a modern animation without mathematics! The IMA seeks to make this information available (without the need to understand the maths in detail) with its Mathematics Matters series of case studies [7].

50 Years of Maths in Industry

Iain Gray, Chief Executive of the Technology Strategy Board, spoke on the past and future contribution of mathematics to the UK economy at the IMA’s 50th Anniversary Celebration on 14 May 2014.

How does maths affect the lives of ordinary people? How does it benefit us all, improving our quality of life? And how best can we bring mathematicians and business people together, so that maths can continue to contribute to our economy in the UK?

These were some of the issues that we discussed recently, as we celebrated the fiftieth anniversary of the Institute of Mathematics and its Applications. The occasion provided an opportunity to reflect on the contribution of maths to industry over the last half century, and to look to the future.

For the last seven years I have been the Chief Executive of the Technology Strategy Board. Our job is to accelerate economic growth by stimulating business-led innovation. One way we do this is through funding – since 2007 we have enabled investment of about £3bn in innovation projects in industry. And we do it through partnerships with all the right people. We partner with the Government. We partner with UK universities. We partner with thousands of businesses, large and small. We make those critical connections that help businesses on the journey from concept to commercialisation, and the mathematics community is a vital part of this.

I am also an engineer, and of course, maths is at the heart of engineering. In my own career at Airbus, the importance of mathematics in delivering safer, quieter and cleaner aircraft, was visible to me every day. When we were faced with the challenge of trying to understand a landing gear failure, for example, it was industrial maths that we turned to, to help us solve the problem – identifying stress concentrations, through complex grid analysis, that were not picked up earlier, and (more importantly) pointing to geometry solutions that were not identified by the traditional designers. I had always been aware of the mathematicians behind stress and fatigue analysis, but it was in solving problems like this that I was first convinced of the need for business to involve experts in applied mathematics early in the industrial problem-solving process.

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It was at that point that I realised that industrial maths, and applied mathematicians, were building analysis capability across different sectors, and helping to establish world-leading businesses for the UK. It was at that point that I became a real advocate of industrial maths, and the importance of ensuring that there is strong industrial maths knowledge transfer across the innovation landscape.

Now at the Technology Strategy Board I see, pretty much every day, how mathematics leads to the development of new products, processes and services for many different kinds of businesses, in many different sectors.

Take the work of one of the companies that we at the Technology Strategy Board have supported in several projects, and that I follow closely – OC Robotics, based in Bristol. OC Robotics make snake-arm robots for use in confined spaces or hazardous environments, or for working with toxic or corrosive materials. These are robots that can reach into places where your arm could not get, or where you really would not want to put it. They are long, slender robotic arms, more like flexible endoscopes than the powerful industrial robots used to assemble cars. Instead of rigid links, interconnected by joints like the human arm, they have a fluid, curving shape like a human spine. The robot arms are capable of very subtle movements, as they twist and turn to get where they need to be. And each of those movements is underpinned by complex maths.

**The mathematics of the everyday**

But it is a key challenge for us to convey to a wider audience just how important mathematics is to industry projects, and to emphasise to business entrepreneurs the role that industrial mathematics can play in securing business success.

In every aspect of our lives these days, applied maths is there, behind the scenes. Imagine for a moment a man living a typical life. He gets up in the morning and makes himself a coffee. He doesn’t know that the beans were grown using an app that provides farming intelligence for weather and disease, based on satellite data, compiled from multiple sources by an analytical predicting algorithm, drawing upon expertise from universities and research organisations.

And he doesn’t know it, but the milk in his coffee has been collected using a new flow meter, which makes the process of milking cows much more efficient. The pulses of a milking machine, and the mixture of milk and air inside it, mean that the dynamics of milk flow are extremely complex. But the new equipment has been designed with input from a team of mathematicians, who were aware of how similar problems of flow are tackled in the oil and gas sector.

The coffee puts our man in a good mood, so he buys his wife a present online. He pays for it with his credit card, confident that the site he is using is safe. He is blissfully unaware that encryption techniques developed at GCHQ are protecting his transaction.

Our man gets out his vacuum cleaner to give his house a clean. He doesn’t know that the noise has been reduced by better design, using mathematical models of multi-modal wave propagation in a duct with linings consisting of arrays of Helmholtz resonators made from acoustic metamaterials.

It’s coming up to lunch time, and our man, who is a diabetic, needs to give himself an insulin shot before he eats. In the old days, he would have had to stick himself in the finger with a needle and do a blood sugar measurement to calculate his dose. Soon he will be able to look into an eye scanner instead, and get a reliable measurement from there. It is possible to infer blood glucose from the nature of light reflected from the eye – if you use an active curve selection algorithm to identify the proper signal, noise reduction algorithms to smooth out that signal, and statistical models to calibrate the equipment.

Our man decides to plan his next holiday, and thinks that he might try a bit of scuba diving. When they are diving deep, divers must surface slowly and manage their decompression, to avoid the bends. This is a big area of uncertainty, though, and there is a good deal of variability in the advice about what is and isn’t safe, despite over a hundred years of diving experience. However, pretty soon divers will have a much better understanding of what they need to do, thanks to new algorithms based on a more scientific approach to decompression modelling in the body.

On the way home at the end of his busy day, our man fills up his car with petrol. It seems expensive these days, but it would be much more expensive if the oilfield reservoir managers didn’t have access to advanced mathematics – for example, algorithms used to build an understanding of oil well characteristics, analysing reservoir performance and forecasting future production, all of which are being improved in collaboration with university researchers.

At the end of his day, our man watches the Grand Prix on the TV. He’s never heard of Navier-Stokes equations, nor does he know about computational fluid dynamics. But if the McLaren engineers had not spent time working with their mathematician partners in universities on these things, their car wouldn’t be in the running.

Many of these examples come from projects that we have supported at the Technology Strategy Board. And I hope they show that industrial maths is not just about innovative businesses doing sums. Advanced maths done by academic specialists is often an important part of the innovation support that companies tap into. Ultimately, this can deliver significant new innovation and economic value – and transform lives.

In the UK we have a long and proud history of applying advanced maths to real-world problems. From Isaac Newton through to Kelvin and beyond, we have been at the forefront of industrial maths, putting our academic strengths at the service of the wider economy. You could say that applied mathematics is a British invention.

But the question is, how do we support that process in the best way possible? What’s the best model for bringing mathematicians together with business people?
The future of support for maths in industry

Over the years, universities, industry and government have all set up institutions to further industrial mathematics, trying to create a free flow of ideas and talented people between academia and industry, and bringing academic and industrial researchers together, to work on real-world problems encountered by businesses.

And with the creation of the Department of Applied Mathematics and Theoretical Physics at Cambridge, the Oxford Centre for Industrial and Applied Mathematics, the Institute of Mathematics and its Applications, and more recently the Smith Institute, the UK now leads the world in industrial maths.

The Smith Institute model I think it is particularly interesting, with its Technology Translators – typically mathematics PhDs, who get to understand different industry sectors, and how the UK mathematics community can be deployed to address the challenges that those sectors face, as well as mapping the UK mathematics landscape to identify areas of common need and problems that are worthy of study.

The creation 15 years ago of the Industrial Mathematics Faraday Partnership, later the Industrial Maths Knowledge Transfer Network, has proven to be a particular success. It has provided a forum for interaction between mathematical modellers in academia, large businesses and SMEs, and government departments and agencies. We in the Technology Strategy Board took responsibility for supporting the KTN when we were established in 2007.

Now, UK industrial mathematics is at an important point in its development. As from April this year, with the merging of all the KTNs and their communities, the Industrial Mathematics community and network has been subsumed into a single Knowledge Transfer Network. The operating model for the unified Knowledge Transfer Network is different. But we at the Technology Strategy Board continue to recognise the value of industrial maths for business innovation, and give the greatest strategic importance to this discipline.

The new Knowledge Transfer Network will maintain support for the industrial maths community. Indeed, there is a significant opportunity here to build new connections for mathematicians, way beyond those industries that have typically recognised the need for advanced maths – in those other business areas, also supported by the Knowledge Transfer Network, that have so far missed out on this valuable opportunity.

And of course, the Knowledge Transfer Network is only one part of our wide portfolio of help that we at the Technology Strategy Board provide for innovative businesses.

We have supported innovative projects involving around 5,000 companies, offering a wide range of help, from connections to funding. Our support is often focused on specific themes or technology areas – such as through our competitions for collaborative R&D projects, which enable small and large companies to work with each other and with universities. We also have programmes to help companies with great ideas in any sector, such as our Smart scheme, which funds SMEs to develop proofs of concept or prototypes of their ideas.

We also have the Catapults, which we have set up over the last couple of years. These are a major new force for innovation – physical centres where the very best of the UK’s businesses, scientists and engineers work side by side on late-stage research and development, transforming ‘high potential’ ideas into new products and services, to generate economic growth. The network of Catapult centres now covers seven specific areas which are strategically important for the UK, and which have a large global market potential.

We’re also helping government to be a better, more intelligent customer for the innovative new solutions that our most creative SMEs can offer. Our Small Business Research Initiative (SBRI) is designed to encourage this. We’re also helping government to be a better regulator, and to set standards that help businesses plan their innovations for a future market that is better understood.

The UK has some of the best universities in the world. Our innovation toolset also includes Knowledge Transfer Partnerships (or KTPs), which help businesses to access the expertise in our universities, to gain a competitive advantage.

And through networking, we aim to introduce an ever-growing number of high-potential businesses to opportunities and support for innovation.

Through the new unified Knowledge Transfer Network, the power of industrial mathematics can be brought into many of these projects and programmes that we support.

As we look back over fifty years of maths and its contribution to industry, then, we can see plenty of success stories. But we in the UK need to make much more of our industrial mathematics, and that depends upon providing the right kinds of support, to help get our mathematicians and business people together.

Companies should be able to engage confidently with mathematics, use maths to help drive innovation, and expect great results. We in the Technology Strategy Board will continue to do all we can, to help make this a reality, for the benefit of the UK and its future prosperity.

Iain Gray CBE FREng
Technology Strategy Board