

OCTOBER 2015 | Issue 4

# Institute for **Manufacturing** REVIEW

**50 years of manufacturing at Cambridge**

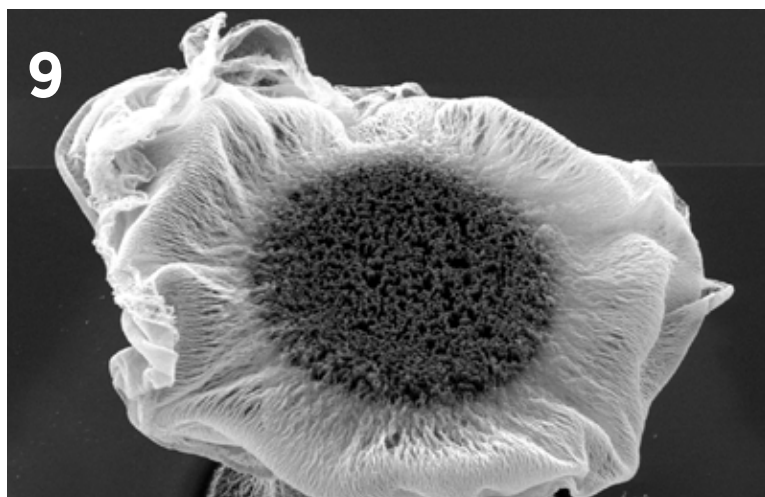
**Giving evidence to government**

**Carbon nanotubes: a manufacturing challenge**

**New thinking on next generation supply networks**

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**Cover image:** Flower-shaped microstructures made out of carbon nanowires. Credit: Michaël de Volder



# Welcome



It is with great pleasure that I introduce both this latest issue of the *Review* and, to those of you who don't yet know me, myself as the new head of the IfM. 2015 is a rather momentous year for us. We say goodbye to Mike Gregory, whose vision and indefatigability have achieved great things both here in Cambridge

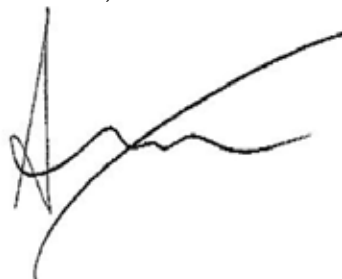
and for the manufacturing community as a whole. We are also celebrating the 50th intake of students on our taught MPhil course, which took a pioneering approach to postgraduate education and in many ways exemplifies what the IfM is about today: doing new things that are genuinely useful for industry. So it seemed like a good idea to look back and see how we've got here and what we have achieved on the way (page 12).

And today we are busier than ever developing new insights and working with businesses and policymakers to put those insights into practice. This year, for example, we have hosted the EPSRC Manufacturing the Future conference and convened a policy forum with UK and US government officials in the White House. We are working on a major government and industry-funded project to redesign the UK's pharmaceutical

supply chains, we are contributing to the UK National Strategy on Additive Manufacturing and we are in the middle of landscaping high value manufacturing in the UK on behalf of Innovate UK. And these are just a few of the things we are involved in! In this issue of the *Review* you can read about some of our other activities whether it's tackling the challenge of manufacturing carbon nanotubes en masse or helping a multinational company turn its IT experts into 'trusted advisors'.

So there is much going on and much more to do. But we can't do it without our partners in industry and government. If our research is to have value it needs to address real needs, so we are always looking for people who want to work with us. If that could be you, please do get in touch.

Best wishes,



Professor Andy Neely  
*Head, Institute for Manufacturing*



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[www.ifm.eng.cam.ac.uk/ifm-review](http://www.ifm.eng.cam.ac.uk/ifm-review)

**Editor:** Sarah Fell  
**Email:** [skbf2@cam.ac.uk](mailto:skbf2@cam.ac.uk)

**Editorial advisory board:** Professor Ian Hutchings, Dr Dai Morgan, Professor Andy Neely, Dr Rob Phaal, Dr Jag Srai, Peter Templeton, Dr Chander Velu

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# IfM news

## Professor Sir Mike Gregory retires

On 30 September colleagues from the IfM and the Department of Engineering gathered with old friends and collaborators to wish Mike a happy retirement and to welcome his successor, Professor Andy Neely.



*Manufacturing the Future* networking event took place in the AirSpace Aircraft Hall at the Imperial War Museum Duxford.

## IfM hosts EPSRC Manufacturing the Future Conference

Nearly 300 of the UK's top academics, industrialists and government representatives were in Cambridge in September to discuss how to support innovation and world-class manufacturing in the UK.

The conference was opened by Professor Sir Mike Gregory followed by a video presentation from the Secretary of State for Business, Innovation and Skills (BIS), Sajid Javid. Delegates also heard from Philip Nelson, Chief Executive of EPSRC, Amanda Brooks, Head of Innovation at BIS, and companies such as Caterpillar, Dyson, Rolls-Royce, Siemens and Toyota, as well as representatives from the EPSRC's Centres for Innovative Manufacturing and from Innovate UK's Catapults. All speakers considered how academic research is already having an impact and what more needs to be done to ensure the UK improves its competitiveness in key sectors. The conference proceedings are available online at: [www.ukmanufacturing2015.eng.cam.ac.uk/proceedings](http://www.ukmanufacturing2015.eng.cam.ac.uk/proceedings)



Professor Bill O'Neill, Head of the IfM's **Centre for Industrial Photonics** and conference chair.



Professor Sir Mike Gregory in a panel discussion with Dr Zoe Webster, Head of Manufacturing, Innovate UK.



## 2015 Design Show

Every year the third-year **Manufacturing Engineering Tripos** students work in teams to develop a new product which has real business potential. The students need to identify a customer need, research the market, develop original design concepts and a full business plan.

This year's projects included a device to collect and sort shuttlecocks, an adjustable wheelchair which allows users in India to interact socially at floor level, a machine for recycling scrap plastic from 3D printing into new cartridges (above) and a laser music visualisation system (below).

Find out more about the projects and watch the students' videos at: [bit.ly/METdesign15](http://bit.ly/METdesign15)





## Better ways to build houses

The IfM's **Distributed Information and Automation Laboratory** (DIAL) is working with the Cambridge Engineering Design Centre (EDC), Laing O'Rourke and 20 consortium partners on a major government-funded project to improve the construction industry's supply chain.

The project aims to address the UK's gap in housing supply by creating a new off-site manufacturing facility for 10,000 new homes each year. DIAL and the EDC are involved in the Integrated Design for Manufacturing and Assembly research work stream, looking at how to improve the resilience of products used in homes, buildings and infrastructure and their associated design and manufacturing processes.

The Cambridge team will be addressing, amongst other things, the construction industry's fragmented approach to delivery by adopting some of the engineering tools and processes used by the highly efficient automotive and aerospace industries. The team will also help the industry use early design decision-making to manufacture new components in an advanced, highly automated, yet reconfigurable manufacturing plant. For more information contact Dr Tariq Masood: [tm487@cam.ac.uk](mailto:tm487@cam.ac.uk)



## Redesigning UK pharmaceutical supply chains

The REMEDIES (RE-configuring MEDICines End-to-end Supply) project has accelerated into its next phase following the approval of government funding in August. The REMEDIES project was launched in 2014, headed by GlaxoSmithKline with research led by the IfM's **Centre for International Manufacturing** (CIM). It brings together key players in the end-to-end supply chain to address inefficiencies which add costs and reduce productivity. At the same time, new technologies are emerging which have the potential to improve medicine manufacturing and supply, and offer more personalised, faster and cheaper drug delivery. The project aims to find innovative ways to tackle inefficiencies and capitalise on these new opportunities.

The project, due to be completed in March 2018, has several technology-based application projects underpinned by two platform projects: clinical trials supply chains, led by GSK, and commercial supply chains led by CIM.

For more information, go to: <http://remediesproject.com> or contact Dr Jag Srαι, REMEDIES Research Director: [jss46@cam.ac.uk](mailto:jss46@cam.ac.uk)



The REMEDIES project team

## New Strategic Intellectual Property Forum

Dr Frank Tietze from the IfM's **Centre for Technology Management** has launched a new forum to help companies manage their IP and use it more effectively when making strategic decisions. The forum is open to anyone with an interest in IP, such as CTOs, portfolio managers, VPs Technology, Heads of Innovation, IP or Licensing from a variety of companies and sectors to become part of an expert community. The first meeting looked at IP strategies and strategic business perspectives. The next forum will take place on 8 December. For more information go to: [www.ifm.eng.cam.ac.uk/events/sjpf-december](http://www.ifm.eng.cam.ac.uk/events/sjpf-december) or contact Frank Tietze: [frank.tietze@eng.cam.ac.uk](mailto:frank.tietze@eng.cam.ac.uk)

## Building strategic university-industry partnerships: lessons from the UK and US

The **Centre for Science, Technology and Innovation Policy** (CSTI) has published a report discussing key lessons and effective practices based on UK and US experiences of building and nurturing mutually beneficial strategic university-industry partnerships.

This report – authored by Tomas Coates Ulrichsen and Eoin O'Sullivan – draws on the insights and experiences of more than 70 senior thought-leaders from leading UK and US universities, major research-intensive multinational firms, and UK and US government funding agencies.

Download the report at: [bit.ly/uni-indpartners](http://bit.ly/uni-indpartners)



# IfM ECS news

## Work with Linde Gases leads to prestigious 'Red Dot' award

In 2014 IfM ECS helped Linde Gases develop its technologically advanced gas cylinder valve, EVOS™ Ci. On 29 June Linde received the 2015 'Red Dot' award for Product Design, seeing off competition from nearly 5,000 other entries.

Colin Haden, then Head of Centre of Excellence, Packaged Good Products at Linde (and now Senior Industrial Fellow with IfM ECS), described how the Linde team's first encounter with Dr James Moultrie from the IfM's Centre for Design Management, revolutionised their thinking: "He inspired us to think in completely new ways about the new valve design specification and to develop new approaches to achieve it." IfM ECS supported Linde throughout the project, until the valve's launch in October 2014.

Read about IfM ECS's work with the Linde Group at: [www.ifm.eng.cam.ac.uk/research/ifm-review/issue-2/innovation-by-design/](http://www.ifm.eng.cam.ac.uk/research/ifm-review/issue-2/innovation-by-design/)

## Technology roadmap for the UK marine industries

IfM ECS has delivered a roadmapping project for the UK's marine industries on behalf of Innovate UK. We have previously run similar projects for other key sectors such as Quantum Technologies, Synthetic Biology and Robotics and Autonomous Systems. The UK marine industry is globally competitive with strengths across a variety of technologies. The aim of the roadmap is to develop a shared vision so that industry and government can work together to develop export-led growth.

The roadmap looks at those parts of the industry that are engaged in building vessels or supplying equipment or services for the commercial, leisure, naval and marine science sectors. It identifies key opportunities in which industry and government should invest to support export growth and it maps the main technical capabilities needed to capitalise on these opportunities. The roadmap will be published on 18 November 2015.



## New people



**Colin Haden**, Senior Industrial Fellow  
Colin was previously with the Linde Group, holding management and functional roles in technical, marketing and business development within global functions and operating businesses. He was Head of the CoE for Gases Packaging team which won two Red Dot Awards for product design and was recognised for his work in market assessment and strategy planning.



**Nick Sherwen**, Senior Industrial Fellow  
Nick has more than 25 years' experience in manufacturing industry across Europe. He spent 15 years with Amcor, a leading global packaging manufacturer, in general management, operations and strategy roles. Much of his experience has been with mid-sized organisations, including private equity owned businesses. He has helped businesses with issues ranging from operational improvement and new product development to post-merger integration and restructuring.



**Peter Thornton**, Senior Industrial Fellow  
Peter has extensive business and management experience across many industries and functions. He specialises in the design, development and delivery of customised executive development programmes. He has worked with organisations across continents to deliver educational programmes that develop their focus, align their efforts and improve their processes to deliver their business goals more effectively.



**Amanda Bamford**, Executive and Professional Development Facilitator  
This is Amanda's second role at the IfM, as she previously worked as an Industrial Tutor for ISMM. In between, she worked in Industrial Inkjet at Xaar plc as Technical Training Manager. She has held a variety of different roles in the field of manufacturing, including project management, implementing production planning systems and applying manufacturing principles to healthcare processes in the NHS.

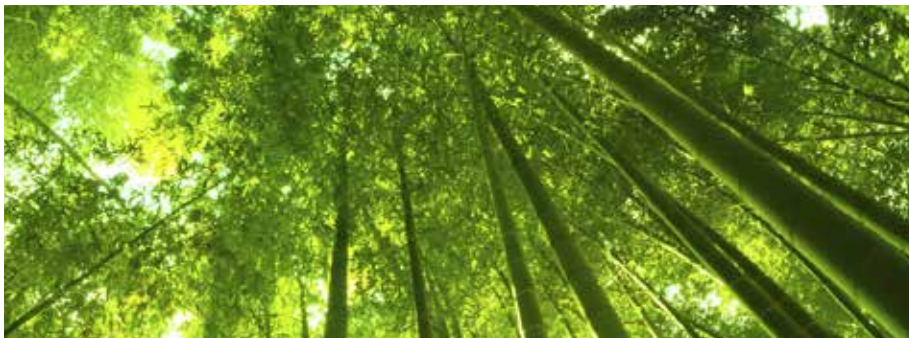


## Supporting sustainable growth in the East of England

A three-year project has significantly enhanced the growth prospects of 120 manufacturing SMEs across the Eastern Region, leading to the creation of approximately 140 new jobs and safeguarding many more.

The PrISMS (Practical & Innovative Solutions for Manufacturing Sustainability) project helped start-ups and SMEs in the East of England grow their businesses while reducing their costs and overall carbon footprint. Photofabrication, a photochemical machining firm, was one of the companies IfM ECS worked with. Paul Rea, Operations Director, said: "We worked closely with IfM ECS and we see the benefits. It allowed us to tap into resources we don't have, to see things in a different way and to make decisions on that basis. We have a different mindset – it's about getting better all the time."

The PrISMS programme was funded by the European Regional Development Fund (ERDF), with match funding from the EPSRC Centre for Innovative Manufacturing in Industrial Sustainability, ideaSpace and IfM ECS.



## Sharing approaches to innovation and technology management with Poland's top scientists

75 Polish scientists spent the summer in Cambridge, learning how to manage collaborative research projects and bring high-technology products to market.

They have been here as part of Poland's 'Top 500 Innovators' programme, set up by the Polish government to help bridge the gap between academia and business. The programme of training and practical activities, organised by Cambridge Enterprise, was designed to share the University's considerable expertise in knowledge transfer.

IfM ECS, with its extensive experience of using research-based tools and techniques to help companies turn R&D into successful businesses, was asked to share its knowledge of innovation and technology management with the Polish scientists.



## Identifying priorities for manufacturing research in Europe



IfM ECS has been running a series of roadmapping workshops to advise the European Commission on research priorities to improve manufacturing productivity and competitiveness across Europe. Road4FAME is an EU-funded project to develop a 'Strategic Research and Innovation Roadmap for Future Architectures and Services for Manufacturing in Europe'. It is run by a consortium of leading companies, manufacturing research centres and technology transfer organisations working together to examine industry needs. The consortium publishes recommendations on key topics in manufacturing information and communications technology (ICT) for inclusion in the European Commission's Horizon 2020 research and innovation programme.



## Become an IfM member

The IfM has two membership schemes which aim to build closer, long-term relationships between companies and our wide range of expertise, and to provide tailored support.

**Corporate membership:** for access to research-based strategic, technical and business expertise, geared to the needs of large international companies.

**Company membership:** for access to strategy and capability development for small and medium-sized companies, plus discounts on IfM services, training programmes and workshops.

For more information, go to: [www.ifm.eng.cam.ac.uk/membership](http://www.ifm.eng.cam.ac.uk/membership)

# Given in evidence

**QUESTION:** How do we get better at taking the research knowledge from our science and engineering base and turning it into technologies, industries and economic wealth





## The IfM's Centre for Science, Technology and Innovation Policy (CSTI) aims to give policymakers the information they need to provide effective support for emerging technologies and industries.

There is concern among some policymakers that the UK is not as good as it might be at turning its world-class research into thriving industries and businesses. In recent years, the UK government has been looking for new and more reliable ways to ensure valuable innovations can cross the so-called 'valley of death' – the point at which they often fail to translate into a technology that can be scaled up and commercialised. However, for government initiatives to be effective, the people who design them (and invest taxpayers' money in funding them) and the people who put them into practice need to have a better understanding both of the technologies themselves and of the industries within which they are deployed.

Which is where CSTI comes in.

### A clear sense of direction

Before coming to the IfM, its founder and director, Dr Eoin O'Sullivan, was part of the team that set up Science Foundation Ireland. Encounters with research councils and government agencies informed his view that much of the R&D and innovation policy research coming out of universities was ineffective in informing the strategies and programmes of innovation agencies because it was not getting to the right level of detail with regard to technologies and manufacturing systems.

Eoin contends: "For some innovation policy challenges you need to open up the 'black box', particularly when you are looking at the specific needs of a new research field or emerging technology. If you don't do that, the people who are making policy and investment decisions about which technologies, manufacturing processes and sectors to support are doing it in the dark."

Eoin joined the IfM in 2007, working initially on its Emerging Industries programme. He was also on part-time secondment to the Department for Business Innovation and Skills (BIS), giving him the opportunity to further explore its evidence needs first hand and to make sure that relevant findings from Emerging Industries were communicated to the right people in BIS, Innovate UK (then TSB) and the research councils. Then in 2012, with funding from the Gatsby Foundation, he was able to establish the Centre for

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Science, Technology and Innovation Policy – a new research centre dedicated to doing the kinds of research which would provide policy practitioners with evidence that could offer firm foundations for their decision-making.

### An engineering contribution to innovation policy

At first glance, the IfM may not seem to be the obvious home for an innovation policy research unit. They tend to be found in business schools or economics faculties. But the IfM is, arguably, exactly the right place for it. CSTI is embedded within a research environment which is actively engaged in understanding the whole spectrum of manufacturing activity, from cutting edge work in nano- and ultra-precision manufacturing processes and production technologies, through product design, technology and innovation management to global supply chains and developing new service-oriented and sustainable business models. This means that policy research here is surrounded by – and highly attuned to – the real

manufacturability, scale-up, operational and management challenges which emerging science and technologies face.

But it is not just absorption by osmosis, useful though that is. CSTI offers policy research support to a number of IfM research programmes, including the EPSRC and ESRC-funded 'Bit-by-Bit' project looking at the interconnected technological, commercial and policy issues around the emergence of 3D printing. It is also collaborating with a new IfM research group, Fluids in Advanced Manufacturing, through the 'Pathways to Manufacturing' project, which, again, is concerned with the risks and challenges associated with manufacturing a new technology at a commercial scale.

Forging connections with researchers beyond the IfM is also important. Eoin believes that to understand fully the economic aspects of emerging technologies, engineers, economists and management researchers need to pool their expertise: no one discipline is capable of making significant progress on its own. The Babbage Industrial Network (see box) is a CSTI-hosted initiative designed to share ideas and develop a common language across these different specialisms.

### Close links with government

As well as making connections across the research community – and contributing to their research findings and recommendations – it is vital for the CSTI team to have close working relationships with government and agency officials in order to understand their evidence needs and, where possible, co-design research projects to address them. ➤➤

### Babbage Industrial Policy Network

This is a forum for bringing together experts from economics, engineering and operations management to address some of the most important challenges around emerging technologies, manufacturing and their role in the economy – challenges which no single discipline can address on its own. The Forum has attracted some very high profile speakers from both the academic and policy communities and the Babbage community is continuing to grow.

In September, CSTI hosted the first Babbage Symposium, bringing together internationally leading economists, political scientists and engineers with policymakers from around the world to consider the question 'What future for manufacturing?'

To this end, there is a steady two-way flow of traffic between CSTI and government departments. Research Associate Dr Charles Featherston, for example, has spent time embedded within the manufacturing policy team at BIS, looking at how different policy levers can be used to nurture emerging manufacturing technologies. Paul McCaffrey, based in the Government Office of Science and project manager for the Government's recent Foresight project on the future of manufacturing, came to the IfM to reflect on what had been learnt from running the Foresight exercise and to integrate those findings with CSTI's analysis of how such things are done in other countries. Belinda Clarke, now the Director of AgriTech East, spent time at CSTI in 2014, while she was the lead technologist for Synthetic Biology at Innovate UK, building an evidence base for her calls for funding.

CSTI is also directly involved in developing and delivering services that IfM Education and Consultancy Services (IfM ECS) provides to national and regional governments around the world, helping them understand the global industrial landscape, their place within it and the opportunities and challenges they face. This includes work IfM ECS is currently doing on behalf of BIS and Innovate UK, looking at high value manufacturing in the UK in order to prioritise investment in key areas of potential growth.

### **An ambitious research agenda**

CSTI's research addresses a range of difficult questions. What kinds of infrastructure, for example, does an emerging technology need as it 'pushes' out of the science base? As a country adopts more proactive industrial sector strategies, what are the particular competitiveness challenges faced by each sector for which there may be innovation, technology or R&D solutions? Standards and regulations are also important: knowing the 'rules of the game' and the very direct effect they have on the context for emerging technologies and industries.

University-industry knowledge exchange is another of CSTI's core research themes. The distinctive CSTI approach is also evident here: getting into the details of the technology to unpick why it is that programmes work for some categories of technology and for certain types of maturity in certain sectors, and not in others. Research Associate Tomas Coates Ulrichsen recently ran a US-UK workshop on long-term strategic partnerships with a distinguished set of participants from

Berkeley, MIT and Georgia Tech as well as GSK, Boeing and Rolls-Royce. Eoin explained: "By involving the right people and really drilling down into the detail, we uncovered some interesting implications for universities and funding bodies, arising from the fact that big companies are increasingly choosing to work with just a handful of world-class universities."

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**"We like to think we are providing a certain type of research-based but practical evidence which is of real value to policymakers and programme planners and which no-one else is really geared up to give them."**

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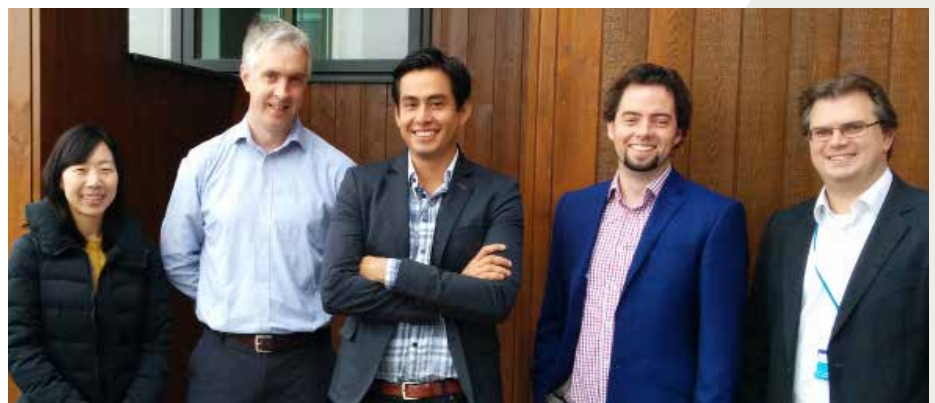
Turning science into technologies and then into economic wealth is an international race. To have any chance of competing, policymakers need to understand what makes some countries faster and better at it than others. This has become a key focus of CSTI activity and the team has developed a robust framework for undertaking country comparisons. It recently contributed to the Hauser report on the UK's Catapult network, looking at how similar bodies work in other countries and what lessons might be learnt for the UK. The team is currently working on a study commissioned by the EPSRC on how different countries are investing in quantum technologies.

In addition to these comparative studies, Research Associate, Dr Carlos López-Gómez, has established a series of International Policy Forums, at which academics and policymakers come together to understand how policy institutions and processes work in different countries. Three have been held

so far, focusing on Japan, Singapore and Germany. Carlos is about to go on secondment jointly with the University of Tokyo and the Centre for Research and Development Strategy, part of the Japanese Science and Technology Agency. He will be looking at the role of government-funded bodies – akin to Catapults – which support the translation of science into commercially successful technologies.

CSTI has also been centrally involved in setting up a more policy-practice series of international workshops, convened by IfM, at which senior UK government, agency and industrial representatives build closer links with their counterparts in key countries and share their experiences and best practice. So far, workshops have been held in Japan, India and the USA (at the White House). Another is planned for Berlin early next year, looking particularly at foresight exercises and emerging technology strategy development, with participation from the BIS Innovation Directorate and the Government Office for Science.

Ultimately, all these countries are facing similar challenges: how do they develop effective policies for manufacturing, for key technologies and sectors and how do they join all of that into a coherent industrial strategy? Getting this right, clearly, has enormous implications for national prosperity. And CSTI is determined to play its part. By working with scientists, engineers, management researchers and economists and by not being afraid to open up that 'black box', the team at Cambridge is doing something new and distinctive. Eoin said: "We like to think we are providing a certain type of research-based but practical evidence which is of real value to policymakers and programme planners and which no-one else is really geared up to give them."



From left: Jane Ho (doctoral student), Eoin O'Sullivan, Carlos López-Gómez, Charles Featherston, Tomas Coates Ulrichsen



A scanning electron microscope (SEM) image showing a dense network of carbon nanotubes. The nanotubes are thin, cylindrical structures that are interconnected and form a complex, porous-looking structure. The image is in grayscale, with the nanotubes appearing as bright, fibrous lines against a dark background.

# Small but mighty the manufacturing challenges of nanotechnology

Head of NanoManufacturing at the IfM, Dr Michaël de Volder explains why manufacturing carbon nanotubes is so difficult – and so important.



We all know that graphene is the new wonder material – a sheet of carbon just one atom thick which is unbelievably strong, amazingly lightweight, virtually transparent and brilliant at conducting electricity and heat. It has the potential to revolutionise the way we store our energy, clean our drinking water and create a whole new generation of flexible electronic devices. Nanotechnology, in short, is the future. And all this will come from particles which are a hundred thousand times smaller than the width of a human hair.

While much of the hype has tended to be around 'two-dimensional' graphene, carbon nanotubes (CNTs) – rolled up sheets of graphene – have been quietly stealing a march. In fact, CNTs have been with us a lot longer than graphene. We know that hollow carbon nanofibres were observed as far back as the 1950s and researchers have been actively researching CNTs since the early 1990s. As a result, the manufacturing techniques for CNTs are comparatively mature, with several thousand tons being produced each year – unlike high quality graphene which is still very difficult to manufacture in large quantities.

But this is by no means the end of the story. While this advance in production capacity is impressive, there are still major challenges to overcome before carbon nanotubes can really start to fulfil their potential. Most engineering applications need materials which are made up of multiple carbon nanotubes – and therein lies the difficulty. While an individual nanoparticle displays all those extraordinary properties, put one next to lots of others without carefully engineering the interactions between them and they start to lose their special powers. In fact, the mechanical and electrical figures of merit of a collection of nanoparticles drop off by at least an order of magnitude when compared to a single particle.

We understand how to make carbon nanotubes and can do so in relatively large quantities. What we now need to learn is how to structure and organise them in such a way that they retain their properties when assembled into a



PhD student Sarah Jessl investigating CNT properties with a thermographic analysis tool.

device. And this, to a large extent, is a manufacturing challenge. At the moment, most carbon nanotube products are processed using traditional manufacturing techniques, such as injection moulding of CNT-polymer composites which do not give us any structural control over how the nanoparticles are arranged – and limit the material properties they can deliver. By developing new technologies which allow us to make devices containing well-organised nanoparticles we should be able to achieve a dramatic improvement in their performance and open up a whole raft of new application possibilities.

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**We are now at the point where we understand how to make carbon nanotubes and can do so in relatively large quantities. What we now need to learn is how to structure and organise them in such a way that they retain their properties when assembled into a device.**

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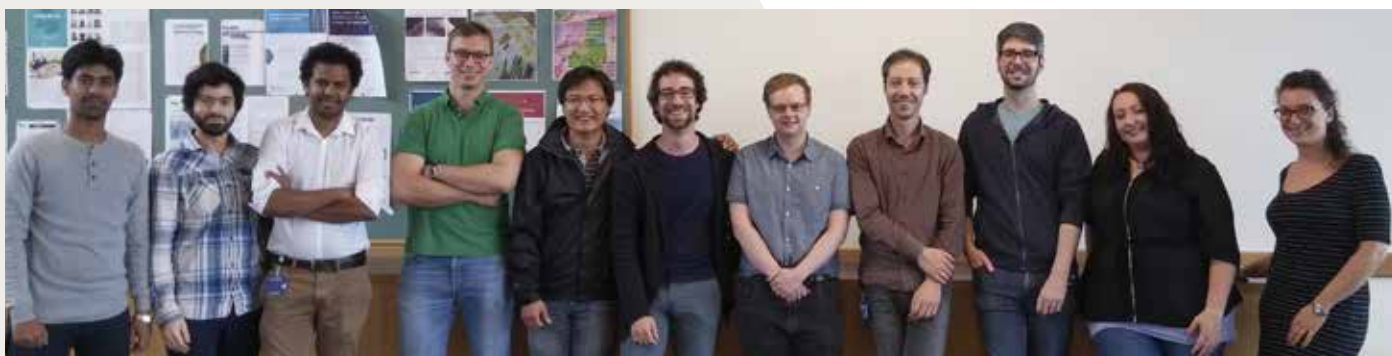
Which is exactly what the IfM's NanoManufacturing Group is trying to do. The team was founded just two years ago and is itself a demonstration of rapid scale up, with five engineers, four chemists, two physicists and two material scientists already in post. The nanomanufacturing challenge is such a complex one that we need a multidisciplinary team to

address it, as well as the collaboration of other universities, a broad spectrum of industries, and closer to home, collaborators in the Departments of Engineering, Materials Science, Chemistry, Chemical Engineering, and the Cavendish Laboratory. We also work very closely with other research centres at the IfM which are similarly engaged in developing new advanced materials and manufacturing processes.

A good example of this collaborative approach is the EPSRC-funded project, 'Advanced Nanotube Application and Manufacturing Initiative', which is bringing together engineers and materials scientists from the Universities of Cambridge and Ulster with a group of industrial partners to scale up a unique method for fabricating sheets and yarns of aligned carbon nanotubes. These will be used in next-generation lightweight composites, and can provide a much lighter alternative to copper wires in, for example, aerospace applications and high performance electric motors.

The IfM's NanoManufacturing Group is also focusing on the development of technologies which can organise nanoparticles into hierarchical superstructures. To achieve this, we are researching how to simultaneously optimise material properties at three length scales: at the nanoscale on surface chemistry, at the microscale on form and structure and at the large scale to integrate the particles into devices. With funding from the European Research



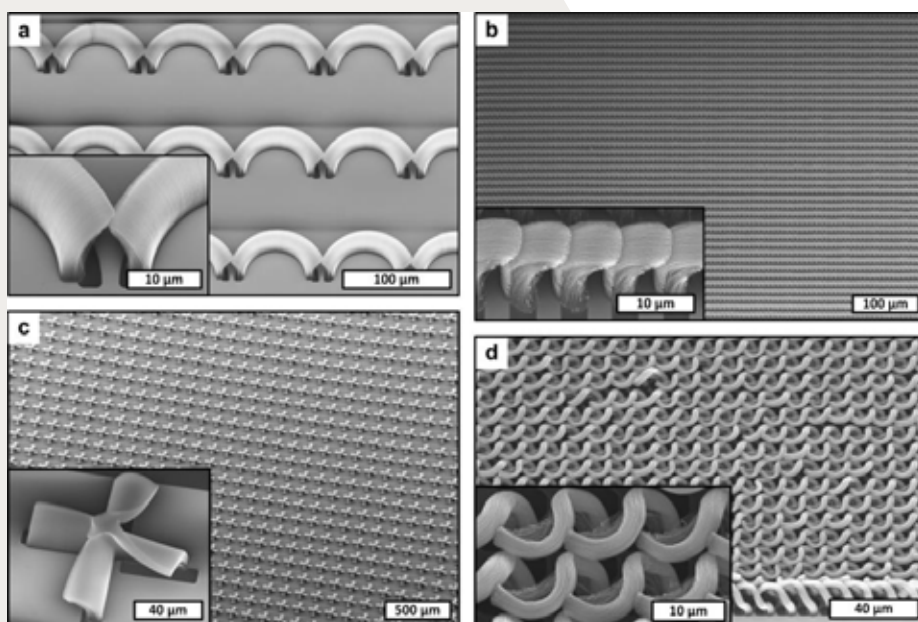


From left to right: Shahab Ahmad, Hadi Modarres, George Chandramohan, Jean de la Verpilliere, Jae-Hee Han (Visiting Professor), Michaël De Volder, David Beesley, Nicolo Chiodarelli, Davor Copic, Sarah Jessl, Laura Maggini

Council, the European Union's Marie Curie scheme and the EPSRC, the Group is exploring new ways of fabricating such carbon nanotube-based devices by, for instance, combining lithography with chemical engineering techniques.

We have already made a significant breakthrough in the manufacturing of microstructured surfaces, which was published in a recent issue of *Nature Communications*. Microstructured surfaces can exhibit a variety of useful properties, including controllable mechanical stiffness and strength. They can even replicate the intricate structures found on the skins of certain plants and animals, making it possible to produce surfaces which have, say, the water-repellent or adhesive characteristics displayed by some insects. This particular technique works by causing carbon nanotubes to bend as they grow and form controllable complex shapes in three dimensions (see right). The process could also be used to engineer other properties, such as electrical and thermal conductivity and chemical reactivity, by attaching various coatings to the carbon nanotubes. In the meantime, our technique is already being put to good use, making surfaces which are being used as chemical microsensors, batteries and biomimetic smart surfaces.

The promise of nanotechnology is such that billions of dollars of public money have been and continue to be spent on research by national governments. We are now reaching a tipping point where we understand the physical properties of



A variety of 3D CNT microstructures fabricated by a process developed by IfM's NanoManufacturing group in collaboration with the Mechanosynthesis Group at MIT.

many nanoparticles and how to produce them sufficiently well to start them on their journey to commercialisation. Indeed, it may come as a surprise to learn that CNTs are already being used commercially in a variety of products ranging from sporting goods and batteries to cars and bullet proof vests. This is only the beginning: we will soon see these small but mighty structures being put to many different uses.



1966: students on the first Advanced Course in Production Methods and Management (now the MPhil Industrial Systems, Manufacture and Management)

# 50 years of manufacturing at Cambridge



**2015 is an important year for the IfM. This October sees the 50th annual intake of students on its MPhil in Industrial Systems, Manufacture and Management. This was a pioneering course when it was first conceived and its twenty-first century graduates are more sought after than ever. October 2015 is also when Professor Sir Mike Gregory retires after 20 years leading manufacturing research, education and practice at the University of Cambridge and we welcome his successor, Professor Andy Neely.**

It seemed, then, an opportune moment to pause and reflect on how we have got here. As with all such endeavours, the journey has been part strategic and part serendipitous but underpinning it all has been a commitment to furthering our knowledge of manufacturing in its broadest sense, and passing that knowledge on to industry and government and to successive generations of talented students.

In many respects, the IfM is following in the footsteps of James Stuart, the first 'true' Professor of Engineering at Cambridge (1875-1890). An educational innovator and a passionate advocate of putting theory into practice, he challenged the conventions of his day. When faced with what he considered to be inadequate teaching facilities, undeterred he created a workshop for his students in a wooden hut and, less popularly, installed a foundry in Free School Lane. The story of manufacturing at Cambridge is imbued with his indomitable spirit.

## THE 1950s, 60s AND 70s

### **The start of manufacturing education in Cambridge: the Advanced Course in Production Methods and Management**

In the 1950s Britain was still an industrial Goliath. Manufacturing accounted for around a third of the national output and employed 40 per cent of the workforce. It played a vital role in rebuilding post-war Britain but for a number of reasons – including a lack of serious competition and an expectation that it would provide high levels of employment – there was

little incentive for companies to modernise their factories or improve the skills of their managers and workers.

In those days, it was the norm for engineering graduates to go into industry as 'graduate apprentices' for a period of up to two years. In practice, this was often badly organised, resulting in disappointment and frustration for all concerned.

Sir William Hawthorne, Professor of Applied Thermodynamics (and later Head of Department and Master of Churchill College), was himself an unimpressed recipient of graduate training. He likened apprenticeships to an unpleasant initiation ritual "in which people had their noses rubbed in it and then rubbed other peoples' noses in it." Even if you were lucky enough to avoid having your nose rubbed in anything, your apprenticeship probably involved "standing next to Nelly and watching what they did". Hawthorne could see that this approach perpetuated current practice and inhibited innovation and entrepreneurship.

He decided that Cambridge could – and should – do something about it and asked his colleagues John Reddaway and David Marples to devise some short industrial courses for graduates. These comprised lectures, discussions and site visits and looked at how a whole company operated – how it organised its engineering design, production control, welfare and marketing. And the courses seemed to work. They were run very successfully for the aircraft engine manufacturer, D. Napier & Son Ltd. and based on this experience, Reddaway, Marples and Napier's head of personnel J. D. A. Radford, wrote a paper on "An approach to the techniques of graduate training". They presented this paper to the Institution of Mechanical Engineers in 1956 with the suggestion that it would

take over the running of these courses and make them widely available. Although the courses – and the paper – were well received, with no sense of urgency over the need to improve current practice, the enterprise succumbed to a lack of funding. In the meantime, Reddaway had been asked by the University to produce a plan for a course similar in style and content that would last a year. This became known as the Reddaway Plan. But there was no money to recruit someone to run it so the plan gathered dust for the best part of ten years.

During those ten years concern was beginning to mount over Britain's lagging productivity and its declining share of world export markets. Successive governments embarked on a series of policy interventions and manufacturing became something of a national preoccupation. When John Reddaway was asked to talk about his plan at a conference of the Cambridge University Engineering Association in 1965, there was perhaps a greater imperative for change. In attendance was Sir Eric Mensforth, the Chairman of Westland Aircraft. Coincidentally, Reddaway had been an apprentice at Westland and when Mensforth established a scholarship at Cambridge, Reddaway had been its first recipient. Mensforth offered the University £5,000 if they could get the Reddaway Plan off the ground.

Also in the audience was Cambridge alumnus, Mike Sharman, who immediately volunteered to leave his lectureship at Hatfield Polytechnic to run the course, even though Mensforth's contribution amounted to just two years' worth of funding.

The Advanced Course in Production Methods and Management was up and running the following year, with its



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first intake of 12 students. Lasting a full calendar year, and designed to emulate professional rather than student tasks and disciplines, the course involved an intense series of real two-to-three week projects in factories across the country, interspersed with lectures from practitioners as well as academics.

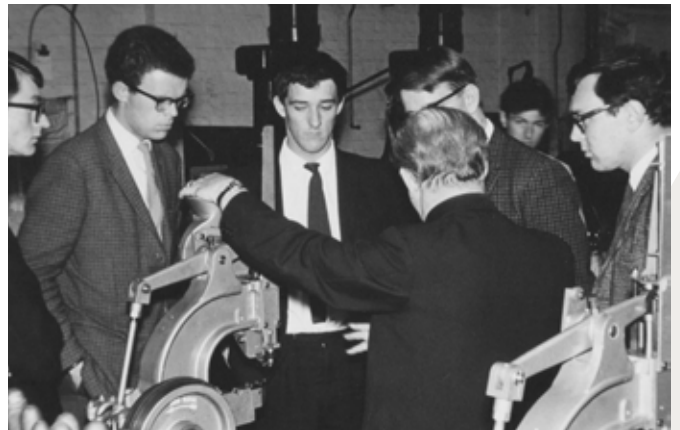
The projects, typically analysing and improving factory operations, were almost always successful – sometimes spectacularly so. Industry responded well to seeing these students getting to grips with the practicalities of engineering and manufacturing and graduates from the course were, and continue to be, much in demand. The notion that going into a factory and undertaking short, intensive projects would be an effective way of learning was nothing short of

revolutionary. It stretched the students and gave them the confidence to tackle increasingly difficult tasks, developing them very rapidly into people who really could go on to become ‘captains of industry’.

Mike Gregory took the course in its fourth year: “For many of us who were introduced to the world of engineering and manufacturing through the ACPMM, the experience was quite literally life changing. We students were swept along by Mike Sharman’s enthusiasm, not to mention the thrill of travelling around the UK and overseas, visiting and working in all manner of factories. How to make a Volkswagen Beetle, how to make a tennis racket, how to put the flavour on both sides of a potato crisp – we learnt all this and much, much more.”

In 1987 a design option was added to ACPMM and it changed its name to the Advanced Course in Design, Manufacture and Management (ACDMM). This was in response to the growing recognition of the importance of design as a competitive differentiator.

But the path of ACPMM/ACDMM did not always run smooth. For many years the course occupied an anomalous position within the University, which remained suspicious of it and would periodically try to close it down. Until 1984, when Wolfson College agreed to take it in, it did not have a proper University home which meant the students were not members of the University. Funding was a perpetual problem, particularly when universities were required to be more accountable for their spending. For many years, ACPMM



The first year of ACPMM





Year 17 ACPMM students emerging from a mine

did not have a qualification attached to it and the University Grants Committee (UCG) would only fund universities on the basis of the numbers of students who were awarded degrees or diplomas.

Another unusual aspect of the course was that in the 1970s it developed relationships first with the University of Lancaster and then Durham as a way of both expanding its teaching expertise and extending its geographical reach into companies the length and breadth of Britain. This became an additional complication when funds began to be allocated on the basis of student numbers and the administrative task of sharing the funding equitably between the partners proved to be too difficult to resolve. In 1996 Cambridge was left to forge ahead on its own.

The qualification problem was solved when Professor Colin Andrew arrived in the mid-80s and set about devising an examination which would allow for the awarding of a diploma. He managed to persuade both Mike Sharman and the University that this was a good thing to do. But as one hurdle was surmounted another would appear. Other funding shortfalls emerged as the awarding bodies offered fewer studentships and cut support for staff. In this not entirely conducive environment, ACDMM was

looking to increase its student numbers. At this point, David Sainsbury (now Lord Sainsbury of Turville and Chancellor of the University) and the Gatsby Charitable Foundation intervened. The continuation of ACDMM was consistent with one of Gatsby's primary charitable objectives – to strengthen science and engineering skills within the UK – so Gatsby agreed to provide funding for a five-year period.

Mike Sharman finally retired in 1995, having been awarded an MBE the previous year for his endeavours. Tom Ridgman

arrived from the University of Warwick with a 20-year career in the automotive industry behind him and took over as Course Director in 1996. In 2004, still facing funding challenges and after a thorough review of the options, the course was renamed again – Industrial Systems, Manufacture and Management (ISMM) – and became an MPhil. It was reduced to an intensive nine months, concluding with a major dissertation. This resulted in an immediate increase in student numbers and the course today, under the stewardship of Simon Pattinson, is oversubscribed by a factor of five, and attracts candidates of an exceptionally high calibre from all over the world.

### A new course for undergraduates: Production Engineering Trip

In the 1950s and 60s an undergraduate degree in engineering at Cambridge was all about science and mathematics – management was very much the poor relation. David Newland, who went on to be Head of Department between 1996 and 2002, recalls that as an undergraduate in the 1950s there were just two lectures a week on management, timetabled for Saturday mornings, “which was when most people played sport and, in any case, there was a perception that you could just waffle your way through the exam questions.”

By the 1970s, Britain's manufacturers were >>>



Recent ISMM students on an overseas study tour

seeing their share of global export markets continue to decline and were facing an array of domestic challenges, not least in the area of labour relations.

Governments continued to pursue industrial policies and announced that the University Grants Commission would consider applications for a four-year engineering degree course rather than the conventional three years, as long as the focus was on preparing graduates for industry rather than research. The Department of Engineering responded with a proposal, which was accepted, to establish the Production Engineering Tripos (PET). This was a first for Cambridge: it allowed engineering students to specialise for their last two years in learning about manufacturing both from an engineering and a management perspective. The intention was to equip these very bright students with the theoretical and practical knowledge and ability to solve real industrial problems – and the skills and experience to hold their own in a factory setting.

Mike Gregory who had been recruited in 1975 by Mike Sharman to work on ACPMM moved across to set up the new PET course. In 1988 PET changed its name to Manufacturing Engineering Tripos (MET) to reflect the breadth of its approach. From the early days of John Reddaway's short courses there had been a recognition that manufacturing was concerned with much more than just 'production' and encompassed a range of activities which included understanding markets and technologies, product and process design and performance, supply chain management and service delivery.

By 1997 Mike, as we shall see, was increasingly busy and passed the running of the course on to Ken Platts. Ken steered MET through its first teaching quality assessment before handing it over first to Jim Platts and then to Claire Barlow who ran it successfully for many years. Today's MET students, like 'ISMMs', are very much sought after and the course has produced a string of distinguished alumni who have launched successful start-ups, transformed

existing manufacturing organisations, developed new technologies and delivered a wide range of new products and services around the world.



Mike Gregory and MET students on the overseas research project, 1988.

## THE 1980s AND 90s

### Research and practice go hand in hand

During the 1980s and 1990s UK manufacturing continued to shrink as a proportion of national output. But if manufacturing in the UK was in decline, it was proliferating in both scale and complexity elsewhere. Japan, in particular, was combining automation with innovative working practices and was achieving spectacular results both in terms of quality and productivity. Manufacturers of all nationalities were going global, building new factories in developing countries giving them access both to rapidly growing new markets and cheaper sources of labour. Now manufacturers were in the business of managing interconnected global production networks and taking an even broader view of their role – subcontracting parts of their operation to other businesses.

While large companies were becoming increasingly international, entrepreneurship was thriving close to home. The 'Cambridge Phenomenon' – a cluster of technology, life sciences and service-based start-ups – was underway

and beginning to attract the attention of researchers.

When Colin Andrew was appointed as Professor of Mechanics in 1986, the name of the chair, at his request, was changed to Manufacturing Engineering. This signalled a new direction for the Department and a growing recognition that manufacturing was an important subject for academic engagement. Around the same time, Mike Gregory admitted to harbouring an ambition to establish a manufacturing institute. Colin was sympathetic to the idea, but counselled that a convincing academic track record was a prerequisite for such a task. With characteristic energy, Mike took up the challenge and set about developing a set of research activities which would reflect the broad definition of manufacturing that was already informing both undergraduate and postgraduate teaching.

Ten years later the foundations were in place. In 1994, on Colin Andrew's retirement, Mike was appointed as Professor of Manufacturing and Head of a new Manufacturing and Management Division within the Department of Engineering. An embryonic Manufacturing Systems Research Group was beginning to make a name for itself. Had James Stuart been around, he would have recognised a fellow unstoppable force.

### Management research

Following a series of industrial and academic consultations in 1985 and 1986 an EPSRC Research Grant, Manufacturing Audit, was won. It explored how manufacturing strategies might be understood and designed in a business context. The recruitment of Ken Platts from TI's research labs in 1987, and his pursuit of the project as a PhD topic, resulted in a sharper academic focus and the publication of a workbook on behalf of the Department for Trade and Industry, *Competitive Manufacturing: a practical approach to the development of manufacturing strategy*.

Ken's appointment was important in a number of ways. It established the precedent for bringing in people with



industrial experience to research posts and it embedded the principle that manufacturing research at Cambridge should be useful for industry, both in its subject matter and in its outputs. The workbook became the blueprint for a distinctive way of working. For each major research project, a book would be produced that would give managers working in industry a set of tools and approaches they could apply themselves. The fact that this first attempt went on to sell in the region of 10,000 copies was also helpful in establishing Cambridge's credentials.

Ken's work demonstrated the potential for taking an 'action research' approach to management. In other words, instead of relying on surveys and case studies, important though these were, the researchers would take their theoretical models into companies and test them in real-life situations. This strand of research led to the Centre for Strategy and Performance and established an approach that would be widely adopted across the IfM. Ken's early work also attracted funding from the Engineering and Physical Sciences Research Council. This large, rolling grant enabled the recruitment of additional researchers, including one Andy Neely, and established Cambridge as a serious player in the field of manufacturing strategy and performance measurement.

The next key research appointment was of David Probert in 1992, another ACPMM alumnus who, like Ken, came from industry. Building on the foundations laid by Mike and Ken in manufacturing strategy, David identified and focused on what was becoming an increasingly common conundrum: whether a manufacturer should make a product or part itself, or outsource it to a supplier. David's work in this area gained immediate traction with companies and his framework was adopted by Rolls-Royce amongst others. This led directly to EPSRC-funded work on technology management which has since developed into a highly successful and wide-ranging research programme. A principal focus has been on creating robust technology management systems to help companies turn new ideas into

successful products and services. This work coalesced around five key processes: how to identify, select, acquire, exploit and protect new technologies. Strength in this area was bolstered by the addition of James Moultrie's expertise in industrial design and new product development, and, more recently, by the arrival of Frank Tietze with his research interest in innovation and intellectual property. Research into widely applicable business management tools has also emerged as a fruitful area of investigation, with Rob Phaal establishing the IfM as a centre of expertise in roadmapping.

Much of this research activity has been most applicable to large and mid-size companies but there has also been significant interest in more entrepreneurial technology-based activities, not least those taking place in the 'Cambridge Cluster' and the challenges inherent in trying to commercialise new technologies. This work was pioneered by Elizabeth Garnsey in the 1980s and is continued by today by Tim Minshall and his Technology Enterprise Group.

In 1994 Yongjiang Shi joined this small band of researchers to start his PhD on international manufacturing networks. This was the beginning of a whole new research strand which initially focused on 'manufacturing footprint'. Its groundbreaking work in this area led to a major collaboration with Caterpillar and the IfM's Industry Links Unit (more of which later) and the development

of a set of approaches that would help multinational companies 'make the right things in the right places'. As international manufacturing has become increasingly complex and dispersed, the research, under the leadership of Jag Srari, has broadened to encompass end-to-end supply chains, designing global value networks and creating more resilient and sustainable networks. As with the early work on manufacturing footprint, this new research is carried out in partnership with industrial collaborators.

## Technology research

Significant progress had been made in management and operations research when Duncan McFarlane joined the fledgling Division in 1995 bringing his expertise in industrial automation and adding an important technical dimension to the team. Duncan went on to establish the Cambridge Auto-ID Lab, one of a group of seven labs worldwide, leading work on the tracking and tracing of objects within the supply chain using RFID. It was this group that coined the phrase the 'internet of things' and has gone on to lead research in this area. Duncan's team subsequently expanded to encompass a wider range of interests, looking at how smart systems and smart data both within factories and across supply chains can be used to create more intelligent products and services. Ajith Parlikad's work on asset management has become a key part of this research programme and is also integral to the innovative



Installing robots in Mill Lane

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work Cambridge's Centre for Smart Infrastructure and Construction is doing to improve the UK's infrastructure and built environment.

Production processes were clearly an important topic for a manufacturing research programme and a new group drawing on work from across the Division was set up to address it in the late 1990s. In 2001, GKN funded a new chair in Manufacturing Engineering to which Ian Hutchings was appointed. Ian came from the Department of Materials Science and Metallurgy and had an international reputation for his work in tribology. He further developed the Production Processes Group, which brought together a number of research activities including Claire Barlow's work on developing more sustainable processes. In 2005, Ian set up the Inkjet Research Centre with EPSRC funding to work with a group of UK companies, including a number in the local Cambridge cluster, to carry out research both into the science behind this important technology and its use as a production process.

In 2003, Bill O'Neill had joined the IfM from the University of Liverpool, bringing with him his EPSRC Innovative Manufacturing Research Centre (IMRC) in laser-based micro-engineering. This became the Centre for Industrial Photonics which is now, with Cranfield University, home to the EPSRC Centre for Innovative Manufacturing in Ultra Precision and the EPSRC Centre for Doctoral Training in Ultra Precision. Both the Distributed Information and Automation Laboratory and the Centre for Industrial Photonics have been able to commercialise their intellectual property through spin-outs, the former setting up RedBite, a 'track and trace' solutions company and the latter, Laser Fusion Technologies which uses laser fusion cold spray technology for a wide range of energy, manufacturing and aerospace applications.

## A new identity

Mike's ambition to create a manufacturing institute finally came to fruition in 1998 when an alliance was forged with the Foundation for Manufacturing and Industry

(the FM&I). This was an organisation set up to help companies understand how economic and policy considerations would affect their businesses and to enhance the public profile of manufacturing in the UK. It brought with it a large network of industrial partners and complemented the Division's now considerable strength and breadth in manufacturing and management research and its embryonic Industry Links Unit (see below). The Institute for Manufacturing was born, embedded in the Engineering Department's Manufacturing and Management Division but with a distinct character and set of capabilities which enabled it to address the challenges manufacturers were facing – and the policy context in which they were operating.

## Policy research

One of Mike's aspirations for the new Institute was to use its manufacturing expertise – both strategic and technical – to support government thinking and to raise awareness of the continued importance of manufacturing in the context of an increasingly service-oriented economy. The merger with the FM&I added an economics and policy dimension to the IfM. This would develop into an important research strand asking the fundamental question: why are some countries better than others at translating scientific and engineering research into new industries and economic prosperity? The IfM's policy research team, founded by Finbarr Livesey and today led by Eoin O'Sullivan, is very actively engaged with the policy community in addressing these questions (see page 6).

As with all IfM undertakings, the intention was that research in this area should prove useful. It is based, therefore, on practical engagement with policymakers to understand their needs and provide outputs which support them in their decision-making. In 2003, Mike also established the Manufacturing Professors' Forum, an annual event which brings together the UK's leading manufacturing academics, industrialists and policymakers to develop a shared understanding of how to create the conditions in which UK manufacturing can flourish.



Farewell to Mill Lane

## Putting research into practice

That notion that the research carried out at the IfM should be of real value to its industrial and governmental collaborators was enshrined in the creation of an Industry Links Unit (ILU) which had been set up in 1997, a year before the IfM came into being. At that time, stimulating fruitful collaborations between universities and industries was not a priority for public funding. The Gatsby Charitable Foundation, which had previously played a critical part in sustaining ACPMM through tricky financial times, believed that fostering such interactions was key to developing long-term economic growth – and that the proposed new unit could have a useful part to play in this regard. It





provided initial funding for the ILU which allowed it to develop the three main strands of activity designed to facilitate the transfer of knowledge: education, consultancy and publications. Gatsby also encouraged the ILU to put itself on a clear commercial footing by setting up a separate, University-owned company (Cambridge Manufacturing Industry Links or CMIL) through which it could generate income from the ILU's activities to fund future research.

CMIL was successfully nurtured through its early years first by John Lucas and then by Paul Christodoulou. In 2003, Peter Templeton was recruited as Chief Executive and by 2009 the range and

scale of its activities had grown to such an extent that the decision was taken to merge ILU and CMIL into IfM Education and Consultancy Services Limited. This created a clearer organisational structure and a name that 'does what it says on the tin'.

### Education services

CMIL aimed to transfer knowledge and skills to people working in industry through a variety of courses, some of which were one- or two-day practical workshops while others were longer programmes such as the Manufacturing Leaders' Programme, a two-year course for talented mid-career engineers and technologists who had the potential

to move into more strategic roles in industry. In 2006, CMIL set up an MSc in Industrial Innovation, Education and Management for the University of Trinidad and Tobago which ran very successfully until 2013 and demonstrated a capability for exporting IfM educational practice. Creating customised courses for very large companies was – and continues to be – an important activity.

### Consultancy Services

By appointing 'industrial fellows', many of them alumni of ACPMM and MET, CMIL was able to establish a consultancy arm which could disseminate and apply the IfM's research outputs to companies of all sizes, from multinationals to start-ups and with national and regional governments. Initially, much of the focus was on small and medium sized manufacturers which, according to former Chairman and CEO of Jaguar Land Rover and longstanding friend and advisor to the IfM, Bob Dover, had been largely neglected by academics. The intention was to give an academic rigour to the decisions the companies were taking, underpinned by research from the Centre for Strategy and Performance. This led to the development of ECS's 'prioritisation' tool which has now been used with more than 750 companies and its 'fast-start' approach to business strategy development.

The consultancy programme has grown steadily in recent years, delivering projects which have had a real impact on the organisations concerned and the wider manufacturing environment. IfM ECS, for example, has facilitated many of the roadmaps which define the vision and implementation plans for new technologies in the UK, such as synthetic biology, robotics and autonomous systems and quantum technologies. In 2012, it was commissioned by the Technology Strategy Board (now Innovate UK) to carry out a landscaping exercise looking at opportunities for high value manufacturing across the UK. It is currently engaged in 'refreshing' the landscape to establish clear priorities for the government and, in particular, to identify areas where investment in manufacturing capabilities ➤➤





The proposed position of the new building on the West Cambridge site

can be maximised by co-ordinating the efforts of delivery agencies.

IfM ECS also carries out a wide range of research-based consultancy activities with companies, including major projects with multinationals to redesign their production networks or end-to-end supply chains. It works with companies of all shapes and sizes to align their technology and business strategies and help them turn new technologies into successful products or services.

## 2000s AND 2010s

### Rapid expansion – and a new home

Since 2000, the manufacturing landscape has changed very rapidly. Disruptive technologies and new business models present threats and opportunities which

industry and governments need to understand, and act upon. An increasingly pressing concern is how we can continue to satisfy the world's appetite for products and services without destroying the planet in the process.

As we have already seen, research, education and practice at the IfM were expanding at speed as we entered the new millennium. In 2001 the IfM was awarded a major grant and became home to one of the EPSRC's flagship Innovative Manufacturing Research Centres which,





19 November 2009: the Duke of Edinburgh unveils the plaque at the opening of the new building, applauded by Dame Alison Richard, the Vice-Chancellor of the University of Cambridge at the time.

when joined with Bill O'Neill's IMRC in 2003, created an organisation of significant size and scope. However, it was operating out of a rather ramshackle set of offices and laboratories in Mill Lane in the centre of Cambridge and this was becoming a limiting factor, to the extent that the new photonics team was exiled to the Science Park.

A fundraising campaign raised £15 million from a number of very generous benefactors, including Alan Reece through the Reece Foundation, and the Gatsby Charitable Foundation, which was enough to build the IfM a new home. In 2009, it moved to its current purpose-built premises on the West Cambridge site. This was a hugely significant development, not only from the perspective of staff comfort and morale. It meant the IfM could host a whole range of events and activities which were useful in themselves but also gave more and more people a glimpse of the work going on there and led to further interest in research collaborations and consultancy projects.

The new building also enabled further expansion of the research programme, through increased office space and laboratory facilities. In 2010, Professor

Andy Neely returned to the IfM from Cranfield – having worked with Ken Platts on performance measurement in the 1990s – to found the Cambridge Service Alliance, which brings together academics and multinational companies to address the challenge an organisation faces when moving from being a maker of products to a provider of services.

A cross-disciplinary Sustainable Manufacturing Group had been operating at the IfM since the late 1990s and developing sustainable industrial practice has been a common thread running through the IfM's various research programmes. In 2011 this was given a significant boost when the EPSRC Centre for Innovative Manufacturing in Industrial Sustainability led by Steve Evans was established within the IfM. This is a collaboration between four universities (Cambridge, Cranfield, Imperial College, London and Loughborough), with a membership programme to ensure manufacturing businesses both help set the research agenda and actively participate in its projects.

Understanding business models is at the heart of many of the IfM's research activities: how can a company add a

service dimension to its business, for example, or learn to operate in a more sustainable way? What impact will new technologies such as 3D printing have on both established firms and new market entrants? How should businesses redesign their operations networks in response to disruptive technologies? Chander Velu has set up a new research initiative which takes a management and economics approach to business model innovation and aims to bring together different perspectives from across the IfM and key UK and international universities to establish a co-ordinated research agenda.

More lab space has allowed the IfM to extend its science and technology research interests, recently acquiring multidisciplinary teams looking at how to manufacture new materials at scale, such as carbon nanotubes (see page 9) and biosensors, led by Michaël De Volder and Ronan Daly respectively. By working with colleagues with policy, management and operations expertise, these teams are able to address the scientific and technological challenges within the broader context of the manufacturing value chain in order to understand the risk factors early on and maximise the chances of successful commercialisation.





IfM common room – a space designed to encourage networking and collaboration.

IfM ECS has continued to expand the range of services it offers. For example, it is currently running a bespoke executive and professional development programme for Atos (see page 27) and is actively expanding its portfolio of open courses and workshops to reflect new research emerging from the IfM's research centres. Similarly, the number of tools and techniques IfM ECS has at its disposal to support industry and government through consultancy is growing to encompass activities such as product design and servitization.

In 2010 IfM ECS took on the management of ideaSpace, an innovation hub in Cambridge which provides flexible office space and networking opportunities for entrepreneurs and innovators looking to start up new, high impact enterprises. As well as helping to create successful new businesses and economic value, ideaSpace also works with governments, agencies and universities to develop policies, strategies and programmes which support a thriving start-up sector.

### Taking stock

Manufacturing research, education and practice at Cambridge have come a long way in the last 50 years but they still remain true to the vision of Hawthorne and Reddaway: manufacturing is about



much more than shaping materials. To understand the complexities of modern industrial systems with their engineering, managerial and economic dimensions you need to be fully engaged with the people and companies that do it 'for real'. The research programme here is now extensive, covering the full spectrum of manufacturing activities. This year the University of Cambridge as a whole received more EPSRC funding for manufacturing research than any other UK university. IfM has an important role

to play not only in doing its share of that research but in facilitating manufacturing research across the University.

Education is thriving. The ISMM and MET courses go from strength to strength and this year we have more than 75 students doing PhDs or research MPhils.

IfM ECS continues to grow, putting IfM research into practice whether redesigning multinational companies' operations networks, helping to develop robust





Using the scanning electron microscope in the Centre for Industrial Photonics

innovation and technology strategies and systems, or delivering executive and professional development programmes and open courses.

### Looking to the future

So where will the next 50 years take the IfM? Our strong sense of purpose will not change – we remain committed to making a difference to the world by improving the performance and sustainability of manufacturing. We will continue to create knowledge, insights and technologies which have real value to new and established manufacturing industries and to the associated policy community. And we will continue to ensure that our knowledge has an impact, through our education and consultancy activities.

But the IfM is fundamentally about innovation. So while we will carry on doing what we do best, we will also look for opportunities to do things differently. We have ambitious plans for the future which include the possible development of a 'scale-up centre', a physical space devoted to supporting the transition of ideas and concepts from lab-based prototypes into scalable industrial applications. James Stuart would have approved of the energy and determination that has gone into



James Moultrie inspiring recent MET students

creating the IfM as we know it today and his pioneering spirit will continue to inspire us. This way we hope to ensure that the next 50 years are even more productive and enjoyable than the last 50.

This article was written by Sarah Fell based on interviews conducted by IfM doctoral students Chara Makri, Katharina Greve and Kirsten Van Fossen with members of staff past and present and with long-standing friends of IfM.



# Connecting the unconnected



**New thinking on  
next generation  
supply chains**



**As the annual Cambridge International Manufacturing Symposium marks its twentieth year Dr Tomás Harrington, Dr Jag Srail and Paul Christodoulou from the IfM's Centre for International Manufacturing (CIM) reflect on the new supply chain thinking that is emerging from companies such as Cisco, Coca-Cola, Jaguar Land Rover, Johnson Matthey, Cambridge University Press and Schneider Electric.**

Supply chain directors from some of the world's leading companies come to our annual Symposium to share their experiences, talk about the challenges they face and the steps they are taking to address them. The audience is a mix of academics and industrialists keen to share ideas and consider new possibilities. This year's Symposium represented something of a turning point. We saw a consensus building around the need for radical transformation towards a new type of supply network.

Dr Tomás Harrington, Senior Research Associate, said: "Four key – and connected – themes emerged loud and clear: developing a 'cleverer together' philosophy; designing more agile and customer-focused supply chains; exploiting the potential of the digital revolution; and addressing the environmental impact of supply chain activities." Running through all of this was a common thread which emphasised the need to connect, network and collaborate across the supply chain, whether through enterprise-wide IT integration at one end of the spectrum or by targeting engagement with supply chain partners at the other.

### **Smarter networking**

This drive towards collaboration was articulated through the mantra of 'better together' – developing a more 'sophisticated' approach to networking by sharing more information, aligning KPIs across the network partners and operating as a community. Being 'cleverer together' was perceived to be an opportunity to drive growth by, ultimately, allowing companies to improve the service they could deliver to their customers.

**"We are looking for increased visibility which allows for proactive resolution leading to better decision-making and, ultimately, a better customer experience."**

*Senior Vice-President, Global Supply Chain Transformation*

Which, of course, is easy to say and hard to do. How do you align and collaborate with multiple network partners, scattered across the globe, all with different specialisms and their own strategic objectives?

Dr Jag Srail, Head of the Centre for International Manufacturing, said: "This challenge resonates with many of CIM's research interests. How, for example can you design a connected end-to-end supply chain? How do you develop successful multi-partner service supply chains? How might changing consumer behaviours and new production technologies influence future supply chain design? We are also starting to think about different ways in which we can further reduce supply network complexity by displacing or eliminating traditional intermediaries who may previously have played a key part in the flow of materials or information. Preliminary thinking suggests that these kinds of 'disintermediation' strategies may, in certain circumstances, offer an alternative route to network optimisation than the usual network integration approaches. They may also help reveal the motivations and challenges firms and their respective networks face in terms of future performance and behaviours."

### **Designing the 'new' supply chain organisation**

Our Symposium speakers talked about a strong correlation between innovation and the supply chain, stressing the importance of reducing time to market and delivering more responsive customer service. Shorter product life cycles are also forcing companies to speed up their decision-making. In the future, supply chain-driven companies will look to organise themselves around agile business processes, and better tailor their supply chain KPIs and incentives to their particular business model. It is definitely not a 'one size fits all' approach.

Paul Christodoulou, Principal Industrial Fellow, explained: "We see a different type of customer-focused and dynamic organisation emerging with agile supply

chains which increasingly cut across business units, functions and geography and a new emphasis on cross-network collaboration. Again, companies will need to make a judgement about the 'level' of collaboration that should exist between partners, whether it should be purely transactional ('arm's length') or strategic (a 'marriage')."

Whichever route they choose, they will need to deal with non-traditional supply chain challenges and to develop a new set of competences across people, processes, products and data to support new business models.

**"Devising clever ways to get supply chain efficiencies through collaboration, despite not owning the business decisions or relationships."**

*Supply Chain Director*

### **A digital future**

One of the answers to this challenge may well lie in the digital future. In recent years we have seen the development of new routes to market, partly driven by innovative e-commerce initiatives, with dominant players such as Amazon having a huge impact on many organisations' supply chains. In the business-to-consumer context, we are seeing vastly improved levels of customer service in various sectors and in the world of business-to-business, smart supply chains are able to deliver 'just-in-time' or 'just-in-sequence'.

Those companies with advanced supply chain capabilities are already harnessing 'big data' analytics and social media to innovate their business model and supply chain design. They are also starting to experience real benefits from bringing together the 'physical' with the 'digital' in the context of end-to-end supply chain integration. Meanwhile, the so-called 'internet of things' is beginning to give supply chain professionals a new set of tools to connect people, products and processes.



This trend is reflected in the work we are doing in CIM as part of the ReMediES project, looking at the UK pharmaceutical supply chain (see page 3). Jag, who is Research Director for ReMediES, said: “As part of the project we are going to look at ‘informating’ next generation supply networks and how IT-enabled and e-commerce-based supply chains are changing the role of information. Equally critical will be how technology developments can reshape the capability of supply chains right through to the consumer or, in this case, the patient.

### Sustainable supply networks

Supply chains and sustainability featured prominently across the two days. Companies are operating in increasingly regulated environments. They are under pressure from their shareholders, customers, local communities, employees (and even interviewees) to demonstrate their commitment to reducing their environmental impact. And, as their international manufacturing and supply chains serve increasingly far-flung markets, they may find themselves imposing stresses on natural resources. Indeed, some are already facing water shortages in

some of the locations they operate in and serve.

The commitment to sustainability, therefore, represents an integral part of future supply chain thinking. In many cases, companies are already addressing this by setting themselves stringent environmental targets. By 2020 Coca-Cola, for example, is aiming to reduce the carbon footprint of every bottle of Coke by a third. Since 2007 Jaguar Land Rover has reduced its carbon footprint by a quarter and, by using cutting-edge lightweight materials and technologies and more recycling it aims to cut it by a further quarter by 2020.

Making these kinds of commitments has implications for everything from company footprint, location decisions, product format, supply and service models. And, even if the company itself is able to address these challenges, how can it be sure that everyone across its supply network is playing by the same rules? And so we come back to our model of collaboration and transparency, enabled by the emergence of digital supply networks.

### A new approach to network design?

So what lessons can we learn from this year’s Symposium? It seems that the larger companies are taking a radical approach to supply chain development – designing new, more responsive, more customer-focused, more sustainable networks. Within complex organisations and across ever more complex networks, digitisation will inevitably play a key part in this transformation, giving companies the information they need to make better and faster decisions and ultimately to capture value from their ability to serve their customers better than their competitors.

But we must not underestimate the scale of organisational change which will be required and the new set of capabilities supply chain professionals will need to develop. Jag says: “CIM will pursue these themes across a number of projects, including ReMediES, but also by extending our work on sustainable and resilient supply networks in particular. We look forward to sharing our findings at next year’s Symposium.”



Mike Gregory gets a standing ovation from delegates at the 2015 Symposium in recognition of his contribution to the field of international manufacturing

## The Cambridge International Manufacturing Symposium

We held our first Symposium in 1995 and since then it has become an integral part of the CIM research programme. It allows us to engage with senior industrialists from a wide range of non-competitive sectors who are willing to share their experiences and insights in open session. As a result, we often find ourselves identifying ‘hot topics’ – such as re-shoring – well before they hit the newsstands. The Symposium helps us to understand companies’ challenges and opportunities, test our thinking and develop shared research agendas.

On day two of the conference we look to integrate rich insights from day one with those from leading academics on the analysis, design and operation of global supply networks, in order to ‘connect’ our future research activities with practice.

**Symposium Director 2015:** Dr Tomás Harrington, Senior Research Associate

Email: tsh32@cam.ac.uk

**Symposium Chair and Head of Centre for International Manufacturing:** Dr Jag Srai

Email: jss46@cam.ac.uk

**Practice Lead:** Paul Christodoulou, Principal Industrial Fellow, IfM ECS

Email: pac46@cam.ac.uk

### 2015 Speakers

Vincent Megglé, *Senior Vice-President, Global Supply Chain Transformation, Schneider Electric*

Paul Mayhew, *Global Supply Chain Director, ECT Division, Johnson Matthey*

Mark Lincoln, *Global Supply Chain Director, Cambridge University Press*

Steve Adams, *Director Supply Chain Operations & Nicholas Nixon, Operations Director, Coca-Cola Enterprises*

Dr Ralf Speth, *Chief Executive & Dr Wolfgang K. Epple, Director, Research and Technology, Jaguar Land Rover*

Mike Lydon, *Vice-President Worldwide Supply Chain Management, Cisco*



# Seeing the bigger picture

How experts at Atos are becoming 'trusted advisors'



## IfM Education and Consultancy Services (IfM ECS) has developed a bespoke executive education programme for IT experts at the global technology company, Atos.

All technology and manufacturing companies face the same challenge. Your business relies on people with outstanding expertise. These experts, by definition, need to be specialists but they also need to have an end-to-end view of how the business works – to see ‘the big picture’ – if they are to find new and better ways to meet their customers’ needs. However, experts are often given training and development which deepens their expertise but does not necessarily broaden their knowledge of organisations. Atos decided to address this challenge by developing a wide-ranging executive education programme specifically for its most talented experts.

Atos SE is a huge global company with annual revenues of around €11 billion and 93,000 staff working in 72 countries. It provides a range of digital services such as consulting and systems integration, cloud operations, big data and cyber security as well as payment and transactional services. Atos’s ambition is to be the undisputed partner of choice for customer digital transformation. It must, therefore provide a fully integrated view, right from infrastructure to application and functional domain to satisfy the needs of its customers and help them become more competitive. Ramon van Knippenberg, from Atos’s Global Talent team, said: “With our experts working in so many different countries and service lines, we need them to see beyond their own geographical and functional boundaries and develop an ‘end-to-end’ view of the business – understanding what the client (and often the client’s customer) wants and how the whole organisation works together to make that happen.”

Atos also regards its experts as important catalysts for change. Ramon said: “Management structures and reward systems can sometimes militate against change. But experts tend to be less constrained by such things. They just want the best solution for their clients.”

Having acknowledged the value of experts, Atos is determined to attract and retain the very best in each area in which it operates. “We want to show that there’s a real career path for experts in this company. You do not need to become a manager to make a career for yourself in Atos.”

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**“With our experts working in so many different countries and service lines, we need them to see beyond their geographical and functional boundaries and develop an ‘end-to-end’ view of the business – understanding what the client (and often the client’s customer) wants and how the whole organisation works together to make that happen.”**

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Which is why, in 2013, Atos started looking for a provider of executive education that could develop a talent development programme for its experts that would mirror its existing ‘Gold for Managers’ business leadership development programme. From the start, the Global Talent team had a clear sense of the kind of education provider it wanted. To give the programme the appropriate level of prestige within the organisation it had to be one of the world’s leading universities or business schools and it had to be willing to create a programme tailored very precisely to Atos’s needs. Those needs included working with the University of Paderborn in Germany.

Getting two universities to collaborate on programme development and delivery certainly added to the complexity of the task. But Atos had a very good reason for insisting. When it acquired Siemens IT and Solutions in 2011, it also took over its relationship with the Cooperative Computing and Communication Laboratory at Paderborn, known as C-LAB. C-LAB is a joint research and development laboratory, originally set up by the pioneering German computer company Nixdorf – itself taken over by Siemens in 1990 – in which academics and experts from Atos work together on a range of research projects. For the Gold for Experts programme, C-Lab was always going to be a core part of the delivery team.

Atos presented its requirements to some of the top institutions in Europe and the US and chose the University of Cambridge’s Institute for Manufacturing. Ramon said: “We were very much looking

for a partnership – an organisation which would be willing to co-develop a course with us. If you buy something off the shelf, your competitors can do the same. This was not our philosophy. The IfM had the expertise we were looking for around innovation and technology management, the experience of developing and delivering successful executive education programmes and was prepared to work with us and our colleagues in Paderborn to create a programme that is unique to Atos.”

The Universities of Paderborn and Cambridge have some similar features. Paderborn may only be 40 years old but it is recognised as a leading centre of computing research and is home to the world’s largest computer museum, the Heinz Nixdorf MuseumsForum.

Cambridge, meanwhile, has been in the business of advancing knowledge for more than 800 years endowing the city with a very unique architectural and cultural heritage. Judith Shawcross, Head, Executive and Professional Development at IfM ECS said: “Those of us who live in and around Cambridge take it for granted but it does provide a genuinely inspirational setting for our courses.”

From Paderborn’s perspective, working with IfM ECS was also an opportunity to hone its own executive and professional education capabilities. Professor Gregor Engels from the Faculty of Computer Science, Electrical Engineering and Mathematics at the University of Paderborn said: “Extending our teaching beyond students to people working in industry is one of the University’s primary objectives. Working alongside an experienced education provider like the IfM ECS has taught us a lot about how to structure and present courses to industry.”

### Creating the course

IfM ECS uses the Kirkpatrick Business Partnership Model to underpin its executive and professional development programmes. To get a clear picture of the context for the programme, Atos’s first recourse was to Journey 2016, a report produced every two years by Atos’s ‘Scientific Community’ – a group of the company’s top experts – which anticipates the technology shifts that will affect the



business environment over the following four years.

The IfM ECS team then worked with Atos's senior executives to understand the business, its strategy and challenges, how they defined their 'expert talent' and what they wanted them to achieve. Armed with this information, IfM ECS was able to guide a process of programme development structured around clear themes which integrated IfM's expertise on innovation and technology management and Paderborn's on the technologies themselves. The result was a programme of three one-week modules taking place over a sixth-month period, the first and last held in Cambridge and the middle one in Paderborn. In both locations, the course is delivered by a combination of Paderborn and Cambridge tutors and very senior executives from Atos.

Ramon said: "Cambridge has guided us very well through the process of defining programme aims, module aims and learning outcomes of all the sessions. The end result is an integrated programme with a variety of sessions, some existing Cambridge and Paderborn ones tailored to our needs, some newly designed sessions and some provided by Atos people."

### Going for Gold

It is hard to get on the Gold for Experts course. Just 30 people are selected by the Atos Group Executive Committee to join each intake and the programme is only run twice a year. The chosen participants, understandably, have very high expectations of it. Ramon observes that the profiles of the experts can present something of a challenge: "With

the experts, every group is different with different interests which means no course is ever the same."

Feedback from the participants can reflect the demands they make on the course. A member of the most recent cohort, while expressing his appreciation, made it abundantly clear that he was not prepared to take anything as read: "You interested me, challenged me, surprised me, even irritated me sometimes but you certainly did not leave me indifferent. I have had some very inspiring times and appreciated all this knowledge put in its global perspective giving a consistent vision of the challenges we, as Atos, but also as individuals, are going to face in the coming years."

### Learning through doing

'Active learning' is central to IfM ECS's design ethos: applying new principles both within the modules and back in the workplace so that they are fully understood and assimilated. A further benefit of this highly interactive approach is the bond it forms between participants. After six months they know each other extremely well, and leave with a network of fellow experts they can call on from across the business. A key component of active learning is project work. Every participant submits a project proposal designed to address a real issue of strategic importance. Six projects are selected by Atos and the participants choose which ones they would like to work on. Based on those preferences, five are assigned to each project, supervised by three tutors: one from the IfM, one from Paderborn and one from Atos. They work on the projects throughout the sixth

months of the programme and present their findings on the last day to a panel of very senior Atos Executives.

Some of the project ideas have already been taken up and are being developed within the business. For example, the thinking behind Atos's current new offering for Hyperscale Virtual Desktop Infrastructure Hyperscale Services, due to be launched in 2016, was developed as a project idea. These services are already live for a number of customers and further innovations in this area are on their way.

Judith Shawcross said: "Projects are a really important way of ensuring that new skills and knowledge are fully assimilated by the delegates. Putting what you have learnt into practice, with the support of your tutors and in-house sponsors, is an effective way of learning and can, of course, have very immediate benefits for the company."

Atos has just signed up for another two years. The Global Talent team is already seeing higher than average retention levels amongst those who have been on the course. And, as Ramon explained: "What we are getting out of the programme are 'trusted advisors' and 'networked influencers'. 'Trusted advisor' is an important concept at Atos. To be trusted you need to know what you are talking about but, crucially, you also need to recognise your limitations and know who to ask to get the right answers. And that's why being part of a network is so important." As more and more experts go through the programme, the network expands. And this is going to be critical in helping Atos realise its ambitions.



Atos delegates getting to grips with servitization with help from Andy Neely,

IfM ECS runs bespoke executive and professional development programmes for large manufacturing and technology companies.

To find out more, contact Judith Shawcross, Head of Executive and Professional Education at IfM ECS: [jks45@cam.ac.uk](mailto:jks45@cam.ac.uk)

[www.ifm.eng.cam.ac.uk/  
executiveeducation](http://www.ifm.eng.cam.ac.uk/executiveeducation)

## The alumni interviews

# MET over lunch



Jonathan Duck, CEO, Amtico

Jonathan Duck took the Production Engineering Tripos (PET) 1981-1983, when it was only in its third year. It was renamed the Manufacturing Engineering Tripos (MET) soon after.

Jonathan is currently CEO of Amtico, a design-led flooring manufacturer. In 2003 he invested in a management buyout of the company and then led a secondary buyout in 2006. In 2012 he sold Amtico to the US company, Mannington Mills.

After graduating from PET, Jonathan became a management consultant, first with the Boston Consulting Group and then McKinsey. He then went to Bass PLC, where he was Divisional Director running various drinks, gaming and retailing business units before becoming the CEO of Access Self Storage, a private equity-backed property company.

Jonathan also has an MBA from Harvard Business School.

He was talking about PET and how it has influenced his career to Dr Ronan Daly, head of the IfM's Fluids in Advanced Manufacturing Group and a lecturer on today's MET course.

### **What made you choose PET?**

I think I was quite unusual in that when I applied I already knew that I wanted to do a 'Monty Finniston' course. Sir Monty Finniston was Chairman of British Steel and he had been asked to head up a committee addressing the UK's shortage of qualified engineers. His point was that the country needed engineers who understood business and he recommended that universities should offer much broader, business-based engineering courses - which is what PET was. This seemed a very sensible approach and I had this confirmed when I arrived

by friends in the years above who told me what good fun PET was proving to be. They were still doing some numbers and applied maths but they were also doing lots of other things which I felt would be a much better training for business than just following the pure engineering route.

### **I gather that you had to have some experience of using workshop tools before you started?**

It used to be the case that you couldn't do Part IA unless you had done four weeks in an apprentice training school learning how to weld and use

a lathe and so on. You also had to spend something like eight weeks on the shop floor. It was very useful to do that before starting university because once you are on a course or have graduated you are known as 'the student'. But if you turn up when you are 17 or 18 you are just mucking in with everyone else and you see the factory from the perspective of the shop floor - and that is a very different view of what's going on than the one management has. You only have that opportunity once. It also teaches you some other very valuable lessons such as that just because you've been

to university doesn't make you any cleverer than people who haven't and some of the most astute people you meet are on the shop floor. When I was doing my apprentice training at Kodak we were asked to explain how an SLR camera worked. The task was given to one of my fellow apprentices who had left school at 15 and he was absolutely brilliant. He knew much more about it than I did or any of the rest of us who had done physics A- and S-levels.

### **Was it always the business side of manufacturing that you were interested in?**

Yes, the bits I found most interesting were microeconomics, the theory of the firm. But the course was incredibly varied. We did some employment law and went off to a couple of industrial tribunals. We also learned about organisational behaviour, decision-making and corporate finance. And this was all being taught to us at a reasonably advanced level. When I went to Harvard Business School, I was pleasantly surprised to find I'd already done quite a lot of the syllabus. We were also given the option of taking the Certified Diploma in Accounting and Finance which about half of us did because



Cambridge always has this reputation of being about questioning, trying to understand what's really going on.

it was useful to understand the basics of inventory and management accounting and I still find myself using all that now. Again, that seemed to cover about half the first year finance syllabus at Harvard. PET gave us a very good general business grounding.

**What about the production engineering aspect of the course?**

We did all that stuff about debottlenecking and reducing cycle times. People talk about lean manufacturing now but it's really just a packaged up version of what we learnt here. Mike Gregory had a session once a week where he would hand out, say, a set of plugs and a hammer to smash them up with. You had to work out how they had been made – which bit was cast, which was forged, which was stamped, why they were made from a particular sort of plastic. And you might have an expensive plug and a cheap plug and have to work out how costs had been saved on the cheap one. It is very useful to understand how and why something has been made in a certain way.

The production engineering side of the course definitely gave me the knowledge to



The Amtico factory in Coventry

do the practical stuff when I need to – and also to know when to get someone else in! I sometimes wander around Amtico late in the evening and there may be a problem with the process machinery. I don't understand the machine in any detail but I know enough to identify the likely source of the problem.

**What about student projects? Were they useful?**

Ours was developing an industrial hoist. The idea was that you set up your own company and as well as doing the design you had to come up with all your profit and loss, balance sheet and crucially, cash flow forecasts. And this was awkward because we didn't have software in those days so I had several bits of A3 stuck together with the numbers on them and if someone changed an assumption in Month One I had to cascade it through my spreadsheet and work it out 'by hand'.

But this whole experience of pitching for finance, structuring a business plan and making sure you would get a return on your equity investment turned into something I revisited when I borrowed money from banks and private equity to do management buyouts. I've now done this three times and a lot of the basic principles came out of my PET student project.

**When you are recruiting graduates, what are the things you are looking for?**

Cambridge always has this reputation of being about questioning, trying to understand what's really going on. There's a certain independence and free spirit of thinking that gets honed on this course. When recruiting you want people who will challenge the status quo. I suppose in a way just going down your regular engineering course is following a path – doing PET is a little bit different so the people coming out of it are a little bit different. When I was working for the

At least once a week you would laugh until you cried. >>>



This course has had a very profound effect on what I've done in the rest of my life in ways I would not have expected.

with your old mates when you see them again. We all stay in touch.

**How did you end up at Amtico?**

It came around at the right time. I was looking for a business which could be improved and it was around the time people were starting to talk about rebalancing the UK industrial economy. But that was something that Mike had already drummed into us on PET: how vital manufacturing is to a national economy. So my role at Amtico has been twofold: first, the simple task of making a business better and, second, trying to rebalance my little part of the West Midlands economy, to actually export something and to compete with Chinese manufacturing. Which I'm pleased to say we've been able to do.

We were reshoring seven or eight years ago before it became fashionable and since then we have been able to steadily increase the number of jobs both in our US and UK factories. That is a really important part of what we do. And the process has been an interesting example of PET principles – you can compete with the Far East if you think about what you are doing. Not long after I arrived I introduced a new product

line which I decided to make in China. This meant we were able to see what the Chinese were doing and adopt their best ideas when we brought the production back. A lot of what I learnt about production on PET came in very useful and certainly helped us to get down to the Chinese cost position.

**How important has PET been in your career?**

This course has had a very profound effect on what I've done in the rest of my life in ways I would not have expected. I'm convinced that Amtico could have gone backwards and given up all its manufacturing. And it certainly would have done if I'd listened to everybody including all the banks. But I deliberately went in the other direction. PET taught me to take a different path and it drummed into me the message that manufacturing is important. You can't live off banking alone – that's a house where the plumbing has taken over.

Boston Consulting Group and McKinsey and doing regular undergraduate recruitment we would go out of our way to look for people coming out of MET. For one thing, they had graduated the previous year so you knew what class of degree they had got and, secondly, they had already had a go at working on student projects so they had been 'housetrained' around what you do and what you don't do when you get deposited in a company. They already had the ability to diagnose and make recommendations within a two to three week time frame. Quite honestly, it gave them an unfair advantage.

**I get the impression that you quite enjoyed the course...?**

The first two years of the engineering degree was all lectures and rather theoretical. The PET course was an enormous amount of fun. Partly because it's a bit like having away matches in sports teams – you are off doing your industrial projects, staying in dubious hotels, working in companies with all sorts of problems but you are doing it with your fellow students and you get really close to them and that meant it was a very, very enjoyable couple of years. At least once a week you would laugh until you cried. And you pick up very quickly





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To find out more, contact Judith Shawcross: [jks45@cam.ac.uk](mailto:jks45@cam.ac.uk)

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