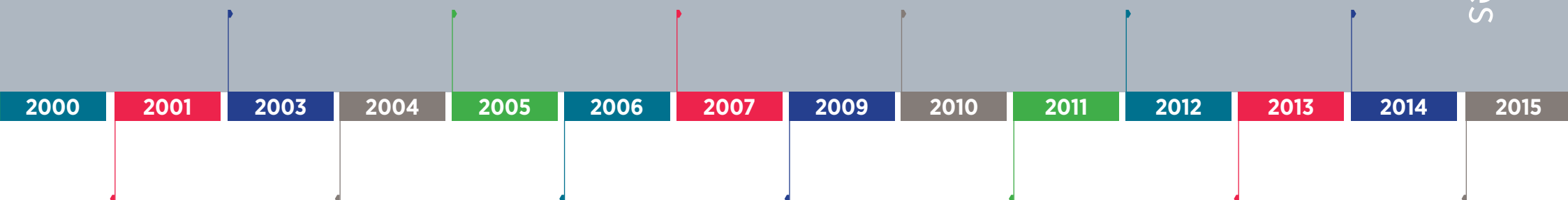


people, projects and activities

2016

50

# INSTITUTE FOR MANUFACTURING



## INSTITUTE FOR MANUFACTURING (IfM)

With a focus on manufacturing industries, the IfM creates, develops and deploys new insights into management, technology and policy. We strive to be the partner of choice for businesses and policymakers, as they enhance manufacturing processes, systems and supply chains to deliver sustainable economic growth through productivity and innovation.

Our primary mission is scholarship, world-leading research and education that:

- ▶ Creates knowledge, insights and technologies of value to established and emerging manufacturing industries and the associated policy community.
- ▶ Develops the skills and capabilities of people – researchers, students and engineers/managers – by providing a stimulating educational environment and a great place to work.
- ▶ Has an impact through knowledge transfer and application, as well as by influencing future research directions.

## IFM EDUCATION & CONSULTANCY SERVICES LIMITED (IFM ECS)

IfM ECS works with companies of all sizes to help them create and capture value and with national and regional governments to support and grow their industrial sectors. It does this by transferring the new ideas and approaches developed by researchers at the IfM through a programme of education and consultancy services. IfM ECS is owned by the University of Cambridge. Its profits are gifted to the University to fund future research activities.



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# The Institute for Manufacturing 2015–16

2015 was a busy year for the IfM. In September we said goodbye to our founder Professor Sir Mike Gregory and I was delighted to take over as his successor. September also saw us hosting the EPSRC Manufacturing the Future Conference, in the same year that the University of Cambridge received more EPSRC funding for manufacturing research than any other UK university. And in October we celebrated the arrival of the fiftieth intake on our postgraduate course in Industrial Systems, Manufacture and Management.

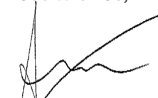
Other notable achievements during 2015, included:

- ▶ Convening an international policy forum at the White House with senior UK and US government officials
- ▶ Moving into the next phase of the £22m REMEDIES project to redesign the UK's pharmaceutical supply chain
- ▶ Concluding the three-year ERDF-funded PrISMS project, having helped 126 small and medium-sized companies improve their business processes and, in many cases, achieve significant growth.
- ▶ Undertaking a review of the UK's high value manufacturing landscape on behalf of Innovate UK

2016 promises to be equally busy as we continue to develop and share our insights into some of the big issues facing manufacturers today: how to harness the potential of the digital revolution, how to adopt the right business models and how to do all of this while preserving the planet for future generations.

We look forward to addressing these challenges with our academic, industrial and policy partners. Only by working together can we hope to make significant progress.

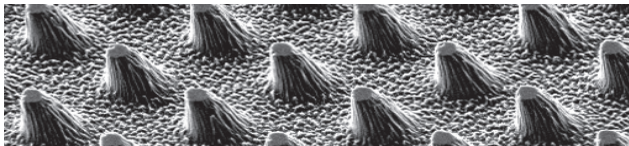
Best wishes,



Andy Neely

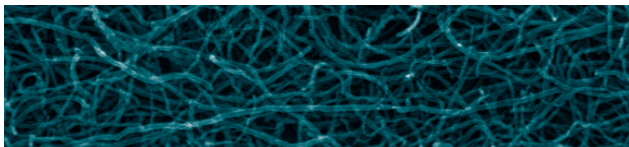
# ▶ NanoManufacturing

Our research focuses on the development of scalable technologies to structure nanoparticles such as carbon nanotubes, graphene, and metal oxides into well-defined superstructures. These may find application in sensors, electronics, catalysis, energy storage, water purification, and smart materials.



## Smart materials

Etched glassy carbon micro and nanostructures



## Scalable coating techniques

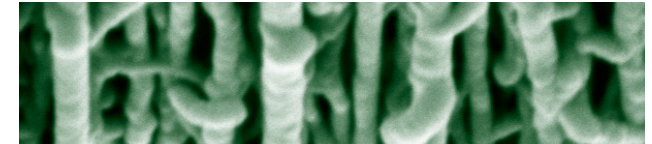
Nanoparticle suspension, printing, and roll to roll processing

## Background

Worldwide commercial interest in nanoparticles is reflected in an exponential increase in their production capacity. For instance, the current production capacity of carbon nanotubes (CNTs) now exceeds several thousand tons per years. These nanoparticles are used in diverse commercial products ranging from rechargeable batteries, automotive parts, and sporting goods to boat hulls and water filters.

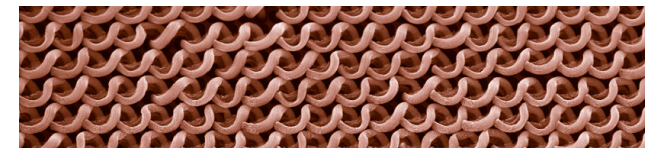
## Current challenges

Unprecedented mechanical and electrical properties are reported for individual nanoparticles. However, most engineering applications require the assembly of tens to millions of these nanoparticles into one device. Unfortunately, the figures of merit of such assembled materials typically drop by at least an order of magnitude in comparison to the constituent nanoparticles. It is therefore mandatory to expand our knowledge about manufacturing processes enabling more controlled nanoparticle organisation.



## Synthesis of Hybrid Materials

Metal and metal oxide decorated hybrid nanomaterials



## Bottom up self-assembly of nanoparticles

Capillary and stress induced interactions for nanotube self-assembly

## PEOPLE

**Centre Head:** Michaël De Volder

**Researchers:** Shahab Ahmad, David Beesly, Davor Copic, Nicolo Chiodarelli Chadramohan George, Laura Maggini

**Research students:** Simon Engelke, Sarah Jessl, M. Hadi Modarres, Jean de la Verpilliere

**Contact:** [mfld2@cam.ac.uk](mailto:mfld2@cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/nanomanufacturing](http://www.ifm.eng.cam.ac.uk/nanomanufacturing)

## ➤ Inkjet Research Centre

The Inkjet Research Centre (IRC) carries out research into the generic science which underlies this important technology. We have expertise in drop-on-demand and continuous inkjet processes, related fluid mechanics, high-speed visualisation, analysis and computation to study jet and drop creation, drop flight and drop/surface interaction.

### Current research

Our research is currently focused on applying methods of image analysis to liquid jets and drops, assisting in the development of international standards for measurement of droplet size and velocity, and investigating aerodynamic and electrostatic effects in inkjet printing.

### ➤ Innovation in industrial inkjet technology: I4T: 2010-2015

The IRC led a consortium which was awarded a £5 million EPSRC grant to investigate fundamental questions in inkjet printing technology and improve its value for manufacturing and printing applications.

Consortium members included two other Cambridge departments, the Universities of Durham and Leeds and a group of eight companies which included the major UK players in the inkjet sector.

The award, with additional funding from industry, supported a five-year programme of research to study the formulation, jetting and deposition of specialist printing fluids, and develop an overall process model.

This work led to improvements in the robustness of industrial inkjet printing and will help companies develop new applications for the technology such as flat-panel displays, printed electronics, and photovoltaic cells for power generation.

### ➤ Additive manufacturing

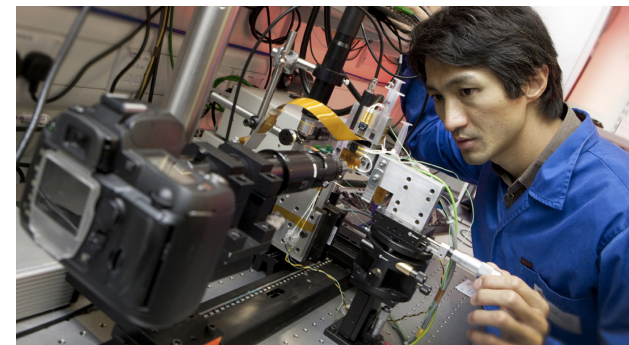
The IRC is investigating the use of micro-extrusion methods for the fabrication of 3-D components, with potential for multimaterial processing.

### ➤ Impact acceleration

Several projects involving university-industry partnerships have been funded by the EPSRC Impact Acceleration Scheme. These are short projects in which researchers spend part of their time with a company and part at the university in order to help transfer knowledge developed during our inkjet research and extend the work into relevant technology development.

### ➤ Electrohydrodynamic printing

In a recent short project in collaboration with Queen Mary, University of London, we used our visualisation and analysis tools to study electrospray systems designed at QMUL which are capable of creating very small drops with orders of magnitude less volume than conventional inkjet. We have been extending this work to investigate a novel mode of electrostatically-controlled drop generation.



### PEOPLE

**GKN Professor of Manufacturing Engineering:**  
Ian Hutchings

**Director of Inkjet Research Centre:** Graham Martin

**Researchers:** Ching-Hsien Chen, Ronan Daly, Steve Hoath, Cristina Rodriguez-Rivero

**Centre Administrator:** Alice Cozens

**Contact:** [irc-enquiries@eng.cam.ac.uk](mailto:irc-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/irc](http://www.ifm.eng.cam.ac.uk/irc)

# ➤ Fluids in Advanced Manufacturing

As we get better at developing advanced functional materials, we need new manufacturing techniques coupled with scientific understanding to turn them into real products and devices. The FIAM group examines firstly the chemical and physical phenomena of polymeric, biological and nanoscale materials when used in advanced fluid-based manufacturing techniques and fluidic devices. This allows us to then research new device platforms and manufacturing techniques that will bring these emerging technologies to an industrial scale. Our work is divided into four themes:

## 1: Soft matter and fluid flow

We research polymeric, biological, and nanoscale materials to learn about their behaviour under a range of forces while also controlling their final function. Activities include the study of:

- Mechano-chemical effects on macromolecules during manufacturing
- Interfacial phenomena of microdroplets
- Supramolecular self-assembly
- Fluid-based self-organisation techniques

## 2: Advanced digital manufacturing with fluids

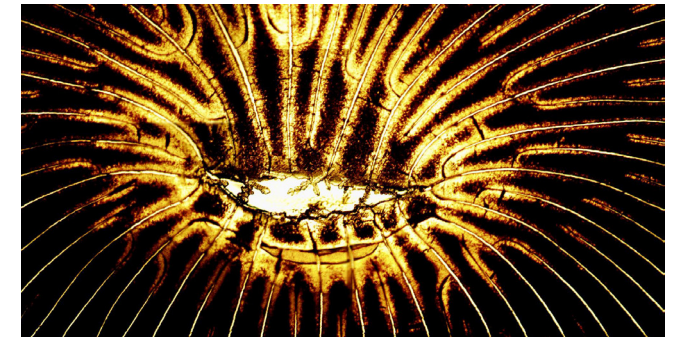
Working with the IfM's Inkjet Research Centre, we strive to enhance the capabilities of inkjet printing as it grows into a powerful additive manufacturing tool. We also create and research new digital manufacturing routes for advanced functional materials. Activities include the study of:

- Inkjet printing of biological and nanoscale materials
- Microscale 3D printing
- Hybrid inkjet/laser manufacturing research
- Inkjet printed fabrication of porous polymer biomaterials

## 3: Fluidic device platforms

The study of interfacial science and fluid flow phenomena allows us to drive breakthroughs in a range of new device platforms. Activities include:

- Improving control of microfluidic flow in channels and porous media
- Point-of-care diagnostic device fabrication
- Acoustic sensor technique optimisation
- Novel biosensing element design and fabrication



## 4: The science of scale-up

We are examining how to identify and tackle scale-up challenges of emerging technologies at an earlier stage in their development. Activities include:

- Identifying risk factors facing emerging technologies during scale-up
- Early lab-based investigation of scale-up challenges
- Automation of additive manufacturing

### PEOPLE

**Head of Group:** Ronan Daly

**Research students:** Yoanna Shams, Qingxin Zhangr, Cassi Henderson, Tadas Kartanas

**Contact:** rd439@cam.ac.uk

**Web:** www.ifm.eng.cam.ac.uk/fiam

# Centre for Industrial Photonics

The Centre for Industrial Photonics (CIP) is engaged in a wide range of research and development topics that focus on advancing the state of laser and ion beam manufacturing technologies across length scales from nanometres to hundreds of metres.

Research activities go beyond the traditional application of lasers, like localised delivery of optical energy, to perform materials processing operations such as cutting, welding and heat treatment.

CIP focuses on novel laser matter interactions through the application of ultrafast laser pulses, conditioned laser energy profiles that lead to designer materials, efficient laser-based production routes and in-process control methodologies.

## Key research areas

### ► Metal coatings

This is a Cambridge-developed production process that enables novel combinations of materials and metals to be deposited on a substrate for the production of 3D components. The process is in its final stages of commercial development, and is being taken to market by a new University spin-out company, Laser Fusion Technologies Ltd.

### ► Manufacturing processes

New programmes starting this year include: the development of a low-cost laser 3D printer aimed at the schools market; a laser-based gasification technology for extracting energy products from fossil fuels; laser processing of carbon nano tubes and wires for improved electrical performance; high-speed, laser-based additive fabrication technology for metals; and a laser-forging process for shock hardening of metals.

## Working with industry

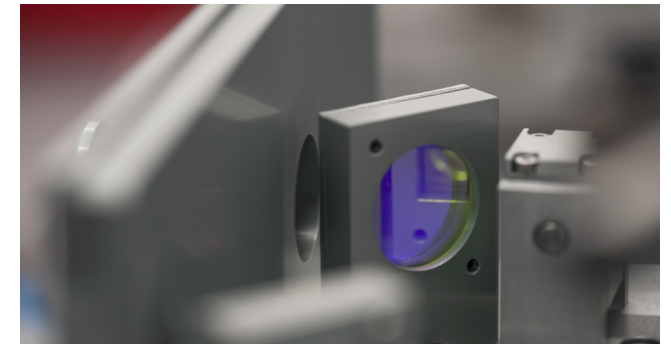
CIP's work is supported by national and international firms that compete in sectors including medical devices, packaging, photonics, communications technologies, oil and gas, energy generation, automotive and aerospace. It is well placed to deliver innovative solutions to industry as well as skilled postgraduates that can take new technologies into industry and increase the global competitiveness of the UK manufacturing base.

## EPSRC Initiative

CIP is home to the Cambridge arm of the EPSRC Centre for Innovative Manufacturing in Ultra Precision, the EPSRC Centre for Innovative Manufacturing in Laser-based Production Processes, and the EPSRC Centre for Doctoral Training in Ultra Precision.

## EPSRC Centre for Doctoral Training in Ultra Precision

The CDT in Ultra Precision is a part-taught, part-research course studying the application of ultra precision technologies. Modules are split between Cranfield and Cambridge, covering conventional and non-conventional machining precision manufacturing techniques. The MRes provides a platform from which students can build their PhD studies.



## PEOPLE

**Centre Head:** Bill O'Neill

**Researchers:** Andrew Cockburn, Krste Pangovski, Martin Sparkes, John Bulmer

**Embedded Researcher:** David Hopkinson

**Research students:** Matthew Bannister, Sam Brown, Tianqi Dong, Wenhe Feng, Jiho Han, Laurent Michaux, Francisco Orozco, Jon Parkins, Andy Payne, Nicky Soane, Jason Ten, Chris Wright, Karen Yu, Alexandre Diaz, Daniel Gortat

**MRes students:** Lily Delimata, Nadeem Gabbani, William Fowler, Katjana Lange, James Ryley

**Centre Administrators:** Alice Cozens, Sophie Fuller

**Technician:** Franco Ussi

**Contact:** [cip-enquiries@eng.cam.ac.uk](mailto:cip-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/cip](http://www.ifm.eng.cam.ac.uk/cip)

# ➤ Distributed Information and Automation Laboratory

The Distributed Information and Automation Laboratory (DIAL) studies ways in which advanced information systems and automated identification technologies, such as radio-frequency identification (RFID), can be combined with advanced emerging industrial automation and asset management systems to create and deploy smart products, flexible, reconfigurable operations and innovative services.

## Key research projects

**Industrial uses of internet of things:** an early initiator of the 'internet of things' concept, DIAL is examining its role in manufacturing.

**Infrastructure asset management:** development of whole-life value models for key infrastructural assets, and strategies for ensuring futureproofing of infrastructure in the face of disruption events and changes in usage.

**Integrating 3D printing into distributed production networks:** examining control and automation challenges associated with the integration of additive manufacturing techniques into more conventional manufacturing environments.

**IT Architectures for Logistics Integration (ITALI)** is developing new logistics IT architectures to enable more efficient and flexible logistics operations.

**Disruption Tolerant Automated Lean Factories (DisTAL):** a 3-year project funded by Boeing, to improve the resilience of manufacturing automation in the face of operational disruptions.

**Reconfigurable off-site production of modular housing:** Working with Laing O'Rourke and supply chain partners developing strategies for future production environments for modular housing such that the automation and supply chain logistics are resilient to future changes.

**Virtual Intelligent Prediction & Response (VIPR):** a three-year project funded by Boeing on how to make use of third-party data to predict and anticipate supply chain disruptions.

DIAL has three tools designed to help companies overcome some key operational challenges:

- **Automation Assessment Tool:** for companies considering automation, this is a quick and effective way of assessing the opportunities and the feasibility of implementation.
- **Industrial Resilience Audit:** diagnoses where processes are experiencing disruption, the impact of disruptions, and helps identify short-term fixes and define longer-term plans to develop more flexible production processes.
- **Information Quality Assessment Tool:** analyses the risks that poor information quality poses to companies in their asset management and identifies the best way to mitigate the risk.

**Contact:** [dial-enquiries@eng.cam.ac.uk](mailto:dial-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/dial](http://www.ifm.eng.cam.ac.uk/dial)



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## PEOPLE

**Centre Head:** Duncan McFarlane

**Deputy Director, DIAL:** Ajith Parlikad

**Technical Officer, DIAL:** Alan Thorne

**Researchers:** Phil Catton, Rachel Cuthbert, Vaggelis Giannikas, Tariq Masood, Alena Puchkova, Raj Srinivasan, Jумыung Um, Pascal Wichmann, Philip Woodall, Alexandra Brintrup

**Research students:** Joel Adams, Mudassar Ahmed, Torben Jess, Zhenglin Liang, Wenrong Lu, Nipat Rasmekomen, JiaQiang Wang, Brian Robertson, Hao Li

**Centre Administrator:** Petra Kasmanova

**Technician:** Simon Sennitt

**Industrial practitioners:** Liz Salter, Nick Sherwin



## ➤ Asset Management Group

Asset Management is one of the key focus areas of research within DIAL. The Asset Management Group studies innovative ways in which industrial assets and systems should be maintained and managed in order to deliver maximum performance while minimising costs and risks over their whole life. In particular, the group is interested in exploring how emerging trends in information systems such as predictive analytics and Big Data can be exploited for better asset management.

### Key research projects

**Whole-life management of infrastructure assets:** funded by the Centre for Smart Infrastructure and Construction, this project focuses on developing tools and methodologies to support through-life decision-making and information management for infrastructure assets such as rail networks, bridges and highways.

**Prognosis-based maintenance:** funded by Hitachi Rail, this activity focuses on developing tools for scheduling maintenance for complex systems based on predictive analytics.

**Maintenance of complex systems:** focuses on developing condition-based maintenance policies for systems that involve complex phenomena such as interactive deterioration and fault propagation amongst their components.

**Asset management performance:** focuses on helping asset-intensive organisations to design an effective performance measurement system that allows monitoring and management of their asset management systems.

**Criticality-based maintenance:** aims to develop a model that will combine several multi-criteria decision making techniques to identify factors that influence changes in criticality and to exploit the dynamic nature of criticality to generate dynamic CBM strategies adjusted to business needs.

**SUSTAIN-OWNER:** funded by the EU H2020 programme, this projects aims to develop a framework that helps industries understand and manage the whole-life cost and value generated by their assets.

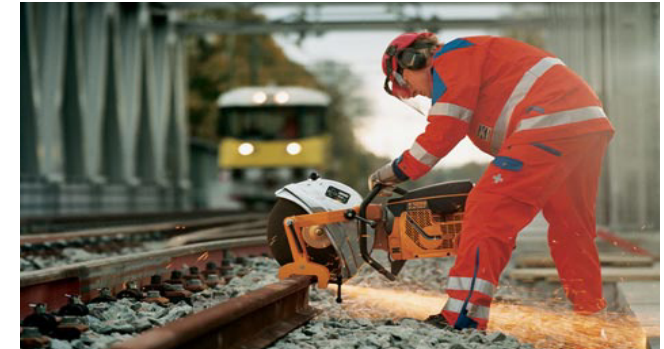
**Facebook for Machines:** a new research activity that aims to deliver a step change in efficiency and performance to the world of manufacturing by bringing together the advances in three domains – the Internet of Things, Social Networking and Engineering Asset Management.

**Reconfigurable off-site production of modular housing:** Working with Laing O'Rourke and supply chain partners developing strategies for future production environments for modular housing such that the automation and supply chain logistics are resilient to future changes.

**Virtual Intelligent Prediction & Response (VIPR):** a three-year project funded by Boeing on how to make use of third-party data to predict and anticipate supply chain disruptions.

**Contact:** [dial-enquiries@eng.cam.ac.uk](mailto:dial-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/asset-management](http://www.ifm.eng.cam.ac.uk/asset-management)



### PEOPLE

**Group Head:** Ajith Parlikad

**Researchers:** Phil Catton, Tariq Masood, Raj Srinivasan

**Research students:** Joel Adams, Mudassar Ahmed, Torben Jess, Zhenglin Liang, Wenrong Lu, Nipat Rasmekomen, JiaQiang Wang, Brian Robertson, Hao Li

**Centre Administrator:** Petra Kasmanova

# ➤ Centre for Strategy and Performance

The Centre for Strategy and Performance (CSP) combines academic objectivity with industrial know-how to help companies tackle their strategy and performance management. We aim to understand and improve the way strategic choices are made, plans are developed and implemented, and performance is measured and achieved.

## Research themes

- Strategy modelling and visualisation
- Strategic decision making
- Competences, capability and resource analysis
- Performance measurement
- Innovation strategies and systems
- Start-up strategy

## Approach

- Developing effective techniques for formulating strategy and designing performance measurement systems
- Working closely with industry so that our understanding of best practice is constantly updated
- Providing practical tools for industrial managers and consultants
- Interpreting and disseminate research findings

## Key projects include

**Strategy for start-ups:** developing strategy for start-ups when bringing a new technology, product or service to market.

**Innovation ecosystems:** investigating the attributes and enablers of innovation ecosystems. This is a multiple country study, initially comprising Finland, Germany and countries in the Middle East and North Africa.

**Business strategy process:** developing a facilitated process that helps identify markets and competences, and create vision and action in small and medium manufacturers.

**Capability and resource analysis:** studying the way companies co-ordinate resources to improve capabilities and performance.

**Performance measurement systems:** developing systems to evaluate and improve performance measurement in industrial companies.



## PEOPLE

**Centre Head:** Ken Platts

**Deputy Head:** Mohamed (Mark) Khater

**Research students:** Carmina Buzuloiu, Tanya Edwards, Philipp Egger, Rich Morales, Tomasz Szejner, Claus Weidinger

**Industrial practitioners:** Nicky Athanassopoulou, Derek Ford, Duncan Hurlstone, Steve Chicken, Andi Jones, Liz Salter, Nick Sherwen, Martin Smith, Nick Sullivan, John Thomas

**Contact:** [csp-enquiries@eng.cam.ac.uk](mailto:csp-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/csp](http://www.ifm.eng.cam.ac.uk/csp)

# Centre for Technology Management

The Centre for Technology Management (CTM) is concerned with the effective integration of technological considerations into business decision making. We support industrial managers and the wider technology management community by providing a focus for practical research, a forum for industry-academic discussion, a professional interface with industry and a range of industrially related services.

## Approach

- ▶ Working closely with industry in a wide range of sectors including aerospace, automotive, utilities, pharmaceuticals, telecommunications, steel-making and fast moving consumer goods
- ▶ Disseminating our research findings to companies through reports, workshops and forums
- ▶ Developing technology managers through bespoke executive education
- ▶ Strategic Technology and Innovation Management Consortium – practice-oriented research and networking collaboration with industrial partners.

**Contact:** [ctm-enquiries@eng.cam.ac.uk](mailto:ctm-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/ctm](http://www.ifm.eng.cam.ac.uk/ctm)

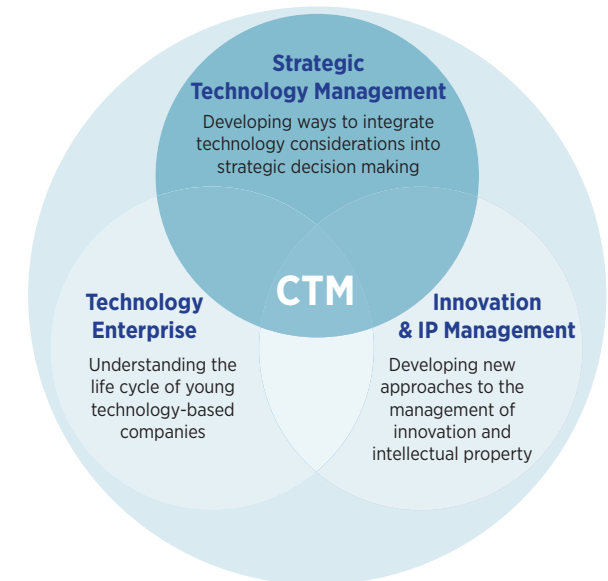
## Key projects

**Digital fabrication:** cross-disciplinary research to understand the emergence of additive manufacturing technologies, effective business models, and their impact on the UK economy.

**Visualisation for strategy and innovation:** improving understanding and practice for supporting strategic dialogue and communication.

**Strategic technology management toolkits:** how methods such as roadmapping, project selection, portfolio management, patent analytics and scenario planning can be integrated in a systematic and practical way.

**Strategic intellectual property management:** supporting decision making and technology transactions as part of the innovation process.



## PEOPLE

**Centre Head:** David Probert

**Academic staff:** Tim Minshall, Frank Tietze

**Researchers:** Mélanie Despeisse, Clare Farrukh, Simon Ford, Clive Kerr, Rick Mitchell, Letizia Mortara, Rob Phaal

**Research students:** Dayo Abinusawa, Dominik Deradjat, Mingjin Guo, Nitish Gupta, Yuta Hirose, Kyounglim Lee, Zhenyu Liu, Mohd Nazri Mahmud, Ahmed Mashhour, Elliott More, Hyunkyung Park, Judith Shawcross, Sullivan Songhe Ye, Tianyi Wang, Mark Wilson, Bang Ming Yong, Bingqing Zhao

**Research Assistant:** Geraldine Guceri

**Industrial practitioners:** Nicky Athanassopoulou, Clemens Chaskel, Bill Colquhoun, Andrew Gill, Colin Haden, Jonathan Hughes, Imoh Ilevbare, Steve Mann, Ricardo Nakazawa, Dominic Oughton, Jim Trueman, Michèle Routley, John Saiz, Nick Sherwin.

# ➤ Technology Enterprise Group

The Technology Enterprise Group (TEG) is focused on research and education relating to the origins, start-up and growth of technology-based ventures and their impact upon the economy.

## Research themes

- Open innovation
- Emerging technologies
- Skills development for technology enterprise and innovation

## Key projects

- Value creation and capture from additive manufacturing/3D printing (AM/3DP)
- Role of AM/3DP in the re-distribution of manufacturing operations
- Innovation ecosystems for emerging technologies
- Strategic uses of corporate venture capture
- Business models for open innovation.
- Development of technology-based social enterprises
- Skills development for emerging technology-related enterprise and innovation

## Activities

### ➤ Bit by Bit: 3D Printing Interest Group

As part of the Bit by Bit research project on “Capturing Value from the Digital Fabrication ‘Revolution’”, TEG is using social media to support the debate on the emergence of 3D printing.

[www.dfab.info](http://www.dfab.info) and [www.twitter.com/dfab\\_info](https://www.twitter.com/dfab_info)

### ➤ Open Innovation Research Forum (OIRF)

OIRF is an international network of researchers looking at the challenges of implementing open innovation, supported by the Institute for Technology, Enterprise and Competitiveness (ITEC) at Doshisha University in Japan.

[www.oirf.net](http://www.oirf.net) and [www.twitter.com/camoinet](https://www.twitter.com/camoinet)

### ➤ Cambridge Technopole

TEG provides resources to support debate on the evolution of the Cambridge high tech business cluster.

[www.cambridgetechnopole.org.uk](http://www.cambridgetechnopole.org.uk) and [www.twitter.com/camtechpole](https://www.twitter.com/camtechpole)

### ➤ University enterprise activities

Activities supported by TEG include the University Enterprise Network, Cambridge University Entrepreneurs, and the i-Teams programme.

[www.enterprisenetwork.group.cam.ac.uk](http://www.enterprisenetwork.group.cam.ac.uk)



## PEOPLE

**Head of Group:** Tim Minshall

**Researchers:** Mélanie Despeisse, Simon Ford, Letizia Mortara

**Research students:** Dayo Abinusawa, Dominik Deradjat, Sullivan Songhe Ye, David Weiss, Mark Wilson, Bang Ming Yong

**Contact:** [tim.minshall@eng.cam.ac.uk](mailto:tim.minshall@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/teg](http://www.ifm.eng.cam.ac.uk/teg)

# ➤ Design Management Group

It is widely accepted that the design of great products and services has a key part to play in a firm's success. The way in which the product development process is managed is critical to this success. The Design Management Group is interested in how design can be effectively managed to create sustainable, desirable, usable and producible new products and services. We are also active in understanding and promoting the importance of design at a national level.

## Research themes

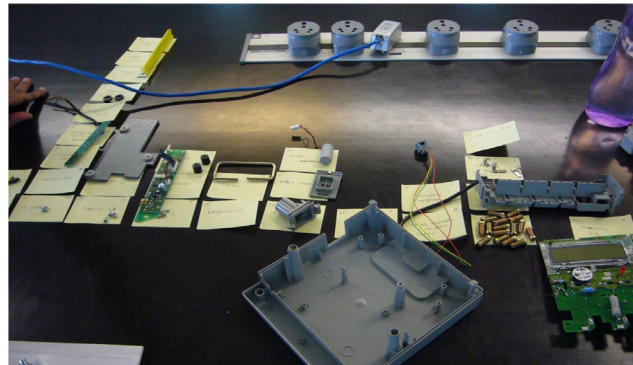
- Measuring the value of design
- Integrating design and technology
- Designing sustainable new products
- New approaches to managing product development
- Design trends and strategic design management

## Activities

### Cambridge Academic Design Management

**Conference:** hosting a biennial international conference

**Tools for managing new product development:** in partnership with IfM Education and Consultancy Services, we are developing simple visual tools for the improvement of product development management, especially in small firms.



## Key projects include

**A simple approach to design for manufacture:** there are a range of methods for helping designers evaluate the producibility of new products. We have developed a simplified form of these for use in a workshop setting.

**User involvement in New Product Development (NPD):** exploring the ways in which firms involve users in new product development.

**A toolkit for sustainable design:** enabling designers and engineers to better understand the complexities of sustainable design.

**Design management in the retail industry:** exploring the tension between the role and contribution of design management in large retailers in the UK, US and EU.

**Design in science:** the role of design in the early stages of technology development, working with Cambridge scientific research projects.

## PEOPLE

**Head of Group:** James Moultrie

**Researcher:** Zicheng Zhu

**Research students:** Wei Liu, Clara Aranda-Jan, Jayné Franck, Yuuki Shigemoto, Bohao (Richard) Li, Thomas Whitney

**Industrial practitioners:** Colin Haden, Steve Mann

**Contact:** [dmg-enquiries@eng.cam.ac.uk](mailto:dmg-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/dmg](http://www.ifm.eng.cam.ac.uk/dmg)

# Centre for International Manufacturing

The Centre for International Manufacturing (CIM) focuses on strategic and operations management in close collaboration with industrial partners. The Centre provides expertise and support in the areas of international manufacturing and supply networks, particularly factory/plant management, operations network configuration and design and the development of capabilities.

## Research themes

### Strategic network design

**Designing a production footprint to reduce cost and increase responsiveness.** Global production networks design projects aim to reduce cost, improve access to growing markets and vital resources, and improve agility and resilience in the face of changing market conditions.

**Gaining competitive advantage across the end-to-end supply chain.** Research addresses the key challenge associated with taking a more extended or even end-to-end supply chain perspective – the alignment of configuration and capability across both internal functions and external partners.

**Developing a successful service supply network.** A new set of approaches has been developed to help companies configure these complex multi-organisational networks of service partners.

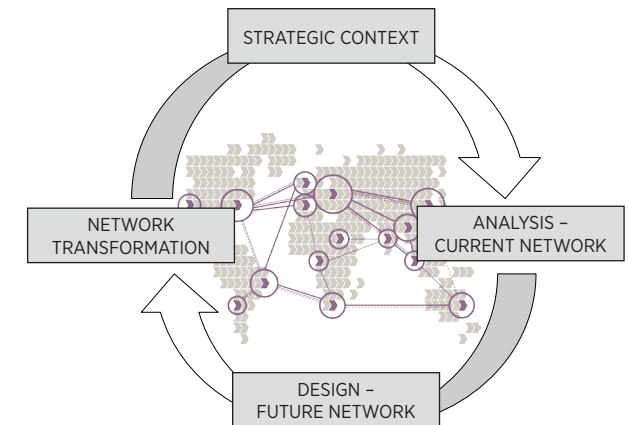
**Configuring global value networks.** Structured approaches that support the needs of both the corporate strategist and the national policymaker to guide the mapping of complex industrial ecosystems, the configuration of new and disrupted global value networks, and the integration of these networks to enhance performance.

## Emerging themes

- Risk and resilience
- Sustainable supply networks
- E-commerce-driven 'last-mile' logistics
- Digital supply chain design
- Network integration and (disinter-)mediation
- Reshoring-offshoring and distributed manufacturing models

## Approach and activities

- Researching new approaches to the understanding of industrial systems from a complex network perspective.
- Investigating disruptive supply networks that support novel business models.
- Developing a strong academic-industrial-institutional community where network design requires both industrial and policy perspectives.
- Hosting the annual Cambridge International Manufacturing Symposium bringing together industry, researchers and policymakers to discuss key themes.
- Working with multinational companies across a range of sectors on capturing value from their global operations networks.



## PEOPLE

**Centre Head:** Jag Srai

**Researchers:** Paul Beecher, Tomás Harrington, Paul Hennelly, Dimitra Kalaitzi, Mukesh Kumar, Ettore Settanni, Yongjiang Shi, Nikolaos Trokanas, Naoum Tsolakis, Ekaterina Yatskovskaya

**Research students:** Yuanjun Chen, Arsalan Ghani, Xingkun Liang, Stanley Lim, Yang (Jonathan) Liu, Yuankun (Luke) Luo, Pavan Manocha, Huey Yuen Ng, Mark Phillips, Xianwei Shi, Guangbo (Norman) Zhang, Yinjie (Jessy) Zhou

**Centre Administrator:** Karen Smith

**Industrial practitioners:** Paul Christodoulou, Don Fleet, Eric Harris

**Contact:** [cim-enquiries@eng.cam.ac.uk](mailto:cim-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/cim](http://www.ifm.eng.cam.ac.uk/cim)

# ➤ Cambridge Service Alliance

**The Cambridge Service Alliance** brings together industrial and academic partners to find innovative solutions to the challenges of designing and delivering high-performance complex services.

## From products to solutions

Complex service provision is becoming increasingly important as the business models of technology and manufacturing companies become more service- and less product-oriented.

Close to 60% of US manufacturing firms now offer services and solutions to supplement their products. In the public sector, governments are commissioning based on outcomes and delivery. Even traditional, product-oriented industries such as aerospace, defence and transportation are becoming increasingly service-based.

The services provided (and used) in these industries are examples of complex service systems, where organisations must manage several areas of complexity simultaneously

The Cambridge Service Alliance exists to help companies address these challenges. Working with our partners, we define and execute agreed programmes of research designed to push the boundaries of knowledge, as well as deliver practical benefits to Alliance members.

## Key research areas for 2016

- business models – understanding value
- data and analytics
- making the shift to services

## Cambridge Service Week 2016

Held every October, Service Week includes events for academics, practitioners and member organisations of the Alliance to address the evolving challenges facing service education, research, practice and policy.

## Cambridge Service Alliance partners

University of Cambridge, BAE Systems, Caterpillar, IBM, Pearson, Rolls-Royce.



## PEOPLE

**Alliance Director:** Andy Neely

**Professor of Industrial Information Engineering:** Duncan McFarlane

**Researchers:** Ornella Benedettini, Tor Boe-Lillegraven, Ivanka Visnjic Kastalli, Veronica Martinez, Janet McColl-Kennedy, Ajith Parlikad, Florian Urmetzer, Chander Velu, Anna Viljakainen, Mohamed Zaki

**Research students:** Katharina Greve, Xia Han, Jingchen Hou, Jianyu Ji, Chara Makri, Zimeng Zhang

**Support:** Jacqueline Brown, Angela Walters

**Industrial practitioners:** Andrew Gill, Colin Haden, Duncan Hurlstone, Charlotte Mitchell, Michèle Routley Liz Salter, Nick Sullivan

**Contact:** [contact@cambridgeservicealliance.org](mailto:contact@cambridgeservicealliance.org)

**Web:** [www.cambridgeservicealliance.org](http://www.cambridgeservicealliance.org)

# Business Model Innovation

This research programme applies economic and management theories to innovation issues, with a particular focus on the reasons for, and consequences, of business model innovation. It collaborates with a number of IfM research centres on business model innovation, covering technology, management and policy. It also runs courses on business model innovation based on the ongoing research.

## Key research projects

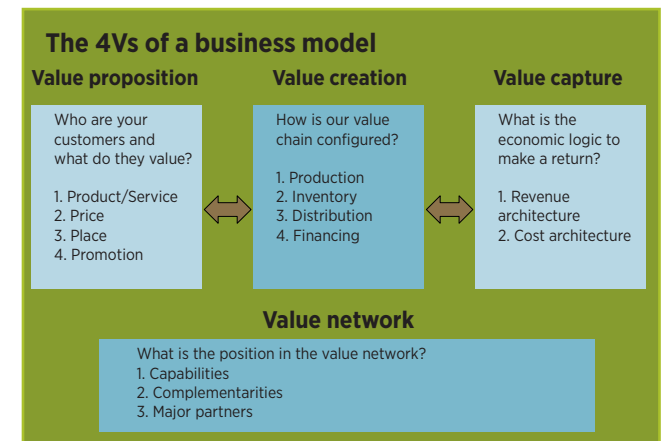
**Business model innovation in digital fabrication:** examines the emergence of new business models in relation to digital fabrication technologies and the business model transition challenges faced by incumbent firms. This research is funded by EPSRC and ESRC grants and done collaboratively with the Centre for Technology Management and the Inkjet Research Centre.

**Business model innovation and business ecosystems:** studies firms moving from a relatively closed to a more collaborative innovation business model with an ecosystem of firms. It has three main strands:

- ▶ The type of governance systems firms need to be better at identifying and responding to intelligence gathered through working with ecosystem partners.
- ▶ Similarities and differences between manufacturing and service firms in their approaches to searching for new ideas in the market place.
- ▶ The transformation challenges of firms moving to a service-based business model with an ecosystem of firms (Project within the Cambridge Service Alliance).

**Business model innovation and entrepreneurship:** examines how the degree of technology dependence of business models of start-up firms influences the survival of these firms. It also considers how the innovative nature of incumbent firms influences entrepreneurial spawning.

**Business model innovation and economic development:** examining the role of business models and technology for economic development, particularly for countries that have experienced some economic development and are looking to accelerate growth to catch up with more advanced economies. The research group is part of the Malaysia-UK Innovation Alliance and seeks to support the exchange of knowledge and intellectual property between Malaysia and the UK through the application of science, technology and innovation. A number of scholarships for PhD students to examine these issues have already been set up and further collaborations are planned.



Source: Chander Velu (2015)

## PEOPLE

**Head of programme:** Chander Velu

**Researchers:** Nicky Athanassopoulou, Imoh Ilevbare, Simon Ford, Veronica Martinez, Letizia Mortara, Doroteya Vladimirova, Mohamed Zaki

**Research students:** Ghanim Al-Sulaiti, Alexander Koupstov, Nitish Gupta, Stanley Frederick W. T. Lim, Chara Makri, Zurina Moktar, Mark Phillips

**Contact:** [c.velu@eng.cam.ac.uk](mailto:c.velu@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/bmi](http://www.ifm.eng.cam.ac.uk/bmi)



# Centre for Industrial Sustainability

The Centre for Industrial Sustainability (CIS) provides knowledge, expertise and tools for business to compete in a resource constrained world. With over 20 tools developed to date, the Centre has helped over 200 businesses innovate towards sustainability.

## Research themes

- ▶ Eco-efficient manufacturing: identifying waste and model factory resource flows
- ▶ Eco-factory technologies: resource-efficient manufacturing; eco-intelligent control systems
- ▶ Sustainable business innovation: mapping existing value to re-think business models and create new models, integrating 'circularity' into business
- ▶ Industrial system transformation: planning for manufacturing of the future

## Approach

CIS works collaboratively with research centres across the IfM and with other universities and industrial partners. Within CIS is the EPSRC funded Centre for Industrial Sustainability, a collaboration of 4 universities – Cambridge, Cranfield, Imperial, and Loughborough – and industrial partners comprising 60 researchers and staff.

## Working with industry

Centre researchers work closely with industry providing intervention workshops, in-company training, R&D membership, bespoke research, and access to leading edge tools.

## Policy support for decision-makers

The Centre provides knowledge, expertise and leading research to inform effective policy making.

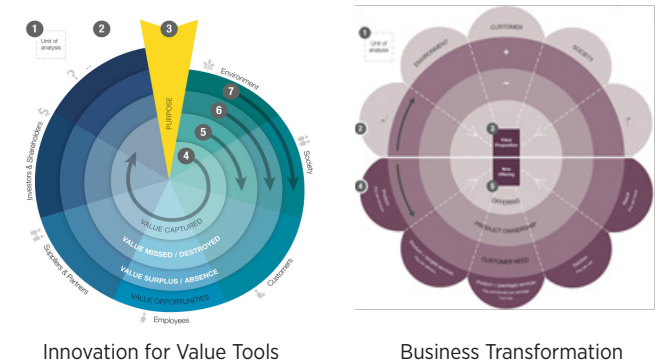


## Key projects and outputs include:

The Centre has produced a number of tools to help manufacturers become more sustainable.

They include:

- ▶ Mapping value in business networks
- ▶ Lifecycle analysis of uncaptured value
- ▶ Transforming businesses to capture new value
- ▶ Manufacturing efficiency toolkit
- ▶ Energy saving activities for factory staff
- ▶ Circularity thinking toolkit
- ▶ Systems mapping and capability assessment



## PEOPLE

**Centre Head:** Steve Evans

**Commercial Director:** Ian Bamford

**Researchers:** Claire Barlow, Nancy Bocken, Maria Holgado Granados, Dai Morgan, Doroteya Vladimirova, Curie Park

**Research students:** Jee-Yeon Choi, Lloyd Fernando, Zahit Ergun Gungor, Na Jiao, Sotirios Levakos, Yan Li, Lampros Litos, Pu Liu, Ioannis Mastoris, Sudhir Rama Murthy, Daniel Summerbell, Yuan Tao, Kirsten Van Fossen, Ilaria Frau, Wen Liu, Olamide Oguntoye, Paulo Savaget Nascimento

**Marketing and Networking Coordinator:** Dee Dee Frawley

**Centre Administrator:** Sharon Mey

**Contact:** cis-enquiries@eng.cam.ac.uk

**Web:** www.ifm.eng.cam.ac.uk/cis

# Centre for Science, Technology & Innovation Policy

The Centre for Science, Technology and Innovation Policy (CSTI) is an applied policy research unit exploring what makes national innovation systems effective at translating new science and engineering ideas into novel technologies and emerging industries.

Research projects are designed to support the evidence needs of Science, Technology & Innovation (STI) policymakers, in particular those officials in public research agencies who are responsible for programme design, portfolio management and strategy development.

## Research themes

**The public research base & the dynamics of innovation:** exploring the evolving contribution of public research and higher education organisations to technological and industrial change, and growth.

**Technological, manufacturing & industrial systems:** characterising enabling technologies, production technologies, value chains to better understand the dynamics of S&T-based industrial change

**Science, technology & industrial emergence:** developing innovation system functions-based approaches to analysing emerging technology dynamics; and practical foresight-related analyses for policy and public research strategy development.

**Innovation system institutions - regulation & standards:** exploring the evolving role of standardisation and regulatory activities on the emergence of new technologies and industries.

**Economic value capture from industrial-innovation systems:** analysing sources of national economic value capture from modern manufacturing systems, in particular during technological and industrial change.

## Approach

The CSTI research agenda is shaped in collaboration with policy and research agency partners. CSTI's applied research activities are distinguished, in particular, by its efforts to:

- characterise more carefully the technologies, application systems and industrial structures involved in the journey from research to economic wealth
- ensure that research outputs are directly relevant to the evidence needs of those government agencies supporting the research and innovation base.

## PEOPLE

**Centre Head:** Eoin O'Sullivan

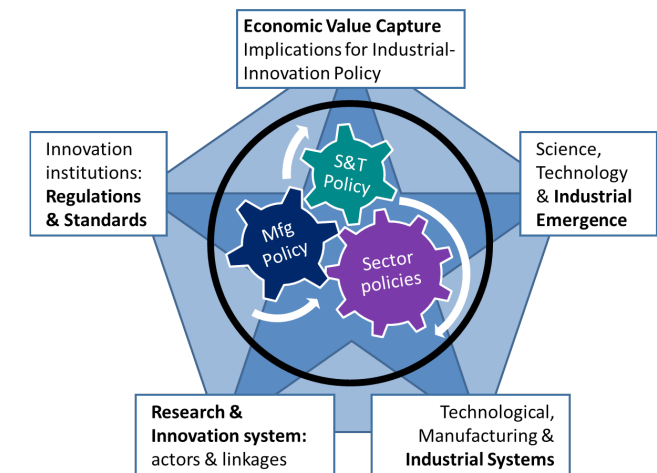
**Researchers:** Charles Featherston, Carlos López-Gómez, Tomas Ulrichsen

**Research student:** Jae-Yun (Jane) Ho

**Affiliate:** Laure Dodin

**Contact:** [csti-enquiries@eng.cam.ac.uk](mailto:csti-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/csti](http://www.ifm.eng.cam.ac.uk/csti)



## Activities

CSTI hosts a series of international policy workshops and seminars in the UK and partner countries in which policy officials, academics and industrialists share experiences and address key questions in the areas of technology, manufacturing and innovation policy. As well as a number of events in Cambridge, CSTI has hosted workshops in which UK policy officials are 'paired' with counterparts in Japan (University of Tokyo), US (White House), and Germany (British Embassy, Berlin).

CSTI is also home to the **Babbage Industrial Policy Network**, an international forum bringing together leading experts from economics, engineering and management with a shared interest in manufacturing and industrial policy.

# ➤ Manufacturing Industry Education Research Group

The Manufacturing Industry Education Group (MIERG) looks at educational issues related to manufacturing industry. It aims to research areas where new knowledge will benefit the learning and development of:

- **people** in becoming effective and excellent practitioners in manufacturing industry roles
- **manufacturing industry companies** in developing and sustaining the capabilities needed to compete in the global industrial ecosystem.

## Research interests

- How can Higher Education support the initial professional development of graduates destined for manufacturing industry?
- How graduate-level work skills are developed as part of Higher Education programmes?
- Competence assessment of registered engineers
- Technician skills for High Value Manufacturing
- How do we define and develop the advanced skills required for a 'high value manufacturing world'?
- How individuals acquire new knowledge in practice and the implications for Engineering Education
- What are the perceptions of Engineering as a subject and a career option?

## Key projects include

**Development of advanced graduate-level skills for industry:** examining how students develop such skills during an IfM MPhil programme. Work is currently focused on the short industrial placements that the students undertake, defining the activities that they need to do and constructing a skills development framework.

**Perceptions of engineering:** exploration of the ways in which schoolchildren, teachers and parents develop their knowledge of engineering as a subject and career option.

**Understanding the changing knowledge and learning needs of engineers in practice:** investigating how engineers engage in learning aspects of other disciplines in interdisciplinary development projects. The current focus is on how engineers learn about knowledge in projects that integrate engineering and the life sciences.

Collaborating with others in the community to build and increase the impact of the Engineering Education Community in the UK.



## PEOPLE

**Programme co-ordinator:** Judith Shawcross

**Researchers:** Claire Barlow, Ronan Daly, Tim Minshall, Tom Ridgman

**Research students:** Mohd Nazri Mahmud, Judith Shawcross

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

“

I have come to realise quite quickly just how useful a degree MET is. Not only do I owe my current job at Williams to one of my placements, there is no way I could be doing the breadth of interesting things I am doing with a degree in 'real' engineering.

*Nick Schulman, MET 2013-15*



Some of the products designed by the 2015 MET IIA students for their Design Projects.

**Nearly 200 companies host IfM student projects, including:**

- Bakkavör
- Bespak
- Bosch
- Coopers Lighting
- Edwards High Vacuum
- GKN Aerospace
- Honeywell
- Jaguar Land Rover
- Laing O'Rourke
- MAHLE Powertrain
- M & H Plastics
- McLaren
- MK Electric
- Mondelēz
- Perkins
- Princes
- Rolls-Royce
- Samworth Bros
- Siemens
- Servomex
- Titon Hardware
- Williams F1

**EDUCATION**



# ➤ Manufacturing Engineering Tripos (MET)

The Manufacturing Engineering Tripos (MET) is a two-year programme for 3rd and 4th-year undergraduate students who have successfully completed the first two years of a Cambridge engineering degree. It offers a thorough theoretical grounding combined with the chance to put ideas into practice in industry. The programme includes lectures, industrial visits, business skills development, company-based projects and a major project researching and designing a novel product.

## MET IIA (3rd year)

In their first year, MET students follow courses in:

- Materials into products
- Operation and control of production machines and systems
- Product design
- Operations management
- Industrial engineering
- Organisational behaviour
- Managing business and people
- Financial and management accounting
- Industrial economics, strategy and governance
- Contemporary issues in manufacturing

### Company visits

A programme of industry visits to see theory put into practice.

### Skills programme

A structured programme to develop specific business skills.

### Design project

Students research the market for a product, prepare a design and manufacturing plan, and draw up a business plan for a company to produce the product.

## MET IIB (4th year)

The second year of MET is very different from a standard undergraduate course. Intensive taught modules, normally lasting a week, are interspersed with two-week company-based projects. Module topics include: enterprise, globalisation and policy; production technologies and materials; manufacturing systems engineering, sustainable manufacturing; industrial systems, operations and services; managing people; technology and innovation management; and strategy and marketing.

### Industrial projects

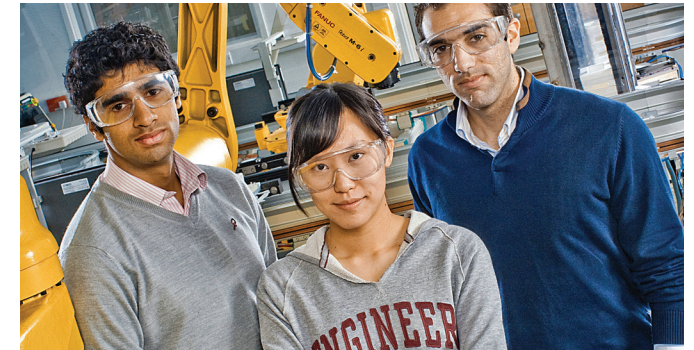
Each student undertakes four projects in different manufacturing companies, where the students work on real problems identified by the company concerned, drawing on the material covered in the taught modules. The last project is an individual dissertation project that runs for the final seven weeks of the course.

### Automation project

A hands-on group project in the IfM's automation lab, involving designing and building an automated manufacturing system.

### International project

Throughout the year students work on an international research project that culminates in an overseas study tour.



## PEOPLE

**Course Directors:** Tim Minshall, James Moultrie

**Academic staff:** Claire Barlow, Ronan Daly, Michaël De Volder, Mike Gregory, Ian Hutchings, Duncan McFarlane, Tim Minshall, James Moultrie, Bill O'Neill, Ajith Parlikad, Jim Platts, Ken Platts, David Probert, Alan Thorne, Frank Tietze, Chander Velu

**Support:** Shane Strawson, Mitha Madhu

**Contact:** [met-enquiries@eng.cam.ac.uk](mailto:met-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/met](http://www.ifm.eng.cam.ac.uk/met)

# ➤ Industrial Systems, Manufacturing and Management (ISMM)

A one-year, taught MPhil programme that prepares graduates for fast-track careers in manufacturing and management.

- It equips course members with the skills and experience they need to be immediately effective in industry, leading to accelerated promotion.
- It provides industry with highly motivated and effective potential managers with experience in both practical industrial problem solving and rigorous academic research.

## Course programme

ISMM consists of:

- 8 weeks of project work
- 16 weeks of taught modules
- 2-week overseas study tour either in mainland Europe or further afield
- 18-week dissertation project

### Taught course

Manufacturing is taught as a 'business'. It is taught by both academics and industrialists and involves lectures, exercises and case studies.

### Company visits

Visits are arranged to a broad spectrum of companies demonstrating best practice in operations and management in technology-driven environments.

### Industrial projects

Real problems tackled in teams of two or three, under normal commercial pressures, produces individuals with the self-reliance and confidence to rise to exceptional challenges.

### Research project

Extended pieces of individual research, covering a range of topics chosen from technology, economics, management, services or policy areas.

### Study tour

A two-week overseas tour providing an opportunity to experience industries and working environments outside the UK.



## PEOPLE

**Course Director:** Tom Ridgman

**Tutors:** Gerry Frizelle, Vanessa McNiven, Tom Ridgman, David Schwarz, Yongjiang Shi, John Sullivan

**Module leaders and project supervisors:** Nicky Athanassopoulou, Steve Evans, Florian Urmetzer, Frank Tietze

**Support:** Pauline Diejomaoh, Sally King

**Contact:** [ismm-enquiries@eng.cam.ac.uk](mailto:ismm-enquiries@eng.cam.ac.uk)

**Web:** [www.ifm.eng.cam.ac.uk/ismm](http://www.ifm.eng.cam.ac.uk/ismm)

# ➤ MRes & PhD in Ultra Precision Engineering

The MRes & PhD programme in Ultra Precision trains postgraduate students to be the precision engineers of the future. The programme is structured in two phases: a one-year taught MRes course at the University of Cambridge and Cranfield University followed by a three-year PhD research programme at Cranfield, Cambridge or another UK university.

## MRes

During the MRes the students will learn advanced high precision techniques and processes, including: high energy laser micro/nano-processing; focused ion beam machining; reactive atom plasma processing; nanofabrication; graphene engineering; printed electronics; machine design; and advanced metrology systems.

The MRes is designed to give a balance between taught courses, lab sessions and research projects to allow students to develop a range of skills.

## PhD

Upon successful completion of the MRes, the students progress to their PhD, choosing from a vast range of topics including: manufacturing engineering; laser processes; photonics; materials science; control systems; and machine design.

## Working in industry

During their PhD many students will be offered the opportunity to work alongside industrial partners allowing them to gain valuable business experience whilst receiving an additional maintenance top-up, bringing their stipend up to a possible £20,000 pa tax free.

## Future careers

Many industrial sectors require a high level of precision, such as aerospace, medical devices, automotive, energy, security and defence. Students completing the MRes and PhD will be central players in the ultra high precision wealth creation economy.

- We welcome applicants from any field of science or engineering who have obtained a first or upper second class honours degree.
- Full EPSRC funding is available for UK students and EU students who have studied for three years full time in the UK.

### EPSRC Centre for Doctoral Training in Ultra Precision

University of Cambridge  
Cranfield University



**Course administrator:** Sophie Fuller

**Web:** [www.CDT-UP.eng.cam.ac.uk](http://www.CDT-UP.eng.cam.ac.uk)

## ➤ Research degrees: PhDs and MPhils

The Department of Engineering offers one-year MPhil and three-year PhD research degrees. Research topics within the IfM cover the full range of management, technology and policy issues addressed by our research centres and interdisciplinary programmes. Student research builds upon work in existing areas or develops along new avenues. We actively encourage applicants who have previous industrial or public sector experience.

### Current and recent PhD topics

#### **Roadmapping to understand and manage risks associated with sustainability**

Manufacturing firms face challenges in evaluating sustainability issues – specifically resource scarcity – when devising business strategy. As many resources become ever more constrained in the future, firms will increasingly be forced to switch to more sustainable production methods. This research examines the potential for roadmapping as a strategy tool to help firms recognise future resource constraints.

#### **High speed mask-less laser-controlled precision additive manufacture**

Additive methods at both the nano and micron scale are used to develop advanced functional materials such as graphene and carbon nanotubes to manufacture next-generation functional devices. This project looks at depositing materials with lasers at high deposition rates and with high precision, with a view to developing a ‘one-stop’ laser manufacture platform.

#### **Standards for emerging industries**

This research explores the conditions that support innovation and successful transition of new scientific and technological research into emerging industries. It focuses on strategic frameworks and processes that can be used by policymakers and standards organisations to manage technical standards in a timely and anticipatory way.

#### **Benefiting from product intelligence: the case of customer-oriented logistics**

This research examined automated methods for enabling a customer of a logistics service to have an ongoing influence over the shipment of his order. It used artificial intelligence approaches to represent the customer’s interests and to interface these requirements with the logistics providers planning system. The aim is to allow a customer to automatically expedite, reroute or alter orders if needed.

#### **‘Through-life accountability’ within complex service networks**

This project aims to develop a methodology for mapping ‘through-life accountability’. It is envisaged that this framework will help identify the sources of potential failure of product-service systems and, in turn, provide key insights for improving their safety.

#### **Self-assembly for polymer microstructures**

Liquid engineering can be used to build polymer microstructures containing functional materials. This research combines a self-assembly technique with a controllable digital patterning of liquid drops to liquid surfaces and then guiding their self-organisation into patterns.



### Applications

Admission to Cambridge research degrees is managed by the University’s Board of Graduate Studies. Full details of how to apply can be found on its website: [www.admin.cam.ac.uk/offices/gradstud](http://www.admin.cam.ac.uk/offices/gradstud)

Information specific to the Department of Engineering can be found at: [www.eng.cam.ac.uk/graduate/postgrad](http://www.eng.cam.ac.uk/graduate/postgrad)

Applicants are encouraged to discuss their proposed research topic with the IfM research centre concerned. Some funded studentships are available but early application is strongly advised.



“

“We highly value our work with the IfM in contributing inspiring thinking to help us constantly step up in our approach to optimising end-to-end operations.”

“... the foundation from which we will develop an explicit technology strategy going forwards and clear global technology areas of focus.”

WORKING WITH INDUSTRY,  
GOVERNMENTS &  
UNIVERSITIES



## ▶ Working with industry

IfM Education and Consultancy Services (IfM ECS) provides a range of consultancy services based on IfM research. Our industrial practitioners, all with many years of senior management experience, provide support for companies and public sector organisations. Their approach is very different to conventional consultancy – they work collaboratively to develop solutions and focus on transferring knowledge as well as delivering business results.

Working with industry both informs and funds future IfM research.

IfM ECS works with companies around the world to help them:

### ▶ Develop their innovation and technology management strategies and capabilities

We can help companies develop and put in place robust innovation and technology management strategies and systems. We use a range of research-based approaches and techniques adapted to each company's specific context and requirements.

### ▶ Capture value from global networks

Using a set of structured approaches developed by IfM's Centre for International Manufacturing, IfM ECS helps multinational companies redesign their global operations networks to achieve strategic and operational advantage.

### ▶ Move to service-based business models

Introducing innovative, customer-focused service models – while effectively managing risk – into highly complex multinational manufacturing companies is a challenging task. IfM ECS supports this process using a range of approaches and techniques developed by researchers from the Cambridge Service Alliance.

### ▶ Transform their businesses through product design

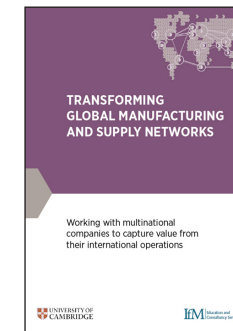
We work with companies to guide their design management processes in order to develop innovative products that meet their customers needs and potentially transform the business.

### ▶ Develop a successful business strategy

IfM ECS has a fast and effective approach to business strategy development and a process to refresh the strategy on a regular basis. We are using both of these approaches with companies in the UK's aerospace supply chain as part of a £110m programme aimed at developing the UK's capabilities in this sector.

### ▶ Develop a successful manufacturing strategy and the performance measurements to support it

Developing and putting in place a successful operations strategy is critical to business performance. We work with manufacturers to increase productivity and develop performance management capabilities which drive successful behaviours.



### ▶ Understand what and when to automate

We work with companies to understand their automation needs and develop a plan to address them. We recently worked with an oilfield services giant to identify automation opportunities across its 50 manufacturing sites and develop a consistent set of project plans across all of them.

**Chief Executive:** Peter Templeton

**Contact:** pwt23@cam.ac.uk

**Web:** [www.ifm.eng.cam.ac.uk/services/large](http://www.ifm.eng.cam.ac.uk/services/large)

# Working with governments

IfM ECS has worked with both the UK government and with other national and regional governments around the world to understand the opportunities for developing thriving industrial sectors and creating the conditions that will turn new ideas into emerging industries.

## National landscaping

### High value manufacturing: understanding the UK landscape

In 2012 IfM and IfM ECS published a report for the Technology Strategy Board (now Innovate UK) to help identify key opportunities for manufacturing growth in the UK. A new project is underway to update this study with particular focus on areas where investment in manufacturing capabilities can be maximised by co-ordinating the efforts of delivery agencies. The findings will be made available in 2016.



## Supporting European manufacturing

IfM ECS has helped EU-funded project Road4FAME create a roadmap which prioritises future information and communication technology (ICT) research in line with the needs of European manufacturing businesses.

## National sector and technology roadmapping



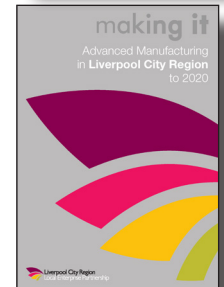
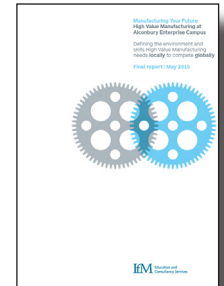
Technology roadmap for the UK marine industry on behalf of Innovate UK. The roadmap develops a shared vision of the sector so that industry and government can work together to support long-term growth. IfM ECS has previously run similar projects for other key sectors including, Synthetic Biology and Robotics and Autonomous Systems.

- Key sector roadmaps for the Chilean government  
IfM ECS developed strategic roadmaps on behalf of Antofagasta's regional government for their key mining and food production sectors to identify their primary opportunities by carefully aligning the necessary technological developments with external and market drivers.

## Local manufacturing strategies

IfM ECS has been working with local industry and government agencies to develop a set of priorities for the Alconbury Campus to help them compete nationally and globally in high value manufacturing.

Previous projects have helped the Liverpool City Region and Swindon and Wiltshire Local Enterprise Partnerships develop their respective visions and strategies for high value manufacturing.



To find out more about the work we do with governments, go to: [www.ifm.eng.cam.ac.uk/services/government](http://www.ifm.eng.cam.ac.uk/services/government)

**Chief Executive:** Peter Templeton  
**Contact:** [pwt23@cam.ac.uk](mailto:pwt23@cam.ac.uk)

## ➤ Working with universities

IfM ECS works with universities and research funding bodies in the UK and internationally to support the commercialisation of their research outputs. We specialise in bringing industry and academia together to help:

- Universities identify industry needs and shape their research agendas accordingly.
- Identify potential commercial applications for new technologies developed within a university environment.
- Universities around the world support the development of industrial strategy.

### Recent projects

- [Roadmap for the EPSRC Centre for Innovative Manufacturing in Ultra Precision Micro-Manufacturing Research Platform](#)

This project brought industrialists and researchers together to explore potential applications for the technology. The group identified the best commercial opportunities for micro-manufacturing research and then created a roadmap for development plans and performance targets.

We have carried out similar projects for the EPSRC Centre for Innovative Manufacturing in Ultra Precision's [Reel-to-Reel Platform](#) and for the EPSRC Centres for Innovative Manufacturing in [Large-Area Electronics](#) and [Laser-based Production Processes](#).

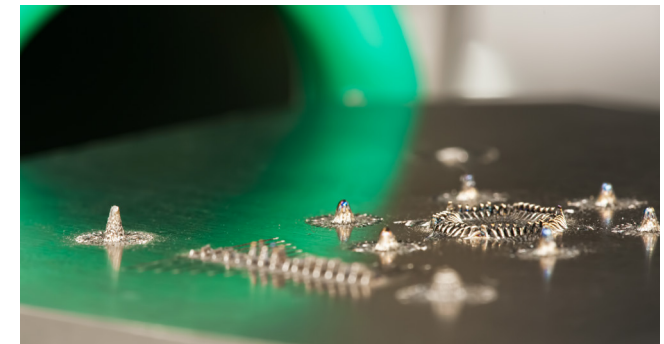
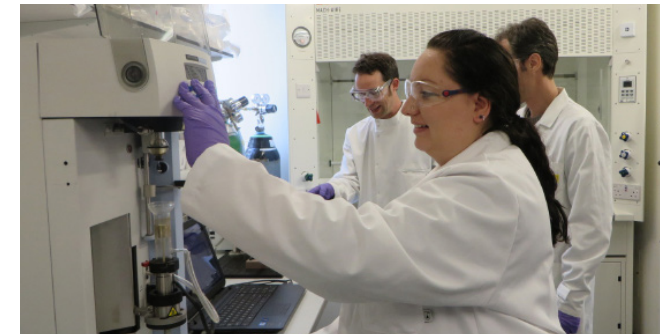
### Working with other universities to support sector and technology strategies

#### Chile

Working with IncubaUC, the business incubator for the Pontifical Catholic University of Chile, IfM ECS developed strategic roadmaps on behalf of Antofagasta's regional government for its mining and food production sectors.

#### Australia

Working in close collaboration with the Australian National University (ANU), IfM ECS used technology roadmapping to help develop a clearly articulated strategy for the Australian automotive and rail industries



**Chief Executive:** Peter Templeton  
**Contact:** [pwt23@cam.ac.uk](mailto:pwt23@cam.ac.uk)  
**Web:** [www.ifm.eng.cam.ac.uk/services](http://www.ifm.eng.cam.ac.uk/services)

# Executive and professional development

IfM ECS is an experienced provider of executive and professional development offering a range of tailored and open courses based on research carried out at the IfM and developed by educational specialists to deliver real and lasting benefits to organisations.

Our executive and professional development programmes are based on:

Active research programmes so that delegates get access to the latest thinking from the University of Cambridge in a wide range of manufacturing management areas such as: **technology and innovation management, sustainability, global operations networks** and **service capability**.

- ▶ An unrivalled understanding of manufacturing industry, the change it is undergoing and the challenges it faces.
- ▶ Excellent teaching practice that changes mind-sets and gives delegates a wide range of skills and tools that are immediately applicable in the workplace.
- ▶ A proven track record of working with industry both through consultancy and the delivery of education.



## Bespoke talent programmes

IfM ECS designs and delivers programmes to meet manufacturing or technological companies' strategic capabilities and talent development needs. We offer:

- ▶ Programmes aimed at talented technology, R&D and manufacturing business specialists who have the potential to take on senior and strategic roles in the company. These are typically delivered in three or four one-week modules over a six month period.
- ▶ Short, in-company programmes on a particular theme, typically lasting one to three days.

## Open programmes

IfM ECS runs a series of successful open courses and workshops covering a range of manufacturing management themes, including:

- ▶ **Roadmapping** – aligning your organisation's strategic and technology objectives
- ▶ **Visual approaches for strategy and innovation management** – using visual design to present management information
- ▶ **Technology and innovation management** – maximising the potential of new technologies
- ▶ **Technology intelligence** – identifying technological opportunities and threats that could affect the future of your business
- ▶ **Valuing and selecting technology projects** – applying tools and techniques to help you choose the right technology projects
- ▶ **'Make or buy'** – a structured approach to deciding whether to produce in-house or use an outside supplier
- ▶ **New tools for sustainable businesses** – learn where and how to get new and sustainable value from your business
- ▶ **Making the shift to services** – how to design new services and improve existing ones.

**Contact:** Judith Shawcross  
Head, Executive and Professional Development  
**Email:** [jks45@cam.ac.uk](mailto:jks45@cam.ac.uk)  
**Web:** [www.ifm.eng.cam.ac.uk/executiveeducation](http://www.ifm.eng.cam.ac.uk/executiveeducation)

# ideaSpace

**ideaSpace is a community of people starting high impact new ventures in Cambridge, Europe's most successful technology cluster.**

## **Who can join?**

Anyone with the drive to create new business models which have the potential to benefit millions of people within a few years of start-up.

## **Building an innovation community**

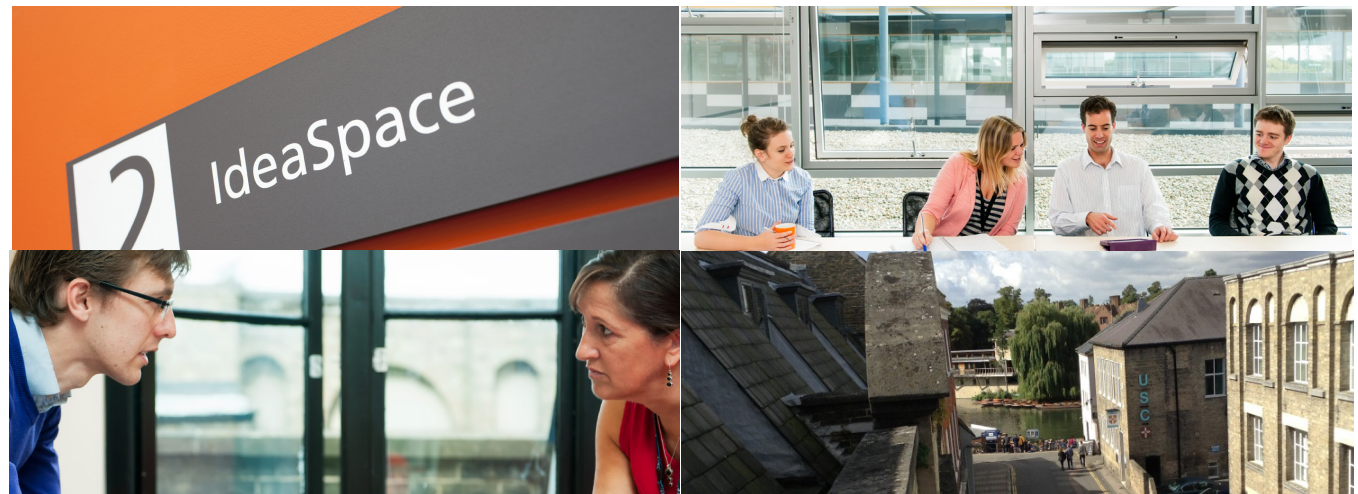
ideaSpace members benefit from a stimulating working environment, the ability to share experiences with like-minded start-up founders and gain access to some of the UK's most successful entrepreneurs and investors.

## **The ideaSpace mission**

Being a part of the University of Cambridge is central to ideaSpace's sense of purpose. It shares the University's commitment to excellence and to making a meaningful contribution to society by supporting the development of high impact new ventures.

## **Ones to watch – ideaSpace alumni include:**

- Audio Analytic • Arachnys • Cambridge Intelligence • Cambridge Science Centre • Knowledge Transmission • PragmatIC Printing



## **Supporting growth through innovation**

As well as helping start-ups create successful businesses and economic value, ideaSpace works with governments, agencies and higher education institutions to develop policies, strategies and programmes to support a thriving start-up sector. ideaSpace also informs, and provides cases for research and development activities at the University of Cambridge relating to early-stage ventures and their ecosystems.

ideaSpace is part of the University of Cambridge. Day-to-day management is provided by IfM Education and Consultancy Services Ltd.

ideaSpace West, 3 Charles Babbage Road, Cambridge, CB3 0GT, UK  
T: +44 (0)1223 330970  
E: [info@ideaspace.cam.ac.uk](mailto:info@ideaspace.cam.ac.uk)

ideaSpace City, 3 Laundress Lane, Cambridge, CB2 1SD, UK  
T: +44 (0)1223 330971  
E: [info@ideaspace.cam.ac.uk](mailto:info@ideaspace.cam.ac.uk)  
[www.ideaspace.cam.ac.uk](http://www.ideaspace.cam.ac.uk)

# Outreach



## Cambridge Science Festival

The IfM took part in the University's annual Science Festival once again in March 2015. This highly popular event is now a firm fixture in our annual calendar and we welcomed well over 1,000 children and their parents to the IfM to take part in a wide range of activities. These included tours of the laser labs, seeing water droplets freeze in mid-air and using a laser to power rockets along a line.

Dr Tim Minshall, Reader in Technology and Innovation Management and Head of the Technology Enterprise Group, gave a talk on how engineers make the world a better place, using new technologies such as 3D printing, smartphones and solar energy.

## Engineers of the Future

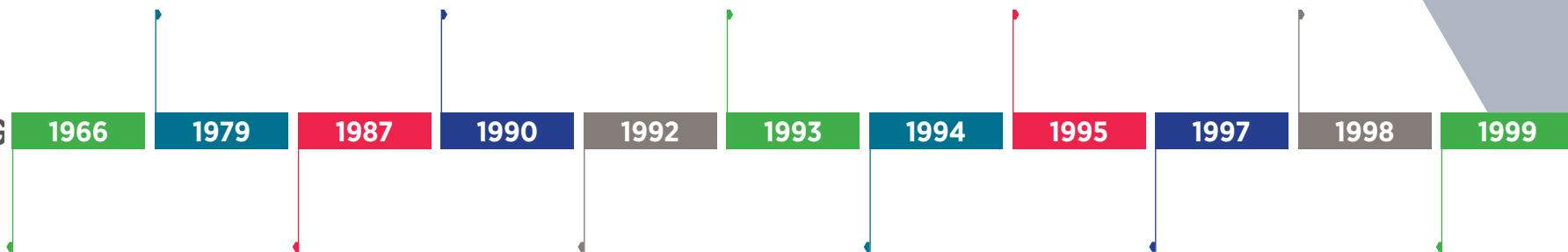
A group of 14 and 15-year-olds from Chelmer Valley College in Chelmsford visited the IfM to find out more about the excitement of engineering in a university research environment. The students were challenged to build a load-bearing crane using paper and cardboard tubes. The students also listened to Tim Minshall talking about 'what engineers really do' before playing 'the JIT game', led by Derek Ford, in which participants apply elements of Just-in-Time manufacturing to better understand this management philosophy.





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YEARS OF  
**MANUFACTURING**  
AT CAMBRIDGE



Find out more about 50 years of manufacturing at Cambridge at: [www.ifm.eng.cam.ac.uk/news/50-years-of-manufacturing-at-cambridge](http://www.ifm.eng.cam.ac.uk/news/50-years-of-manufacturing-at-cambridge)