Manufacturing REVIEW

Advanced manufacturing research Management tools and toolkits Is big data still big news? High value manufacturing landscapes The Joseph Joseph story





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Cover image: A region of Indium Tin Oxide patterned with the number 9 to identify the experimental sample. The coloured regions are due to changes in the refractive index of the material caused by the laser machining process. Jonathon Parkins, Centre for Industrial Photonics.

Welcome



The *IfM Review* is rapidly becoming one of the most important windows on the IfM, thanks to excellent work by the editorial team. They have brought together a publication which provides a blend of 'news' and more in-depth features which we hope you will find engaging and informative.

At the beginning of the year, we set out four themes we wanted to address – 'scale up', business models, tools and landscaping – and we are making good progress on all these fronts.

By 'scale up' we mean the ability to turn an emerging technology into something which can be manufactured commercially. This is vital if we are to reap the social and economic rewards of new research. But the obstacles to successful scale up are many and various: as well as the underlying science and manufacturing challenges, a whole array of operational, management and policy issues needs to be considered. At the IfM we are ideally placed to bring together expertise in all these areas. On page 7 Ronan Daly describes how his new Fluids in Advanced Manufacturing group is doing just that.

The term business models can cover a multitude of sins but a clear understanding of what they are and how they work is becoming increasingly important. A lively cross-IfM group is pursuing this agenda and bringing together industrialists and academics to identify where the challenges and opportunities lie. You can find a brief overview of progress to date on page 2.

Tools and methods have long been a feature of IfM's activities. Over the years many ways of doing this have evolved. We are now taking stock and capturing what works best in which circumstances. We hope this will lead to more effective tools and methods and also help us identify at the start of a research programme what the most appropriate style of eventual tool or method might be. On page 9, Clive Kerr and Rob Phaal talk about some of the challenges of developing effective management tools and toolkits.

By no means least in our current work is the 'refresh' of the UK High Value Manufacturing (HVM) Landscape. Some of you may recall that we had the privilege of conducting the first landscape exercise in 2012 on behalf of Innovate UK (formerly TSB) and we are very pleased to have been asked to refresh it. The first exercise was significant in influencing the emergence of the now very successful High Value Manufacturing Catapults as well as EPSRC and Innovate UK investments more broadly. On page 16 you can read about how the national landscaping exercise is also informing HVM priorities in the regions.

Do please get in touch with us if you would like to contribute to the HVM landscape or, indeed, if any of our work catches your attention. We would be delighted to tell you more about what we are up to and visitors are always welcome.

Professor Sir Mike Gregory Head, Institute for Manufacturing



Credit: Jonathon Parkins: Pulsed laser deposited metal on glass



IfM Review is published twice a year. Sign up to receive a copy by email and to hear about other IfM news at: **www.ifm.eng.cam.ac.uk/ifm-review**

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IfM news

3D printing research project

The IfM, which is already leading the government-funded 'Bit by Bit' project on digital fabrication, has been awarded a second EPSRC and ESRC grant in this area. This new two-year study aims to 'define the research agenda for 3D printing-enabled re-distributed manufacturing'.

The project, known as 3DP-RDM, is led by **Dr Tim Minshall**, head of the IfM's Technology Enterprise Group and Professor Phill Dickens from the University of Nottingham. **Dr Simon Ford**, from the IfM's Centre for Technology Management, is the Network Coordinator. An initial scoping workshop was held at the IfM in January which brought together 37 academics and industrialists interested in how the development of additive manufacturing technologies may change the way manufacturing is done in the future, from both an operational and economic perspective.

Find out more about the IfM's work on 3D printing – and read the Bit by Bit blog – at: www.ifm.eng.cam.ac.uk/bitbybit



3D printing lab for students

The IfM now has a 3D printing lab, funded by a University teaching grant to support the **Manufacturing Engineering Tripos** (MET) Design modules. During the first year of the MET course, students work in teams to develop a new product with real business potential. The 3D printing lab allows them to turn their design ideas rapidly into prototypes.

As well as helping students develop their design and manufacturing skills, it also gives them an opportunity to get first-hand experience of 3D printing techniques.

Help for technology intelligence specialists

Technology Intelligence (TI) is how companies gather and use the information they need to understand technology threats and opportunities. But this information is only useful if corporate decision-makers listen to it and act upon it. In this new practice guide, **Dr Letizia Mortara** from the IfM's **Centre for Technology Management** explains why this does not always happen and explores ways in which intelligence can be better communicated to decision-makers.

This guide derives from work carried out in the **Strategic Technology and Innovation Management** (STIM) consortium. This consortium brings together researchers and practitioners to develop new approaches to some of the key challenges facing manufacturing and technology-intensive companies. Read the guide at: bit.ly/1Bcv2n9

Business model innovation: new research programme

Research into business model innovation has become an increasingly important part of IfM research across a number of different areas including: technology and innovation management, servitization, sustainability,



global value network design and policy development. Business model research also underpins the work of **IfM Education and Consultancy Services** in developing and applying research-based toolkits for business improvement.

Dr Chander Velu (above) is heading a new IfM programme which, as well as carrying out its own research, will provide a focal point for bringing together related research themes from across the IfM.

He also wants to help develop a coherent research agenda across the wider research community. Last year, a group of academics and industrialists met at the IfM to identify possible areas for investigation. This was followed in December by a workshop for UK researchers and a further workshop is planned for the summer to pursue this agenda with researchers from a range of international universities. This workshop will be hosted jointly with the University of Exeter and the ESRC.



Carbon nanotubes: breakthrough manufacturing technique

An international team of researchers led by the IfM's **Dr Michaël De Volder** has developed a new way of manufacturing strong, lightweight materials with specific surface properties – in large volumes. The technique works by making carbon nanotubes bend into predictable shapes as they grow.

By attaching different coatings to the carbon nanotubes, it is possible to create surfaces with different properties: they could be exceptionally rigid and strong or very flexible and resilient. This approach may also allow the intricate structures found on the skins of certain plants and animals to be replicated with high levels of precision. This, in turn, could make it possible to mass produce surfaces with specialised characteristics, such as the water-repellent or adhesive properties of some insects.

The paper was published in Nature Communications 5, July 2014.



Credit: Dr Michaël De Volder: Complex shapes of carbon nanotubes

Portal for policy practitioners

The IfM's Centre for Science, Technology and Innovation Policy (CSTI) is launching a new portal for policymakers and government agency officials. It includes:

- Country profiles overviews of the actors, policies and programmes in leading industrial countries
- Briefing notes, workshop reports and benchmarking studies for policy practitioners
- A searchable database of international policies and 'foresight' studies relating to manufacturing.

The Manufacturing Policy Portal will available from the end of March and accessible via the CSTI website: www.ifm.eng.cam.ac.uk/research/csti

19th Cambridge International Manufacturing Symposium

The Symposium is a chance to hear from world-leading business figures and thinkers on the challenges facing modern manufacturing. The 2015 Symposium will be held in Cambridge on 24 and 25 September. Its theme is 'International manufacturing revisited: embracing new technologies, capabilities and markets'.

For more information go to: www.ifm.eng. cam.ac.uk/events/cimsymposium15

Asset management systems for complex service providers

In November **Dr Florian Urmetzer**, **Dr Ajith Kumar Parlikad**, **Chris Pearson** and **Professor Andy Neely** published a Cambridge Service Alliance executive briefing considering the issues facing complex services providers when designing an asset management system. This requires the co-operation of potentially large numbers of organisations within an often complex ecosystem.

The research team looked at current asset management practice and conducted interviews with organisations across a number of sectors to identify best practice and make key recommendations.

Read the report online at: bit.ly/1wLOOGc



IfM ECS news

High value manufacturing: understanding the UK landscape

In 2012 IfM and IfM ECS published a report for the Technology Strategy Board (now Innovate UK) on high value manufacturing in the UK to help identify key opportunities for growth. Innovate UK has asked us to revisit this study with a view to refining the analyses in the context of the Government's 'Eight Great Technologies' initiative and industrial sector strategies. The project will focus particularly on areas where investment in manufacturing capabilities can be maximised by co-ordinating the efforts of delivery agencies. The HVM Catapults will also use the findings to identify and target areas where they are currently not doing enough to support emerging industries.

The study is well under way and involves written submissions and landscaping workshops. The final report will be published later this year.

Quantum technologies roadmap

Quantum technology has been identified by the UK Government as having the potential to deliver significant benefits to the UK economy. In 2013 it announced that £270 million would be invested over five years to develop a network of quantum technology centres to help commercialise research.

IfM ECS was asked by Innovate UK and the EPSRC to facilitate two workshops bringing together the 'quantum community' – academic and industrial researchers, policymakers and funding bodies – to define a vision for the commercialisation of quantum technologies in the UK. The results of the workshops will be used to help shape a National Quantum Roadmap, which can be used by everyone in the sector to inform their activities.



New people



Eric Harris, Senior Industrial Fellow Eric has held senior posts at Unilver, Seagram, Esselte and ICI Paints, heading up planning and logistics operations in Europe. More recently, he has applied this experience through consultancy, with a focus on the design and delivery of supply chain, planning and logistics improvement within multinational businesses. **Email**: ejh80@cam.ac.uk



Clemens Chaskel, Industrial Fellow Clemens has a background in the aerospace and defence sector and in technology consultancy. His work has included R&D process optimisation, requirements management and project management. At IfM ECS he works with medium and large organisations around the world, with a particular focus on German-speaking countries. Email: cdc31@cam.ac.uk

Ricardo Gonzalez Nakazawa, Senior Industrial Fellow Ricardo has been a consultant for more than 15 years, working primarily in strategy, innovation, technology management, foresight and market research. He has been working with the IfM's Centre for Technology Management and IfM ECS for more than seven years, with expertise particularly in roadmapping and the use of workshop tools for technology, innovation and strategic management. Email: rg409@cam.ac.uk



Laure Dodin, Industrial Fellow Laure has a particular interest in helping organisations understand the policy, regulatory and standards landscape for a given technology or industry. She has worked as a representative for a parliamentary group at the National Assembly in Paris, then as an adviser to the Minister of Health. She spent nine years as a research associate at the IfM specialising in the policy and regulatory dimensions of innovation systems. Email: Id308@cam.ac.uk

Events for small and medium-sized companies

IfM ECS has launched a series of events aimed at senior executives in small and mediumsized manufacturing companies. The first of these **Manufacturing Growth Series** events was held at Christ's College, Cambridge in January and was focused around the topic Finance for Growth. The guest speaker was Ian McKernan, Group CEO of the Molecular Product Group Ltd.

The series is sponsored by the Business Growth Fund (BGF), which was set up to help firms with a turnover between £5m and £100m.

For more information on the Manufacturing Growth Series, contact Dr Karen Smith, head of IfM ECS's Sector Development and SME Support Business Unit: ks203@cam.ac.uk or 01223 760503.



Smell the coffee and power a building

The Food and FMCG **Open Innovation (OI) Forum** held its third pitching event in November at Food Matters Live in London. Eighteen innovative ideas were presented to the Forum members, a group of senior executives from global brands such as Mars, Unilever, General Mills, Tate & Lyle, Tesco and Crown Packaging. The ideas pitched included alternatives to sugar, algae-based products and antibacterial packaging solutions.

The winner was bio-bean, a London-based green energy company that transforms waste coffee grounds into two carbon-neutral biofuel products – biomass pellets and biodiesel. bio-bean sells these biofuels to London's businesses who use them to power buildings and transport.

The OI Forum was set up in 2010 by IfM ECS to provide support and opportunities for companies involved in the Food and FMCG value chain.

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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

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

Working with mid-size manufacturing and technology companies

IfM ECS has published a new document describing the ways in which we can help mid-size companies - and individual business units of global companies achieve their ambitions. Using a range of approaches based on IfM research, our consultants help companies identify and prioritise key business opportunities, and develop their business strategies and the technology and operations strategies and capabilities to support them. We also look at factory performance and address the challenges of adding a service dimension to a business. And we can help companies do all of this in a way that is both environmentally sustainable and more effective at capturing value at every point of their product and service lifecycles.

Find out more at: www.ifm.eng.cam.ac.uk/ services/overview/mid-size



Advanced manufacturing



From research to real products

Dr Ronan Daly, from the IfM's Inkjet Research Centre and founder of the new Fluids in Advanced Manufacturing Group, explains why taking a cross-disciplinary approach to advanced manufacturing research has the potential to deliver solutions to some of the world's most pressing problems.

Advances are being made all the time in our understanding of – and ability to create and manipulate – biological and synthetic building blocks and nanoscale materials. Research in these areas has the potential to help us tackle a host of important global challenges: reducing the amount of energy we use, removing pollutants from our environment, identifying diseases more rapidly and inexpensively and delivering medication personalised to each patient.

However, while these new materials hold much promise they are often extremely fragile or sensitive to their environment. If they are to be developed for commercial use, we need new manufacturing technologies that can integrate these very delicate components into functional materials, sensors and bio-diagnostic devices.

Last year we set up the Fluids in Advanced Manufacturing (FIAM) group at the IfM to do something genuinely new. It brings together fundamental laboratory research in a range of disciplines – chemistry, nanoscience, fluid mechanics and interfacial science – with research into manufacturing techniques and processes. It is because we understand the sensitivity of the components at the molecular scale during processing that we are so well placed to develop new and effective fabrication techniques.

We aim to use insights from our research to develop groundbreaking, simple, robust and affordable solutions that can be made at a commercial scale. The IfM provides a unique environment in which to do this, with science and technology researchers - many of them with industrial experience - working alongside experts in management and policy. So our research is grounded in a broader manufacturing context which takes account of things like the technology management challenges associated with R&D and the supply chain, service and sustainability issues underpinning the commercialisation of new technologies as well as the

We aim to use insights from our research to develop groundbreaking, simple, robust and affordable solutions that can be made at a commercial scale.

implications of national and international policy developments. The IfM approach is also predicated on collaboration with industry. This is particularly important for FIAM, where close links with industry are necessary both to further the research and to understand the particular challenges of manufacturing scale up.

Our research is centred around four research themes, the first of which is concerned with the creation and manipulation of soft matter while the second focuses on manufacturing technologies that can shape these new materials into active elements such as sensors. The third theme looks at novel ways of integrating these materials into 3D microscale architectures to create new devices. We do all of this within the context of the fourth theme: understanding the broader challenges of transforming laboratory research into an appropriately scaled-up proposition.

Soft matter manufacturing research

We control, manipulate and structure polymers, gels and biological materials, in order to develop highly versatile materials with a vast array of different chemical, physical and biological properties. The challenge is that they all need to be processed carefully because they are highly susceptible to damage or alteration during manufacturing. Stresses during flows or temperature gradients can change the chemical structure completely and lead to unpredictable behaviour. To counter this, we are combining top-down patterning techniques with molecular scale and microscale self-assembly to control the positioning and structure of these materials, while maintaining their molecular function.

One of the areas we are most interested in is tissue engineering applications and drug delivery devices. To create better in vitro techniques for testing new drugs and also to improve cell, tissue and organ replacement therapies, we want to replicate the natural conditions for cell growth and tissue formation. FIAM doctoral student, Qingxin Zhang, is looking at how liquid engineering can be used to build polymer microstructures containing materials such as small-molecule drugs. To tackle the manufacturing challenge, she is combining a self-assembly technique with a controllable digital patterning of liquid drops (by inkjet printing) on to liquid surfaces. These are then guided to selforganise into patterns that will eventually support cell growth and the slow release of drugs.

We are also working with the School of Chemistry in Trinity College Dublin to look at complex self-assembled systems at the molecular scale and their integration into manufacturing. Other projects in the pipeline include the development of reactive inks for 3D manufacturing and inkjet printing of pharmaceuticals into usable devices.

New digital manufacturing techniques

Responding to insights emerging from the UK Government's 2013 Foresight report on the Future of Manufacturing, we are particularly interested in low-volume, flexible manufacturing techniques. These techniques help manufacturers switch rapidly between different product variants or change to entirely new lines through simple reprogramming. They will support the development of a new generation of business models based on product personalisation.

Our research focuses on using digital fabrication techniques to enable novel platform technologies that can be used in

environmental sensing, biosensing, drug delivery and biomaterial design. These techniques need to be compatible with a new range of materials and must be able to integrate biological components (antibodies and proteins, for example) as well as advanced functional materials, such as nanowires, carbon nanotubes and a range of 2D materials.

FIAM's Yoanna Shams is researching a hybrid technology which combines additive techniques such as advanced lithography with subtractive techniques, using ultra precision lasers to remove and shape the materials. This combined approach allows us to overcome some of the challenges that inkjet techniques still face and to manufacture sensors from a wide range of advanced functional materials. The project brings together support from the EPSRC Centre for Doctoral Training in Ultra Precision, industrial partner M-Solv Ltd and the Centre for Science, Technology and Innovation Policy (CSTI) to put into practice our approach of ensuring laboratory research has a path to real application.

Device fabrication

Later this year we will be starting a project on the fabrication of point-ofcare diagnostics, in collaboration with Professor Lisa Hall from the University's Department of Chemical Engineering and Biotechnology. This is a rapidly growing area within the medical technology sector where low-volume, personalised manufacturing has the potential to revolutionise healthcare. In this context, we are particularly interested in paper as a substrate material. It has the great advantage of being an inexpensive, sustainable material and we already know a lot about its absorbance, chemical and optical properties. We want to use it to absorb a sample which then reacts with a sensing element to generate a diagnostic result. The downside of paper is the random nature of both its structure and chemistry: our research aims to integrate the biological and sensing components into it in such a way that the device remains both sensitive and robust.

Pathways to manufacturing

Our fourth theme is as much about the research culture of the group as it is a distinct area of research. The theme, developed in collaboration with the Centre for Science, Technology and Innovation Policy, examines the broader challenges of translating emerging technologies from laboratory research to a commercial scale.

The 'scale-up journey' needs to take account of a range of manufacturing

challenges, such as production technologies, system integration, downstream supply chain effects, sustainability, regulatory demands and so on. Working with CSTI colleagues, we are developing a systematic approach to identifying and addressing risk factors early on in order to maximise the chances of successful commercialisation.

The future

We are passionate about each of these four areas of research and success in any one of them will result in significant economic and social benefits. By bringing them together in such a way as to understand the scientific, manufacturing and business and policy challenges, we are in a position to do something really exciting. Advanced manufacturing research needs to be able to bridge these disciplines and we are building a team of people and partner companies determined to create breakthrough opportunities for emerging technology enterprises.

FIAM is looking for industrial partners. If you would like to find out more, contact Dr Ronan Daly. Email: rd439@cam.ac.uk



After graduating from the University of Edinburgh with an MEng in Chemical Engineering with European Studies, Ronan became a Process Technology Manager for Unilever R&D,

working with global brand teams to tackle formulation, scale-up and supply chain innovation challenges. His PhD from the School of Chemistry and the Centre for Research in Adaptive Nanostructures and Nanodevices (CRANN), Trinity College Dublin led to a new-found passion for novel manufacturing techniques. In 2011 he joined the IfM's Inkjet Research Centre to continue his work on biosensor platforms using digital fabrication techniques and inexpensive materials for commerciallytargeted tests.



Doctoral students, Yoanna Shams (left) and Qingxin Zhang, with Ronan in the lab.

Key Vision Co (5) Management tools and toolkits: the good, the bad and the ugly

HEZK

Dr Clive Kerr and Dr Rob Phaal from the IfM's Centre for Technology Management (CTM) are looking at better ways to design and use management tools and toolkits.

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If you are a manager today, you have a plethora of management tools at your disposal. A book published by Pearson in 2013 catalogues the '80+ key tools for every manager to build a winning strategy', ranging from SWOT and Porter's 'five forces' to scenarios, portfolio matrices and strategy maps, to name but a few. Given the abundance of methods available, are you satisfied that the tools you use really address your management and business challenges, can they be adapted to your particular context and can they be combined together into a seamless management toolkit?

If not, why not? First and foremost, you need the right tools for the job. And with so many to choose from that's not always as easy as it sounds. Then when you start to use tools in 'real life', getting acceptance from colleagues and ensuring the tools are properly configured and embedded within the wider corporate system is often a challenge. To compound your difficulties, new tools and variations of existing tools are constantly being introduced, leading to further confusion over which one does what, along with, on occasion, unhelpful overstatements of their capabilities.

And using tools effectively, even – or perhaps especially – the ones we are most familiar with, is not straightforward. Consider the ubiquitous SWOT analysis. It is very often used in a highly simplified form which produces a neat, bulletpointed list of strengths, weaknesses, opportunities and threats. But these are of little value without a structured analysis of the organisation's ability either to exploit a strength or address a weakness, some relative measures of the value or risk they may have for the business, and a way of understanding the different factors and their implications. The SWOT analysis tool that most people use simply does not incorporate any of these critical dimensions.

But the news is not all bad. There are some very useful tools out there, if they are chosen well and adapted to meet the particular needs of your organisation.

The benefits of structured templates

There are some key things we believe tools must be able to do: define, quantify, compare and contrast, and map – causally, spatially and conceptually. And whichever of those functions you might want a particular tool to perform, they must be clear to everyone as the tool is being used. For instance, you might want to do something around visioning or futures development. Which sounds reasonably straightforward. But is the task to define a vision? Or both to define and quantify a vision? Or compare possible visions



or scenarios? Or map possible visions or futures? Actually, when you come to think about it, what are the underlying components that constitute a meaningful vision? In other words, you need to define very precisely what you want to achieve and make that explicit – otherwise you are likely to end up in a place you didn't necessarily want to be.

One of the areas we are looking at is how to use structured templates that guide users through the process of applying a tool. For example, to make better use of the PESTLE (Political, Economic, Socio-cultural, Technological, Legal and Environmental) tool, we have designed a template which helps users think about and describe the important factors in terms of: types of trends and drivers, the timeframe, the likelihood and potential impact of each factor, their relevance and the implications for the organisation.

CTM's seven principles of tool development

First, all tools should be 'human-centric' by which we mean they should be designed so that everyone involved participates fully. Without this you cannot have proper strategic dialogue and co-created solutions which everyone buys into. Second, they should be activity-based using workshops and small-group activities with structured tasks for addressing and solving strategic problems. Third, if the activities are to be facilitated then the facilitators must be neutral - they should focus on the process and make no direct contributions to content. Fourth, the tools should be as 'lightweight' as possible so that all workshops, templates and activities can accommodate a degree of flexibility and not be overly prescriptive. Toolkits should always be built in a modular fashion so that the constituent tools can be readily integrated with one another. They should also be scalable so they can be used at different hierarchical system levels both inside and outside (if appropriate) the organisation in order to provide a wide dynamic range. Last but not least, to be

The news is not all bad. There are some very useful tools out there, if they are chosen well and adapted to meet the particular needs of your organisation.

effective the tools must be visual – both when they are being used, for example as workshop charts and templates, and when communicating the outputs whether as full reports or summaries.

Creating toolkits

CTM is particularly interested in how individual tools can be integrated into robust toolkits that are designed for use within specific organisational contexts. If tools are used in isolation – which they often are – with little, if any, consideration of how they relate either to one another or to the existing business architecture, the chances are their effectiveness will be compromised.

We have developed a scalable toolkit platform which provides the building blocks to rapidly design and deploy a set of tools for addressing a wide range of strategic planning, technology management and innovation activities. The platform is based on a minimum core set of three tools (roadmaps, portfolio matrices, interlinked grids) operating at two different levels within a hierarchical definition of the business system being addressed. The key tool in the platform is the roadmap. Given the flexibility and power of its underpinning framework (Why-What-How-When-Where-Who), it acts as a central 'hub' to which other tools can easily connect. It also provides a natural starting point, since it can be used as a structured brainstorm for initiating stakeholder input and interactions. And it also works well as a canvas for communicating outputs.

Roadmaps should be primarily used to align and plan. They enable different groups or disciplines to achieve consensus on how best to move forward and realise a vision. The second type of tool in the platform are portfolio matrices, typically in the form of 2x2 matrices which are very common in most organisations. Such tools should be used to prioritise and balance and hence provide focus, whether on specific layers or areas of a roadmap or on the analysis resulting from an interlinked grid. Interlinked grids are the third type of tool in the platform. This tool type is very broad, ranging from basic tabular tools through to highly structured grids, such as those used in Quality Function Deployment. Whatever their level of sophistication, the role of interlinked grids is to plot and weight. Plotting is used to uncover relationships, unravel complex interconnections, emphasise interdependencies and highlight gaps or overlaps. Weighting can then be applied to provide contrast and significance to the plots.

With just this set of three tools at two different levels, there are 57 possible sets of tool combinations and an associated 1,950 possible sequence permutations which clearly provides plenty of scope and options for practical toolkit arrangements, with the potential to include additional tools where required. To help organisations construct management toolkits, we have developed a visual prototyping method for toolkit creation that maps the contribution from each tool in the toolkit in terms of roles, functions, decisions and deliverables. The approach instils a rigorous emphasis on the combined utility of the tools and embraces the need to be 'fit for purpose' given the organisational environment.

Putting them into practice

Creating a toolkit is, arguably, the easy bit. Using them in practice is often where the real challenge lies. If it is to have any chance of succeeding, the toolkit must be embedded into the current organisational systems and processes and aligned with the business cycle. Training and guidance needs to be in place, as do processes for monitoring outputs and putting them into practice, for making ongoing refinements based on user feedback, managing resource constraints and corporate expectations. The CTM mantra is 'start small and iterate fast', so you can fine tune quickly and easily.

If you need help...

CTM currently offers both public course modules and in-company executive education on tools and toolkits so that organisations can better understand and more effectively use such tools. The training provides a solid foundation on the subject, with the standard material covering 12 tools: SWOT, PESTLE, Porter's five forces, value chain, scenarios, roadmapping, portfolios, interlinked grids, options/decision trees, concept mapping, balanced scorecard and the business model canvas. The training also gives you the opportunity to explore which tools would work best in your organisation, incorporating other tools you are already using or those with which you are already familiar, as required.

Tools and toolkits are a growing area of work for CTM, so enquiries are always welcome. Research, training and consulting engagements are available. For more information, please contact Dr Clive Kerr.

Email: civk2@cam.ac.uk



Dr Clive Kerr



Dr Rob Phaal





The internet, social media, cloud computing and mobile devices have created previously unimaginable quantities of data. People talk about 'data being the new oil', a natural resource that companies need to exploit and refine. But is this really true or are we in the realm of hype? Dr Mohamed Zaki, Research Associate at the Cambridge Service Alliance, explains that while many companies are already benefiting from big data, it also presents some tough challenges.

Businesses and governments certainly seem to believe in big data. Government agencies have announced major plans to accelerate research into it and, in 2013, according to a Gartner survey, 64% of companies said they were investing - or intending to invest – in big data technology. But Gartner also pointed out that while companies seem to be persuaded of the merits of big data, many are struggling to get value from it. The problem may be that they tend to focus on the technological aspects of data collection rather than thinking about how it can create value.

But big data is already creating value for some very large companies and some very small ones. Established companies in a number of sectors are using big data to improve their current business practices and services and, at the other end of the spectrum, start-ups are using it to create a whole raft of innovative products and business models.

Big data for big business?

At the Cambridge Service Alliance, we work with a number of leading companies from a range of sectors and see first-hand both the opportunities and challenges associated with big data.

Take a company which makes, sells and leases its products and also provides maintenance and repair services for them. Its products contain sensors which collect vast amounts of data, allowing the company to monitor them remotely and diagnose any problems. If this data is combined with existing operational data, advanced engineering analytics and forward-looking business intelligence, the company can offer a 'condition-based monitoring service', able to analyse and predict equipment faults. For the customer, unexpected downtime becomes a thing of the past, repair costs are reduced and the intervals between services increased. Intelligent analytics can even show them how to use the equipment at optimum efficiency. OEMs and dealers see this as a way of growing their parts and repairs business and

But big data is already creating value for some very large companies and some very small ones.

increasing the sales of spare parts. It also strengthens relationships with existing customers and attracts new ones looking for a service maintenance contract.

In a completely different sector, an education revolution is underway. Big data is underpinning a new way of learning otherwise known as 'competencybased education', which is currently being developed in the US. A group of universities and colleges is using data to personalise the delivery of their courses so that each student progresses at a pace that suits them, whenever and wherever they like. In the old model, thousands of students arrive on campus at the start of the academic year and, regardless of their individual levels of attainment, work their way through their course until the point of graduation.

In the new data-driven model, universities will be able to monitor and measure a student's performance, see how long it takes them to complete particular assignments and with what degree of success. Their curriculum is tailored to take account of their preferences, their achievements and any difficulties they may have. For the students, this means a much more flexible way of working which suits their needs and gives them the opportunity to graduate more quickly. For the institutions, it means delivering better quality education and hence achieving better student outcomes, and being able to deploy their staff more efficiently and more in line with their skills and interests.

No-one ever said it would be easy

To get value out of big data, however, organisations need to be able to capture,

store, analyse, visualise and interpret it. None of which is straightforward. One of the main barriers seems to be the lack of a 'data culture', where data is wholly embedded in organisational thinking and practices. But companies also face a very long list of challenges to do with data management and processing. Conditionmonitoring services, for example, rely on data transmission, often using satellite systems or digital telephone systems: but sometimes there simply is no coverage.

Most organisations have vast amounts of data stored in different systems in a variety of formats: bringing these together in one place is difficult. The whole issue of data ownership is problematic in a service contract environment, where the customer considers it to be their data, generated by their usage, while the service provider may consider it to be theirs as it is processed by their system. In complex data landscapes, security - managing access to the data and creating robust audit trails - can also be a major challenge as, sometimes, is complying with the legislation around data protection. Many organisations also suffer from a lack of techniques such as data and text-mining models, which include statistical modelling, forecasting, predictive modelling and agent-based models (or optimisation simulations).

New data, new business models

Where established organisations may find it hard to move away from their entrenched ways of doing things, start-



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ups have the luxury of being able to invent new business models at will. At the Cambridge Service Alliance we have also been looking at these new ways of doing things in order to understand what business models that rely on data really look like. The results should help companies of all sizes – not just start-ups – understand how big data may be able to transform their businesses. We have identified six distinct types of business model:

Free data collector and aggregator:

companies such as Gnip collect data from vast numbers of different, mostly free, sources then filter it, enrich it and supply it to customers in the format they want.

Analytics-as-a-service: these are companies providing analytics, usually on data provided by their customers. Sendify, for example, provides businesses with real-time caller intelligence, so when a call comes in they see a whole lot of additional information relating to the caller which helps them maximise the sales opportunity.

Data generation and analysis: these could be companies which generate their own data through crowdsourcing, or through smartphones or other sensors. They may also provide analytics. Examples include GoSquared, Mixpanel and Spinnakr which collect data by using a tracking code on their customers' websites, analyse the data and provide reports on it using a web interface. Free data knowledge discovery: the model here is to take freely available data and analyse it. Gild, for example, helps companies recruit developers by automatically evaluating the code they publish and scoring it.

Data-aggregation-as-a-service: these companies aggregate data from multiple internal sources for their customers, then present it back to them through a range of user-friendly, often highly visual interfaces. In the education sector, Always Prepped helps teachers monitor their students' performance by aggregating data from multiple education programmes and websites.

Multi-source data mash-up and analysis:

these companies aggregate data provided by their customers with other external, mostly free data sources, and perform analytics on this data to enrich or benchmark customer data. Welovroi is a web-based digital marketing, monitoring and analysing tool that enables companies to track a large number of different metrics. It also integrates external data and allows benchmarking of the success of marketing campaigns.

So what does this tell us? That agile and innovative start-ups are creating entirely new business models based on big data and being hugely successful at it. These models can also inspire larger companies (SMEs as much as multinationals) to think about new ways in which they can capture value from their data. But these more If companies can't innovate when the opportunity arises, they may lose competitive advantage and be left struggling to 'catch up' with their competitors.

established companies face significant barriers to doing so and may have to deconstruct their current business models if they are to succeed. In the world of fleet and engines this could be by moving to a condition-based monitoring service or, in the education sector, delivering teaching in a completely new way. If companies can't innovate when the opportunity arises, they may lose competitive advantage and be left struggling to catch up with their competitors.

More on big data from the Cambridge Service Alliance

Big data is one of the Cambridge Service Alliance's core research themes. You can find out more about it on the Alliance website at: www.cambridgeservicealliance.org

Resources include:

Working paper: *Big data for big business* by Philipp Max Hartmann, Mohamed Zaki, Niels Feldmann and Andy Neely.

Webinar: Mohamed Zaki talks about big data for big business.

Podcast: Andy Neely, Director of the Cambridge Service Alliance, explains why SMEs need to understand and engage with big data.

The Cambridge Service Alliance

The Alliance brings together industrial and academic partners to find innovative solutions to the challenges of designing and delivering high-performance complex services. The current partners are: University of Cambridge, BAE Systems, Caterpillar, IBM, Pearson and Zoetis.



Understanding the landscape

High value manufacturing strategies for the regions »

What do Wiltshire and Liverpool have in common? Wiltshire brings to mind Salisbury Cathedral, Stonehenge and beautiful rolling countryside. With Liverpool, we tend to think of a vibrant commercial centre, at the heart of the UK's industrial past and present. When deciding national priorities and putting in place national programmes to help industry thrive, how do we go about doing that in such very different places?

And, of course, it's not just Wiltshire and Liverpool. Every region of the UK has a diverse set of opportunities and challenges. Which industrial sectors are currently thriving or in decline? What kind of skills bases do they have? What is the education provision like in the area? How good are the existing transport and communications infrastructures?

In 2011 the UK Government invited local authorities and businesses to set up Local Enterprise Partnerships (LEPs), and gave them a remit to decide the investment priorities that will best support local business. If MECS has been working with two of them: Swindon and Wiltshire LEP and the Liverpool City Region LEP. The aim of both projects was to help the respective LEPs develop their own vision for high value manufacturing in their regions, and to do so in a way that supports national initiatives. In each case, they started by getting a clear picture of where they sit in both the global and national industrial 'landscape', and how competitive they are - particularly in those sectors designated as national priorities. This picture underpinned the next part of the process: identifying their most promising opportunities for growth and creating development plans to capitalise on those opportunities.

One of the reasons it made good sense for IfM ECS to help these two LEPs with this task, is that in 2012 IfM and IfM ECS produced a report for the Technology Strategy Board (now Innovate UK) on the growth of high value manufacturing in the UK. A landscape for the future of UK manufacturing looked at the global manufacturing context in which UK companies were then competing and identified those high value sectors in which the UK could become an important player over the next 15 to 20 years. The report was instrumental in establishing the Government's catapult strategy which to date has resulted in the creation of seven 'catapults' - or technology and innovation centres - in areas such as process innovation, manufacturing technology and composites. The aim of the catapults is to bring together businesses with publicly-funded science and engineering to help bridge that tricky gap between early innovation and industrial-scale manufacturing. If M and IfM ECS are currently working on a new version of the report, which refines the approach to take account of what has been happening globally and nationally in the last three years, in this very fastmoving environment.

In its work with LEPs, IfM ECS was ideally placed to use the 'HVM framework' the IfM had helped develop for Innovate UK to understand the national picture. This framework is based around a classification of industrial capabilities or the ability to deliver products – and services – which meet customer needs, are competitive and can respond to opportunities. These are matched with a set of key 'national competences' – in other words, things we are good at and which allow us to respond to changing global trends and drivers in a way that captures value. Using a common framework is clearly important if the LEPs' plans and priorities are to support national ones, and if the regions are to take advantage of any national funding opportunities.

A mixed economy

Swindon and Wiltshire LEP faces a number of challenges in developing a thriving high value manufacturing sector. On the plus side, it has a flourishing base of small and medium-sized companies with a good track record of innovation. There is also a strong military presence in the area, including the Defence Science and Technology Laboratory at Porton Down, which could provide promising opportunities for collaboration. But it has a very mixed rural and urban economy which lacks a strong sense of itself as a centre of high value manufacturing. If anything, people can be wary of manufacturing, expressing concerns particularly around environmental impact and sustainability.

Andrew Gill, Principal Industrial Fellow at IfM ECS (and lead consultant on the national HVM project), worked with the Swindon and Wiltshire LEP to develop a '2025 HVM' vision for the area. To do this they brought together a mix of 35 local businesses and government agencies. By using questionnaires, interviews and structured workshops, Andrew helped them arrive at a vision for the future and an outline plan to achieve it.

The vision has a number of key elements: making sure that the area derives



maximum benefit from its military presence, supporting small and mediumsized companies and developing technology centres of excellence in biosciences, in renewable energy and sustainable materials and in coatings. Sectors which were seen as presenting particularly promising opportunities included food, biotechnology, aerospace, automotive, energy and the digital economy.

Having the right skills and capabilities is clearly vital, so the project also makes recommendations for education provision. It also encourages companies to get better at telling schools and colleges both what they need their prospective employees to know – particularly in regard to the STEM (Science, Technology, Engineering and Mathematics) subjects – and what opportunities they have to offer.

Of the landscaping project, Barry Dennington, Chairman, Swindon and Wiltshire LEP, said:

"To fully develop the high value manufacturing opportunities in the area, the Swindon and Wiltshire Local Enterprise Partnership led a working group which gathered together leaders from private sector manufacturing businesses to work with IfM ECS. This powerful combined knowledge created a clear plan to deliver the key 'must haves' for the region including better education and skills provision, sustainable manufacturing practices and more collaboration between companies. The process provided a great platform from which we can build on our current strengths to deliver significant economic and social benefits for the area."

Building on strength

The Liverpool City Region provides something of a contrast to Swindon

and Wiltshire. Home to companies such as Jaguar Land Rover, Unilever and Cammell Laird, it has a proud tradition of manufacturing. There are more than 3,000 manufacturing companies in the region, providing jobs for more than 50,000 people. As well as the household names there are plenty of smaller manufacturers often playing a key part in their larger counterparts' supply chains. Manufacturing currently generates £3.2bn for the Liverpool City Region economy and the LEP has ambitious plans to maximise its potential to create both jobs and deliver economic growth. But the LEP is also conscious that its manufacturers face considerable challenges, not least from rapidly changing technologies and supply chains, and for some, the need to develop more service-based or environmentally sustainable business models.

Bill Colquhoun, Principal Industrial Fellow, led this project for IfM ECS, working with the LEP to identify how it could best achieve both long-term competitive advantage and some short-term 'quick wins' through its industrial strategy. The 'Making It' project, as it was known, brought together Liverpool City Region's manufacturing community to review and agree their opportunities and priorities.

Like the Swindon and Wiltshire project, 'Making It' used the national Innovate UK framework and involved a series of workshops with industry experts. What emerged from it was a detailed understanding of the global and national landscape for advanced manufacturing and how Liverpool is positioned within it. From there, the stakeholders developed a shared vision for what is possible in the region and a focus on the competencies the region will need if it is to achieve sustained competitive advantage, aligned with national priorities. Simon Reid, Sector Manager for Advanced Manufacturing, Liverpool City Region, LEP, said:

"The 'Making It' project is the most in-depth study of its kind in the UK. It has identified the longer term competencies that the Liverpool City Region needs in order to remain competitive. These opportunities provide a justification for future investment through the national manufacturing strategy. The IfM ECS team was hugely instrumental in helping us with the research process, bringing with it both knowledge of the national landscaping methodology as well as a wealth of expertise in stakeholder engagement and facilitation."

An early – and very positive – outcome of the process was that last year the Liverpool City Region successfully bid for a University Enterprise Zone, 'Sensor City'.

For both Swindon and Wiltshire and the Liverpool City Region, areas with very different sets of challenges and aspirations, this common approach to 'landscaping' has led to a compelling vision for their respective futures. And the hard work of making it all happen is already under way.



Creating the conditions for growth outlines how IfM ECS can work with policymakers who are supporting national and regional growth in key industry sectors. Read it online and at: www.ifm.eng. cam.ac.uk/services/government

Getting creative in the kitchen

Richard Joseph took the one-year postgraduate Advanced Course in Design, Manufacture and Management (ACDMM, now Industrial Systems, Manufacture and Management, or ISMM) at the IfM in 1998. In 2003 he set up Joseph Joseph, the innovative kitchenware company, with his twin brother Anthony. It now has a turnover of £40 million, sells its products in 104 countries and has 80 employees.

Richard was talking to Andy Neely, Director of the Cambridge Service Alliance and the Royal Academy of Engineering Professor of Complex Services at the University of Cambridge.



Andy: Why did you apply for ACDMM?

Richard: Anthony and I both did A-levels in design and technology, and Anthony did art which he was very, very good at. We both went on to do industrial design at university, Anthony at Central Saint Martins, which was more about aesthetics, and I went to Loughborough, which was more engineering oriented. In my last year at Loughborough, a friend told me about ACDMM. I got a place but deferred it for a year as I had also been offered a job as a design engineer at Dyson and I wanted to give that a try first.

In the end, I decided to leave Dyson for ACDMM and it was absolutely the right decision. I always knew that I wanted to work for myself but I wasn't sure at what and the course in Cambridge was perfect, giving me exposure to lots of different industries and businesses.

What were the best things about it?

Definitely the practical aspects. Going out into industry and doing one and two-week projects all over the UK. And between projects we were visiting companies and were able to ask them questions which really allowed me to explore my thoughts and ideas and to understand how businesses work. I would never have got that from another course.

The coursework and the lectures all had a practical aspect and gave you a set of skills and knowledge that you could take



Richard (right) and Anthony Joseph

into a business and understand and solve a problem. It also taught you to go round a firm and talk to everybody. You have got to have good communication skills and be able to engage with people. A lot of the people in my year went off to do management consultancy and became very successful at it. Others have joined blue chip firms doing similar project work and have also done very well.

So how did Joseph Joseph come about?

I came out of ACDMM keener than ever to work for myself but still not knowing at what. We had a family glass manufacturing business which my grandfather had set up in Birmingham in the 1930s. Dad said that if I wanted to set up my own business, I had to know how to sell, and that I should come and sell for him.

At the time, Dad had a subsidiary of the main manufacturing business which wasn't doing so well. It had about 25 employees and made glass cutting boards. He asked if I would step in as managing director. Meanwhile, Anthony had become a very successful freelance designer in London, working for a lot of major consumer goods brands. He did some modern designs for the boards and I was doing the sales and understanding the business and trying to turn it round. We had a really interesting time and learnt a lot but in the end we couldn't save it. We sold everything except the glass cutting boards. And that became Joseph Joseph, which we launched in 2003, with four products and 15 customers.

The idea was that Anthony would look after the design side and I would look after the commercial, although we both have a keen interest in design. But that was how we were going to keep our roles separate. When you are twins it is very important to

To experience the whole journey of designing a product, making it and then selling it is really a wonderful thing

have your areas of specialty. The two of us are guite competitive, particularly with each other, so it works well and spurs us on to drive our own areas of the business. At the start we had rather an eclectic mix of products. The glass cutting boards were our number one product but we also had a few gift items. It was a conversation with a fantastic buyer at the department store, Alders (now closed) which made us become more focused. She said: "I'm the kitchenware buyer. If you do more kitchenware, I'll buy it from you because the chopping boards are doing well but I don't buy clocks - that's the clock buyer - and I don't buy mugs - that's the mug buyer."

We rationalised the range and just did chopping boards for the next three years. Our aim was to do the best plastic, wood and glass chopping boards on the market. Luckily, chopping boards are a very international product - there is very little cultural difference between a chopping board in Japan and one in the UK. In those early days we were just on the hunt for customers so we threw a bag of samples in Ant's Ford Ka and set off on a tour of Europe, sleeping in the car. Within 18 months, we'd got distribution in France, Germany and Japan. And then it really was a case of trying to grow the product range and the distribution in a focused way.

Specialising in kitchenware was perfect for us because it's highly functional and the products are used every day. And what we want to do is design things that are different, innovative and problemsolving. So function came first and then we applied aesthetic and brand, because we wanted people to connect to our products emotionally, so they not only wanted to buy them because they work but also because they would be proud to own them. And because we are designers we will always want to design stuff that looks great.

So who was the first customer?

Alders. That first big order kept us going. We very nearly went bust twice in the first year. We had four products, three of which were duds. The duds were sitting as stock in our warehouse tying up our cash. But Alders really got behind us and gave us the step up which you need as a very small company. One of the big problems we faced was that some of the other large department stores in the UK would say: "We love what you are doing but you are too small. We can't list you as a supplier because you've only got four products. We don't know if you are financially sound. Until you are more established, we can't talk to you."

You understand that but it doesn't help you get started.

How did you scale up?

In the early days we were able to get bank finance. It takes us two years to develop a product from initial brief, through concept generation, product development, tooling, product testing, safety testing and certification, to get to launch. It's about two and half years by the time we get paid for the initial idea. So bank finance was really important.

Did you get step changes in order where you get a really big customer and suddenly have to go from say 50,000 units to 100,000?

We were doubling in size for four years in a row, managing not only the financing of it but also the scaling up of the staff. When you are growing at that speed, your systems and your staff are never ahead of the curve. Worldwide, we now sell about 7 to 8 million units a year so scaling up production capacity to meet demand was also challenging.

Export is about 75% our business. We sell in 104 markets worldwide, and as well as our UK head office, we have US and French subsidiaries, with local teams in those markets. Everywhere else we use local distributors or go direct to key retailers. We launch two collections a year and our goal is to deliver them to all 104 markets on the same day. We have a supply chain team based here and three warehouse locations, one in southern China, one in Wolverhampton and one on the east coast of America. Our global supply chain is set up so that we can grow in all our markets at the same time.

Where's your manufacturing done?

We still manufacture the glass chopping boards in the UK. When Dad sold his business we bought the machines and set them up in a 6,000 square foot factory just outside Birmingham. The rest of it is in the Far East, predominantly in southern China.

When you go through the design process, are the designs commissioned by retailers or are you pitching to them?

We pitch. What we are looking for are opportunities to make products that work better or which solve a problem. Storage is a good example. As people increasingly move to urban areas where space is at a premium, things need to work more efficiently in the space you have. We do the research to identify opportunities and then we create design briefs. Then we go to the retailers and pitch the ideas. We have an in-house design team of 16, and we use external designers as well so we get a great breadth of ideas to choose from. We have calculated our hit rate is about 3% ideas to launch and we have about 200 in development at the moment. 3% is not a great hit rate but it's ok if the 97% get killed early enough. That's a skill in itself.

How do you involve consumers in the front-end? There is lots of talk now about creating customer personas, images of individuals you might be designing for and so on. Do you do anything like that? No. We do studies of consumer behaviour within the kitchen environment to get ideas and insights as to whether people will use the products in the way we expect or if they will find other uses for them. We don't really have consumer panels or create personas because we have such a broad demographic and such an international customer base that it's hard to identify customer types.

What's been the most difficult moment?

We have been very fortunate – we found something we both thoroughly enjoy and are good at. But it is challenging and a lot of hard work. You need a very forgiving and supportive family. Perhaps the most difficult thing we have to deal with is counterfeiting and copying product in the Far East. When you have poured blood, sweat and tears into a product and risked huge amounts of money and time, then the copiers bring an identical product to market six months later is both frustrating and dangerous for the business. We have no choice but to be as aggressive as possible in fighting it. In 2010 we spent more money defending our designs than on designing new products which, as a creative business, is a dreadful place to be.

If you had one piece of advice for someone starting their own business, what would it be?

Get a mentor. It was one of things we did very early on. We approached someone I knew through selling for my father, Roger Crudgington, who had worked for Gillette. He started off mentoring us once a month and is now our chairman. He has been massively instrumental in helping us grow the business. You've got a wise head which has experienced 90% of the issues you have.

What's next for Joseph Joseph?

To drive our product development into new categories for the kitchen and our international expansion in all the key markets. We have some fantastic products in development and are very excited about the future. To experience the whole journey of designing a product, making it and then selling it, is really a wonderful thing.





Anna Viljakainen, Business Tool Developer, IfM Education and Consultancy Services

COURSES AT THE IfM

IfM runs a series of courses and workshops throughout the year. For more information go to: **www.ifm.eng.cam.ac.uk/events**

> Evaluating and selecting technology-based projects

How to evaluate and choose the right projects in conditions of uncertainty when detailed factual information is scarce.

> Making the shift to services

New approaches that will help transform your organisation from a product-based business to one that can also provide its customers with services and solutions.

> New tools for sustainable businesses

Learn to analyse how value is created in your business and how to use that knowledge to enhance your competitive advantage.

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How to encourage innovation, spot the ideas with the most potential, choose the right business models to exploit them, identify and manage risks and protect your intellectual property.

> Strategic roadmapping

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The IfM is part of the University of Cambridge. It brings together expertise in management, technology and policy to address the full spectrum of issues which can help industry and governments create sustainable economic growth.

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