The Cambridge-MIT Institute

ACCELERATING INNOVATION BY CROSSING BOUNDARIES

The Cambridge-MIT Institute
2000 – 2006

Acknowledgements

CMI represented a major collaborative effort between universities, industry and government. Over one hundred universities and one thousand companies, and thousands of researchers and students participated in its activities. Individual contributions are too numerous to mention, but the enthusiastic involvement of people, organisations and institutions is warmly acknowledged. Many of the partnerships, collaborations and friendships developed though CMI continue to flourish.

The Cambridge-MIT Institute
www.cambridge-mit.org

Contents

Executive Summary

In 2000, the UK Government invited the University of Cambridge and the Massachusetts Institute of Technology (MIT) to form a joint venture that would work with other universities to look for ways to enhance competitiveness in the UK.

Funded through the predecessors to the Department for Innovation, Universities and Skills, with additional financial support from the public and private sectors, the Cambridge-MIT Institute (CMI) set out to enhance competitiveness and innovation by improving knowledge exchange between universities and industry.

Since 2000, CMI has worked with over 100 universities and more than 1000 companies and public enterprises on a series of challenging projects involving education, research and knowledge exchange. If there is a single message that emerges from CMI, it is that the integrated system of activities at a university – the constructive interplay of education and research, and formal and informal engagement with industry and enterprise – has the greatest potential to substantially enhance knowledge exchange and accelerate innovation.

Education for Innovation

CMI set out to accelerate innovation by developing courses – both undergraduate and graduate – that would give students an understanding and appreciation of innovation, and the skills and knowledge that they would need in their roles as knowledge exchange agents, innovators and potential future entrepreneurs.

Significant curriculum developments, including six innovative new interdisciplinary Master's degrees integrating science, technology and management studies, were facilitated. Over 350 students have already graduated from these courses. At the undergraduate level, the Enterprisers programme has provided new awareness and skills, and encouraged the rapid growth of student-run innovation clubs and competitions. Over 30 spin-outs have been generated by this programme alone.

Innovation also needs individuals who are comfortable to cross boundaries between disciplines. CMI has drawn on its interdisciplinary research programmes in the development of new courses in biological engineering and microelectromechanical systems (MEMS), two interdisciplinary areas of research and industry that are growing rapidly, and where the UK has both academic and commercial excellence.

Key findings from the *Education for Innovation* programme include: insights into how to better prepare students for their roles as future entrepreneurs through education that develops a firm understanding of a relevant field of study, professional confidence through hands-on experience, and the development of entrepreneurial skills.

Knowledge Integration in Research

Even the best research will do little for innovation if it is unknown territory for the businesses and enterprises that seek to build on it to create new products and services. CMI supported research that met the usual criteria of peer review, but also required 'consideration of use'. This reflected the guiding principle that benefits flow from the consideration of the needs of society and industry during the design of research. Researchers must nevertheless maintain a strong connection to underlying science, so that they can understand when to 'pull through' important new ideas.

Research into new biomaterials for bone substitutes, for example, has led to a spin-out company, OrthoMimetics. Its products, developed in conjunction with surgeons, have the potential to dramatically extend the lifetime of bone and joint replacements.

The creation of Knowledge Integration Communities (KICs) has proved particularly fruitful. These substantial research programmes explicitly involved external stakeholders from industry, government, non-governmental organisations and other universities in the UK to bring together all the participants needed to address a challenge and to accelerate innovation.

A good example of the KIC approach is the Silent Aircraft Initiative which addressed the major challenge of reducing aircraft noise. A multidisciplinary transatlantic team of researchers working closely with companies, user groups and regulators developed radical new technologies, designs and ways of working which are already being adopted.

Key findings from the *Knowledge Integration in Research* programme include: how to translate research into a more important instrument of innovation and knowledge exchange by encouraging early consideration of use; by increasing awareness of the needs of society, industry and enterprise; and by developing integrated communities of students, scholars, industry and enterprise.

Engaging Industry in Knowledge Exchange

It is a fundamental principle of CMI that the UK can improve its capacity to innovate, and to commercialise ideas more quickly, by improving knowledge exchange between universities, businesses and other enterprises.

A wide range of projects with businesses, and others who benefit from academic research, developed a better understanding of how universities and enterprises interact, and identified new ways to enhance knowledge exchange. Industry was actively engaged in the practice of knowledge exchange, helping to shape research programmes as equal partners.

Clear mechanisms were devised and demonstrated, with formalised opportunities for academics and enterprises to exchange ideas in workshops, conferences and regular review meetings, supported by professional management and facilitation.

CMI's Electricity Policy Forum has evolved into a network of leading academics, industrialists and regulators from Europe and the US who meet regularly to address issues of electricity and emission markets and regulation.

The Programme on Regional Innovation continues to work with Regional Development Agencies to provide the evidence for improved policy and practice in regional innovation and competitiveness, and to provide cross-disciplinary forums that encourage knowledge exchange between academic researchers and policy makers.

Key findings from *Engaging with Industry* include: the importance of universities' proactive involvement with industry and enterprise in prolonged engagements; developing and enabling agents of innovation and knowledge exchange; and developing structures and incentives that encourage interactions between universities and industry.

The Way Ahead

The need for a constructive interplay of education, research, and formal and informal engagement with industry and enterprise highlights the need for interaction of these activities across a broad front. Knowledge exchange builds upon and integrates the long-standing role of the university in education but requires informal and human interactions with industry, supported by more formal mechanisms such as publication and licensing, which are a necessary, but not sufficient, underpinning for effective knowledge exchange.

CMI identified a set of approaches, or 'effective practices', that can improve knowledge exchange involving collaborative research, knowledge integration, curriculum development, student engagement and entrepreneurial education. They continue to be shared with the wider community.

CMI can already point to significant achievements in research, education and knowledge exchange, but the full impact of its main mission, improving the competitiveness of the UK, will only become fully apparent as its innovations become embedded in everyday practice over the coming years.

An analogy may be helpful. Rolls-Royce extends the capability of its aero-engines by building demonstrator machines to develop and evaluate emerging technologies. Knowledge generated from the demonstrator then feeds into the creation of new engines designed for a range of purposes. The knowledge emerging from CMI has already been incorporated into a range of new 'engines' for research, education and industrial engagement. That knowledge will continue to influence practice in these areas for many years to come.

Introduction

This report summarises the key activities and lessons from the Cambridge-MIT Institute (CMI) between 2000 and 2006.

CMI was established to explore how academics, industrialists and educators might work together to stimulate competitiveness, productivity and entrepreneurship in the UK.

CMI undertook a wide range of projects, many in partnership with other academic institutions and with industry. Over the period covered by this report, more than 100 universities and 1000 companies participated.

There were three main areas of activity:

- **Education for Innovation**
- **Knowledge Integration in Research**
- **Engaging Industry in Knowledge Exchange**

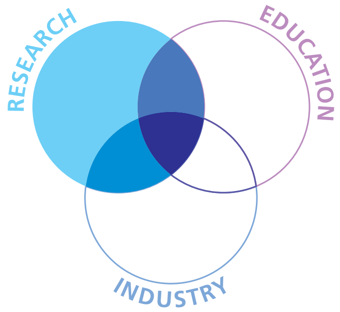
Many of the new activities and networks that emerged from CMI are now flourishing independently, though they remain part of the CMI 'family'. Examples of continuing activities include: the Communications Research Network, the national training programme Praxis, the Programme on Regional Innovation, and the Silent Aircraft Initiative.

The University of Cambridge and the Massachusetts Institute of Technology have been privileged to be involved in this unique activity. We believe that it has already had a significant impact on education, research and practice. This impact is likely to grow as universities and other organisations continue to apply and develop the ideas that emerge from the CMI community.

We hope in particular that the work of CMI will add to the growing body of expertise and experience in university–industry engagement in the UK. Our brochure, *Working in Partnership,* focuses particularly on CMI's industrial impact (available at www.cambridge-mit.org).

As CMI evolves into the CMI Partnership Programme, involving wider communities and partnerships, we offer our warmest thanks to the many individuals, organisations and companies who have collaborated with us in this adventurous initiative.

The Silent Aircraft Initiative



"A radical approach to the challenges of the future comes more naturally from Academia than Industry, but the outcome will carry credibility only if the team is sufficiently strong and if it has the support of Industry and access to modern design methods. The SAI team has shown how this can be done."

DR JOHN GREEN
CHAIRMAN OF THE SCIENCE AND TECHNOLOGY SUB-GROUP, GREENER BY DESIGN

The Silent Aircraft Initiative (SAI), a CMI Knowledge Integration Community, brought together a unique group of interested parties. These partners worked collaboratively to reduce aircraft noise, not only because this would directly advantage communities situated close to airports, but also because it would provide a major boost to the UK's aerospace industry, and help UK airlines and airports to operate more productively.

The SAI discovered new ways to reduce aircraft noise dramatically, to the point where it would be virtually unnoticeable outside an airport's perimeter. The initiative developed a series of designs including its most recent, the fuel-efficient SAX-40.

In order to succeed in reducing aircraft noise, the SAI had to consider every aspect of aircraft design and operation. This holistic view allowed engineering trade-offs to be made across the aircraft design and operation.

Students involved in this project benefited from a superb training. As part of the SAI, they learned to work as an integrated team, as well as to focus on their specialised roles in order to pull the designs together.

Behind the success of this project also lies a strong and dedicated team of researchers who sought to maximise results by exploiting each other's complementary skills. Through the SAI, existing relationships between senior staff were strengthened and extended to the newer faculty members who, in turn, fostered those collaborations.

As with many of its projects, CMI provided professional public relations and outreach support. SAI, in particular, obtained significant media coverage, and, with CMI's help, gained the necessary skills to interact effectively with the press and disseminate research outputs.

Background and Approaches of CMI

The UK is a world leader in academic research. Reviews over the years have shown that the country's universities head the citation statistics in many fields. They also show that British scientists are more productive than their counterparts in many countries. Though there are increasing numbers of successful examples, the UK has not always translated that excellence in research into excellence in innovation and business performance.

1.1 Introduction

The UK, through the Department of Trade and Industry (DTI), supported the University of Cambridge and the Massachusetts Institute of Technology (MIT) to come together to form the Cambridge-MIT Institute (CMI) as a joint venture. The mission of CMI was to look for ways to enhance competitiveness by accelerating innovation through, for example, better exchange of information between the various players in the innovation process.

"The availability of EU funding has meant that our links with North America have been somewhat neglected. That's where the Cambridge-MIT Institute will play a major role: the way in which we can form partnerships across the Atlantic."

PROF. SIR PETER KNIGHT
PRINCIPAL OF THE FACULTY OF NATURAL SCIENCES
IMPERIAL COLLEGE LONDON

The message from the UK and US is consistent: competitiveness is increased by innovation, which, in turn, is enhanced by knowledge exchange. Without knowledge exchange, good ideas can languish. As Gordon Brown, then Chancellor of the Exchequer, said at the announcement of the creation of CMI, *"We need to do much better at turning knowledge into enterprise and we want universities to see this as their co-mission."*

1.2 Competitiveness through Knowledge Exchange

Economic policies in the UK have, over the past two decades, improved competitiveness. Continued economic success is likely to depend on developing a competitive advantage through innovative products and processes. One way to accelerate such innovation is through better flow of information and knowledge between universities and industry.

Knowledge exchange has been a guiding theme for CMI. This term was used, rather than the more traditional 'knowledge transfer', because knowledge exchange describes the multidirectional flow of information between universities and other enterprises in the pursuit of solutions to shared problems or challenges. Knowledge exchange can involve academics, educators, businesses (small, medium and large), policy makers, funding bodies, venture capitalists and community groups. The exchange process can be formal or informal: it can involve the exchange of thoughts and ideas, documents and people.

The challenge for CMI has been to improve our understanding of the processes involved in knowledge exchange. Only then can we ensure that we have implemented the most appropriate procedures for sharing knowledge.

In the past, proposals to promote knowledge exchange often focused on policies, incentives and institutional arrangements. While these are important supporting mechanisms, knowledge exchange actually happens through personal interaction and through the flow of ideas, processes that are harder to measure and to promote. CMI paid particular attention to knowledge exchange in the context of emerging ideas and technologies.

1.3 The Cambridge-MIT Institute

Over the past decade, the UK has enhanced the role of its universities in stimulating economic growth through a number of initiatives, including the University Challenge Seed Fund, Science Enterprise Centres, Faraday Partnerships and the Higher Education Innovation Fund. A wide range of organisations are also engaged in promoting knowledge transfer from the research base.

Funded by government, business and charities, CMI began operations towards the end of 2000 with the mission:

To enhance the competitiveness, productivity and entrepreneurship of the UK economy… by improving the effectiveness of knowledge exchange between university and industry, educating leaders, creating new ideas, and developing programmes for change in universities, industry and government… using a partnership of Cambridge and MIT, and an extended network of participants.

To achieve this mission, six strands were developed in CMI's evolving programme of work:

- Conduct experiments designed to understand and enhance knowledge exchange
- Set these experiments in the context of research programmes informed by the interests of potential end-users
- Educate a generation of students at all levels in the practices of knowledge exchange through the creation of new course materials, teaching approaches and programmes
- Support and promote knowledge exchange and innovation in existing companies, and the creation and growth of entrepreneurial ventures
- Support the implementation in universities of programmes that enhance knowledge exchange practices
- Contribute to government policies on universities and industry related to knowledge exchange

The first three strands emphasise the core processes, conducting experiments in knowledge exchange within the principal activities of a university – research and education. The latter three strands reflect the practice of working with external stakeholders – industry, universities and government – to understand and influence their processes and policies.

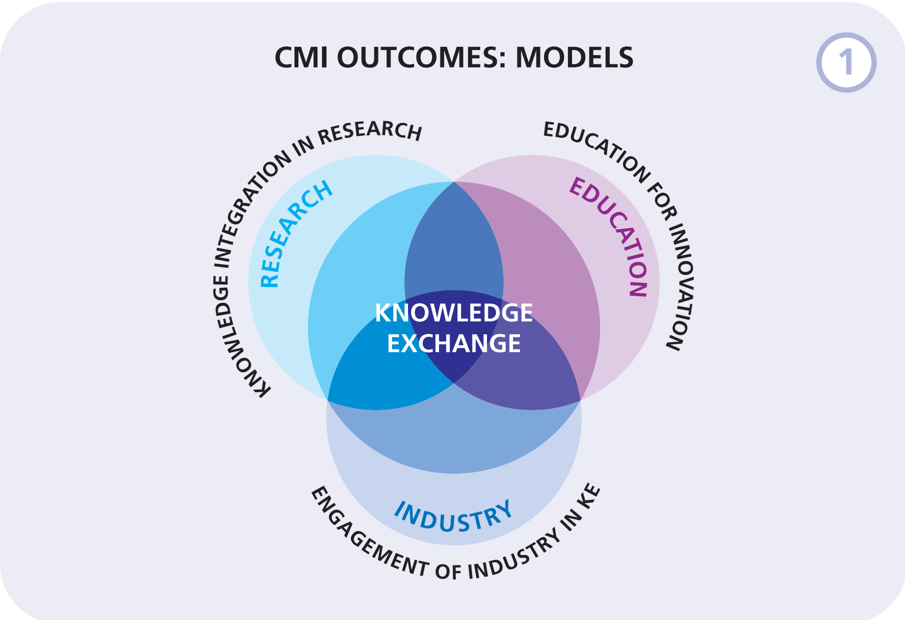
1.4 Strategy

CMI's strategy, informed by its internal and external stakeholders, focused on knowledge exchange by:

- emphasising interactions between people and the flow of ideas and problems;
- identifying effective practices, patterns of behaviour and actions that improve knowledge exchange;
- refining and communicating those effective practices to the wider community.

1.5 Knowledge Exchange and the CMI Programme Areas

Universities typically operate in three domains: education, research, and engagement with industry and society. Rather than distinct streams, CMI addressed these as integrated and overlapping activities, each with an important contribution to the flow of knowledge, as shown below.



Knowledge exchange emerges from interacting activities in these three domains. Consistent with this view, CMI developed programmes in three main areas:

- Knowledge Integration in Research
- Education for Innovation
- Engaging Industry in Knowledge Exchange

In each area, CMI set out to demonstrate how knowledge exchange between stakeholders could bring value to each without compromising their primary interests. For example, research projects used the same criteria of peer review that would apply in other academic research projects, but with added elements of knowledge exchange and informed by end-user requirements, that is with 'a consideration of use'. This meant that in setting the research agenda, proposers would give consideration to where that research might find application, even though this may not have been the original stimulus for the idea.

"The work that Enterprisers does is key to encouraging graduates to stay within the region. We've been involved with the Cambridge-MIT Institute for a couple of years now and really appreciate the outcomes that they achieve."

DAVID SMITH
INITIATIVE MANAGER
ONE NORTHEAST

CMI Enterprisers, Durham January 2005

1.5.1 Education for Innovation

Students are likely to be better prepared for their potential roles as knowledge exchange agents, innovators and future entrepreneurs by an education that develops:

- a firm understanding of the relevant field of study;
- personal and interpersonal skills and associated 'professional confidence', especially when learned through hands-on experiences;
- entrepreneurial skills and 'professional confidence' and the opportunity to apply them to entrepreneurship.

CMI funded projects in education that brought together disciplines and built new connections among bodies of knowledge necessary for innovation. The projects placed great emphasis on skills, including 'generic skills' as well as those specific to innovation. It is important for students not only to learn these skills, but to develop 'professional confidence' or 'self-efficacy' in their ability to apply them, thus preparing them to take the risks inherent in innovation.

1.5.2 Knowledge Integration in Research

Making the research enterprise a more important instrument of innovation and knowledge may involve:

- the pursuit of fundamental new ideas, developed with a consideration of use;
- an increased awareness of the needs of society, industry and enterprise;
- the development of integrated communities of students, scholars, industry, enterprise, government and others.

CMI selected projects that met one or more of these objectives and that also had the potential to develop technologies in areas in which the UK is industrially competitive, such as aerospace and pharmaceuticals, but also those with long-term potential, such as quantum engineering and micro-technologies. There was also significant investment in research that is relevant to sectors that are important to the national infrastructure, including cities, healthcare and transport.

1.5.3 Engaging Industry in Knowledge Exchange

Knowledge exchange and innovation are likely to be enhanced by industry interactions with universities that:

- proactively engage industry and enterprise in prolonged interaction around research and educational programmes that address their needs;
- develop and enable agents of innovation and knowledge exchange including students, faculty, managers and technology transfer professionals;
- develop structures and incentives that encourage interactions between universities and industry.

In its programmes aimed at engagement with industry, including enterprises of all sizes, CMI emphasised personal interactions and long-term mutually beneficial relationships. By establishing and sustaining two-way communication between industry and academia, the results of university research can flow naturally to industry. The programmes developed to achieve this objective include Knowledge Integration Communities (KICs), Digital Spaces for Knowledge Exchange, and a range of professional education activities.

"This project has brought industry, academia and other stakeholders together around a 'grand challenge' that has captured the enthusiasm and imagination of all partners: there has been effective collaboration, knowledge exchange, and development of a real team approach. The students involved have learnt a lot as members of this integrated product team."

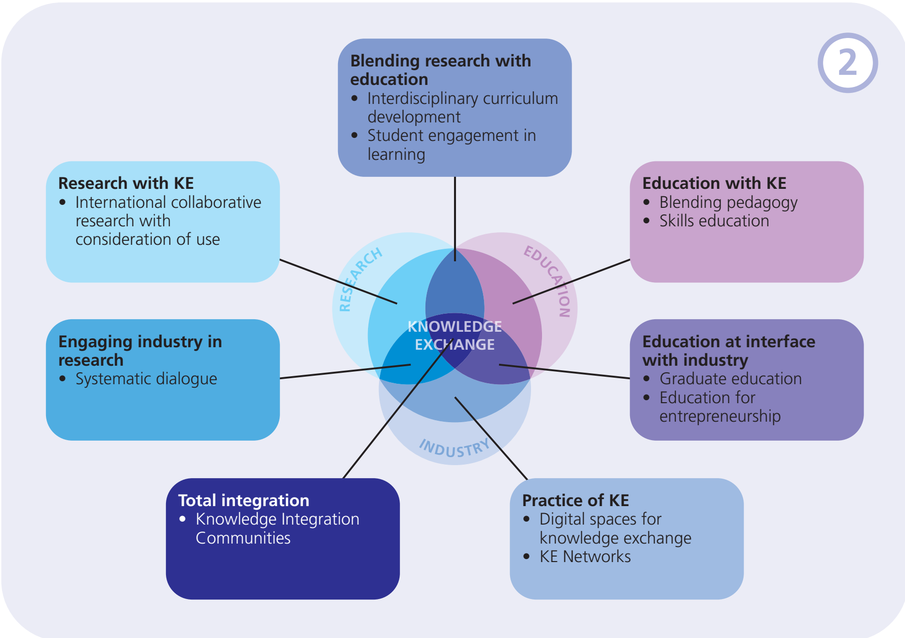
PROF. ANN DOWLING
DEPARTMENT OF ENGINEERING
UNIVERSITY OF CAMBRIDGE

1.6 Effective Practice in Knowledge Exchange

No matter how good the research conducted in the UK's universities, it will have an impact on innovation only if knowledge exchange happens in an effective way that is in keeping with the needs of the people and organisations that will turn that new knowledge into innovative products and services. It was a part of CMI's remit to investigate how best to promote and manage the flow of knowledge between the various players in the innovation chain. Through its experiments, CMI identified a series of 'effective practices' in knowledge exchange between universities, industry and enterprise (see Appendix I). These examples of effective practice can provide practical reference points for universities, industry and government (see Figure 2).

By examining innovation processes in the US and the UK, CMI identified effective practices which it then integrated into its programme. For example, it established the Electricity Policy Forum to enable industry to influence university research and to gain rapid access to the results of that research. This programme, which is now independent and has attracted funding from government and industry, contributes to the debate on energy policy in the UK. It drew upon the experience of MIT's Center for Energy and Environmental Policy Research (CEEPR), whose Executive Director spent six months in Cambridge working on the programme's development and industry outreach.

CMI also devised new ways of operating that would cross boundaries between universities and industry. These involved new approaches to engaging industry in projects and to building networks between universities and local entrepreneurial communities.



New ways of bringing together and integrating the three streams – education, research and engagement with industry – underpinned the programme to create more unified processes of knowledge exchange.

1.7 Crossing Boundaries

An essential part of the programme was to understand boundaries between the three key domains of research, education and external enterprises and to devise mechanisms to cross those boundaries. The barriers that can exist within these domains, for example between different research disciplines, could then be tackled. Boundaries between individuals, organisations and subject areas can also be obstacles to innovation.

CMI set out to understand and tackle these boundaries in several ways by:

- addressing those boundaries between institutions, finding synergies and complementarities of Cambridge and MIT, among students, staff and faculty, and bringing these together in ways that exceeded the sum of the parts;
- identifying, building and refining effective practices;
- developing new ways of operating, crossing boundaries between education, research and engagement with the economy and society, between universities and industry, through an integrative approach to innovation enhanced by knowledge exchange.

"Working in this interface between disciplines pays real dividends and the Cambridge-MIT Institute is a good model for this. It's a model for the future."

PROF. JEFF TESTER
HP MEISSNER PROFESSOR OF CHEMICAL ENGINEERING
MIT

Additionally, boundaries between disciplines were addressed through the creation of problem-focused interdisciplinary efforts.

Projects were supported in the areas of policy, business and regulation as well as science and technology. As an example of the synergies between institutions, the Geotechnical Research Group in the Department of Engineering at Cambridge worked with MIT's Civil and Environmental Engineering Department to instrument infrastructure in the US and UK. The combination of Cambridge's expertise in underground tunnelling and construction with MIT's expertise in building low-cost, wireless sensor networks enabled a team of students and faculty to develop, in only three months, a system to monitor the Channel Tunnel Rail Link project for London & Continental Railways.

1.8 Benefiting Stakeholders

CMI set out to deliver benefits to a wide range of stakeholders. For Cambridge and MIT, new programmes of research, education and engagement with industry have brought the two universities closer and have established pathways for future collaboration. Both universities have embedded a wide variety of these courses and research programmes in their core activities.

Benefits to industry and enterprise included new ideas from research and the education of students who could act as agents of innovation and knowledge exchange. In addition, industry participated in shaping the direction of university education and research, helping to increase the impact on competitiveness of investments in universities by government and industry.

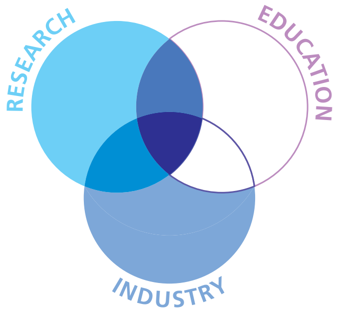
CMI worked in partnership with other universities, exchanging and sharing approaches to good practice. Together they developed programmes and made the outputs widely available. Between 2000 and 2006, CMI engaged with over 100 universities in the UK, often in close relationships involving numerous workshops and training programmes.

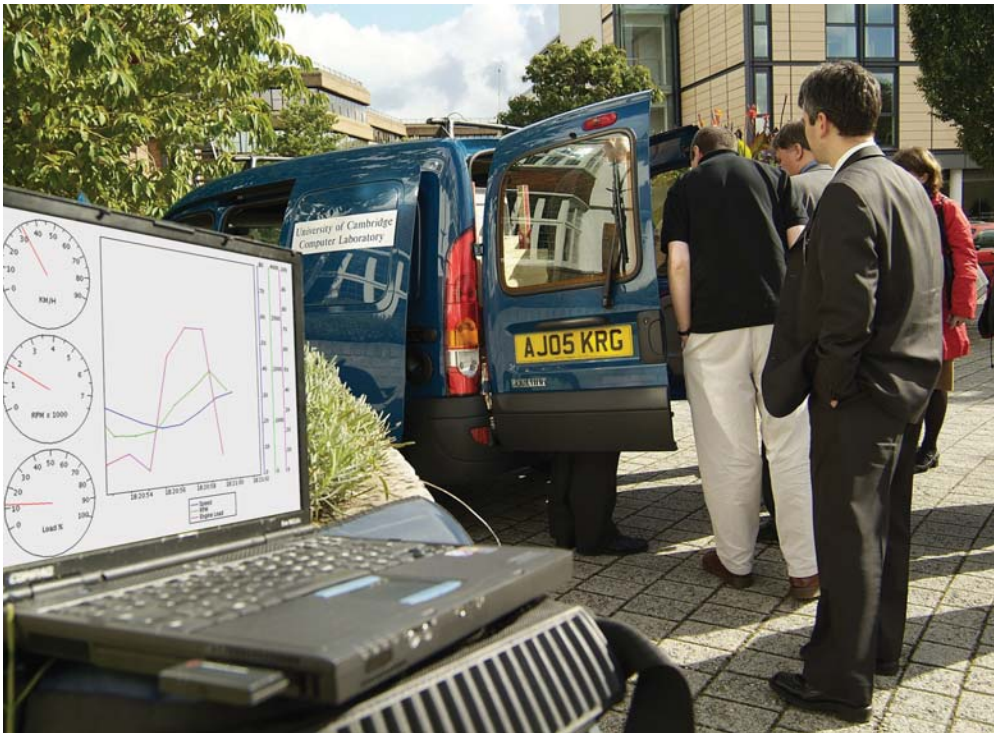
CMI also worked with regional agencies to strengthen their capacity and capability in innovation, helping some regions to develop local innovation strategies. Work on new metrics, and the evidence it is creating, will form the foundation for informed policy making. Recommendations on policy, institutional agreements and incentives are designed to strengthen the national approach to innovation and knowledge exchange.

1.9 Conclusion

If there is a single message that emerges from CMI, it is that it takes an integrated system of activities at a university – the constructive interplay of education and research, and formal and informal engagement with industry and enterprise – to bring about substantial improvements in knowledge exchange and to accelerate innovation. That interplay then needs support from systematic and well-managed mechanisms of the kind captured in CMI's examples of effective practices in knowledge exchange.

Communications Research Network





"The value of the Communications Research Network is two fold: the contacts and the place. Cambridge is a world class university and there's a strong interest in Nokia to understand and be involved in what is going on there."

DIRK TROSSEN
PRINCIPAL SCIENTIST, NOKIA

CMI funded the Communications Research Network (CRN), a CMI Knowledge Integration Community, to facilitate knowledge exchange in the communications sector. Working closely with its MIT-based sister, the Communications Futures Program (CFP), the CRN brought together a wide range of industry specialists and academics to research topics of crucial importance to the future of communications and to stimulate cooperation between them.

A broad range of disciplines, from physics, engineering and computer sciences to economics and more general social sciences, were selected to ensure a diversity of perspectives that would inform the research and other activities.

The CRN set out to build knowledge exchange around the core community of researchers by organising events and establishing working groups to strengthen the collaboration between the industry and academic researchers, and to widen the base of individuals exposed to the research.

The CRN's research partnership with the US-based CFP was very successful, more so than would have been possible with other UK or European collaborators. This is because researchers from the University of Cambridge and MIT seek funding from different sources in their respective countries, and there is no competition for limited funds and therefore no perceived risk in sharing ideas. This has helped the CRN to stay ahead.

In April 2006, the CRN was spun out from CMI as a company limited by guarantee to continue its work beyond the period of CMI sponsorship.

In addition to its own activities, the CRN has been a driving force behind the development of a DTI-funded Digital Communications Knowledge Transfer Network. This will be a continuing forum for knowledge exchange in the communications industry in the UK.

Education for Innovation

Emphasis on Education for Innovation is the glue that binds together programmes across the boundaries of research and knowledge exchange, academia and industry. This connection comes from recognising that long-term investment in learners is important if the UK is to meet its long-term mission of enhancing competitiveness through innovation. The defining outcomes of these programmes include new degree offerings, national entrepreneurship workshops, innovative curricular materials, web-based teaching resources and novel educational research methods.

2.1 Introduction

Today's students will be the researchers, managers and entrepreneurs of tomorrow. It is their knowledge, skills and attitudes that will form the culture of innovation, university-business relations and knowledge exchange. CMI's educational programmes set out to enhance the knowledge, skills, innovative capability and attitudes of future generations of students.

Cambridge-MIT Exchange students with Dr John Archer, May 2002

This means that students should acquire not just the skills they will need as engineers but also a 'professional confidence' in their ability to deploy those skills effectively. For example, research in education for science and engineering consistently finds confidence in mathematics to be a major factor in an individual's choice and determined pursuit of a career in science and engineering.

From its own studies, CMI concluded that students will be better prepared to act as knowledge exchange agents and innovators and to become entrepreneurs by an education that develops:

- a firm understanding of the relevant field of study;
- personal and interpersonal skills and associated 'professional confidence', especially when learned through hands-on experiences;
- entrepreneurial skills and the opportunity to apply them.

To provide students with an education that embodies these components, CMI developed several programmes and initiatives in Education for Innovation:

- Cambridge-MIT Exchange
- Interdisciplinary Curriculum Development
- Undergraduate Researchers
- Student Engagement in Learning
- Skills Education
- Graduate Education in Technology and Innovation
- Education for Entrepreneurship

2.2 Cambridge-MIT Exchange

CMI set up the Cambridge-MIT Exchange (CME) as its first major undergraduate programme. The exchange involved many faculty members in some 14 subject areas at MIT and in Cambridge. Between 2000 and 2006, more than 400 students participated in CME, providing them with important insights into the different educational practices at both universities.

"The exchange of knowledge, resources and expertise between MIT and Cambridge has accelerated the pace of innovation."

DR KEITH JOHNSTONE
DEPARTMENT OF PLANT SCIENCES
UNIVERSITY OF CAMBRIDGE

CME enabled students at Cambridge and MIT – reading the same subjects and at the same stage in their degree courses – to swap places for one year. Academics from both universities agreed which courses the students should take, so that students received full academic credit for work done in the year away and the exchange did not delay their educational progress.

CME is now a part of the standard provision of both institutions, and has stimulated other such engagements and programmes.

2.3 Interdisciplinary Curriculum Development

The most fruitful opportunities for innovation are often at the boundaries between disciplines or in emerging areas of thinking. Interdisciplinary education can prepare students to contribute to emerging sectors.

CMI recognised early on that it could build on its support for interdisciplinary research to contribute to curriculum development for emerging disciplines. By funding curriculum development, CMI could fill a gap left by national funding agencies.

New curricula can link learning across disciplines – to emerging needs and opportunities in society and industry. CMI created a series of projects involving Interdisciplinary Curriculum Development to gauge how best to support emerging interdisciplinary fields.

Novel curricula were developed in two rapidly growing and economically important fields: biological engineering and microelectromechanical systems (MEMS). In both cases, both universities have followed CMI's investments with substantial commitments of their own resources.

Biological Engineering Undergraduate Curriculum Development

Biological engineering is concerned with the application of engineering principles and techniques to the study of many classes of biological problem. At MIT, Biological Engineering was approved as the first new major course in 25 years. At Cambridge, a new professorship and several new lectureships signalled the launch of the degree option Engineering for the Life Sciences in the Department of Engineering.

The collaboration – between Bioengineering at MIT, the departments of the School of the Biological Sciences at Cambridge, and the Department of Engineering at Cambridge – that emerged from the development of Engineering for the Life Sciences would not have occurred without CMI.

MEMS Undergraduate Education

Cambridge's Department of Engineering has also developed internationally recognised research and advanced undergraduate teaching programmes in microelectromechanical systems (MEMS). CMI supported the development of an interdisciplinary course involving synchronous instruction between Cambridge and MIT. In each case, these important experiments provided proof of concept for subsequent major curricular developments.

MPhil in Computational Biology

In creating the MPhil in Computational Biology, CMI funded a new research group in the Department of Applied Mathematics and Theoretical Physics. At Cambridge, the MPhil is taught by members of departments in four Schools. The Department of Engineering has used some of the lectures from this course to introduce undergraduates to biology.

2.4 Skills Education

MIT and Cambridge have long worked with industry on the need for engineering graduates to acquire better team-working skills, such as the ability to communicate and to work in groups, which they will need in their careers. CMI based its strategy in Skills Education on the engagement of MIT and Cambridge with industry and with professional bodies, such as the Accreditation Board of Engineering and Technology, and on the work of such organisations as the Conceive-Design-Implement-Operate initiative.

Outputs from the Multidisciplinary Design Project include a book on design techniques, a suite of design software, a low-cost microprocessor system, electronics and a web-based interchange area.

Multidisciplinary Design Project

To foster team-work experience and emphasise communication, CMI supported faculty across engineering disciplines to devise new laboratory materials, teaching resources and ways of organising courses. For example, the Multidisciplinary Design Project created a resource CD with industry standard software and design tools that enable students to build and rapidly reconfigure prototype design.

Sudden Impact

Sudden Impact, a second skills education project exploiting techniques for designing new IT hardware, combines hardware configuration and software-based simulation of its effects. These hardware/software co-design courses provide relevant and inexpensive experiences that open the inner workings of common IT devices. They allow students to simulate the construction of novel hardware using the same techniques and facilities that industry would use.

Instructor Resource Modules

A third initiative in Skills Education, Instructor Resource Modules, created support materials to facilitate online teaching of key skills. These modules, now hosted online as part of the Improving Engineering Education (ImpEE) project website, will allow thousands of faculty in the UK to access the material.

CMI also established other projects, including the Intelligent Book and Automated Computing Teaching programmes, which advanced the use of expert systems to facilitate more natural, interactive learning of computer languages. Users are now testing this within MIT's Open CourseWare Programme.

An important insight from CMI's work with the two institutions was that students develop many of their personal and interpersonal skills in extra-curricular activities. A key contributor to this at MIT is the engagement of undergraduates in ongoing research programmes.

2.5 Undergraduate Research Opportunity Programme

More than 80 per cent of undergraduates at MIT spend time in faculty research laboratories under the Undergraduate Research Opportunity Program (UROP). While some students do this work for course credit or as volunteers, over 70 per cent do so as paid employment, either alongside their academic work or during vacations.

CMI UROP student in wind tunnel, Summer 2003

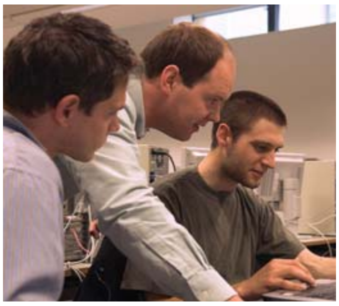
Highly thought of by staff and students, UROP has existed at MIT for over 30 years. Many see it as one of the university's most successful educational innovations. The value of this activity is reflected in the funding that MIT receives, in addition to standard research grants, to support UROP.

In the light of MIT's practice, CMI established UROP at Cambridge. Initially on the basis of summer exchanges in 2001 and 2002, UROP saw Cambridge students going to MIT, and vice versa, to work in research groups as paid assistants. A local version followed, with Cambridge students working through the summer with research groups in a number of departments at Cambridge. Funding from the Isaac Newton Trust will ensure the continuation and expansion of UROP at Cambridge.

UROP-like activities have existed on a small scale in many institutions in the UK for some years, notably at Imperial College. During the lifetime of CMI, the value of this activity has been recognised nationally, as witnessed by, for example, funding from the BBSRC and the EPSRC for trial programmes, and the establishment of the Centre for Excellence in Teaching and Learning at Oxford Brookes University, which is dedicated to research experiences for undergraduates.

2.6 Student Engagement in Learning

Early experience with the Cambridge-MIT Exchange programme gave insights into the educational practices at both institutions. The students' experiences and their feedback prompted several initiatives in Student Engagement in Learning. Within this activity, CMI designed experimental courses that explored the teaching systems of the two universities. These complemented the development of web-based platforms to share teaching resources and analyse their effectiveness.



Dr Robert Hunt talking to an undergraduate student working on a CATAM project, Cambridge Computer Laboratory

Disseminating Proven Teaching Methods

Today, around 90 per cent of Cambridge's undergraduate mathematics students take the course in Computer-Aided Teaching of All Mathematics (CATAM). They use personal computers to investigate questions such as the speed at which evolution takes place, or what happens to the flow of blood through veins when a heart attack is happening.

Through a CMI-funded collaboration, CATAM has contributed to the development of the Project Laboratory in Mathematics, a new course at MIT. "The CATAM course gives Maths students the chance to learn and explore computational techniques," says Dr Robert Hunt from Cambridge's Mathematics Faculty. "More importantly, as the projects are connected with their other courses – for example in fluid dynamics, general relativity or number theory – they can put the theories they have learned into practice, and acquire a deeper understanding of them."

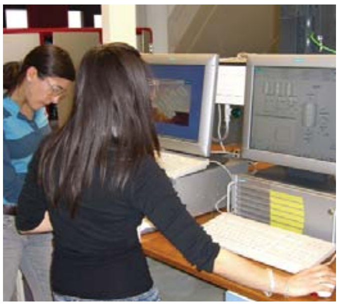
That, according to Haynes Miller, Professor of Mathematics at MIT, was an element missing for his students. All MIT undergraduates have to take a Laboratory Course, choosing one from a specified list. But until the Project Laboratory in Mathematics was founded, there was no Laboratory course in Mathematics. "Our students would instead do Lab courses in physics, astronomy – even managerial psychology," he says. "It had long seemed to me that we were missing an opportunity". The CMI-funded collaboration has helped MIT to grasp that opportunity.

Computer Aided Teaching of All Mathematics (CATAM)

Experiments in Student Engagement in Learning began with a development of Computer Aided Teaching of All Mathematics (CATAM), which originated in Cambridge in the early 1970s. A pilot version of these practical exercises in mathematics at MIT became the first undergraduate Laboratory in Mathematics there. Finally, this variant returned to Cambridge for further development in a cycle of continuous improvement.

Weblabs in Chemical Engineering

Another collaboration between the University of Cambridge and MIT resulted in the development of CMI's Weblabs. Sparked off by a visiting Cambridge



"There is an urgent need in the chemical industry for robust and realistic training in these remotely operated processes – and that is what the Cambridge-MIT Institute's Weblabs project is starting to provide."

DR MARKUS KRAFT
CHEMICAL ENGINEERING
DEPARTMENT UNIVERSITY OF
CAMBRIDGE

student at MIT, this network of laboratory equipment was used to explore new teaching methods in chemical engineering, building on the experience of the iCampus initiative at MIT. The Weblabs enabled students from around the world to perform experiments over the Web.

Due to its flexible design, the equipment can be used for more than one assignment, such as the one developed for the use in the teaching of process dynamics and control at Imperial College London.

The Cambridge team secured support from Siemens, enabling the use of state-of-the-art industrial process control equipment. With Cambridge as the UK node in the international iCampus network, the Weblabs technology is also available to other universities.

2.7 Education for Entrepreneurship

There has been a perception that, compared with the US, too few individuals in the UK are prepared to use their knowledge of what is happening at the frontiers of research, to commercialise it and to develop it into new ventures. In practice, there is growing evidence that this is changing but there is still plenty of room for improvement on this front. In particular, the UK needs postgraduates with a conviction that they can become the entrepreneurs of tomorrow.

Student Engagement to Deliver New Learning Tools

In the first year of the CMI student exchange, Richard West, a chemical engineering student at Cambridge, completed a UROP placement at MIT. At the time, MIT was struggling to facilitate web-based remote access to laboratory equipment. Richard quickly resolved challenging technical issues, leading him to use MIT's Weblabs as a pilot upon his return to Cambridge.

With Weblabs, students can get laboratory experience at any time and perform experiments from any location that has internet access. Due to the remote operation, the experimental equipment can be easily shared and used around the clock from anywhere in the world. This drastically changes the economics of providing laboratory experiments to students and, potentially, a huge number of experiments can be available for use.

In December 2006, the Science director from the German Embassy in London inaugurated the Weblab at the Department of Chemical Engineering in Cambridge, celebrating with guests from the UK and overseas the investment of over £100,000 by Siemens. This shining example of industrial engagement created new teaching facilities with industry-leading equipment, now being used by students around the world.

CMI implemented several programmes that set out to make students more confident that they can put into practice the knowledge and skills that they have acquired in their university education. The approach emphasises the importance of an individual's perception of him or herself as an effective person who can achieve goals on the basis of their own knowledge and skills. This is known as their 'Perceived Self-Efficacy', a concept that is known to underpin the capacity of successful innovators and entrepreneurs.

Throughout its undergraduate programmes, CMI has charted the impact of its interventions on a student's sense of self-efficacy, and has identified practices that contribute to this.

"Enterprisers is a fantastic opportunity for students to talk to entrepreneurs that they would not normally meet. This kind of interaction only happens because of the Cambridge-MIT Institute, and it has great benefits."

SANDY SPARKS
MERCIA INSTITUTE OF ENTERPRISE
CMI ENTERPRISERS

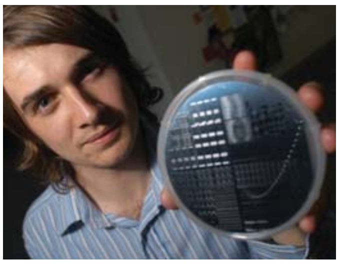
Enterprisers

Within Education for Entrepreneurship, CMI launched Connections in 2002 – subsequently renamed Enterprisers in 2004 – as a series of week-long undergraduate workshops with entrepreneurial elements, tailored to the local environment. Business leaders as well as students and faculty from MIT and Cambridge participated, drawing on over 100 contributors from universities and industry. More than 500 undergraduates participated in these courses. Cambridge's Centre for Entrepreneurial Learning continues to deliver this programme to other groups throughout the UK.

Graduates who participated in Enterprisers have gone on to form student entrepreneurship societies and to launch companies. Enterprisers is now a self-sustaining programme in the UK.

Student Entrepreneurship Societies

A key indicator of the changing culture in Cambridge at the student level has been the rapid growth of two student entrepreneurship societies – the Cambridge University Entrepreneurs (CUE) and the Cambridge University Technology and Enterprise Club (CUTEC) – the largest in Europe. CMI has helped them directly with advice and funds, but also indirectly through the education of those who enter the societies' highly successful business-plan competitions (see Chapter 4).



Owlstone, winner of the 2003-04 CU Entrepreneurs £50k Business Plan Competition

A number of these direct involvements in entrepreneurship education have been at both the undergraduate and postgraduate levels. CMI has also developed a suite of Master's courses which directly trains students at the interface of business and science.

2.8 Graduate Education

An interdisciplinary focus runs through CMI's research programmes. MIT's centres and non-departmental units supporting research, teaching and work experience offered many lessons on working across conventional disciplines.

CMI set out to create programmes that would blend instruction in social science and management of innovation subjects with disciplinary subjects in engineering, science and technology. While it had already been possible to combine subjects in this way at Cambridge at the undergraduate and MEng levels, it had not been possible to do so at the Master's level prior to CMI.

Interdisciplinary MPhils

MPhil field trip to Bears Down Wind Farm, Cornwall

CMI supported the creation of six one-year Master's degrees, initially modelled in part on MIT's experience in developing professional practice programmes. Course development costs were reduced by sharing the development of modules between departments. A series of six taught degrees that combined advanced technical material with management and innovation were established, filling an important gap between specialised MPhils and the MBA. They included the MPhils in Advanced Chemical Engineering, Bioscience Enterprise, Computational Biology, Engineering for Sustainable Development, Micro- and Nanotechnology Enterprise, and Technology Policy. The programmes have all continued to run after their CMI funding came to an end and currently account for about 10 per cent of the University's MPhil student population (see Case Study 4).

Management of Technology and Innovation (MOTI)

Modules on Management of Technology and Innovation (MOTI) were an important part of the new interdisciplinary MPhil courses at Cambridge. In addition to 48 hours of lectures, students undertake internships in local organisations where they work on a six-week consultancy project for a real client (see Case Study 4). In all, more than 100 companies and public sector organisations, ranging from BT to small start-ups, hosted CMI MPhil students between 2000 and 2006.

MOTI introduces students to the reality of managing innovation and running a high-tech business. This experience seems to be paying real dividends for the students, who report a significant rise in their professional self-confidence related to working in a corporate environment. In two out of the past three years, students from these programmes have won the Cambridge University Entrepreneurs competition, going on to launch their own companies.

"I got a job at PricewaterhouseCoopers, and I think one of the reasons I was successful was because I was able to talk about the MOTI project during my interview. It's the kind of real experience that employers want."

JOANNA SIMMS
GRADUATE, MPHIL IN BIOSCIENCE ENTERPRISE, 2005

Harnessing Student Creativity in Real Situations

All CMI MPhil students take a module on Management of Technology and Innovation (MOTI) which involves a placement with local organisations looking at innovation to solve real problems.

BT's Innovations Central hosted five students from the MPhil in Chemical Engineering Practice. "In the past, it's been quite labour intensive working with students," said Gordon Wright, Innovations Consultant at BT Innovation Central. "But on this occasion, the MPhil students were very self-sufficient. As their supervisor, it was a completely pain free experience."

The MPhil students were drafted in to help to assess how effective Innovation Central has been in creating and delivering BT's innovation strategy. "Everything that they came up with was useful," says Wright. "Because the students hadn't been involved in the projects beforehand, their insights were new and fresh. The students built up comprehensive case studies, the quality of which was so high that I plan to use them in future to describe to potential clients the work that Innovation Central does."

MOTI gives students vital, first-hand experience of the reality of managing innovation and running a high-tech business. This experience seems to be paying real dividends for the students. In two out of the last three years, students from these programmes have won the Cambridge University Entrepreneurs competition, going on to launch their own companies.

2.9 Lessons for the Future

It takes time for changes in education to influence the behaviour of graduates or the culture of universities. These are early days for CMI's activities in education. Only by sustaining these educational innovations for a considerable period will we know if they have had a measurable impact on society and the economy.

However, CMI has had a lasting impact on education at Cambridge, MIT and beyond. The MPhil programmes in Graduate Education in Technology and Innovation have created a cohort of students who are confident in their capacity to innovate and to transform their chosen fields. The Cambridge-MIT Exchange programme, and subsequent projects in Student Engagement in Learning, catalysed major changes, both in educational innovation and in international education, at MIT and Cambridge.

The Enterprisers programme prepared students who launched over 30 new student-led companies and ventures. It has influenced the national dialogue and players in entrepreneurship education in the UK and beyond by involving the National Engineering Programme of the Royal Academy of Engineering.

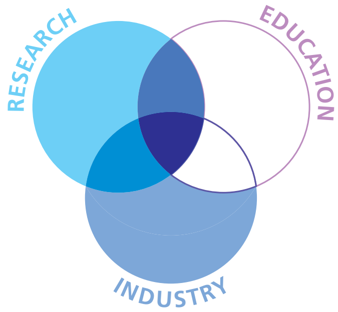
From the perspective of the learner, CMI's education programmes have influenced students at over 50 universities world-wide through Enterprisers. Graduates of this programme have gone on to form new student entrepreneurship societies and to launch new companies.

2.10 Conclusion

CMI has provided a stimulus to thinking across boundaries of disciplines, technical and education staff, and cultures at Cambridge and MIT that could not have taken place without its resources and strategic purpose. Programmes such as Biological Engineering now instil cross-boundary knowledge at the undergraduate level, while Enterprisers and the MPhil courses create the self-efficacy in technical and venturing challenges that will allow graduates to have a long-term impact.

Our summary observation in Education for Innovation is that students will be better prepared to act as knowledge exchange agents, innovators and as entrepreneurs by an education that develops a deep, conceptual understanding of a discipline or inter-discipline; personal and interpersonal skills and associated self-efficacy, especially learned through authentic experiences; and entrepreneurial skills and self-efficacy, with the associated empowerment to apply knowledge and skills to entrepreneurship.

Smart Infrastructure



"We've had a long running connection to the Smart Infrastructure group. A big payback for working with the research team is that we get access to the latest technology and, in return, they get great field trial opportunities."

KEITH BOWERS
ASSOCIATE DIRECTOR (ARUP) &
SENIOR TUNNEL DESIGN MANAGER
(CTRL) ARUP; CHANNEL TUNNEL
RAIL LINK

Maintaining the transport infrastructure frequently requires closure of roads and rail links for vital manual checks. The Smart Infrastructure project developed and tested innovative new sensor systems for monitoring the condition of infrastructure such as tunnels, roads and bridges. This could reduce the need for manual site checks and help to target maintenance work more effectively, lowering costs and leading to fewer disruptions to the transport system.

With major urban construction projects, such as the development of the Olympic Games sites in London, knowledge of how existing infrastructure is bearing up to disturbance is becoming even more important. CMI funded the Smart Infrastructure project to address these complexities.

Smart Infrastructure combined complementary expertise between the University of Cambridge team, specialising in fibre-optics, and the researchers at MIT, who focussed on developing, installing and monitoring wireless sensor networks.

Both groups worked closely with industry partners, including Thames Water, Network Rail, Channel Tunnel Rail Link, Intel and the Boston Water and Sewer Commission. All of these organisations were keen to offer their infrastructure as test beds for the project's technology, yielding useful data for the companies and the researchers alike.

The importance of the group's work was recognised by a grant of £1.4 million from the EPSRC. The funding will allow the researchers to collaborate with Imperial College London, and to examine the potential of smart infrastructure technologies for water supply systems, tunnels and bridges.

By funding Smart Infrastructure, CMI gave the team the opportunity to experiment with cutting-edge technologies, and to develop the experience and confidence needed to apply for that grant. The outcomes of Smart Infrastructure gave the team the results and the credibility to persuade the EPSRC that this would be a successful project.

Knowledge Integration in Research

Research is fundamental to the work of the university. CMI set out to do more than support world-leading research in Cambridge, MIT and other universities; it also embedded that research in a programme where knowledge exchange was considered from the very beginning. It did this by highlighting 'consideration of use', encouraging researchers to consider the needs of society and industry in the selection and design of their research. Through such mechanisms as professionally managed Knowledge Integration Communities, CMI developed ways in which industry and enterprise, as well as people from governmental, regulatory and public-interest groups, could work directly with scholars to advance the pace of knowledge exchange among the participants.

3.1 Introduction

CMI set out not only to support research excellence but also to support ideas that would both advance scientific knowledge and enhance education and knowledge exchange.

The research programme was built around the concept of 'knowledge integration in research', so that researchers would benefit from a better understanding of the needs of business and society, while companies and other enterprises would benefit from better links with academic research and the potential applications of fundamental research. Closer contact with the results of research should bring new ideas to market more quickly. CMI's projects were therefore expected to contribute to Knowledge Integration in Research as well as delivering conventional research results.

From its own studies, CMI concluded that making the research enterprise a more important instrument of innovation and knowledge may involve:

- the pursuit of fundamental new ideas, developed with a consideration of use;
- an increased awareness of the needs of society, industry and enterprise;
- the development of integrated communities of students, scholars, industry, enterprise, government and others.

In order to meet its objectives, CMI developed several research projects that focused on consideration of use and knowledge exchange:

- Knowledge Integration Communities
- Research to Address Real-World Challenges in:
  - Energy and the Environment
  - Healthcare and Biotechnology
  - Tomorrow's Technology
  - Communications and Networks

3.2 Consideration of Use

Throughout its activities, CMI set out to support projects that could demonstrate that effective knowledge exchange would be more likely if researchers worked with a 'consideration of use'. This meant that research – be it in a university, a publicly funded research laboratory or in a company – would be more likely to enhance competitiveness where the researchers understood and appreciated the possible business uses of the results of the research and, on the other side of the exchange, where business had a better appreciation of academic research, the capabilities of the researchers and the possibilities that they create.

CMI took a broad approach to the consideration of use within individual research projects, taking care to ensure that end use did not reduce the research to short-term problem solving. In other words, thinking about the end use of the research should not compromise the quality of the resulting science. For example, CMI supported some projects that would be thought to be fundamental in nature, but by engaging industry in that research, anticipated a greater and quicker take up of the results.

One way to ensure a consideration of use, and an appreciation of the potential applications of the research, was to have direct industry participation in projects. An alternative approach was to encourage faculty at both Cambridge and MIT to address acknowledged needs or 'grand challenges', such as energy technology and climate change.

Researchers themselves can identify possible applications of their research, but they may not know how to commercialise their knowledge. A further mechanism for considering use in research within CMI was to assist academic researchers in identifying promising outcomes as they emerged, and then to support them through the commercialisation process.

3.3 Knowledge Integration Communities

As a part of its work in knowledge exchange, CMI created Knowledge Integration Communities (KICs). These grew out of extended discussions with business leaders and industry representatives in areas where they saw greatest need for a concerted effort, and where they also anticipated significant opportunities for innovation.

KICs were larger research programmes with embedded professional management that explicitly involved external stakeholders from industry, government departments or non-governmental organisations. Ideally, a KIC had strong links to a taught educational programme, drew in elements of the industrial supply chain, and included innovations in knowledge exchange and the study and dissemination of results.

While KICs centred on collaborative research teams at Cambridge and MIT, they also included participants from other universities in the UK. The intent was to bring together all the participants needed to address a challenge, and to accelerate innovation. In the period to 2006, more than 200 companies participated in KICs. For several projects, company involvement was a major force in the researchers' understanding of the needs of industry and society and in shaping the research of the centres. For example, Rolls-Royce, Boeing and British Airways became major sponsors of the Silent Aircraft Initiative (see Case Study 1).

As well as promoting collaboration between businesses and academics, KICs acted as catalysts for interactions between companies, with larger companies drawing in smaller enterprises that are a part of their supply chains. Companies also drew in other members of their own industries.

In all, CMI set up six KICs to enhance knowledge exchange between academia and industry:

- Centre for Competitiveness and Innovation – brought together organisations in fostering and sustaining innovation;
- Communications Research Network – gave a forum to the communications industry to discuss the issues facing the industry as networks converge;
- Next-Generation Drug Discovery – addressed severe bottlenecks in discovery and development of new therapeutics;
- Quantum Technologies Group – accelerated the commercialisation of quantum technologies;
- Silent Aircraft Initiative – brought together interested parties to radically reduce aircraft noise;
- Smart Infrastructure – developed and implemented sensor systems to monitor and assess the condition of ageing infrastructure.

"The Executive Education programme is an excellent opportunity to get away, reflect and challenge yourself about what you should be doing."

GARETH DAVIES
MANUFACTURING ENGINEERING &
BUSINESS DEVELOPMENT
ROLLS-ROYCE

Four first-generation integrated communities worked on problems jointly identified by academics and reviewed at workshops with industry. Two second-generation centres evolved out of earlier CMI collaborative projects.

All six KICs set out to attract industry participation. To ensure effective and sustained knowledge exchange, each KIC had professional staff, including a manager with significant experience in industry, as well as separate funds for their industry activities.

Centre for Competitiveness and Innovation

The Centre for Competitiveness and Innovation (CCI) brought organisations together to study how value is created, delivered and captured from innovation in products and processes. Several organisations have been involved with the CCI through its research, events, teaching and executive education. CCI received financial support from BT, Danfoss, Ford, Oracle and EDS. The KIC also formed partnerships with Boston University, Imperial College London and Warwick Business School.

The team successfully developed the Management of Technology and Innovation module (MOTI) for the MPhil programmes (see Section 2.8). This delivered management teaching to more than 350 students and involved over 100 organisations, largely technology-focused companies.

"Many of the other projects under the Cambridge-MIT programme are delivering real results, which we believe will have a global application."

LORD BROWNE
GROUP EXECUTIVE
BP

Communications Research Network

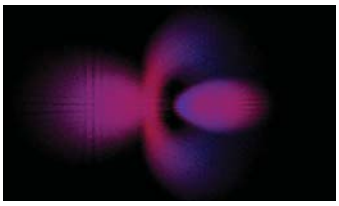
The Communications Research Network (CRN) supported the communications industry through an interdisciplinary research team of academics from Cambridge, MIT, Oxford and University College London, complemented by partners from British companies. The network's research had two main themes: to better understand the value chain of the industry and explore roadmaps to possible futures; and to conceive and demonstrate unexpected and disruptive visions of the future.

CRN helped to inform industry about the barriers at which to focus innovation, and to inform academics about the research that would have greatest impact on industry. The work of the CRN continues in a national network (see Case Study 2).

Next-Generation Drug Discovery

Next-Generation Drug Discovery (NGDD) set out to address bottlenecks in the discovery and development of new therapeutics. The community involved companies in pharmaceuticals, IT and healthcare, with substantial involvement from major businesses such as IBM and AstraZeneca.

NGDD was associated with the Cambridge Computational Biology Institute, which brings together the unique strengths in medicine, biology, mathematics and the physical sciences in Cambridge, and MIT's Computational and Systems Biology Initiative, a university-wide education and research programme that links biology, computer science and engineering in a multidisciplinary approach to the systematic analysis and computational modelling of complex biological phenomena. NGDD also engaged with over 15 companies that provided internship placements for students.



"Our field is becoming more established, but it takes time to develop the kind of common vocabulary we need to take Quantum forward. The Cambridge-MIT Institute is helping us popularise our vocabulary through the Quantum Technologies Group."

PROF. SIR PETER KNIGHT
PRINCIPAL OF THE FACULTY OF NATURAL SCIENCES
IMPERIAL COLLEGE LONDON

Quantum Technologies Group

The Quantum Technologies Group arose from a successful CMI research project. The group focused on developing technologies required to commercialise quantum cryptography, communication, metrology and computation by bringing together researchers from academia and industry, and establishing the UK at the forefront of this emerging technology.

CMI initially funded researchers from MIT and Cambridge, but the collaboration eventually included Oxford, Imperial College London, and other international universities. Substantial contributions were secured from Fujitsu Laboratories of Europe and Hewlett-Packard. More recently, the group has collaborated with the National Institute of Standards and Technology, the federal technology agency that develops and promotes measurement, standards, and technology in the US. Together, they have initiated a drive towards establishing a set of industry standards for quantum information technologies to aid the commercialisation of secure quantum communication and information processing systems.

"Boeing congratulates the Silent Aircraft Initiative for undertaking a very challenging research assignment. This collaboration has stretched our imagination and generated some noise mitigation ideas that we will be able to study for potential future use."

JIM MORRIS
VICE PRESIDENT OF ENGINEERING AND MANUFACTURING, COMMERCIAL AIRPLANES, BOEING

Silent Aircraft Initiative

CMI's Silent Aircraft Initiative (SAI) set out to improve competitiveness in the UK's aerospace sector by changing the way research is undertaken (see Case Study 1). The project's partners included British Airways, the Civil Aviation Authority, a regional aerospace company, Rolls-Royce, National Air Traffic Services, Boeing and Cranfield University. In pursuit of this goal, the SAI aimed to reduce aircraft noise to the point where it would be inaudible beyond the airport's boundary.

As an aircraft lands, the airframe generates about as much noise as the engines. Analysis shows that the noise generated by the airframe falls quickly as the aircraft's speed falls. The proposed designs of the new aircraft use a very efficient airframe, which has a high ratio of lift-to-drag forces. The efficient airframe enables a slower approach. The low-noise designs have no flaps, a drooped leading edge rather than slats, and a simplified and streamlined undercarriage.

One early benefit of the research involved testing new low-noise continuous descent approaches at a regional UK airport which also incorporated other low-noise techniques of Precision Area Navigation – allowing the procedure to be programmed into the aircraft Flight Management System to optimise the approach path – and low power/low drag, to keep the aircraft in a clean aerodynamic configuration. Flight trials showed reductions in noise, fuel burn and emissions from the participating aircraft.

Smart Infrastructure

Smart Infrastructure team conducting work in tunnel, February 2006

Maintaining the transport infrastructure frequently requires road and rail closures for vital manual checks. The Smart Infrastructure project has developed and tested innovative new sensor systems for monitoring infrastructure, such as tunnels, roads and bridges, that could reduce the need for manual site checks and help to target maintenance work more effectively, leading to less disruption to the transport system.

The team has worked with industry partners including Thames Water, Network Rail, Channel Tunnel Rail Link, Intel and the Boston Water and Sewer Commission. As well as working in the field with industrial partners, Smart Infrastructure also developed emerging sensor technologies, such as microelectromechanical systems (MEMS). These devices can detect tiny changes in their environment, and have astonishingly low power consumption.

The importance of the group's work was recognised by a £1.4 million grant from the EPSRC. The funding will allow the group to collaborate with Imperial College London, examining three potential application areas for Smart Infrastructure systems: water supply systems, tunnels and bridges (see Case Study 3).

3.4 Research to Address Real-World Challenges

In addition to the research conducted in the KICs, CMI funded projects under broad themes that addressed major challenges facing society and where the UK has considerable commercial interests. Examples of this research are presented below; further information can be found on the CMI Website and in the *Working in Partnership* brochure.

3.4.1 Energy and the Environment

Energy security, and the need to devise energy strategies and technologies that reduce emissions of carbon dioxide, raise significant technical issues. CMI sponsored projects that focus on 'green' technologies, from multidisciplinary research into low-energy building design, to developing new materials that could reduce stress on the environment. These projects aimed to reduce energy use.

"One of the exciting aspects of the Cambridge-MIT Institute project, as shown in the development of the E-Stack system, has been the close relationship between fundamental modelling of the heat and mass transfer processes in buildings, and the direct application of that work in order to produce innovative new solutions for energy conservation."

PROF. ANDY WOODS
BP INSTITUTE
UNIVERSITY OF CAMBRIDGE

Building using the E-Stack system for natural ventilation: Aldwyck Housing, Luton, UK

Natural Ventilation, Solar Heating and Integrated Low-Energy Building Design

A team of architects and engineers from Cambridge, MIT and BP Solar developed designs and technologies for buildings, with the goal of reducing energy cost, improving air quality and coping with ventilation in emergencies. Much of the knowledge gained through this research has been encapsulated in a design tool for architects to estimate the opportunity for using green building technologies. The tool is now being used as the basis for educating professionals in this domain.

The project focused on the use of natural ventilation, solar power and better building materials. The team contributed to the design of a new building at University College London and another for 1600 British Petroleum (BP) staff in Aberdeen. BP contributed substantially to the project and funded a spin-off company, E-Stack, which is commercialising technologies for the natural ventilation of buildings (see Case Study 5).

The team presented workshops for design professionals, engineers and planners explaining the guidelines for natural ventilation and detailing experimental and computational design tools. These were given at seminars and professional conferences held at the University of Cambridge, MIT, and in Edinburgh and Chicago.

"The Cambridge-MIT Institute has proved to be an ideal vehicle for fostering collaborative ventures."

PROF. BILL CLYNE
DEPARTMENT OF MATERIALS SCIENCE AND METALLURGY
UNIVERSITY OF CAMBRIDGE

Improving Performance and Fuel Consumption

Very light, stiff and strong sheet metal offers economic and environmental advantages suitable for a range of applications such as reducing vehicle body weight, thereby decreasing fuel consumption and pollution. CMI supported the teams of researchers from Cambridge and MIT, in collaboration with Volvo, to develop stiffer, stronger and ultra-light metallic sheets.

During an initial feasibility stage of the project, the team developed a revolutionary lightweight wafer thin (1-2 mm) metal sandwich of stainless steel fibres bonded between two thin stainless steel faceplates. The first sheets of this innovative material were produced at FibreTech, the world leader in manufacturing a wide range of metallic fibres. FibreTech provided the capacity to produce ultra-light metal sheets in sufficient quantities that both academic and industrial partners could undertake further studies and development, under much better quality control conditions than had previously been possible.

New Ultra-Light Metallic Sheet Material

Researchers developed a revolutionary new sheet metal with unprecedented combinations of low aerial density, high beam stiffness, good corrosion resistance, attractive thermal insulation and acoustic damping properties, and excellent formability and weldability.

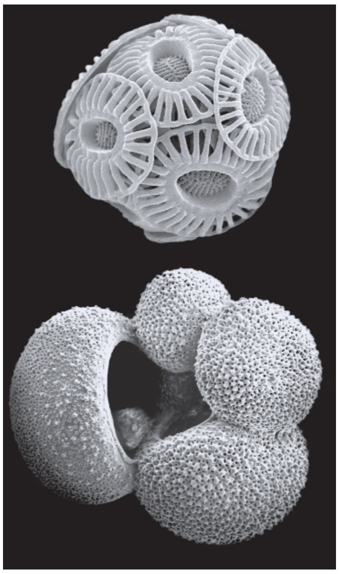
The project team formed a partnership with FibreTech, a specialist materials company, to manufacture the material and to market it to industrial and institutional partners. The Defence Science and Technology Laboratory (DSTL) and the Ministry of Defence are testing it for body armour and lightweight vehicles. The team, working with FibreTech and Avcen Ltd, recently won a significant grant from EPSRC to research acoustic damping in jet engines.

Synthesis of organic compounds in supercritical carbon dioxide

Sustainable Chemical Processes in Environmentally-Friendly Media

This project brought together three research groups in an interdisciplinary collaboration to develop commercial chemical processes in environmentally-friendly media such as supercritical carbon dioxide. It demonstrated the production of this solvent for 'green' processing of molecules used in pharmaceuticals and semiconductor manufacturing. The group also built first- and second-generation reactors that demonstrated the technology.

Sustainable Chemical Processes in Environmentally-Friendly Media involved the University of Birmingham and resulted in an active working relationship with industry partners, including AstraZeneca, Goehringer-Ingelheim, Bristol Myers Squibb, Merck and Pfizer.



Research into the ocean's role in modulating atmospheric CO_2 has shown that the shells of these foraminifera have halved in weight as levels of carbon dioxide have risen since the last ice age.

Research in energy and the environment also included projects on: global warming and the role of the oceans in modulating the carbon dioxide content of the atmosphere; characterisation of carbonate rock formations typical of those containing petroleum deposits, in cooperation with Schlumberger; the use of ceramic encapsulation to develop long-term solutions to the encapsulation and storage of radioactive materials; reducing the environmental impact of car transportation by intelligent traffic management; and developing new detergent compositions to reduce the environmental load on waste disposal systems.

3.4.2 Healthcare and Biotechnology

In line with CMI's goal of supporting work in areas where the UK has business strengths and where there are major social challenges, research in biotechnology was a significant part of the programme. Projects were developed involving multiple departments at both MIT and Cambridge, from materials science and engineering to medicine and chemical engineering.

A Vehicle for Important Drug Developments

CMI researchers have identified a fast and cheap way to screen and produce new drugs. The harmless bacterium *Rhodococcus* has the potential to be a cellular factory for the production of the right chemicals. The research is investigating the potential of such bacteria for the treatment of infectious diseases such as AIDS and TB.

The CMI team is also working with Chirotech, a company specialising in producing chiral pharmaceuticals – that is, pharmaceuticals where the physical geometry of the molecules determines their activity. The pharmaceutical company Biotica, with expertise in synthetic biology of natural products, is working with the Cambridge team to boost its efficiency at expressing *Rhodococcus* genes to produce new and improved antibiotics, anti-cancer drugs and anti-fungal drugs. The newest area, the work focused on a new anti-tubercular drug, has led to initial collaboration with Dow, the world-leading material science innovators, for testing the drug's effectiveness.

Interdisciplinary Research Cluster in Biomaterials and Tissue Engineering

An Interdisciplinary Research Cluster (IRC) in Biomaterials and Tissue Engineering was established to develop second-generation bone-substitute biomaterials. The research resulted in several patents and a spin-off company, OrthoMimetics, which has raised over £5 million from private equity. The company is developing novel products that will allow the body to regenerate damaged cartilage and restore joint function.

"This project is one group in two places with a no-blame culture. This collaboration is amazing."

DR JOHN ARCHER
DEPARTMENT OF GENETICS
UNIVERSITY OF CAMBRIDGE

Rhodococcus as Biological Catalysts for Chiral Synthesis and Novel Pharmaceuticals

A collaborative team, *Rhodococcus as Biological Catalysts for Chiral Synthesis and Novel Pharmaceuticals*, studied metabolic pathways and biological products from the bacterium *Rhodococcus*, to characterise and genetically engineer useful bioconversion processes. Potential applications of this technology include better production of new antibiotics and of cis-amino indanol, a precursor to the AIDS drug Crixivan. The researchers have entered into collaborations with the companies Solexa and 454 Life Sciences for gene sequencing.

Responsive Polymer Research Enterprise

A joint Responsive Polymer Research Enterprise team developed a sound basis for the design, synthesis, characterisation, implementation and commercialisation of responsive polymer systems, such as encapsulating drugs in bioreactive polymers to assist with delivery into the human body. This work led to many industry partnerships. For example, Panvax tested nanoparticles as vaccine adjuvants in mice, declaring the results 'very encouraging', and Lonza Biologicals evaluated materials from this research for gene delivery. GE Healthcare also tested materials for in vivo tumour imaging in mice. Merck is signing a non-disclosure agreement to permit exchange of Cambridge materials for testing in brain imaging.

"I'm confident in saying that OrthoMimetics wouldn't be here if it wasn't for the support we've had from the Cambridge-MIT Institute. Without the Cambridge-MIT Institute, the researchers wouldn't have got together in the first place."

DR ANDREW LYNN
CEO, EXECUTIVE DIRECTOR
ORTHOMIMETICS

Microfabricated Stem-Cell Bioreactors

CMI's projects in healthcare and biotechnology also included the Development of Microfabricated Stem-Cell Bioreactors for Optimising Haematopoietic Stem-Cell Self-Renewal in Culture. The aim was to use these cells for bone-marrow transplants and other cell therapies, and for gene therapy for genetic diseases affecting haematopoietic cells, such as sickle-cell anaemia, thalassaemia, and disorders of the immune system. The research resulted in a number of patents, including one based on a method for stimulating haematopoietic stem-cell growth and potentially removing the need for the controversial practice of harvesting embryonic stem cells.

3.4.3 Tomorrow's Technology

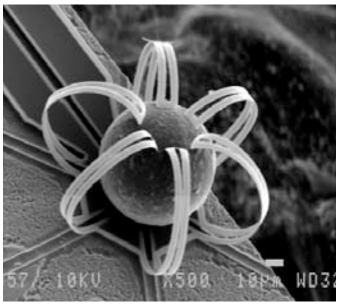
CMI launched several projects under the umbrella of 'Tomorrow's Technology' that hold significant opportunities both for research and innovative businesses. The work supported activities in areas, such as nanotechnology and microelectronics (sometimes referred to as 'tiny technology'), where there is intense international activity both in universities and in commercial laboratories.

Projects ranged from research into nanoscale magnetic rings, which led to the development of prototypes of magnetoresistive random access memory (MRAM), to research that characterised material properties down to the micro- and nanoscale so that engineers can easily identify candidate materials for tiny technology projects.

Magnetoelectronic Devices

Scientists at Cambridge and MIT have developed fabrication methods and prototype electronic devices that exploit the electron's magnetic properties. One prototype application was a non-volatile memory device that is much faster than the 'flash' memory currently used in mobile telephones and digital cameras.

The researchers have won follow-on research funding from the US National Science Foundation and the EPSRC. They have also advised a small start-up called (coincidentally) CMInnovations, which is developing an MRAM and is producing devices in Shrewsbury, Massachusetts.



The MEMS project developed a microgripper measuring less than one-hundred-millionth of a metre. The microgripper opens and closes when a minute electric pulse is applied, and is suitable for trapping and holding biological specimens, such as cells, without damaging them.

Microelectromechanical Systems

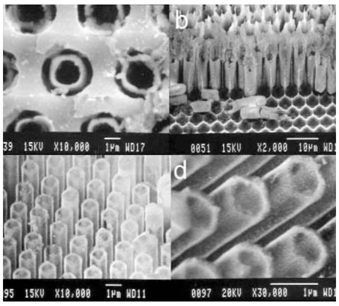
This research developed future generations of microelectromechanical systems (MEMS) by processing diamond like carbon (DLC) and by developing design and test methods. This research involved optimisation of DLC for MEMS, specifically for moving micro-actuators, and the development of processing methods for stress-controlled deposition and fabrication of the materials.

The research has led to four more projects, with very substantial funding from the Sixth Framework Programme (FP6) of the European Union, Cavendish Kinetics Ltd, Research Institute Korea and the EPSRC. One outcome from the project – a prototype MEMS microgripper – led to a business plan that won finalist at Oxford and semi-finalist at MIT competitions. The research also fed into teaching material on MEMS for undergraduates (see Section 2.3).

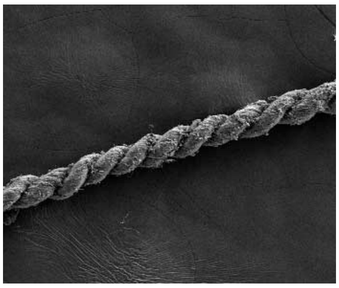
Carbon Nanotube Materials

This project brought together MIT's expertise in nanocomposites, and Cambridge's experience in the synthesis and processing of carbon nanotubes. The result was a carbon nanotube of record length.

The teams collaborated with Thomas Swan and Co. Ltd, which manufactures performance and speciality chemicals, to resolve technical issues in commercial scale-up of laboratory production techniques. This work has led to a fully operational plant at the company's manufacturing site in north-east England.



Ferroelectric nanotube arrays fabricated by the Optical Properties of Nanoscale Arrays team



The Carbon Nanotube Materials project has developed a method of manufacturing carbon nanotubes, producing this extremely fine, but strong, long thread that can carry an electrical current.

Making a Versatile New Material More Economic

Carbon nanotubes are extremely rigid, are excellent conductors of electricity and are 100 times stronger than steel per unit of weight. These properties give them a wide range of applications.

However, organising carbon nanotubes into useable structures cost-effectively has proved difficult. CMI brought together MIT expertise in the mechanics of nanotubes and University of Cambridge expertise in carbon nanotube synthesis and processing. The outcomes of the collaboration include a carbon nanotube of record-breaking length. The continuous manufacture of carbon nanotube fibres during nanotube production employs a spindle winding the fibres into a thread, at several centimetres per second. The result is an extremely fine, long, strong, black thread which can carry an electrical current. This new technology makes using carbon nanotubes an economic proposition for a wide diversity of applications.

Projects in tiny technologies also included the development of electrically actuated digital mechatronic binary actuators, which led to prototypes of low-cost plastic actuators that could replace solenoids in cost-sensitive applications or in magnetic environments, such as MRI machines. Another project studied photonic devices, such as computer memory based upon nanoscale arrays of bismuth-based ferroelectric crystals.

3.4.4 Communications and Networks

Recognising the UK's competitiveness in the telecommunications sector, CMI brought together a unique community of pioneering academic researchers, industrialists and high-level policy makers to research, map and shape the future of the communications industry. Projects devised new communications techniques so that geographically separated teams could collaborate more effectively. New mechanisms were introduced to involve the 'end users' of research, companies and others who will turn the results into commercial products and services.

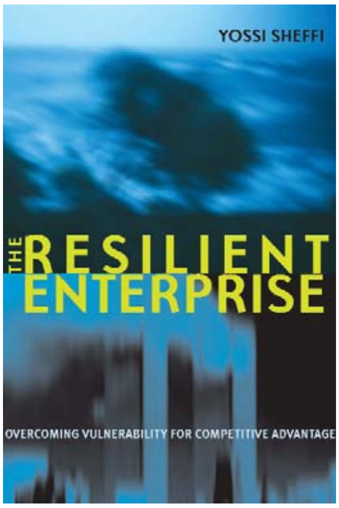
CMI sponsored several projects that focused on communications, including new technologies for distributed teams to work together at a distance, standardised protocols designed to enable global adoption of devices for radio-frequency identification (RFID), and methodologies for companies to make their supply chains more robust and secure.

Distributed Work

Drawing on studies of human communication and workplace practices in the social sciences and architecture, the Distributed Work project developed a novel framework for the analysis of communication and collaboration between distributed teams, using remote collaboration facilities to conduct skilled knowledge intensive activities. The team has collaborated with a variety of companies, including ARM, BT, GE Energy, Nokia and SAP, and has been studying the problems they face in managing distributed teams.

RFID/Auto ID

CMI researchers in the Cambridge Auto-ID Lab worked closely with leading players in the pharmaceutical sector within the Drug Security Network to establish how unique identification and electronic pedigrees, enabled by Radio-Frequency Identification (RFID), could dramatically improve the safety and security of the pharmaceutical supply chain, and enable the detection and elimination of counterfeit medicines. The CMI project was also instrumental in the launch of the Aerospace ID technologies programme.



Yossi Sheffi's book *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage*

Smart Media: The Flexible Media Prototype Research Experiment

The Flexible Media Prototype Research Experiment combined expertise from various partners, including BTexact Technologies, the Cambridge University Moving Image Studio, Digital Studios (Department of Architecture, University of Cambridge) and the Norwegian Film School. Each contributed specialised input. Together they forged a new media content form, new presentation formats for projects, and new tools for creating and exhibiting digital media stories and programmes. The knowledge and experience gained from the Flexible Media Prototype Research Experiment has also been instrumental in the incubation of Real Time Content (RTC), a BT Venture company funded by BT and by New Venture partners.

Supply Chains under Stress

Terrorism and natural disasters affect the supply of goods and services in ways we do not currently understand. The project Supply Chains under Stress: Implications of Critical Events and International Terrorism examined the challenges facing the supply chains of manufacturers, retailers and distributors in the Western world. It also investigated new methods for ensuring security within the transportation system. The project gave rise to a book, *The Resilient Enterprise*, which won the 2005 Book of the Year Award from ForeWord Magazine and was named one the Best Business Books of the Year by the *Financial Times*.

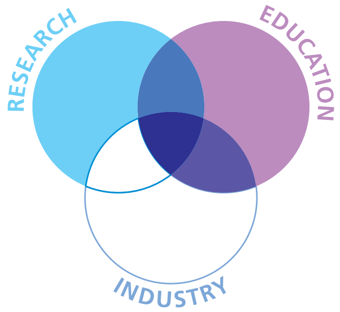
CMI's projects in communications and networks also included research on remote collaboration technologies for teams working together from different locations. Another project examined the development and use of technology in supporting knowledge communities in healthcare, working with industry, including BT, Drug Security Network, EPCglobal Healthcare Life Sciences Business Action Group, GlaxoSmithKline and Pfizer.

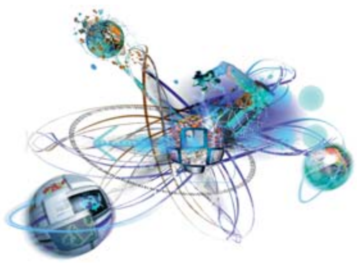
3.5 Conclusions

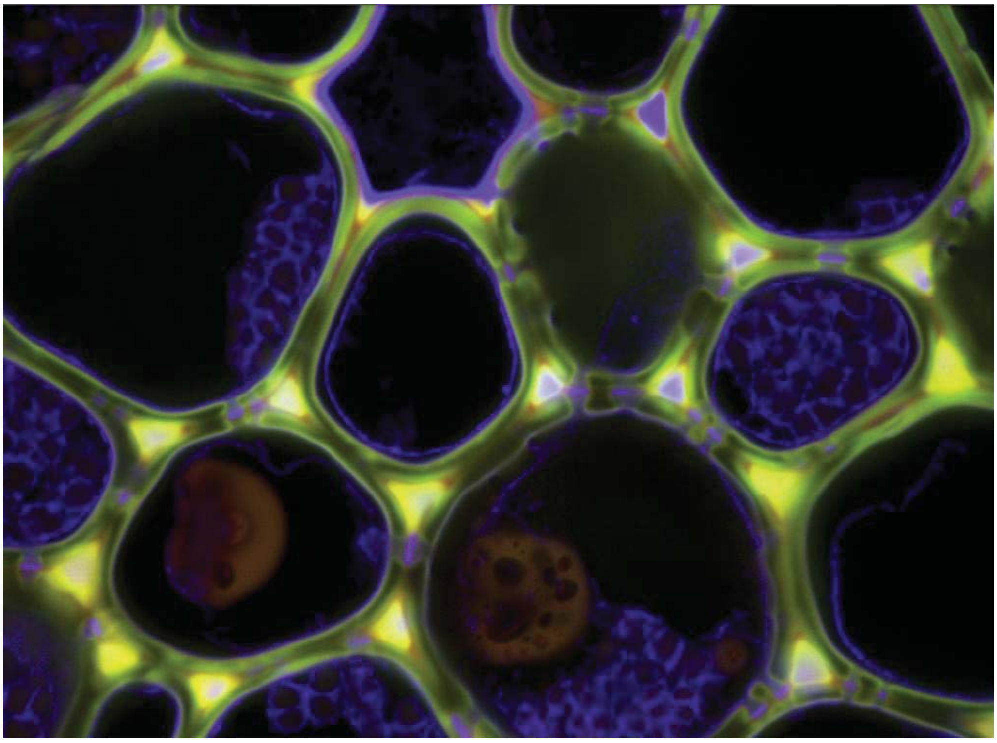
KICs and the other research projects have been very successful at bringing together industry and academic researchers in collaborative work, forming an important part of the activity *Engaging Industry in Knowledge Exchange* (see Chapter 4). They have built on CMI's principle that research should proceed with a consideration of use, and that researchers should consider the needs of society and industry in the selection and design of their research.

CMI's summary observation in *Knowledge Integration in Research* is that research enterprise can become a more important instrument of innovation and knowledge exchange through the pursuit of fundamental new ideas, when developed with a consideration of use and with an increased awareness of the needs of society, industry and enterprise, and when working together with integrated communities of students, scholars, industry, enterprise, government and others.

Interdisciplinary MPhils







"I was attracted to the Cambridge-MIT Institute's MPhil in Engineering for Sustainable Development because it takes the best of what MIT has to offer and combines it with Cambridge University's unrivalled global reach."

FRANCIS MILLS
STUDENT, MPHIL IN ENGINEERING FOR SUSTAINABLE DEVELOPMENT, 2005

In 2000 CMI began exploring different aspects of the institutional structures and cultures at MIT and Cambridge.

As a result, six new interdisciplinary Master's degrees (MPhils) were established for students and industry participants at the University of Cambridge: Advanced Chemical Engineering, Bioscience Enterprise, Computational Biology, Engineering for Sustainable Development, Micro- and Nanotechnology Enterprise, and Technology Policy.

At the heart of all of the CMI MPhil courses is a module on the Management of Technology for Innovation (MOTI), which introduces students to the management context of new business development. As part of MOTI, students attend lectures and then undertake consultancy projects with local organisations. They look at a technology-related business issue or an opportunity identified by the client organisation.

As well as defining the courses and helping them until they became self-sustaining, CMI supported the operation of the courses through its MPhil Working Party Group. This group helped the courses to pool knowledge on administrative and operational procedures, and allowed the courses to operate efficiently and to build on each other's experience.

The MPhil Working Group has now become the Multidisciplinary MPhil Forum, a platform to represent the views of technically orientated MPhils to the University, and has widened its membership to include established MPhils, including Interdisciplinary Design for the Built Environment and Industrial Systems Manufacturing and Management. Working at the interface of science and engineering, business and management, and policy and social domains is the key feature of this initiative. All the courses have novel and distinctive structures, are self-sustaining and continue to recruit strongly for 2008–09.

Engaging Industry in Knowledge Exchange

CMI worked with businesses and others who benefit from academic research to develop a better understanding of how universities and enterprises interact, and to devise new ways to enhance knowledge exchange. To achieve effective knowledge exchange and innovation, universities need to engage industry and enterprise in prolonged interactions around research and educational programmes that address their needs. Universities must also educate and empower agents of innovation and knowledge exchange, including students, faculty, managers and technology-transfer professionals. A culture can be developed in both universities and industry that values interactions between the two, and that promotes within universities a willingness to become involved in the problems of industry and society. Through various forums, networks and professional educational programmes, CMI actively engaged industry in the practice of knowledge exchange, inviting industry, the public sector and other enterprises to be equal partners in the work of the Knowledge Integration Communities, for example, and to help shape their research programmes.

Engaging Industry in Knowledge Exchange

4.1 Introduction

Universities play important roles in the innovation process. In particular, they are sources of knowledge, new ideas and techniques from research. Earlier attempts to foster university–industry knowledge exchange often involved mechanisms that are familiar and easy to measure, such as patents, licensing and the creation of new ventures. CMI set out to look beyond these obvious innovation channels to address the tacit and informal mechanisms that enhance competitiveness, productivity and innovation. For example, innovation also happens when researchers move between the academic and commercial worlds, when new graduates move into jobs in companies and public bodies, and when companies take up tools and techniques developed during the course of academic research.

Bringing the Electricity Industry Together

CMI brought together economists at Cambridge with MIT's Center for Energy and Environmental Policy Research to promote innovation and productivity in the electricity supply industry. The initial research project with two faculty members and a research assistant grew into the Electricity Policy Research Group (EPRG), a team of seventeen researchers and support staff.

The EPRG focuses on issues that affect electricity markets internationally, including regulatory challenges to liberalisation, pricing, security of supply, competition, emissions trading, low-carbon power and network technologies. The group's discussions consider policy implications and frame questions for future research. The EPRG secured very substantial funding from the EPSRC to continue this work. Following the success of the EPRG, the participants established the Electricity Policy Forum (EPF) as a membership body to engage in and influence the policy debate; improve understanding of the drivers for change; and leverage publicly funded research.

The EPF is refining new ways of sharing research findings so that members can make better use of the work carried out under the banner of the EPRG. The forum supports individual organisations in their strategic decision making.

Activities in knowledge exchange addressed both formal as well as informal processes. The objectives were to:

- proactively engage industry and enterprise in prolonged interaction around research and educational programmes that address their needs;
- develop and enable agents of innovation and knowledge exchange, including students, faculty, managers and technology transfer professionals;
- develop structures and incentives that encourage interactions between universities and industry.

To achieve its objectives, CMI established and sustained two-way communication between industry and academia. With this approach, the results of university research can flow naturally to industry. The programmes developed to achieve this included:

- Networks for Knowledge Exchange
- Professional Education Activities
- Digital Spaces for Knowledge Exchange
- The Programme on Regional Innovation

4.2 Networks for Knowledge Exchange

Innovation frequently happens at interfaces within and between organisations and depends on the development of networks that cross those interfaces. In the US, and especially in areas of high-growth innovation such as Boston and the Silicon Valley, these networks and relationships are well developed. Research commissioned by CMI suggested that such regional networks were less well developed in the UK .

CMI therefore developed initiatives to foster skills and networks to support entrepreneurially minded students, researchers and professionals, helping to build networks that bridge boundaries within the greater Cambridge and MIT communities, and throughout the UK. These groups and networks included representatives from the business community, academics and providers of support services working through three types of networks:

- student entrepreneurship networks across disciplines within universities and between universities;
- cross-sector, domain specific networks through the Knowledge Integration Communities (KICs) and Special Interest Groups (SIGs);
- networks of knowledge exchange specialists and professionals within universities, government, industry and intermediaries, through CMI's National Competitiveness Network.

CU Entrepreneurs 2005-06 Business Plan Competition, May 2006

4.2.1 Student Entrepreneurship Networks

CMI sponsored several student entrepreneurship networks with the aim of increasing the number of graduates who develop new ventures and commercialise their research. These networks also set out to boost students' confidence and to help them make the most of the skills and knowledge they acquired while at university (see Section 2.7). One of these networks, Cambridge University Entrepreneurs (CUE), now organises the most successful business planning and creation competition in Europe. It has resulted in over 40 companies worth more than £42 million.

More importantly, organisations such as CUE and the Cambridge University Technology and Enterprise Club have stimulated a change in entrepreneurial culture at the University of Cambridge and throughout the UK.

Other projects within Student Entrepreneurship Networks included i-Teams, the Annual Gala Networking Reception and Dinner, and Acumen-UK, a national network in support of student enterprise societies.

4.2.2 KICs and SIGs: Systematic and Sustained Dialogue

An important aspect of CMI's work has been in its use of systematic and sustained dialogues with industry when setting the agendas for new research activities. Here the goal was to understand what research was important for businesses and what would engage their interest. It was important that they were genuine stakeholders rather than interested bystanders.

Professor Hasso Plattner, co-founder of the software giant SAP AG, delivering a keynote speech at the University of Cambridge Technology Ventures Conference, June 2005

Nurturing Entrepreneurship

Developing entrepreneurship among students is an excellent way to develop skills that will be useful in starting businesses and working for commercial organisations. To assist this process, CMI was a major supporter of two student entrepreneurship organisations: Cambridge University Entrepreneurs (CUE) and the Cambridge University Technology and Enterprise Club (CUTEC).

CUE now organises one of the most successful student business plan competitions in Europe, running a portfolio of annual competitions. It has distributed more than £320,000 through these competitions and has helped in the launch of over 40 companies. These have since raised over £28 million in capital finance and have been valued at more than £42 million. With support from CMI, CUE also developed a handbook to assist student organisations at other universities in running their own business-plan competitions. This activity has brought together students, faculty and early-stage individual and institutional investors interested in creating new ventures.

CUTEC, which started in 2003, is devoted to effecting entrepreneurial culture change within the university. Its annual venture capital conference promotes entrepreneurship and makes important connections between the investment community and the university. CUTEC has become a key supporter of another CMI enterprise initiative, i-Teams, a hands-on entrepreneurial education programme for postgraduates inspired by a similar activity at MIT. Working in teams of five, students have six weeks to investigate 'go-to-market' strategies for real research projects. CUTEC and i-Teams provide students with some of the skills they need to successfully commercialise research.

"The initial Electricity Policy Forum was funded by the Cambridge-MIT Institute and has been at the core of our work for the past three and a half years. Their support allowed us to grow and secure large scale funding from the EPSRC."

PROF DAVID NEWBERY
CHAIRMAN
ELECTRICITY POLICY RESEARCH GROUP

The starting point for this process was to work with enterprises to develop a regional or national agenda that addresses key issues – such as healthcare, energy security, transport and so on – or strategies to exploit emergent technologies or new business processes, or to fulfil educational needs. Having established the agenda, the next stage brought academics into the process, to collaborate with stakeholders to identify the roles that university-based research and education can play, and to develop and implement a programme to realise the stakeholders' vision. CMI used this approach in the formation of projects such as the Electricity Policy Research Group and the Energy Security Initiative which aimed to address the UK's need to increase security and reduce the country's exposure to the uncertainties of the international fuel supply chain.

Harnessing Research to Improve Competitiveness

CMI's National Competitiveness Network (NCN) was founded as a forum for the exchange of ideas for the Science Enterprise Centres established by leading universities. The forum was initially fully supported by CMI and later partially funded. Since the period of support from CMI has finished, UK SEC, the national network for enterprise educators, has developed into a self-sustaining network of universities concerned with developing competitiveness and entrepreneurship.

NCN linked universities, businesses and government organisations, providing a forum where ideas could be exchanged, findings could be shared and issues relating to competitiveness, productivity and entrepreneurship could be explored in depth.

Through various channels, NCN disseminated the outputs of CMI and provided forums for knowledge exchange, aiming to turn research findings into practical measures to enhance competitiveness in the UK. These channels included the National Competitiveness Summit, the Competitiveness Forum, the Competitiveness Workshops and a range of electronic media. The NCN acted as a means of identifying areas where competitiveness, productivity and entrepreneurship could be improved in the UK, and where CMI could respond to such shortfalls.

Beyond these successful initiatives, several thousand academics and professionals have attended NCN events raising awareness of competitiveness and the need to foster entrepreneurship.

Prof. Alan Hughes, Kirsty Wark and Prof. Richard Lester at the 2004 NCN Summit "Exchanging Knowledge – Boosting Competitiveness"

4.2.3 National Competitiveness Network

The National Competitiveness Network (NCN) brought together universities, businesses and government organisations. Operating through various channels, including the National Competitiveness Summit, the Competitiveness Forum, Competitiveness Workshops and electronic media, the NCN's role was to improve knowledge exchange between universities, government, business and other stakeholders.

Lita Nelsen and David Secher at the first Praxis course, November 2002

Participants in the network explored issues relating to competitiveness, productivity and entrepreneurship. The NCN organised more than 45 events with over 2,000 participants and provided the impetus for Praxis, Enterprisers and the Entrepreneurship Development Programme.The work initiated by the NCN provided significant added value by brokering the links between world-class faculties in both institutions. It also developed links to the key UK policy-making institutions in the areas of innovation policy, including DIUS, ODPM (and those employed in its successor), and the UK Regional Development Agencies. Through these various mechanisms, the NCN identified a need for research that could provide evidence for improved policy and practice for advancing knowledge-based growth in urban and regional economies.

NCN has evolved into the Programme on Regional Innovation (see Section 4.5), which focuses on the creation of new models for developing world-class research and knowledge exchange mechanisms to improve regional – and thereby national – competitiveness.

4.3 Professional Education Activities

CMI established forums, networks and professional educational programmes to share with institutions in the UK the results of its work in engaging with industry and to bring others into the debate as to what constitutes effective practice in knowledge exchange.

It also played a pivotal role in establishing Praxis, a national training programme for technology transfer professionals. Praxis has provided training to over 1200 individuals. It is primarily aimed at staff from technology transfer or contracts offices in academic institutions, public sector research establishments and the National Health Service.

Delegates at the MEETS First Weekend, February 2005

Professional Education activities also included the UK Entrepreneurship Development Programme (UK-EDP), the Women in Technology Conference and Mid-Career Enterprise Education for Technology and Science (MEETS), helping mid-career women overcome barriers to innovation and realise their full potential.

4.4 Digital Spaces for Knowledge Exchange

Advances in communications technology can dramatically reduce the costs and other barriers to university–industry knowledge exchange. In its initiatives on Digital Spaces for Knowledge Exchange (DSKE), CMI designed experiments to understand how best to exploit the opportunities presented by these technologies and to develop a new kind of knowledge exchange infrastructure for storing and sharing the intellectual output of a university.

In July 2006, DSpace became a strategic service to the University of Cambridge, managed jointly by the Cambridge University Library and the University Computing Service.

DSpace is a digital repository system that captures, stores, indexes, preserves and redistributes an organisation's research data. It is open-source software developed in cooperation with Cambridge, Hewlett-Packard and MIT to capture, distribute and preserve intellectual output from the university. DSpace accepts all forms of digital material, including articles, reports, theses, learning objects, electronic records and audiovisual files. Researchers in industry and universities can access the information via the Web.

Cambridge and MIT led in the development of DSpace, encouraging and supporting the development of DSpace repositories at universities across the UK, and developing the institutional and governance mechanisms to operate the DSpace Federation. A DSpace user group for the UK and Ireland has been launched.

DSpace is now firmly embedded at the University of Cambridge and at MIT, has been adopted by hundreds of other institutions in over 40 countries and has substantial industrial support. CMI has sponsored the development of the DSpace Federation to coordinate the planning, research, development and distribution of DSpace as an open-source digital repository system.

Facilitating the Transition from Research to Business in the UK

From its work on the National Competitiveness Council, CMI identified a need for training among technology transfer professionals in the UK. Support for this view came in a report from the Bank of England which found that, while there were over 1200 technology transfer professionals in the UK, there was a shortage of training for them.

An exchange of licensing professionals between MIT and Cambridge led to the idea of developing a training programme suited to UK needs. Supported by CMI, volunteer teachers delivered four highly successful courses in 2002-03.

In April 2004, this effort gave rise to CMI's first spin-out company, Praxis Courses Ltd. Courses range from the fundamentals of technology transfer and research contracts to advanced licensing, developing intellectual property, and setting up spin-out companies. Praxis is now the UK's leading national training programme aimed at technology transfer professionals. The courses are overseen by a programme committee that carefully reviews feedback from each course, creating a "market-led" syllabus. Praxis tailors its training for staff from technology transfer or contracts offices in academic institutions, public sector research establishments and the National Health Service. Nearly 1200 individuals from more than 100 organisations in the UK have now taken part in more than 4000 training days.

4.5 Regional Innovation

Regional bodies in the UK, such as the Regional Development Agencies (RDAs) in England and their counterparts in Scotland, Wales and Northern Ireland, play an increasing role in promoting knowledge-based growth in urban and regional economies. CMI's Programme on Regional Innovation (PRI) supports this activity by undertaking novel and detailed theoretical and empirical research into how regional and urban economies compete in the global marketplace, and how they contribute to national economic performance. The programme also involves:

- developing a programme on the economic and social dimensions of urban and regional competitiveness;
- educating students and practitioners in techniques for understanding and influencing local and regional systems of innovation;
- informing evidence-based regional policy development and providing cross-disciplinary forums to share best practice and the latest research findings.

"In facilitating this transatlantic Leadership Exchange between Ipswich, England and Worcester, Massachusetts, the Cambridge-MIT Institute is creating an unprecedented opportunity for these two regional communities to share the keys to their success."

GERARD D'AMICO
FORMER MASSACHUSETTS STATE SENATOR

PRI also works with RDAs to address strategic issues. A recent study into the economic potential of the greater South East was conducted with the London Development Agency, the East of England Development Agency and the South East Development Agency. In this way, the programme has collaborated with the RDAs to provide research support and to work with stakeholders in the development of a science and innovation strategy for the South East.

The newest of CMI's programmes of collaborative development, PRI represents a different approach to working with stakeholders. It tightly couples research activities with informing the development of policy and the practice of regional innovation and growth through workshops.

4.6 Working with Industry

Over 1000 companies have participated in CMI-related activities, be it through direct involvement in a CMI project or by taking part in one of CMI's many events, conferences and workshops. Several of these organisations were large multinationals, such as BP, Pfizer and Rolls-Royce. The majority, however, were small and medium enterprises (SMEs).

In Education for Innovation for instance, the Management of Technology and Innovation (MOTI) – the core module of all six CMI MPhils at the University of Cambridge – worked with over 100 companies (see Section 2.8). MOTI students were placed in many UK SMEs, including Alphamerix, BlueGnome, Loughborough Surface Analysis and Plastic Logic.

"We are delighted to be working with the Cambridge-MIT team on this project. We are always interested in developing new technologies and new markets for our products and the new facility is helping us do just that."

PETER ROONEY
MANAGING DIRECTOR
FIBRETECH

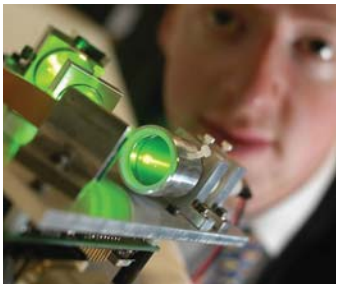
Research-based projects, such as New Ultra-Light Metallic Sheet Material (see Section 3.4.1), forged a relationship with Volvo, but also with the smaller Fibretech. Together they have produced and successfully commercialised an outcome of their collaboration: Fibrecore™.

As part of its programme on Engaging Industry in Knowledge Exchange, CMI interacted with hundreds of company representatives, mostly through the National Competitiveness Network (see Section 4.2.3). Student entrepreneurship networks have also resulted in more than 40 new ventures (see Section 4.2.1), including the 2003-04 winner of the £50K Business Plan Competition, Light Blue Optics, which has recently secured $26 million for the development of its miniature laser projectors.

4.7 Conclusions

Universities have significant influence over the education and research that are within their domain. CMI worked with businesses and others who benefit from academic research to develop a better understanding of how universities and enterprises interact and to devise new ways to encourage participation on knowledge exchange.

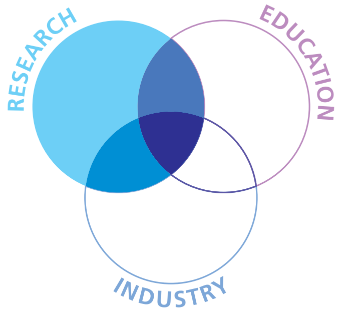
CMI actively engaged stakeholders in the practice of knowledge exchange, inviting industry, the public sector and other enterprises to become equal partners in the work of the KICs, for example, and to help shape their research programmes.



Light Blue Optics, winner of the 2003-04 CU Entrepreneurs £50k Business Plan Competition

Our summary observation in Engaging Industry in Knowledge Exchange is that industry can enhance knowledge exchange and innovation by an array of formal and especially informal interactions that are long term and sustained. These should occur not only in research, but also in education. Such interactions can be facilitated by aligned rewards and incentives, well-trained professional staff acting as facilitators, and students, as well as academic and industrial staff organisationally and culturally empowered to interact successfully.

Natural Ventilation



Natural ventilation is a key characteristic in the design of this new building for University College London

Buildings consume about 40 per cent of the energy used in the UK through heating, air-conditioning, lighting and ancillary equipment, such as computers. Reducing the energy consumption of our built environment is vital if the UK is to meet its targets for emissions of carbon dioxide and other greenhouse gases. A collaborative project with British Petroleum (BP), set out to design buildings that consume less energy.

The project brought together experts in architectural design, building engineering, natural ventilation processes, as well as those involved in building and environmental safety. Through a combination of complementary fundamental research, and a joint design project for a specific building, the team has helped to lay the foundations of a new discipline of integrated low-energy building design.

The researchers at Cambridge modelled real buildings, using scale models to estimate the flow of air through full-size buildings. In the laboratory, small-scale model buildings were immersed in a water bath and currents of dye-coloured hot and cold water are pumped through them at different speeds to simulate the flow of hot and cold air through a building. With their findings they developed models and control strategies for natural ventilation flows.

At MIT, the research team developed accurate computer techniques to predict natural ventilation flow in buildings. These have been used in conjunction with the water studies done at Cambridge and the experimental results from actual buildings.

MIT is developing a computerised design tool that allows architects to visualise the air flow and estimate the comfort conditions in complex multistorey buildings under the combined action of wind and buoyancy forces.

The research team has spun out a company, E-Stack, to commercialise the technology. The researchers have also been backed by a new commercialisation grant from BP.

"We are one of the world's largest energy companies and, looking at the long-term future of the energy sector, we recognise growing concerns regarding oil prices, climate change and energy security. We have to find and develop novel technologies that will address some of these challenges. BP believes the technology E-Stack is developing has real potential to do that in the decades ahead."

JUSTIN ADAMS
DIRECTOR OF LONG TERM TECHNOLOGY
BP

The Way Ahead

In 2000, the UK Government invited the University of Cambridge and the Massachusetts Institute of Technology (MIT) to form a joint venture that would work with other universities to look for ways to enhance competitiveness in the UK. In particular, the goal of the Cambridge-MIT Institute was to explore and develop ways to accelerate innovation through, for example, better exchange of information between the various players in the innovation process. In this chapter, we draw some broad lessons from this innovative and imaginative experiment in education, research and knowledge exchange.

5

5.1 Context

Between 2000 and 2006, CMI achieved its mission through a series of innovative experiments in the selection, management and operation of education, research and knowledge exchange. CMI's unique nature allowed it to cross boundaries not just between institutions and subject areas, but, crucially, between the three key strands of a university's activities – education, research and knowledge exchange.

"The Cambridge-MIT Institute has been successful in developing new ways for business and universities to work together."

LORD SAINSBURY
FORMER PARLIAMENTARY UNDER SECRETARY OF STATE FOR SCIENCE AND INNOVATION
DTI

When governments and other agencies set out to improve a nation's innovative capabilities, they usually do so through initiatives that involve just one of these three strands. They launch research programmes that they hope will lead to innovation in particular areas of science and technology or regions of the country. They fund educational initiatives that aim to make people more innovative, or they set in place knowledge exchange schemes with the intention that they will enhance the take-up of new ideas by industry.

Effective innovation needs all three of these: good education, excellent research and effective knowledge exchange. Experiments in how to select, carry out and manage these three activities are rare enough. Experiments that involved all three domains are even rarer. That is just what CMI set out to do.

5.2 What Did CMI Deliver?

The outcomes from CMI's activities are many. Most obviously they include the results of our research projects and new education programmes, as described in the earlier chapters.

Perhaps less visible are the developments at the interfaces of the main activities that would not have happened without CMI's programmes and projects. In particular, the efforts to bring together researchers and external enterprises – with students also a part of this mix – have inspired continuing activities.

The experience developed through CMI's activities has been captured as a series of 'effective practices', which others may consult and adapt (see Appendix I). These effective practices are founded on the high-level lessons in Knowledge Integration in Research, Education for Innovation, and Engaging Industry in Knowledge Exchange. They describe patterns of behaviour at a university and at the interface with industry that have the potential to accelerate innovation by enhancing university–industry knowledge exchange across organisational, institutional and cultural boundaries.

The practices build on specific experiences and examples, and are intended to support practitioners in the pursuit of knowledge exchange as they develop arrangements that meet their own circumstances and needs.

The recurring message from CMI programmes is that success in knowledge exchange typically requires an integrated system of activities with a constructive interplay of education and research and formal and informal engagement with industry and enterprise. It is this integration of a university's main roles that has the greatest potential to substantially enhance knowledge exchange and accelerate innovation.

5.3 Crossing Institutional Boundaries

MIT undergraduate exchange students at the University of Cambridge, October 2002

While MIT and Cambridge are the major partners in CMI, many other UK universities collaborated in specific projects in education, research and knowledge exchange, contributing their expertise and experience to the development of new approaches.

CMI's work in education has also delivered benefits to, and lessons for, other universities in the UK. CMI's research projects drew in collaborators from universities and other institutions, and helped academic groups to devise their own interdisciplinary educational programmes.

5.4 Education for Innovation

The innovation 'food chain' starts with the education of the people who will go on to do the projects that feed innovation, and who will themselves become the innovators of tomorrow. For this reason, in its work on Education for Innovation, CMI set out to understand what it takes to create innovators. It then set up imaginative projects that would test that understanding, provide the requisite knowledge to students and promote entrepreneurial attitudes.

CMI's ability to draw on the experience of the many interdisciplinary and multidisciplinary teams at Cambridge and MIT provided valuable insights into an issue of increasing concern for innovative businesses. Where do they find employees with deep knowledge of new areas, who are happy and comfortable to cross the boundaries between disciplines, and who have the aptitude for innovation? After all, significant advances in science and technology often occur at the interfaces between disciplines. The new Master's degrees at the University of Cambridge and courses in skills and learning help to meet these requirements.

Universities conventionally teach students along disciplinary or subject lines. Some progress towards interdisciplinary training can be achieved by the addition of new modules. The CMI experience, however, suggests that bringing together teachers, active researchers and education professionals dramatically improves the richness and integration of programmes.

CMI drew on its interdisciplinary environment to support the development of new undergraduate courses in biological engineering and microelectro-mechanical systems (MEMS), two interdisciplinary areas that are growing rapidly and where the UK has both academic and commercial excellence. At the postgraduate level, the interdisciplinary MPhils adopted under CMI are now well established.

It takes time for undergraduate education to influence not only research, but also the success of graduates as innovators. CMI's experience suggests that university education must not only provide a deep conceptual understanding of a subject, but also the personal and interpersonal skills, and above all the self-confidence to deploy that knowledge and those skills, which are the attributes required of an entrepreneur.

Our summary observation is that students will be better prepared to act as knowledge exchange agents, innovators and as entrepreneurs by an education that develops a deep, conceptual understanding of a discipline or inter-discipline; personal and interpersonal skills and associated self-efficacy, especially learned through authentic experiences; and entrepreneurial skills and self-efficacy, with the associated empowerment to apply knowledge and skills to entrepreneurship.

5.5 Knowledge Integration in Research

While it is certainly important to have researchers who are more attuned to the possibilities of innovation, their task will be more difficult if the research itself is not also commissioned, organised and reported so as to support their willingness to innovate.

A common thread throughout CMI's activities was knowledge exchange. While effective education is not a one-way process, the real emphasis on knowledge exchange entered into the picture most strongly when CMI set out to experiment with new ways of doing research. Research in itself provides only knowledge. It takes an extra effort to ensure the exchange of that knowledge, which is why CMI embedded knowledge exchange in everything that it did.

As the phrase suggests, knowledge exchange has to be a two-way process if it is to go beyond researchers simply disseminating their knowledge out into the wider world. They too have to gain knowledge from the people who will take their research as a basis for innovation. For the researcher, the most valuable knowledge can be an understanding of what an innovator might make of their research.

We have used the term 'consideration of use' to describe this process. By this we mean that research – be it in a university, a publicly funded research laboratory or in a company – would be more likely to enhance the competitiveness of the UK if the researchers understood and appreciated the possible uses of the results of the research. On the other side of the exchange, innovation would also improve if business had a better appreciation of academic research, the capabilities of the researchers and the possibilities that they create.

CMI's summary observation in the research domain is that the research enterprise can become a more important instrument of innovation and knowledge exchange through the pursuit of fundamental new ideas, developed with a consideration of use; through an increased awareness of the needs of society, industry and enterprise; and through collaborative work with integrated communities of students, scholars, industry, enterprise, government and others.

5.6 Engaging Industry in Knowledge Exchange

Industry can be a greater challenge when it comes to influencing behaviour. Whereas students and researchers are something of a 'captive audience' for universities, external enterprises need convincing. It is a sign of CMI's success that industry has taken over and adapted several of the Knowledge Integration Communities (KICs) and other networks that were described in Chapter 4. For example, the Electricity Policy Forum continues to promote innovation and productivity in the electricity supply industry while the Digital Communications Knowledge Transfer Network also lives on as an industry-backed national network (see Case Study 2).

"Crucially, the Cambridge-MIT Institute has succeeded in engaging all parties who can actually implement the results of the research in real projects where the gains can be exploited."

DR NIGEL BIRCH
FORMER CHIEF OF NOISE ENGINEERING
ROLLS-ROYCE

CMI created the KICs specifically to attract industry and to provide a well-managed, properly funded forum for researchers and innovators to come together to address issues identified as being of mutual interest. New approaches were developed to engage industry by understanding their needs through dialogue and networking.

Our summary observation is that knowledge exchange and innovation can be enhanced by industry interactions that are prolonged and sustained in research, education and innovation involving well-trained professional staff acting as facilitators, and supported by a culture that values interaction between universities and industry.

5.7 In the Longer Term

"The Cambridge-MIT Institute is a great example where working together in a collaborative manner is bringing so much more than we could do on our own."

BEN VERWAAYEN
CHIEF EXECUTIVE
BT

The range of CMI activities has done much to throw light upon the role of knowledge exchange as part of an innovation system. Many of these experiences and insights have been captured as practices that others can use in their own activities to enhance the power of research in promoting innovation (see Appendix I).

From the beginning, CMI set out to engage with universities and other agencies, and to communicate its findings. We have worked with most of the universities in the UK, the Higher Education Academy and the Royal Academy of Engineering, among others. Here we have used several dissemination mechanisms, including publications, workshops, conferences and press releases.

CMI has also worked with the UK Government, national and regional, through such mechanisms as support of the Science Enterprise Centres and events with the Regional Development Agencies (RDAs). For example, CMI helped RDAs in the South East to develop a joint approach to regional economic development. Our role was to help them to develop a better understanding of the role of universities in economic growth.

Given guidance and a sound intellectual underpinning, it is possible to be more 'scientific' in how we go about innovation. We can achieve this by allowing researchers to address subjects where there is already considerable business success, or where there are 'grand challenges' that society must face up to. Industry representatives will then enthusiastically join in the debate, helping researchers see how they can have a bigger impact on innovation. Significant financial resources, similar to those made available to CMI, are likely to be essential in bringing this about.

5.8 Key Messages

There are lessons from CMI for universities, businesses and other enterprises, and for government at national and regional levels. We have already described many of the ways in which universities can enhance their performance in knowledge exchange.

The 'effective practices' set out in Appendix I describe some of the ways in which CMI projects were able to develop and demonstrate new approaches to engagement. A number of more general observations can be made.

5.8.1 Lessons for Universities

Over the past decade, there has been enormous progress in the engagement of universities with industry, commerce and government. It is now widely accepted that substantial mutual benefits can follow from such engagements which can cover a broad range of informal and formal interactions.

Dr Andy Cosh giving a talk on "International Innovation Benchmarking and the Determinants of Business Success" at the 2004 National Competitiveness Summit

There are many opportunities for universities to enhance their core roles of education and research while contributing to industry, commerce and society at large. But if they are to fulfil this potential, universities need structures and policies which can accommodate and balance the different demands of education, research and industrial engagement.

Effective practices, such as those described in Appendix I, are most likely to flourish in environments where universities, industry and government have a coordinated view and realistic expectations of each other's requirements and capabilities.

As with all organisations, the incentives in universities must be matched to the desired outcomes. Traditional measures of academic excellence will rightly continue to be assessed through peer review in international communities of scholars. Education will be assessed by the teachers, professional groups, and the students themselves. The increasingly important industry engagement needs new methods of evaluation and assessment which will encourage and enhance performance in this area without compromising research or education.

Funding for programmes in innovation and knowledge exchange, along the lines of the Higher Education Innovation Fund (HEIF), is particularly important in encouraging and enabling the integrated delivery of university expertise to meet the needs of industry and society. For example, there may well be a need for new roles within the university, involving professionals and academics, by individuals whose primary role is building and facilitating industry–academic communities.

5.8.2 Lessons for Industry and Enterprise

The first challenge for industry and enterprise is to realise that it too must play an active part in knowledge exchange, which is, after all, a two-way process. As recipients both of trained graduates and research results, businesses owe it to themselves to communicate their own needs to the universities that supply these essential ingredients. For example, they should help universities to identify long-term research needs as well as their requirements for the training they expect from recruits.

Industry, commerce and enterprise hire most of the university graduates. They should act as advocates for the creation of new educational programmes and should be willing to invest in the development of educational materials. Industry should also make it known that it values, and seeks out, graduates whose education and training give them the required combination of knowledge and skills.

"The Cambridge-MIT Institute certainly walks the talk. You'd be hard pressed to find two more enterprising and creative places than Cambridge and Boston."

BARRY GARDINER MP
FORMER UNDER SECRETARY OF STATE FOR COMPETITIVENESS
DTI

Above all, industry must become more active participants in knowledge exchange, more in line with the approach taken by leading companies (see Chapter 1). Businesses are in no position to complain about the work of the universities if all that they do is 'sit on the sidelines'.

5.8.3 Lessons for Government

Governments fund university research and are customers for some of the outputs, both in terms of graduates and research findings. They set policy, not just for education and research, but also for regional policy and development strategies. Governments and other agencies, such as the Research Councils, can act as catalysts for knowledge exchange between universities and industry, and work with universities to help to shape education.

Through its projects, CMI has learned that for universities to deliver integrated research, education and engagement with industry, thereby strengthening knowledge exchange and innovation, stable and adequate funding must be provided. A diverse but coordinated set of funding opportunities should involve some based on peer review and others based on consideration of use and mission to encourage, and sustain, funding of efforts that integrate education, research and engagement with industry.

5.9 Conclusions

Creating CMI was a radical and original idea. The aim was to break new ground and to pioneer novel approaches to stimulating the creation and exploitation of ideas to benefit the economy and society. Some 100 universities and 1000 companies have participated in CMI activities. The lessons learned reflect the experience of many members of the academic and industrial communities – not just Cambridge and MIT. CMI has generated a significant body of reference material and many examples of effective practice that can guide future initiatives.

CMI's activities ranged from the systematic collection of effective practices to radical new approaches. The lessons continue to be shared with communities that are involved in state-of-the-art education, research and practice.

APPENDICES

A

The 11 effective practices summarised below arose from the direct observation of CMI's programmes and the experience and expertise of a wide range of institutions and programmes in the UK and around the world. We list them here as a reference for others involved in the design of programmes in research, education and industry engagement.

1: Collaborative Research with Consideration of Use

Collaborative Research with a Consideration of Use involves participants from diverse disciplines, and potentially various institutions, who unite to exploit emerging ideas, the further development of which is undertaken with a 'consideration of use', i.e. they are motivated by a problem of society, industry or enterprise.

Rationale:
Research is more likely to have societal and competitive impact if, from relatively early stages, it is motivated and guided by an important problem or challenge. Breakthrough opportunities often exist at the intersection of disciplines and through recognising potential complementarities amongst researchers and institutions.

Key elements:
- Research undertaken with a societal or commercial use in mind
- Research direction influenced by industry and other beneficiaries
- Link to fundamental or emerging underlying science, technology or thought
- Collaborations based around complementary expertise and resources
- Collaborators distributed across disciplines and/or geography
- Expected high net-value outcomes, such that the benefits of collaboration outweigh the difficulties

2: Knowledge Integration Communities (KICs)

Knowledge Integration Communities are larger-scale, research-centred collaborative communities engaging industry and enterprise along the supply chain from small to large business, and including governmental, regulatory and public-interest groups. These participants work directly with scholars to influence research focus, approach problems holistically, and advance the pace of knowledge exchange among the participants. These communities bring together all key stakeholders to craft, own and run an integrated programme of research, education and industrial engagement on topics that support competitiveness.

Rationale:
The engagement of all stakeholders at an early stage and throughout the research process helps to inform and direct research. It also creates a more seamless interface between academia and the targeted sector to facilitate the deployment of the research outcomes. The two-way exchange of people, practices and ideas, and integrated educational efforts can help to prepare a cadre of future leaders of the chosen domain.

Key elements:

- Motivation provided by overarching 'grand challenge' goals
- Fundamental research, with a 'consideration of use'
- Integrated communities of university researchers and students, industry, government and others, working together in close partnership
- Integrated or closely aligned educational programmes
- Integrated knowledge exchange mechanisms, such as IT-enhanced communication, industry workshops and professional courses, visits, and project-based courses deployed to enhance knowledge exchange between the participants
- Funding at a scale to reach critical mass
- Well-defined organisation to manage interactions and projects, and support the community
- Deliberate innovations in knowledge exchange within these communities and the reflection on those innovations for continuous improvement

3: Interdisciplinary Curriculum Development

Interdisciplinary Curriculum Development supports the creation of new curricular programmes which facilitate student learning of emerging disciplines (or 'inter-disciplines'), technologies or bodies of thought, and which span traditional departmental or disciplinary boundaries.

Rationale:
Innovation often occurs at the boundaries between disciplines, or in areas of new emerging thought. Interdisciplinary education can prepare students to contribute to emerging sectors and help to accelerate innovation. Existing boundaries at universities sometimes create barriers to the development of such new programmes.

Key elements:

- Development of a curriculum unconstrained by existing departmental or disciplinary structures, allowing emerging "inter-disciplines" to become institutionally recognised
- Rapid migration of emerging ideas into educational programmes
- New curricula drawing from the very beginning upon good practice in teaching and learning, and in instructional design, in particular interdisciplinary reflection and communication

4: Undergraduate Researchers

Undergraduate Researchers is a programmatic structure that facilitates research partnerships between undergraduates and faculty as part of core faculty research activities or student-proposed activities that involve faculty mentoring.

Rationale:
This type of authentic experience empowers students through the application of their newly acquired knowledge, building conceptual understanding and increasing student self-efficacy. It introduces students to the real process of discovery and development, building students' excitement and interests and

allowing them to identify career opportunities in research more clearly. Because of their direct exposure to emerging research results, students potentially become agents of knowledge exchange.

Key elements:

- Recognition that student participation in faculty or independent research is important to the undergraduate learning
- Student-identified research opportunities that fit flexibly within a course or as a designated co-curricular activity, and involve meaningful faculty mentoring and supervision
- Student participation in authentic aspects of the research process, including proposal preparation and planning, conducting of experiments and data analysis, as well as written and oral presentations
- Student access to emerging research results

5: Student Engagement in Learning

Student Engagement in Learning deploys new learning methods and technologies, which more strongly engage students in learning and encourage higher-level reflection on their learning. This includes the development of new web-based laboratories and tutorials, and approaches to small group and classroom instruction – based on good practices in teaching and education – and draw upon distinct models of instruction from the UK and the US.

Rationale:

Students develop deeper conceptual understanding when they are able to engage more actively with instructors and problems. By examining contrasting teaching models in a controlled manner, hybrid practices of teaching and learning that stress active engagement within specific subjects, as well as evidence-based methods that are more generic across disciplines, can evolve.

Key elements:

- Identification and exploitation of opportunities to compare and contrast the efficacy of different approaches to enhancing learning
- Linking experts in education to teaching staff in course design, delivery and assessment, and employing evidence-based interventions
- Learner-centred teaching methods and alignment of assessment with learner objectives
- Exploitation of technology to enhance learning and provide a framework for the community of teaching and educational staff engaged in developing innovative practice

6: Skills Education

Skills Education develops curricular approaches, hands-on, design-built laboratory exercises and materials, and associated teaching resources that build student capabilities in personal skills, such as critical thinking, interpersonal skills (including teamwork), communications and other core skills that support innovation.

Rationale:
Curriculum reform that embeds skills teaching within core disciplinary subjects, rather than as extraneous material, provides enhanced student skills and confidence in hands-on engagement with the challenges associated with innovation.

Key elements:
- Engagement with broad community of stakeholders (graduates, government, industry, faculty) to agree on skills that graduates should possess
- Emphasis on hands-on, authentic experiences in classrooms and/or laboratories to build skills in team-engagement with real world problems
- Infusion of skills teaching as inherent part of core disciplinary instruction, with eye to pedagogical and resource implications
- Exploitation of technology to support adoption of skills teaching materials and approaches by teaching staff

7: Graduate Education in Technology and Innovation

Graduate Education in Technology and Innovation develops cross-disciplinary professional practice programmes that blend instruction in social science and management of innovation subjects (e.g. economic and social impact, leadership, team building) with disciplinary subjects in engineering, science and technology.

Rationale:
Taught graduate degrees with an emphasis on management of innovation within an emerging technical field could yield graduates with a blend of enhanced technical and management expertise and efficacy, leading to a higher likelihood of societal impact and new venture creation.

Key elements:
- Joint delivery of management and technical material in order to focus innovation into more high-value areas of problem definition and needs assessment
- Emphasis on entrepreneurial application of technical skills in order to give graduates confidence to act as change agents in introducing fundamentally new approaches to delivering products and services in their field
- Modular programme design to share courses wherever possible, and bring together students from different disciplines

8: Education for Entrepreneurship

Education for Entrepreneurship involves educational experiences for undergraduates and mid-career professionals, and stresses venturing skills and development of an acceptance of risk, rather than a conventional approach based on knowledge transfer. The model is grounded in a theoretical model of self-efficacy as a driver of innovation and pre-entrepreneurial behaviour.

Rationale:
Building self-efficacy in venturing skills, and developing an acceptance of risk increases the likely entrepreneurial behaviour and suggests higher probability for creation of high-growth companies.

Key elements:

- Focus on building general self-confidence in capacity to create and develop new ventures collaboratively, and in willingness to take risks
- Theoretical grounding in enhancing self-efficacy in terms of addressing unstructured problems, and other factors proven to predict disposition towards entrepreneurship
- Engagement with entrepreneurs as part of the content development and delivery process

9: Systematic Dialogue

Systematic Dialogue is a structured and facilitated process for engaging external stakeholders and beneficiaries of university endeavours to help shape research and educational agendas, and to advance informal knowledge exchange in ways that will accelerate innovation.

Rationale:
A structured process for providing stakeholder input into the development of university-based research and educational activities can elicit longer time scale stakeholders needs, and connect them to a broad range of academic capabilities. This will increase consideration of use within the university, industry participation and knowledge exchange in ways that will accelerate and improve the innovation process.

Key elements:

- Reliance on a structured process with specific outputs at each step that represent and/or address the needs of stakeholder participants
- Skilled facilitation to ensure that diverse view points are represented, understood and addressed, which is particularly valuable if numerous representatives from within a sector or supply chain are involved
- Steps that effectively develop trust among participants to ensure that relevant views are openly expressed
- Outcomes that include the development of research communities and new educational programmes, potentially with the active participation of external stakeholders

10: Digital Spaces for Knowledge Exchange

Digital Spaces for Knowledge Exchange include web-based virtual networks providing resources to capture, archive, and distribute research and educational artefacts, specialised knowledge, and other information and materials.

Rationale:
Advances in communications technology have shifted the economics of knowledge exchange in ways that can dramatically reduce the costs and other barriers to effective exchange or archival knowledge, and can move it towards a costless, real-time, on-demand service for the user.

Key elements:
- Open access to web-based resources
- Repositories that are multidisciplinary and provide low cost of entry or utilisation to leverage low marginal cost of access to online resources
- Digital spaces that involve participants with diverse specialties and from each of the public, university and industrial sectors, such that benefits flow to all parties
- Networks and spaces that are active in responding to the evolving needs of constituent communities by providing easy mechanisms for adding new content
- Standards-based implementation to facilitate inter-networking

11: Knowledge Exchange Networks

Knowledge Exchange Networks are professional and organisational networks designed to create and strengthen linkages among scientists and engineers, entrepreneurs, faculty and students, sources of capital, and industry for the purpose of advancing economic performance.

Rationale:
As described by the theory of social capital, social and organisational networks, when guided by suitable cultural and business conditions and operating principles, can be important contributors to knowledge exchange, innovation and economic performance.

Key elements:
- Low cost of participation to leverage network effects in which the value of participation increases as participation increases
- Networks that are dynamic in nature to stay vital by responding to the evolving needs of constituent communities and delivering events and educational content that are responsive to their needs
- Peer-level sharing of best practices and skills
- Affinity among members based on common professional interests

Conclusion on Practice

It is an integrated system of activities at a university – the constructive interplay of education and research and formal and informal engagement with industry and enterprise – that has the greatest potential to substantially enhance knowledge exchange and accelerate innovation.

The CMI models of effective practice, if successfully implemented, will substantially contribute to creating the conditions suggested by the three CMI high-level lessons on knowledge exchange, to improving university–industry knowledge exchange, and to accelerating innovation.

Appendix II: CMI Ongoing Activities

Research Projects

Ceramic Encapsulation of Radioactive Waste Materials
The team is now shifting its focus to finding better performing materials for storing radioactive waste safely and there is interest from BNFL to invest.

Communication and Synchronisation in Future Embedded System Architectures
The project has been given funding for a number of follow-on projects including Chip-to-Chip communication, a wired sensor network project and two further PhDs.

Digital Multiscale 3D-Characterisation of Carbonate Rocks: Canning Basin, Western Australia
The models created are being refined with the integration of further analyses.

Electricity Policy Research Group (EPRG)
The Electricity Policy Forum received a £2.5m million grant to form the Electricity Policy Research Group to continue work on productivity and innovation in electricity and related emissions markets.

IRC in Biomaterials and Tissue Engineering
The spin-out company, OrthoMimetics Ltd, is currently focused on establishing production facilities, completing preclinical trials, preparing clinical trials and a submission for CE-Mark approval of ChondroMimetic, with a view to bringing it to market in the EU in 2008 and in the US in 2009. Development of its ligament-repair and tendon-repair products is ongoing.

Magnetoelectronic Devices
The ring architecture developed has resulted in a design of MRAM which is being commercialised by Motorola, Infineon and IBM. There is an ongoing partnership with the 4G gene sequencing team at the University of Southampton, and work on a spin diode is being applied to the development of new biosensors, on the back of which a biomagnetism spin-off company could be founded within a year.

MEMS Research Proposal: Materials Design and Processing for MMAS
The MEMS research has led directly to four continuing research projects which have won over £1 million in funding and the team are presently in discussion with Philips, EPSRC, TUDenmark and Imperial College London regarding possible interactions.

Natural Ventilation, Solar Heating and Integrated Low-Energy Building Design
The team is now trialling the E-Stack prototype in a number of schools and planning to incorporate their technology in a planned new energy-efficient office building in Aberdeen. MIT is developing a computerised design tool that allows architects to visualise the air flow and estimate the comfort conditions in complex multistorey buildings under the combined action of wind and buoyancy forces.

New Technologies for Condition Assessment and Monitoring of Ageing Infrastructure (Smart Infrastructure)
Smart Infrastructure have received a £1.4 million grant from the EPSRC which will allow the group to collaborate with Imperial College London to examine three potential application areas for Smart Infrastructure systems.

New Ultra-Light Metallic Sheet Material
Fibrecore™, one of the products that emerged from the collaboration, is now available to order and potential markets are being researched.

Next-Generation Drug Discovery (NGDD)
Both project research areas, in stem-cells and bioinformatics, have established a base of interdisciplinary accomplishment from which they can move forward with initiatives towards garnering resources to further pursue these important new directions of research and education.

Optical Properties of Nanoscale Arrays
The team continues its research on ferroelectric crystals in liquid form and the development of a final prototype, and are additionally looking into potential healthcare applications for carbon nanotubes.

Responsive Polymer Research Enterprise
A UK hospital has expressed interest in using the fluorescent imaging in order to locate heart boils in patients and an Italian clothing firm is interested in using the mussel glue for outdoor wear.

***Rhodococcus* as Biological Catalysts for Chiral Synthesis and Novel Pharmaceuticals**
Work continues in several areas: on a genetic and metabolic 'roadmap' of *Rhodococcus*; with Chirotech and Biotica to produce new and improved antibiotics, anti-cancer drugs and anti-fungal drugs; on testing the effectiveness of a new anti-tubercular drug with Dow; and, at MIT, on work that could potentially produce a protease inhibitor, an AIDS treatment.

Silent Aircraft Initiative
The team continues work on turning its design concept into a reality and on new descent trajectories and protocols for the aircraft of today.

Ultimate Polymer: Carbon Nanotube Enabled Materials
The team aims to improve the strength of carbon nanotube fibres by 10-fold in the next year or so, bringing their use in industrial production closer to fruition.

Networks

Communications Research Network (CRN)
Two years after it was launched by CMI, CRN spun out into a not-for-profit company limited by guarantee. It remains devoted to researching, mapping and shaping the future of the global communications industry.

Construction SIG
The Construction SIG holds quarterly meetings of major clients of the industry to promote the exchange of expertise and learning of experience from other projects.

Electricity Policy Forum (EPF)
The EPF meets three times a year to promote a three-way dialogue between industry, regulators and academics on matters concerning electricity markets and regulation and related emissions markets.

Energy Security Initiative
The Energy Security Initiative continues to be a neutral space where stakeholders, government and academia can debate challenges to energy security.

Healthcare Systems Initiative
The group has led to MIT and Imperial College London submitting a proposal for EU FP7 funding.

Knowledge Resource Network (KRN)
Various re-use of these teaching materials projects, such as the RLO-CETL (www.rlo-cetl.ac.uk), continue and their relationship with the Open University – who have gone on to launch the OpenLearn Initiative (http://openlearn.open.ac.uk) – is still strong.

National Competitiveness Network (NCN)
The NCN has now become UK SEC, the national network for enterprise educators, which is self-sustaining, independent and has in its membership over 60 of the UK's most enterprising Higher Education Institutions. NCN has also led to the establishment of the Programme on Regional Innovation.

Courses

Accelerated Studio: The Joint Urban Design Studio
In the UK, the Studio has influenced the revision of the Cambridge Structure Plan and in the US, MIT and the City of Cambridge are using some of their recommendations.

Centre for Competitiveness and Innovation (CCI)
CCI has become embedded within Judge Business School to be the school's focus for teaching, research and industry-related events, and partnerships in the innovation domain.

Education for High Growth Innovation Project (EHGI)
EHGI is developing the tools to assess different kinds of educational experiences and their outcomes, and is sharing them with a wide consortium of UK and US universities.

Engineering for Life Sciences
Engineering for Life Sciences is now embedded in the teaching and research activities of the University of Cambridge Engineering Department.

Management of Technology and Innovation Module (MOTI)
MOTI remains embedded in the six MPhil courses originally founded by CMI and continues to give students first-hand experience of managing innovation and running a high-tech business.

MEMS Undergraduate Education: Materials Design and Processing for MMAs
This MEMS course has now become an embedded offering.

MPhil Degrees at the University of Cambridge
The six new CMI Master's degrees – in Advanced Chemical Engineering, Bioscience Enterprise, Computational Biology, Engineering for Sustainable Development, Micro- and Nanotechnology Enterprise, and Technology Policy – continue to offer multi-disciplinary education to students at the University of Cambridge.

Praxis: UK Technology Transfer Training Programme
Praxis has secured funding and is now an independent, not-for-profit company offering a full programme of events and courses planned right through to the end of the year and beyond.

Workshops

CMI Enterprisers
With backing from more than 30 sponsoring organisations, the Enterprisers workshops are being taken beyond universities to include industry.

Mid-Career Enterprise Education for Technology and Science (MEETS)
The MEETS format may be adapted for personal development schemes in other university departments.

Other Activities

Cambridge-MIT Exchange (CME)
CME is currently seeking long-term funding of the bursaries which cover the students' additional expenses and keeping under review the opportunity to extend the programme to other subjects and activities.

Cambridge University Entrepreneurs (CUE)
CUE continues to organise the most successful student-run business planning and creation competitions in Europe, and to foster a culture of entrepreneurship among students and academics.

Cambridge University Technology and Enterprise Club (CUTEC)
CUTEC has attracted a wide range of sponsorship from commercial organisations such as 3i and Microsoft, and continues to hold its annual Technology Ventures Conference and support i-Teams.

Developing Institutionally Based Digital Archives in the United Kingdom (DSpace)
D-Space continues to grow its base of users. It is now a strategic service to the University of Cambridge, managed jointly by the Cambridge University Library and the University Computing Service.

i-Teams
iTeams has branched out to produce highly valuable consultancy for projects outside the Cambridge-MIT portfolio.

Programme on Regional Innovation (PRI)
PRI's current activities include convening academic-policy interchange, providing research support and policy guidance to several RDAs and holding interdisciplinary workshops for young researchers.

Regional Partnerships and Intermediaries: Ipswich & Worcester
The relationships established have remained strong and exchanges between the towns continue.

Transport Information Monitoring Environment (TIME)
Time is continuing to use Cambridge as a test bed to learn how to gather data for the research, application development and deployment of transport monitoring systems.

Undergraduate Research Opportunities Programme (UROP)
UROP has secured funding in part from the Isaac Newton Trust which will allow it to grow into an established and sustainable programme.

Weblabs in Chemical Engineering
A recent investment of £100,000 by Siemens is helping Weblabs become a permanent part of the Department of Chemical Engineering at Cambridge and to spread to educational institutions worldwide.

Further information on CMI projects and activities can be found on our website at www.cambridge-mit.org.

Appendix III: CMI Projects, 2000–2006

21st Century Construction

Accelerated Studio: the Joint Urban Design Studio

Acumen- UK: Fostering a UK Wide Student Network to Share Best Practices

Analysis and Evaluation of Remote Collaboration Technologies in the Design Studio and Elsewhere

Assessing the Effectiveness of KE among Universities and Industry

Automated Delivery of Computing Teaching

Biological Engineering Undergraduate Curriculum Development

Building a Biomedical Business: Effectively Translating Biomedical Science and Engineering into Business

Building a Technology Transfer Infrastructure for CMI and Extending it as a Model for UK Universities

Cambridge University Entrepreneurs Sponsorship

Cambridge University Technology and Enterprise Club Sponsorship

Cambridge-MIT Exchange

CATAM: Development of Mathematics Project Course Material

Centre for Competitiveness and Innovation

Ceramic Encapsulation of Radioactive Waste Materials

CMI at Adastral Park

CMI Enterprisers

CMI New Engineering Modules

Common Course on Cell and Tissue Engineering

Communication and Synchronisation in Future Embedded System Architectures

Communications Research Network

Coursework - Lecture Integration

Creating Places for Enterprise Development

Design and Implementation of Third Generation Peer to Peer Systems

Developing & Managing a Successful Technology & Product Strategy: Designing a Distance Offering

Developing Institutionally Based Digital Archives in the United Kingdom

Development of a New Ultra-Light Metallic Sheet Material

Development of Microfabricated Stem-Cell Bioreactors and Real-Time Assays for Optimising Haematopoietic Stem-Cell Self-Renewal in Culture

Development of Speech Processing Technology for Computer Assisted Language Learning

Development, Deployment and Use of DSpace

Digital Multiscale 3D-Characterisation of Carbonate Rocks: Canning Basin Western Australia

Distributed Work A

Distributed Work B

Durham-CMI Knowledge Exchange Laboratory

Dynamics of Networked Innovation: Barriers to Knowledge Transfer

Education for High Growth Innovation Project

Energy Security

Enhancing KE in the Quantum Information Community

Enhancing University-Industry Collaboration for Competitiveness

Enterprise Forum UK

Fabricate Voltage-Tunable Photonic Devices Filled with Ferroelectrics

Framework for Pebbles in Oxygen and Autohan

Fundamental Studies of Digital Mechatronics and its Potential Applications

Appendix III: CMI Projects

Geography of Innovation: Proposal for Support for Seminar and a Book

Global Environmental Change: Biomineral Proxies of Ocean Chemistry and Climate

Globalising Behaviour of UK Firms in a Comparative Context

Healthcare Systems Initiative

Infrastructure Survey and Needs Specification for CMI Remote Collaboration and Educational ICT Initiatives

Innovation Futures UK

Innovative Supply Chains Systems for Sustainable Competitiveness

Institutionally Based Digital Archives in the UK

Intelligent Book

Interdisciplinary Research Cluster in Biomaterials and Tissue Engineering

International Innovation Benchmarking and the Determinants of Business Success

Internet Security Group

i-Teams

Knowledge Resource Network

Leaders for Manufacturing: UK Internship Project

Magnetoelectronic Devices

Management of Technology and Innovation Module

Managing Change and Innovations in Work and Organisations

Material and Process Selection Short Course

MEMS Research Proposal: Materials Design and Processing for MMAs

MEMS Undergraduate Education: Materials Design and Processing for MMAs

Mid-career Education for Tech-Based Innovation and E-Ship

Modelling the 'Deep Structure' of Business Activities and their Complementary Assets

MPhil in Advanced Chemical Engineering

MPhil in Bioscience Enterprise

MPhil in Computational Biology

MPhil in Engineering for Sustainable Development

MPhil in Micro- and Nanotechnology Enterprise

MPhil in Technology Policy

Multidisciplinary Design Project

National Competitiveness Network

National Transport Data Framework

Natural Ventilation, Solar Heating and Integrated Low-energy Energy Building Design

New Century Cities

Next-Generation Drug Discovery

OKI: Development and Evaluation of a Generic Learning Management System

Optical Properties of Nanoscale Arrays

Possible Approaches for Co-formulating Enzymes and Bleaches in Aqueous Liquid Detergent Compositions.

Praxis: UK Technology Transfer Training Programme

Preparatory Study of a New Ultra-Light Metallic Sheet Material

Programme in Technology-Based Entrepreneurship for Engineering and Management Science Students

Programme on Regional Innovation

Project to Extend DSpace into the University of Cambridge and the United Kingdom

Promoting Innovation and Productivity in Electricity Markets

Quantum Information Theory and Technology

Regional Partnerships and Intermediaries

Responsive Polymer Research Enterprise

RFID

Rhodococcus as Biological Catalysts for Chiral Synthesis and Novel Pharmaceuticals

Security of Crypto APIs

Sentient Vehicle: Mobility and the Environment

SIE-CMI Knowledge Exchange Laboratory

Silent Aircraft Initiative

Small Company Focused Internships

Smart Infrastructure: New Technologies for Condition Assessment and Monitoring of Ageing Infrastructure

Smart Media

Sudden Impact: Using Real-World Contexts and Hands-on Experience to Develop Transferable Engineering Skills

Supply Chains under Stress: Implications of Critical Events and International Terrorism

Support for CMI Educational Publication and Dissemination Activities

Sustainable Chemical Processes in Environmentally-Friendly Media

Teaching and Learning of Professional Engineering Skills

Teaching and Learning Engineering and Technology

Teaching for Learning Network

Teaching Hardware / Software Co-design

Teaching the Fundamentals: A Study of Pedagogical Approaches

Teleworking and the Latent Functions of Work

TIME: Transport Information Monitoring Environment

Transferring Successful Design Strategies across Sectors

Transport SIG

Turning Innovation into Value: Weil Workshop

UK-EDP

Ultimate Polymer: Carbon Nanotube Enabled Materials

Undergraduate Research Opportunities Programme

Understanding the Development and Commercialisation of Digital Technologies

Universities and their Role in Systems of Innovation: A Comparative Assessment of UK and US Institutions and Locales

Visual Tracking for Modelling and Interaction

Weblabs in Chemical Engineering

Windows on Science

Women in Technology Community

Appendix IV: CMI Principal Investigators

Hal Abelson, MIT
E Eric Adams, MIT
Tom Allen, MIT
Ross Anderson, UC
John A C Archer, UC
Krste Asanovic, MIT
Michael Barrett, UC
Christie Baxter, MIT
Suzanne Berger, MIT
Alan Blackwell, UC
Mark Blamire, UC
J Anthony C Bland, UC
Pablo Boczkowski, MIT
William Bonfield, UC
Duane S Boning, MIT
Edward Boyle, MIT
Rex Britter, UC
Louis Bucciarelli, MIT
Andy Buckley, UC
Brendan J Burchell, UC
David Cardwell, UC
Steven Casper, UC
David Cebon, UC
Roberto Cipolla, UC
David Clark, MIT
John Clarkson, UC
Trevor William Clyne, UC
Nick Collings, UC
Clark Colton, MIT
Charles Cooney, MIT
Sarah Cooper, University of Strathclyde
Andy Cosh, UC
Jon Crowcroft, UC
Jonathon Cummings, MIT
Mary Cunningham Boyce, MIT
Joel Cutcher-Gershenfeld, MIT
Rick L Danheiser, MIT
Trevor Darrell, MIT
Mark De Rond, UC
Simon Deakin, UC
John Dennis, UC
John A D Dickson, UC
Martin D Dove, UC
Ann Dowling, UC
Thomas Drummond, UC
Steven Dubowsky, MIT
Marcel Echenique, UC
Claudia Eckert, UC
Herbert Einstein, MIT
Artur K Ekert, UC
Harry Elderfield, UC
Denny Ellerman, MIT
Daniel W Engels, MIT
Richard Fenner, UC
Norman A Fleck, UC
C J H Fowler, University of Essex
Peter Fox, UC
Lorna J Gibson, MIT
James Glass, MIT
Leon Glicksman, MIT
Keith Glover, UC
David Good, UC
Martha Gray, MIT
Anthony Green, UC
Edward M Greitzer, MIT
Linda Griffith, MIT
Eric Grimson, MIT
John P Grotzinger, MIT
Steve Hall, MIT
Douglas Hart, MIT
Daniel Hastings, MIT
Trevor Alan Hatton, MIT
Rebecca Henderson, MIT
Joe Herbert, UC
John Heywood, MIT
Linn W Hobbs, MIT
Andrew B Holmes, UC
Malcom Horner, University of Dundee
Ray Hudson, Durham University
Alan Hughes, UC
Hugh Hunt, UC
Robert Hunt, UC
Frans Kaashoek, MIT
Thomas Kochan, MIT
Kirk Kolenbrander, MIT
Markus Kraft, UC
Vijay Kumar, MIT
Peter Landshoff, UC

Appendix IV: CMI Principal Investigators

Christel Lane, UC
Doug Lauffenburger, MIT
Steven Leeb, MIT
Bernard Leong, UC
Philip A Lessard, MIT
Richard Lester, MIT
Seth Lloyd, MIT
Harvey Lodish, MIT
Peter Long, UC
Chris Lowe, UC
Thomas Lozano-Perez, MIT
William A Lucas, MIT
Robert J Mair, UC
Thomas Malone, MIT
Charles Marshall, MIT
Ron Martin, UC
Matthew Mattox, Technology Review
Duncan McFarlane, UC
Stewart McTavish, UC
Anton Middelberg, UC
Haynes Miller, MIT
William I Milne, UC
Tim Minshall, UC
Jagadeesh S Moodera, MIT
Simon Moore, UC
Kamel Munir, UC
Fiona Murray, MIT
Lita Nelsen, MIT
Keith A Nelson, MIT
David Newberry, UC
Dava Newman, MIT
Richard Nicol, UC
D Norman, UC
Bill Nuttall, UC
Nick Oliver, UC
Wanda Orlikowski, MIT
Sergio Pellegrino, UC
Francois Penz, UC
Jane Pickering, MIT
Karen R Polenske, MIT
Michael Pollitt, UC
William Porter, MIT
Jem Rashbass, UC
Andrew Rhomberg, Gate 5
Ronald Rivest, MIT
Peter Robinson, UC
Dan Roos, MIT
Don Rosenfeld, MIT
Caroline A Ross, MIT
Jochen Runde, UC
Donald Sadoway, MIT
Bishwapriya Sanyal, MIT
Sanjay Sarma, MIT
Martin Arnold Schmidt, MIT
James Scott, UC
David Secher, UC
Warren Seering, MIT
Stephanie Seneff, MIT
Yossi Sheffi, MIT
Jasdeep Singh, UC
Anthony J Sinskey, MIT
Nigel K H Slater, UC
Alex Slocum, MIT
David Smith, Mr
Kenichi Soga, UC
Mark Spearing, MIT
Jennifer Stine, MIT
Veronica Sutherland, UC
Brian Tanner, Durham University
Jefferson W Tester, MIT
Janet Tully, Durham University
Peter Tyler, UC
Shai Vyakarnam, UC
Stephen A Ward, MIT
Andrew Whittle, MIT
Tomasz Wierzbicki, MIT
John Williams, UC
John Williams, MIT
Alan Windle, UC
Ann Wolpert, MIT
Andy Woods, UC
Steve Young, UC

Appendix V: Governance as at September 2006

CMI Board

Sir Nicholas Scheele	Chairman CMI Board
Professor Gordon Edge	Founder The Generics Group Ltd
Dr Susan Hockfield	President Massachusetts Institute of Technology
Professor Alison Richard	Vice-Chancellor University of Cambridge
Professor Phillip Clay	Chancellor Massachusetts Institute of Technology
Professor Ann Dowling	Professor of Mechanical Engineering University of Cambridge
Professor Edward Crawley	Executive Director CMI, Massachusetts Institute of Technology
Professor Michael Gregory	Executive Director CMI, University of Cambridge
Dr Graeme Reid (Observer)	Director, Exploitation Department of Trade and Industry
Professor Ian Leslie (Observer)	Pro-Vice-Chancellor for Research University of Cambridge

Advisory Board

Professor Gordon Edge	Chairman, CMI Advisory Board Founder, The Generics Group Ltd
Professor Neil Alford	Consultant, Technical Programmes The Gatsby Charitable Foundation
Dr Dougal Goodman	Director The Foundation for Science and Technology
Mr Stephen Heal	Business Development Director Tesco Stores Ltd
Dr Jean-Louis Liévin	Head, Brand & Communication BTexact Technologies, Adastral Park
Dr Tony Meggs	Group Vice President of Technology BP plc
Lord Ron Oxburgh	Department of Earth Sciences University of Cambridge
Dr Sarah Webb	Assistant Director, Knowledge Transfer Department of Trade and Industry

Programme Review Committee

Mr Philip Ruffles	Chairman, CMI PRC Rolls-Royce, formerly
Sir David Durie	Department of Trade and Technology, formerly
Dr Ray Leopold	Motorola, formerly

Appendix V: Governance as at September 2006

Professor Mary Ritter	Pro-Rector, Postgraduate Affairs Imperial College London
Professor Sherri Sheppard	Stanford University
Professor Edward Crawley	Executive Director CMI, Massachusetts Institute of Technology
Professor Michael Gregory	Executive Director CMI, University of Cambridge

Audit Committee

Professor Ann Dowling	Professor of Mechanical Engineering University of Cambridge
Mr Andrew Reid	Director of Finance University of Cambridge
Mr James Morgan	Financial Controller Massachusetts Institute of Technology
Professor Phillip Clay	Chancellor Massachusetts Institute of Technology

Previous CMI Executive Directors

Professor Michael Kelly	CMI, University of Cambridge 2003-2005
Dr David Livesey	CMI, University of Cambridge 1999-2000
Professor John Vander Sande	CMI, MIT 2000-2003
Professor Alan Windle	CMI, University of Cambridge 2000-2003

Founding Academic Directors

Dr David A Good	CMI, University of Cambridge
Professor Alan Hughes	CMI, University of Cambridge
Mr Michael Kitson	CMI, University of Cambridge
Professor J David Litster	CMI, Massachusetts Institute of Technology
Dr William A Lucas	CMI, Massachusetts Institute of Technology
Professor Nick Oliver	CMI, University of Cambridge
Professor Ekhard Salje	CMI, University of Cambridge
Professor Michael Scott Morton	CMI, Massachusetts Institute of Technology
Professor Robert P Redwine	CMI, Massachusetts Institute of Technology
Professor Daniel Roos	CMI, Massachusetts Institute of Technology

CMI Staff

The CMI staff team, full-time and part-time at Cambridge and MIT, provided tremendous support to the activity across the whole range of programme management, events, communication, finance and administration.

E. Acworth, R. Albutt, H. Aldridge, J. Bannerman, M. Barton, M. Bell, L.Breede, S. Carroll, Y. Chua, K. L. Cofield, E. Cooper, P. Coppham, G.Cosier, J. Croghan, N. Crosby, J. Damant, V. de Juan, P. de Mas, C. Dennis,K. Durand, L. Edwards, M. Enders, A. Foley, S. Ghose, M. Giordono, N.Goodman, L. Grantham, S.Greenwald, T. Gritton, C. Hall, N. Hickinson, M. L.Holland, J. Jacobs, S. Jamieson, P. Kattuman, J. Keller, L. King, R.Langley, R. Lee, S. Lisanti, K. Longworth, E. Mace, L. Mansfield, A.Marshall, N. Mayerhofer Bell, D. McGowan, T. McKinley, C. Middleton, A.Mitchell, A. Mokady, T. Moran, K. Morley, K. Morse, M. Nazombe, X. Ngazimbi, R. Nicol, C. O'Neill, J. Ouchikh, J. Palmer, J. Patman, T. Payne, M. Phenna, R. Robins, N. Robinson, T. Roukaerts, E. Sahlstrom, S. Samarawickrama, K.Schuldt, M. Sharpe, K. Sherwood, J. Shumaker, S. Shurtleff, G.Sigurjonsdottir, R. Simpson, B. Smith, J. Straggas, D. Strother, M. van Leeuwen, J. Wallace, R. Wallach, R. Weichman, C. Williams and N. Williamson.