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University–industry engagement: The formation of the Knowledge Integration Community (KIC) model at the Cambridge-MIT Institute

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ABSTRACT

Many countries are seeking to strengthen global economic competitiveness by building a 'knowledge economy' capability. A popular approach is supporting university–industry knowledge exchange linkages. The purpose of this paper is to show how a model developed by the Cambridge-MIT Institute (CMI) for the UK offers a more effective approach to knowledge sharing, and to present the results from one of the first projects launched by CMI. CMI looked at the background literature and relevant government policy, benchmarked peer grant-making organisations, studied the Massachusetts Institute of Technology and Cambridge University institutions, and organized expert consultation through a strategic planning process including 27 stakeholder groups. Based on these inputs, CMI formulated its Knowledge Integration Community (KIC) model hypothesis. This paper describes the functional components, support mechanisms, organisational structure, review processes and mechanisms for knowledge exchange. Beginning in 2003, CMI built seven experimental KICs: five completely new, and two built up from existing, more traditional research projects. One of these is the Silent Aircraft KIC, which is presented as a case study. The paper makes an early analysis of the outcomes and additionalities of the KIC, and presents the lessons and future implications for the KIC. The paper concludes by describing the broader relevance of this approach for other institutions and countries, and suggests it is something other university-, government- and industry-based research institutions could embark upon.

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1. Introduction

The intensifying technology race is compelling countries to search for more effective ways of harnessing research done in elite institutions for commercial purposes. The Massachusetts Institute of Technology (MIT) has proven to be remarkably successful in collaborating with industry and in developing a two-way flow of knowledge that helps to guide and augment university-based research and also facilitates the flow of technology, codified as well as tacit, from the university to the business sector. In order to refine the MIT approach and to transplant it to the UK, the British government in 2000 created the Cambridge-MIT Institute (CMI) and is using it as a vehicle to launch a Knowledge Integration Community (KIC) model to enhance the fruitfulness of university–industry links (UILs). The purpose of this paper is to show how the KIC model offers a comprehensive and effective approach to knowledge sharing and to present the results from one of the first projects launched by CMI.

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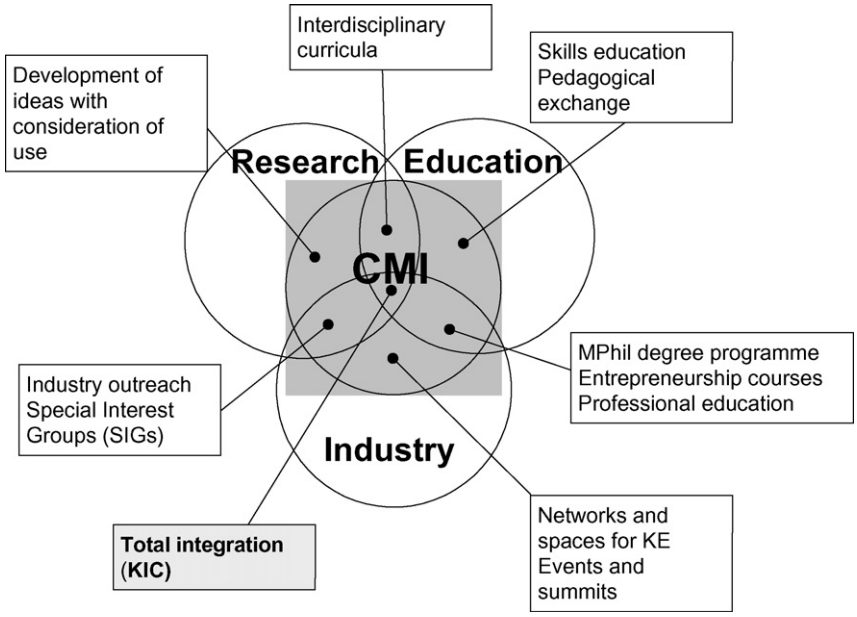

Fig. 1. CMI unites research, education and industry stakeholders in the economy through bold new initiatives in knowledge exchange (KE).

CMI was established in 2000 by the UK government to develop and implement innovative approaches for knowledge exchange (KE)[1] between the academic and industry sectors, thereby fulfilling its mission of enhancing competitiveness, productivity and entrepreneurship. It is an alliance between Cambridge University and MIT, which was funded with a grant of £65.1 m from Her Majesty's Treasury (HM Treasury or HMT), plus £16 m in additional funding from the UK private sector. The initial grant from HM Treasury was managed by the Department of Trade and Industry (now the Department for Business, Enterprise and Regulatory Reform).

The multidirectional process referred to herein as 'knowledge exchange', which goes beyond traditional, unidirectional 'knowledge transfer' from academia to industry, lies at the core of the CMI mission. This multidirectional approach differentiates CMI from other organisations such as Research Councils and DTI initiatives that focus on one-way outbound technology transfer. In seeking to achieve its goal of creating and implementing innovative approaches to knowledge exchange, CMI is supported by Government to operate at the centre of an alliance of stakeholders from the Research, Education and Industry communities (see Fig. 1).

To achieve its major objective of embedding knowledge exchange into its activities, CMI is working with novel approaches for enabling knowledge exchange among the research, education, industrial and government sectors. The KIC model, discussed in this paper, is the most mature iteration of CMI's approach. These collaborative entities, comprising academic researchers and educators, industry participants and government policy makers, are brought together to identify and pursue joint solutions to common problems. These disparate groups, who would normally not have a common basis for interaction, collaborate under the platform of a KIC to develop a comprehensive and multi-faceted solution addressing technological, economic and social issues. Other current CMI initiatives include specific education, commercialization, industry, regional and other projects. These activities are beyond the scope of this paper and are not addressed, except where they contribute to the KIC model.

Because the model we present here is conceptually intricate, our focus is on presenting a concrete example of how it works – a realistic perspective on CMI's experiment – rather than an all-encompassing study or a procedural manual for knowledge exchange. We have chosen to look hard at the formation and management processes rather than at numerous other issues surrounding university–industry interaction, such as intellectual property (IP) ownership and exploitation. This choice mirrors the focus of the interdisciplinary team at the time the model was created. CMI chose to let IP ownership and licensing be handled at the university level rather than setting up an alternate mechanism. We acknowledge the impacts of recent changes in UK law governing ownership of university-derived IP as an additional variable in our model, but for the present have left its study to others.

We illustrate the model with a modified case study that shows one example of its implementation: the Silent Aircraft Initiative (SAI). Our focus here is on the formation and start-up phase; when we gathered our data, the project had by no means reached a steady state. In subsequent studies we plan to present data on the full project lifecycle, and to that end CMI is gathering comprehensive survey data on

[1] CMI defines knowledge exchange as a two-way flow of information, primarily between academia and industry, in which the problems and market needs of the latter are the basis for defining the goals of research for the former. The fruits of this research are fed back in the form of solutions that can be implemented for the benefit of industry and the economy in general.

a semi-annual basis that allows it to monitor this experiment on multiple levels, to evaluate its outcomes, and to optimise the model's efficacy for future iterations.

2. Background

2.1. Literature review

MIT has a long-standing orientation towards the business community and has over time forged the culture of an entrepreneurial university which emphasizes patenting, licensing and other multistranded links with firms (Etzkowitz, 1994). The university has successfully created a 'permeable' organisation allowing companies to interact with faculty. It is argued that this was the result of unplanned bottom-up political and economic forces (Lecuyer, 1998); however, it arose from a complex inter-related system including a resource base, faculty, supporting organisational mechanisms and policies and culture, all within a reinforcing historical context and a local regional environment (O'Shea et al., 2007). More recently, MIT has come to exemplify the university's contribution to regional economic competitiveness not only through education and research but also through knowledge transfer (Etzkowitz, 2002; Etzkowitz and Klofsten, 2005; BankBoston, 1997).

The increase in such university technology transfer in the last two decades and the process through which it is occurring is beginning to attract greater attention (Mowery and Shane, 2002). While there are a number of factors influencing the success of technology transfer from universities, intermediary functions are cited as having an important role—in particular, the role of intermediaries in facilitating links between universities and the potential users of knowledge, notably, commercial firms. Howells has provided perhaps the most recent comprehensive literature review on intermediaries and their specific roles and functions (Howells, 2006), while Gill and co-workers provide excellent case studies of intermediary factors in the US and Israel contexts (Gill et al., 2000, 2002).

The key intermediary elements identified from the literature that are of relevance for the CMI-KIC case are described below.

2.1.1. Scale

O'Shea et al. (2005) describe factors that contribute to university commercialization activity, mostly related to the scale of the university system. The larger and more established the university in terms of experience, staff, finances and research funding, the greater the likely number of spin-outs. Other studies describe some of the same factors, and add the availability of venture capital (Di Gregorio and Shane, 2003; Wright et al., 2006). Lecuyer (2005) cites industry collaboration and commercialization as a guiding force of significance comparable to government military research and development (R&D) funding.

2.1.2. Scanning, convening, introductions

In addition to scale, the propensity of firms to *search*, *screen* and *signal* correlate with increased university–industry interaction (Fontana et al., 2006). However, the fruitfulness of such interaction can be enhanced by convening diverse groups to stimulate interdisciplinary collaboration and knowledge exchange and also by the efforts of intermediaries to actively managing knowledge flows through heterogeneous networks (Aldrich and von Glinow, 1992; Callon, 1994).

2.1.3. Contractual and financial frameworks

Lecuyer, the eminent Stanford technology historian, who has studied university–industry collaboration around the Silicon Valley region, asserts that keys to success include both the social factors – unhierarchical social structures, breakaway teams, irreverence – as well as the financial ones—patent-management strategies, financing, 'entrepreneurial' corporatism and stock option ownership (Lecuyer, 2006). To this should be added the functions of identifying and attracting potential partners, and supporting the contractual, intellectual property and financial arrangements, all of which help build the intermediating conduits through which knowledge can be channelled from universities to businesses (Watkins and Horley, 1986).

2.1.4. Innovation partnerships

The innovation partnerships recommended by Roberts (2002) can also boost research collaboration between universities and businesses. In order for such partnerships to congeal: research needed to be business-led and focused on commercially oriented R&D; the partnerships based on clusters of businesses with particular research interests, either nationally or regionally; the government to invest in each partnership alongside the primary funders (business and higher education and RDAs); partnerships to be virtual or to have a physical centre, depending on the nature of the research and the participants in the partnership; for each partnership needed to have an explicit core aim of prioritising skills training for SET students and graduates, building a critical mass of SET students and graduates with experience in commercial research and development, and encouraging the interchange of people and technology between business and academia.[2]

The KIC model stimulates an effective transfer of knowledge by incorporating these above factors. Further, in order to facilitate the utilization of research outputs to promote economic growth and societal benefit, CMI has chosen to focus on initiatives with "a consideration of use". Research with a "consideration of use" is application-driven, but no less fundamental in its scholarly impact. It aims to develop important products and viable solutions that benefit society and contribute to the economy's competitiveness.[3]

Also, the KIC model embodies Roberts' suggestion that a partnership can be virtual, rather than based in a physical centre. With principal investigators (PIs) located at universities on each side of the Atlantic, and industrial par-

[2] These governing principles for innovation partnerships or innovation communities as Lynn et al. (1996) label them are in line with criteria of accessibility, mobility and receptivity defined by Seaton and Cordey-Hayes (1993).

[3] This concept, known as Pasteur's Quadrant, is described at length in Stokes' (1996) work of the same title.

ticipants working from various sites, it is a departure from the equation of proximity and innovation epitomized on a large scale by California's Silicon Valley, the Route 128 high-tech zone in Massachusetts, Cambridge's 'Silicon Fen', and Scotland's 'Silicon Glen', and seen on a smaller level in 'technology parks' and 'campuses' of individual companies. These setups are often reminiscent of university research facilities.

2.2. Benchmark study

CMI's models are considered to be bold and innovative experiments in knowledge exchange. Towards this end, CMI's KIC model is expected to have elements that are unique from other organisations and initiatives that operate in the broader remit of research funding and programme management.

To baseline CMI activities, a benchmark study was conducted to identify areas of uniqueness as well as common ground with a set of UK organisations. The initial study set comprised six UK-based organisations and initiatives, in addition to CMI itself. These were shortlisted from a larger group by identifying those that had a broad fit with CMI's scope and mission. The overall study set can broadly be divided into two subsets: The first subset is Research Councils and foundations with a specific mission for funding academic research—this subset included the Engineering and Physical Sciences Research Council (EPSRC), the Biotechnology and Biological Sciences Research Council (BBSRC) and the Foresight Programme and the Wellcome Trust. The second subset is government initiatives (including funding) with a primary objective of bringing university and industry together on research problems—this subset included the Faraday Partnerships and the Knowledge Transfer Partnerships (KTPs).

All six of these organisations are actively engaged in some or all of CMI's key functional areas including funding, programme management, knowledge exchange and technology transfer. Table 1 gives a summary of the key features of the organisations included in this study. This study set has been added to as more organisations have been identified with common themes and missions to CMI.

The Research Councils' and foundations' primary activity is to support research projects through grants. They are responsible for creating and sustaining research programmes, largely at academic institutions. The KTPs and the Faraday Partnerships are fundamentally different from the Research Councils in that they are initiatives, both from the DTI, and therefore do not fund research projects themselves. For financial support, they turn to Research Councils and other public agencies. They are designed to facilitate knowledge transfer from the academic research base to industry for solutions to specific problems faced by companies in any industrial sectors. They act as network agents to bring together academic and industry groups who are then able to seek funding for their collaborative projects from Research Councils and other agencies. Upstream from the funding process, the initiatives often play a visible role in the management of the project once they have been launched.

KTP projects tend to be focussed on one-to-one engagements between university research groups and industry, with particularly high involvement from the SME sector. Funding for the KTPs comes directly from the DTI who review all KTP grant applications. Sponsors of the DTI's KTP programme include various Research Councils.

The Faraday Partnerships have a broadly similar scope to the KTP, but are larger in terms of partnership size, strategic scope and duration of the partnership. A partnership will typically involve a number of members from academia and industry in which a core group is involved in the initial proposal and overall management. The impetus to create the Faraday Partnerships came in response to a specific call made by the DTI in 1997, followed by a second one in 2003, with a specific provision for start-up costs of £1.2 m over a 3-year period.

Although the organisations in the study set have broad similarities with CMI's mission and functions, there are also some clear differentiating characteristics among them with respect to the level of engagement at each stage. For example, Research Councils whose remit is largely for funding academic research projects have more engagement in the early phase of a project lifecycle whilst in initiatives like the Faraday Partnerships, programme management activities (mid- to late-phase) are also significant.

The apparent differences between the organisations are aligned with their relative involvement in three main areas of activity, namely support during preparation of the proposal, project funding and project management. The funding bodies (Research Councils and the Wellcome Trust) are fully involved in the project funding process and play a very small role in supporting proposal preparation or management of launched projects. The two initiatives, the Faraday Partnerships and the KTPs, play a much more active role in the pre- and post-funding stages.

2.3. Stakeholder consultation

We studied MIT's and CU's organisation and management of research, multidisciplinary projects, multi-institution collaboration and university–industry collaborations and organized expert consultation through the strategic planning process including 27 leading stakeholder groups. The first phase of this strategic planning process was devoted to stakeholder identification—essential if CMI were to be responsive to broader social needs. CMI identified and contacted a total of 27 stakeholder groups via interviews and correspondence. Next, 30 individuals, representing all stakeholder groups, worked out the initial architecture of the KIC model at a 2-day offsite conference in early 2003. Although the studies cited above were inputs to the group's deliberations, the most direct precedents for the KIC model were the immediate, informal contributions of the experts present at the conference—"vision statements" and lively dialogue (Acworth et al., 2004).

2.4. Assessment

Perhaps the most distinctive aspect of CMI's approach to knowledge exchange is that it is grounded in rigorous scientific method. Using analytical and investigatory

Table 1
The study set of organisations included in the study for benchmarking the CMI with related UK organisations and initiatives

Organisation	Description	Scope and size
CMI	UK government initiative funded by HM Treasury in 2000 to create and implement novel mechanism for knowledge exchange primarily between academia and industry to enhance UK competitiveness and productivity	Founded in 2000 with a 5-year remit £65 m funding from DTI over 5 years Mission to implement knowledge exchange activities
EPSRC	The Engineering and Physical Sciences Research Council (EPSRC) is the UK government's leading funding agency for research and training in engineering and the physical sciences	Invest primarily though universities in science and engineering Investment of ca. £500 m per year Supports research projects, fellowships, platform grants and special calls
BBSRC	The Biotechnology and Biological Sciences is the UK's principal funding body for basic, strategic and applied research related to biological systems	Ca. £200 m funding per year for the biological sciences Largely funds university research LINK programme for promoting university–industry collaboration
Wellcome Trust	The Wellcome Trust is an independent charity funding research with the aim of improving human and animal health	Largest charity supporting biomedical research Funded ca. £400 m per year Funding includes research grants and fellowships
Faraday Partnerships	The Faraday Partnership is an alliance of organisations and institutions dedicated to the improvement of the competitiveness of UK industry through research, development and knowledge transfer and exploitation of science and technology	Founded in 1994 Organisations of 5 and 5000 Largely a consultancy
KTP	Knowledge Transfer Partnerships are collaborative engagements between academia and industry funded by the DTI to facilitate the transfer of knowledge between the partners	Established in 1975 Part funded by government Approximately 1000 partnerships per year

methods derived from science, CMI views each of its initiatives as an experiment. CMI's 'experiments' focus mainly on the human drivers of knowledge exchange: communities and cultures that encourage individuals to participate in knowledge exchange and teach them how to function as knowledge exchange agents, and the processes that enable these interactions.

Studying the process of how knowledge exchange encourages innovation, and codifying and disseminating the outcomes of each experiment, are also central to the CMI mission. In seeking to develop multiple metrics for evaluating these outcomes, CMI hopes to go beyond traditional patent output or bibliometric statistics, often used as a proxy for evaluating the quality of science produced by a nation or other entity. There are two traditional variables: (1) number of original publications and (2) number of citations of those publications. Citation frequency indicates 'quality' as perceived by other members of the scientific community.[4]

According to a DTI (2001) report, "while objective metrics such as scientific papers and citations point to the high quality of academic science in the UK, higher education institutions (HEIs) have historically shown weak commercial awareness. HEI/business interaction has improved to some extent in recent years; more HEIs are undertaking collaborative research, establishing business networks, running courses for industry, developing incubation, spinning off companies and paying increased attention to the skills needs of business. The HEI/business interface can only operate effectively for the diffusion, transfer and exploitation of knowledge and know-how, where both partners are willing and able to interact. The challenge for public policy is, therefore, to create an environment where business and HEIs are able to forge links with each other, often with the participation of intermediaries. However, nearly all the major industrial countries are concerned to improve the interface between HEIs and industry. . .. [T]there is no evidence that UK HEIs are less well orientated towards industry than the majority of their foreign counterparts. A more important problem is the lack of ability of UK industry to exploit the results of scientific research" (p. 9).[5]

The KIC model, as noted above, had its genesis in a wide-scale brainstorming and strategy process near the midpoint of CMI's first funding cycle. The government had provided a high-level brief in originally defining CMI's mission; it

[4] The US easily heads the list of nations in the volume of publications and citations. The United Kingdom is second, with about 11.6% of citations as of 2001 (Porter, 2003; King, 2004).

[5] "UK innovation performance: strengths, weaknesses, opportunities, threats and main problems" (Department of Trade and Industry [DTI], 2001).

was up to CMI to determine how that brief could best be implemented over the next 3 years.

3. The model: CMI's Knowledge Integration Communities

Investing in Innovation, a white paper published by HMT shortly before the midpoint in CMI's history, noted: CMI is now starting to deliver tangible benefits to UK research and business. Although funded separately from the entrepreneurship activities developed in Science Enterprise Centres, the CMI is increasingly integrated into this UK network to deliver wider benefits beyond the Cambridge-MIT axis. The Government as a major investor (with business co-finance) will continue to require substantial dividends in the form of enterprise education and research for the UK in return for continued backing over the remaining 3 years of the funding period (HMT, 2002, p.73).

During the years immediately after CMI's launch, about 35 research projects and an approximately equal number of non-research projects were funded to run as primarily collaborations between groups at Cambridge University and MIT. These largely did not involve external stakeholder collaborations or purport to explore theoretical aspects of knowledge exchange but did feed into the eventual development of the KIC model.

Each KIC addresses a 'grand challenge' in science or technology, which defines its overarching purpose. To maximize its economic and societal impact, the solution must have a "consideration of use" (be application driven). Initial round funding is comprehensive enough to enable significant initiatives to be launched that include participants from multiple backgrounds and disciplines. To reach scale, usually requires £1–2 m per annum at a minimum. Each KIC has the potential to drive economic growth not only at the company level but also industry-wide. A KIC's goal is often a research-based solution; therefore, the main stakeholder groups of the present KICs are its academic and industry participants. A KIC's research activities are usually its most active component and receive the largest share of the budget (see Fig. 2).

CMI's decision to pursue a smaller set of grand-scale projects – projects with the potential for "substantial dividends" – drove the development of the KIC model. The class of project appropriate for funding through KICs was considerably narrower than those funded in the first stage. In assessing and scoring funding proposals, CMI applies a set of objective metrics to determine which projects are good candidates for inclusion in a KIC but also makes a qualitative analysis of the 'fit' of individual proposals into a broader group. The KIC model is suitable for initiatives with a strong cross-disciplinary flavour, and/or those that require multiple types of inputs. For example, economic studies as well as materials tests have been integral for the Silent Aircraft KIC. Also, a KIC typically consists of several related problems – and seeks several solutions – around a common theme.

Government policy-makers and special interest groups are secondary but important stakeholders because, for each KIC, inputs extend far beyond technical research: social impact; economic benefits; policy issues will also be relevant to and reflected in the KIC's activities. Within each project, knowledge exchange activities and the evaluation of knowledge exchange processes are considered to be outcomes just as important to the KIC's work as its substantive research outcomes.

The advantage of the KIC model over traditional funding mechanisms is that it gives researchers access to a broader range of inputs than is possible in traditional research at the university level. CMI chose this model over other forms of economic intermediation because it allows a team-based, multidisciplinary and multidirectional approach that goes beyond the standard knowledge transfer model used by university technology transfer offices. In 'classic' knowledge transfer, university research outputs move unidirectionally into the industrial sector. By contrast, a KIC brings together a broader range of inputs and a diverse group of people who may not naturally have a common platform for interaction. Through its members it embodies multiple elements of the knowledge creation and trans-

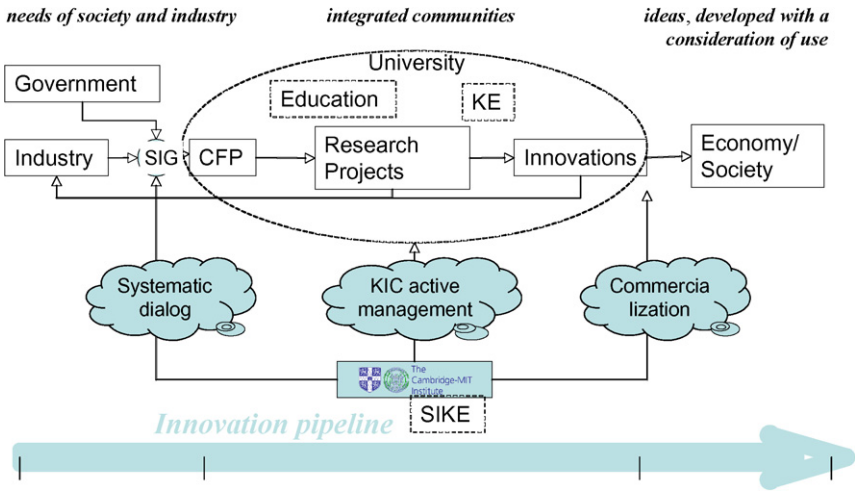

Fig. 2. A Knowledge Integration Community (KIC) is a mechanism CMI uses to support disparate groups by bringing them together to address a range of issues. The result: new knowledge and new relationships that enhance economic competitiveness.

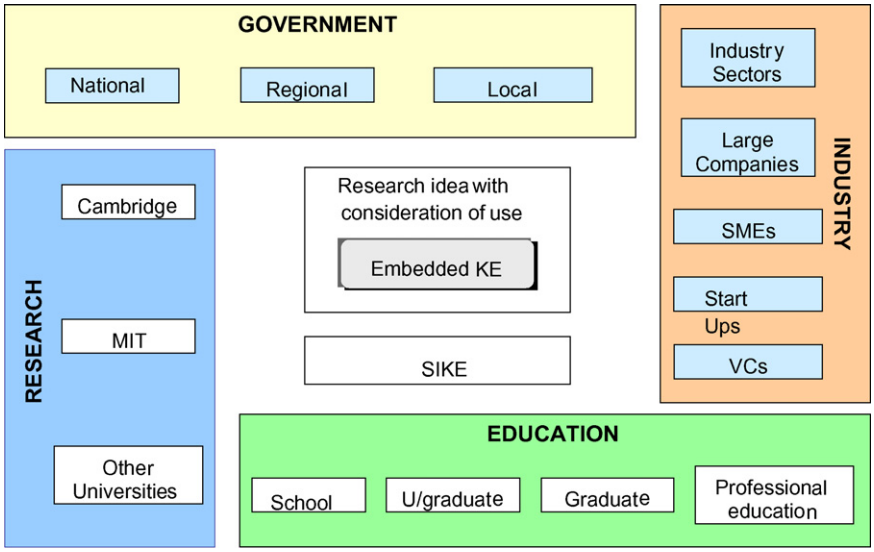

Fig. 3. The six-component model of a Knowledge Integration Community brings together four institutional sectors (Industry, Government, Research and Education) through two binding mechanisms: knowledge exchange (KE) and the study of innovations in knowledge exchange (SIKE).

fer process, including education, research and knowledge transfer. CMI hopes that the integration of a range of inputs around an application-driven idea or technology use will broaden each KIC's access to working capital for its future activities. There are currently five KICs in operation. They include the Silent Aircraft Initiative, Next Generation Drug Discovery (NGDD), Pervasive Computing, Communications Innovation Institute (CII) and the Centre for Competitiveness and Innovation (CCI). All five arose from the CMI's call for proposals in 2003. Although they vary in their topical focus, they share functional similarities related to their knowledge exchange activities.

3.1. Key components of the KIC model

A KIC has six components (see Fig. 3). Of these, four are human groups from key institutional sectors: research universities, industry, government and education.[6] These four groups are involved with planning and delivery of the KIC objectives. In addition, the model incorporates two concept-based components: knowledge exchange and the study of innovations in knowledge exchange (SIKE).

3.1.1. University research

University researchers are a key group in a KIC's organisational structure and generally lead its research activities, although the KIC strives for significant input from the industrial partners. While the present KICs are largely based on collaborations between Cambridge University and MIT, other universities are participating where they can contribute to and benefit from the programme. In fact there's no reason that a KIC could not be centred at any research institution or set of institutions—academic, industrial or government.

[6] For purposes of this discussion, "education" excludes university research.

Under the revisions made to CMI's strategy in 2003, each scientific research proposal is required to be collaborative and multidisciplinary, and place strong emphasis on the consideration of use. In line with the CMI mission, the research proposal must also identify its potential to have a competitive impact on the UK economy through the transformation and improvement of business at the company and/or industry level.

3.1.2. Industry

Each KIC must have a strong element of industry participation. CMI anticipates that industry will provide useful input to the definition of the KIC's research problem so that the KIC can develop solutions that are well aligned with industry needs. Further, KICs must demonstrate a high level of engagement with industry that provides for the development of a network of university–industry relationships to enable effective knowledge exchange.

A KIC can involve any industry sector – existing, newly created or future – where the sector has the promise of global leadership. The current KICs operate in key competitive sectors: aeronautics, biotechnology, communications, innovation management and computing.

In addition to sector representation, CMI tries to engage participation from all sizes and types of businesses, from large established corporations to small and medium enterprises (SMEs) and start-ups. CMI's focus so far has been on larger corporations, with a view of creating high-impact relationships early in the programme. CMI anticipates that in the future, the level of industry participation will vary among individual KICs, ranging from an individual company interested in using research outcomes to address a specific technical problem, to an entire industry or economic sector whose focus is on global business functions of organisations, such as supply chain management.

3.1.3. Government

Part of the KICs remit is that they should serve as models and sources of lessons learned for the UK government. They should, therefore, be able to identify mechanisms for engaging with various organisations and networks in the private and non-profit sectors, with the goal of promoting competitiveness, productivity and entrepreneurship. Furthermore, the KICs are charged with creating opportunities for public education and training programmes in collaboration with public bodies.

Public-sector participants can offer guidance on how the KIC's efforts can be integrated into the broader context of economic development for public benefit, and can enhance those efforts by crafting responsive new policy. These participants may include representatives of the national and devolved governments as well as regional development agencies (RDAs) and other public initiatives. Involvement of government agencies and regional groups is particularly important where there is a significant need for input on matters relating to policy and regulation.

3.1.4. Education

A KIC's education component empowers students to engage in effective knowledge exchange activities at both the theoretical and practical level. While a KIC's major activities will focus on the undergraduate and postgraduate levels, the remit extends to learners at all levels, including for example schoolchildren, mature students and professionals. Another objective is to involve undergraduates, postgraduates and postdoctoral researchers in research projects that have a defined consideration of use.

Delivery of this component is through team-based interdisciplinary educational programmes that foster innovation through experiential learning in the context of KIC projects. These can include, for example, postgraduate degree programmes with a strong practice component, programmes for educating and training technology entrepreneurs, or short courses and workshops that engage industry professionals more closely with university activities.

While CMI's priority is to support the research activity of each KIC with a broader set of educational activities, it also welcomes proposals in other topic areas that align with CMI's strategy for enhancing knowledge exchange at the university–industry interface. Each proposal should include a scheme for continued support of its educational activities beyond the CMI funding period from external sources.

3.1.5. Knowledge exchange

Knowledge exchange is one of the two theoretical components in the KIC model. It is the central theme that ties the four human components together. It also lies at the core of the CMI mission and is a key differentiator of CMI from other organisations such as research funding councils and DTI initiatives. As described earlier, CMI stresses the multidirectional aspect of its knowledge exchange activities and distinguishes this from more traditional 'knowledge transfer', that implies a unidirectional flow.

Knowledge exchange is affected by the incorporation of numerous specific mechanisms within the KIC. For example, annual and semi-annual workshops including participants from all stakeholder groups (not just academics), personnel exchanges, web spaces and e-newsletters, videoconferencing, professional communications and PR, formal business development programs, etc.

The benefit of knowledge exchange is nicely summarised by the following statements from the US Council on Competitiveness (1998): "Partnerships matter. Interconnectedness is one of the keys to competitiveness in the knowledge-based economy. The nation which fosters an infrastructure of linkages among and between firms, universities and government gains competitive advantage through quicker information diffusion and product deployment. Partnerships enable faster rates of learning" (p. 14).

3.1.6. Study of innovation in knowledge exchange

The sixth component is the scholarly assessment and study of the KICs to generate new and innovative ideas for facilitating knowledge exchange. This allows for learning in the event of both success and failure (the 'lessons learnt' concept), and continuous improvement of the model.

The goal of this component is codification and dissemination of knowledge exchange methods within the wider community. This aligns with a core CMI objective: to develop best practice models for innovation in research, education and knowledge exchange and formally assess their effectiveness.

The SIKE component has two subcomponents of special importance: identifying how ideas or questions initiated by industry or the public sector translate into responsive research projects, and studying the process by which the outcomes of research projects translate into practical use by industry and the public sector. One project in this area which bridges to multiple KICs (SAI and CCI) is an investigation of best practices for university–industry collaboration.

Such studies are deeply integrated within the KIC programme of activities, in the form of 'instruments' for collecting data and analyzing outcomes of specific KIC policies. Data can be in quantitative form (e.g. number and quality of publications, intellectual property, etc.), and can be qualitative (e.g. social sciences-based surveys and analysis). SIKE may also be considered as a stand-alone project if a strong case is made for how that study can result in improved propagation of knowledge generation and exchange among all stakeholders of the CMI mission.

3.2. Organisational structure

Through its team of relationship managers, CMI supports KIC activities, particularly in industry outreach, external communications, positioning of a KIC Manager and overall management of each KIC programme. However, the KIC's overall management during the period of its initial funding is driven from within. As shown in Fig. 4, the top level of management comprises three individuals with equal status: two lead PIs (one each from Cambridge University and MIT) and a KIC Manager. In addition to their KIC management function, the lead PIs are also responsible for supervision of the research projects that they head, similar to their role as a PI on any research grant.

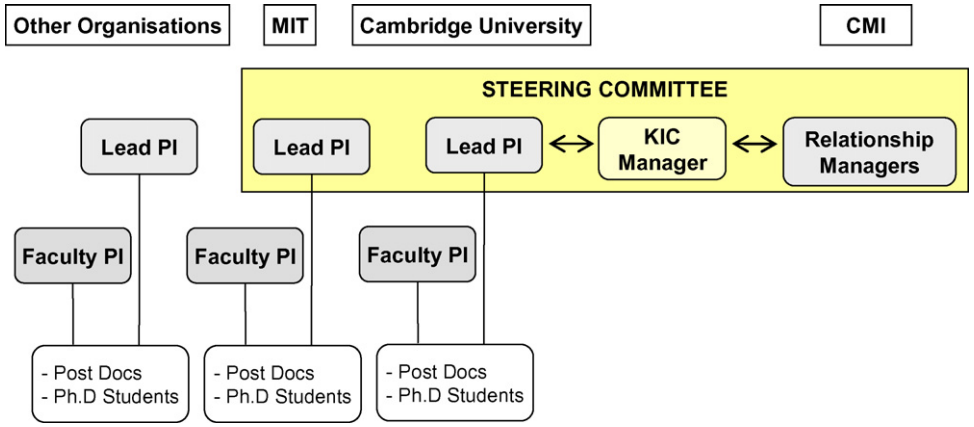

Fig. 4. The organisational structure currently implemented for existing KICs. The lead PIs and KIC Manager are the management team while the Faculty PIs and researchers are most actively engaged with research and knowledge exchange activities.

The KIC Manager is not usually expected to take on any significant responsibility as a researcher or research supervisor; his or her major task is coordinating the KIC's various activities and initiating and managing non-research elements. This individual has a key role in ensuring that the KIC maintains its focus on the core agenda of knowledge exchange and does not become too heavily focussed on its academic research activities.

At the next level are additional faculty PIs. Primarily responsible for their individual research projects, they are not generally charged with oversight functions for the KIC as a whole. Each PI has their research team, typically including postdoctoral researchers and PhD students.

Not depicted in the formal staffing structure of the KIC but critical to its mission are individuals from the other three human components (education, industry and government). These individuals are often from different levels within their respective organisations. Managing the interaction of these groups and their divergent expectations has rapidly emerged as a critical aspect of the KIC Manager role.

A KIC is not intended to be a closed-end project like those funded by most Research Council funded grants, but rather meant to develop into a long-term self-sustaining entity. The KIC Manager is expected to pursue an agenda for long-term sustainability in order to create sufficient inward investment for KIC activities from the private and public sectors.

4. The Silent Aircraft Initiative KIC

In this section we will examine the Silent Aircraft Initiative to evaluate the practical application of the KIC concept. Following CMI's 2003 call for proposals, the SAI was one of five proposals initially accepted for funding as a KIC. The SAI's stakeholders share a set of common problems related to aircraft noise. As its name suggests, the SAI's research outcomes are aimed to create a next-generation aircraft with significantly lowered noise levels.

4.1. Problem statement

While access to convenient air transport is a significant driver of economic growth on both the regional and national level, aircraft noise has historically posed a major obstacle to such growth. Local communities resist the siting of new airports near them and the expansion of the physical footprint or operating hours of existing airports. They believe that aircraft noise disrupts quality of life, making the surrounding areas undesirable places to live and work.

This problem has evaded a solution not only because of constraints of existing technology – for five decades there have been no major changes in the basic design of civil transport aircraft – but also because of its complexity. Diverse technological, human, economic and institutional interests must be identified, considered and balanced.

Advances in engineering design now raise the real possibility of using innovative low-noise strategies in aircraft and engine system design and operation.

4.2. Stakeholder identification

Stakeholders in aircraft noise are a disparate group, and include:

- The aerospace industry: not only the companies that manufacture aircraft engines (the popular culprit in aircraft noise) but also manufacturers and sellers of airframes (another key source of noise) and other aircraft components.
- Airport operators and service providers.
- Airlines: those who are currently serving the UK as well as those whose market entry is currently barred by lack of capacity at existing airports.
- University researchers in multiple disciplines: acoustics, propulsion, aerodynamics, turbomachinery, aircraft design and operations, flow control and manipulation, system identification, and advanced signal processing and diagnostic techniques and airline and regional economics. Finding appropriate expertise in all these fields means drawing on the resources of multiple departments at more than one university.
- Industry-based engineers focused on product development.

- Government agencies involved with promoting economic growth at the national, regional and local level, such as the DTI, RDAs and local authorities.
- The regulatory community, including the Department for Transport (UK), the Civil Aviation Authority (CAA) and environmental agencies.
- Non-profits and trade associations in related areas.
- Local residents and community action groups.
- Local businesses, which may experience either positive or negative impacts.

4.3. The SAI proposal

The proposal that gave rise to the SAI KIC was submitted jointly by principal investigators Dr. A.P. Dowling, Professor of Engineering at Cambridge University, and Dr. E.M. Greitzer, Professor of Aeronautics at MIT. It called for participation from 10 academic researchers primarily at Cambridge University and MIT, with input into five research areas: (1) low-noise airframe technologies, (2) low-noise engine technologies, (3) silent aircraft design/noise integration, (4) aircraft operations and (5) economics. At the preliminary stage industry participation was limited to Rolls-Royce, but the group had the specific aim of building industry and RDA engagement during the life of the project. In the final proposal submitted to CMI, there were 18 principal academic participants and additional industry collaboration from five British aviation-related companies and one regulatory body (the CAA). The total funding for the SAI KIC was £2.37 m (£1.32 m to Cambridge University and £1.05 m to MIT) divided among five research themes.

The proposal team identified three main elements that their solution would include: defining the physical limits of, and the corresponding benefits of, the "value of silence". This requires assessing the technology, the business case, the regional and national economies and the surrounding policy issues. Establishing a model for university–industry collaboration that involves the entire aviation supply chain and aims to provide new avenues for knowledge exchange. This requires educating engineers to understand the strategic context of their work and drive the knowledge exchange process. Bringing about widespread public enthusiasm for the challenges of aerospace, especially among schoolchildren, with an exciting, high-visibility project.

The SAI team's solution consisted of short-, medium- and long-range components. In the short term, aircraft noise impacts on the community would be decreased through development and implementation of new operational procedures. In the medium term, noise reduction technology would be developed for application to the engines and airframe of evolutionary aircraft designs. In the long term, a 'silent aircraft' would be introduced to the global aviation market. This revolutionary commercial transport will generate noise at levels below that of the urban environment and therefore be almost imperceptible to the surrounding community.

5. Outcomes

In this subsection we will map the four human and two theoretical bases of the KIC model to the experience of the SAI participants since 2003. These six factors are described at more length in the subsection entitled "The Model: CMI's Knowledge Integration Communities". The SAI KIC has developed all six components, and these are depicted graphically in Fig. 5.

5.1. University research

When the SAI KIC started in 2003, its research activities were more or less evenly distributed between Cambridge University and MIT over the duration of the project. Most of the researchers on the UK projects were PhD students and postdoctoral workers while MIT had a greater number of master's degree candidates. As a result the MIT team were able to start their research programme as soon as the CMI contract was received using available master's degree students, while Cambridge had a slower start because of the need to recruit. The bulk of the SAI's research has, therefore, shifted from being predominantly at MIT in the first

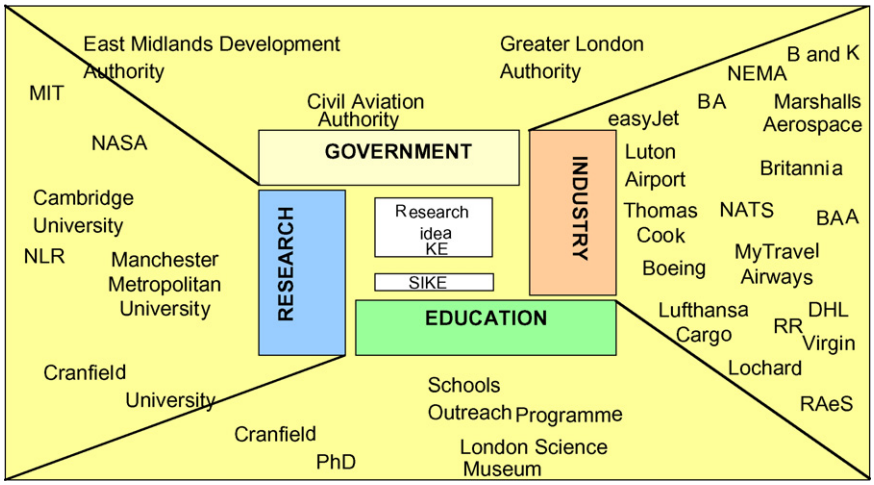

Fig. 5. A graphical representation of the Silent Aircraft KIC components and participants.

year and is sited at Cambridge now. This has led to some imbalance in the collaboration, which is recognized as an important lesson learnt.

The SAI KIC consortium was most recently strengthened by the addition of two research groups from another UK institution, Cranfield University, with significant experience in holistic aircraft design. These groups are working on projects funded by the Engineering and Physical Sciences Research Council, and entered the KIC to engage with its engineering research project and participate in knowledge exchange with its industry and government partners.

Although some of the KIC's research activities are in the technical sector, others study related economic problems. One of the projects is an airline economic analysis of a silent aircraft and another is a regional- and national-level economic study prepared in collaboration with a number of industrial partners and government agencies.

5.2. Industry

The final SAI proposal had five industry participants: Rolls-Royce, which has had a longstanding relationship with Cambridge University engineering faculty; Marshall Aerospace of Cambridge, an airport operator and a local aviation design and testing facility; National Air Traffic Services Ltd. (NATS), a recently privatised entity; British Airways (BA), where noise issues have been at the forefront of its business concerns; Cambridge Econometrics, a consultancy with experience in economic modelling. The current partnership has about 15 active members and has grown as a result of the multiple research issues that need to be addressed and the variety of stakeholder interests in the project.

So far, most of the industry contribution to the SAI has been in-kind through supplying in-house design codes, equipment and engineers' time. The SAI would like to develop enhanced Continuous Descent Approach (CDA) as a new and environmentally friendly approach to noise abatement. It will demonstrate a clear benefit for reduced noise during the landing approach. However, this research will require the use of aircraft and airport facilities during commercial operations as well as approval of new air traffic management procedures and will only be possible if there is collaboration and buy-in from all of the KIC's industry participants. Airline operators are keen to take part in such trials free of charge— a contribution that would be worth more than £100 k. Engagement of seven industry groups, involving an even larger number of partners, has been made possible by careful alignment between the research and a common near-term need of the sector.

An additional role for industry may be as a funder of the KIC's longer-range objectives, which extend well beyond the CMI grant period. The SAI is currently pursuing the possibility of developing consulting opportunities within the industrial partners as an alternative revenue channel that will support the costs associated with its research projects.

5.3. Government

The Civil Aviation Authority, which regulates air transport in the UK, joined the SAI at the second stage of the proposal process. Its active engagement played a critical role during a recent development at SAI. SAI was interested in conducting trials for the Continuous Descent Approach, a noise reduction technology. This required full buy-in from private airline companies including BA and Easy-Jet, regional airports and development agencies including Luton and Nottingham East Midlands Airports, and NATS. After a lengthy series of negotiations and discussions, a number of airlines had signed onto the trials programme for the CDA. However, SAI found that it would need to go through the full government approval process if the trials were to go forward. This was likely to cause significant problems with the participating airports for a variety of reasons, largely related to airspace changes. The problem was resolved favourably by engaging directly with the policy directorate of the CAA that had a more positive response toward the trials and was able to clarify the uncertainty and misunderstanding surrounding the approvals process and move the trials discussions back onto the SAI schedule.

5.4. Education

The SAI's solutions involve education at two levels. Schools: SAI is endeavouring to bring about widespread public enthusiasm for the challenges of aerospace, especially among schoolchildren, with an exciting, high-visibility project. Many undergraduate, graduate and postgraduate student researchers are involved in SAI. Professionals: to achieve its objectives, SAI will need to educate engineers throughout the aviation supply chain about the strategic context of SAI's work.

5.5. Knowledge exchange

A primary KE mechanism practiced at the SAI KIC are major workshops that include many stakeholders in the KIC—these events have been held every 6–12 months and have had over 100 attendees each. Another mechanism has been bilateral meetings and visits to the industrial partner sites, mostly to Rolls-Royce. Such visits result in personal interactions for the purposes of addressing specific issues of a technical nature. Other visits of a more general nature offer a 'taste' of a partner's activities in their field of expertise and have included exchange of personnel for substantial periods. The visits involve members of the industry partners' technical teams from a number of different business units. These visits now also include the teams from Cranfield and are to be opened up to the wider KIC community in the near future.

The SAI has its own website which includes information and links to the various stakeholders' work. It is updated frequently with news items, which are disseminated through a e-newsletter.

Exchanges of faculty, industry personnel and students for short (1 to a few days) and longer duration (1–3 weeks) between institutions had further assisted knowledge exchange. CMI has discovered that knowledge exchange is a 'full contact sport', and there is no substitute for people moving around and meeting face-to-face.

5.6. Study of innovations in knowledge exchange

A full, analytical examination of the SAI's SIKE component would be premature. This paper focuses on SAI's formation and early operational stage, at which point neither SAI nor CMI itself could fairly draw conclusions based on project experience. Throughout the lifecycle of the SAI KIC, CMI has been using a variety of instruments and project assessment tools to measure the SAI's innovations, including bibliometrics, a semi-annual online project data collection and assessment system, and multidisciplinary project review meetings.

On the anecdotal level, SAI have already drawn one important conclusion regarding practical operation of the KIC model: relationship management is critical, particularly in a KIC of the size and scope as the SAI. In such a context, it is particularly important to establish relationships early in the project and bring together as many participants as possible. Each KIC partner is likely to have its own agenda, and naturally they will vary widely. For example, within the SAI aircraft engine and equipment manufacturers, airlines, freight carriers, airports, regional development agencies and regulatory bodies all have their own view of priorities, making the task even more complex.

An example of the need for constant engagement and managing relationships with the various participants in the SAI KIC was brought to light during the negotiations for the CDA trials programme, discussed in Section 5.3. SAI was interested in conducting trials for the CDA. Each participant had its own agenda. These multiple agendas were effectively aligned when brought onto a common platform with the help of an industry partner to champion the cause. Having these discussions and building strong relationships took over 9 months but resulted in six airlines signing up for the trials. It then took a further 4 months to obtain agreement from other stakeholders on a viable venue for the trial.

6. Lessons learnt to date

CMI's KIC model is a unique experiment in terms of its all-encompassing structure, its international academic alliance, the participation of multiple stakeholders from research, education, industry and government, and its emphasis on knowledge exchange mechanisms and the continuous assessment and improvement of these mechanisms. The KICs had been operational for just over a year at the time data for this paper were assembled, and key lessons from their activities are only now beginning to emerge. The major issues that need to be addressed as well as some general CMI lessons are highlighted in this section.

The time, resources and expertise required to get a KIC up and running and to a steady state are not to be underestimated. Considerable effort goes into identifying appropriate challenges and research activities that can be integrated into a KIC and, subsequently, into developing activities related to the different KIC components. The dialogue with industry and government to determine themes for research needs to be constantly nurtured. CMI is already establishing the parameters for the next set of KICs and has determined that the first step in forming them will be a systematic dialogue with industry and government to determine themes for research. Engaging non-academic stakeholders before the next call for proposals is released – rather than after submission of initial responses – will ensure that research topics funded not only have a consideration of use, but are critical enough that industry will be motivated to contribute funds to make the KICs self-sustaining.

The geographical dispersion of CMI's projects poses some limitations on their performance, assessment and management. Despite the availability of advanced communication technologies, the problem of distance, that often has been shown to have a negative impact on dispersed work teams, will always remain. Although there are situations where the benefits of combining best-of-class resources from geographically disperse locations far outweighs the costs.

The information and knowledge required for the start-up stages can be adapted from the existing funding mechanisms of research councils. However, the process of including additional components for converting a set of research-only projects into a KIC is relatively new. Administrative and management resources must be made explicitly available and fenced off from the research funds. In fact, we have every reason to believe that KICs can be build around existing research grants funded from traditional sources, with the additional KIC elements costing on the order of 3–7% of the research budget.

The complexity of the SAI is a particularly good example of the difficulties faced in putting together a large collaborative effort involving a number of different groups such as airports, airlines, regional development agencies and regulatory bodies. In such collaboration, expectations can be quite different and to ensure that the expectations are well aligned, it is important to engage all the stakeholders in the group early and communicate openly with them on an ongoing basis. Timelines, deliverables schedules and cash flows are some of the most differently perceived aspects.

The inclusion of collaborative components in each KIC also takes the academic participants outside their comfort zone of research activities. The need to reach out into educational reform and connect with other universities and industries that have institutionalised knowledge exchange programmes imposes additional demands on the researchers. While the carrot – available research funding through an alternative source – is attractive, the stick – increased workload due to non-research tasks – may lead to disengagement from members of the research community. Of particular concern are those relatively short-term research-driven priorities that tend to upstage the KICs' long-term and strategic objectives. Change will be easier once the tangible benefits of KIC activities become evident. Time must be allowed for full buy-in from the various institutional and individual participants.

The role of the KIC Manager has been recognised to be very critical within the KIC organisation. S/he must act very much like an entrepreneur with great passion and initiative. The KIC Manager is the liaison between many groups and must manage the overall progress of the KIC. In order to manage the expectations of various groups, a more coherent, detailed and standard job description of the KIC Manager is crucial. To date, the importance of his

or her role in relationship management has been seriously understated. In addition to clear guidance of the job roles, the KIC manager must be given real power in the form of budget authority for at least the non-research activities. Performance incentives also need to be introduced.

The KIC manager also needs to help maintain researchers' focus on sustainability. During the early phase of the KIC programme, when CMI funding is available, the quest for additional funding has not been seen as a priority for many participants and therefore, balancing short-term objectives with long-term needs is somewhat difficult. The KIC's long-term goals often risk being delayed beyond the point where time and resources are sufficient for effective action.

Another dilemma CMI faces is how to balance the disparity between project, individual and institutional life cycles. Most of the PIs on the current KICs are tenured faculty with long-term or 'permanent' appointments at their universities. There is less job stability among administrative staff (potentially including KIC managers), degree candidates and postdoctoral students. On the industry side, increased career mobility means that a key function within a stakeholder company might be filled in sequence by two or more different individuals over the KIC's lifecycle. Funders are yet another variable. Public funding, and particularly funding at the scale of CMI's initial grant from the central government, is subject to political factors largely beyond the control of the research teams.

Interest levels of human participants are variable, and individual PIs commitment to a KIC's long-range goal may be dependent on personal priorities as well as availability of ongoing funds for the KIC.

Intellectual property assignment has been another source of lessons learnt. When designing the KIC structure, CMI elected not to create new rules for IP use and transfer. The KICs today follow IP procedures used for standard university–industry collaborations in the US, and CMI brought personnel from MIT to CU to help them modernise their technology transfer office. Since 2003, this has shown to be unsuitable for the KICs, which often have multiple participants with different agendas and are engaged in long-range strategic activities. In addition, transaction costs of following this 'traditional' model have been high. Both when sponsored research funds are coming into the university system in exchange for IP rights, and also at when new innovations are being licensed out to industry.

Information systems are a vital tool for assisting with the management process, especially for organisations as complex as KICs. KICs can be managed and actively supported through the entire lifecycle more effectively using IT systems based on Customer Resource Management (CRM) and Product Lifecycle Management (PLM) philosophies. CMI has developed its own web-based application that has reduced faculty reporting effort, systematically collected rich longitudinal data, and appears to be on course to increase output for example in the form of patents.

7. Future directions

The existing KIC programmes have now come through the start-up period and entered the development phase. The research projects are underway and the communities have grown to include many new academic and industry partners that have joined since inception. The Silent Aircraft Initiative has generated six iterations of a quiet aircraft, in addition to more short- and medium-term outputs. Key lessons from the ongoing programmes are being documented and new tasks have been identified for the near future that will help create a more robust foundation on which to build the next generation of KICs and KE activities.

At a strategic level, CMI is already looking at a refinement of the current KIC model in which the call for proposals will be preceded by active solicitation of industry input. Next-generation KICs will arise by first engaging industry to identify areas where research could contribute to a solution, and then bringing researchers on board to research and develop such solutions for implementation (see Fig. 2). This channel for KIC formation reflects CMI's mission of disseminating its models to the wider community.

CMI is working to complete the benchmarking study described earlier in this paper. The study will look at the full project lifecycle at these and other organisations and identify areas where CMI has novel and useful approaches. This will enable CMI to refine and disseminate its more innovative processes. For the purposes of internal evaluation CMI is seeking both to improve its existing assessment tool and to add additional metrics that reflect the KICs' focus on human capital and cultural change, both of which are classically very important but difficult to measure. The existing KICs have been monitored and instrumented throughout their life cycle and this data will be critical to future experimental design.

CMI believes that the creation of new KICs will be most effective and have maximum impact when the lessons learnt from the ongoing programmes can be consolidated into best practices for the new programmes. Thus, from the benchmarking exercise there will be a natural progression into a best practice study. This study will look at the key processes at CMI, with a focus on the novel and innovative ones, and it will try to identify how these processes can be improved to most effectively deliver their objectives. The best practice study will draw significantly on lessons learnt from the ongoing KICs and integrate them into new processes for more effective implementation in CMI's next-generation activities. The best practice study will also look to align processes with ISO 9000 standards so they can be more easily adopted by external organisations.

A long-term goal of CMI's knowledge exchange experiment is to broaden the scope and application of the KIC model to other UK universities and international alliances and the SME industry sector. Likewise CMI intends to familiarise Research Councils and funding bodies with the KIC model. This is an important consideration given CMI's relatively short-term remit. The significantly greater geographical reach and scope of the research funding bodies can prove an attractive and effective channel for dissemination of CMI's strategy.

As befitting "grand and overarching schemes", each KIC has long-range objectives that will not be attained during the current funding cycle. For example, the education-sector aspect of a knowledge exchange initiative may not

bear fruit until the current generation of schoolchildren moves into the workforce, or (at the soonest) enter university or career training programmes. Therefore, one ongoing challenge is how each KIC can become self-sustaining after the initial funding period. In the traditional model of knowledge transfer, funded research becomes self-sustaining by engendering a spin-off company or a licence. Licences and spin-offs may come out of a KIC, but probably will not be lucrative enough in the short or medium term to support the full range of the KIC's activity.

One area that requires more detailed consideration is intellectual property. Many participants have identified significant issues with regard to ownership and licensing of the IP produced by the KIC's research projects. Within the KIC scenario, IP is a high priority item that needs to be flagged early in the process to ensure full visibility of the issue to all groups involved. Once the UK's new laws governing university-generated IP ownership and licensing have been more extensively interpreted and implemented, CMI will rethink the IP transfer issues arising from the KIC model.

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