Research Interactions Between University and Industry in Computer Science in the United States and United Kingdom

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ABSTRACT

Title : Research Interactions Between Universities and Industry in Computer Science in the United States and United Kingdom.

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Summary:

The academic discipline of computer science owes its existence to the industrial development of computer technology; the computer industry owes its existence to work undertaken by academic researchers. Close links have always existed between the two, and ideas, equipment and personnel have flowed between them.

The funding of academic research by industry, and the 'exploitation' of research results by universities, are now the subject of more interest and activity than ever before. This report examines the current state of relations between universities and industry in computer science, with particular reference to the characteristics of different kinds of formal and informal relationship, such as research sponsorship, consultancy agreements and technology licensing, and the advantages and disadvantages which each potentially offers to participants. Considerable attention is paid to the special characteristics of computer technology, computer science research and the computer industry which make certain kinds of interaction more productive and widespread than others.

Polices regarding ownership of intellectual property, the establishment of start-up companies and other controversial topics are examined. The role of personal relationships and tacit knowledge is scrutinised, as are the different roles given to formal university bodies in regulating what are essentially relationships between individuals. Where significant, differences between observed activities in the UK and US are analysed.

Primary source material is a series of 27 in depth interviews undertaken with a range of professionals working in university departments and research teams, central university offices and corporate managerial capacities in both the US and UK. These are supplemented by references to a range of research literature and by a concise account of the historical and political background to current patterns of research support.

Thanks to : All the interviewees, my supervisor Richard Girodano, Suzi Howe at Brown, John Leech at MIT, Henry Lowendorf at Yale, AUTM, Jeff Butler at the Business School, Simon Ritchie at BT and Andy & Mark, my long suffering proof readers. Also to ICL for sponsorship through out my degree programme.

Special Thanks to Chris Batty and the **Royal Academy of Engineering** who made this work possible with a bursary to meet the costs of visiting the US and by providing further support for travel within the UK. Also to the **Blau-Shane family** for hospitality above and beyond the call of duty.

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1. INTRODUCTION

This report is based on work undertaken between August 1994 and May 1995 to investigate the current state of research relationships between universities and industry in the field of computer science. It is a slightly revised version of a project report used to satisfy requirements for the degree of M.Eng. in Systems Integration within the computer science department of the University of Manchester.

The most important input to the report is a series of 27 in-depth interviews with those, in both the UK and US, whose work has given them extensive personal experience of a range of different forms of research interaction, particularly sponsored research, consultancy and technology transfer.[1] Participants included a diverse mix of corporate managers, prominent university researchers and departmental heads and the staff of central university offices responsible for interactions of different kinds with industry. Organisations participating included some of the best known in their fields, amongst them MIT, IBM, Cambridge University, Harvard University, Xerox and Yale University.

The diversity of the perspectives given by this material provides an insight into the way in which different parties perceive the same issues and activities. It also results in a wide-ranging survey of the different forms such relationships can take, and the ways in which different universities have dealt with the issues involved. Including in the sample two rather different countries allows an examination of similarities as well as differences between their respective approaches.

These interviews have been supplemented by a considerable number of other sources. As well as written material produced by participant organisations, changing government policy towards research funding and technology transfer in the two countries is summarised, as are historical and legal frameworks within which patterns of research interaction have developed. A wealth of research on science and technology is used to place in context and to support and develop my arguments. However, the interview findings retain their primary importance - other material is introduced to support their analysis rather than vice versa.

1.1 IMPORTANCE OF THE TOPIC

During the fifty year history of the digital computer, academic researchers have played key roles in the many of the most important chapters of its evolution. The first digital computers were constructed at universities, and concepts vital to the design of every modern computer - such as operating systems, time-sharing virtual memory and high level languages were originated and pioneered within universities.

There are also numerous examples of technologies which, although originated in industry, only received general recognition and maturity through their adoption by academics. RISC processors, the Unix operating system and much workstation technology fall into this category. Companies such as DEC and SUN have been founded by former university researchers.

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[1] The term *research interaction* has been used to include all forms of relationship where research and/or development is conducted on a joint basis, or where the results of research (tangible or intangible) are deliberately transferred (formally or informally) from one party to another.

Government policy, in both the UK and US, favours the deepening and formalisation of links between universities and industry in all fields of technology. In Britain, policy is directed towards 'research for wealth creation' and a fundamental restructuring of higher education is underway, with one of its objectives the increased relevance of university research to industrial needs. In the US federal funding for research is under threat and attempts are being made to divert technical expertise from military to industrial fields. Universities are being forced to seek new sources of funding in order to maintain their central research and teaching activities. At the same time companies are facing ever more fierce competition and are having to restructure themselves constantly and seek maximal value in every aspect of their operations.

Two activities on which particular emphasis been placed recently are the diffusion and licensing of technologies developed in universities to companies for commercial exploitation - a process known as technology transfer, and to the industrial funding of university research in specified areas - industrially sponsored research. Many universities have made considerable investments in the setting up of specialist offices, staffed by expert professionals, in an attempt to maximise revenues from technology licensing.

1.2 Report Structure

Chapter 2 details the **historical and political background** to the development of computer science and technology transfer in both the US and the UK. In each case, changing patterns of funding are summarised and the recent governmental sources of research funding and technology policies examined. Both countries have recently reorganised and redirected their support for research and development, and each has deployed a number of initiatives designed to encourage research partnerships and technology transfer between public and private sectors.

Chapter 3 examines the **range of functions** to support and encourage research interactions which different universities perform via various **central bodies**. The functions supported and their integration into different offices and university companies varies greatly in the sample of universities surveyed. These differences are summarised and overall structures in place at a number of different institutions are sketched.

Chapter 4 looks at ongoing **research relationships**. It begins with an analysis of research and development in **corporations**, with particular reference to the function of industrial basis research and the complex nature of the relationship between research and development in the computer industry, as well as the ongoing structural changes in that industry. This provides the context for an examination of the **changing nature of research collaborations**, which are increasingly driven by companies' direct financial interests. Case studies illustrate the potential for complex, symbiotic relationships and the advantages and disadvantages of cooperative projects. **Different types of relationship** are examined in some detail, with stress on the importance of longer term informal and strategic relationships. The role of formal industrial liaison programmes is also assessed, and university policies as to preferred and accepted types of agreement and exploitation terms for research documented.

Chapter 5 is concerned with **technology transfer, both formal and informal**. It begins in general terms with the role of technology as organisational expertise and the changing nature of companies' attitudes to technology acquisition, before looking in some detail at the different types of protection available for intellectual property and the suitability of computer technologies for formal licensing. The procedures used to evaluate and market technologies are investigated, as are

particular issues involved in the exploitation of computer technology. The chapter concludes with an examination of the different kinds of **start-up companies**, both privately and university owned, which can be created to commercialise university research and of the very different climate and attitudes found between the two countries in this respect.

Chapter 6 concerns overall **conclusions**. A consideration of the limitations imposed by my methodology is followed by a restatement of the principles findings of the project. Because of the broad nature of this investigation, many important aspects of these findings require further investigation, particularly of a quantitative nature, and so some of the avenues for future research which have become apparent are outlined. The report finishes with a brief discussion of the prospects for future developments in research interaction between universities and industry in computer science.

An index of **abbreviations** (7) and a **bibliography** listing all sources referenced (8) follow in the usual manner.

Summaries of the interviews themselves are presented as an appendix, which is numbered separately for ease of reference. In each case the summary contains all the relevant points of substance made during the course of the interview. The interviewee themselves has been allowed to review the summary prior to its inclusion here, and a number of them took advantage of the opportunity to correct and clarify their comments. In a few cases the summaries were substantially rewritten, more details of the process used to produce the summaries is given in the discussion of Methodology below. Their format uses précis to convey items of background and information, with direct quotation favoured when opinions or experiences of particular interest are being reported. It is hoped that these summaries might be of use to others with an interest in the topic.

1.3 Document Conventions

Quotations from referenced sources are presented in the usual way.

> This is a quotation from a referenced source. This is a quotation from a referenced source. This is a quotation from a referenced source. This is a quotation from a referenced source. This is a quotation from a referenced source.
>
> [Source, page 25]

Full citation details are presented in the bibliography.

A slightly different convention has been used to presented selected material from the interview summaries themselves.

> This indented paragraph is a section of précis of an interviewees statements, which has been approved by the interviewee themselves. ‘In quotations, this is a piece of direct speech transcribed from the interview.’
>
> > ‘Also in quotations, and indented further, this is an entire quoted paragraph transcribed from an interview. Also in quotations, and indented, this is an entire quoted paragraph transcribed from an interview.’[2]

---

[2] See 9.1.2.3 - Interview with Joe Bloggs of the XYZ Office of Public Statements

Wherever material is quoted from an interview summary, this is referenced via a footnote also containing the name and organisation of the interviewee to the appropriate section number of the appendix which contains the full summary of that interview. '*Occasionally, snippets of directly quoted speech are mixed with body paragraphs - these are in quotes and italic text'*

Sometimes an interviewee has quoted a third party, as in

> 'Suppliers often come to us and say "Let us sell you some equipment." We tend to look very closely at a number of different attributes...'

In these cases, double quotes have been used for all such nested quotations. Whilst this is not strictly grammatical it adds considerable clarity, and was essential for comprehensibility when e-mailing summaries to participants. Where Americans are involved, American English spellings have been used in directly quoted material and in capitalised nouns.

Finally, slightly different conventions have been used in the interview summaries themselves. For clarity all directly quoted text has been placed in italics as well as quotations.

1.4 METHODOLOGY

As mentioned above, the original research involved in this project took the form of a series of interviews with 27 participants, of which 5 were managers from commercial companies, 13 members of central university bodies and 9 members of computer science or related departments. Because several interviews were conducted with different members of each of the participating universities, this sample spanned 5 companies and 10 universities. The data gathering and analysis method adopted with respect to this sample was qualitative rather than quantitative throughout.

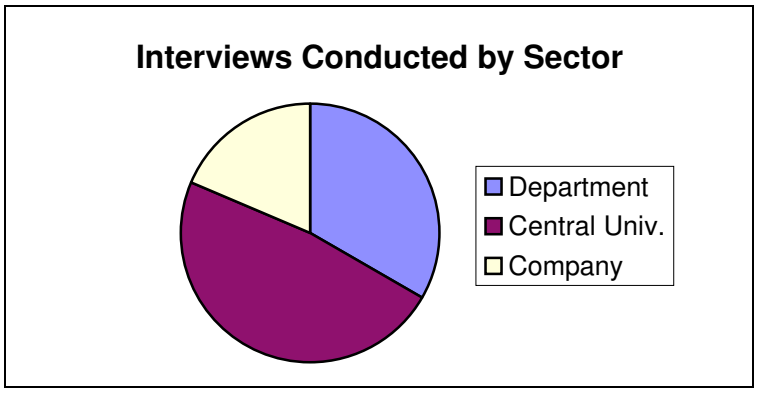

Figure 1-1: Interviews Conducted by Sector

Almost without exception, participants had many years experience of dealing daily with the issues raised by university/ industry interaction. My approach was therefore to allow them significant flexibility to discuss those elements of the relationship which they considered to be the most important, whilst at the same time ensuring that certain broad areas were covered so that comparisons could be made. There was no fixed set of questions or questionnaire; given the diversity of roles undertaken by the interviewees this would have imposed an unhelpful rigidity without resulting in a large enough sample to have any kind of statistical significance.

The interviews were tape recorded (with explicit permission), and in case of technical problems notes were also made. After the conclusion of the interviews, these recordings and notes were

used to produce the interview summaries collected in section **Error! Reference source not found.**. All the summaries were then returned to the interviewees themselves, usually via email but sometimes physically or by fax, to allow them to examine their comments and my précis of them and to make whatever corrections and clarifications they wished. In most cases changes made were small, and involved rephrasing awkward constructions, changes of emphasis and corrections to figures. In some cases controversial statements were removed, and a few participants took the opportunity to substantially rewrite the summaries to reflect official policy. In all cases the wishes of the participants have been respected, where no response was received following an initial transmission and a subsequent reminder this lack of explicit verification is indicated at the head of the summaries themselves.

Each summary is preceded by a heading in a standard format such as:

Interviewee: Professor Norman Badler
Job: Director, Center for Human Modelling and Simulation
Organisation: University of Pennsylvania
Interviewer: Tom Haigh
Date: Thursday 8th September 1994
Location: University of Pennsylvania
Revision: 1

Selection of interview participants was slightly ad-hoc. The American institutions studied were not an accurate cross-section of the US university system: they were all private, east coast institutions and, with the exception of MIT, members of the Ivy League. Practical considerations limited the geographical range of the sample, and these institutions were chosen because as major centres of research, many of them amongst the world's most prestigious, they had well developed and extensive arrangements for the support of research and the licensing of its results. At least two interviews were conducted within each institution, where possible including both academics and administrators.

In almost every institution surveyed, one or more of those responsible for technology transfer were participants. Either the director of the office or the officer with particular responsibility for computer technology were usually interviewed. Interviewees also included those with responsibility for industrial liaison and for corporate development. Researchers interviewed had in all cases substantial experience of industrial collaboration - most of those participating were heads of research groups, many of them heads of department, laboratory or centre.

Participating companies were major corporates, with the exception of two small companies (one controlled by and one partly owned by a university). Those interviewed in most cases had substantial overall responsibility for technology liaison with universities, and the relatively low representation of companies in the overall sample is caused by the relative difficulty involved in identifying and arranging to meet such people.

2. HISTORICAL AND POLITICAL BACKGROUND

An understanding of the current nature, and likely future direction, of links between universities and industry in the field of computer science can only be achieved with the benefit of a considerable amount of background information. This chapter represents an attempt to summarise much of that information for both the US and the UK.

Brief sketches of the development of the research system during the twentieth century are followed by examinations of changing policy towards and funding patterns for university research during the past two decades. Especial attention is paid to the emergence of more widespread attempts to encourage technology transfer since the mid 1970s and the various pieces of legislation and governmental programmes designed to facilitate this. Where possible this information is presented with specific reference to the development of computer science and information technology over the same period.

As well as providing sufficient background on which to build my conclusions, this chapter also provides the context needed to understand points made during my discussion of the interview findings and by participants themselves. It must be emphasised that, although efforts have been made to provide some analysis of and structure to the material in this chapter, its primary function is the support and elucidation of arguments and analysis elsewhere in the report.

2.1 US BACKGROUND

2.1.1 UNIVERSITY RESEARCH 1850 -1970

NOTE: What follows is a very brief sketch designed to provide a minimal historical background to the remainder of the report. General information on the development of university research is condensed from [Bower], information specific to the history of computer science comes mostly from [Hartmarnis & Lin].

Only during the latter half of the nineteenth century did American universities begin to undertake scientific and technological research on a significant scale. At this time land grant institutions were coming into existence following the Morril Act of 1862. Johns Hopkins, founded in 1876, was intended to follow the German model of advanced scientific and technical education with an integrated research component - its creation is conventionally taken as an important landmark of the American scientific institution.

During the early 20th century higher education system grew rapidly, along with the economy. Research funding increased dramatically, much of it from philanthropists - most famously Rockefeller and Carnegie. Federal government expenditure on science, although sizeable, was mostly directed towards applied work done in government organisations. Similarly, the great industrial research laboratories such as those of AT&T and General Electric were established in this period as centres of applied work which did not interact routinely with universities.

Industrial cooperation between universities and industrial organisations was first undertaken on a significant scale during the First World War. During the interwar period some universities maintained traditions of contract research and consultancy work. Despite problems caused by the

Depression and the attendant falls in revenue, this period saw a consolidation of the strength of the major research universities.

During the war the role of the federal government as a contractor of research increased massively. University effort was directed towards a range of applied projects designed to assist the war effort - two of the most famous technological results being the atomic bomb and the digital computer. Following the war a continued growth in pure science was accepted as a national priority, and the necessity of Federal funding in maintaining this recognised. The **National Science Foundation**, or NSF, was established in 1950, and federal funding became the most important source of research funding. Private donations from individual foundations continued to flow, though industrial links were in general actually eroded during the period.

The **Office of Naval Research** (ONR) and **Air Force Office of Scientific Research**, also within the Defense Department, were very active in the late 1940s and early 1950s, funding such well known systems as SAGE and Whirlwind. However, their role diminished relatively as the total scale of funding increased. **NASA** made a significant contribution to the development of reliable and fault tolerant systems for the Apollo program, and the **Atomic Energy Commission** - responsible for the US atomic weapons program - was the principle source of funding for the development of supercomputers and their applications. The development of atomic weapons has always required the most advanced possible simulation techniques, and indeed ENIAC, the first digital computer, was developed for this purpose. COBOL, which was for three decades the standard language for business and commercial software development, was designed by a DOD taskforce in 1958.

A federal body with particular importance for the development of computer science was DARPA, the **Defense Advanced Projects Research Agency**. Founded in 1958 to support research in fields of military interest it was favoured by the Kennedy administration as a means of directing funds efficiently towards areas crucial to national technological progress, which in the years directly after Sputnik was viewed as being a close race with the Soviet Union. Computer research was identified as important to this end - projects were funded at universities and companies and conferences organised for the sharing of information. Together with DARPA Net, which eventually developed into the Internet, these played an important part in the development of computer science as a discipline. DARPA also funded emerging areas such as computer graphics and advanced architectures.

> DARPA has long had a reputation for supporting high-risk, high-gain research in pursuit of military applications. Its style of research support is highly proactive in that DARPA identifies areas of potential interest for military needs and orients its research support mostly toward experimental and prototype system development. Individual program managers have been highly influential, both in articulating areas of need and in stimulating the CS&E [Computer Science and Engineering] community to be interested in these areas. Thus DARPA has often played a key role in defining research agendas for the CS&E field.
>
> [Hartmanis & Lin, page 219]

The NSF only became a major supporter of explicit computer science research in the mid 1970s, prior to this the emphasis had been on funding scientific applications of computing through other disciplines. Previous impetus towards the development of computer science as a discrete field of study may thus be seen as coming primarily from deliberate and targeted military investment.

American science and engineering came to lead the world in most fields, including computing. Within the pure sciences, funding was officially channelled towards scientific excellence, without a

direct concern for exploitable results - at least on the micro-level of distribution of funds between researchers and groups working within the same disciplinary field. Compared to previous European models, individual groups and laboratories generally enjoyed a greater level of autonomy to follow diverse research directions. A relatively small number of elite institutions continued to dominate research.

2.1.2 Changing Priorities In Recent Decades

2.1.2.1 The Emergence of Biotechnology as a Paradigm for Technology Transfer

The event generally recognised as catalytic in the development of a new attitude towards technologies developed by universities was the development, by Cohen and Boyer, of a gene splicing technique crucial to the manipulation and recombination of DNA. When this was published in 1973 it represented a breakthrough in basic research with profound implications for the development of molecular biology. What made it different from previous breakthroughs in pure science was the fact the Stanford university successfully patented it, and by 1976 the biotechnology industry had been born around it with the formation of Genetech Inc - founded jointly by Boyer himself and a venture capitalist. One of the other key biotechnologies, allowing the production of monoclonal antibodies, was developed in Britain in 1975 but its commercial value was not recognised and it was not patented.

During the next few years, a number of other companies were formed to exploit biotechnology, concentrating on pharmaceutical applications. Spectacular success was achieved by a few companies during the 1980s, including Genetech itself, Amgen and Biogen. New companies were founded in great numbers, as venture capitalists were eager to fund scientists founding new companies to develop promising technologies. Investment reached its peak in 1991, when a total of $3.6 billion was raised by biotech firms through public stock offerings alone.[3]

Recently, confidence of investors has diminished sharply. As these companies move the development of their drugs further through the process of development, testing and approval the costs increase sharply at every stage, but the substantial majority of the companies need further finance to meet these costs and, following high profile failures, investors are wary and available funds are not sufficient to support all the companies now active. Most of these companies have only one product, which will begin to produce revenues only at the end of seven to ten years of work, and so tend to rush through development in the hope of success - not an approach likely to produce cautious evaluation of prospects, despite the fact that only around 10% of biotech drugs entering clinical trails are eventually approved.

According to Business Week, 26th September 1994, expectation among analysts was that only around a quarter of the public companies would remain independent. Companies are seeking collaborations with larger pharmaceutical firms - in 1990 Genetech sold 60% of its stock and several other companies have followed suit. Even though many publicly traded biotech firms have disappointed stockholders, though not the venture capitalists who liquidated their stakes on flotation, they have provided a powerful model of entrepreneurial exploitation of cutting-edge technologies by small companies.

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[3] Business Week, 26th September 1994

One feature of the biotechnology field which has attracted considerable interest has been an obvious blurring of the differentiation between 'basic' and 'applied' research. Because fundamental research in this area is recognised as having direct commercial relevance, developments made in universities have been immediately patented and exploited, whilst much research carried out by biotech companies has been pursuing the same goals as that of university research teams. Industrial staff maintained close links with their academic colleagues, and scientists moved far more easily than had been traditional between commercial and academic institutions. Biotechnology, together with other pharmaceutical and medical technologies, continues to be the main focus of many university technology transfer programmes, and a question underlying much of this report is 'To what extent is computer technology like (this general perception of) biotechnology?'

2.1.2.2 University Technology Transfer - Political and Legislative Background

The conspicuous success of the Cohen-Boyer patent greatly increased awareness in universities as to the potential value of the intellectual property of their research. As is normal in the US, policy is heavily influenced by the interaction of highly organised special interest groups, and ownership of intellectual property produced by federally funded research is a valuable prize. Lobbying on behalf of university and industrial groups continues to this day.

Since 1980 and the passing of the Patent and Trademark Amendments act, usually referred to as the **Bayh-Dole Act**, ownership of rights to government funded research can be claimed by the university or non-profit research organisation which undertook the work. Previously policies had varied between agencies, but the new situation encouraged universities to protect and license their ILP. Patented inventions must be routinely disclosed to the government, and universities are expected to attempt licenses which favour manufacturing in the US. The government retains a right to use the invention for its own purposes, and vestigial 'march-in' rights if a patent is not being properly exploited, but essentially complete control rests with the universities themselves.

An additional motivation to universities to seek additional sources of income came with the general decline in public sector funding for non-military research during the Regan administration of the 1980s. Funding categorised under the 'general science' heading was static overall during the early 1980s, and showed very modest growth later in the decade. [NSF]

Because the new legislation made this more practical before, and the high profile success of biotechnology and a handful of university patents, showed the potential for huge rewards, technology licensing appeared a likely source of revenue. Many institutions set up technology licensing offices during the 1980s. The legislation aimed to 'incentivise' successful exploitation by allowing universities to profit from the activity - encouraging more imaginative and concerted attempts than would result from a governmental agency. Most institutions choose to pass on the incentive by providing a significant proportion of royalties to the inventor, though this is not a legal requirement. Current software licensing practices are dealt with in detail in section 5.2.

The **Small Business Innovative Research** programme (SBIR) was initiated following legislation in 1982 which forced federal agencies to direct some of their R&D budget towards small business. This was intended to encourage transfer of technology and encourage innovation in small firms - topics are announced in areas of interest to the agencies for which bids are made competitively. Technologies which have been developed far enough to form the basis of a small company are thus developed further by this route - and many of these small firms have been

created by university researchers around spun-off inventions. Between 1983 and 1991 this programme awarded projects worth a total of $2.8 billion - of which more than one fifth were in computer related fields. [NSF]

One important development in industrial research arrangements came as result of the 1984 **National Cooperative Research Act** (NCRA). American anti-trust laws imposed very strict regulation on contact and collaboration between companies in market competition with each other - which prevented any kind of research collaboration even at the pre-competitive stage. NCRA allows the establishment of research consortia to spread the cost of pre-competitive research - essential in sectors such as the semiconductor and automobile industries where the research underlying future product generations is now far too expensive for individual firms to contemplate. Two of the most important consortia have been the Microelectronics & Computer Technology Corporation (MCC) and the Semiconductor Research Corporation (SRC) - the latter investing more than $125 million in US university research between 1982 and 1990. [NSF]. The leverage provided by cooperation of this kind can thus provide a significant boost to research in universities as well as in industry.

Corporate research has benefited from the tax credit which rewards '**Research and Experimentation**' (R&E) work - the exact set of incentives offered varies periodically, but throughout the 1980s expenditure overall totalled around $1.2bn per annum. [Williamson] Expenditure at this level could be characterised as implying an industrial policy, but because it was not directed, the government was absolved of the responsibility of being seen to select specific areas or companies for support.

2.1.2.3 The Emergence of a Technology Policy

Under the Bush administration, policy drifted towards a more active government role in the funding of research and development of advanced technologies. The American body politic has a cultural aversion to the idea of industrial policy - and a great ideological commitment to the idea of the free market, so technology policy is a controversial area. The reality is of course that vast government subsidies, via lucrative contracts, to defence related industries played a key part in the development of the American technology base. Indeed, attempts by the government to identify technologies of central importance to national security identify as crucial the same advances in semiconductor development on which commercial success rests. As defence spending is reduced, the case for finding other means of delivering this support is strengthened.

Defence spending on R&D has been reduced substantially, from its high of $39bn in 1987 - representing 67% of all Federal funding for R&D, to $33bn. in 1993 - representing around 59% of the total. (The 'general science' category encompassed just 4% of total spending.) President Clinton is pledged to reduce this further to around 50% by 1998 - although defence cuts of any kind are alien to the newly incumbent Republican majorities. In the basic research field - a relatively small component of overall Federal R&D - defence sponsored work fell to 9% in 1994, down from 12% in 1980. Health accounted for 40% of this spending, and 'general science' (including the NSF) another 20%. 62% of this Federally funded basic research was conducted within the academic sector. [NSF]

[Kash & Rycroft] suggests that this is also an appeal of federal funding for R&D in general - it needs no political justification and leaves companies to pick and choose. It also suggests that military technology has become increasingly isolated and specialised, with much research

conducted in secret - so that spin-off benefits have become less common. In several fields, probably including semiconductors, development of the most advanced technologies are driven by civilian projects, and technology transfer takes place into, rather than out of, military development. [Mowery] argues that, although the US military were once the major market for cutting edge technology, this technological divergence, coupled with the growth of civil computing and electronics applications, has radically reduced the importance of military spending to the US semiconductors and computing base since the late 1950s and early 1960s.

> 'Whether government should pick winners has never been a meaningful question. The US federal government has always engaged in 'industrial policy', by supporting sectors of the economy. The problem is that picking winners has been ad-hoc, reactive and fragmentary. Often new federal technology undertakings have been hidden behind some facade like national security.'
>
> [Kash & Rycroft, page 77]

Steps towards an overall framework for technological strategy and technology transfer came in 1988, with the **Technology Competitiveness Act**. The National Bureau of Standards was reborn as the **National Institute of Standards and Technology** (NIST), moved to the Commerce Department, and given responsibility for a number of new programmes, including the **Advanced Technology Program** (ATP). This provides federal funding for generic technologies deemed important to a wide range of products or processes - bids to undertake pre-competitive, high-risk, strategic industrial research are made by commercial firms and consortia. Proposals are screened by teams of business experts as well as for technical merit, and evidence of good business prospects for successful commercialisation is crucial. When the programme was initiated in 1990 its funding was relatively low, but following its perceived success funding was rapidly scaled up with general political support. Claimed benefits include assistance in converting from defence to civilian applications and the formation of strategic alliances as well as financial savings, expanded R&D activity and accelerated development.

In 1994 the ATP was refocused, and the bulk of its activity channelled through programmes with specific technological and business goals - each involving a number of projects. This coordination is intended to maximise the impact of the Program. Another change has been a greatly increased emphasis on the role of the ATP in spotting potential for joint ventures between businesses, universities and government departments or strategic alliances between companies. It also has a role in providing assistance to smaller companies to develop well founded business and commercialisation plans. [ATP]. Intellectual property is vested with industrial partners, rather than universities - which causes concern to universities.

Increased attention has also been focused on the transfer of technologies from national (i.e. defence related) laboratories into civilian sectors. Legislation to enable this began in the 1980s with a series of laws, the first of which was the **Stevenson-Wyldler Technology Innovation Act** of 1980. By the late 80s, a definite upturn in such activity was taking place - the number of cooperative agreements with industry entered into by the Federal labs rose from 108 in 1987 to 975 in 1991. A main thrust of the 1992 **National Technology Initiative** was the redirection of their efforts into collaboration with industry. During recent years new funds have been available to the DOD for defence wide initiatives to promote technology transfer and 'dual use' technologies. A rare growth in the atomic research budget has been in provision for technology transfer activity. [NSF]

A number of changes have been made by President Clinton. His initial policy was the concentration of research funds in six strategic, 'cross-cutting' initiatives, coordinated by the

Federal Coordinating Council for Science, Engineering and Technology (FCCSET) amongst which was the High Performance Computing and Communications initiative detailed in the next section. Projected funding for this programme was £1.0bn in 1994, some of the other initiatives were even larger, such as the one in Biotechnology which was to be funded at $4.3bn. In August 1993 these plans were modified, with the replacement of the FCCSET with the **National Science and Technology Council** (NSTC) and the cancellations of the Biotechnology programme and merger of several others. [NSF] The NSTC has a broad mission to establish national goals in science and technology and to coordinate policy towards their achievement.

2.1.3 Computer Science in the 1990s

NB: All unattributed figures in this section come from [Hartmanis & Lin].

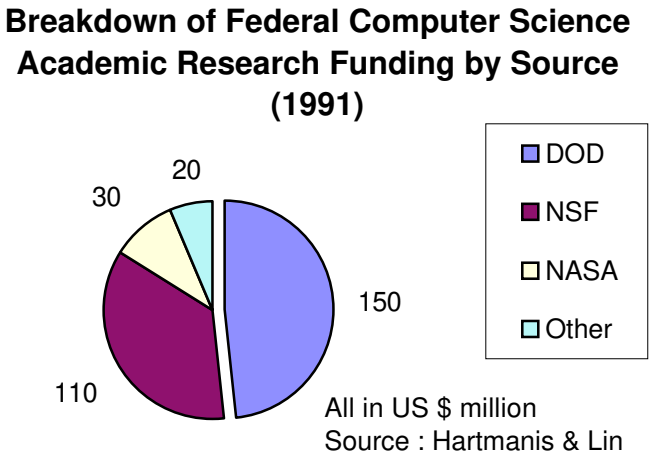

Figure 2-1: Breakdown of US Federal Computer Science Research Funding for Universities by Agency

Computer Science has come into its own as an academic discipline since the early 1970s. In 1977 only 954 doctoral researchers were working in the field, from a total of around 83,000 in science and engineering as a whole - representing just over 1% of the total. By 1989 they comprised 3,860 of a total of 149,000 - 242% growth against an overall increase of 80% (though at almost 2.5% Computer Science was still not amongst the largest disciplines). This rapid growth continued into the early 90s [NSF] and has been accompanied by shifts in patterns of funding.

The **National Science Foundation** has become a major source of funds. By 1992 it had become the funding source which supported the greatest number of academic researchers, and computer science was its fastest growing area of funding. Spectacular growth occurred through the late 1980s, after the consolidation of responsibility for the discipline within a single body within the NSF, the CISE Directorate in 1986. Previously funding had been channelled through a number of directorates, none of which had computing as its primary interest. In 1992 dollars, academic funding increased from a static level of roughly between $30 and $40 million for each year since 1976 to 1983 to around $110 million in 1991.

In the early 1990s the **Department of Defense** remained the largest federal source of funding for academic computer science research. Approximately one third of its overall research funding for computer research was directed towards projects conducted within universities and colleges, and

in 1992 this totalled roughly $150 million. [Hartmanis & Lin, page 218]. Several distinct sources of funding existed within the DOD, the most significant of which was DARPA - now renamed ARPA. The loss of its explicitly defence related mission reflects a general attempt by the Clinton administration to redirect high technology funding and policy towards national competitiveness and away from military applications.

> In recent years, the major areas of concern to DARPA have included high performance computing, networks, software, artificial intelligence (AI), and applications of these areas. DARPA divides its overall computing program into science (including machine translation, scalable software libraries for high-performance computing, software understanding for the future), technology (including speech understanding knowledge representation, embedded microsystems), and applications (including image understanding, natural language processing, transportation planning).
>
> [Hartmanis & Lin, page 218]

Other DOD agencies have continued to fund some work in computer science, particularly the ONR and OSF which have concentrated on small scale theoretical and fundamental projects in a range of areas judged to have possible military applications in the long term.

NASA funded around $30 million of academic computer science research in 1991, specialising in areas such as AI, concurrency and reliability. It also remained a major consumer of applied supercomputing work. The **DOE** funded approximately $4 million of academic research in 1991, a decline of around 50% from its level in 1986. Linked as it was to the development of atomic weapons and the huge national research laboratories, this funding (and their effective subsidy for the now distinctly unhealthy American supercomputer industry) has since declined further.

Federal funding for academic computer science research may thus be seen to have increased sharply over the 1980s, with strong growth in support from both military and civil agencies. Spending on academic research was, again in 1992 dollars, about $70 million in 1976, around $100 million in 1982 and around $310 million in 1991. It is also important to remember that academia only receives a minority of overall federal research expenditure in the field - which rose from around $200 million in 1976 to almost $700 million in 1991.

The rise in the number of researchers has meant that this increase actually represented a slight drop in the available funds per researcher. However, these figures clearly demonstrate that computer science avoided the kinds of pressure which affected federal funding of research in areas with less military potential. Computer Science was the only major scientific field still showing rapid growth in the early 1990s. As a result the perceived financial advantages from industrial collaboration, technology licensing and sponsored research were less critical in this field than in many others.

A major research initiative of the early 1990s has been the **High Performance Computing and Communications** (HPCC) Program. The initiative was based on a report by the White House Office of Science and Technology Policy and involved DARPA, NASA, the DOE, the NSF and a number of other agencies. Additional spending was projected at a total of $1.9 billion over the course of five years from 1992.

The programme focused on four areas:

- High performance computing
- Advanced software technologies and algorithms

- Network technology
- Human resources and basic research (designed to enhance exploitation)

The programme was designed to address ‘grand challenges’ presented in various fields beyond computing itself - working towards the solution of economic and political problems as well as those in the domain of science and engineering. It is thus an important part of a general trend evidenced in both the US and the UK favouring the increasing direction of research funding towards research areas carefully targeted to further national social and industrial progress.

A trend in academic organisation which computer scientists have been increasingly participating in is the move towards interdisciplinary centres focused on a particular area of research or application which spans traditional disciplinary boundaries (see section 4.2.6). A controversial report produced by a committee of the National Research Council entitled *Computing the Future : A Broader Agenda for Computer Science and Computer Engineering* [Hartmanis & Lin] concluded that the way forward for the discipline was to broaden its agenda and to increasingly look at computing practice and to other disciplines for problems upon which to work. This would ensure the continued vitality and relevance of the field, and also have the advantage of broadening the appeal of computer science beyond its traditional funding base - important in a climate of funding shortages. Obviously the core interests of computer science must continue to be researched, but it argues that core research should be supplemented with additional work in these broader areas, and towards contributions to the solution of major social problems.

2.2 UK BACKGROUND

Historically, British development of scientific and technological research and the means of its funding has been very different from that of the US, reflecting fundamental differences between the university systems of the two countries and increasing divergence between their industrial bases and national incomes. This section briefly surveys the growth of public funding of research in the UK, before looking in more detail at government policy for science funding during the 1980s and a number of formal initiatives to encourage university industry research interaction and technology transfer which were initiated during that decade. Recent changes to the government science policy, including the 1993 White Paper and the ongoing Foresight exercise are summarised, as are the new goals of the science funding bodies and associated technology transfer initiatives.

2.2.1 THE GROWTH OF PUBLIC RESEARCH FUNDING

UK public funding of science first became significant in 1916 with the creation of the government Department of Scientific and Industrial Research. Although this body was the main source of support for science many decades, until the Second World War its role was almost exclusively in the support of applied and industrial work. In 1920 the first of the Research Councils, the Medical Research Council (MRC) was set up - distributing funds to university researchers. State funding for science gradually became more widespread. [Bower].

The Second World War was a turning point for perceptions of science, following the direct contribution made to the war effort by scientists in a number of key areas - which in Britain of course included Turing's efforts at Bletchley Park in the breaking of the Enigma code. As in the US, governmental support for science was increased massively in scope after the war, and a number of military and atomic energy research establishments were set up.

In the 1950s, government science funding came principally from the Ministry of Defence (MOD), the Research Councils and the universities themselves. No overall government policy for science or technology existed, and the proportion of total spending devoted to military and nuclear projects was greater than for most other European countries, as it has remained to this day.

An explicit science policy began to emerge during the 1960s. Harold Macmillan appointed the first Minister for Science, but the main development came with the election of Harold Wilson - one of whose best known statements was a pledge to reinvent British industry in the 'white heat of the technological revolution'. To this end a Ministry of Technology was created, a Chief Scientific Advisor appointed and a new body advisory body created. Physics and astronomy were particular growth areas, but the hoped for revolution was conspicuous by its absence. The Science and Technology Act of 1965 reorganised the Research Councils and established SRC - the Science Research Council, which later became SERC, the Science and Engineering Research Council. [Levene & Stewart].

In the 1970s it became apparent that funding could not keep pace with the increasing demands of science, because the costs of undertaking each unit of research were growing faster than inflation and the amount of research proposed also tends to increase exponentially as successful work is likely to uncover an ever growing number of new problems. The rate of increase in funding diminished, and a shift of funding away from physics and towards engineering began. [ABRC]

2.2.2 THE 80S - SHRINKING BUDGETS AND NEW INITIATIVES

2.2.2.1 Government Research Funding 1980 to 1992

Science funding was largely static or shrinking during the 1980s. According to the 1987 report by the Advisory Board for the Research Councils - *A Strategy for the Science Base*

> In contract to the cumulative real growth of the 1960s and early 1970s, the purchasing power of the Science Budget in the 1980s has, at best, been held level.

The report also suggests in 1982 spending in the Maths and Computing field totalled around 4.5% of total government research spending, compared to 3.0% for the USA. A deliberate shift towards applied fields had taken place over the preceding years - between 1975 and 1982 the real value of Physics spending had fallen 18% whilst Engineering funding had risen by about a third. [ABRC]

Significant cuts in funding during the early 1980s saw redundancies and the widespread closure of departments and relocation of staff. Since then tenure has been removed from university staff, and very large numbers of new contracts have been made on a temporary basis - many teaching and research staff are now employed on one year rolling contracts.

At this time the British higher education system included several different types of institution, principally universities and polytechnics. Polytechnics were funded at a lower level, generally had research activity only in specialised and applied areas and were very much a second choice for academically inclined students - with a greater activity in vocational degrees, professional education and part time study for mature students. Until 1988 polytechnics were under the control of local government authorities.

British governmental funding of university research was, and continues to be, provided through the so-called **'Dual Support'** system. The first channel was the **University Grants Council**, which made £622 million pounds worth of research funding available in 1986. Until that year, support was distributed according to a formula which included a major component based on the number of students within an institution - giving all universities a allocation of research funds to spend at their own discretion. During the 1970s funding from this source was allocated for periods of several years - by the 1980s contracts were made annually which made longer term planning harder.

The second channel, which in 1986 contributed £385 to university research, was the **Research Councils** - theoretically autonomous bodies funded through the Department of Education and Science. These funded specified research projects, allocated competitively across institutions. Through the 1980s the Council responsible for computer science and IT, among many other fields, was SERC. All other sources of external research funding - including industry, charity and governmental departments, totalled £253 million. In the polytechnics total research funding totalled only £100 million, with around £60 million of this coming from the government. [ABRC].

1986 saw the beginning of a move towards greater selectivity in research funding, with the amount of level of funding allocated to a university substantially determined by an evaluation of the strength of the research of each of its departments. Each triannual **Research Assessment Exercise** involved the counting of research publications produced and a judgement as to how many members of a department are of national or international excellence. This was used to grade the work of the department as a whole on a scale from 1 to 5 - to determine resource levels

supplied to the university on behalf of the department this grade is multiplied by the number of 'research active' academics. As might be expected, this has resulted in a far greater concentration of research resources in institutions whose concentrations departments are predominantly of grade 4 or 5 status.

During the 1980s, OECD figures show a significant shift in overall government R&D spending viewed by socio-economic objective - defence spending rose from around 43% in 1980 to around 54% in 1987. Germany and Japan spent a much lower proportion of their total expenditure - 15% and 13% respectively, in the same category. A government report suggests that less than 20% of the research conducted by the MOD will have any relevance to civilian spin-off technologies, and so this expenditure was probably not an efficient means of stimulation of the broader high-technology base. [Webster]

By 1989/90, total government spending on science and technology R&D was £4.8 billion.

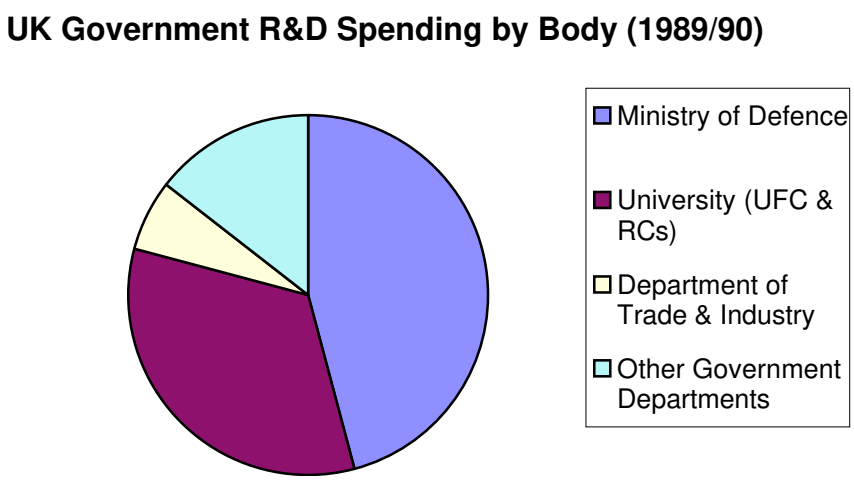

Figure 2-2: Breakdown of UK R&D Funding by Body

£2.2bn (46%) of that was spent by the MOD, the great majority of it outside the university system. A total of £1.6bn (33%) was channelled to universities via the UFC and the Research Councils. The remaining $1bn (21%) was spent by the civil departments of government, £310m of it by the Department of Trade and Industry (DTI). £158.7 million was spent on various technology transfer programs - of this 97% came from the civil departments. [Clement et al]

One important difference between Britain and American patterns of funding is the concentration of university research funding in two civilian agencies, both controlled firmly by the executive. This is in clear contrast with the American funding of areas, such as computer science, with military potential - where enough military expenditure is channelled through universities to make it the major source of basic research funding for the discipline. Thus whilst American computer science did very well out of the military build-up of the 1980s, Britain's continuing high level of defence spending relative to comparable nations has brought very little direct benefit to university science. Those strategic initiatives which have sustained research in the area have been of an industrially oriented nature.

2.2.2.2 Industrial Cooperation and Technology Transfer

Against the background of funding from traditional sources which was increasingly unpredictable and in many areas diminishing in real terms, particularly compared to the actual cost of conducting research (which tends to rise faster than the rate of inflation) it is not surprising that the idea of supplementing their income with funding from industry came to seem attractive to many universities.

This kind of funding was also very attractive to the Conservative governments of Margaret Thatcher - for whom ideals of free markets had a powerful attraction. She felt that science should respond to the universally virtuous principles of value for money and market direction - with universities prepared to bid for contract and applied research from industry. Science and technology research was reinvented as a market, in which industry and government were viewed as customers, and researcher teams as producers or contractors.

In the applied research domain, the so called '**Rothschild principle**' of the supplier-contractor relationship in governmentally funded work, taking its name from a 1971 report, was reinforced. Customers of research were identified within each government department and given responsibility for checking on the progress, evaluation and appraisal of research - in keeping with the general philosophy of deregulation of budgeting and rigorous appraisal within Whitehall brought about by the Financial Management Initiative.

Salford University is well known as an example of an institution which significantly altered its funding base - a dramatic round of government cuts in 1981 saw its funding fall by more than 40%. It gained replacement funding from industry by a significant switch of emphasis to corporate training, consultancy and contract research and development.

The government also moved to incentivise the transfer of university technology to industry. Until 1985, a governmental body known as the **British Technology Group** - and its precursor the NRDC - was entrusted with responsibility for the evaluation and licensing of technologies produced by publicly funded research. Income generated was retained by the government - providing no direct financial incentive to universities or researchers to consider the commercial potential of their work. Although the BTG was not altogether unsuccessful in its task - with key patents for Magnetic Resonance Imaging (MRI) technology providing its most substantial revenue stream - it made a number of well publicised blunders, best know of which was decision that monoclonal antibody technology had no commercial potential. Within the computer field an earlier failure of vision was the disposal of key patents relating to virtual memory for a very small sum.

In 1985 the preferential rights given to the BTG were removed. Universities were now able to choose to retain their IPR over the results of publicly funded research. The BTG now had to offer its services in competition with other brokers, such as the US firm Research Corporation Technology - most universities set up some kind of office or subsidiary company to deal with technology licensing and exploitation but continued to use external expertise in many areas. The BTG was subsequently privatised in 1992, and has altered the focus of its operations - closing regional offices in the UK but expanding its operations internationally, now seeking to represent foreign institutions, with its own US subsidiary based in Pennsylvania, as well as to license to foreign companies. [BTG]. According to Issue 1 of Catalyst, their newsletter, the BTG returned

£14.61 million in revenue to universities and other sources of inventions during 1993, with 80% of its licenses made abroad.

This transfer of IPR to universities mirrors the results of the Bayh-Dole act in the US, and is similarly regarded as a seminal event in the evolution of modern patterns of technology transfer. During the 1980s, this was complemented by a number of initiatives designed to encourage increased collaboration between universities and companies in the actual research process itself and a concentration of work in areas likely to be of strategic importance.

By far the most important initiative of the early 1980s, and one focused on IT, was the Alvey Programme. This is dealt with in some detail below because the results derived by its evaluators provide a valuable insight into many aspects of university/industry research interaction.

2.2.2.3 The Alvey Programme

The Alvey Programme was a five year government IT initiative which began in 1983. Its government sponsors were the Department of Trade and Industry, SERC and the Ministry of Defence but the programme itself was administered by a Directorate manned partly by secondees from industrial and academic organisations. Industrial involvement in research was central to the project - it aimed to boost national competitiveness in IT in response to general problems and the perceived challenge of the Japanese 5th Generation project, another strategic information technology initiative begun in the early 1980s.

The Programme ran on a very large scale, with more than 300 different research and development projects undertaken. Most of these were joint projects involving both industrial and academic research teams. Strategic areas within IT were identified and efforts concentrated in these areas. One of the explicit aims of the programme was to encourage technology transfer from academia into industry to provide competitive advantage, for this reason only technological areas where Britain already had some measure of strength were included. The Programme represented a very significant proportion of overall government spending on research in the computer science field, and so helped to initiate the trend towards increased focusing of research funds. It concentrated on pre-competitive research - an underlying policy belief was that further commercialisation could and should be left to the market itself.

The official evaluation of the Programme [Guy et al], by a team from the Science Policy Research Unit (SPRU) and Manchester's PREST, concluded that direct technological goals were largely met. The aim of the Programme to address structural problems in the UK research infrastructure was also judged to have succeeded - the team found that as a result of the programme the number of researchers in key areas increased and industry was able to benefit from the forging of links with academics. The Programme sought to develop and strengthen ties within research communities, again with some success.

The practical exploitation of research did not occur to the anticipated degree. The evaluators suggest that many companies failed to integrate their research teams with production and management and the lack of capital within the industry worked against commercialisation and longer term strategy. The British IT industry over the period saw a great deal of failure, consolidation and foreign acquisition of industrial project partners which closed off many routes for exploitation. These kinds of structural problems were realistically outside the control of the Programme itself and for this reason the evaluators concluded that a pre-competitive research

programme is insufficient on its own to improve national competitiveness, and suggested that initiatives in other areas by government and industry, including a corporate drive for coherent technology strategies and a greater involvement of users, should complement future projects of this kind.

Some interesting data on the research collaborations involved is presented by the evaluators. A survey showed that overall two thirds of participants felt that the overall benefits outweighed the costs (p. 140) though academics were decidedly more positive than industrial participants. Amongst the industrial teams, those from large companies were more likely to feel positively about the net gains.

> There must be suspicion that even modest increases in collaborative overheads would render the cost/benefit ration unpalatable to firms. Contemporary arrangements in the UK calling for firms to bear some of the cost of academics involved in R&D programmes deserve scrutiny in the light of this finding.
>
> [Guy et al, p. 141]

45% of the industrial teams involved and 39% of the academics felt that as a result of their participation they were able to 'enter new areas' - meaning that it was successful in encouraging activities which would not have otherwise taken place. 54% of the academic teams involved viewed the Alvey funding as a means of maintaining capabilities which would otherwise have been cut. Very revealingly:

> …when industrial teams alone are considered almost the same percentage (46%) regarded Alvey as a means of conducting research which would otherwise have been cut. This is the case even though such work was almost invariably characterised as necessary work conducted in core areas.
>
> [Guy et al, page 149]

Knowledge sharing was explicitly encouraged between participants in the Programme. As well as contact between industrial and academic partners, attempts were made to foster exchange of knowledge between different companies and institutions working on related projects and the strengthening of a broadly based IT community. Success here was mixed - only 22% of industrial and 32% of academic teams saw the Programme as an important way of forming links within their own sector. However 64% of academic and 38% of industrial teams found it was important in establishing university-industry links, and so the Programme must have played an important role in bringing together teams in companies and universities.

With respect to the transfer of expertise and technology from university to industry the results for full collaborative projects were impressive - 59% of industrial project managers found the academic contribution critical and a further 29% found it helpful. The evaluators also found that a large number of the teams went to take part in other national and international collaborative research projects such as ESPRIT II.

Some practical problems with collaborations were noted. 26% complained of lack of interest among collaborators, 43% of general collaborative overheads and 42% of the involved nature of the IPR agreement process. 56% of the academic teams reported that changes affecting collaborators had affected project progress.

The production of directly marketable products was not the main aim of most of the work carried out - the emphasis was on research rather than development and relatively few patents were granted. Only 14% of projects produced marketable products directly. Many projects were designed to improve the skills of project staff and gain familiarity with new tools and techniques.

17% of firms reported the regular use of project results or outputs by their production or business units - a figure significantly lower than expected. Again, internal corporate restructuring or change of strategy during the lifetime of the project was identified as a major factor acting against exploitation of results. The Japanese Fifth Generation project was oriented more towards skill development across design, engineering and manufacturing as well as research and therefore included a much greater emphasis on product production. These figures support the suggestions made in section 4.1.1.2 that progression from research to development is a very complex process.

All IPR from joint projects was vested with the industrial partners. This was criticised by the evaluators as causing delays and restrictions on alternative channels of exploitation without seeming to provide the desired automatic commercialisation of results by the industrial partner. This policy was

> premised on a model of pre-competitive research which anticipated an eventual split as participants ran to market with rival products. In reality this rarely occurred. Instead exploitation routes were often interdependent. In such instances effective exploitation was sometimes compromised and restrained by inappropriate IPR agreements.… exploitation itself will often be a collaborative activity. Complementarity in R&D often carries with it the implication of complementarity in exploitation.… there could be an argument for an expanded role for government in order to safeguard the original investment in R&D.

One very interesting finding was:

> The organisations which best met the aims of strengthening the UK IT R&D base were not those which succeeded at exploiting Alvey outputs in commercial settings. Organisations which performed well in terms of research tended to conduct their Alvey work in relatively autonomous research environments e.g. with projects sanctioned by R&D management rather than by higher management, and on sites separate from production units. In comparison, organisations successful at using and exploiting Alvey R&D in production settings and the market place were those which had developed tightly formulated, business-driven strategies linking their Alvey project portfolios. Organisations which had not linked their Alvey projects either together or to in-house research did not perform as well in terms of exploitation.
>
> [Guy et al, page 169]

Their data make this point very strongly. Expressed in terms of classes of project aims, research based projects worked very much more successfully when isolated from management both physically and in terms of budgetary control. In contrast product driven projects were far more successful when strategically linked to other Alvey and in-house development projects.

2.2.2.4 Other Initiatives of the 1980s

There was no large scale national successor to Alvey, and the government decided not to go ahead with a planned follow-up programme which would include increased stress on exploitation of its results. A general shift in government policy led to a move away from the idea of state support for near market research, this was expressed in the 1987 White Paper *Civil Research and Development*. At the same time the DTI, responsible for industrial initiatives, began to switch its resources away from direct grants to companies and the targeting of technologies as a means of supporting innovation and towards the more general encouragement of technology transfer and collaboration. In 1984/5, 70% of its funding in this area was directed towards particular companies, by 1988/9 this had fallen to 35%, with 40% of its funding directed towards 'non-project' activities such as technology transfer, training and consultancy. [Clement et al].

Its **Joint Framework for Information Technology** (JFIT), administered with SERC, included during the early 1990s many areas of support related to computer science, including Advanced

Information Technology (including Knowledge Based Systems, Software Engineering and Human Computer Interface work), Open Systems and Manufacturing Intelligence - the application of knowledge based techniques to manufacturing industry.

The DTI's new policies included a commitment to regionally based activities, one result of which was the establishment of a number of Regional Technology Centres. These were charged to:

- Co-ordinate and encourage the flow of technology between higher education institutions and local business, particularly small and medium sized enterprises.
- Maintain databases of technology transfer opportunities
- Provide training in the introduction and management of technology
- Develop access to national information on new technology which may be of particular benefit to local industry.

[Clement et al]

An explicit exception to the general ban on support of near-market research was the **Small Firms Merit Award for Research and Technology** or SMART programme, run by the DTI. SMART was conceived as a means of overcoming some of the problems faced by innovative start up companies. They are unlikely to be able to generate revenue rapidly enough to pay for the development of new products and so require injections of finance, but have great difficulty obtaining this support from private investors - not least because overheads are disproportionate for small investments. It was inspired by the American SBIR programme, and made funds available to small firms, with fifty or fewer employees, which had been vetted to make sure that they were suitably innovative and likely to succeed from a business viewpoint. Between its launch in 1986 and 1994 a total of £66 million had been spent in support of more than 1,000 companies. Evidence also exists that firms which raised money in this way were better able to gain additional funding from venture capital sources **-** see [Moore and Garnsas]**.** A companion scheme, Support For Projects Under Research (SPUR), which was launched in 1991 provides support to medium sized companies.

The DTI's main involvement with research came through the **LINK** programme. LINK was set up in 1988, and is a framework which involves a number of programmes, each of which lasts for around five years and is run by a committee of industrial and academic members which sets priority areas for research and evaluates bids. Individual projects involve consortia including at least one industrial and at least one academic member, and support is focused on longer term and pre-competitive projects rather than development work. The government provides 50% of the total cost, with the industrial partners providing the rest. One of the broad areas in which programmes are conducted is 'electronics and communications', and a significant number of projects have involved the participation of university computer science departments. Intellectual property arrangements are negotiated between the partners. By 1993, a total of £200 million had been distributed, of which £70 million came from the Research Councils' budgets. Lead responsibility for the programme was later transferred to the Office of Science and Technology.

The CASE awards for cooperative work by postgraduate students, and the setting up of Interdisciplinary Research centres, though initiated during the 1980s, are described in the next section.

A well publicised report produced by the *Centre for the Exploitation of Science and Technology* - a body set up in 1988 and funded by government and industry - recommended that a network of **Faraday Centres** should be set up, modelled on the German Fraunhofer - a network of 46 specialised institutes with a budget of around £400m. The Fraunhofer is funded roughly equally be local government, federal government and industry, and works on contract research with industry, particularly small and medium sized companies. Most of the institutes are headed by professors, and research students spend time there working on industrial problems - one of the advantages of this approach being the enhanced movement of people and their ideas and expertise back and forward between industrial and academic sectors. Although the Fraunhofer continues to be a widely discussed model, the investment required deterred the government from implementing the proposed Faraday Centres, which were rejected in late 1992 - though the philosophy behind them is intended to inform general policy.

European science and technology objectives are set via a series of **'Framework'** programmes which establish goals and allocate funding over a four or five year period. These goals are pursued via a number of complementary programmes, many of which include an IT element - for example AIM for informatics in medicine, RACE for advanced communications technology and DELTA for the application of IT and telecommunications to education. European policy is that the results of Framework research should be available to all members of the community. Britain has been successful in attracting European funding - receiving around 20% of all European research contracts by value during the 1987-91 period according to [HMSO 93].

For collaborative IT research, the most important European programme of the mid 1980s was **ESPRIT - the European Strategic Programme for Research in IT**. ESPRIT was initiated in 1984, and was intended to be industrially led - with projects funded equally by the EC and the partners composing the project consortia. Each consortium needed to include partners from at least two different states, and it was hoped that collaborative research would avoid needless duplication and allow longer and larger projects than would otherwise be possible, and also lead to better adoption of technical standards such as OSI. ESPRIT had a high rate of participation from large firms - 47% of all contracts were awarded to firms with more than 5,000 employees.

According to [Hare, Launchian & Thompson], page 64, main benefits recognised by participants were International Collaboration (81%) and Industrial/Academic collaboration (71%), but only 26% cited a major change to their R&D direction. Major drawbacks were Overhead Costs (67%) and Bureaucracy (45%). One advantage of the scheme from the viewpoint of participants was a degree of flexibility in the definition of project areas, allowing bids in areas of particular interest to the participants. Expenditure was around 400 million ECU annually.

ESPRIT was continued with ESPRIT II and ESPRIT III. At the time of writing, bidding is underway for a further round. Far more participation by academic institutions as project partners has occurred than originally planned - they had originally been expected to take part principally as subcontractors. In 1989 an office was established with special responsibility for university-industry technology transfer. The ESPRIT model has also given rise to a number of other programmes in different technological areas. Comments from participants in this project (see 4.4.3) suggest that for many of the academic groups involved the financial motivation was far more important than any of the benefits of collaboration intended by the EU, and that considerable cynicism exists as to its overall success.

Another European programme initiated in the 1980s was **EUREKA.** Originally conceived as a response to the apparent boost given to American technological research by the SDI programme it began as a purely intergovernmental agreement in 1985, but expanded its scope considerably and by 1992 had a total value of around 8 billion ECU - similar in scale to the entire Framework programme and accounting for around 2% of total EC R&D activity. It was industrially led and dominated by large firms. Attempts were made to expand the range of contacts known to the collaborators, and proposals were circulated to encourage additional members to join the consortia which occurred in around one third of all cases according to [Peterson]. This also suggests that although EUREKA allowed small and medium sized enterprises to lead projects which would not otherwise have been possible, it paid insufficient concern to non-financial input such as guidance with IPR terms and its effectiveness was compromised by political considerations which led to poor integration of different national initiatives and of Framework basic research, and prevented it from being as focused on near-market activity as was intended.

2.2.2.5 Science Parks

Large corporations are not the only kind of company which are involved in university work. Great faith has, particularly during the 1980s, been placed in the potential of small, innovative companies to generate wealth through technology exploitation. The growth of the biotechnology industry has already been mentioned, but the clusters of companies working in a variety of areas which developed around MIT and Harvard on the east coast and Stanford on the west acted as an inspiration for a number of developments designed to foster such growth areas.

A large number of science parks have been established, in both the UK and US, which seek to emulate this kind of success. By the beginning of 1990, 38 parks were operating in the UK. They aim to encourage the growth of spin-off companies from work undertaken in the university and to provide a home for research units associated with larger companies. Science parks were the most visible expression of regional policies to encourage the growth of high technology companies and effective technology transfer, reflecting a ‘market-led’ philosophy towards infrastructure growth.

> It has become a highly fashionable way to address a group of problems: the revitalisation of declining regional economies; the need to maximise the perceived return to the tax-paying community from universities’ basic research; the nurture of small hitech businesses; and, finally, generally to foster technological innovation.
>
> [Bower, page 94]

Obviously, whilst the existence of such a park and any attached subsidy might play a part in attracting existing businesses and encouraging new ones, it cannot work miracles. If the park is associated with a well known and highly successful institution with strengths in science and engineering then it is more likely to succeed, likewise if a significant local community of innovative companies also exists then the aim of creating a ‘critical mass’ of high-technology industries capable of significant local economic activity is more realistic.

> These have been notoriously difficult to finance and sustain, and have in fact generated relatively few new long-term jobs. The new growth areas - the Silicon Valleys or Glens - of this world grew by a strong combination of a regionally rich concentration of innovative technological expertise and significant defence-related R&D for the state.
>
> [Webster, p. 75]

A survey published by the government suggests that science parks have enjoyed some success in meeting their objectives. In 1987 there were 412 firms located on the parks, employing 5,300

people - by 1992 this had risen to 1,188 firms employing 19,992 people - still not a very significant number on a national scale. By comparing companies located on the parks with those of a similar make-up in off-park locations they concluded that they were more likely to employ scientists and engineers, made more use of university facilities and enjoyed more rapid growth. Most of the growth was concentrated in a handful of firms - in a sample of 251 the 5 most rapidly expanding accounted for 69% of the overall growth. However, there was no evidence that the science park companies were more likely to perceive themselves as being more technologically sophisticated, they were no more likely to expand their operations from services and consultancy into product based activities and manufacturing and they were no more likely to be visited by representatives of local institutions of Higher Education. [Westhead & Storey]

2.2.3 Recent Developments

The initiatives and policies described above were motivated to a considerable extent by ideological considerations. The Thatcher governments had a commitment to the idea of small business as an engine of general economic development which has proved misguided, and also placed faith the emergence of a post-industrial 'Information Economy' based almost entirely on service industries which would replace wealth based on manufacturing. Whilst some political capital was placed in the development of IT, support for industry and technology in general was sporadic and unfocused. The government was often accused of borrowing ideas and initiatives from other countries and failing to fund them at a realistic level or of implementing without the necessary surrounding framework needed to make them successful.

The formation of a central **Office for Science and Technology** following the Conservative victory in the 1992 elections gave rise to a flurry of government activity in the field of science policy. The office was headed by a **Minister for Science** - initially William Waldergrave, holding a cabinet position as Chancellor of the Duchy of Lancaster (a post essentially without portfolio). The effective transfer of responsibility for science away from the Department of Education and Science was intended as a general signal that the government was committed to science. As discussed below, the new overall framework also sought to integrate a number of ongoing schemes and policies initiated previously. These developments parallel the moves already noted in the US towards an overall policy for technology and research - though in the UK the executive has far more ability to set and to enforce such a policy.

> **NOTE:** Since the completion of this report in June 1995, the OST has been placed under the control of the Department of Trade and Industry. The move was an unexpected part of a government reorganisation following John Major's re-election as party leader, and has given rise to further disquiet amongst the scientific community. It seems certain to strengthen further the government's emphasis on links between industry and research and the primary importance of wealth creation as the function of research. [The Guardian, July 21 1995]

As in the US, defence spending has fallen since the end of the cold war, but still represents the most important single category of overall government R&D. In 1991/92, total government spending on R&D was £5.3bn, of which defence counted for 44.3% - almost down to its level in the 1980. [Levene & Stewart]. Compared to the American totals, it can be seen that R&D spending on defence, whilst higher than that of most developed countries, remained lower as a proportion of overall R&D than in the US. Military R&D, funded by the MOD, is projected to fall by about a third by the end of the century. The bulk of this reduction is in development - though a

15% fall in spending over five years from 1993 is projected for the Defence Research Agency which conducts almost all of the MOD's research. The proportion of R&D work for which tenders are invited is to increase significantly.

2.2.3.1 Changes to the University System

The reappraisal of science and technology policy coincided with a major reorganisation of the university system itself. The distinction between universities and polytechnics was removed, and without exception the former polytechnics rechristened themselves as universities. The University Funding Council became HEFCE - the **Higher Education Funding Council of England.** This reorganisation meant that the same funding mechanism was now applied to all institutions - and so former polytechnics were now theoretically free to compete on equal terms with universities, whilst less successful universities would loose any advantages.

The change provided one motivation for an increasing selectivity in research funding - with the number of universities suddenly increased from 51 to 85 it was clearly no longer possible to fund each one to conduct research in a full range of fields. In 1992 the system of research funding was altered, so that universities no longer received any automatic support based on their student numbers - completing the trend away from uniform funding begun in 1986 with the first Research Assessment Exercise. The assessed quality of their departments' research became the sole basis of the calculation. The emergence of an effective 'premier league' of around a dozen elite research institutions, outside of which large scale research activity is concentrated only in departmental pockets of excellence, has been accelerated by this change.

During the early 1990s the government imposed an expansion of the number of students in higher education by making a number of alterations to the formula by which universities received funding for the tuition of students. The number of students in higher education increased from 261,900 in 1988 to 436,200 in 1993. [Economist, 24th September 1994] At this point it became apparent that the government's target of one third of all school leavers going into higher education - originally an ambition for the year 2000, had been reached early and the expansion policy was reversed. Caps on student numbers were abruptly set for each institution.

The result of this expansion was a very significant strain on university teaching resources, including faculty time - imposing further stress on staff trying to combine teaching and research duties and accentuating the emerging division between teaching and research. In addition to the sharp rise in the number of students, which occurred in well established as well as newly designated universities, the decline in teaching funding paid to the university per pupil continued - between 1980 and 1994 it dropped by around 30%. [ibid.] The rise in numbers of mature students and part time students has been disproportionately large, particularly within the former polytechnics. The government incurred widespread criticism for its lack of a coherent long term policy for the expansion of education - with the sudden shifts in policy and ad-hoc nature of funding shifts making, making longer term planning almost impossible and perhaps even undermining the kind of increasing specialisation amongst universities which the government had hoped to encourage.

For the first time, formal government assessment of **teaching standards** across the system has been introduced. During the first round of assessments, during 1994-5, categorisation was made into one of three bands and the results held only very minor direct implications for funding. However, it is widely expected that the importance of the exercise will increase substantially over

coming years and a degree of selectivity comparable to that in the funding of research may emerge.

The long term result of these changes seems likely to be an increasing specialisation of universities, with the elite research institutions becoming increasingly less focused on undergraduate teaching whilst the former polytechnics look for an advantage over older universities by providing teaching more efficiently and in a more focused manner. Many established universities, including a number of the traditional civic universities, may be forced to move away from their traditional mix of teaching and research.

One university which has considerably strengthened its position in the last decade is Warwick - the most successful of the 'New Universities' founded during the 1960s and the only one to appear in most lists of prospective elite institutions. More than half their revenue is derived from business in one form or another. Many of the smaller universities from this era, with records of excellence and innovation in more specialised areas, such as Sussex and East Anglia, are eager to make sure that they maintain strong niche positions.

The most rapidly expanding of the former polytechnics has been DeMontfort University, growing from 8,000 undergraduates in 1987 to 25,000 in 1994. [The Financial Times, 9th November 1994] They have been at the forefront of move towards aggressive advertising campaigns to attract students, and have modelled their management structure on that of a corporation, with an emphasis on executive and managerial skills at the highest levels and a minimal hierarchy. Cost centres are clearly defined and coincide with academic divisions, all of which have their own targets which must be met. Efficiency is paramount, and whilst cross subsidies do occur they are transparent and must be justified.

Like many of the former polytechnics, they have always had stronger links with the local community and with local business than have most universities. At the other extreme, institutions have been experimenting with distance learning, for example Herriot-Watt's business school has grown to be the third largest in the world in terms of student numbers through its reliance on computer based teaching and communications techniques. [Financial Times, 21st April 1994]. Professional education via short courses and industrially oriented Masters qualifications has been another general growth area.

2.2.3.2 Realising Out Potential - The 1993 White Paper

The most important result of the general review of science and technology policy undertaken following the appointment of a Science Minister in 1992 was the 1993 White Paper, *Realising Our Potential*.

> 'The decision for the Government, when it funds science, as it must, is to judge where to place the balance between the freedom for researchers to follow their own instincts and the guidance of large sums of public money towards achieving wider benefits, above all the generation of national prosperity and the improvement of the quality of life.'

It suggests that this can best be achieved by a concentration of funding in areas of strength in science and technology of what is claimed to have been a consistent growth in real terms of investment in the science and engineering base. Every year a **'Forward Look**' is to be published by the government, which as well as including statistics relating to current funding is to include updates to science and technology strategy.

HEFCE is confirmed as the major source of money for basic research. Although the size of the research component of the grant received by a university depends on an evaluation of the quality of work undertaken by each of its departments, funding is supplied as a block grant to be distributed within the university as it sees fit.

> Increasingly there will be specialisation between countries. We need the capacity to maintain flexibility and an ability to understand the achievements of research leaders elsewhere. In some areas we ourselves will lead. But the UK cannot hope to stretch its intellectual or financial resources in an attempt to support work over the entire area of every research field.
>
> [page 25]

The Research Councils are to take account of the needs of their 'customers' in government and industry. The potential for uptake of research results by these users is an important criterion for distributing funding, and targets have been set for the employment of senior staff within the Research Councils from industry. The Research Councils will only support basic research in areas vital to the achievements of their missions.

The **training of postgraduates**, another responsibility of the Research Councils, is also refocused - PhD students are required to begin their postgraduate work with a Masters degree and - given that most cannot expect careers within universities - an increased emphasis on the applicability of their training to industrial careers is stipulated. Similarly, concern is expressed over the high proportion of research staff on short term contracts, most of whom have no prospect of a longer term appointment. To address this better career structuring and guidance are proposed, together with a shift of funding towards Research Fellowships rather than Research Assistantships for promising young scientists and extra support for researchers between projects.

A high profile is given in the White Paper to technology transfer. This is recognised as including a general diffusion of know-how and expertise between sectors and institutions, as well as more formal ventures. The White Paper initiated an exercise known as the **Technology Foresight Programme**. This was described in [Clement et al] as

> looking to the medium to long term, selecting and supporting areas of research considered most likely to produce winning products for British industry. The programme is intended to give early notice of emerging technologies by bringing together scientists and industrialists best placed to assess the significance of technology trends and market opportunities.

The Programme began with the identification of a number of strategic sectors, each of which is receiving its own assessment. A panel collects opinions from a wide range of experts and conducts a consultation process, from which emerge documents identifying key technologies within these sectors which

- have real scientific promise,
- strong research groups are able to carry out research in, and
- companies are willing and able to exploit results relating to.

The approach thus combines the 'science push' of strong research capabilities and the 'demand pull' of industrial interest and capabilities in the evaluation of strategic areas of support.

The results of the Programme are being widely disseminated and form a key part of the government's Forward Look publications - informing judgements such as strategy with respect to international competition and the identification of gaps and imbalances within strategic areas.

2.2.3.3 EPSRC, Its New Mission & Recent Initiatives

An immediate result of the change of emphasis has been the restructuring of the **Research Councils**. A reorganisation which included mergers in some areas and the establishment of new councils responsible for others saw responsibility for IT and Computer Science funding pass from the defunct Science and Engineering Council (SERC) to a new Engineering and Physical Sciences Research Council (EPSRC). The new body remains the largest of the Research Councils and has an overall budget of around £350 million. Another structural change was the appointment of a single Director General of the Research Councils within government, and the incorporation of the former Advisory Boards formerly attached to the Councils within the new Office.

A booklet produced by EPSRC to explain its mission clearly reflects the new governmental agenda. Headed *'Research and Training for Wealth Creation'*, it places particular stress on the need for partnership between industry and the 'research base' and the nurturing of interdisciplinary work.

> This, then, is the mission which the Government's Office of Science and Technology has entrusted to... EPSRC: to stimulate, facilitate and manage training, in the fields of engineering and the physical science, in such a way that industry makes the best use of the UK's research base and the research base attunes itself to the needs of UK industry.

The booklet does, however, stress the need for continued fundamental research - pointing out that wealth may result from unexpected sources and that basic research underlies more profitable undertakings. EPSRC is also responsible for the allocation between institutions of governmental support for postgraduate students and its 8,000 studentships support the vast majority of British research students in its fields.

> On the one hand, it is important that students develop the skills that industry requires, but it is equally important that they are trained to become a human resource in engineering and science that can both anticipate requirements before they arise, and blaze a trail of innovation....
>
> In the past, grants and studentships were roughly divided between purely curiosity-driven research and strategic (potentially applicable) research. Now, EPSRC apportions its resources both to projects that are directly related to industrial sectors, and to nurturing the health of disciplines in the research community. The shift is subtle, but significant.

Quite what the above means, in practical terms at least, remains to be seen. A statement signed by Richard J. Brook and attached to a '*Briefing for Industrialists*' is clearly designed to convey an impression of a more business like approach. He identifies himself as the Chief Executive of EPSRC and refers to their Corporate Plan. His list of objectives includes the following:

- The users of the research output, in industry, commerce, government, and the service sector will have a major say in establishing priorities. These users are the ultimate "customers" of the Councils, paying for research results and trained postgraduates via the taxation system. Users will be encouraged to indicate their needs in a manner which can prompt academic researchers to redirect their research talents to national goals.

- Guided by the OST Foresight exercise, and other inputs, attention will be given to the balance of the programme supported by EPSRC so that it is in tune with the developing national research strategy.

- The EPSRC programme will be judged according to the dual criteria of excellence **and** relevance. Relevance will embrace meeting the needs of specific industrial sectors, building strengths in support of generic technologies, and sustaining the health of the core research disciplines. Applicants for support will be asked the question "who will benefit from this research?".

Changes are also underway in the criteria applied to distribute research funding via HEFCE, the other main channel for government support. Most importantly, guidelines for the next Research Assessment Exercise, due to begin in 1996 although it will cover work undertaken since the last grading, specify that published academic work will no longer be the only material considered in judging the research quality and output levels of departments. Contract research for industry, applied work and patents will all now be considered on an equal basis, and it is likely that the assessment teams themselves will for the first time include industrial representatives. This exercise will also see the number of grades used increased from five to seven, further increasing selectivity of funding.

2.2.3.4 Recent Technology Transfer Initiatives

Many schemes which were already in operation are now regarded as important parts of the new overall strategy for the direction and exploitation of research. These include the LINK programme run by the DTI, the SMART scheme to support innovation in smaller businesses and the **CASE - Cooperative Awards in Science and Engineering** - scheme for joint funding of PhD students. Under this scheme the student gains a slightly enhanced bursary from EPSRC, and a further £2,000 or more from the companies sponsoring them. The company makes a further contribution of at least £1,250 towards the costs of the university department, and must host the student on-site for a portion of their study - in return they gain the chance to set the student to work upon a project of interest to the company.

Another existing initiative which is favoured by the new emphasis involves the IRCs or **Interdisciplinary Research Centres**. These are hosted by one or more academic institutions and receive some funding from EPSRC, in the vicinity of £1 or £2 million each per year, over a period of around ten years - they are also expected to secure industrial support. Each is staffed by 15 to 30 core staff, plus a number of short term researchers (20 to 40) and a number of technicians, support staff and secondees from other institutions and industrial researchers. At the time of writing eight centres were fully established, including one researching Semiconductor Materials and another working with Optoelectronics. They are intended to be internationally competitive and to ensure the application and exploitation of results by industry. See section 4.2.6 for a discussion of the growing importance of interdisciplinary work in computer science.

A new governmental initiative is the ROPA scheme (**Realising Our Potential Awards**) which provide additional funding to selected researchers - an eligibility requirement is to have attracted pre-existing support from industry to a minimum value of £25,000. A **Teaching Company Scheme** provides incentives to companies to employ recent graduates on projects of strategic

importance in collaboration with an academic supervisor - various government bodies act as sponsors, principally the EPSRC and the DTI. In the field of Engineering a new qualification, the **Engineering Doctorate**, is being offered by some institutions. This includes a taught component and is designed to offer skills in areas such as project management, teamwork, leadership and communications skills, financial planning and environmental impact assessment as well as a research project - which must be undertaken in collaboration with a sponsoring company.

3. CENTRAL UNIVERSITY FUNCTIONS AND STRUCTURES

All of the participating universities had at least one office of which the primary function was the commercialisation of inventions made by members of the university. They had all entered into sponsored research agreements with industry, and all had a 'development' capability which included the solicitation of gifts from industry.

There are a number of functions relating to industrial co-operation which are usually or sometimes provided by central university offices. These are summarised in Figure 3-1 over leaf. However, a range of different patterns for the distribution of functions between offices was observed.

This chapter examines how each of these broadly identified groups of functions is handled by the institutions surveyed. Not all the functions are assigned to central university bodies in all of the institutions, and in most cases more than one of the major functionality groups are assigned to a single office. Figure 3-2 shows how these functionality groups are distributed between different offices in each of the ten institutions surveyed. The exact structures employed at several institutions are then documented for both the US and UK, together with interesting aspects of structures in place at the other institutions surveyed.

The emphasis here is firmly on organisational structure rather than procedures and policies. The latter are dealt with in detail in following chapters, but this material is placed separately in order to illuminate the frameworks behind what follows and to allow clear comparisons to be made between the structures in place at the different institutions surveyed.

1	**Corporate Development**
1.1	Cultivation of relationships with highly placed alumni within corporations.
1.2	Solicitation of gifts and grants from companies and their foundations**.**
2	**Industrial Liaison**
2.1	Direction of industrial enquiries to appropriate research groups.
2.2	Compilation of database or listing of university research activity and expertise.
2.3	Involvement of industry via seminars and other schemes. (*)
2.4	Broadening and deepening of existing relationships into new areas. (*)
3	**Sponsored Research:**
3.1	Advice to faculty members over possible industrial research partners. (*)
3.2	Dissemination of information regarding all forms of research support available, including government funds for industrially strategic work and joint projects with industry.
3.3	Negotiation of terms (especially re. IPR and commercialisation) in research contracts.
3.4	Administration of contracts.
4	**Technology Transfer:**
4.1	Routine screening of technologies produced by university research. (*)
4.2	Disclosure of technologies resulting from government funded research (US)
4.3	Evaluation and patenting where appropriate of promising technologies.
4.4	Licensing of technologies to commercial companies.
4.5	Assistance in establishment of spin-off companies. (*)
4.6	Exploitation of technologies through university controlled companies. (*)
4.7	Administration and monitoring of licences.
5	**Consultancy Support:**
5.1	Advice and guidance to faculty regarding terms and conditions.
5.2	Monitoring of potential conflicts of interest. (*)
5.3	Administration of contracts concluded on non-private basis. (*)
6	**Other Activities Outside Scope of Report (sample)**
6.1	Executive education.
6.2	Services and use of university facilities.
6.3	Careers service, provisions for graduate placements and work experience, etc.

Figure 3-1: A taxonomy of research oriented industrial interaction functions sometimes performed by central university bodies.

NB: Those items marked (*) were less frequently performed by a central body.

	1: Corporate Development	2: Industrial Liaison	3: Industrially Sponsored Research	4: Technology Transfer	5: Consultancy
MIT	Corporate Corporate Development	Relations Industrial Liaison Prog.	Office of Sponsored Programs	Technology Licensing Office	Conflict of interest policy, no central regulation
Thayer School of Eng (Dartmouth College)	(Thayer Dartmouth Development	School & College) Offices	(Dartmouth	College) Grants and Contracts Office	Thayer School Dvlp. Office
Brown	Development Office (not IPR clauses)	No central management. (CS dept prog.)	Office of Research Administration (coop. with -->	Brown University Research Foundation	Disclosure to Head of Dept.
Harvard	Development Office	No central facility.	Office of Sponsored Research (not IPR clauses)	Office for Trademark and Technology Licensing.	Scrutiny, COI, etc. mostly on Faculty level.
Harvard Med. School			Office of Transfer and Sponsored	Technology Industrially Research	<--- Advice and Guidance
Pennsylvania	Separate office.	?	Admin separate. Most negotiation -->	Centre for Technology Transfer	?
Yale	Development Office	(coord.)---> CS Dept Prog.	Office of Research	Cooperative (OCR)	<-- Advice & Guidance.
Cambridge	Development Offices in University & Colleges.	Industrial Liaison and Technology Transfer Office	Negotiations and IPR by <--- (Admin separate office)	<-- coordinates. University company is legal mech.	Little formal regulation or policy. <-- Advice
Manchester	little activity, charity grants by -->	Research (Industrial Manager)	Support Unit	University Company (Vuman) <-- liaise	Some contracts administered by RSU.
Newcastle	little activity, charity grants by -->	Research	Services Unit	University Company (NuVentures) <-- liaise	<-- Advice & Guidance

Figure 3-2: The distribution of industrial interaction functions between central university bodies in the institutions surveyed.

3.1 Overall Structures At US Institutions

Whilst the nature of the methodology employed means that most findings are based on a sample too small to permit generalisation, this study does represent a largely complete survey of structures for industrial interaction in Ivy League universities.

3.1.1 Case Study: MIT

MIT was the participant institution with the most extensively developed industrial ties and the one most frequently mentioned as a model by those working in the field.

MIT is unusual in having a well developed Industrial Liaison Program (ILP) conducted on a central basis - the functions identified under (2) above are all the responsibility of this office. Since 1988 the ILP has been grouped with the corporate development function (1) to produce the Office of Corporate Relations. Members of the ILP pay a sizeable fee for access to its services.[4]

The Office of Sponsored Programs (OSP) had, as the name suggests, responsibility for the mechanism by which companies sponsor research. The OSP negotiated and administered research contracts, and performed the other tasks identified under (3). An Intellectual Property Officer assisted principle investigators and administrators during negotiation and provides expert interpretation. The OSP was also responsible for other externally sponsored research, such as government contracts.

The Technology Licensing Office (TLO) was responsible for the functions grouped under (4) above. Interaction between the TLO and OSP occurred to the extent that contractual obligations regarding the exploitation and ownership of results might have been established if the research was conducted under contract. Industrial knowledge and contacts were also shared between the two offices. The TLO was staffed by people with technical and business expertise, and the legal aspects of patenting were performed by external lawyers.

To give an idea of the scale on which this relatively large office operated, the TLO employed a total of 25 people, of whom ten were Technology Licensing Officers and twelve support staff. During FY ‘94 362 disclosures resulted in filings for 225 patents, and the issuing of 125 patents. 83 licences and 15 options were granted, and 14 companies started. Gross revenues totalled $8.7 million, of which $6.7m came from royalties and $1.7m from Patent Reimbursement. Patent costs were $4.1m.[5]

MIT did not operate university controlled companies to exploit results, and so function (4.5) was redundant. Technologies suitable for start-up companies were identified, and introductions made to investors but no financial assistance, preferential treatment or help with business plans were given to the new company and MIT would not have been involved in its management.

Consultancies were handled on a private basis, and so no contracts were administered centrally. MIT had clear and well developed conflict of interest policies and required disclosure of, for

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[4] see **Error! Reference source not found.** - Interview with Dr John Leech of the MIT Industrial Liaison Program.

[5] see **Error! Reference source not found.** - Interview with Alex Laats of the MIT Technology Licensing Office and [MIT].

example, equity positions in firms concluding licences with MIT. Heads of department monitored such situations, and the faculty member would not be have been able to receive research support from the company.

3.1.2 CASE STUDY: DARTMOUTH COLLEGE

In many ways Dartmouth represents the other end of the organisational spectrum from MIT. It was a small, liberal arts college with a very low proportion of graduate students compared to a research oriented institution such as MIT. My research focused on the Thayer School of Engineering - a financially independent and semi-autonomous body within the College.

A single office within the college was responsible for a wide spectrum of industrially oriented functions. As well as including the activities characterised as Corporate Development and Industrial Liaison (function groups 1 and 2 above), it was also active in the placement of students in companies, the establishment of consultancy arrangements for faculty members and the writing of grant proposals. Central offices within the College itself dealt with Foundation Relations and with Grants and Contracts. The Thayer School office worked closely with these.

> The Thayer School office employs three people in its development office. The director handles major gifts and oversees generally, Mark Woodward who handles foundation and corporate relations, and a third person who deals exclusively with the 'Annual Fund'. They work together very closely - ‘we have the same databases, we talk, we know who's talking to whom about what, we give each other leads....’ so that someone initially approached as, for example, a member of the Corporate Advisory Board might also be persuaded to contribute to the annual fund.
>
> > ‘This system - which to my way of thinking is how it should work everywhere - is hardly how it works anywhere. There are a lot of corporate and foundation relations people who are not considered to be integral with the development function in the same way that [we are], there are out there a lot of miscommunication and bad communication and just bad reporting relationships among the various sectors of development functions.... Everyone is envious of me when I talk about how we do things and I don't understand why other people don't.’[6]

Consultancy was not closely supervised or monitored. Conflicts of interests with regard to start-up companies were closely scrutinised by the Grants and Contracts office which tends to the cautious. Faculty contracts specify maximum time allowed for consultancy.

This kind of integration had an obvious relationship to Dartmouth’s relatively small size. However, it appears to have led to a more integrated approach to the managing of the relationships on which these all functions depend. An interesting observation is that Dartmouth appeared to be able to deal more flexibly with companies as a result - so that, for example, when a company was reluctant to make a pure donation and sought something in return, something which they stressed is becoming very common, they were able to offer corporate education or sponsored research in return. *‘Pools of money’* could be tapped from technical, public relations and advertising budgets as well as private foundations which the company might have set up.[7]

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[6] see **Error! Reference source not found.** Interview with Mark Woodward of the Thayer School at Dartmouth College

[7] see **Error! Reference source not found.** - Interview with Peter Knox of Dartmouth College Foundation and Corporate Relations

The establishment and maintenance of a long term relationship, established and maintained on a personal basis, is crucial to development - just as it is to research collaboration. The integration of industrial liaison with corporate development, also noted at MIT, would thus seem to have considerable advantages.

3.1.3 OTHER US INSTITUTIONS.

Brown University differed from the other institutions studied in that its technology transfer functions were handled by the Brown University Research Foundation, under contract, rather than by an actual office of the university itself. The Foundation also plays a part in the negotiation of research contracts with industry, though the Office of Research Administration is responsible for contracts in general. Sometimes they may work with the development team if a company expects some kind of IPR in return for a donation.

At **Harvard**, the Office for Trademark and Technology Licensing is responsible for technology transfer. No central industrial liaison program exists, and sponsored research administration is in general handled by the Office of Sponsored Research, although the OTTL reviews and approves IPR terms in industrial agreements and will join negotiations when requested. The Medical School has its own office, combining responsibility for both technology transfer and industrially sponsored research.[8]

> 'This office is the office of Technology Licensing AND Industry Sponsored Research. I would argue that [the cultivation of industrial research funds] is an important activity which should be handled by the licensing office because the targeting has got to be done in science and technology terms, so you're trying to match up an interesting piece of work with a company which has an interest in that field. They don't give broad brush funding anymore, so that's an essential activity - otherwise research which might be industrially funded will never see the light of day.[9]

Yale vests responsibility for both industrially sponsored research and technology transfer in its Office of Cooperative Research. It has responsibility for industrial liaison programmes, which are focused on a departmental basis. Conflict of Interest emphasise disclosure and monitoring by chair of department, voluntary guidelines exist of consultancy with advice and guidance available from the Office of Cooperative Research to protect their interests.

3.2 OVERALL STRUCTURES AT BRITISH INSTITUTIONS

The three British universities included in the study - Cambridge, Newcastle and Manchester - represent a quite limited selection. A more exhaustive survey would include some of the other leading research institutions with substantial industrial funding, such as Imperial, Warwick, Nottingham and Edinburgh, as well as representatives of the former Polytechnics - which often have a proportionally higher reliance on industrial funding to support their research.

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[8] see **Error! Reference source not found.** - Interview with Donald Walker of Harvard Office of Trademark and Technology Licensing

[9] see **Error! Reference source not found.** - Interview with Peter Williams of Harvard Medical School Office of Technology Licensing and Industry Sponsored Research

3.2.1 CASE STUDY: MANCHESTER & NEWCASTLE

As can be seen from the table, organisation and policy at Manchester and Newcastle were very similar, and can be taken as representative of the situation in the larger civic universities. In both cases a single body, known as the Research Support/Services Unit had responsibility for all aspects of research funding. This included negotiation and administration of industrial research contracts, as well coordination of preparations for the government's Research Assessment Exercise and applications for EU funding (much of which requires industrial partnerships). Newcastle adopted this structure in 1990 and was one of the first of the large civic universities to do so, Manchester followed in 1994.

The advantage of this integrated structure is that academics seeking funding for a project can gain advice on all possible forms of funding form a single office and in a manner which is focused on the project itself. Manchester received a total of around £28 million from HEFCE in 1993/4, grants and contracts totalled a further £39 million - of which approximately £4 million came from industrial sources. The bulk of this came from a few large awards in the medical and life science area.

As in most British universities, Development was a small scale function focused on alumni rather than the solicitation of large scale donations from companies, though the office was newly formed and its activities were to be expanded. Fundraising from charities, which did form a significant source of research funding, was included in the work of the RSU.

At **Newcastle** the industrial total and proportion was similar. Another 10% (£4m) of the grants and contracts were from EU projects, with another £3m coming from the UK government departments - much of it from the DTI (Department of Trade and Industry) and so targeted towards industry through mechanisms such as the LINK programme. The RSU undertook some general promotion work for university research, produced a comprehensive directory of research and helped academics find industrial partners in other EU countries. It also had responsibility for general industrial enquiries - these are much more likely to come from small companies.

In both cases, technology transfer and licensing are undertaken in collaboration with a wholly owned university company rather than an office of the university. The companies were also involved in the negotiation of exploitation terms in sponsored research agreements. At Manchester the company was known as **Vuman** and integration was achieve by making the CEO of Vuman head of the appropriate division of the RSU. Vuman protect and license intellectual property, they also set up companies with majority university ownership to exploit it - something none of the US institutions would consider doing. A number of other subsidiary companies provided mechanisms for marketing university expertise and facilities rather than technology.

Some consultancy arrangements were processed as agreements with the university. The university does not receive revenue, and the consultant benefits from the university's liability insurance and support with negotiation.

More than forty universities have adopted the idea of a university exploitation company, which allows universities to overcome the restrictions on trading imposed by their charitable status.

3.2.2 CASE STUDY: CAMBRIDGE

Because of Cambridge's long history, the organisational patterns which it has evolved are rather complex and can be confusing to the outsider. Particularly distinctive is its collegiate nature, whereby considerable power and financial resources are concentrated in the colleges themselves rather than the university or its academic departments.

As its name suggests, the Industrial Liaison and Technology Transfer Office was responsible for the functions identified as falling into these categories (function groups 3 and 4 above). It was also responsible for negotiations of intellectual property terms in research support contracts, and worked closely with the offices which administered these.

A technology exploitation company, called Lynxvale, existed. It was closely tied to the Industrial Liaison and Technology Transfer Office - the director of the former was a director of the latter. Unlike many university companies, Lynxvale had no employees and existed purely as a legal and financial mechanism. Lynxvale, rather than the University, applied for patents on Research Councils funded work and concluded licences for technology and software with other companies. The Office was also involved in assistance to start-up companies, in which Lynxvale held stakes.

The Industrial Liaison aspect of the Office's function included dealing with speculative enquiries from companies - quite common in Cambridge due to its excellent research reputation and the number of small high technology companies in the area.

Formal regulation of consultancy and other faculty activities was minimal, provided that responsibilities to the university, department and college are being met. Cambridge did not claim rights to inventions made by an member of staff unless they were directly supported by external funds - a policy shared by only a very small number of other British institutions.

4. RESEARCH RELATIONSHIPS

4.1 INDUSTRIAL RESEARCH

A corporate cost centre which funds research in a university is likely to be doing so because the results of the research are in some way valuable to it. Note that 'the results of the research' need not mean simply the analytical findings, papers and intellectual property which ensue, but may include many other things which occur as a result of the research or collaborative process itself taking place.

However, the decision to support work in a university is also a decision not to conduct the same work on a solely in-house basis by a corporate research team. In order to understand why a company might wish to support a piece of university research it is therefore first necessary to have an appreciation of the reasons why companies undertake research in the first place, and of the extent to which the same benefits may be accrued by supporting an external team.

4.1.1 WHY DO COMPANIES CONDUCT RESEARCH?

A distinction is conventionally drawn between basic research, applied research and development work. Basic research is held to be work undertaken without a specific non-scientific goal in mind, simply to expand the limits of human knowledge. Applied research is research towards a particular goal, and development work is the application of techniques resulting from research to produce a product which can be manufactured and sold commercially.

Basic research is often understood as the preserve of the university, and to involve such 'pure' disciplines as physics and astronomy. Applied research is undertaken in corporate labs and in university departments such as engineering and computer science. Development work is not traditionally undertaken by universities, but is the exclusive preserve of industry.

Of the three, development is the only activity which can usually lead directly to revenues for the company, though sometimes research might produce patents which can be licensed or used to create a monopoly. According to the classical, linear, model of the process the function of research within a company is to create new inventions and techniques which can then be fed 'down the pipeline' to development teams, turned into products and sold to produce revenue. In many modern markets, especially IT related fields, the continual introduction of new technologies and the improvement of processes is necessary simply to retain a marketable set of products. A high level of development activity is therefore required simply to remain viable.

4.1.1.1 Basic Research in Corporations

Corporations do sometimes conduct basic research, and indeed IBM and AT&T have been well known for their scientific research capabilities and the contributions they have made to the world of science. A Bell Labs team won the Nobel prize for their discovery of cosmic background radiation, confirming the big bang, whilst an IBM group made the initial discovery which lead to a flurry of developments in higher temperature superconductors in the 1980s. Multinational petrochemical and pharmaceutical corporations maintain sizeable labs.

Such central facilities, conducting strategic and general research, complement more applied and development oriented work conducted in business divisions. Not only do they involve a very substantial financial investment, meaning that only large and profitable firms can afford to maintain them, but it is also the case that only a company with operations spanning a wide range of technological fields is likely to be in a position to make use of a significant proportion of the results of more general research. Companies like IBM and AT&T once enjoyed such dominance within their industries that they could be confident that they would be in a position to benefit from any new technologies with potential to expand their markets. They would also be better placed to exploit the advantage of being the first to introduce a new type of product. It was not necessary that they should be the only company to benefit from research in order for it to be worthwhile for them to undertake it. The further removed a piece of research is from known applications, the greater the inherent risk and the less likely the direct result of the work is to be patentable.

As suggested earlier, (2.1.2.3) the US government also had a part to play in the expansion of research and development activity among American firms.

> The rise of corporate R&D in the US had two sources, Partly it was the result of major increases in private corporate R&D funding, based on optimistic beliefs in the profitability of such investments which, by and large, turned out to be well founded. Partly it was due to massive DOD, and later NASA, investment in new systems. In the mid-60s, private funds accounted for about half of corporate R&D, government funding the other half.
>
> [Nelson]

In a paper entitled *Why do firms do basic research (with their own money),* Nathan Rosenberg suggests that the returns for the company are more likely to be in access to the expertise of the researchers than the direct outputs of their research itself. Further more

> Historically, some of the most fundamental scientific breakthroughs have come from people like Carnot, Pasteur and Jansky, who thought that they were doing applied research.
>
> [Rosenberg a]

Furthermore, scientific research itself is not necessarily free to access. Ostensibly, research findings which are published in a journal can be used by any one - which might suggest that the knowledge produced is now public property. In fact, the information has only been released to a relatively small scientific community, who are not only likely to be the only people to read it but may well also be the only people equipped to understand the results and their importance. A major part of every scientist's job is to keep pace with developments in their specialised field, hence the central importance of journals and conferences to scientific life. The potential importance of new discoveries is therefore only apparent to those sharing what has been called the same paradigmatic background.

By employing a scientist working in a particular area, a company thus gains access not only to his findings but to the findings and insights produced by the whole of his or her particular scientific community. Only with the benefits of such expertise can companies hope to make use the findings of research performed elsewhere. Statistical conformation of this is provided by [Gambardella] with respect to the US pharmaceutical industry, showing that the existence of in-house scientific researchers raised the ability of the firms to take advantage of 'public' science.

> Although knowledge is a public good it cannot be absorbed costlessly. Instead, depending on the type of knowledge and the characteristics of the firm, a certain level of internal R&D has to be conducted in order to create an absorptive capacity.
>
> [OST & PREST]

As well as this specialised professional expertise which is shared by colleagues working in the same field still more specialised expertise and capabilities, often known as 'tacit knowledge', develop as a result of carrying out research. This tacit knowledge will not be available simply from reading a short account of an experiment or procedure in a journal. If we take scientific knowledge as involving the ability to do something, it may be that important aspects of this knowledge cannot easily be formulated and passed on to others through formal mechanisms.

A well known demonstration of this is the study of the diffusion of the TEA Laser presented in [Collins]. An exciting new type of laser was produced by a Canadian laboratory, and announced to the world in 1970. With the right skills, it took no more than a few weeks and a few thousands of pounds to produce one, and so a number of British labs attempted to build their own. Despite the existence of several publications relating to the laser, successful attempts to reproduce it resulted only from direct contact with those who had been successful - via visits, telephone calls or exchange of personnel. The crucial importance of certain elements of the design became apparent only in retrospect when experience had been gained, and only those who had themselves practised the skills involved could pass them on the information in a usable form. Some labs adopted a subtle technique of not passing on important information which was not specifically requested. Many of the successful contacts were based on previous personal relationships.

> The benefits of basic research tend to be localised because they involve the transfer of tacit knowledge. That transfer process is best achieved through people working together, the implication of which is that there needs to be mobility between institutions and sectors.
>
> [HMSO 1994]

When a company allows the results of its research to be published, it does not follow that they see themselves as placing the benefits from that research in the public domain. Some inventions can be protected by patents, and what is published may only be a part of the original research.

> 'Look at publication as a management tool... you need external validation, and all research organisations need that, to make sure that the work which is going on is world class. The fact of publication is a good way assessing your credibility, also it's a good way of "moving the barrier", and as a manager you can insist on certain kinds of publication.... It's also important motivationally that the people feel that they are in a community, and that community is of course providing feedback and the flow of information and knowledge in is often much greater than the flow of information out.'[10]

Bob Anderson, Director of Rank Xerox's Cambridge lab, provided an insight into the other functions which a lab conducting research into techniques involved in 'next generation but two' technologies fulfils for its parent organisation.

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[10] see **Error! Reference source not found.** - Interview with Bob Anderson - Director, Rank Xerox Research Centre

> ‘Envisionments, prototype technologies, design specifications and intelligence. What corporate research does for Xerox is to manage risk, it reduces uncertainty. All these things are outputs by which we reduce uncertainty for Xerox.... We do lots of other things for Xerox that it doesn’t really often recognise it gets - we give it high visibility, we penetrate communities... we provide a certain credibility for some of its longer term envisionments and provide a “feel good factor”....’

These less obvious contributions can be very important. For example, to retain and motivate able and ambitious staff it is essential for a corporation to present a credible future strategy for continued growth and the potential for “exciting” careers. ‘Corporate research provides a part of that internal credibility, and I think that’s something which is often forgotten.’ Equally important is the appeal to customers of knowing that their investment in the relationship is protected by corporate commitment to technological improvement.[11]

4.1.1.2 The Complex Relationship Between Research and Development

> 'Until recently most academics had the concept that you watered the tree of basic research with dollars and the fruits of that tree would be inventions, and in much the same way that an apple falls from a tree, an invention would sort of fall (somehow), in rich fallow ground (somewhere) and spring forth into a new product'.[12]

We have seen that the main advantage gained by companies from conducting research (as opposed to development) is probably the development of expertise and access to externally produced knowledge rather than the generation of results of direct and proprietary commercial significance. We have also seen that in many areas of both science and technology ‘tacit’ knowledge, embedded in people and their skills, is essential to the use of new techniques and to the production of new products.

The idea of a linear flow, whereby an orderly and methodical progression turns the results of basic research conducted in an undirected manner into applied research, which then identifies applications which are developed into prototypes, and eventually products, is no longer generally accepted as a model for the innovative process.

> ‘We used to talk about pipelines... we don’t talk about pipelines anymore, transactions are one thing that we think about - the ways in which we are exchanging between groups.... It’s no longer viewed in this linear way where we “see what’s coming down the line” or try to “speed up the flow”’.[13]

The evaluators of the Alvey Programme identified three factors which cause a non-linear progress from research to project (and therefore make very problematic the attempt to measure exploitation resulting from a research programme.)

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[11] see **Error! Reference source not found.** - Interview with Bob Anderson - Director, Rank Xerox Research Centre

[12] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

[13] see **Error! Reference source not found.** - Interview with Bob Anderson - Director, Rank Xerox Research Centre

- individual end-products often owe much to a multiplicity of R&D inputs other than the discrete input being evaluated;
- discrete R&D inputs can often influence the evolution of a multiplicity of outputs, some quite directly, but many others much more indirectly and subtly;
- the flows of information, influence and impact from input to eventual output are rarely unidirectional, with many feedback steps involved in a complex, non-linear process.

[Guy et al, page 158]

The discussion of their findings in section 2.2.2.3 above, suggests that often research collaborations were regarded as valuable by both participants even though they did not lead directly to patents or products.

> 'If nothing I did in the lab ever ended up in the marketplace then people would start to ask questions, but if 90% of what I do never ended up in the market place that wouldn't necessarily be a disaster - as long as it was clear that we made the decisions and what the basis of those decisions was.'[14]

It has been suggested that research and development patterns can be categorised into 'offensive' and 'defensive' approaches [Webster]. A defensive strategy involves marginal improvements to products and the incorporation of innovative technology only where necessary to maintain competitiveness, an offensive strategy implies a commitment to the research in novel areas in search of radical new innovations.

However, the fact that a company has chosen to allow its researchers to undertake work in a particular area does not imply that it is necessarily interested in transforming whatever prototype is developed into a commercial system. The production of a prototype usually costs only a fraction of the amount needed to bring a product to a manufacturable and economically competitive state, and considerable further investment is required to market, distribute and support a new product. The company will have its own strategic direction, which will usually be driven by their desire to achieve a particular position in the market place by meeting the needs of a particular class of customer. The deployment of innovative technology is a means to meet those needs, rather than an end in itself, and the company must remember that its customers have their own investment in its previous technologies to balance against possible advantages of a new technology. As an organisation a corporation will also have made considerable investment in existing technologies.

> 'If any organisation tells you that they've got a smooth flow from research into development then they're lying to you. It's a political process... it's about negotiation, it's about getting win-win situations, making investments.... Taking a technology, no matter how revolutionary it is, and getting a development group that's made a amount huge investment in personnel and skill to accept it, if that technology actually undermines what they've invested in, is extremely difficult.... '[15]

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[14] see **Error! Reference source not found.** - Interview with Bob Anderson - Director, Rank Xerox Research Centre

[15] see **Error! Reference source not found.** - Interview with Bob Anderson - Director, Rank Xerox Research Centre

In the computer industry, most activity seems to be defensive. This is interesting, because there is no other industry (except perhaps for fashion) in which constant change and development of products is so universal. Customers and suppliers both expect the computer power available for a fixed price to double in less than two years, and outside the most specialised of markets no particular version of a product has a life of more than a few years, whilst software must constantly be updated to support new operating systems, customer demands and integration with other systems. Despite this constant change, it is rare for a system offered by one manufacturer to offer capabilities which differ radically from those offered by other vendors, and rarer still for such features to remain unique. Especially in commodity markets, such as the PC industry, technologies (hardware and software) only become established if supported by most of the major players. In many fields industrial consortia, and sometimes international standards groups, play a key part in defining progress.

Computer products are therefore the embodiment of a complex web of different technologies. Whilst constant improvement to designs is required to maintain the performance and power improvements expected, there is much less scope to introduce new kinds of product if these might be incompatible with existing systems. The industry has its own momentum, and seems increasingly to evolve technologies incrementally - modern PC architecture is a hugely clumsy result of a decade of gradual change. Carrying out basic research and constructing prototypes involving new technologies may give a major computer company competencies in new areas, allowing the development of products involving new technologies when the time is right, but even the largest companies can no longer control the market sufficiently to pursue an independent technological strategy. The products into which new technologies will be incorporated are hard to predict, except to some extent for discreet devices like memory and processor chips or mass storage devices where future demand for increased power, decreased size and so on can confidently be predicted. As Alex Laats at MIT commented, a company is unlikely to be seeking research collaboration to '*establish the standard for high speed computing in the year 2000 or 2005 - they're working on next year's chip*'.[16]

This impression is supported by analysis presented in [Kash & Rycroft]. They argue that shifts in the importance of different types of technology, as evidenced in the breakdown of world trade figures, shows a clear shift from simple products and processes towards complex products and processes. In 1970 simple products and processes, of the kind which can be most easily patented and licensed and the development of which may be adequately described by the linear model, accounted for 58% of world trade by value, but by 1990 this had diminished to just 12%.

The balance has shifted decisively to technologies involving the production of complex products by complex processes. Whilst these technologies often exhibit continuous innovation, changes are usually incremental and involve gradual improvements to existing products. The direct input of science, as opposed to engineering, is minimal and little university research is directly commercialised.

> For complex technologies, however, base understanding often plays little or no role in commercial success. Even when it is linked to product or process innovations, its impact may be difficult to separate from a pattern of cumulative tacit learning and the utilisation of technology provided by other sectors.
>
> [Kash & Rycroft, page 80]

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[16] see **Error! Reference source not found.** - Interview with Alex Laats of the MIT Technology Licensing Office.

4.1.2 The Changing Nature of The Computer Industry

It is not just universities which have changed their attitudes and modes of operation over the last fifteen years. Many industrial organisations have undergone still more profound changes and reorganisation during the period, particularly in the IT field.

Despite the huge technological advances made over the last fifteen years, and the massive increases in unit sales, once dominant firms such as IBM and DEC have lost their stranglehold on the market. The rise of the microcomputer has seen hardware become an inexpensive commodity with very low profit margins - only now Intel commands the kind of profit margins enjoyed by IBM in its prime. In the 1970s the corporate computing market supported a relatively stable industry, improvements were steady but incremental, proprietary systems were almost universal and single-vendor sites the norm - giving rise to a stable customer base with long term commitments.

In the 1990s this has been replaced by fierce competition in every market sector, a convergence on open systems and standards and the widespread usage of heterogeneous systems involving the integration of commodity products from a range of suppliers. At the same time, software companies such as Microsoft release new versions of their products continually and vendors of applications, utilities and tools need to keep pace - with the result that the replacement rate of software, and of hardware capable of running it, have gone up as unit costs have gone down. The main areas of growth and profitability within the IT sector have been in consultancy and service provision.

Corporations have reacted to increased global competition by seeking greater efficiency, encouraged by the free market ethos promoted by governments in both the US and UK during the 1980s. Most large companies have substantially reduced their workforce over the last decade, and many have sought efficiency through the breaking apart of monolithic management structures to create smaller units better able to respond to customer demands. Often this takes the form of a internal marketplace, with different ‘businesses’ serving different customer groups (vertical integration by market) and contracting with each other to provide corporate services. ICL, the British based computing group, has moved so far in this direction as to close down its corporate headquarters all together. IBM, after recording some of the worst losses in financial history in the early 1990s, has moved in the same direction - and at the time of writing is now healthily profitable, having adapted to the loss of its former hegemony.

Because a principle goal of this kind of reorganisation is the elimination of central corporate expenditure which is not directly required to service customer needs, it is not surprising that it has mediated against the continued existence of large, central research organisations undertaking work not directly related to core products. Research funding, whether of an in-house group or an externally sponsored academic team, is now scrutinised far more closely than before. At Xerox, restructuring of relationships has

> ‘forced a closer alignment... in both dimensions. Researchers have become more concerned with knowing how business is going, but the business themselves now realise that they are dependent on research, and since they are paying for it... they ask questions like “How can I make sure that the investments I am making are the right investments for me to make.”[17]

Of course, this theoretically also opens potential opportunities to universities if they are able to show that a contract with them represents better value for money than the employment of an internal team to conduct a particular piece of research.

> ‘In places like Digital and IBM there are two conflicting forces at work - one is a very strong pressure to contain costs in the short term, the other is the sincere realisation of top management that the only hope of these large companies of surviving is to discover these high-overhead applications and to be in that market before everyone else is. On the one hand research is expensive and hard to evaluate - but if you don't do research then basically you're going to end-up building washing machines. The profit margins on building PCs are so razor thin that you can't support a company of the size of Digital or IBM. Research is at least touted as being the best way to do this - whether it is or not is somewhat mysterious.'[18]

This is part of a more general trend towards the ‘outsourcing’ of as much peripheral activity as possible, motivated by the idea that a company will function most efficiently when it is able to concentrate on those aspects of its business in which it has the most unique expertise and is thus best able to ‘add value’. Tasks such as building maintenance, administration and support of computer systems and component production can therefore be transferred to contractors and suppliers of one kind or another, leaving the core organisation smaller and more adaptable. If misapplied this process has potential to weaken a company’s ability to conduct long term research. A similar move to a ‘profit centre’ organisation occurred within the chemical industry during the 1960s and 1970s:

> More than ten years were needed for the most vigorous companies to realise that profit centres were destroying one of the strengths of the chemical company as an institution of technological change - namely its multiproduct character which allowed for the cross fertilisation of technologies and the diversion of some cash flow from prosperous to problematic and emergent sectors... Another common corporate policy was to seek growth and diversification by acquisition of small companies... that policy proved largely unsuccessful as the smaller parties could not impose their technological goals on the established and still thriving corporate technological traditions of the parents.
>
> [Achillandies et al, page 30]

Against this background of globalisation and widespread discussion of the ‘virtual corporation’, much attention has been focused on the places within such a network where ‘added value’ is produced. On a national level, is the most benefit derived from housing a corporation with most of its manufacturing overseas, or from hosting the manufacturing capabilities of a foreign owned company? If a company places research centres overseas in order to benefit from local expertise, are they benefiting unfairly from local investment in scientific infrastructure, or are they strengthening and broadening local activities? [Sparrow] [Granstand, Håkanson & Sojölander]. Some have suggested that multinational corporations are becoming ‘stateless’, capable of shifting

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[17] see **Error! Reference source not found.** - Interview with Bob Anderson - Director, Rank Xerox Research Centre

[18] see **Error! Reference source not found.** - Interview with Maurice Herlihy of Brown University Computer Science Department

their headquarters and research facilities in order to benefit from changing conditions with as little hesitation as they already relocate their factories.[19]

Although the answers to such questions lie well outside the scope of this report, these questions have played an important part in discussions of national science and technology policy and have a direct bearing on technology transfer. It may be that in the future national expertise continues to become more focused on particular activities and technologies - following the pattern seen in the UK over recent years.

[19] Robert Reich, a Harvard economist and US Labour Secretary, is a leading exponent of the idea that nationality of ownership of multinationals has become unimportant.

4.2 COOPERATIVE RESEARCH

Industrial support for research is, across the US university system as a whole, a significant but secondary source of funding. In the US 56% of all academic R&D was funded by federal sources in 1993, down from 68% in 1980. 20% came from the institutions' own funds, and 7.3% was funded by industry - almost twice the 3.9% total reported in 1980. [NSF]

In the UK, those universities with the largest and most successful research programmes have in general been amongst the most successful in gaining industrial funding, at least in absolute terms. In some cases a rather higher proportion of research funding at universities with less activity overall comes from industrial sources. In the list below, Nottingham is notable as an institution which has improved its research standing, and industrial funding, in recent years.

Greatest Recipients of Industrial Research Funding, 1993		
1st	Nottingham University	£6.3 million
2nd	Imperial College, London	£6.2 million
3rd	Cambridge	£5.9 million
4th	Oxford	£4.8 million

Source: University Statistical Bulletin. Quoted in [The Times, 13th December 1994].

Figure 4-1: Greatest UK Recipients of Research Funding

4.2.1 THE DECLINE OF PHILANTHROPIC RESEARCH SUPPORT

Those participating in this study were unanimous in the opinion that, outside of certain specialised areas, 'pure' philanthropy on the part of corporations is no longer a significant source of research support. As Peter Knox of Dartmouth College Development Office made clear:

> 'It's really been a major shift over the last ten years or so. Whereas previously they would give unrestricted funds to colleges and universities in this country, because they just looked at education as a good thing and it was very wide open, now we find it's really a quid pro quo situation - they want some kind of payback and in most cases a direct payback, whether it's in the form of recruiting, or sponsored research as you just mentioned, or advertising - whatever they can get out of it. It makes it more difficult from a fundraising standpoint, but at the same time even at a small college like Dartmouth there is so much going on here that we are usually able to find some kind of match.'

Has the move from traditional philanthropy towards an increasing targeting of corporate funding of universities and research come about as a change of strategy within particular branches of the company, or has the change resulted from one budget being slashed and another entirely separate function expanding?

> 'It's really a mixture of both I'd say.... Many companies, as you know, have their own private foundations set up, their own private by-laws and board of trustees, set up for the express reason of giving away philanthropic dollars. But then within the corporate structure itself there's often pockets of money that we can go towards, whether it comes out of an advertising or public relations budget, or out of a technical marketing budget, or from a technical area - that's where you get more involved in technical arrangements as opposed to the straight philanthropy. We're always looking for any pool of money, wherever we can get it, but the competition for those dollars is really fierce.'

> Given the mass layoffs and harsh economic conditions, being seen as major donors might even damage companies from a PR viewpoint. Money has been directed towards local communities, 'and we've seen a switch away from Higher Education and towards some of the more basic things like the social services - and it's a tough argument to make that Higher Education is more important than these starving people'.[20]

Speaking of the work of the Development Office, Henry Lowendorf of Yale's Office of Cooperative Research said

> 'more and more people in that office will go to industry and say "we would like money for certain kinds of research", so in the past it used to be more gifts, but now it's aimed at something that companies will benefit from.'[21]

One of the main remaining areas of corporate support for higher education is the granting of scholarships for under-represented groups. Even when philanthropic funds are available for universities, their targets might not fit with the universities' own perceptions of important areas. Mark Woodward, of Dartmouth's Thayer School, gave an idea of what other kinds of priority foundations might have:

> I was at a conference six months ago at which a number of corporate foundation people gave talks.... it was amusing because each of them had their own priorities.... They all said "Our priorities are much more specific than they used to be" and they listed some. One of them - a large, well known food processing company - from the examples given seemed to limit its philanthropy almost entirely to named public spaces and facilities that had absolutely no use to the university at all except as a gathering place for students. Maybe it means something to the company to have its name on courtyards and student lounges and gazebos and fountains, but I can't imagine what.... Many of us there laughed afterwards, because we thought "How does that help us at all?". It was an example of a corporate priority that had no match to an institutional priority what so ever.'[22]

He suggested that future success in obtaining such funds would involve carefully targeting a fairly small number of philanthropic bodies and building close, long term relationships with them across a range of activities.

IBM confirmed that their philanthropy was now directed towards primary education, this being perceived as a national priority. '*Companies just don't have the money*' to give away large, open ended sums any more.[23]

Of course, as Bob Anderson of Xerox reminds us:

> Even a philanthropist does things for a reason.[24]

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[20] see **Error! Reference source not found.** - Interview with Peter Knox of Dartmouth College Foundation and Corporate Relations

[21] see **Error! Reference source not found.** - Interview with Henry Lowendorf of Yale Office of Cooperative Research

[22] See **Error! Reference source not found.** - Interview with Mark Woodward of the Thayer School Development Office at Dartmouth

[23] see **Error! Reference source not found.** - Inteview with Hoecker & Greis of IBM US Higher Education Business

Companies have realised that investment of their philanthropic funds in the local community, and in areas perceived as public priorities, will bring them greater returns in terms of good will and public relations. Although corporate philanthropy was traditionally considerably more widespread in the US than in the UK, these comments were echoed by the British universities.

> Currently an appeal to raise £250 million is underway by the development office. However, big companies are now less likely to make large donations with no strings attached - for example whilst a company might once have established a chair in perpetuity they might now fund it for a fixed period and in a more highly specified field. In the current business environment 'just giving money away isn't always favoured, people may not like showing it on their accounts'; most donations come from trusts and from private individuals.[25]

4.2.2 Emphasis on Direct Returns

In keeping with the shift in attitudes to philanthropy documented above, funding for sponsored research has become far more focused, and appears to be increasingly concentrated in areas where companies anticipate a direct and fairly short term payback on their investment.

Legally, gifts are distinctly separate from sponsored research. Under British law, for example, nothing can legally be asked in return for a gift, and the university is able to recover tax from a corporate donation in a way they cannot from a research contract. A similar situation exists in the US, and Garry desGroseilliers of Daimler Benz gave a specific example of how this had affected MIT's industrial liaison programme:

> 'A lot of the memberships of programs like this one at MIT were goodwill gestures on the part of the corporations. In many cases the payment came from the philanthropic side of the company. Around 1980 there was a legal ruling in the states.... that a company's philanthropic organisation could not make a donation to a university and receive a donation in return. This was considered a violation of the gift tax laws... All the memberships in this industrial liaison programme had to be converted from gifts to actual research co-operations paid for out of the research budgets of the companies.'[26]

Thus there has for some time been a necessary legal distinction between research supported by a philanthropic grant, and sponsored research undertaken with a contract. However, the latter may previously have had some philanthropic or public relations motivation, or been seen as a speculative long term investment.

For researchers in a major corporation, support of a research group in a university may once have been viewed as a peripheral and inexpensive activity. This was particularly true in equipment manufacturers, who were able to donate equipment from their own company. Maurice Herlihy, formerly a member of a Digital research group, made this clear

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[24] see **Error! Reference source not found.** - Interview with Bob Anderson - Director, Rank Xerox Research Centre

[25] see **Error! Reference source not found.** - Interview with Richard Jennings - Cambridge Industrial Liaison and Technology Transfer

[26] see **Error! Reference source not found.** - Interview with Gary DesGroseilliers of DaimlerBenz Research and Technology, North America

> At Digital, support for academic research was primarily through grants of equipment - to support a research team in a university his organisation 'needed to come up with 5% of the book value' of the equipment. The remainder was made up by a central subsidy - though as actual costs are secret the extent of the subsidy was unknown to the group, and tax-write-offs are based on the book-value. 'By and large this wasn't considered very expensive' - though it has now been cut severely. Groups supported in this way would be carrying out research relevant to that being carried out by his own group....
>
> > 'If you really think it's of strategic importance then you don't give a handful of workstations to an academic somewhere with high hopes. In some senses we felt we had our hands full doing internal technology transfer. The support for academic research was viewed as a long-shot that you don't put much money into, but it was somewhere where a little bit of money could have a big pay-off.' [27]

The general move in the computer industry towards devolution of budgetary control and responsibility to individual business groups, combined with the greatly increased financial pressure on companies such as Digital and IBM, has eroded this kind of support. IBM in the US no longer subsidised this kind of support with central funds - '*the people who pay for it should be the ones who get the benefit*'.[28] A similar policy applied at ICL, Britain's most important computer company.[29]

The American academic participants were in agreement that industrial support was now far more difficult to obtain than five years previously for open-ended research without an apparent direct relation with the immediate commercial needs of the company. Steve Reiss, well known for his work on programming environments and the designer of a system licensed by Digital, complained that funding problems meant he now had one graduate student working with him rather than five.

> Computing companies have had to cut back on their research budgets - 'probably even more than the Government has - I used to have funding from IBM, Digital, Sun - now I have funding from none of the above.... There are two ways of getting industrial funds - one is to promise to do something, the other is to get them interested enough to fund basically whatever you feel like doing...' [30]

The freedom to follow his own research agenda is what attracted him to a university career in the first place, and in his view an attempt to target the interests of companies is mitigated against by the fact that the very nature of research it is impossible to agree to build something with particular characteristics. His experience suggests that it is no longer easy to gain industrial funding simply by doing completely independent research in an area of direct interest to industry - rather something specific must be offered to the sponsor in return for their investment. The nature of these returns is something which will be examined closely in the remainder of this chapter, and in the chapter on technology transfer which follows.

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[27] see **Error! Reference source not found.** - Interview with Maurice Herlihy of Brown University Computer Science Department

[28] see **Error! Reference source not found.** - Inteview with Hoecker & Greis of IBM US Higher Education Business

[29] See **Error! Reference source not found.** - Interview with Peter Wharton - Chief Engineer of International Computers Limited.

[30] see **Error! Reference source not found.** - Interview with Steve Reiss of Brown Univesity Computer Science Department

4.2.3 THE IMPORTANCE OF GOAL ALIGNMENT

Evidence from some of the academic participants suggested that, in some fields of computer science at least, the goals of both the sponsor and the research group can be achieved without prejudice to either. It is important to remember that a research project has more than one kind of output, and so can satisfy more than one requirement. It is thus not necessary for the goals of the two parties to be identical for them to be complementary. The process of goal alignment takes place in many different dimensions, reflecting the complex concerns involved, but might be visualised in two dimensions as the maximisation of overlap between a pair of partially discreet circles.

> 'What you get... is a role in how the research goes - you're helping to direct it and you're going to be the first to see the result'. This produces an environment where researchers are happy 'doing what they want to do, but with interlock between what they do and what we need'.[31]
>
> 'The reality is that you do two things, you seek to latch into the things that they are seeking - you select among and align yourself with what they see as the objectives of buying external research... they've usually got a fairly clear idea... the alignment may not be perfect but by and large you've got to talk to them and thereby maximise the alignment that already exists in terms of the research that you can undertake.'[32]

Nick Carriero, a member of the team at Yale researching parallel systems, commented that *'everyone seems to have brought into the "let's get a little more practical" side of funding'*. Their experience was of a shift in the nature of industrial support. A decade ago, support for research in parallelism was motivated by the needs of the national laboratories for very high performance and very expensive machines. The group worked with basic research teams from these laboratories and from similarly massive corporate research centres such as Bell Labs. Industrial funding then was for general, exploratory research.

By 1994, the focus of parallelism research in general had shifted towards improvement in cost/performance ratios, to broaden the base of economically viable applications of high performance systems. Yale's own contribution had been the exploitation of parallelism implicit in the networks of high performance workstations owned by most major research centres. The vast majority of processing time on such networks is wasted - if this can be exploited then the result is a parallel machine for the price of a piece of software. They had also moved towards projects which dealt more directly with specific styles of applications and the needs of particular kinds of user - 'packaging' capabilities so that they can be used easily and transparently for practical tasks.

This new direction resulted in new kinds of funding relationship. IBM became a major sponsor, and the group's research moved much closer to product oriented work. However, this did not represent an abandonment of academic virtue.

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[31] see **Error! Reference source not found.** - Inteview with Hoecker & Greis of IBM US Higher Education Business

[32] see **Error! Reference source not found.** - Interview with Tom Anderson of Newcastle's Centre for Software Reliability

> 'The focus has shifted dramatically from exploratory research to practical development, which from IBM's point of view allows them to say "Oh, you want to speed up your application? Well, let's try to work with Yale and we can talk with them...", and there's a much tighter relationship with business activities than we would have had with Bell Labs in the past.'

This development of example case studies allows a 'portfolio of technology demonstrations' and data to be built up for IBM's use. This relationship is symbiotic, as Yale welcome the provision of equipment and real situations for their work.

> 'We don't just want to build parallel systems and let them sit and say "Well, we've done it so let's more on to something else". We want to use them, make sure they work, achieve a certain level of efficiency, understand where the weakness are and improve them - and in the course of doing that work we will naturally develop the kinds of case studies that IBM are interested in.'

This willingness to be involved with real 'industrial codes' is a great strength of the group in its relations with industry. Yale provides 'reasonable access' to IBM, its sales people and its potential customers - most demonstrations are internal within IBM. IBM's contribution is a 'loan of equipment' valued at over $1 million - machines, switches and resources to support them. As far as he knew, no cash was involved. IBM gets the results of the group's efforts for a substantially lower price than it would cost to duplicate them internally, and the group are doing ‘work that they wanted to do’ anyway. An agreement which provided resources for work which was not of direct interest to the group would be counter-productive.[33]

This demonstrates that opportunities exist for companies to gain a direct financial return from their participation in research, without forcing academics to do development work which is contrary to their own interests. To some extent one of the main rewards for IBM - software which provides a set of demonstration of the capabilities of its systems - is a secondary output for the university researchers themselves, who produced it in order to learn the more general principles involved but whose work would inevitably involved producing an experimental implementation on some platform.

The reason the arrangement was attractive to IBM lies in the cost advantage they achieved over carrying out an in-house development programme. Had the university team not been interested in such work, and IBM therefore been required to pay the full cost on a contract basis, it seems unlikely that this would have been the case. We thus see here a major strength of university research as its ability to leverage funding from industrial sponsors with money from other companies and from government. Furthermore it is clear that the researchers themselves felt that the quality and usefulness of their work benefited from the contact with industrial requirements.

This was also apparent at the University of Pennsylvania’s Center for Human Modelling and Simulation. The centre received funding from a large number of different sponsors, most of them governmental. Because funding in the US comes from a potentially broad and diverse spread of agencies and departments, it is possible to gain considerable leverage from each of their dozen major sponsors. Their most important system was ‘Jack’, a simulated human. Any improvements made to the system, and paid for by one of the sponsors, were available to all its users. Because of

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[33] see **Error! Reference source not found.** - Interview with Nick Carriero of Yale University Computer Science Department

cuts in funding from many areas of government, this also had the advantage that the delays and unexpected cancellations of funding which had become common did not cause catastrophic disruption to their research. Because of the practical nature of their work, much of their military funding was coming from development and training budgets, and so could survive a major cutback in military research funding.[34] Andreis van Dam, from his viewpoint as head of a large research team agreed that a broad portfolio of sponsors was essential, because both government and industry were in the process of reducing their support for research.[35]

Requirements as to the outputs of the research are not the exclusive domain of corporate funding - all research funding bodies have their own agendas. Perhaps the relative diversity of US funding patterns, as opposed to the dual support system of the UK, has given research groups more experience of dealing with different expectations. Even the NSF attaches funding to particular projects, and other agencies are becoming more strict in their specification of deliverables.

> 'It used to be that government agencies wanted to know how many Ph.D.s you produced, how many publications, how fat is the final report that you submitted, and "Oh yes, is there any software that we might be able to try". Increasingly it's turned the other way around - most of our sponsors, not all, expect that they will be able to use, literally use, the software which we produce as part of a research project. It's not so important to some of them whether we generate Ph.D.s or write papers - though if we do they like the attribution..... We have found that these are good drivers.... to codify our ideas and research in a way we might not have done previously.'[36]

4.2.4 Advantages and Disadvantages of Industrial Support

The consensus from the university side was that the different regime imposed by industrial sponsors possessed both advantages and disadvantages. The quotation from Nicholas Carriero above alluded to the potential of the relationship as a two way flow of ideas. Researchers investigating areas such as computer architecture, communications and graphics are very likely to be motivated by the demands of real world problems and to welcome input from industrial partners.

> 'active collaborations where we work with people on joint problems, and they may put in a minor amount of time and we put in a major amount of time, but it's still a two-way stream - I thank that's the best, it's even better than research sponsorship because that way you really learn from the other party.'[37]

Roger Needham, head of Cambridge's Computer Laboratory, agreed that the industrial perspective was invaluable.

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[34] see **Error! Reference source not found.** - Interview with Norman Badler of Pennsylvania's Center for Human Modelling and Simulation

[35] see **Error! Reference source not found.** - Interview with Andreis van Dam of Brown University Computer Science Department

[36] see **Error! Reference source not found.** - Interview with Norman Badler of Pennsylvania's Center for Human Modelling and Simulation

[37] see **Error! Reference source not found.** - Interview with Andreis van Dam of Brown University Computer Science Department

> 'I think this is all good.... If there wasn't an industry concerned with making and using computers the subject wouldn't exist. It's not like physics - physics was made by God, but computer science was made by man. It's there because the industry's there.'[38]

Whilst recognising the usefulness of industrial contributions to research, Eugene Charniak, head of Brown's Department of Computer Science, suggested that another incentive was even more important.

> 'One of the key reasons, from my vantage point, for encouraging industrial relations is that it means to the government that you're not some ivory tower intellectuals. That's probably the core benefit that a university gets out of industrial funding - it helps them to look legitimate. I would say that the second most important thing is that it helps them to be legitimate - and we actually do get some feel for what's worrying people in the "real world". Even if you choose not to work on those, I think you should at least be aware of what you're choosing not to work on. The last and least important benefit is the money.'[39]

Industrial money may also be more flexible, according to Charniak, because whilst a sponsor will specify the project on which funding must be used, they may actually give more freedom than would governmental sources over the way in which it is spent. Another advantage, cited by Steve Reiss, is that an industrial grant proposal might consist of one page rather than twenty or thirty for a federal proposal, and the process of making a decision and supplying resources can often take much less time than the year or more seen from federal agencies.[40]

Mark Woodward of Dartmouth's Thayer School made clear that preferences vary between faculty members. Attitudes were changing, but slowly - '*like pushing a glacier*'. Younger faculty were likely to be more open to industrial input.

> 'What we find here in this small school is that because our faculty are eminent at what they do they prefer to rely quite heavily on government funding, and because they are eminent, although the competition is fiercer for government funding they haven't seen much of a drop-off in it yet, so they haven't become convinced that they need to deal with industry more than they have done. The fact is that it's easier to get a couple of hundred thousand dollars from the government with a vague idea of where you're going with it and be set loose to follow your own agenda then it is to have a very specific contract with a company which has to be renewed every year, with time lines and checkpoints and the necessity of moving forward to a goal which that company wants over a specific period of time..... There are faculty members who enjoy that kind of challenge - that's what engineers do - but it's easy to be spoiled and over the year's we've been spoiled.' [41]

Tom Anderson, head of the Centre for Software Reliability within the Computer Science department at Newcastle University, gave an insight into the way in which corporate expectations

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[38] see **Error! Reference source not found.** - Interview with Roger Needham of the University of Cambridge Computer Laboratory.

[39] see **Error! Reference source not found.** - Interview with Eugine Charniak of Brown University Computer Science Department

[40] see **Error! Reference source not found.** - Interview with Steve Reiss of Brown Univesity Computer Science Department

[41] see **Error! Reference source not found.** - Interview with Mark Woodward of the Thayer School Development Office at Dartmouth

of management practices might accompany their support for a project. Like so much else, this would appear to involve a learning exercise for participants on both sides.

> 'They impose demands that follow patterns that they insist on us working to; so they require project plans, time-scales, deadlines - very fixed deliverables, on schedule. They would criticise if these were not adhered to.'
>
> 'I think this is an aspect of what you do see from industry - that's the way industry operates in its own field and they are reluctant to accept that real research, which is what we're genuinely supposed to be doing for them, does not fit that model. What they may do is to say "Yes, we fully accept that it doesn't fit that model" and then ask you to follow the model anyway, because they have nothing else to operate with...'

Adherence to this pattern is 'a little bit artificial for us... but it's easier to adhere to it because they don't pester us, they let us get on with the work. They don't give us as much feedback as we'd like...'. In order to gain feedback from the engineers of one sponsoring company it was necessary to build into the contract additional money to be returned to pay them to take part - although this arrangement initially struck the academics as odd, 'when you think about it, it makes sense... looked at from their perspective.' This kind of cost accounting is an example of the kind of cultural differences which exist between the two sides.

Problems had previously existed in the relationship with one sponsor due to differing expectations of what constitute appropriate management structures.

> 'You can fall into the trap of over specifying, over-stipulating, over-egging the pudding with things that are beneficial. Separate activities, ideas and ways of working when treated on an individual basis can be hard to criticise, but that does not mean that the [totality] of those things, is a good thing - indeed it can be enormously detrimental... Early on we fell into the trap of trying to do too many good things and over-managing the process... We realised that this was the case and now have a much better mechanism in place. Now when good ideas come along for us to do we say "That's a really good idea, which of the last set of good ideas are we going to drop?"... put too much management overhead in and you won't have any research..'[42]

A disadvantage of the new funding climate, in which awards of all kinds are likely to be more focused and harder to obtain, was the amount of time which must be spent by senior academics securing funding for their group's work.

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[42] see **Error! Reference source not found.** - Interview with Tom Anderson of Newcastle's Centre for Software Reliability

> 'I have had to work enormously hard to build up my base of industrial sponsors and keep that portfolio constantly changing as old sponsors drop-out in the process of cost-cutting, and must be replaced by new sponsors. It has been enormously disruptive of my time, and I think trying to make ends meet for a reasonably sized group today is almost a full time job for whoever takes on that responsibility. I think it's a way of surviving and it's something you've got to do - you've got to have a broad portfolio, you can't rely on either government or industry because they're both downsizing and you've got to change who your industrial partners are.... It's constantly looking for opportunities - to support a group with a research lab in it you really have to be very entrepreneurial. And all that time spent being an academic entrepreneur does interfere with research, publishing and other professional obligations. Senior faculty have trouble doing justice to all that they are responsible for, including working with their students. It is not a job for those who want a calm, "scholarly" life as the layman frequently pictures it.'[43]

4.2.5 The Particular Nature of Computer Science Research

Computer science is in some senses a hybrid between science and engineering. Like biotechnology, it is a field in which the frontiers between 'basic' and 'applied' research can be very fuzzy.

Whilst there are undoubtedly some theoretical areas of computing which are not directly oriented to industrial needs, even researchers in areas such as algorithmics and complexity may produce new techniques with direct commercial applicability. Much work in the formal specification of computer systems is motivated by software engineering concerns, and many key areas, such as networking, architecture and graphics, the impetus for research is likely to come directly from practical problems. To quote Roger Needham again:

> 'Our research is pretty well goal directed - but the goals are set by us. In a lot of computing there is no such thing as basic research, excepting some theoretical areas of the subject. We do a lot in networks and communications and so forth - I would assert that there isn't any basic research in networks and communications... the statement "They discovered an important truth about packet switched networks and it's no use for anything" is just inconsistent - it wouldn't be an important truth unless it was useful for something....'

It is incorrect to assume that research which is selected by academics and pursued without the direct involvement of industry is necessarily 'basic'. In the strict sense, of being conducted without a particular goal, very little computer science research is basic though such work may often be reasonably described as 'fundamental'. This can clearly be seen in the work of the researchers described above. The teams profiled, at both Pennsylvania and Yale, were clearly performing novel and important research, they had their own goals but as a direct result of pursuing them technologies of direct practical applicability could be produced.

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[43] see **Error! Reference source not found.** - Interview with Andreis van Dam of Brown University Computer Science Department

> 'It's very fuzzy here - because I think that very few of the students working on Ph.D.s believe that they're doing applied research - they all expect, and I believe for the most part that it's true, that each one of them is doing basic research in the sense that we don't know how to solve these problems. It just so happens that, as a by-product, when they do solve them frequently there is an application or code which actually works.'[44]

At the same time, compared to workers in most engineering subjects, a computer science researcher is probably less likely to discover something which in itself has spectacular and realisable commercial value. This is because computer systems are usually a complex product of a large number of different techniques and technologies, each of which is probably playing only a small part. (See the discussion in section 4.1.1.2). The commercial significance of the whole is far more likely to be a result of market positioning against customer needs than of a single outstanding piece of novel technology. No radical, new and patentable technique produced as a result of computer science research is likely to have a significant commercial impact in the same way that a new chemical process or material might.

Computer software can be particularly hard to categorise. Software is routinely produced by researchers, as a part of fundamental research. Unlike a traditional invention, the reproduction and manufacturing of a piece of software is trivial - if software is saleable then it can easily be physically reproduced. However, the kinds of software produced by an academic in the course of their employment are likely to be little more than crude proofs of principle - scale models of the kinds of program which might form part of a saleable system. To commercialise this requires the same kind of product oriented development, in the form of debugging, porting, interface design, integration into a larger system and enhancement as is required to go from a prototype to a commercialised product; but the point at which a program crosses the line from applied research to finished product is very hard to define. If a crude differentiation between science and technology is expected, then the status of an algorithm is problematic indeed. (Arrangements for the commercialisation of software are examined in section 5.2.4.1)

4.2.6 The Importance of Interdisciplinary and Application Oriented Research

There is a sense in which computer science, perhaps because it is still a young discipline, is inherently interdisciplinary. Computer science research often involves the development and application of concepts developed in a range of other subjects - mathematics, engineering, linguistics, psychology and even biology. The results of computer science research often have important implications for a wide range of academic disciplines, with computer modelling, analysis and simulation techniques increasingly central to many areas of research, as well as to a very large number of different industrial activities.

Because computer science research can, as discussed above, be in some senses both fundamental and applied at the same time, much research is devoted towards particular goals. Whilst these goals may be expressed in broad and general terms, and research will usually not work to directly produce commercial products, research remains 'goal oriented' - and as we also saw above researchers in many cases find useful the stimulation of real world problems.

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[44] see **Error! Reference source not found.** - Interview with Norman Badler of Pennsylvania's Center for Human Modelling and Simulation

The general trend, from both government and industry, towards funding which is more tightly focused and motivated by a concern to address specific problems works strongly to favour the adoption of such goals. I observed in those most successful in obtaining funding a willingness to distinguish between what might be termed strategic and tactical objective. For example, for the Center For Human Modelling and Simulation strategic goals were very broad: '*to do the best job that we can do in understanding humans and simulating them by computer.*'[45] Several subgoals had been identified, each of which involved interdisciplinary work and encompassed a range of potential fields of application.

These strategic goals provide an overall framework into which individual projects can be placed. Because they are so broadly defined, tactical directions chosen can be determined by the particular fields of investigation for which sponsorship and funding are available without compromising the Center's overall mission.

> 'It never hurts to say to them "These are our overall goals, and you can help us move toward them and along the way we will provide back to you the fruits of the labour and your investment.'

The centre is fortunate in that its work has many applications, and to repay sponsors and satisfy their own 'engineering' instincts they are happy to *'turn these things into useful tools and deliver software to sponsors'*. Furthermore, within the overall strategic framework of the centre even work which is viewed by the sponsor as applied can be generalised to provide valuable findings.

> 'Applied research has a slightly different flavour... we do see this from corporates - they outline a problem to us, "Can you help us solve that problem?" and usually the problem is fairly specific and instead of saying "Yes, I'll solve your problem" my preference is to say "I'd like you to fund us to help solve a slightly more general problem of which we hope some of that you really need to solve will be a special case".... I believe that strategy (though it might just be the area that we are working in) has paid off.... We've got a lot of interesting specific problems from sponsors but have built general solutions'.

Official status as a Center (or indeed Centre) has direct advantages, in terms of facilitating interdisciplinary or focused work and providing a high visibility to potential sponsors. According to Tom Anderson of Newcastle's Centre for Software Reliability it provides a

> 'label to hang things on... at that time it consisted of a secretary and a telephone - rather more support than the standard university infrastructure gives an ordinary member of a department.' Increased independence as a centre allows the raising of additional resources - 'secretarial support and then research staff and projects and other activities get attached to your organisation, and before you know it you have something much more substantive.'[46]

Industrial research itself has always tended more towards the interdisciplinary than has academic research, and so if universities are to attract increased funding from industry then they may need to work more flexibly in this respect.

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[45] see **Error! Reference source not found.** - Interview with Norman Badler of Pennsylvania's Center for Human Modelling and Simulation

[46] see **Error! Reference source not found.** - Interview with Tom Anderson of Newcastle's Centre for Software Reliability

However, powerful factors in traditional academic organisation and culture mitigate against interdisciplinary research. Promotion within a particular academic community may require a concentration of work in theoretical areas deemed to be of central importance to the discipline. Projects which span disciplinary boundaries can also be very hard to attract funding for.

> 'An example, a lot of lip service is paid these days out of Washington to so called "interdisciplinary research". It's a total fabrication. Interdisciplinary research does not exist, it is not funded from federal sources. Why? If, for instance, you were a chemist interested in exploring the behaviour of peptide mimics, and you want to explore various clever chemical things like computer aided synthesis... and you wanted to collaborate with your medical school friends just to see how useful this stuff is in an interactive way, where would you send that proposal? If you sent it to the NSF, to which you had sent all your previous chemistry proposals, the National Science Foundation would come back and say "Gee, this looks like a medically related proposal. Dear Researcher, you should send this to the National Institute of Health." You send it to the NIH, they say, "There's an awful lot of chemistry involved here, we think you should send it to the NSF because they handle chemistry." Because the reviewers at the principal basic research funding agencies are all pigeonholed in disciplines, there is no formal mechanism to evaluate an interdisciplinary research proposal.'[47]

Despite this, change is gaining momentum and a number of those interviewed felt that major readjustments in attitudes to interdisciplinary work was underway.

> ‘The traditional departments which make up universities, the Department of Physics, the Department of Chemistry, these things are starting to break down anyway - and what you’re replacing it with is just a big soup of people.... You work in one subject and you end up contributing to another subject - and all the time, when dealing with people in the university doing mechanical engineering and genetics and geology, all the projects that people are getting involved with are all interdisciplinary, multi-disciplinary.... I think that because computers and computer software are so esoteric they tend to permeate almost everything, so that to an extent people in the area of computer software tend to be leading this cultural change.... replacing the conventional barriers within universities with a heterogeneous series of barriers, all of which are project based.’[48]

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[47] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

[48] see **Error! Reference source not found.** - Interview with Peter Moforth of the Turing Institute

4.3 DIFFERENT FORMS OF RELATIONSHIPS AND SUPPORT

4.3.1 THE IMPORTANCE OF PERSONAL AND INFORMAL RELATIONSHIPS

A research relationship between a university and a company is most likely to exist primarily between a group of researchers within that company and a specific research team within the university. In the substantial majority of cases, the contact on which this relationship is founded will have occurred as a result of professional contact between researchers in the two groups, rather than as a result of an initiative concluded at a higher level.

To quote Henry Lowendorf of Yale's Office of Cooperative Research,

> An agreement is "sold" by a researcher and her work. A company comes to Yale not because of a general interest in research (although we do get that) but because there is someone at Yale doing research that is of interest to the company. The company may not be doing specifically that research at the moment, but wants a window on what happens to that research, or a company may have its own research projects going on but wants to keep close tabs on that particular investigator's work.[49]

Richard Jennings, Director of the Industrial Liaison and Technology Transfer Office, agreed.

> '[T]hey're similar people, they read the same journals, they go to the same conferences, they go to the same seminars - therefore they'll meet each other. As a result I feel that the academics themselves are very much at the leading edge of the marketing activity.'[50]

Similar statements were made by all those participants engaged in central support of sponsored research, and by the corporate representatives included in the interviewing process. This would appear to be universally agreed upon.

> 'I have found that some academics are much better than others at [sponsored research], and you learn which ones will be able to serve you the best, and those are the ones which you build a relationship with.'[51]

Sponsored research agreements are thus developed from informal and long term professional contacts between researchers. Roger Needham, head of Cambridge's Computer Laboratory, stressed this particularly.

> Informal relationships are very important, many of which involve no contractual element whatsoever. Companies have provided equipment donations 'because they thought it would be a good thing and they enjoy talking to us.' The best example of this is Olivetti - the head of Olivetti research is a member of faculty, and resources have been supplied to the Lab over a long period, most of them on an informal basis. Such donations bypass the central University mechanisms, which are based around contracts, and so do not appear on official statistics. Many faculty members have good relations with, and sometimes receive support from, various companies.

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[49] see **Error! Reference source not found.** - Interview with Henry Lowendorf of Yale Office of Cooperative Research

[50] see **Error! Reference source not found.** - Interview with Richard Jennings - Cambridge Industrial Liaison and Technology Transfer

[51] see **Error! Reference source not found.** - Interview with Bob Anderson - Director, Rank Xerox Research Centre

> An Interdisciplinary Research Centre is currently being set up to research communications systems - a total of £100,000 has been raised from companies and trusts to employ a senior person to oversee its establishment. Pledges were raised on the strength of long term relationships, rather than particular contracts.....
>
> > 'If you look at formal relations, they underplay the reality. If you insist on formal relations to make the statistics look good then you're not doing anybody a kindness; and the best things are corporate friendships, where you may formally collaborate from time to time, but probably not all the time. When a collaboration is obvious then it happens.'[52]

The establishment of such contacts is inevitably a long term process. The organisation of events such as that mentioned by Tom Anderson of Newcastle's Centre for Software Reliability has the potential to be an important means of strengthening such links. Members of their 'Community Clubs', most of which were industrial, received a newsletter and attended one day events roughly monthly. Their annual three day symposium attracted around 200 delegates.[53] It seems likely that the focused, and industrially applicable, nature of the centre's work makes industrial interest in such contact considerably easier to sustain.

4.3.1.1 How Important is Geographic Location?

As discussed previously with relation to science parks in section 2.2.2.5, and mentioned several times during the discussion in this chapter, contact with a local base of innovative, high technology companies is often perceived as important to the development of a supportive environment for research collaboration and exploitation.

It is clear that geographical location is much more likely to be an important factor in some kinds of relationship, and for kinds of company, than for others. Large scale sponsored research agreements are most likely to exist with larger companies, and as discussed previously to result from professional contacts between researchers. Because academic communities are international in nature, opportunities exist to forge such links regardless of geographical location, and many large companies do adopt a global view when considering the spread of their research funding.[54] Peter Williams suggested that research in Britain need not therefore be unduly handicapped by the relative weakness of British industry in many sectors.

> 'To the extent to which research in Britain continues to be four or five star rated, I think that the infrastructure argument is of secondary importance because it is a world market, and people in tech transfer offices in the UK are going to be speaking to as many American, German and Japanese companies as they are UK companies. Overseas companies are willing to invest.... if the science is good then the UK can sell it.'

As we have seen, companies are increasingly focusing their research funding on projects which are seen as providing direct benefits. Whilst this does indeed suggest that centres of excellence may gain funding from farther afield as companies look to work with the best teams available, it

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[52] see **Error! Reference source not found.** - Interview with Roger Needham of Cambridge's Computer Laboratory

[53] see **Error! Reference source not found.** - Interview with Tom Anderson of Newcastle's Centre for Software Reliability

[54] see **Error! Reference source not found.** - Interview with Mike Taylor of Manchester University Research Support Unit

also suggests an increased emphasis on the company's ability to absorb and gain unique advantage from the results of the research being funded. As discussed elsewhere, in fields such as computer science effective technology transfer often requires close contact and is often reliant on the diffusion of tacit knowledge and expertise and so active collaborations will often be essential for both parties to benefit fully from their relationship. Although improved communications technology may function to make collaboration between teams composed of physically remote members more feasible, there seems little doubt that a company will, other factors being largely neutral, find it very much more convenient to collaborate with a group located within a hundred miles travel than with one on another continent. The shorter the duration of the collaboration and the more directly oriented to the transfer of expertise, the more important location becomes.

However, in some ways geographical remoteness may even serve to increase the perceived value of contact, by making an institution seem more exotic and prestigious. This is likely to be most important for institutions such as Cambridge, Harvard and MIT which are known of around the world. Even the Cambridge Lab, a major research centre in computer science and part of the country's most respected university, felt disadvantaged

> 'At the MIT Media Lab, at lot of companies - including many British companies - subscribe to fund their research without controlling what it is. You can whistle for money from the same companies if you are British, and the companies will spend money at MIT when they won't spend it here, even if they got the same thing for it. It's for the same reason that grocers sell imported delicacies - you tend to think that the thing from overseas is better.'[55]

Smaller companies are more likely to seek short term returns, and are more likely to license technology than the fund research. Technology based small companies may also employ academics as consultants, and will find local expertise more convenient and easier to locate. Small companies are, as discussed in the next section, more likely to rely on university programmes and offices in locating contacts within universities. For all these reasons, geographical location is far more likely to be a crucial factor in dealings with smaller companies. Roger Needham of the Cambridge Computer Laboratory, located amid Britain's best known concentration of innovative small companies, outlined the way in which the needs of these companies are addressed.

> 'A 'supporters club' is run for companies, many but by no means all of which are local. In return for an annual contribution, which varies according to size and wealth, members receive invitations to seminars, copies of technical reports and easy access to faculty. A mutual benefit is the opportunity given to companies to recruit students from the department - smaller companies do not have the resources to participate in the Milkround and so value the annual event where they make presentations to the students. A dinner afterwards allows the companies to form links and to do business with each other - and some formal collaborations have emerged from these relationships.'[56]

Philanthropic funds are also, as discussed in 4.2.1, being targeted far more specifically towards major social problems and to improvements in corporations' own local communities. This can work to the disadvantage of universities whose location is remote from centres of corporate activity. Peter Knox, of Dartmouth College's Development Office, made this clear while talking of the need to raise funds for a programme which gives school teachers computing and Internet skills.

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[55] see **Error! Reference source not found.** - Interview with Roger Needham of Cambridge's Computer Laboratory

[56] see **Error! Reference source not found.** - Interview with Roger Needham of Cambridge's Computer Laboratory

'It's probably going to be a very tough sell, frankly. Because we don't have a corporate base here... Ameritech would probably be more inclined to give their philanthropic dollars to organisations in Chicago as opposed to hand it over to Hampshire where they don't have a presence and don't need one.'[57]

4.3.2 The Development of Strategic Relationships

We have seen that research relationships are essentially based on personal contact between researchers in different organisations. At the same time, aspects of the relationship are handled a higher level between the two institutions. Any formal contract for research support will exist at this level, and will need to be approved by a specialist office within the university. Both sides thus face the difficult task of promoting and managing on a strategic basis what are essentially a set of personal relationships. The organisational patterns adopted by universities are documented in section 4.3.2 and their official provisions for industrial liaison in section 4.3.3.

Computer equipment manufacturers are increasingly likely to target institutions on a strategic basis, and this section illustrates some of the ways in which computer companies may seek to develop their relationships with those universities and departments perceived as being of strategic importance.

IBM North America had gone a long way in integrating its relationships with universities. Following a profound, corporation wide restructuring into a vertical integration by market structure, Higher Education was recognised as a separate industry with its own business division to deliver marketing, consultancy and support services in an integrated manner. This structure, based round marketing and relationships, provided a single clear point of contact between the two organisations.

Sixty six institutions recognised as 'premier' had been allocated their own designated campus executives. These were often senior people - MIT received regular visits from the Senior Vice President of Technology and Research (overall head of research) and MIT's President was a member of the IBM board. Elite institutions were also potentially eligible for special support, such as the Shared University Research (SUR) programme which distributed IBM equipment. These formal initiatives complemented the support agreements reached directly between IBM and university research groups. Managing the overall relationship in this way also allowed coordination between sales activity and research support.[58]

ICL, Europe's major computing firm[59], had not gone so far in the integration of their relationship with universities, but a high level group including technical and sales people met on a quarterly basis to consider overall strategy. All internal research was conducted within ICL's business divisions, which curtailed support for academic research spanning division boundaries - in recognition of this mechanisms to pool the costs between interested divisions were being put in

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[57] see **Error! Reference source not found.** - Interview with Peter Knox of Dartmouth College Foundation and Corporate Relations

[58] see **Error! Reference source not found.** - Inteview with Hoecker & Greis of IBM US Higher Education Business

[59] ICL is in fact largely owned by Fujitsu, but retains its European culture and management and remains a separate business.

place. Research collaboration with universities centred on a handful of universities with particularly relevant research strengths. No formal 'most favoured buyer' status existed for universities, and until recently the supply of equipment to universities had not been a priority - though this was largely because the requirements of universities had diverged from the areas in which ICL were competitive.[60]

As discussed in section 4.2.2, reorganisations of this kind often also have the result that research groups within large corporations wishing to contribute to the support of external research groups were required to meet the full cost of the research. Because many companies are seeking to integrate their internal research operations more closely with their business divisions, the resulting narrowing of focus is still greater.

For manufacturers of computer equipment, such as IBM, Apple and Sun, grants of equipment remained perhaps the most important kind of support given to universities. However an important change of attitudes had taken place in universities, according to IBM -

> 'A lot of universities have discovered [that when] they get a lot of free equipment from people, they end up with this huge mess that costs them more to maintain than they would have paid for it.... Because you get something for free, it doesn't mean it doesn't cost anything.'[61]

At Brown, Eugene Charniak considered this the most important form of direct support received by the department. However, the department has become far more discerning. Like any large site, a computer department can only effectively support, maintain and administer their computing resources if the profusion of incompatible systems is kept to a minimum.

> '[A]t one time we were really looking to build up our equipment, so we would take pretty much anything that anyone would give us. This turned out to be a bad idea because it meant that we were operating on five or six different operating systems and the maintenance people were just going nuts.... We then went to the other extreme which is basically saying that "There's only one platform that we will allow in this department" - we obviously couldn't expect any one vendor to give us enough machines for the entire department but we could and did try to organise a sort of competition among the vendors so that we would get the best possible deal... and that tended to work very well.'[62]

One of the attractions to the company is that students will become used to their equipment, and that when they move into industry they will therefore wish to continue using it - so developing a future skill and customer base for their systems.

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[60] See **Error! Reference source not found.** - Interview with Peter Wharton - Chief Engineer of International Computers Limited.

[61] see **Error! Reference source not found.** - Inteview with Hoecker & Greis of IBM US Higher Education Business

[62] see **Error! Reference source not found.** - Interview with Eugine Charniak of Brown University Computer Science Department

> 'The general feeling... is that by providing outright gifts or steep academic discounts one establishes one's hardware product in an environment where people who are going to be future users and buyers of your equipment are going to be exposed to it, and will be predisposed to want to import it to their companies. We trade on that... I don't know if we're being disingenuous by so doing because the environment being what it is and workstations being outmoded every three to five years anyway, and the major players changing as people with new ideas come in, it's hard to know if five years down the line the people you're accepting equipment from will even be in business...'[63]

The supply of equipment to such a site thereby becomes a crucial part of the development of a strategic relationship such as that sought by IBM. In this event, the contract went to Sun. As IBM commented:

> '[T]hey made themselves such a visible target that they got all the companies involved, including IBM to offer this incredible good deal.... You won, you got the rights to basically give your stuff, but it would be all over computer science at Brown.'[64]

In general, universities were being required to provide more of the cost of equipment than they had once been. However, with the falling price of hardware, longer term considerations were becoming more important on both sides and, in keeping with the IT industry as a whole, the focus was also moving towards support and services. For IBM, the provision of a person to work with a group might be the most expensive part of a support agreement, and additional sale of consultancy and services a major area of potential profit.

4.3.3 Industrial Liaison Programmes

In section 3, a number of 'Industrial Liaison' functions were identified, including the redirection of speculative enquiries from companies towards appropriate research groups, the compilation of directories or databases of university expertise and research activity, the organisation of seminars and other activities on behalf of industrial participants and the overall management, broadening and deepening of existing relationships.

As the overall summary of different patterns of central organisation presented there showed, the provision of such activities was one area where considerable variance was observed in the sample. At many institutions, central activity was limited to the general fielding of speculative enquiries, with the central listing of research expertise becoming a priority for the British institutions. Brown and Yale both had relationship-building industrial liaison programmes specific to their computer departments, the latter being managed by a member of the central Cooperative Research Office. MIT stood out in having a major industrial liaison programme which demanded a substantial fee from the industrial participants.

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[63] see **Error! Reference source not found.** - Interview with Mark Woodward of the Thayer School Development Office at Dartmouth

[64] see **Error! Reference source not found.** - Inteview with Hoecker & Greis of IBM US Higher Education Business

4.3.3.1 Case Study - MIT Industrial Liaison Program

The Industrial Liaison Program at MIT, which with Corporate Development comprises the Office of Corporate Relations, was founded in 1948. It remains the best known programme of its kind, and is manned by a number of Industrial Liaison Officers, each one of which is responsible for a focused portfolio of companies and has responsibility for staying in touch with relevant advances on campus.

Companies pay a fee which varies according to their size, but is far from nominal.[65] Around two hundred companies are currently members. The programme produces an internal surplus, some revenue is returned to MITs general revenues rather than being earmarked for particular industrially linked projects. Some 10% of gross income is returned to faculty members on a pro-rata basis in return for their participation in activities such as company visits.

The fee entitles the company to use of the ILP's facilities without further charge. These include specialised information services, such as a seminar series which is free of charge to member companies - in 1994 topics included *'Designing the 21st Century Organisation*' and '*Global Communications Networks: Corporate Visions*'. A monthly newsletter is distributed which includes details of ongoing research at MIT and outlines findings and new inventions, helping to promote opportunities for research sponsorship. The ILP also produces the directory of MIT research activity, which is now organised by area of expertise to make it easier to track down faculty with particular interest, and has a role in organising faculty visits to companies and setting up meetings between interested companies and faculty members with relevent expertise - such meetings often result in consultancy or research sponsorship.[66]

IBM felt that their membership was valuable, although as a large company it used the ILP more to support relationships then to provide entirely new opportunities.

> For a company like IBM it is useful to provide another way of maintaining relationships, but 'it can be very beneficial for smaller companies that don't necessarily have the resources or the relationships, because these folks at the ILP can really help a company negotiate the MIT maze and find out where things are of interest.'

Daimler-Benz suggested that the main benefit gained from their membership of the ILP was convenience,

> 'MIT is the only university where we have a formal, established, contractual relationship.... The main reason that we have not entered into that kind of a relationship with other universities is that there are very few other universities which have the breadth and scope and importance of research that MIT has.'
>
> Because their office is located in Massachusetts, they can maintain a higher level of contact and have regular meetings with MIT faculty, making the agreement good value.

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[65] MIT are reluctant to reveal exact amounts, my impression is of several tens of thousands of dollars.

[66] see **Error! Reference source not found.** - Interview with Dr John Leech of the MIT Industrial Liaison Program. Also 'MIT Office of Corporate Relations Industrial Liaison Program, Executive Summary for Faculty and Research Staff'.

> 'Another reason that we do not pay other universities for this kind of access is that it's not always necessary - most universities are relatively open places, and we can call a faculty member at any university in the US, and if they are working on a project that is of interest to Daimler-Benz, and if we have people who are working on that same subject then it is very easy to schedule a meeting and to have discussions with anyone at any university in the US....'

> Even at MIT faculty members would usually be willing to talk to a representative of any major company. 'The access that we gain through the ILP is really quite general - what we get is an hour or two of a person's time to discuss to discuss a general interest in a topic.'[67]

Other participants sometimes mentioned MIT as a special case, and felt doubtful that other institutions could hope to derive the same levels of commitment from companies.

> 'MIT in my view is unique in all the world... even Stanford doesn't hold a candle to MIT's leading position in many developing technologies. People are willing to join their industrial liaison programme at a considerable price... and many, many, many companies are members of that affiliate programme, and they get nothing other than some glossy newsletters and the right to sit for a little time with faculty members when they come to campus and invitations to seminars which are put on specially for them, but there's no technology transfer other than discussions.'[68]

IBM considered it possible that a similar scheme might be successful elsewhere.

> Would the approach work for anywhere apart from MIT? 'If you identify a very motivated, bright group of people to do it then I think other universities could do it, but I think the less visible and the less known they are the more they have to get out there, and they might need to be more flexible about what they ask from the companies.' The best approach might be to identify corporations, work with them for a year on a trial basis and then ask them to help support the costs involved. 'Good seminars' are invaluable, to 'show companies what they're getting'.

4.3.3.2 Other Industrial Liaison Activities

Although MIT's was the only fee-paying, university wide scheme in operation at the universities surveyed, both Brown and Yale had relationship oriented programmes in operation at the departmental level for computer science.

Brown's scheme is known as the 'Industrial Partners Program', and stresses opportunities for collaboration with staff and students. This offers a package of activities to the company, including a series of special seminars on specific topics involving speakers from industry - the most recent having been on the theme of '*Ubiquitous Computing*'. Other benefits include invitations to departmental seminars and colloquia, copies of technical reports and research papers, access to faculty, use of university and departmental facilities, the chance to recruit students and a subscription to the department's newsletter. Their material,[69] documented six member companies,

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[67] see **Error! Reference source not found.** - Interview with Gary DesGroseilliers of DaimlerBenz Research and Technology, North America

[68] see **Error! Reference source not found.** - Interview with Bill Jackson of Brown University Research Foundation.

[69] A booklet entitled 'Industrial Partners Program'.

and a basic fee of $35,000 but since my visit they have reduced the fee, finding computer companies very conscious of their expenditure. The programme at Yale had a similar form.

As mentioned previously, Cambridge's Computer Laboratory ran a 'supporter's club', and Newcastle's Centre for Software Reliability operated a 'club' for companies interested in the centre's work.

> [Relationships with firms] are strengthened through the approximately monthly events organised by the centre. These are based round 'community clubs', most of the members of which come from industry. These are mostly one day affairs, though some are longer and a three day symposium on safety systems with around 200 delegates is held annually. Club members which contribute a small 'participation fee' receive a newsletter and a discount on the cost of participating in the events - income from which is the other source of funding for the clubs. At present the clubs' income does not cover costs, in the longer term it will have to do so.[70]

Cambridge was the only one of the British institutions to have a separate office responsible for Industrial Liaison - both Newcastle and Manchester had integrated responsibility for the compilation of a research directory and response to industrial enquiries into their main Research Support/Services Units. The Office of Industrial Liaison and Technology Transfer does not operate a membership based scheme, and is very much smaller than MIT's operation.

General agreement existed that general enquiries regarding work underway at the university or expertise available was more likely to come from smaller companies, which do not have the same range of professional contacts available through their own researchers as do larger companies.

> 'Always, the perennial difficult question is - how do universities link with small companies? My answer to that question is rather facile, and is "With great difficulty". There isn't at first sight a natural basis for collaboration, because the small companies don't have the resources, they don't do research - they are product and market oriented and the timescales on which they act are in general very much shorter and more immediate than those on which most university research activity occurs. Having said that, it's the exceptions that prove the rule and there are increasingly high-tech companies which are more research focused and the start-ups do increasingly undertake research activities with the University.'
>
> 'In general the links are to do with specific problem solving, in many cases consultancy type activity on a single person basis. Participation in more applied student projects and things of that nature can be very effective... you can get a bright undergraduate to work on a project for a month, and somebody good... can make a very valuable contribution to a company provided the management issues are addressed. Sources of material, exchange of materials, use of equipment, use of libraries - transfer of knowledge in a very broad sense is clearly a very real thing.'[71]

4.3.4 Consultancy Agreements

Under a consultancy agreement, an academic contracts to supply consulting services to a firm. Consultancy agreements are usually private arrangements made directly between the academic

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[70] see **Error! Reference source not found.** - Interview with Tom Anderson of Newcastle's Centre for Software Reliability

[71] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

and the company involved, with the formal involvement of the university confined to possible vetting of controversial agreements and the provision of advice and guidance to safeguard the academic's interests.

Terms vary substantially between agreements. A typical agreement would run for one to three years, and involves the provision of a specified number of days consultancy, usually ten to twenty five. Some consultancy agreements may be exclusive with regard to particular scientific areas. [Harvard].

Andreis van Dam outlined the advantages of consultancy for both sides.

> 'I think it's very important and I've done it all my professional life. I started consulting when I was still a graduate student and I found it a very, very useful way of keeping anchored in reality - a source of problems and also a way of learning what the really important issues are. Plus there are a number of very smart people who you come into contact with through consulting who you wouldn't otherwise meet, it keeps you from getting in-bred.... It's also a way in which academics can afford to teach....'
>
> 'I think typically companies are looking to bring in a heavy-hitter from outside who has expertise in a particular area that they don't have in-house, or they use it to check the expertise that is in-house, but it's a way for them to get somebody on a temporary basis that they otherwise would have to hire and pay a lot of money to - temporary employment basically.'[72]

Valuable as it is, consultancy represents a considerable additional workload for already busy academics. As van Dam made clear, to discharge all his responsibilities demands a routine seven day week.

> 'If you want weekends to yourself you don't have time to consult and still be a contributing academic - you're allowed a day a week for consulting but if you took it on a regular basis, it would destroy your research and publishing productivity... if you're going to do consultancy then basically it has to come out of your spare time'

As well as providing academics with valuable exposure to industrial concerns and financial support, consultancy also plays an important part in the development and maintenance of other links, both formal and informal, with companies. A particular form of consultancy involves membership of a company's 'scientific advisory board'. Such boards are a particularly important feature of smaller, high-technology companies in fields such as computing and biotechnology.

Consultancy agreements routinely accompany technology licensing agreements (see 4.4.2). Although revenues from licenses themselves are usually shared between the inventor, the university as a whole and perhaps the inventor's department, accompanying consultancy agreements are private and income goes directly to the individual concerned.

Consultancy can also be the beginning of formal contact between an academic and a company which later results in other collaborations between them. Whilst the direct contact is between a particular individual and the company involved, their opinion of the work of the academic's department as a whole will be substantially determined by their impression of the quality of

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[72] see **Error! Reference source not found.** - Interview with Andreis van Dam of Brown University Computer Science Department

consultancy given. Good work may result in the hiring of graduate students by the company, in future research support agreements or in grants of equipment.

> 'I consult for Digital in a purely private capacity, but it's because I consult that so many of our students are taken on as summer interns in their research lab, and it's because Digital know me so well that they're lending us some equipment to use in a research project, but none of this is written down.'[73]

Whilst consultancy is clearly distinct from large scale collaborative work and strategic research, it is not always clearly possible to distinguish it from applied, contract research. At Manchester, some consultancies were processed as contracts with the university.

> Even centrally processed consultancy agreements do not generate direct revenue for the university. They are permitted and encouraged because they motivate academics and stimulate more general relationships with companies. Whilst it is not practical to centrally support very small pieces of work, some 'fairly significant' projects are undertaken on a consultative basis. Consultancy agreements can also be made directly between the individual and the company - these cannot include significant use of university time or resources. Private arrangements are carried out at the individual's own risk and do not benefit from the university's liability insurance.[74]

Even when consultancy work is very much oriented towards small scale contract development, the stimulation provided by contact with a new environment and a new set of problems may help to stimulate new ideas and lead to insights which can be fed back into an academic's work, which must remain their priority.

> 'It would be bad it we were diverted by the need to get money in this way from doing what we are good at and what we are for. It's good if you pick up good ideas from talking about industrially relevant projects, and it happens sometimes. We did some consulting the other year to do with burglar alarms which gave us some very interesting ideas and we got several papers out of it.'[75]

The expertise and knowledge for which an academic is hired have also tended to become more specific, and more related to their own current research. Consultancy has therefore come to overlap more with specific technology transfer, as opposed to general expertise transfer.

> 'It used to be that someone in chemistry would be hired as a consultant because he knew something about catalytic chemistry, and not specifically to consult on his own research. That's changed - more and more consultancy requires faculty to talk about, and give advice about and respond to questions about research very close to, or even in, the investigator's own area of specific research.'[76]

This shift produces increased scope for conflict of interest problems and ownership disputes. For example: if an invention results from this discussion, based on the faculty member's ideas, who

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[73] see **Error! Reference source not found.** - Interview with Roger Needham of Cambridge's Computer Laboratory

[74] see **Error! Reference source not found.** - Interview with Mike Taylor of Manchester University Research Support Unit

[75] see **Error! Reference source not found.** - Interview with Roger Needham of the University of Cambridge Computer Laboratory.

[76] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

owns it? This underlines the need to ensure that terms in sponsorship agreements do not conflict with general policies regarding the ownership of university research.

4.4 PROVISIONS OF SPONSORED RESEARCH AGREEMENTS

As we have seen, the impetus for research collaboration will almost always come from the researchers themselves. However, the final sponsored research agreement exists between the company and the university rather than with the researchers themselves. Whilst the particular arrangements varied from university to university, all the participant institutions had a designated office with responsibility for participating in negotiations and concluding agreements.

The university offices with specific responsibility for sponsored research agreements are likely become involved some time after exploratory negotiations have begun. As Richard Tomlin, Head of Research Services at Newcastle University made clear, some academics deal with these negotiations much better than others.

> 'There's almost a triage in these things - there are those academics who know how to do it, because they've done it before. They do it well and basically they come across to us with three quarters formed projects and deals, which are essentially fine. At the other end of the spectrum there are people who turn up with something so comprehensively awful and done at the last minute that there's not really anything we can do with it... and then there's the group in the middle... of people who come fairly early on in the conception of a relationship with a company and come to talk about customer pricing and what kind of an agreement would the university look for....'[77]

The Intellectual Property Guide of Harvard Medical School contains a concise summary of the negotiating process. They emphasis that it is essential to clearly identify at the exploratory stage exactly what the goals of both parties are, what the innovative ideas of the scientists are and what they can bring to the company.

Before these shared objectives can be extended to an agreement in principle, it is essential that representatives on both sides with the power to make commitments are involved. Detailed negotiations can then take place as to the exact terms, with the whole process usually taking six to twelve months. It suggests that the following issues must be addressed for all kind of agreement, including consulting and technology licensing as well as sponsored research:

- Term of the agreement
- Exclusivity of the agreement
- Definition of the scientific or technological field covered by the agreement
- Compensation
- Publication rights
- Confidentiality of information
- Rights to, and compensation for, intellectual property
- Rights to terminate

[Harvard, page 9]

These concerns were shared by the other institutions surveyed. The three most controversial are the ownership of intellectual property, the right to publish and the need for confidentiality of information.

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[77] see **Error! Reference source not found.** - Interview with Richard Tomlin of Newcastle University Research Services Unit

4.4.1 ACCEPTABLE KINDS OF AGREEMENT

None of the American institutions participating in the survey were willing to conduct research which could not be published, and whilst policies were less absolute in Britain, none of the participant universities had undertaken any such research in the computer science field. Incentives for faculty to conduct such research were, in any event, limited, because academics career progression is to a large extent determined by the quality and frequency of their publications - though the British government is currently attempting to alter this by giving equal weighting to confidential research in its research assessments.

The general opinion was also that companies would have no desire to see important, proprietary research done by university teams. Some of the research groups themselves saw the potential for flexibility if the terms were right, but felt it unlikely that companies would be willing to pay enough to justify this. As Eugene Charniak of Brown remarked,

> 'if someone waved a very large cheque in front of me I might reconsider. In my experience, though, companies don't wave cheques that large anyway - so it's probably not a situation that's ever actually going to occur.' [78]

Neither did universities feel able to carry out this kind of work.

> 'Many companies have scaled down their in-house R&D, and that's a bit of a worry because I don't really want the university to be doing research which is of such central commercial importance to a company that if it goes wrong or it gets leaked at a critical moment then some major calamity is going to befall the company. Companies need to think carefully about why they are commissioning research within a university.'[79]

IBM were in agreement with this.

> 'Most companies don't go to universities and say "I want you to produce this confidential piece of work that only I will ever see" because that's just not practical.' However university may be given confidential corporate information to work with - which is itself problematic. 'The last thing I want is having some guy who spends all his time surfing the Internet having my information with no restrictions on it'.[80]

In terms of formal policy, at least, there was a distinct difference in attitudes between the American and British institutions. Harvard had perhaps the strictest policy, allowing agreements which gave the sponsor rights to see results before publication, but not before submission.

> 'Many companies, in their proposals for industrial research, will require the researcher to submit the paper to the sponsor before they submit it for publication. That, of course, is not acceptable - not in my cases.'[81]

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[78] see **Error! Reference source not found.** - Interview with Eugine Charniak of Brown University Computer Science Department

[79] see **Error! Reference source not found.** - Interview with Richard Tomlin of Newcastle University's Research Services Unit

[80] see **Error! Reference source not found.** - Inteview with Hoecker & Greis of IBM US Higher Education Business

[81] see **Error! Reference source not found.** - Interview with Donald Walker of Harvard Office of Trademark and Technology Licensing

MIT were prepared to allow the sponsor the right to a short delay before publication, but not to allow any kind of veto on publication of the research itself. In the US, university charters sometimes forbid research which is too applied, and restrictions imposed by their legal status prohibits 'work for hire'. However, definitions of 'applied' are in practice quite flexible - usually any work for which a graduate student could be awarded a thesis on the basis of will be acceptable.

> 'It depends who is doing the defining, usually - and I know this may sound a little cynical - if a professor is employed by a company to do some research, he is apt to find that research basic or useful, and not apt to find it applied in that definition.'[82]

In Britain, attitudes were less absolute. As discussed previously, the government is keen to encourage universities to become suppliers of all kinds of research to industry. However, in the small sample of institutions and researcher surveyed, no confidential research was taking place in the computer field. The kinds of research which academics find worthwhile, and which universities are well positioned to undertake, are unlikely to be so commercially sensitive that they cannot be published.

A clear distinction was draw here between the research findings themselves and confidential information supplied by the sponsor. General agreement was observed on the part of the universities that restrictions on publishing the central theoretical results and findings of a researcher's work were unacceptable; however if the particular problem on which the research was based had been supplied by a sponsor, and so contained detailed and commercially sensitive information, then it was acceptable for the company to insist that the details of its activity should not be revealed. Providing both sides interpret this reasonably, and that the company is able make a quick decision on the release of its information[83] and does not employ bureaucratic procedures which leave researchers waiting for months or to seek excessive control over findings, then these arrangements are unlikely to prove too problematic in practice.

It is very important for there to be clear agreement over exactly what research is covered by the agreement, as well as what the exact nature of rights over that research are. Many of the institutions reported companies drafting terms so as to gain rights over research which they were not actually paying for.

> 'The key thing in all these contracts is that you define the results by what you deliver in the report to the company. That's where we have to be careful that we don't deliver results that haven't been genuinely funded by the company, because that becomes the basis for any exclusive licensing or ownership by the company.'[84]

Companies must also understand that, although a contract is being signed, the university is not actually agreeing to produce anything of use. If the utility and exact nature of the results were already known then there would be little point in carrying it out. Hence the contract can only

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[82] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

[83] see **Error! Reference source not found.** - Interview with Tom Anderson of Newcastle's Centre for Software Reliability

[84] see **Error! Reference source not found.** - Interview with Nick Cook of Newcastle University Computer Science Department

document the area to be investigated, time and effort to be spent, procedures used and status of the results. Even the exact format which the results will take cannot be assured, and it may not be possible to give a timescale on which they will become known.[85]

4.4.2 EXPLOITATION TERMS

Although it is not the only benefit which companies gain from sponsoring research, they are in most cases concerned to gain rights to exploit any of the results of research which have commercial value to them. These rights can take a number of different forms, and much negotiation takes place on a case by case basis, however in general the experience of UK institutions was that companies were more likely to demand ownership of research results and less likely to accept licensing of exploitation rights as a separate process. As documented in section 3, in most cases the office or company responsible for technology licensing plays a part in drafting and negotiating terms relating to ownership and exploitation in sponsored research agreements.

> 'Sponsored research has a real sharp point to it, and what I mean by that is that a company will come in, speak to a particular professor - because that professor has particular expertise in an area of interest - and enter into discussions with the professor to undertake certain set of experiments or body of work, they'll pay for that and if any inventions come from that they'll want rights.'[86]

At MIT, most agreements allow research sponsors a six month period from the identification of a patentable technology produced during the research to elect to license it, and an expression of interest on the part of the sponsoring company will often be the most important part of the decision to patent the invention. The sponsor must negotiate licensing terms in the same manner as any other company, though if they decline the chance to license and the technology is eventually licensed by a another company they receive 25% of royalties from such agreements.

Harvard took a firm stance: whilst it was acceptable to offer companies rights to see a researcher's work, there could be no guarantee than the sponsorship of research would automatically make them licensees of results. It was not acceptable for a company to

> 'establish licensing terms as conditions which are buried in the grant document; [Harvard] won't participate in that... it is inappropriate to lock in and make captive the research activity of a university laboratory. The faculty could then become indentured researchers for the companies supplying the money... the influence can become quite pervasive.'[87]

The right to be the first to negotiate is subtly different from the right of first refusal. Policies differ - Pennsylvania were reluctant to grant a right of first refusal, [88] whereas Brown and Yale appeared happy to offer the right of first refusal of a licence (in Brown's case exclusive). None of

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[85] see **Error! Reference source not found.** - Interview with Andreis van Dam of Brown University Computer Science Department

[86] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

[87] see **Error! Reference source not found.** - Interview with Donald Walker of Harvard Office of Trademark and Technology Licensing

[88] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

the American institutions were willing to assign ownership of the rights to the results of sponsored research to the sponsoring companies.

> 'What one has to be very careful about in that process is not ever to feel that the granting of a research contract to an investigator is a suitable substitute to payment for the intellectual property rights granted. That's why we like to keep them as separate agreements and negotiate them separately, otherwise you under collect.'[89]

> Whilst gratitude is expressed for sponsored research support, results of the research are 'discreet bits of technology' and the company must pay the market rate for them - 'they'll try to connect it, when you get into licensing negotiation, but it fails'.[90]

American institutions, at least those in the elite group surveyed here, seemed reluctant to give up ownership of IPR over research to sponsors under any circumstances. Some of them were actively involved in the political process to ensure that their rights to all Federally funded research, granted under the Bayh-Dole act, were not eroded.

> 'In recent years the creation of a new 'Advanced Technology Program' by federal agencies effectively counter key provisions of the [Bayh-Dole Act]. There is also another 'Technology Reinvestment Program' which, while not precluding university ownership of intellectual property, nonetheless places control of the research in the hands of the for-profit partner, and places the university in a disadvantageous negotiating position. And, there is draft legislation being considered by the US congress that would create a government-operated corporation to centralise and control all federally-related technology transfer-including, perhaps, university inventions.'[91]

In Britain, by contrast, universities seemed in general prepared to compromise on virtually any aspect of ownership providing compensation was sufficient to make the agreement appear attractive when taken as a whole.

> 'It's a cultural thing too - different countries are happy with different arrangements. In America companies in general are quite comfortable for the university to retain ownership, comfortable to have an option to license. British companies traditionally go for assignment and ownership.'[92]

Although companies can sometimes be satisfied with a right to negotiate and an assurance of 'fair and reasonable' terms, in other cases it is necessary to assign ownership or agree to a cap on royalties. The two specific things which Newcastle University were unwilling to consider compromise on were the rights to publish and the right to use results as the basis of future work -

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[89] see **Error! Reference source not found.** - Interview with Bill Jackson of Brown University Research Foundation.

[90] see **Error! Reference source not found.** - Interview with Henry Lowendorf of Yale Office of Cooperative Research

[91] see **Error! Reference source not found.** - Interview with Donald Walker of Harvard Office of Trademark and Technology Licensing

[92] see **Error! Reference source not found.** - Interview with Richard Jennings - Cambridge Industrial Liaison and Technology Transfer

> 'providing we can arrive at that we are happy to enter into almost any arrangement that makes both parties feel comfortable.'[93]
>
> '[IPR ownership and fees payable] are obviously linked - if the university retains ownership of all the intellectual property then one would expect the amount of funding to vary because they are not buying the results - they're buying the right to exploit the results rather than the actual ownership.'[94]

This was mirrored in the attitudes expressed at Manchester, where it was also made clear that moves toward a more definite policy were afoot. One problem, alluded to earlier, is that by the time the specialists in a university's central administration become involved, preliminary negotiations will often have taken place during which academics will have taken positions incompatible with university policy. Policies must therefore not just be formulated, but disseminated widely throughout the university.

> 'There's a complete spectrum here - from the sponsor claiming rights to not just what comes out of the research but everything the investigators find in the next fifty years to no rights being conceded to the sponsor. We are trying to put some policy in place - there is quite a long education job there because often the researcher has more or less agreed all the terms before he comes into the Research Support Unit... the researcher can't commit the University, but in practice the University is seen in a bad light if after something has been purportedly agreed by a researcher somebody in the centre says "No, you can't do that." We want to get all of that clear, the fact is that we are keen to see intellectual property exploited, but we are not keen to see the University exploited by industry. We want fair reward for the inventive efforts of out staff.'[95]

It is, of course, possible to set up a strong framework for future licensing terms within a sponsored research agreement, establishing principles for due-diligence and so on, but to leave discussions as to the exact rates of royalties and terms of the agreement until the results of the research become known. Because these depend crucially on the exact nature of the inventions, plans of the company and state of the market, as discussed in section 5.2.2, it is unlikely that arrangements made entirely in advance will be fair to either party.

There would appear to be a potential transfer of risk here. As the discussion in section 5.2 makes clear, most research produces no inventions worth patenting, of those which are patented most are not licensed, and of those which are licensed, most do not recover costs. These universities which have earned very large sums from technology licensing have done it from a handful (usually a single) patent which has been spectacularly successful, and in many cases is not even a product of exceptional scientific research. By allowing ownership to rest with the sponsor, agreeing caps on royalties or allowing terms to be agreed in advance, the university is selling its lottery ticket to the sponsor, rather than keeping it for itself. In most cases the rights will be worthless, and so the university will benefit from whatever negotiating advantage was gained in return, but the occasional spectacular success from which millions of pounds might result will be sacrificed.

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[93] see **Error! Reference source not found.** - Interview with Richard Tomlin of Newcastle University's Research Services Unit

[94] see **Error! Reference source not found.** - Interview with Nick Cook of Newcastle University Computer Science Department

[95] see **Error! Reference source not found.**- Interview with Peter Schaefer of Vuman (University of Manchester)

4.4.3 EXPERIENCES OF GOVERNMENT FUNDED SCHEMES

As discussed previously, a variety of initiatives have been established by governments in both the US and UK to encourage technology transfer and cooperative research. Obviously a full scale evaluation of these programmes is not within the scope of this report, but many participants did mention their own experiences of these programmes and so some of these are summarised below. In general experiences seemed somewhat negative.

Although ESPRIT (see 2.2.2.4) was a major source of funding for many British participants,, and was supporting work which would not otherwise have happened, its modes of operation were not regarded as helpful.

> 'I regard it as a total a waste of time. We were in there right at the start, and we've been involved in a dozen different ESPRIT projects in one way or another, and I can't think of a single useful bit of technology we generated, or a case where we did something that led to any kind of genuine commercial business or a technology produced as an ESPRIT result actually went out and was commercially successful for Europe. The only beneficiaries I have actually witnessed are the international airlines and the hotels. I'm extremely cynical....'

The projects involved work with organisations of all kinds, including large and small companies and universities. 'I suppose we have made some interesting links, but I honestly there's any business has come from them.' However, a further ESPRIT proposal is currently under preparation. Preferred projects are those 'in the corners' of a diagram which are not reliant on the inputs of other groups.

> 'It really has to be a piece of code that you've already written, or failing that - which would be annoying - something that you had to do anyway.... You've also got to make sure that there's a member in Greece or Portugal to hold your summer management meetings and someone near Grenoble for your winter meetings - quality of life. Given the amount of money that's gone into ESPRIT it would have been far better used if people had made these projects much smaller, with a much much lower bureaucratic overhead.'[96]

Roger Needham suggested that Cambridge's experience of ESPRIT had been similar.

> The Lab has also been involved as minor participants in a number of the large scale ESPRIT projects with international industrial partners. 'My observation, which I hope is untypical, but I fear isn't, is that if you're going to waste that much money there must be easier ways.' Companies often try to base projects on work which they have already undertaken, are subcontracting or planned to do anyway, whilst often most of the work in a project comes primarily from one of the partners. However, some projects have achieved 'respectable' results, and of course, the process does encourage greater contact between European companies - 'but it's hard to think that you couldn't achieve this amount of conversation slightly more cheaply.'

Their experience of collaboration with other academic institutions, via '*Basic Research Actions*' has been

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[96] see **Error! Reference source not found.** - Interview with Peter Moforth of the Turing Institute

> 'entirely favourable, we are involved in a number of them and I am sure that this has increased greatly our contact with Continental European universities. It's an interesting observation that people of my generation tend to look west for collaboration, because when we were young there wasn't much going on in Europe to collaborate with, whereas my colleagues twenty years younger tend to look to Europe.'[97]

This was echoed by Tom Anderson at Newcastle, who also felt that basic research collaborations worked far more smoothly than those with industrial partners.

> 'in collaborations with industry the partners often have very different drivers which can lead to different directions with the collaborative project.'[98]

Several participants had also been involved with schemes such as the DTI LINK programme to encourage collaborative research. Whilst welcome in principle, these schemes were also agreed to have practical problems. (See section 2.2.2.4 and 2.2.3.4 for details of the schemes). CASE awards were mentioned as successful and inexpensive examples of beneficial collaboration, whilst Richard Tomlin[99] of Newcastle suggested that, despite their relatively low value, the new ROPA (additional grants only available to teams with existing industrial sponsorship) might successfully act as a catalyst in encouraging industrial funding. According to Richard Jennings of Cambridge, the attractiveness of the schemes to the smaller companies at which they are aimed is limited by the bureaucracy involved - the LINK scheme, for example, does not even have a sample agreement to act as a guide to negotiations (unlike the much criticised ESPRIT).

> 'These sponsored awards are very helpful in principle, the problem with all of them is that small companies see them as bureaucratic and difficult and see an enormous opportunity cost associated with them.... LINK is a very good programme in principle but it's a bureaucratic nightmare - everybody's been saying that from the very beginning but there's no will by the DTI or anyone to sort it out - the people involved are just saying "Oh you sort it out, we're government, we don't get involved in that sort of thing" and that's not helpful.'[100]

Participants in the US placed less emphasis on the role of specific government programmes in encouraging collaborative research, though it must not be forgotten that much corporate research and development work is made possible through tax credits, and that companies can receive substantial tax advantages from gifts to universities. These incentives are much more general and programmes such as LINK or even ESPRIT.

What specific programmes do exist in the US, such as SBIR (the model for SMART) and the ATP (see section 2.1.2.3) are oriented towards the support of small innovative companies as a means of encouraging exploitation of universities research. These are discussed further in section 5.3.3.

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[97] see **Error! Reference source not found.** - Roger Needham of the University of Cambridge Computer Laboratory.

[98] see **Error! Reference source not found.** - Interview with Tom Anderson of Newcastle's Centre for Software Reliability

[99] see **Error! Reference source not found.** - Interview with Richard Tomlin of Newcastle University's Research Services Unit

[100] see **Error! Reference source not found.** - Interview with Richard Jennings - Cambridge Industrial Liaison and Technology Transfer

5. TECHNOLOGY TRANSFER

5.1 WHAT IS TECHNOLOGY TRANSFER?

Technology Transfer is a phrase much used when discussing research. In its broadest sense it can be used to describe and movement of a technology or technique from one context to another, and indeed it is often used when discussing the movement of technologies from developed countries to the third world. However, its use in relation with scientific research is usually to denote the movement of technologies developed in research laboratories into the market place, and hence to describe the process whereby technology is commercially exploited. The particular flow of technologies which we are most concerned with here is from universities to companies, but it must be remembered that for many companies the most important transfers of technology will be internal and that the transition from corporate lab to corporate product is a more important one.

American Universities, in official policy at least, tend to view technology transfer as a matter of providing benefit to the public. MIT's policy and procedures document on Technology begins its discussion of commercial development as follows

> It has long been acknowledged that the primary functions of a university are education, research and public service. It is in the context of public service that MIT supports efforts directed towards bringing the fruits of MIT research to public use and benefit.
>
> In many cases, mere publication of research results will be sufficient to transfer MIT research to the public. In other case, it is necessary to encourage industry, by the granting of license rights, to invest its resources to develop products and processes for use by the public.
>
> [MIT, page 13]

There is a very real sense in which all the mechanisms of research oriented interaction discussed previously, including sponsored research agreements and consultancy agreements, are motivated primarily by the transfer of technology. The assimilation of a new technology is likely to involve much more than the simple movement of an artefact from one party to another, and although the licensing of a piece of clearly defined or tangible intellectual property often plays an important part in such transfers its importance is easy to overstate. This chapter thus focuses on technology transfer in its broadest sense, including an examination of the different moments of technology which might be transferred and the importance of different formal and informal mechanisms for doing so.

5.1.1 TECHNOLOGY AS ORGANISATIONAL EXPERTISE

> 'Technology licensing is a good thing, and I think it needs to be considered, but I don't think it's the primary mechanism of technology transfer. I think the primary mechanism for technology transfer is direct contact between researchers in similar fields where they exchange information and know-how.... It's normally exchanged freely on the basis that it's of benefit to both parties. It doesn't cost anyone anything.... it's an informant network.'[101]

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[101] see **Error! Reference source not found.** - Interview with Gary DesGroseilliers of DaimlerBenz Research and Technology, North America

[Rosenberg b] investigates industrial innovation in detail, and comes to conclusions regarding technology within companies which amplify the importance of 'tacit' knowledge and the development of organisational capabilities through accumulation of scientific expertise which were noted in section 4.1.1.2. It suggests that the reason that inventions are primarily made in companies rather than universities is that the technologies and needs of industries are not known within universities - such inventions come from the interaction of market needs with research expertise and so companies develop what are essentially their own specific technologies.

Such technologies are specific because, in many industries, patentability is not a key consideration and expertise is crucial. The results of his questionnaires reveal that patents are most important in industries where chemical composition is important, such as the chemical, pharmaceutical and materials industries. Patents are also important where products are devices which can be easily copied.

However, in other fields the importance of patentability is negligible. He suggests that for products such as missiles and aircraft it is likely to cost an imitator around 75% of the original development cost to successfully copy a design. This is because learning details of the technology is crucial to the duplication of its functionality, so almost the same expertise is required to understand and copy the design of the product as to produce it in the first place. This very specific expertise is what makes the technology proprietary.

It follows that the transfusion of such technology is a product of the spread of expertise, rather than a matter of licensing a patent or reading an article in a journal. Informal networks of information exchange and personnel movement are far more important, and the main role of patents may be to guard against potential infringement suits from others.

> I suspect that patent licensing... is basically the tip of the iceberg of technology trading and sharing, most of which does not involve explicit licensing.
>
> [Rosenberg b]

It seems likely that the IT industry represents another field where the role of patents is firmly secondary to that of expertise.

Rosenberg's research also investigates the perceived importance of research, and university research, in different disciplines across a wide selection of different industries. His findings show that computer science research is viewed as crucial to a large number of industries. Fields such as chemistry and, especially, physics, displayed a high perceived importance but a obtained low marks for the relevance of university research, whilst academic computer science research scored just as highly as the field in general.

Some quantitative data on the importance of formal technology transfer as a motivation for research collaboration is provided by [Cokar], which is based on an examination of 35 university collaborations in one company. Of these collaborations, 49% were intended to involve transfer of both technology and knowledge, 34% to transfer knowledge alone and 17% to transfer technology alone. In 43% of collaborations the professor involved was known to the corporate collaborator before the project, and in a further 31% of cases they knew of them by reputation. 57% of projects were judged to have successfully transferred information, 31% to have transferred materials, devices and software and just 3% (i.e. 1 so this is probably not a very reliable figure) to have transferred 'technology' (presumably patentable). In as much as these

results may be generalised, they suggest that formal technology transfer is an uncommon result and is very rarely the only planned outcome of a collaboration.

A more substantive evaluation comes from a survey by the US General Accounting Office quoted in [Feller]. 168 firms were asked their motivations for taking part in the NSF Research Centers scheme. Of a total of 15 suggested motivations, the production of patentable products came last. Selected results are shown below:

Motivation:	**% of sample citing**
'Match between research interests'	89%
'Interest in "state of the art" research.	88%
'Leverage of research funding'	48%
/\/	/\/\/\/
'The production of patentable products'	8%

Figure 5-1: Selected Results from US GAO Survey of Participants in NSF Centers scheme

5.1.2 FROM R&D TO TECHNOLOGY ACQUISITION

Today, attention is focused on 'innovation' rather than invention. Innovation is a continual process, involving feedback, and is considered in a business context, involving the successful deployment of products and processes as well as their development. Successful innovation involves the use of new technology, which may have been developed in-house or acquired from elsewhere. Jeff Solash suggested that there are factors in corporate culture which have mitigated against technology transfer.

> If a company are offered a piece of technology, they will often send it through internal channels to an expert in R&D, together with a vague covering memo asking him to evaluate it. The natural reaction this causes is often one of suspicion and resentment, worry for his own job security and an instinctive rejection of the technology - 'Why don't you increase my funding instead?'. A switch is required away from thinking in terms of a 'Research and Development' department to a 'Technology Acquisition' department - 'the president of Technology Acquisition should be in the business of acquiring technology whether it comes from internal or external sources'. This department also needs to be better integrated with sales and marketing efforts.[102]

A company may acquire new technologies in a number of ways. One traditional way has been the use of suppliers and contractors - the producers of automobiles or aeroplanes often gain the benefit of new technologies via their adoption by the manufacturers of components. Another traditional way has been to develop it within the company. A smaller company which has developed a novel technology may be acquired or brought into an alliance, or a group of companies may come together in a consortium to pool the costs of research.

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[102] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

One thing which companies seek to do is to involve the risks inherent in product development. Like all projects, there is a risk that a development programme designed to lead in time to a new product may fail - at early stages this may be due to technical problems, other companies may establish themselves in a stronger position with equivalent or better technology, the market may alter or management conflicts may prevent the successful conclusion of the project. A corporation therefore wishes to hold a broad 'portfolio' of projects in different stages of development, to introduce new products as rapidly as possible and to have as much flexibility as possible. Many of these considerations lead naturally to a consideration of joint research and development ventures and to the licensing of technology. [Bower].

The shift from technology development to technology acquisition has undoubtedly been accelerated by the restructuring of major corporations, which as discussed previously has in general caused closer integration between research and development activity and business divisions, and by the huge complexity and expense of new products in many industries.

> 'companies no longer think .... if they don't develop it internally then it's bad. Companies are recognising that with everything from legal work to menial work to R&D that they can piggy-back off R&D that is being funded by the government or they can cheaply, by funding MIT research, take advantage of all the MIT overhead and equipment and experience to take a technology and move it forwards.... companies will start to recognise that it's the same thing, by giving up a little bit of a big pie you have more than if you try to keep all of a small pie. That's the way to make money. Industry is looking to be flexible in its R&D and to capitalise on opportunities to collaborate, not only with universities but with other companies.'
>
> 'More than anything else, whether you really believe in it or whether you're cynical about it - it's more popular, it's the buzz. Licensing out is acceptable, it doesn't mean that you're weak - it means that you're nimble and competitive.... It's seen now as smart business. '[103]
>
> 'People looking very much at what their core business is, considering whether to spend money internally or outsource, ultimately this must benefit the universities. The good news is that it's reached the top of the industrial agenda - when I started in this office seven years ago, one felt that, both in companies and universities, industrial liaison officers were somewhat marginal. Now, both are much more a part of the core business, and the quality and the exchange has increased dramatically, as has the support in both sectors.'[104]

Small firms are unlikely to be able to take part in longer term research projects. As discussed previously, they are less likely to have either the resources or the long term focus needed to invest in such schemes, which from the point of view of the company involved in highly speculative. Other mechanisms of technology transfer are therefore more important for such companies. These include the kind of informal links discussed in 4.3.14.3.1. The employment of graduate students can be an important mechanism for such companies.

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[103] see **Error! Reference source not found.** - Interview with Alex Laats of the MIT Technology Licensing Office

[104] see **Error! Reference source not found.** - Interview with Richard Jennings - Cambridge Industrial Liaison and Technology Transfer

> ‘Small local technology companies are increasingly employing graduates, and that’s a very real, and in some ways the most important, source of technology transfer: the movement of intelligent people.’[105]

5.1.3 BRIDGING THE DEVELOPMENT GAP

Although, as discussed in 4.1.1.2, the progression from basic research to product is often far from linear, by the time that a piece of technology has been assessed as being of likely commercial value, and is under consideration for patenting, at least one commercial application must have been observed for it. Unfortunately for technology transfer offices, the state in which a university research programme is likely to have left the embryonic technology is not usually sufficiently advanced for a company to be able to easily adopt it and turn it into a viable product with a minimum of effort or risk. Alex Laats at MIT stressed the centrality of these problems to technology transfer.

> 'The real difficulty in terms of taking technologies and getting them from an embryonic stage to a product stage, and then from a product stage through a scale up to a large market is funding along each step of the process. Whether it be an industrial sponsor or the US government that is funding research here at MIT, MIT is not in the business of delivering products - its role tends to be more open-ended - taking the technology to a very embryonic stage'.

> The first stage is research - 'MIT all the way', followed by development - generally also funded by the sponsor and carried out at MIT. However, the government rarely goes beyond these to the next stage - 'the creation of prototypes on a bench in the lab'. Still more rarely will it fund trial manufacturing of a product. Industry by contrast, is usually much more interested in an idea if it can be presented in the form of a manufacturable prototype which they can then investigate the scaling up and marketing of. 'The problem is in the gap between R&D and the things that industry is interested in capitalising on'.[106]

Most technology transfer initiatives, such as the US Advanced Technology Program (see 2.1.2.3) are designed to help overcome this, by supporting the development of technologies until they reach a more commercially viable stage.

One of the attractions of an ongoing active research collaboration is that technology will often be transferred to the company as it is developed (at least in the informal sense - they may have to license IPR separately) and so transfer will be from an internal research group to an internal, product oriented product development group. Even in this case, however, the biggest hurdle which the project has to jump is not from university to industry but from research teams (university and industry) to product development teams. As Alvey Programme showed, even when research collaboration has been highly successful and ownership is clear, its commercialisation is far from automatic (see 2.2.2.3).

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[105] see **Error! Reference source not found.** - Interview with Richard Jennings - Cambridge Industrial Liaison and Technology Transfer

[106] see **Error! Reference source not found.** - Interview with Alex Laats of the MIT Technology Licensing Office

5.2 TECHNOLOGY LICENSING

> 'Everyone says that technology transfer is truly wonderful, but everybody also says that universities ought to "exploit" the technology which they have generated for money, as effectively as they possibly can. These two things are actually slightly opposed to each other.'[107]

There are undoubtedly some situations in which formal licensing works well and is necessary. As implied previously, these often occur in fields where a clearly defined process or product has a direct and clear commercial value and can be patented, or where a piece of software can be licensed under patent. Often the exclusivity which can be gained by a formal license is necessary to make product development worthwhile for a company.

Although, at least in the US, university policy may stress the importance of technology transfer as a service to society and a means of making good the public's investment in research, there can be little doubt that a considerable part of the motivation towards the widespread establishment of technology transfer offices has come from the spectacular revenues derived by a few patents. Even at Harvard, the most conservative of the institutions surveyed, some financial motivation was admitted.

> 'Although nobody [in the university's central administration] looks at our small group with a totally 'green eyeshade' viewpoint, they have been known to ask us to project what our royalty revenues will be next year....'[108]

As Alex Laats emphasised, many patents only realise their full value after some time when products finally reach the marketplace. Similarly, an equity stake in a start-up company may only be realised several years later when, and if, the company becomes public.

> 'I have a business plan on my desk for a technology where I'm seeking a 5% royalty, and the business plan calls for revenues $26 million in a couple of years. I'm making $1.3 million, and that's if the company doesn't take off. That's a lot of money - it's not Michael Gates of Microsoft, but 5% of sales for any good company could be huge. It [technology licensing at MIT] has only been around in its current form since 1984 or so, a lot of the pay-offs are in the future'.[109]

A small number of well known patents have generated very large sums. These include the Cohen-Boyer patent mentioned in section 2.1.2.1, also a patent for a successful breed of strawberry, the patent for fluoride in toothpaste and a patent for the soft drink 'Gatorade'. These patents are each worth tens of millions of dollars annually, and in many cases are responsible for the vast bulk of revenues generated by the offices concerned.

Figures from the University of Wisconsin, which was one of the first institutions to actively pursue patents, show from the 2,426 disclosures made between 1925 and 1985, 448 patents resulted, of which only 203 have ever been licensed. Whilst 100 of these resulted in income

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[107] see **Error! Reference source not found.** - Roger Needham of the University of Cambridge Computer Laboratory.

[108] see **Error! Reference source not found.** - Interview with Donald Walker of Harvard Office of Trademark and Technology Licensing

[109] see **Error! Reference source not found.** - Interview with Alex Laats of the MIT Technology Licensing Office

greater than licensing expenses, over the entire period just 10 patents were responsible for 90% of the overall revenue. [Feller] concludes from these figures that the establishment of a technology licensing office is like buying a lottery ticket and that for most institutions costs will probably never be recovered.

> There is little reason to expect, based on past performance, that any sizeable reallocation of faculty efforts towards commercially oriented R&D will generate appreciable new net revenues for other than a select handful of universities.... Profitable or not, these ventures serve to shift academic researchers from the social roles in which they are most efficient - as suppliers of a collective good - scientific knowledge.
>
> [Feller, page 334]

Feller's suggestion of scientific knowledge as a collective good is, as argued previously, rather naive - at least in technological fields - but it seems likely that, whilst a university which produces a number of valuable inventions might be able to profit by their exploitation, that a reorganisation of research motivated by the hope of increasing licensing revenues, something which UK government policy might encourage, would be profoundly misguided. The most valuable patents are not necessarily those which emerge from the most important research (as the case of Gatorade shows), and in many cases the patentable invention is an unexpected result, or even a by-product, of the researcher's work. Richard Jennings at Cambridge commented, '*I feel very strongly that what we deal with is often a by-product*'.

> 'Despite the role of this office I think that it's crucial that we don't eat our future seedcorn - there is some extraordinary naiveté around in government, it suits current party dogma. That's what I find so distressing - they are intelligent people, they know the situation and yet they pretend that it's different from what everybody tells them it is.'[110]

In 1991 a total of 1,324 patents were awarded to universities in the US, compared to 437 in 1981. During this period the proportion awarded to the top 100 research institutions rose (to 85%), though the proportion to the top 10 institutions fell significantly - representing a substantial increase in activity amongst the mid-tier research institutions. 197 exclusive licenses generated $29.3 million, primarily in medically related areas, whilst 339 non-exclusive licenses were worth a total of $52.7 million.[NSF]

5.2.1 Intellectual Property

In both the US and UK, universities usually hold the rights to intellectual property resulting from research undertaken with government funds, and of course to any work paid for with their own income. As discussed in section 4.4.2, they will usually retain ownership to industrially sponsored research - the most important exception to this amongst the participants in this research being Cambridge's policy that the rights of internally funded research may be vested with the researcher themselves. These legal rights take several distinct forms. Intellectual property is owned by its originator but can in general be brought and sold in same way as other kinds of property. It may pass by contract of transfer (sale or licensing) or contract of employment to another owner.

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[110] see **Error! Reference source not found.** - Interview with Richard Jennings - Cambridge Industrial Liaison and Technology Transfer

5.2.1.1 Patenting

The best known form of protection available for an idea is its **patenting**. Once an invention has been patented all rights to its use are held by the inventor for a specified period. Only something which can be characterised as an invention can be patented - American law allows for the patenting of a quite wide range of inventions: as well as machines, processes and articles of manufacture protection can be extended to 'compositions of matter', asexually reproduced plants and - famously - a genetically engineered mouse. Improvements to existing inventions can also be patented.

British law differs somewhat here, and the Patents Act 1977 specifically excludes a number of categories - including varieties of plants and animals and computer programs.

For a patent to be granted, the invention must fulfil three, rather subjective, criteria. It must be:

- Novel - clearly distinct from previous inventions disclosed to any member of the public,
- Non-obvious - to someone knowledgeable in the field, and
- Useful - in some way of greater utility than existing methods.

> The patents system exists to encourage innovation. At its heart is a bargain between the Government and an inventor whereby the inventor is rewarded for revealing full details of the invention by the grant of a patent which provides an absolute monopoly in the invention for 20 years.[111] The country also benefits by gaining full knowledge of the innovation.
>
> [Irish - page 109]

This explains the strict requirements for novelty. Any publication or disclosure, anywhere in the world, is sufficient to destroy the patentability of an invention - this includes, of course, the normal kinds of academic communication via conferences, papers and electronic systems. Once an invention has been disclosed before a patent application has been filed it cannot then be patented by anyone.[112]

Before a patent is issued, checks are carried out by patent examiners to ensure that it does indeed appear to be novel. In some fields, especially computer software, a very high proportion of patents applied for and issued fail to meet this criteria but are not detected due to lack of expert knowledge and resources on the part of the examiners. Although software is not, in itself, patentable it is in general possible to protect systems of which software forms a key part. In the US a number of important cases have involved the patenting of algorithms, which is increasingly widespread within the computer industry.

Patenting is an expensive process, involving legal fees for the preparation of the application and the payment of a fee to the patent office itself. In the US, these fees total around $4,000 - $8,000 per application. [Harvard]. However, there is no such thing as a 'world patent'. Essentially, a

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[111] This reflects the situation in Britain. In the US, protection is usually for 17 years. Harmonisation is underway as a result of GATT provisions.

[112] US law allows patenting within one year of disclosure - however rights will still have been lost for most other countries wherever the disclosure is made.

separate application has to be made for every country for which protection is sought - although the EU has moved towards a single patent system and the Patent Cooperation Treaty provides a simplifying mechanism for initial claims. The costs of obtaining international protection are thus much greater, and in practice only states in North America, Australia and parts of the Far East are worth seeking protection in for most inventions. Details of patent law vary between countries, though harmonisation is taking place as a result of the GATT agreement.

The other expense associated with patents is in their defence. A patent grants its holder a legal monopoly - but if the holder wishes to maintain this monopoly they must be willing to take legal action against infringers. This is an expensive process, because even when a patent has been granted its validity can still be challenged and therefore it is not sufficient to show that a competitor is using the invention. The infringer can attempt to show that at the time the patent was applied for the invention, or one sufficiently like it to make it no longer novel and non-obvious, had already been disclosed somewhere in the world. In the UK most cases are settled out of court. A convicted infringer may be required to compensate for loss of revenue.

In the US, the consequences of deliberate patent infringement can now be severe. At one time the most severe punishment likely was 'reasonable royalties.' Companies could therefore routinely infringe patents, and treat any damages eventually awarded as a part of normal costs. A ruling by CAFCE - the Court of Appeals for Federal Court - changed this, allowing the specialisation of appeals judges in the arcane and case based field of patent law. They have enforced the law far more rigorously, and some high profile cases have resulted such as one involving triple damages running to hundreds of millions of dollars awarded against Kodak[113]. Judges are also willing to enforce injunctions on the sale of disputed products, and because the costs of licensing of technology are usually small compared to the sums invested in manufacturing, marketing and commercialising the technology, potential lost revenue being risked is likely to be much greater than the cost of licensing.

Of course, universities do not typically patent inventions because they themselves wish to enjoy a monopoly on their use. Usually a patent is filed with a view to subsequent licensing to a commercial organisation on either an exclusive or non-exclusive basis. The minimum criterion is obviously that the licence fees cover costs involved in patenting and licensing. However, a license to use a patented invention is clearly only a good investment for a company if it seems likely that action will be taken against a competitor who attempts to use the same invention without licensing it. If a patent is valuable then the competitors of licensees may seek to challenge its validity. The possible costs of such action are an important risk which must be considered when patenting policy is being formulated.

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[113] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

> 'you have potential infringement suit problems, and let's face it: if you are a licensee who is selling goods and making money, chances are there is someone else out there who will try and take their business away'. Patent infringement suits are expensive both in terms of dollars expended and the time required from technology licensing professionals and the inventors themselves in dealing with them. In North Carolina a university has incurred more than $5 million from their royalty stream in direct legal costs, in addition to tying up the head of their office for two years doing almost nothing apart from managing the case and requiring the inventors to seek release from their faculty duties for the duration to handle the workload imposed. The latter represent a loss of skilled time and opportunities which is very hard to quantify. These kinds of potential costs can easily be overlooked when considering potential income from patents.[114]

5.2.1.2 **Other Forms of Intellectual Property**

Copyright is another important form of protection. This applies to 'works', which include computer programs, microcode and cable programmes (including networked databases and the like) as well as more traditional works such as books, films and photographs. Copyright is automatically present in works, without the need to register them or to make an application, and endures until fifty years after the death of the author. Copyright in computer generated works rests with the programmer of the computer.

In most cases, copyright is vested in the author of the work - though if it is created in the course of employment then it will usually rest with the employer. When a university undertakes contract research, copyright is carefully negotiated.

Whilst, in order to be eligible for copyright, a work must be original there is no requirement that it be different from all previous works - merely that it has not been copied. A complicated situation arises with respect to 'derivative works' - some kind of transformation or reworking, which at its simplest might be a film adaption or translation of a novel. A new copyright protects the derivative work, but the work on which it was based continues to posses its own copyright and copying of the derivative work would infringe both.

The status of derivative work can often be an important consideration for universities. Often a piece of software will include material developed under a number of different arrangements, being for example the result of further work on a system originally developed as part of a research contract.

> 'That's a very hard issue to resolve... I am still looking for ways to measure the relative intellectual input to derivative works... simple examination of the code is clearly inadequate.... It's hard to know who "owns" what portion of a program after it's gone through multiple revisions.'[115]

Other specialised forms of intellectual property include confidential information, trademarks and industrial designs - which can be registered in a process analogous to patenting. In both the US and the UK, special provisions are made for the protection of semiconductor designs. In the

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[114] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

[115] see **Error! Reference source not found.** - Interview with Donald Walker of Harvard Office of Trademark and Technology Licensing

UK layouts are protected under the Design Right (Semiconductor Topographics) Regulations 1989 - protection lasts for ten years from exploitation. In the America the US Semiconductor Chip Protection Act of 1984 introduced a new form of intellectual property - the 'mask work'. Protection is a hybrid of copyright and patent, requires registration and applies only to topographies which have been incorporated into a product.

5.2.2 Evaluating and Marketing of Technologies

The involvement of a university office of Technology Licensing or Technology Transfer with a particular technology usually begins when a researcher reports that an 'invention' with possible commercial significance has been made. A standard 'invention disclosure' form is usually available for this purpose, upon which the researcher responsible for the invention provides a general description of the invention, in a form oriented towards an assessment of patentability, and an indication of its commercial potential.

Because the disclosure of inventions is, in practice, normally largely a voluntary activity, technology licensing offices must make sure that faculty know of their existence and of the way in which they work. The financial rewards are one incentive to researchers, but another priority must be the establishment of procedures which make the process as simple and easy for inventors as possible. [MIT]

Within the offices surveyed, responsibility for each specific field within the university was assigned to a particular officer, who could therefore build up expertise in the evaluation and marketing of particular types of technology and a network of industrial contacts working in relevent companies. Individual officers tend to develop different means of working which are appropriate to their field.

> 'We all do our [marketing] tasks quite differently - due simply to the difference in technology and the diverse nature of the markets being served.' In the broad field of physics, for example, when reviewing a new report of an invention and thinking about how he would market the technology, no single "road map" comes to mind. By contrast, he thinks that a colleague evaluating a discovery in, say, the molecular pharmacology field, may well have in mind a "short list" of industry companies that can be approached with licensing in mind.[116]

As discussed in section 5.2.1, in order for an invention to be patentable it must be novel, non-obvious and useful. It is not wise to patent all inventions regarding which patents might be granted, because the costs involved are considerable and so patents should only be pursued for technologies which seem likely to generate licensing revenues which at least cover the administrative and legal costs involved. Evaluation of the commercial value of a technology is thus crucial.

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[116] see **Error! Reference source not found.** - Interview with Donald Walker of Harvard Office of Trademark and Technology Licensing

> 'On both sides of the Atlantic you get institutions that patent anything and everything, and in my view this is flawed. Optimally you have to be selective, and admit that you are taking some risks. "Patent everything" is a risk minimization strategy that doesn't work - you spend so much money that it is difficult to show a return, and the managers dilute their efforts across a large number of cases with poor commercial value. The result shows up in poor performance ratios of income per employee, per patent filed, income to expense or non-reimbursable patent expenses... but NOT in simple measures like number of patents filed or gross income. Performance is now a concern in both the UK and USA. We continue to file patents on 50% or less of inventions reported.'[117]

In many cases the decision to patent was based on exploratory negotiations with companies to determine the commercial significance of the technology. Such discussions were usually be non-confidential, a licensing officer having a network of contacts which can be called upon for advice as to current levels of interest in technologies related to a particular area.

> 'If we are find that we're getting a reasonably positive response from a number of companies to this sort of initial test question then that would give us the courage to go forward with the expense of patenting something.' It may be difficult to gain an informed opinion without giving away the nature of the invention, so sometimes an invention in a very promising area must be patented before this is risked.

In some cases it may be possible to use non-disclosure agreements to protect the technology during discussions prior to patenting. Alex Laats at MIT suggested that 'marketing' constituted about a third to a half of his job, and involved '*understanding the markets, trying to determine whether or not the technology will fit, whether someone out there is going to be interested in it.'*[118]

Usually an inventor will have their own idea as to which companies are most likely to be interested in their invention. These are taken seriously - as Jeff Solash at Penn explained, '*Your inventors are often the best sources of information as to who is really interested - though their field of view is limited.'*[119] Because of the severe pressures which exist on the time of technology licensing officers, if these companies can be licensed to in a satisfactory manner then there is little incentive to look for other potential licensees. However, if possible the inventor would usually welcome interest from several companies and an auction of rights.

Don Walker at Harvard suggests that *'In licensing you try and find the industry leader, because you feel that their direction is the most 'real world' as well as most likely to result in revenues which lead to high royalties*.' Such a company is therefore more likely to provide high quality feedback to the researchers involved and so contribute more to the ongoing relationship.

Other sources of information mentioned by Solash include library work and consultation with students at the business school. Technology licensing people themselves network with each other, via professional meetings and electronic systems. Much of the discussion on the Techno-L

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[117] see **Error! Reference source not found.** - Interview with Peter Williams of Harvard Medical School Office of Technology Licensing and Industry Sponsored Research

[118] see **Error! Reference source not found.** - Interview with Alex Laats of the MIT Technology Licensing Office

[119] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

discussion group (an Internet list server) relates to the utility of different reports and information sources, licensing professionals can also seek the advice of their colleagues regarding dealings with particular companies or agencies and regarding new types of agreement.

Less directed methods of technology marketing may also be employed, involving the listing of technologies available for licensing. Many American universities have now set up technology licensing pages on the World Wide Web, and a number of commercial electronic databases with search facilities have been set up on-line to allow listing of technologies from a number of sources.

No empirical value can be assigned to a technology, all that is ever known is the eventual value of the license. The inventor themselves has some idea as to the worth of their invention, but in many cases this may be exaggerated. According to Henry Lowendorf at Yale, '*The inventor usually has a very high valuation of his own invention.*'

Estimation of commercial worth also involves a consideration of the risks involved in commercialisation. A patent which forms the basis of a new drug might potentially be worth many millions of pounds, but this must be set against the relatively slim chance that it will pass through all stages of development and clinical trials, and the huge costs involved in each of these stages.

Lowendorf stressed that the kinds of license which would best suit the technology also play an important part in its evaluation.

> 'We first have to identify companies that are interested in the technology. We have to look at the technology and determine if it is patentable, or is it something that would be licensed without being patented, such as a cell line or antibodies or something like that. We look at whether it would be the kind of technology that would be licensed non-exclusively or exclusively, whether it is a technology that might make sense to encourage a company to start up around, whether the technology can be divided up into fields of use so that we could license exclusively in one field of use to one company, and exclusively in another field of use to another company - or if we might want to divide it up geographically.'[120]

The issue of whether to license a technology to an existing company or use it as the basis of a start-up is one area where important differences emerged between the institutions surveyed. Procedures and policies here are discussed in section 5.3.

Reproduced overleaf is part of a form compiled by David Jones, Manager of Prototype Development at UBC/UILO in Canada which was distributed to technology licensing professionals via the Techno-L discussion group. Whilst not all offices employ formal checklists of this kind, it serves to illustrate the range of factors which must be considered during the technology evaluation process before a decision to patent can be made.

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[120] see **Error! Reference source not found.** - Interview with Henry Lowendorf of Yale Office of Cooperative Research

BACKGROUND TESTS:	No Low	Yes High	Rating 1–5
1. Patent search completed and clean.	___	___	___
2. Literature search completed and clean.	___	___	___
3. Invention remains confidential.	___	___	___
4. No publications pending.	___	___	___
5. No prior claims to the technology.	___	___	___
6. Technology protectable by patents.	___	___	___
TECHNOLOGY TESTS:			
1. Technology basis of a new industry or company (major breakthrough).	___	___	___
2. Technology state of the art.	___	___	___
3. Easy to demonstrate technology.	___	___	___
4. Identifiable and significant benefits.	___	___	___
5. Functioning prototype.	___	___	___
6. Addition to existing UBC patents.	___	___	___
7. Long product cycle.	___	___	___
MARKET TESTS:			
1. Fills identifiable & marketable need.	___	___	___
2. Market sizeable and growing.	___	___	___
3. Believable but indeterminate large upside potential.	___	___	___
4. Absence of direct competitive products.	___	___	___
5. Definable niche market.	___	___	___
6. Market accessible (no dominant technology).	___	___	___
7. Technology has low dissonance.	___	___	___
COMMERCIAL TESTS			
1. Result of industry funded research.	___	___	___
2. Prospective licensee identified.	___	___	___
3. Improvements / cost reduction >20%.	___	___	___
4. Low financial risk.	___	___	___
5. Technology basis for a spin-off company.	___	___	___
6. Sustainable competitive advantage.	___	___	___
7. Conforms to relevant standards.	___	___	___
MANAGEMENT TESTS			
1. Inventor technology champion.	___	___	___
2. Inventor has realistic expectations.	___	___	___
3. Inventor team player.	___	___	___

What is the biggest concern/ problem?
What is biggest upside opportunity?
Critical information missing?
Estimated costs: Patenting $ Time:
Estimated return to UBS: $ Timespan (yrs):

RECOMMENDATION:
Return to Inventor Return for Research Patent Application

Figure 5-2: Example checklist for evaluation of technology prior to patenting decision.

5.2.3 LICENSING AGREEMENTS

Once interested companies have been identified, and protection ensured via a patent if applicable, the details of a licensing agreement must be negotiated. Licensing agreements may be exclusive or non-exclusive. Exclusive agreements are the norm in areas such as pharmaceuticals where development costs are so great as to deter companies unless they are guaranteed a monopoly in the event that a successful product is produced. For computer related technologies and software non-exclusive licensing is more practical, allowing a spreading of costs.

Jeff Solash at Penn emphasises the importance of having a good idea of the realistic worth of the technology to the prospective licensee.

> When companies have been interested, strategy and negotiating positions must be established. 'Even there it pays to do your homework, and that is where I often depart from the company of a lot of my peers'. A case must be made to the company in terms of business opportunity, in a business like way. Companies will have carefully analysed the business worth of the technology, done Net Present Value calculations, formulated marketing ideas and so on. Despite the great pressures of work on technology transfer officers, they need more than a 'vague idea' as to the possible worth of the technology or they will face 'a rather severe disadvantage.'[121]

Whilst it is important to make sure that a reasonable return is derived from licenses, particularly given the licensing officers are the custodians of other people's intellectual property, it is also important to strike a balance between protection of the university's interests and maximisation of licensing opportunities. As Gary desGroseilliers, now working on technology liaison for Daimler-Benz but formerly part of the MIT Industrial Liaison Programme explained,

> 'a few years ago [the Technology Licensing Office at MIT] was run by lawyers, and their main interest and activity was to protect the rights of MIT in any negotiation over a technology. The result of that was that they were so good about protecting it that MIT was never able to license anything or gain any advantage or know that the technology was being used.... They got rid of all the lawyers, the patenting process is something which is handled by outside attorneys now and that's not the major part of their activity - the major part is that when there's a technology that is worth commercialising is to find an outlet for that technology and to structure a deal that is favourable to both parties….
>
> If a company is taking a technology from a university then they're making a major investment... it usually require a large investment of capital to commercialise it and if they're charged too much money or they're not given some kind of guarantee that they have at least a lead time... then they won't make the investment so it could be a very good technology but no-one will use it.'[122]

An agreement will often specify a number of 'milestones' at which further payments must be made. Each of these would correspond to a new stage in the commercialisation of the product, the classic example being the progression of a drug through the various stages of clinical testing. This system provides an equitable handling of risk - the initial payment is not prohibitively large in

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[121] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

[122] see **Error! Reference source not found.** - Interview with Gary DesGroseilliers of DaimlerBenz Research and Technology, North America

the event that a technology is not successfully commercialised, but neither is the university tied to a low level of income from what may become a successful product.

Another important part of most agreements are clauses demanding ‘due diligence’ on the part of the licensee. If a company licenses a technology and fails to exploit it then no royalties will be triggered, and if the licence is exclusive then competitors will be excluded from using it, the technology will languish and the university and the inventor will receive no royalties. Clauses which specify acceptable periods for each stage of the commercialisation process, or the investment of a certain amount of effort by the company, allow the reversion of rights to the university if no attempts are being made to exploit the technology.

All the institutions surveyed assigned a proportion of the revenue from licensing to the inventors themselves. Many also assigned a portion to the inventor’s department or research group. In the UK a standard formula exists for inventions funded by the Research Councils. In the US exact policies varied, for example at MIT a fairly complex arrangement gives the first 15% of gross income to the Technology Licensing Office towards expenses, one third of the remainder to the inventors and adjusts what is left to reflect TLO operating costs before splitting it equally between a general fund and the specific laboratory or department. [MIT]. Some institutions adjust the proportion going to each beneficiary according to the magnitude of the royalties. For example, Brown operates a sliding scale from an even split on the first $100,000 of income to a 20%/80% split in favour of the university for revenues over $1 million.[123]

A particular concern is that the university retain rights to use whatever is being licensed as ‘background’ intellectual property for future research. Whilst there is nothing to stop anyone (including the university) carrying out research based on a particular patent, it would be very hard to license the results of such research to another company (and therefore to obtain sponsorship for the research itself) if the original patent had been licensed exclusively and without any special clauses.[124]

To some extent, preferences as to the most appropriate forms of license remain subjective. Perhaps the most important principle is the maintenance of flexibility to deal with each case in the most important manner. As Jeff Solash concluded:

> 'We try and evaluate the best place and spot for the technology.... Who's got the best philosophy? There are some early indications of the best mode if you're interested in maximising in licensing revenue, but in my view it's too early to draw any firm conclusions.'

5.2.4 Licensing and Protecting Computer Technology

Software is usually licensed on an ‘as is’ basis, without support or any guarantees as to usability. Further support and adaptation must be paid for, via consultancy agreements. This policy was stressed by both Alex Laats at MIT and Don Walker at Harvard.

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[123] see **Error! Reference source not found.** - Interview with Bill Jackson of Brown University Research Foundation.

[124] see **Error! Reference source not found.** - Interview with Richard Tomlin of Newcastle University’s Research Services Unit

> The exclusion of support and maintenance from software licenses is one area in which Walker 'will not yield.' Improvements will be considered if they fall naturally within the direction of on-going research in the area and the research interests of those involved, but 'we cannot be a development house.' (At the time of the interview, Walker described a situation wherein a licensee was arguing to reduce royalty payments on the grounds that support from Harvard had not been forthcoming. Aside from the fact that the language of the agreement clearly stipulated the "as is" condition of the program, Walker's counterpoint was that the fee and royalties the licensee had paid were perhaps only a tenth of what it would have cost them to develop the software on their own.)[125]

Although software technologies can be patented in the same way as other technologies, in most cases software is sufficiently protected simply by copyright. The advantage gained through software licensing is usually a saving of time and cost compared with developing similar code in-house, rather than access to any unique technologies embodied in the software. Laats suggests that due to the fast changing nature of the software industry a saving of six months to a year on overall development time would be enough to justify licensing code, especially if the development was for a new platform. Unnecessary patenting would slow the licensing process and so diminish this advantage, a point made by Don Walker.

> 'Seeking patent protection for [scientific] software is rare at Harvard. I may have influenced that policy: I'm convinced that, with few exceptions, copyright protection is both timely and adequate, given the dynamics of the market. The sole patent [filed for software by Harvard] has yet to be licensed. I'm sure that's a coincidence, but the fact isn't lost on me when I consider how to quickly make the technology available to the public.'

In the UK, Roger Needham, head of Cambridge's Computer Lab, agreed that patents were unlikely to be particularly important in computer science.

> 'I think that there is a very widespread view among university people, unfortunately, that what they had developed is worth more than it actually is. In the computer field patents that are worth anything are quite uncommon - I have my name on two or three patents, but they are not worth the paper that they're written on, in my opinion. Much of it is know-how, and know-how resides with people. You get the people by hiring them and paying them what they're worth.'[126]

5.2.4.1 Exploitation Structures for Computer Software

Any research oriented institution which develops software which has significant potential value to a number of other users is likely to consider licensing it to them. This has considerable appeal for both parties - the licensees can receive software at considerably below the cost of development, whilst the licenser is spreading the cost of its own work. They also have the satisfaction of knowing that their work is in more general use.

If a considerable market emerges for the system, there will eventually come a point where increased demands are being placed upon its authors for support, further development, ports to different platforms and other academically uninteresting work. The system is becoming a product,

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[125] see **Error! Reference source not found.** - Interview with Donald Walker of Harvard Office of Trademark and Technology Licensing

[126] see **Error! Reference source not found.** - Roger Needham of the University of Cambridge Computer Laboratory.

and the university environment is not a suitable place in which to develop and support shrink-wrapped products.

> 'As a research institution you quickly begin to feel the pressures on your normal activities from dealing with software distribution and support in dealing with something that has become popular in the outside world.'

The Jack system for human simulation, produced by the Centre for Human Modelling and Simulation at the University of Pennsylvania, had been licensed to more than 50 sites. Such a system demands considerable support and maintenance - neither of these are jobs which can realistically form the major occupation of academics or of graduate students.

Yale's parallelism researchers had already successfully established such an arrangement.

> They now have a co-operative arrangement with a local software house for the distribution of their software with a local company who has 'opened the doors to a number of different environments' - providing a point of contact with the financial, petroleum and microelectronics simulation communities and developing finished code for industrial use. 'This company for the most part is the one that takes on the responsibility of doing the serious, commercial grade research and development of the software'. This arrangement is very beneficial, as the group aims to produce software 'which people will use' but cannot practically aim to produce and support finished products itself.[127]

The agreement provided Yale with a share of software royalties, some of which went to the department, some to the researchers and some to a central fund, in keeping with general licensing policy. Because the research itself had already been funded, they were not seeking to recover their own development costs, and these royalties were not a major factor - they see the strength of the agreement in the financial support and organisational structure it gives to commercialisation and continuing development of the systems. The SBIR (see 2.1.2.2) government grants provide support to such companies, in an attempt to 'bridge the gap' from research to development.

> Another advantage of the arrangement is that companies are 'less generally interested' in funding general research and 'much more interested, both in their in-house research activities and in their dealings with others, in research projects for which there is not some mysterious leap of faith between that research project and something of practical interest to the company'. If the company deals with another company, rather than directly with the university, they have the feeling that 'they are dealing with a serious organisation that knows and understands' the way companies function, corporate culture and so forth.[128]

Commercially oriented R&D contractors, as well as university groups, can also fell the need to transfer product support and maintenance to another company. The Turing Institute suggested that products may emerge gradually from doing very similar pieces of contract R&D in the same field.

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[127] see **Error! Reference source not found.** - Interview with Nick Carriero of Yale University Computer Science Department

[128] see **Error! Reference source not found.** - Interview with Nick Carriero of Yale University Computer Science Department

> 'It's an interesting question - how often do you do repeat business before contract R&D become a product. If you do the same bit of contract R&D twenty times then it begins to look very much like a product. One way to migrate a technology from contract R&D to being a commercial product, which is a completely different business with almost nothing in common, is to do the same thing over and over again. I say that because the contract R&D business has a culture and a community of people in it whose interests are in "pushing the envelope", they have academic and scientific interests to "boldly go" - whereas in a products company everything's about the bottom line, and it's basically 99% marketing and sales and 1% yesterday's technology. It's likely that our organisation may split in the coming years, because of the cultural problems of keeping the products side in parallel with contract R&D.'[129]

Licensing a software system also allows the involvement of smaller companies which are not in a position to fund speculative research, or to conduct large scale in-house development, but may find the results of university research valuable. Penn's Jack system has been licensed widely, as well as receiving development funding from a number of governmental and private sponsors. Licensing helps to provide further leverage for research funding.

> 'we haven't got that much money off those firms for research, but we do get them for license fees for example.... so essentially they are buying into a research project without the investment... everyone benefits and there's no unknown there'.[130]

It is, of course, by no means certain that computer science researchers will wish to assist the university in gaining revenues from their work. They may feel that the public good, which is after all ostensibly a prime motivation, will be best served by making their work publicly available - and it seems likely that, in many cases, they will be right. Because, as discussed in 4.1.1.2, most computer technologies are non-exclusive, do not have the same degree of risk involved in their development as do, for example, pharmaceuticals and are less likely to make a crucial difference to a product's success in the marketplace if follows that the need to allow a company a monopoly on exploitation to make development worthwhile is less pronounced.

Alex Laats at MIT suggested that a technology which was licensed to a company was more likely to reach users than one which was placed in the public domain.

> 'Sometimes the value to a company is in preventing other people from making, using or selling.' In that case only a patented invention is valuable. Sometimes 'an inventor who thinks they are broadly disseminating their invention by not patenting it and letting it go free to whoever wants it are actually producing the opposite result because they don't have any commercial engine to distribute it. Putting something on the Internet, for example - the Internet is so big and there's so much on it, only those few people who are really keyed up to exactly what they are looking for are going to find it. It's not going to be widely distributed'

Some of the researchers surveyed had themselves made their work available without charge. Speaking of their decision to allow companies to implement their Cambridge Ring network design without paying royalties, Roger Needham said '*Our policy was that we wanted to see it used, not exploited'*. Similarly, Steve Reiss at Brown was adamant that, when he licensed a system to

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[129] see **Error! Reference source not found.** - Interview with Peter Moforth of the Turing Institute

[130] see **Error! Reference source not found.** - Interview with Norman Badler of Pennsylvania's Center for Human Modelling and Simulation

Digital, the charge was for his code, not the ideas and research behind it. Sun and Hewlett Packard were allowed to base their own systems on the same research, and no attempt was made to patent his ideas. Partly this was because this process would have taken up valuable time, but as he saw it

> 'I'm in the business of producing ideas... I'm very happy when people pick up on my ideas and use them. If I patent them then that's less likely to happen. It depends how you want to measure success...'[131]

[131] see **Error! Reference source not found.** - Interview with Steve Reiss of Brown Univesity Computer Science Department

5.3 UNIVERSITIES AND START-UP COMPANIES

5.3.1 POLICIES FOR THE ESTABLISHMENT OF 'SPIN-OFF' COMPANIES

A much publicised part of the technology transfer activities of many universities is the setting up of start-up companies to exploit technology licensed from the university. It was in regard to this activity that the biggest differences in policy between the institutions surveyed was observed.

MIT is well known for the part it has played in the formation of a large number of high technology companies, many of them in the immediate vicinity of Cambridge and Boston. Most of these companies were not set up as a direct result of efforts by the university itself, rather they may have been set up by former students or faculty members or simply attracted by the amount of expertise and specialist support in the area.

However, a substantial number of companies have been set up with the support and assistance of the Office of Technology Licensing. Their records show that over the period 1984 to 1993 technology transfer agreements created or assisted in the creation of a total of 64 companies. Fourteen of these companies were set up in 1988 alone. A number of such companies were based around computer technology, including Cirrus Logic and the now defunct Thinking Machines.

MIT's procedures include the routine examination of technologies to determine their suitability for start-up companies, and between 5 and 10% of all licenses are with start-ups. [MIT b] The ideal technology for a spin-off company has, according to Laats, several characteristics.

- It must offer a considerable performance improvements at comparable or better costs compared to existing commercial technologies.
- It should have at least some applications which can be easily brought to market, so as to generate an income stream and reduce risk. The closer the technology already is to commercial development the better.
- It should form the potential basis of a number of distinct product opportunities, to provide the company with scope for growth and development.

In addition it is very helpful if the inventor themselves is entrepreneurially minded, and has the skills and inclination to play a leading part in the commercial development of the technology. Laats suggests that MIT's track record has allowed the cultivation of a group of venture capitalists who are prepared to meet inventors and '*are willing to come on board because it is MIT*', at least the extent of giving the proposal serious consideration without requiring that elaborate business plans have already been set up.

Technological excellence is not enough the ensure the success of the new company.

> 'You need to have marketing and sales… you need to be able to identify the markets which are attainable for the resources you have and obtain profitability at a quick enough rate that you can capitalise on other markets. Once you have shown that ability then you can raise sufficient equity capital to enter into other markets, but all of the key is marketing and sales - the technology has to make a good sales story but if you can't sell it…'

> Another of MITs strengths is the 'MIT Enterprise Forum' - an organisation 'dedicated to starting new enterprises and helping new enterprises develop'. They provide seminars and training to help provide marketing awareness to technical people. The TLO itself will help an entrepreneurial inventor by drafting their own summary of 'potential markets, what we think the performance improvements are, what we think we can establish as an intellectual property position and use this to identify potential investors.' These investors help the inventor set up a management team - usually including 'someone who is more sales and marketing oriented who can work with the technical inventor to take the product to market'.[132]

MIT does not itself take a management role in the company, or seats on the board. They do not directly assemble management teams, and have no formal incubator site for use by the new companies. The role of the investors in establishing the business on a sound basis is therefore crucial. Usually these investors are specialist venture capital firms.

Licenses are concluded with these new companies in the same way that they would be with any other company, with the same kinds of royalty payments expected and no automatic free access to future MIT developments. However, a minority share in equity may be accepted in partial lieu of the initial licensing fee and the on-going royalties. Faculty have no numerical limit on the size of their personal equity holdings, but conflict of interest policies restrict some subsequent activities - for example they may not then accept consultancy from the company. [MIT b].

Many of the other American institutions studied had also been involved in the creation of start-up companies, although not with the same frequency as MIT. For example, Brown reported success with a closely linked company set up to develop a medical technique to treat Parkinson's disease. They licensed a technology to the company, for which they will receive royalties, have accepted a research contract from the new company to fund additional research in the university and have successfully liquidated their equity stake for more than $1 million.[133]

Yale confirmed the crucial importance of the entrepreneurial nature of at least one of the inventors as a crucial factor in deciding whether to move towards the establishment of a start-up.

> Usually the decision on whether to license a technology or form a start-up around it is easy. When inventors want to start a company, 'in my experience we take that seriously as an important opportunity'. Likewise, if no existing company can be persuaded to license but the technology seems viable then this is a strong option. The hard decision is faced when neither the inventors themselves, nor any existing company, are interested. Venture capitalists might then be approached 'but they're not going to do it unless they can get some kind of help, in terms of consulting or something like that, from the inventors' and so complex technologies cannot easily be treated this way. Yale has not so far started-up companies without the involvement of inventors, though the possibility has been examined on occasion.[134]

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[132] see **Error! Reference source not found.** - Interview with Alex Laats of the MIT Technology Licensing Office

[133] see **Error! Reference source not found.** - Interview with Bill Jackson of Brown University Research Foundation.

[134] see **Error! Reference source not found.** - Interview with Henry Lowendorf of Yale Office of Cooperative Research

Harvard had the most conservative policies regarding the establishment of start-up companies. Its policies regarding acceptance of equity in (partial) lieu of license fees and royalties were in a state of transition from the prohibition imposed by the former President.

> There has been moderate activity with respect to helping launch start-ups, but Harvard's experience is certainly not as great as that of other universities, and nowhere close to MIT's. 'Financial risk issues aside, there's always the spectre of a real or perceived conflict of interest (COI) issue which arises in start-ups, where the involved faculty member's ongoing university research is the sole basis of the company's existence.' Walker believes the best way to minimise the potential for COI is to market the new technology to a firm or venture capital group in which the inventor is a disinterested financial party. Failing that, one might license the invention to a firm in which the university researcher's financial interest is 'not substantial.' Just what this latter term means is subject to a great range of interpretations. There are, of course, problems whatever course is taken. If a technology is successfully licensed to an existing company but the inventor is not prepared to champion the technology and work closely with the company, either for personal or professional reasons, then the discovery may not flourish.[135]

None of the American institutions surveyed were prepared to accept more than a small portion of equity in a company, or to become too closely involved in its management. A principle cause of this reluctance is a fear of the possibility of incurring product liability.

> Product liability is a particularly important issue 'which Yale tries to stay as far away from as possible'. 'The concomitant care is taken that we don't try to be involved in the company's plans - marketing and so forth' although they do ask for a business plan as evidence of the company's seriousness. 'We try to keep out of the company's business, partly because we're not experts in that and that's not our job, but partly to keep the liability question in the company's pocket'. This would be particularly dangerous in the case of a small company, where its limited resources might make Yale a tempting target.[136]

Jeff Solash at Penn echoed these comments. In the US product liability insurance is almost impossible to get and prohibitively expensive, whilst potential damages are likely to be unpredictably high. Risks involved in taking even a small amount of stock from a company must be balanced against the likely returns - which will of course only be realised if the company is eventually floated.[137] The uncertainty of the university's stake becoming liquid is another deterrent - he suggested that some institutions say

> '"To heck with small companies, 90% of them fail, they make all kinds of ridiculous demands, they give me stock, I don't care for stock, it's worthless - the best I can do is stick it on my wall and hope it goes with my colour scheme. I want cash up front, I'm going to license to big companies."'[138]

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[135] see **Error! Reference source not found.** - Interview with Donald Walker of Harvard Office of Trademark and Technology Licensing

[136] see **Error! Reference source not found.** - Interview with Henry Lowendorf of Yale Office of Cooperative Research

[137] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

[138] see **Error! Reference source not found.** - Interview with Jeff Solash of the University of Pennsylvania Technology Transfer Centre.

5.3.2 Difficulties Forming Start-ups in the UK

The situation in the UK is very different. A review of innovation literature in [Bower] reveals that Britain files more patents per head of population than most comparable countries, and British technology is licensed extensively abroad - with the British Technology Group alone receiving $47 million in royalties during 1990, against $45 million for all US universities and research institutes combined. This is taken to suggest that Britain's record of producing, protecting and even internationally marketing inventions is excellent, however the performance of British companies in licensing and successfully marketing such inventions is far less impressive. The fact that 80% of the BTG's revenue in 1993 came from abroad [BTG] supports this suggestion, although because the BTG no longer has a monopoly over technology licensing this datum probably represents an overstatement of the overall proportion of overseas licensing activity, given that universities are more likely to rely on in-house expertise when licensing technology domestically.

The main limiting factor on the establishment of small, innovative high technology companies, including these based on technology explicitly licensed from universities, is usually taken to be the shortage of investment capital available to such companies. Compared to Germany or Japan the real cost of capital is significantly higher in the UK, meaning that corporate investment in long term projects, including research and development, is less attractive. However, according to the figures cited in [Bower], capital was in general no more expensive in the UK than the USA.

What does differ is the amount and nature of capital available to start-up companies, particularly in technological areas. According to a report by the British Venture Capital Association [The Financial Times, 23rd September 1994] in 1992 just £91 million, representing only 7.4% of total venture capital investment in the UK, representing, was invested in companies working with high technology and the life sciences. Although the overall amount increased substantially in 1993, most of this went to buy-outs and later stage expansion - and the total start-up and early stage investment fell further to just £69 million. This erosion of early stage funding is caused by the companies' preferences for larger investments in order to minimise overheads and where venture capital is available for high technology start-up companies, it often comes from foreign sources. The same article suggests that venture capital funds specialising in high technology companies themselves find it very hard to raise money. The UK's tax regime is such as to make pension funds a very attractive investment mechanism - and pension fund managers are understandably unwilling to invest in start-ups.

A survey conducted by the US Small Business Administration, and cited in [Bower], reveals that private investors, often refereed to as 'angels' are the major source of external equity capital for start-up firms - investing '*at least two or three times the $4bn invested annually by US venture capital managers*'. Such investments are usually in very small firms, and are spread between a few individuals who hold their investments for around five years and also make their business expertise available to the company.

[Bower] also includes a comparison between the availability of public development capital for small to medium firms in the UK and US. This concludes that trading volumes and liquidity were far lower on the British USM (Unlisted Securities Market) than the US NASDQ, and the range of listable companies smaller, making the main potential method of liquidation of equity the private sale of the entire company. This obviously limits the attractiveness to investors of holding such initial stakes.

Britain has been addressing these problems, with the imminent replacement of the USM by a new mechanism, the Alternative Investment Market (AIM), and relaxation of rules for listing so that a forecast of profit within a year, impossible for companies which have not yet brought products to market, is no longer required. Another new initiative establishes Venture Capital Trusts (VCTs) with special tax status to encourage private investment in unquoted companies. The VCT itself is fully listed, providing liquidity to the private investors involved. Another scheme, the Enterprise Investment Scheme, launched in 1994, provides tax breaks to direct investment in trading companies but has so far met with little success in encouraging start-ups. [The Guardian, 30th May 1995]. The government's SMART scheme, described in section 2.2.2.4, provides funding to support innovative small companies. A European market tailored to small companies, comparable to NASDAQ in the US, is currently under discussion.

There may also be a cultural element at work. Because start-up funds are harder to raise, potential academic entrepreneurs are less likely to be aware of successful ventures by their colleagues. This might contribute towards a greater reluctance to take risks and cause involvement in an unsuccessful company to represent a greater stigma on future careers.

These general problems is raising start-up capital were reflected in the experiences and attitudes of participant institutions. Cambridge University is well known as the centre of a major concentration of around 1,200 small, innovative companies.

> The Office deals with a 'steady trickle' of start-up companies, and is usually involved in two or three at any given time. There are two local seedcorn venture funds - the Cambridge Quantum fund and Cambridge Research and Innovation Ltd, which 'I'm afraid in Britain this is almost a unique resource - the shortage of funds needed to get over the so-called development gap is as bad as ever.' A number of companies have been set up with the help of these funds, with stakes also held by Lynxvale on behalf of the university and by the individuals themselves. Equity stakes are now held in around ten companies, and the rate of activity is increasing.[139]

In as much as it was possible to assist in start-up activity, Jennings' considerations seemed similar to those of his colleagues in the US.

> 'You need a platform of technology within a company which you can spin products off from - you can't base your companies around a single product approach. It's always been the problem in Cambridge - you set up a company with a nice bit of technology, well what do you do for an encore? That's one of the major weaknesses of many high-tech companies.'

In particular he identified biotechnology, an area where Britain's industrial presence has conspicuously failed to reflect its strength in academic research or pharmaceuticals in general, as a field of growing strength, to some extent replacing the computing and communications companies of the 1980s as the major source of local growth.

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[139] see **Error! Reference source not found.** - Interview with Richard Jennings - Cambridge Industrial Liaison and Technology Transfer

> Currently attitudes towards biotechnology in the UK are 'optimistic but realistic' and there has been a lot of interest in the area recently. An advantage of the shortage of venture funding in the UK has been that those companies which have managed to raise funding are in general well conceived and attractive to investors - in contrast to the American situation where during a period of optimism and hype large number of companies were started without good prospects in the longer term. In his view 'we are getting increasingly more intelligent investors, it's fairly slow but it is onwards and upwards' - and people now realise the need for companies to have a strong technological base.

Peter Schaefer, of Manchester's exploitation company Vuman, suggested that conditions were so different between the UK and US that, interesting as the experiences of American universities were, there was little chance of applying them directly.

> 'it's very hard to draw analogies... there's such a different culture, especially in the investment community, that's it's very difficult to apply that over here. People there are very much less concerned about risk, they realise that risk is necessary and that if you're going to risk then failure is inevitable in a number of cases - you play the percentages. Universities don't like risk, venture capitalists don't tend to like risk, there is not much of a market in start-up funds. Making the investment and managing the investment is out of all proportion to the return which you are likely to make in the early stages.'[140]

5.3.3 University Owned Technology Exploitation Companies

Such a lack of available private investment for start-up companies restricts the options available to British universities.

As noted in section 3.2.1, British universities have established their own model of technology licensing in which a wholly owned university company takes responsibility for all technology licensing activities, and in some cases establishes subsidiaries to market university expertise and to exploit university technology. This is in direct contrast to the American institutions surveyed, none of which were prepared to consider licensing to a company in which they held a substantial stake.

> 'In the model emerging the university will set up a separate wholly owned subsidiary company that will undertake technology transfer - the people in that company will be working full time on technology transfer and in many cases it will mean that they are paid a living wage, they won't be tied to academic salaries. Sometimes those companies try and raise their own seed-corn venture capital funds. It's interesting that perhaps the universities doing this, following the US pattern by employing full time professionals, are in some ways more adventurous than some US universities. We have more of a free hand in deciding what is worth licensing to industry - if you like we're more commercially driven....'[141]

Section 5.3.1 made clear that a major motivation behind the reluctance of US universities to own, or become directly involved in, spin-off companies was the risk of incurring product liability. Due perhaps to differences in the legal situation in the UK (including the general tendency to the award of much lower damages) and a culture which is in general less litigious, no such fear was in evidence at the UK institutions surveyed.

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[140] see **Error! Reference source not found.**- Interview with Peter Schaefer of Vuman (University of Manchester)

[141] see **Error! Reference source not found.** - Interview with Peter Williams of Harvard Medical School Office of Technology Licensing and Industry Sponsored Research. (Formerly of Newcastle University).

> 'Legal entities are legal entities... and unless there is fraud, dishonesty or anything else like that then the liability remains with the company.' [142]

Manchester's exploitation company, Vuman, had set up ten subsidiary companies, all but one of which retained the University as the major owner. Most of the companies were set up to exploit university expertise and facilities rather than particular technologies, though one was based around a set of patents and another around a suite of software. Another divergence from American practices came with the minimal involvement of faculty as stakeholders, which occurred in only one of the subsidiary companies. Surplus profits from the companies were transferred back to the departments involved.

The Turing Institute in Glasgow has been through several incarnations, including a spell as a commercial, for-profit, company and is now a non-profit contract R&D organisation owned jointly by the University of Glasgow and the Glasgow Development Agency - the University's investment takes the form a repayable loan for a fixed sum. This dual status allows it the flexibility to gain the advantages associated with being part of the university as well as those reserved for companies, giving a considerable advantage in the marketplace.

> These advantages include cheap accommodation, low cost network access and IT infrastructure and access to graduate students. 'We're a small company - at the moment we only have seven members of staff, although there's quite a number of PhD students.' Their links with the university give them advantages comparable to those enjoyed by members of a huge corporate research lab, such as access to experts in a vast number of fields, but with none of the massive cost overheads which such organisations entail for their parent companies.
>
> > 'Depending on where you're coming from you can see the organisation in different ways. One way of reading the articles and memoranda is that we are a part of the University, and that is very important because it means that success that we have in winning R&D moneys, in publishing papers and running PhD students are counted within the University's success, and as such they get a better score in comparative studies with other universities... and they get a larger block grant. That's the main benefit that they see out of it. As far as we're concerned we have this access to cheap labour and cheap infrastructure, it's symbiotic - quite mutual.'
> >
> > 'However, when we talk to commercial companies it is very important to stress that we are an independent, commercial company and we tend not to stress the university involvement. I'm not talking confidentially here, because a lot of other organisations do this, but when we talk to suppliers about getting equipment and they say "Are you part of the University?" we say "Oh yes, we're part of the University", because you get your academic discount. There are other sums of public money which you can only get access to if you're a commercial company - universities don't have access to that, we do. Basically you're dealing with an organisation which has a big hat rack: some commercial and some academic. Every new situation that comes along you adjust your presentation to optimise the amount of resources that you get. It's very simple.'[143]

This also serves to expose what is perhaps a more fundamental difference in attitudes between the British and American approaches. As shown earlier in this chapter, American policies (and legislation) stress that technology transfer should be undertaken for 'public good'. The American

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[142] see **Error! Reference source not found.**- Interview with Peter Schaefer of Vuman (University of Manchester)

[143] see **Error! Reference source not found.** - Interview with Peter Moforth of the Turing Institute

emotional commitment to the appearance of a free market makes private investment in small, innovative firms based round university technology very much a Good Thing - these firms then create jobs, wealth and demonstrate returns to the nation from its investment of public funds in universities. Universities are already involved in political lobbying to preserve their IPR assignments, and do not wish to be seen as employing their public funding to gain competitive advantage for subsidiaries, not least because this might compromise their non-profit status.[144]

In Britain, by contrast, universities, like hospitals and schools, are being asked not only to serve the needs of the market, but are themselves forced to participate in pseudo-markets designed to engender the relentless seeking of opportunities to maximise resources. Signs that universities are becoming entrepreneurial and seeking profits are therefore politically desirable rather than inflammatory.

This is undoubtedly a simplification of the range of attitudes which exist within the two countries - discussions on the Techno-L electronic forum suggest that some institutions will go much further than others in terms of ownership and management of start-up companies, and indeed this is the subject of the next conference of AUTM (the professional body for technology transfer officers in universities). However, at least with regard to the participants in this project it does seem to be a generalisation with a degree of validity.

[144] In conversation with me, an MIT professor not involved in the study itself suggested that this motivation is in fact more important than the fear of profit liability in detering many universities from owning their own comanies.

6. CONCLUSIONS

This chapter is intended to briefly outline general conclusions which can be drawn from the material presented here and to go some way toward evaluating and setting in context the utility of the results obtained. Because of the large numbers of different topics addressed during the course of this report, and the diversity of participants involved in its research, no attempt to summarise all of the observations during the course of the report is made, and so in this sense conclusions are also distributed through the previous chapters. Suggestions for future research are made, and some of the more general aspects of academic and industrial organisation on which future development of research interaction rest are identified.

6.1 LIMITATIONS OF METHODOLOGY & POSSIBLE FUTURE WORK

As can be clearly seen, the methodology employed in this project was qualitative. Wherever possible findings have been supplemented with the results of other studies, particularly where these involve quantitative data, but this can only be a partial substitute. In particular, there seems to be a lack of hard evidence relating to research interaction between universities and industry in IT in the contemporary period. Recent studies seem to address themselves far more towards the chemical and pharmaceutical sectors.

The selection of academic institutions which participated in this study was somewhat restrictive. A policy of concentrating on well known and successful research institutions was vindicated in as much as it revealed a wide range of well established systems of research interaction and led to the participants of a number of individuals and offices which are highly respected by those working in the field. However, these participants were, for that very reason, clearly not representative of academic institutions as a whole - many of them enjoying considerable advantages in terms of prestige and quality of research which probably had a profound effect on the kinds of involvement which appear attractive to industrial partners.

Building on the broad insights into research interaction derived from this project, a complementary approach which would address this weakness might be to concentrate on a number of institutions of different types to be found in geographical proximity - for example in and around Boston, London or Manchester. Such institutions all share the same base of potential industrial partners, and the range of different styles of interaction which different classes of institution had evolved could be profitably compared. More specific conclusions might then be drawn as to the models most appropriate for specific institutions.

Similarly, the range of companies participating was limited, although approaches were made to a number of smaller companies during the course of the project. A more geographically focused study would permit the examination of a wide range of different firms operating in a specific areas, and might include a questionnaire based survey to form the basis of a rigorous attempt to identify different industrial models of interaction.

Basing original research on loosely structured interview, and making use of direct quotations, might be seen as introducing an unfortunate degree of subjectivity and individual personalities into this study. This may, however, be seen as its primary strength - participants were intelligent, educated people whose professional communities are (primarily in some cases, secondarily in others) deeply concerned with issues arising from university industry research interaction. By

investigating not only participants' personal experiences and formal institutional polices but also their opinions as to more general issues it has been possible to indirectly include the experiences and attitudes of these wider communities and so to provide a richer and more substantial account than would have been possible had a less flexible methodology been adopted. Furthermore, the findings of any research based on a sample of this size must inevitably be shaped by the personal experiences and particular quirks of its participants - by systematically quoting them and rigorously referring back to the approved summary this has been made explicit and transparent.

Allowing participants the option to modify, and indeed censor, their comments after the conclusion of the interview might be argued to undermine the independence of the research process. This view is mistaken: not only was this essential to obtain involvement of many of the participants, but it also has in many cases increased accuracy and coherence of the summaries presented here, and where participants have had cause to remove controversial comments this has, at least, had the virtue of better presenting institutional policy. Given that the interviews were conducted 'on the record' and interviewees were therefore aware when speaking of the need for diplomacy, such distortion was in any event present in the original exchange itself.

6.2 Overall Findings

The most general conclusion to be drawn from this work is the primary importance of long term and informal cooperative links and active research collaboration to successful research interactions between universities and industry in the computer science field. Many areas of computer science research can, by their very nature, benefit from the involvement with 'real world' concerns and demands which collaborative research brings, and the most successful relationships would appear to be those in which both partners concentrate on doing the things which they are best at within a framework which has been designed to make explicit and satisfy (possibly with different end products) the needs of both. Because much computer science research is simultaneously both fundamental and has direct potential for application, there are at least some fields in which real and under exploited potential exists for mutually beneficial interaction.

It must also be recognised that some valid and necessary fields of academic computer science research do not offer the prospect of likely returns on industrial investment and so cannot be expected to be funded by industrial sources; also that many R&D activities perused by companies are not suitable for contracting to university development teams. A widespread shift towards secret and proprietary development work in universities, seen by American participants as a possible future scenario and by some British participants as a goal of current government policy, would not serve the long term interests of either partner and seems unlikely to occur in recognised centres of research excellence. Whilst there are factors in traditional academic culture which might mitigate against even rewarding and valuable collaboration with industrial bodies, concerted attempts to impose industrial culture on academics are likely to prove counterproductive for a variety of practical reasons. A career in academic research can only be embarked upon by an individual talented enough to obtain considerably greater remuneration in the industrial sector, but temperamentally unattracted to, and quite possibly unsuited to, such a role. Forcing universities to become cut-price contractors of industrial research would only serve to drive such individuals into genuine industrial careers.

Because cooperation with firms involves the establishment and maintenance of a wide range of personal, and often informal, relationships there is an increasing overlap between industrial liaison and development roles. All industrial spending is becoming more tightly focused, and donations

will often be made to support specific research. Although the kinds of contacts with industry cultivated by researchers might seem very different from the alumni-centric approach of much traditional development work, as both come increasingly to rely on long term, mutually beneficial, relationships the gap is narrowing. Furthermore, although activities might be viewed in different ways, I suspect that on a practical level what is perceived by a development officer as systematic exploitation of alumni loyalties is not always so very different from the way in which an academic might maintain contact with a former student or colleague working within industry via the normal processes of professional networking. Motivations and labels are different, but results might be similar.

In general the degree of similarity observed between the opinions and experience of UK and US participants was startling. This convergence has perhaps become more pronounced during the last decades as universities in both counties have gained responsibility for their own technology licensing and British universities have become more reliant on project based research funding. Policies regarding the role and ownership of start-up companies, and the importance of university ownership of IPR to sponsored research were the main areas of divergence, and as explained previously, these policies are reactions to differing conditions in the wider environment.

The formal licensing of patentable technology does not seem to be of great importance for computer science. Whilst software licensing is quite widespread, this provides the recipient with savings in development times and cost, rather than being a payment for the rights to use particular research findings or concepts. Rather, sponsored research, recruitment and consultancy would appear to be the main vectors for the transfer of technology, which is in most cases substantially composed of tacit knowledge and expertise. This is to some extent due to the difficulties in protecting and licensing algorithms and basic computing concepts, and to some extent to cultural traditions of the free distribution of software and ideas, and so it is possible that the formal licensing of IPR might in future become more important and legal mechanisms become better established.

Thus although computer science is like that paradigm of technology transfer, biotechnology, in that university research may have potentially important and immediate commercial implications, it differs in that mechanisms for licensing and exploiting the most important findings are only weakly established. In addition, the computer industry has now matured to the point where greater divergence is apparent between the kinds of research being conducted in universities and that conducted in companies, and because computer systems are so complex and involve many interdependent technologies the importance of any particular piece of university technology is likely to be marginal to the commercial success of a major product. The proportion of overall computer research and development conducted within universities is now such a small proportion of overall activity (compared to the expenditure of firms such as Intel) that key future technologies cannot reliably be expected to develop to a patentable state within universities, and this consideration also strengthens further the suggestion that university research maximises its utility by complementing, rather than by substituting for, industrial research and development activity.

6.3 Broader Issues and Likely Future Trends

Participants had differing views as to whether changing patterns in corporate organisation were likely to lead to an overall greater contribution to the funding of university research via a greater reliance on ‘outsourced’ work, or simply to a similar or diminished total spent far more carefully.

Empirical studies of the implications of the process seem to be sparse, and as discussed previously the computer industry is undergoing a particularly profound set of transitions which have changed it beyond all recognition during the past decade.

The future importance to universities of industrial research interaction will be determined by more general changes to the nature and role of the university. Politicians on both sides of the Atlantic no longer accept that universities repay society simply by delivering trained individuals and an output of research papers. In Britain, of course, the government has far more control over universities and is engaged in a process of fundamental change the outcome of which is still far from clear. It seems likely that greater specialisation of institutional roles will result, with some institutions specialising in teaching, some in traditional research, some combining both roles and perhaps some reliant on industrial funds for applied research and development to preserve even minimal research activity

Current debate as to the acceptability of restrictions on publishing and on ‘secret’ industrial research seem likely, at least for non-elite institutions to be settled by market forces. However, it cannot be assumed that universities are a particularly suitable place for most such research to take place and, whilst pragmatism on both sides might lead to the consideration of such arrangements, any regular need for development expertise on a contract basis might be better handled by private research organisations which are oriented solely to such work. The continuing development of university owned technology and expertise exploitation companies might give universities a substantial role in such organisations.

US participants felt that the university sector was likely to see a general ‘shakeout’ in coming years, the current rate of tuition increase being unsustainable and student numbers insufficient to cover costs in a climate of governmental cuts. Weaker institutions may close or merge, and general cultural changes spread across the system. However, leading departments viewed modest shrinkage (especially in numbers of graduate students) as a possible fate but did not envisage a need for radical changes of direction. Some suggested that unrealistic expectations of industry as a saviour of research funding were held in some quarters. In the UK, a more radical reorganisation was underway, and some participants speculated that many institutions might be forced to reorganise along corporate lines and to adopt an entrepreneurial and market driven approach at the highest level.

Research funding, from both government and industry, has become far more focused than previously. The former, although still very much more important, was perceived by participants as in decline - in the US this decline is relative to the previous rapid growth of computer science and may do no more than to put its funding on the same basis as that of other scientific fields. In the UK this decline is, for many institutions, absolute. A result of the emerging funding patterns is an increased perception of the importance of industrial funding: whilst amounts involved may not increase they are seen as relatively more important and, perhaps more importantly, governmental funding directed towards ‘relevant’ and ‘exploitable’ areas of research can be obtained much more easily with proven industrial funding as proof of virtue.

It seems likely that these new patterns will require more flexibility from researchers and institutions. Whilst most of the institutions which are most successful in this new climate are likely to be those which already enjoy a strong reputation for research and a good degree of name recognition - these qualities being attractive to industry just as they are to other funding bodies - there may be opportunities for institutions which react faster and with more flexibility to whatever

opportunities present themselves to improve their relative standing. As several participants observed, both former and emergent patterns of funding represent the rules of a game which must be played. Different strategies and organisational patterns constantly evolve to maximise returns from this game, but under neither set of rules is anything as abstract as ‘academic freedom’ the prime concern of those signing the cheques.

7. ABBREVIATIONS

AI	Artificial Intelligence
AIM	Alternative Investments Market (UK)
ARPA	Advanced Projects Research Agency (formerly DARPA)
AT&T	American Telephones and Telegraph International
AURIL	(Successor to UDIL - UK group for technology transfer and industrial liaison managers within universities).
AUTM	Association of University Technology Managers (US)
BTG	British Technology Group
CASE	Cooperative Awards in Science and Engineering.
CBI	Confederation of British Industry
CEST	Centre for Exploitation of Science and Technology
CS	Computer Science
CS&E	Computer Science and Engineering
DARPA	Defense Advanced Projects Research Agency (now ARPA)
DEC	Digital Equipment Corporation
DOD	Department of Defense (US government)
DOE	Department of Energy (US government)
DTI	Department of Trade and Industry (UK)
EC/EEC	European (Economic) Community. (Now EU.)
EPSRC	Engineering and Physical Sciences Research Council (UK)
ESPRIT	European Strategic Programme for Research in IT
EU	European Union (successor to EC, EEC)
EUREKA	European Research and Co-ordination Agency
GAO	General Accounting Office (US)

HEFCE	Higher Education Funding Council for England & Wales
IBM	International Business Machines
ICL	International Computers Limited
ILP	Industrial Liaison Program (at MIT)
IPR	Intellectual Property Rights
IT	Information Technology
KBS	Knowledge Based Systems
KSR	Kendal Square Research
LINK	(Although LINK is always capitalised it does not appear to stand for anything.)
MIT	Massachusetts Institute of Science and Technology
MOD	Ministry of Defence (UK)
NASA	National Aeronautics & Space Administration
NASDAQ	National Association of Securities Dealers Automated Quotation national market system (US)
NRDC	National Research and Development Corporation
NSF	National Science Foundation (US)
ONR	Office of Naval Research
OST	Office of Science & Technology (UK government)
PARC	Palo Alto Research Centre (Xerox facility)
R&D	Research and Development
SDI	Strategic Defense Initiative (‘Star Wars’)
SERC	Science & Engineering Research Council (precursor to EPSRC)
SMART	Small firms Merit Award for Research and Technology
TLO	Technology Licensing Office (at MIT)
UDIL	University Directors of Industrial Liaison (replaced by AURIL)
UFC	Universities Funding Council - precursor to HEFCE

UGC	University Grants Council - precursor to UFC
USM	Unlisted Securities Market (UK)

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