Exploding the Myths of UK Innovation Policy:

How 'Soft Companies' and R&D Contracts for Customers Drive the Growth of the Hi-Tech Economy

January 2010

By David Connell and Jocelyn Probert
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Research Commissioned on Behalf of the East of England Science and Industry Council by the East of England Development Agency

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The Centre was established in 2009 in response to Lord Sainsbury's recommendation in his review of UK Science and Innovation Policy, "Race to the Top", published in 2007 and adopted in the Government's 'Innovation Nation' White Paper in March 2008. It is jointly funded by the Department for Business, Innovation and Skills, the Economic and Social Research Council, the National Endowment for Science, Technology and the Arts, and the Technology Strategy Board.

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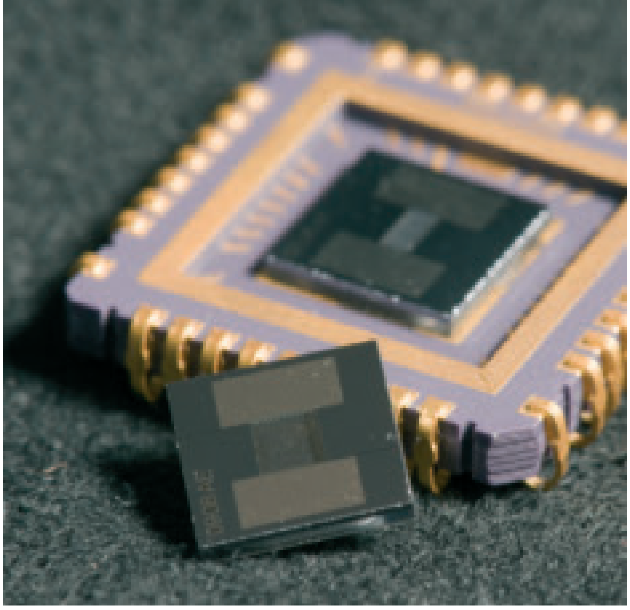

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Executive Summary

Chapter 1: Introduction

The role of innovation and commercial exploitation of the UK science base has assumed increasing importance in national policy in recent years. And Cambridge, with the surrounding region, remains the leading example of a science and technology 'cluster' in the UK and, arguably, the rest of Europe. However, observers have long noted that many 'Cambridge Phenomenon' companies have adopted a business model based on carrying out R&D contracts for customers – the so-called 'soft' model – rather than developing standard 'hard' products. Over time the pivotal role played by these companies in building the cluster as a whole, directly and through spin-offs, has become increasingly apparent.

In this report we adopt the following definition of a soft company:

> A soft company is a science or technology based company whose business model is to provide R&D based services (e.g. technical consulting, contract R&D) and which draws on its expertise and/or proprietary technologies to provide bespoke offerings for a range of customers and applications.

The phrase 'soft company' has been coined to indicate how companies adopting this model can remould their 'offer' to meet a wide range of customer needs in different industries, based on their expertise. This model provides much greater flexibility and a wider choice of early customers compared with the rather fixed strategy of 'hard' companies with a narrow range of standard products.

The aim of this report is to document and explain the overall impact of the 'soft company' model on the East of England (EE) region. It seeks to:

1. Identify as many important 'soft' companies in the region as possible and analyse their role in regional economic development.
2. Analyse the role that government R&D contracts play in economic development in the region.
3. Identify policy actions to encourage economic development through government R&D contracts and other measures that support the 'soft' model.

Data were collected through 52 interviews with founders or senior managers of major firms operating some form of soft business model, and with various business intermediaries (Module 1 firms). To capture the dynamic element of the research, and recognising that older 'hard' firms may have operated a softer model in their younger days, we examined how business models evolved from the beginning of each firm's life. In a second phase of data collection we conducted a small survey of government R&D grant winners in the East of England region, with follow-up telephone interviews, to enable us to analyse the importance of R&D contracts compared with other sources of R&D funding among smaller, early stage technology firms (Module 2 firms).

Chapter 2: Soft and Hard Start-up Strategies

When entrepreneurs start a technology business, a whole range of strategies is open to them, each offering different levels of risk and return. Risks revolve around uncertainty (technology; market; competition), investment (cost to develop a product or service and bring it to market; cost to breakeven), and level of management complexity.

In the simplest (softest) level of the business model, a group of individuals with specialist technological expertise can sell their time in the form of consultancy projects for customers seeking help with analysing specific problems. It is an activity with low overheads and requiring little in the way of up front investment. And the only real uncertainty is how long it will take to win the next contract. Management skills – project management, people management and rudimentary financial management – can be learned on the job as the business grows.

Carrying out R&D contracts – delivering demonstrators, prototypes or 'ready to use' physical deliverables –

usually involves higher costs and higher risks: higher costs, because of the cost of selling projects and developing deliverables, and sometimes the cost of equipment required; and more risky, because of the difficulty in predicting how long it will take to develop the technology. As with consultancy, the client assumes all market and competition risks. Financial success depends on timely delivery and on keeping people busy, but managing technical risk assumes greater importance than in pure paper-based consulting and is a key strength of successful contract R&D companies. Contract R&D is a viable start-up model in many sectors.

Contract R&D companies frequently have opportunities to move into subcontracting and small volume manufacture on behalf of individual clients. The new skills acquired – in costing, production management and after-sales service – help support later transition to a 'hard company' model if proprietary products are developed. The parallel creation and exploitation of intellectual property around a different application of a technology developed under contract can also move the firm into more speculative R&D activity, although IP ownership and commercialisation rights must be managed carefully to establish a robust IP package for licensing out or assignment to a new venture.

The cash flow valley for a soft company is far shallower than for a hard company because fewer start-up costs are involved and customer revenues can be generated quickly. Some soft start-ups effectively never experience a cash negative position. On the other hand the growth rate once profitable is much slower than for a hard company, as the rate at which headcount, and hence revenues, can be grown in a soft company is much more limited. This makes the soft model generally unattractive for venture capital investment.

Chapter 3: Early 'Soft' Examples from the 'Cambridge Phenomenon'

The tendency for new science and engineering-based firms to spring up around Cambridge over the last 30-40 years is well recorded. A number of firms and research facilities that played a central role in the Cambridge Phenomenon followed a soft business model. Among the earliest examples were Cambridge Consultants, founded in the early 1960s by Cambridge University engineering graduates, and the MinTech Atlas Centre (later CADCentre, now AVEVA), a government-funded research institute for computer graphics in engineering design set up in the late 1960s. Both organisations remain important even today, demonstrating the soft business model's potential for longevity and its capacity to adapt to changing circumstances.

Another early firm that initially followed the soft model and was crucial to the development of the high tech cluster around Cambridge was Cambridge Processing Unit, the precursor to Acorn Computers and ARM plc. Acorn's R&D group later became the Olivetti Research Laboratory (ORL) and operated as an innovative intermediate R&D institute with many of the same characteristics as an independent soft company, even though it was funded by corporate sponsors. The BBC contract for Acorn's computers in the 1980s illustrates powerfully how contracts from public sector customers can stimulate the high tech industrial base.

Chiroscience (in biotechnology) and Symbionics (in wireless telecommunications) were other important early examples, the former using the soft start model to become one of the UK's first successful biotechnology companies. The latter pioneered a concept much copied later by other high tech firms: licensing out IP to leverage its way into larger product development contracts for derivative designs for individual customers.

Each of these companies was founded by talented scientists and engineers who built distinctive customer-focused business models to overcome the heavy capital demands of developing proprietary technology. Personal savings funded start-up, sometimes with modest investments from family and friends, supplemented by customer consultancy work and occasionally by local bank lending. By not relying on venture capital, firms remained in greater control of their destiny, could adapt their business model to suit changing circumstances, and were able to remain locally based for many years. The region retained its entrepreneurs, engineers, scientists and technological expertise, and key players re-emerged as serial entrepreneurs, investors or advisors, enabling new entrepreneurial businesses to spring up based on that expertise.

Chapter 4: How the Soft Model Operates in Different Industries

There are many variants of the soft model, reflecting the different development timescales, scientific complexity, capital requirements, industry structures and regulatory regimes that drive different industries.

Image courtesy of TTP LabTech Limited

Broadly-Based Technology Development Consultancies

The four large Cambridge technology consultancies – Cambridge Consultants, PA Technology, Sagentia and TTP Group – represent the 'purest' form of soft business model. Their contract R&D work, involving many science and engineering disciplines and projects for multiple clients in a range of industries, fosters an accumulation of know-how and IP that can be productised through licensing arrangements, product-based subsidiaries, or spin-outs (often backed by venture capital). The model retains its industrial logic nearly 50 years after it first emerged, helped by the diversity of technologies on which customers need to draw and the continual emergence of new areas of technology in which expertise is scarce. By working for multiple clients in the same technological space, driven by their market needs, such firms gradually acquire a unique knowledge base around which to create their own intellectual property. Managing the IP they generate and negotiating contracts with customers to retain as much control of it as possible is an essential aspect of technology development consultancies.

The absence of any mass manufacturing activity contributes to the relatively small size (typically 200-300 employees) of technology consultancies, beyond which spin-outs or walk-outs tend to occur. The model is not associated with large economies of scale, because firms depend almost entirely on brain power. Project-driven work conducted within constantly re-forming teams provides the flexibility to incubate new technologies and respond to new market opportunities in a way that typically highly focused, venture capital-backed businesses cannot. Resources can also be allocated to different parts of the business according to the ebb and flow of contracts, and business divisions are regularly reconfigured, reflecting new opportunities and market pull. The ability to evaluate and manage high risk, rapid product development is a key skill of all technology consultancies.

These firms demonstrate the benefits of using the 'softer', contract-based activity as a profitable core business that from time to time generates harder product businesses. These in turn give additional returns to investors and create many more jobs. Start-up costs are largely funded by customers and retained profits. Technologists learn multiple business- and project-related skills; and career progression can be effected through organic growth and through spin-outs.

The inter-disciplinary nature of these firms gives them significant flexibility in responding to market needs, as the breadth of scientific disciplines covered offers both protection against sector maturity and the ability to perform at the leading edge of emergent technologies and applications markets. Perhaps most importantly, by carrying out R&D contracts for customers and discussing future technology needs, these firms in effect conduct continuous real time market research that helps them remain relevant and allows them to identify new markets for contract R&D and opportunities for new IP and product-based ventures.

Specialised Technology and Innovation Consultancies

The East of England region also boasts a wide range of more specialised consultancies, ranging in size from one- or two-man bands up to firms of around 100 people. Some were set up by former employees of the broadly-based consultancies; others emerged from industrial employers; and in a third category are firms emerging from the scientific research base to offer specialised services to a range of industries. The basic model is contract R&D focused on a relatively narrow range of disciplines or industries, or in a function such as product engineering or industrial design. Specialised consultancies generally lack the resources to generate successful product-based spin-outs, but some have successfully adopted an out-licensing strategy that assures an on-going revenue stream in addition to contract revenues. The larger specialist firms possess a sophisticated understanding of how to manage risk in complex technology projects. Rather than directly employing additional scientists or engineers, these firms may tap into a network of other small firms and specialist contractors to supply missing skill-sets required for individual projects. Whilst the broadly-based consultancies operate in a truly global market place, some of the specialist firms tend to interact with the local high-tech community in a more intense way.

Drug Discovery

Although biotechnology is normally seen as an investment- and IP-intensive industry with very high barriers to entry, significant development and regulatory costs, and very long timescales, the use of a 'soft' business model often represents a viable complement, or sometimes even an alternative, to the better-publicised VC-backed drug discovery model. In the soft model, fees-for-time research services or a platform technology or research tool that aids the drug discovery process provide the basis for contracts for other biotechnology or pharmaceutical company customers. The revenues generated in this way can then be used to finance proprietary therapeutics discovery work up to the point where drug candidates can be licensed to, or co-developed with, a partner.

A revenue-generating platform technology model backed by a strong patent position can finance at least the early stages of transition to a product company, as Cambridge Antibody Technology demonstrated when it became the first UK biotech to structure partnership deals in the form of escalating milestones as successive technological hurdles were passed. And interactions with Big Pharma during contract-based work are invaluable in building credibility for subsequent partnering opportunities. As in the consultancies, contract R&D has a positive impact on the development of scientists at all levels as they collaborate and interact with peers in other organisations and are constantly exposed to activities and commercial pressures they would not otherwise experience. The model also provides flexibility, since firms can apply more resources to revenue-earning contract work if funds for proprietary research are running out. Combining contract and proprietary drug discovery work is still a difficult juggling act. One dilemma for firms is how much revenue to plough back into marketing and growing the fee-for-service business, and how much to invest in the risky drug discovery side; another is how best to manage human resource allocation between the two activities. In practice, even firms that successfully manage the balance usually consider splitting them into separate subsidiaries at some point.

Automotive Engineering

Several specialist engineering companies serving the motorsport industry operate in the East of England region, each having achieved growth through a soft business model. Mainstream automotive manufacturers also turn to these specialist firms to develop advanced systems and materials, because of the complexity of the electronics, software, composite materials, etc. that go into modern vehicles. In this industry, customer contracts based on proprietary concepts are used to fund costly technological development by means of substantial up-front payments and milestones; collaborative research projects with major automotive and engineering firms are not uncommon; there is also the potential to turn innovations into product businesses. Firms in this group include Beru F1 Systems, Lotus Engineering and Pi Research.

Instrumentation and 'Research Tool' Businesses

Companies working on proprietary physics-based technologies often have multiple potential applications, but with fragmented markets that are so specialised that they can neither adopt a pure 'soft start' model based on customer contracts, nor justify a pure VC-financed hard company strategy. VCs are interested only in large scalable opportunities that can deliver good returns, not niche markets, and they expect higher rates of growth than these firms can achieve, at least over the ten-year lifetime of most VC funds. Instead the strategy of these firms depends on a combination of customer contracts and VC or angel investor backing. The external validation process of finding a customer prepared to pay for costly development work is a strong endorsement of the value of the technology, both to investors and to other buyers. This is especially true when the technology platform has multiple potential specialist applications and it is unclear where the best opportunities lie. Hence customer contracts can play a crucial role in 'softening' the strategy, by bringing in cash for R&D and by helping to test and validate applications. Firms such as Owlstone Nanotech, Syrris and TeraView all fit into this category.

Software and ICT

The leading software and ICT players in the region are all 'hard' companies with a portfolio of standard product offerings. But nearly all have 'soft' origins, either because they used revenues from early one-off projects for individual customers to fund the development of standard products, or because they spun out from other soft companies or intermediate (non-university) research institutions where the environment was similar to the standard soft company model. Notable originating organisations are Cambridge Consultants (Alphamosaic and CSR), CADCentre (which eventually became AVEVA, whilst its walk-out, Cambridge

Interactive Systems, went on to spawn Smallworld and Geneva Technology) and ORL (Adaptive Broadband and Cambridge Broadband Networks). Acorn Computers transitioned rapidly to a hard model, but customer contracts played a key role in funding the teams that later established the semiconductor firms ARM and Element 14.

In the software industry itself the 'soft' business model is often transient, with customisation for different clients representing a shade of grey between bespoke and standard product. The fairly common practice of conducting a good deal of development work after winning an order has advantages in the early days of a company, but substantial disadvantages when firms become larger because of the resource requirements involved and the difficulty of integrating product architectures. Many software companies are entirely self-funded, whether they pursue a soft start-up model based on paid contracts for customers or simply find a way of getting their first product onto the market so quickly that the founders can fund it themselves or with help from family and friends. Neurodynamics, which was established to exploit neural network algorithms and was the precursor to Autonomy plc, is a prime example of the latter route.

Intermediate Research Institutes

These are non-academic research organisations with a mission to develop technology for commercial application, but with substantial core funding enabling investment in long-term programmes and/or R&D to support government objectives. That funding may come from Research Council or Regional Development Agency grants, from membership fees, or even from a parent firm which holds its laboratories at arm's length and tasks them with generating innovative technologies rather than supporting existing revenue streams. CADCentre in the 1970s and TWI (The Welding Institute) are examples.

These research institutes provide a wide range of services in consultancy, applied research, design and technology development. Some also make early-stage investments in commercial exploitation. Their networking capabilities, their technology research and development activities, and their strategies of trying to exploit proprietary IP through licensing or spin-outs make them exemplars of various aspects of the soft business model, even if they are not literally 'soft' companies.

Chapter 5: Importance of the Soft Model

A soft business model brings benefits to companies at different stages in their development:

- As a start-up model: it requires limited capital investment or equipment; is relatively easy to manage; provides a means of accessing a wide range of client companies; and enables an unrestricted product strategy through which both start-up and clients can explore new techniques and solutions in a relatively risk-free manner.
- As a growth model: it allows the gradual build-up of capabilities and market understanding; exploits the creative talents of scientists and engineers; facilitates progressively larger projects as resources increase; permits more or less self-funded growth; generates cash for some degree of investment in IP; and enables technically oriented managers to learn on the job.
- As a platform for transition into product: it provides a mechanism for on-going intelligence gathering about emerging customer needs; can turn modest investments in IP into additional revenue streams, e.g. through licensing; and can enable standard products to emerge in a variety of ways, e.g. through consortium-funded technology developments or as a result of 'orphan' projects discontinued by clients.
- As a mechanism for exploring applications of platform technologies: it enables different commercial applications of science or engineering breakthroughs to be explored with a variety of potential customers; and helps address the problem of funding lengthy development and manufacturing scale-up timeframes.

Although the management demands raised by the soft model are multiple, they are relatively uncomplicated compared with the financial, production, market and people management challenges immediately encountered by product-based companies. A soft business model enables firms to conduct 'real world' market research, test and refine their technology proposition, build credibility with customers, and develop a robust and competent team of people. These factors are crucial to the longevity of a firm.

If a soft company decides to transition into a product business, venture capital financing will nevertheless often play a key role. Though the further the transition can be taken with internal funds, the larger the equity stake the original owners are likely to retain until exit is reached.

Chapter 6: Economic Benefits of the Soft Model

We next consider the soft model's economic contributions to the East of England region in terms of employment, revenue generation and new firm creation, as well as some less direct impacts.

The soft model firms we interviewed that continue to operate as separate entities directly employed around 3,525 people and generated over £435 million in revenues in the last year. These figures represent the bare minimum contributions of soft model firms to the regional economy, since (i) they exclude the earlier contributions of firms that followed a soft business model but are no longer in independent existence, and (ii) we believe many other firms in the region than those we interviewed also follow some version of the model (other research found 19,000 R&D jobs in the East of England region in 2001, for example, of which some proportion is likely to be in customer-funded contract work).

Since soft companies tend to grow relatively slowly and do not engage in high volume manufacturing, their product-based spin-out companies tend to be bigger contributors to the local economy than they are. Cambridge Consultants has created over a dozen spin-out firms, including Domino Printing and Cambridge Silicon Radio, that together employ over 3,500 people – well over 10 times its own current headcount; Acorn Computers, a hard company whose founders pursued a soft start approach, nurtured internally the team that established ARM; and ORL/AT&T Labs and its alumni created numerous new businesses in the region.

Soft model firms also generate significant indirect economic benefits to the East of England region, as an important source of complementary expertise for local 'hard' start-ups and in the form of value-added through technology conceived to enhance clients' productivity.

We point also to the important continuing contributions of ex soft-start entrepreneurs who have become advisors to the local technology community, and important early-stage investors. By enabling them to retain control of their businesses as they grow and minimise founder dilution, the soft start up model has played a key role in building the business angel community. This contrasts with the VC-backed, hard start-up model under which the rewards even to successful founders and managers are often much less than generally imagined, resulting from the punitive dilution that goes with successive venture capital rounds. Furthermore, soft firms have greater potential for longevity and continued location in the region than VC-backed firms, bringing continuing benefits to the community through the trickle-through of expertise and expenditure. Even if sold to a larger firm the acquirer of a soft company is likely to remain dependent on the expertise of its technologists and less likely to rationalise operations.

Chapter 7: Government Funding for R&D in Firms

The trigger to begin the transition from a soft to a hard business, and thus accelerate growth and job creation, is the ability to retain IP and fund the development of proprietary products. We examined the extent to which government R&D funding policies support this process and how easy it is for firms to access and use the different sources of funding, using responses to our small-scale survey of R&D grant recipients as well as our interview data.

Grants for R&D

Some of the successful soft start firms we interviewed had made good use of single firm government R&D grants (GRAD) and the predecessor 'Smart' grants programme during their early years. And our second group of small firms (Module 2), sampled from a database of recent grant winners, not surprisingly found them beneficial. However, all grants were relatively modest in size compared with awards received by US firms under the Small Business Innovation Research programme. Nine Module 2 firms each received the largest "Development Project" category, averaging £150k in each case, but requiring at least one and a half times as much from the company in matching funding. None of the firms in this sample had been awarded the larger "Exceptional Grants" (worth up to £500k), though one of the Module 1 firms we interviewed – Syrris – had been successful in winning an exceptional award in its early years.

Collaborative R&D Grants

Multi-partner collaboration is the dominant model through which government funds R&D projects in companies and is worth many times as much per year

Image courtesy of TWI

as single company grants. However, collaborative R&D programmes, whether run by the UK Technology Strategy Board or the European Commission, attracted rather little enthusiasm amongst the firms we interviewed. The main exceptions were the intermediate research institutes. Criticisms centred on lengthy timescales, the bureaucracy involved (which was costly, especially for small firms with few resources), the non-availability of 100% funding except when working as a subcontractor, and the non-commercial (pre-competitive) focus of programmes. IP ownership was also flagged as an issue. However, one small firm pointed out that the legitimating effect of collaborating with larger partners enabled it to 'punch above its weight'. We conclude that whilst, as presently structured, collaborative R&D grants may work well for universities and R&D groups in large companies with ongoing long term programmes that can benefit from subsidy, they are currently ill-designed to help SMEs.

Public Sector R&D Contracts

There was little or no recent involvement by any of our firms in public sector-funded R&D contracts, although 20-30 years ago public sector contracts helped lay the foundations for some of our soft model firms' later technology successes (e.g. Acorn's BBC Micro contract and Cambridge Consultants' expertise in inkjet printing starting with work for the Bank of England). This calls into question statistics published by DTI and BERR between 2005 and 2008 on the extent of government R&D contracts with SMEs, which implied annual expenditure five to ten times the value of single firm R&D grants per annum. Indeed, these statistics are no longer published.

In contrast with UK public sector R&D contracts, Owlstone, which is a Cambridge-based, majority US-owned firm, has won $4 million in US government-funded R&D contracts, starting with two Small Business Innovation Research awards that helped it onto the first rung of the Department of Defense procurement ladder.

We conclude that very few UK public sector R&D contracts are awarded each year and, indeed, all the firms we interviewed effectively discounted the UK public sector as a customer for innovation, certainly outside the defence sector. This is a disappointing finding given the contribution that private sector-funded technology contracts make to building science and technology companies and economic growth, and the emphasis placed by the Government on innovative procurement in recent years.

R&D Tax Credits

The R&D tax credits scheme is a form of government innovation support that is both widely used and highly appreciated, perhaps because credits are easy to claim and highly predictable. A few firms confirmed the view of sceptics, however, that the impact on their R&D expenditure was marginal, raising the issue of whether the scheme is money well spent.

Chapter 8: Relationships with Universities

Over the last 15 years the UK Government has added a focus on collaborating with business and the exploitation of academic IP to universities' traditional missions of teaching and research, and universities are undoubtedly important contributors to the wealth of the region. But despite the strong science base of East of England universities we found few direct IP relationships between universities and our firms, except where survey firm founders were attempting to commercialise their own PhD research. Relationships mostly appear to revolve around people, rather than direct IP transfers.

The main contribution of universities to our firms is through the recruitment of science and engineering graduates and post-graduates. Other links entail firms hosting student projects and providing summer internships, and the occasional use of specialised university equipment, Knowledge Technology Partnerships, and subcontracting. While acknowledging the depth of scientific expertise to be found in universities, firms were critical of the university sector's tendency to overstate the market readiness, and hence value, of its IP and the slow pace of collaborative work.

As for the University of Cambridge, we concur that its infrastructure investments and its laissez-faire attitude towards entrepreneurial academics until the late 1990s were very important to the growth of the high tech cluster, but argue that the relationship with technology-based firms is often less direct than is assumed by government policymakers. Private sector companies, and in particular soft companies, are a more important source of ideas for new businesses than the University itself, at least in terms of job creation.

We believe there should in principle be more scope for technology consultancy firms and intermediate research institutes to act as a bridging mechanism between academia and industry, particularly where platform technologies with the potential for application in many industries are involved. However current policies do not encourage this.

Chapter 9: Policy Implications and Recommendations

This report highlights the initially important role that customer-funded R&D contracts play in the growth of technology-based SMEs and the multiple contributions that 'soft' companies make to the development of social and economic capital in the East of England region. Yet we have also shown that in recent years such R&D contracts have derived almost entirely from the private sector and that there is little appetite among government agencies to engage with SMEs on a similar basis, let alone in the sustained way that US federal agencies procure technology from small firms through programmes such as the SBIR.

We conclude that much of UK science and innovation policymaking rests on three mistaken assumptions:

......that university research is the key source of technology and innovation.

University IP does have a role to play, but its effect on local and national economic development is modest in the short to medium term. The over-glamorised notion of the university boffin as the prime source of inventions that can rebuild the UK's scientific industrial base is seriously misleading. Instead, we must ensure that greater attention is paid to helping **all** entrepreneurial start-ups, especially spin-outs from research intensive companies.

......that VC funding is the primary financial resource for technology-based start-ups.

A high proportion of the East of England region's most successful science and technology companies originated through a 'soft' start, either directly or via incubation in a soft company before spin-out. Venture capital was either not involved or came later. Soft start-ups, being controlled by their founders, also seem to survive longer as independent entities. The Government should devote at least as much attention as it gives to venture capital funds to encouraging the private and public sector customer R&D contracts on which the soft model depends.

......that co-funding collaborative research is the best way to support technology development

The failure to design the UK's most important (by value) R&D project funding policy in a way that makes it attractive to SMEs is a major missed opportunity. Most successful soft companies regard collaborative R&D as irrelevant, even though it ought in principle to be able to help them overcome the challenges associated with trying to build value-creating IP positions to accelerate growth when clients own the IP generated during normal contract R&D business. Furthermore, for those SMEs that are tempted to use the collaborative grant mechanism, it pushes them in the direction of expensive, slow, pre-competitive, multi-partner research, often weak project management and divergent objectives, and away from the tight, customer-focused developments where they need to focus. Whilst both the Technology Strategy Board and European Commission have sought to make the collaborative R&D model more appropriate to SMEs, much, much more needs to be done to create new policy models that achieve this.

We believe that, as a result of relying on these false assumptions, UK innovation policies are poorly aligned with the needs of many of the entrepreneurs and SMEs best able to build the high technology economy the UK needs. To address this we propose new or improved policies under four main headings:

Recommendation 1. Enhance Government Technology Procurement Programmes

Government procurement plays a major role in the overall economy, yet it remains virtually absent as a lead customer for trials of new technology through either R&D contracts or prototype purchases. Despite the well-managed effort of the TSB to promote the Small Business Research Initiative (SBRI) to government departments, the rate of adoption continues to disappoint, although EEDA has played an important catalytic role through its pilot scheme with NHS East. We call on the Government to make ring-fenced funds available so that the SBRI programme can be significantly expanded and extended to all major government spending departments, and to encourage other RDAs and local agencies to initiate their own pilot schemes.

To achieve this we propose that the TSB is allocated £75 million per annum to co-fund SBRI competitions by user and specifier departments.

We also propose that €800 million per annum is switched from European Commission collaborative R&D programmes into co-funding SBIR-type programmes run by member states.

Recommendation 2. Revise TSB Collaborative R&D Programmes to Encourage Bilateral Contracts with Lead Customers

The soft company model is at present dependent on R&D contracts from the private sector, but not all private companies place such contracts. TSB rules for collaborative R&D grants should be reviewed to encourage more bilateral contracts between private sector customers and suppliers, especially small, specialist technology companies. We believe that bilateral projects should account for 50% of TSB R&D grant expenditure, taking advantage of recent changes in EU State Aid Regulations that allow up to 80% of SME R&D costs to be covered in this situation.

Recommendation 3. Revisit the Venture Capital Funding Model

The Government and EEDA should encourage the development of new investment models that enable a different engagement with soft start-ups than is found in conventional venture capital funds, probably involving smaller scale investments, a longer time horizon and a more hands-off approach. These features would be more appropriate for many science and technology businesses that start in the East of England region than the 10-year limited partnership structures currently prevalent, and are likely to be as relevant elsewhere in the UK.

Recommendation 4. Establish Focused, Fixed-Term Intermediate R&D Institutes

Whilst most senior academics do not want to move into industry, in many disciplines there is no 'halfway house' in which they can develop new technologies to the point where they begin to become commercially viable whilst staying in research. The intermediate research laboratory concept as practised in Germany and elsewhere – focused on emerging technology areas, partly core funded by government and partly funded through R&D contracts for customers, and with staff motivated to work flexibly across different projects and to commercialise rather than publish and teach – could help to catalyse exploitation of the region's science base. Time-limited institutes of this kind, twinned with appropriate university departments, could encourage development of commercially important areas of science and technology whose timescales are too long for either private sector soft companies or venture capital.

We recommend that Government studies how this model could be used, with a view to making some pilot investments.


Image courtesy of the East of England Development Agency

Image courtesy of Cambridge Design Partnership Limited

Chapter 1: Introduction

The role of innovation and commercial exploitation of the UK science base has assumed increasing importance in national policy in recent years, and a string of Government reports has tried to fine tune individual programmes to support this mission.[1]

Cambridge, with the surrounding region, remains the leading example of a science and technology 'cluster' in the UK[2] and, arguably, the rest of Europe. Its growth has been extensively documented[3] and it is regularly visited by UK politicians as well as delegations from all over the world seeking to replicate its success.

Nevertheless, many of the innovation policy challenges have been intractable. Nationally the percentage of GDP spent on R&D remains stubbornly fixed at about 1.8% despite a Government commitment to increase it to 2.5% by 2014.[4] And the returns to early stage science and technology based venture capital funds have been consistently disappointing over 20 years – a key signal, surely, that without some form of government support, the UK cannot rely on early stage VC funds to finance science and technology businesses.

In Cambridge itself there is also widespread concern amongst scientists and entrepreneurs that opportunities are being lost. Few science and technology companies have grown to more than two or three hundred employees. Companies developing successful products are all too frequently sold to foreign multinationals early in the commercialisation process, often to be closed down soon afterwards, when the acquirer's financial results dictate some retrenchment.

1.1 Emergence of 'Soft' Companies

The Cambridge 'Phenomenon' first achieved prominence in the early 1980s and from early on observers noted that many of the area's companies had adopted a business model based on carrying out R&D contracts for customers, rather than developing standard products. Over time the pivotal role played by these companies in building the cluster as a whole – directly and through spin-outs – has become increasingly apparent.

The term 'soft company' was first coined for this business model in 1983 by Matthew Bullock, a Barclays Bank manager who played a key part in financing some of the early Cambridge technology companies, though it was based as much on research he undertook into the financing of technology companies in the US as on his experience of lending in the UK.[5]

The aim of this report is to document and explain the overall impact of the 'soft company' model on the East of England region.

We believe that standard UK policy thinking about technology innovation has been too narrow, tending to ignore firms built around customer contracts and solving real world customer problems – the so-called 'soft company' model. Instead, public policy is dominated by the needs of (i) large science and technology based companies such as GSK, BAE Systems or Rolls Royce, which must spend significantly on internal R&D (and, to a lesser extent, on external R&D) in order to maintain the competitiveness of their existing businesses; and (ii) early-stage, venture capital-backed firms established to convert new technologies into standard products and intellectual property (IP) which they can sell or license – the so-called 'Silicon

1 Most recently these include Lord Sainsbury of Turville (2007) The Race to the Top: A Review of Government's Science and Innovation Policies; DIUS (2008) Innovation Nation; and HM Government (2009) New Industries, New Jobs.

2 In Cambridgeshire, high-tech businesses accounted for 14.5% of all jobs in 2006, with Cambridge City (17.2%) and South Cambridgeshire (25.4%) generating above-average employment for the county. See Cambridgeshire County Council Research Group (2006) Employment in the Hi-tech "Community".

3 See, for example, Segal Quince & Partners (1985) The Cambridge Phenomenon: The Growth of High Tech Industry in a University Town; Segal Quince Wicksteed (2000) The Cambridge Phenomenon Revisited; and Herriot, W. & Minshall, T. (2006) Cambridge Technopole: An overview of the UK's leading high-technology business cluster.

4 The Lisbon Agenda, set out by a European Council meeting in 2000, aimed to turn the EU by 2010 into the most competitive knowledge-based economy in the world. Among its goals was that member countries should be investing 3.0% of GDP in R&D by 2010, but the UK Government laid out a lower – and slower – long-term objective in its Science and Innovation Framework 2004-2014, published in July 2004.

5 See Bullock, M. (1983) Academic Enterprise, Industrial Innovation, and the Development of High Technology Financing in the United States. The model was further developed jointly with David Connell over subsequent years – see Connell, D. (1985) Starting a High Technology Company.

Valley' model. However, research[6,7] shows that venture capital plays only a tiny role in the financing plans of small and medium-sized enterprises (SMEs). We believe that the needs of technology-oriented SMEs that do not pursue the Silicon Valley model have been poorly served by innovation policy. Only by thoroughly understanding the business models pursued by science and technology firms in practice, and designing policies that support and reinforce these 'natural' processes, can we expect to have successful national and regional policies.

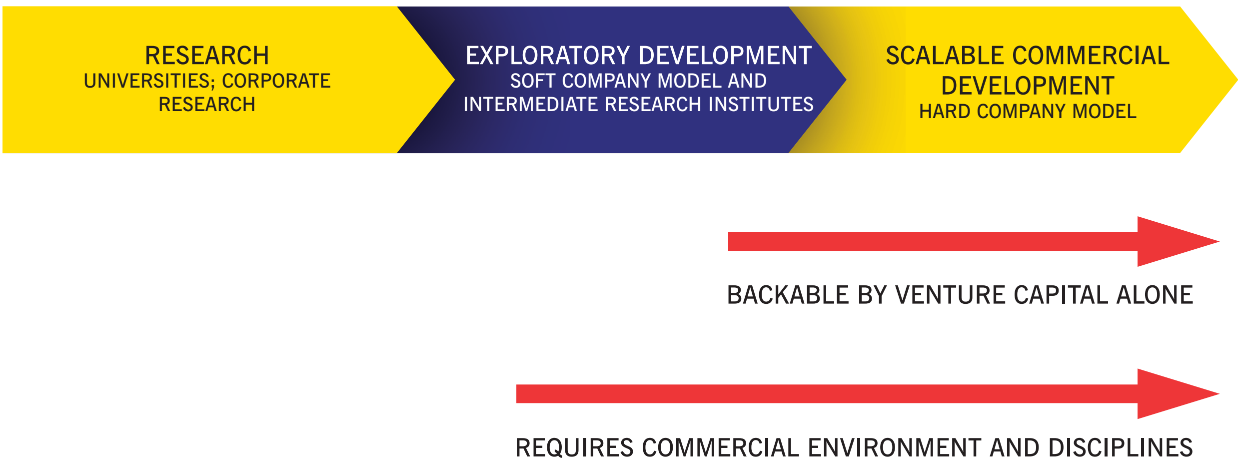
One of the key challenges for government policy is to help fill any 'funding gaps' arising because of market failure or for other reasons. The phrase is usually used to describe the difficulty that companies face in raising small accounts of equity investment – typically up to £0.5 million. However, we believe there is a more important funding gap when it comes to commercialising research in universities and large corporate laboratories (see Figure 1).

The most important commercial opportunities generated by research organisations are typically platform technologies with multiple applications, which usually require a good deal of further development and testing with potential users before they can provide the basis for a venture capital-backable business. If new materials, devices or process technology is involved, scaling up manufacture to commercial volume can take many years. This 'exploratory' stage of development must be undertaken within a commercial or quasi-commercial, mission-driven environment, rather than a university, so that it can be properly managed and full-time resources can be devoted to developing and testing the technology with users. However, this stage of the exploitation process cannot readily be financed by venture capital as the timescales are too long and the risks and uncertainties too high. The venture capital model is much more appropriate to a 'hard' company requiring funding to scale an already well-defined business idea or develop and market new applications of proven technologies. In this report we argue that the funding gap we highlight is at least partially filled by R&D contracts with lead customers to finance the development of demonstrators, either alone or alongside venture capital.

Some companies pursuing an entirely 'soft' model have been able to fund the 'exploratory' stage of development wholly from customer contracts, leading eventually to the development of a scalable product or 'hard' business. For UK firms, such R&D contracts come almost entirely from large private sector corporations seeking innovative solutions to technological problems. But the model would operate far more effectively, and would be a powerful contributor to the UK innovation effort, were public sector innovation contracts also available to these small and medium-sized technology firms – as is the case, for example, in the United States through the federal Small Business Innovation Research (SBIR) programme and other government procurement-based innovation programmes.[8]

We explore in this report how the 'soft' model currently works in practice in different industry sectors, and in

Figure 1: Commercial Exploitation of the UK Science Base



6 Cosh, A. et al (2007) Financing UK Small and Medium-sized Enterprises.
7 A report by Paul Kedrosky at the Ewing Marion Kauffman Foundation, Right-Sizing the US Venture Capital Industry (2009), indicates that only one-sixth of growth companies raise venture capital.
8 See David Connell (2006) "Secrets" of the World's Largest Seed Capital Fund.

the final chapter we outline recommendations on how the public sector could play a greater role in stimulating innovation to help the UK towards its Lisbon Agenda target.

The geographic focus of the research is the East of England region, comprising the counties of Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Norfolk and Suffolk. Although the 'Greater Cambridge' area accounts for much of the high tech and 'soft' activity identified, we nevertheless highlight a number of case studies and examples from other parts of the region. Our research is limited to companies in the East of England, but we believe our findings and recommendations are applicable at the national level.

1.2 Definitions: What do We Mean by a 'Soft' Company?

In this report we adopt the following definition of a soft company:

> A soft company is a science or technology based company whose business model is to provide R&D based services (e.g. technical consulting, contract R&D) and which draws on its expertise and/or proprietary technologies to provide bespoke offerings for a range of customers and applications.

This definition highlights the 'demand pull' approach to technology development common to most soft companies. It contrasts with the 'technology push' approach generally found in 'hard' start-up businesses whose purpose is to engage in the development and commercialisation of 'standard' products prior to any customer commitment to purchase them. The phrase 'soft company' has been coined to indicate how companies adopting this model can remould their 'offer' to meet a wide range of customer needs in different industries, based on their expertise. This model provides much greater flexibility and a wider choice of early customers compared with the rather fixed strategy of 'hard' companies.

There are several variations around the basic 'soft' theme. Many R&D based companies use a soft business model as a start-up mechanism to identify opportunities to develop proprietary products and to fund the eventual creation of a harder business model based around standard offerings. Some companies operating in specialist industrial sectors choose to retain a purely soft model and never move closer to the product-based end of the spectrum; others may retain the soft model for their core business while spinning out product-based activities as separate ventures. Some firms move through a soft phase of development very rapidly, transitioning within a few months into a product business; while others may spend much longer passing through the soft phase as they exploit a variety of potential applications of their technology before focusing on the best opportunities for a hard product. We explore the variations of the business model and the funding mechanism used in different industries in Chapter 4 of this report.

1.3 Research Objectives

The research underpinning this report has three main objectives:

1. **To identify as many important 'soft' companies in the region as possible and analyse their role in its economic development.**

The role of soft companies is poorly described in both published statistics and in the research literature. The amount of research and development conducted on behalf of customers does not appear as a separate entry in statutory data returns and the relative importance of the activity therefore remains hidden from view; nor are soft companies easy to identify from statutory financial accounts. As a result, their impact on economic development tends to be overlooked. This research identifies the most significant companies in the East of England region that follow – or have in the past followed – the soft model, and the industries in which they operate. Many of the best-known 'hard' companies in the region, for example Cambridge Silicon Radio and The Automation Partnership, were spawned by soft companies, building on many years of bespoke R&D projects for customers.

2. **To analyse the part that government R&D contracts play in economic development in the region.**

Commercial R&D contracts are vitally important to the emergence and growth of high tech companies in the region. We emphasise the importance of customer contracts for technology development, as opposed to financial support in the form of grants or collaborative funding, because of the powerful role that paid contracts play in specifying real customer needs and ensuring that product developments are demand led. In addition to mapping the prevalence of firms that rely on such contracts for all or part of their business model, we examine the extent to which public sector technology procurement contracts (as opposed to private sector R&D contracts) contribute to economic growth in the region. Prima facie evidence suggests that current UK government procurement processes are ill-suited to promoting the development of small and medium-sized innovative firms.

In addition to determining the balance between public and private sector R&D contracts won by East of England soft companies, we attempt to find out whether SMEs have had previous opportunities to work on government-funded technology projects.

3. **To identify policy actions to encourage economic development through government R&D contracts and other measures that support the 'soft' model.**

As well as examining access to government R&D contracts we also look at alternative R&D funding sources for SMEs, namely the provision of government R&D grants – both single firm grants and collaborative funding – and the extent to which firms are able to win and then use this kind of project funding to further their commercial objectives. Through an investigation of attitudes towards – and the actual use of – grants, collaborative research programmes, R&D tax credits and the like, we explore the extent to which policy mechanisms work as planned and indicate how they may distort behaviour in potentially less productive ways. We suggest policy actions that would support 'soft' company development and promote effective use of public sector R&D contracts, drawing comparisons in particular with the effective use in the US economy of R&D contracts placed by federal government agencies. Notably, though it is by no means the sole mechanism, the Small Business Innovation Research (SBIR) programme appears to play a significant role in encouraging exploitation of the US science base by small and medium enterprises through technology contracts, enabling firms to create a track record that eases subsequent sales to other public or private sector customers. We argue that the Small Business Research Initiative (SBRI) introduced in the UK in recent years could play a key role in stimulating innovation and economic development through government agency calls for imaginative technology solutions to help address key problems and policy goals. However, this will depend on a commitment by the Government to invest money in the programme – something which has, so far, been illusory.

1.4 Methodology

Figure 2 gives a schematic representation of the methodology we have adopted for this research. It has been designed to develop a robust evidence base from which to analyse the prevalence and practices of 'soft' companies and the role that R&D contracts play in the innovation process and in economic development more generally.

Desk Research

We first examined relevant sets of academic literature, including theory on the growth of firms, innovation intermediation (a subset of the knowledge-intensive business services literature) and financing models for technology firms; and we also looked at previous studies of science and technology policy conducted by bodies such as ACOST and PACEC.

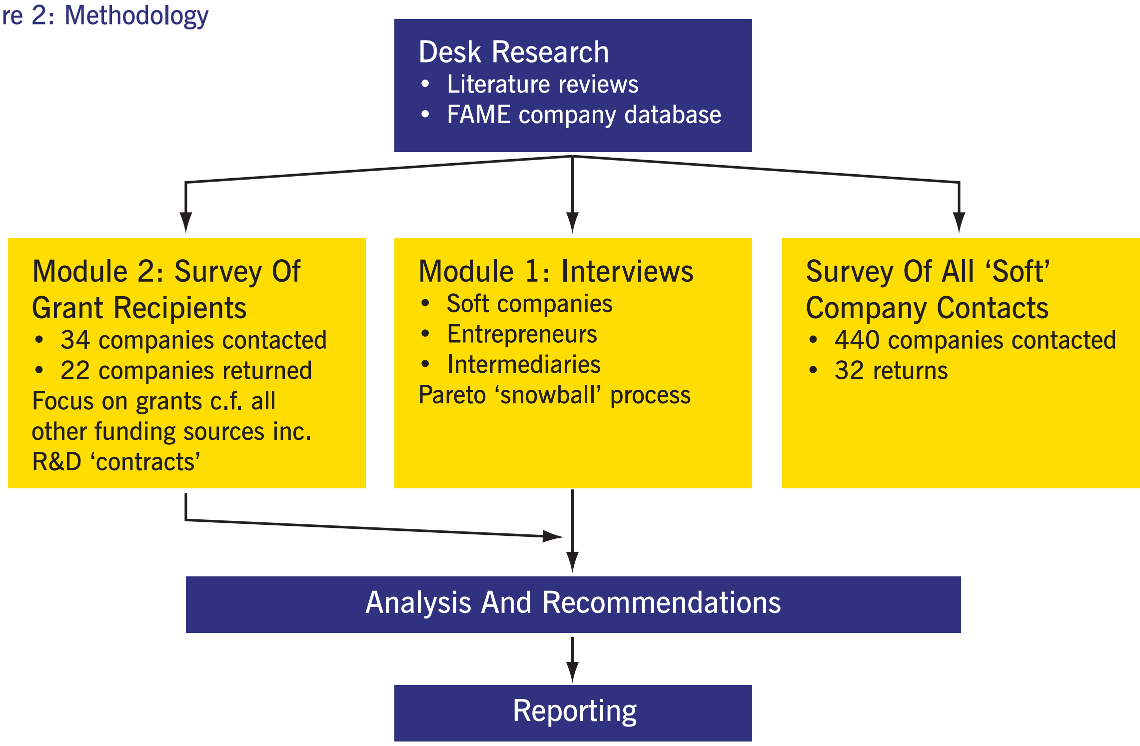
Module 1

Our main focus has been on studying the way that soft companies in the region operate by uncovering, through case study examples, the circumstances in which a 'soft' business model can function successfully in different industries, and by describing their historical development.

Our starting point was to use a Pareto approach using personal contacts to identify the best-known 'soft' companies in the region. Drawing on one of the authors' long-standing and extensive knowledge of entrepreneurial firms and key business network players, particularly in the Cambridge area, it was possible to conduct interviews with the founders or senior managers of most of the major firms that could be regarded as operating some form of soft business model at some stage in their history. During these interviews we explored the characteristics of the 'soft' company model each company pursued and, importantly, sought to extend our list of such companies through snowballing techniques, i.e. by asking our respondents to identify other firms that they thought operated a similar business model.

Since we are interested in the contribution of soft firms past and present to the East of England region, research that is focused entirely on a dataset of current firms

Figure 2: Methodology



would introduce survivor bias into our sample. Given the nature of 'softness', it is possible that older firms which now appear to be hard companies may have had an element of softness in their younger days; similarly, it is possible for firms to move in and out of the soft model as their portfolio of activities changes; and finally – and probably most importantly – there are a number of firms that played a critical role in seeding technological activity in the region in the past, but which no longer exist today. To capture the dynamic element of the research, therefore, we sought to examine how business models had evolved from the beginning of each firm's life, including those of firms known to have played an earlier pivotal role in the region's economic development. This focus on the origins of the 'soft start' gives us further insights into the well-documented history of the Cambridge Phenomenon and enables us to achieve a deeper analysis of the economic impact of soft firms in terms of their employment and the revenues generated.

Module 2

The first Module enabled us to identify the most significant and better known firms within the EEDA region for whom the 'soft' model is, or has been, important. We also wished to analyse the importance of R&D contracts compared with other sources of R&D funding among a representative sample of smaller, early stage firms. Module 2 was designed to achieve this by collating data on government R&D grant winners in the East of England region, and, with the help of the EEDA grants team, surveying a sample of grant recipients. An 8-page survey was sent to 34 companies for whom a grant had been approved and/or was already operational in January-June 2006. Twenty-two companies responded and follow-up telephone interviews were conducted with sixteen of them. We discuss the data collected from this survey of grant recipients primarily in the chapter on funding sources (Chapter 7).

Module 3

To supplement the list of interviewed firms identified in Modules 1 and 2 we endeavoured to survey a broader dataset of companies in the region for whom R&D contracts appeared to play a role in their business. This element of the research was higher risk in nature, as it was not clear that an adequate response rate could be achieved.[9] The survey recipients were selected from the commercially available FAME (Financial Analysis Made Easy) database.[10] Focusing on the six counties comprising the East of England region (Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Norfolk and Suffolk) we screened the 'activity' fields of company

9 The survey was financed partly from the Newton Trust funding element and by the Centre for Business Research, rather than by EEDA.
10 FAME provides detailed company information on public and private companies in the UK based on Companies' House records and other data sources.

records for key terms (including 'R&D', 'research', 'development', 'process', 'technology', 'innovative solutions' and 'design') and in a second stage performed a cross-check against a list of SIC[11] codes for high technology sectors (to eliminate market research and similar firms). After further data cleaning (e.g. to eliminate firms misclassified in the FAME database, subsidiaries of multinational companies, and firms that had gone bankrupt or moved from the region) we ended with a list of 440 candidate firms that appeared to have the characteristics of 'soft' activity. A brief 3-page questionnaire was designed to elicit information regarding contract research or development activity and funding methods.

Despite piloting the survey and making adjustments based on helpful feedback, only 32 completed questionnaires were returned even after two follow-up reminders were sent. We attribute the very disappointing response rate to two main reasons: first, that the concept of 'soft' activity is difficult to communicate in a brief paragraph and in sufficiently universal terms that it suits all industries, so that recipients did not see it as relevant; and second, the data requested did not conform to statutory information routinely contained in official statistics and therefore required too much effort to recalculate from company accounts. In the end, then, we were unable to use these data, although the overall number of candidate soft firms – 440 out of 18,711 initially selected – illustrates the potential size of the hidden soft company sector.

Hence the analysis that follows in this report relies more on rich qualitative data from the 52 interviews we conducted than it does on statistical data to gauge the presence and economic impact of soft firms in the region. (Appendix A lists the organisations and individuals who generously gave their time to talk to us.) We use the interview data to develop case studies of firms in the different industries where soft companies are to be found and include additional mini-studies of individual firms, particular aspects of their soft activity, and instances of transitions to hard product activity.

1.5 'Spin-outs' Versus 'Walk-outs'

In our discussion of new firms emerging from existing businesses we distinguish, where possible, between 'spin-outs' and 'walk-outs'. In the former case the new ventures are sponsored to a greater or lesser extent by the management team of the 'parent'; in the latter case a group of employees voluntarily departs to set up a new business without the blessing of their employer. A walk-out could take place, for example, because of disagreements over strategy (e.g. over the extent to which the company seeks to capture the value of its scientists' innovations), a desire to develop a particular technology in a different direction, or the wish simply to 'be one's own boss'. A less voluntary form of walk-out occurs when redundancies are made and a team sets up business on its own account. With the passage of time the distinction between a spin-out and a walk-out from any given firm may blur, but it is nevertheless important to try to include the walk-outs in our analysis of 'soft' companies.

1.6 Report Structure

The remainder of the report is structured as follows:

Chapter 2 outlines the various possible strategies of 'soft' and 'hard' start-up firms, establishing a spectrum of activity that will be examined in greater depth in later chapters.

Chapter 3 briefly discusses some of the firms comprising the Cambridge Phenomenon that were early users of the soft model in one form or another.

Chapter 4 presents, through a series of case studies and examples derived from our Module 1 interviews, applications of the soft model in a variety of industries.

We explore in Chapter 5 the significance of the soft model as a strategy during different periods in a firm's life: at start-up, during growth phases, as a platform from which to move into hard product activity, and as a means of exploring technology platform applications.

Chapter 6 lays out the economic benefits derived from firms pursuing the soft model in the East of England region.

Chapter 7 analyses the contribution to firms' growth made by various funding sources, for which we draw on data collected from respondents in both Module 1 and Module 2.

Relationships with academic institutions are considered in Chapter 8.

Finally, in Chapter 9 we draw out the policy implications of our findings and make recommendations for policy actions to stimulate the innovation capacity of the region and the UK more generally.

11 Standard Industrial Classification (used to classify business establishments by the type of economic activity in which they are engaged).

Image courtesy of Syrris Limited

Chapter 2: Soft and Hard Start-up Strategies

When an entrepreneur or a group of entrepreneurs starts a technology business a whole range of strategies is open to them, each offering different levels of risk and return (Figure 3). Risk in this context has three components. First is the level of uncertainty: can the firm make the technology work? Is there a market? Will competitors get there first? Second, how much will the technology cost to develop and market, and what will be the investment to break even? Third, how difficult is it going to be to manage the business as it progresses? [12]

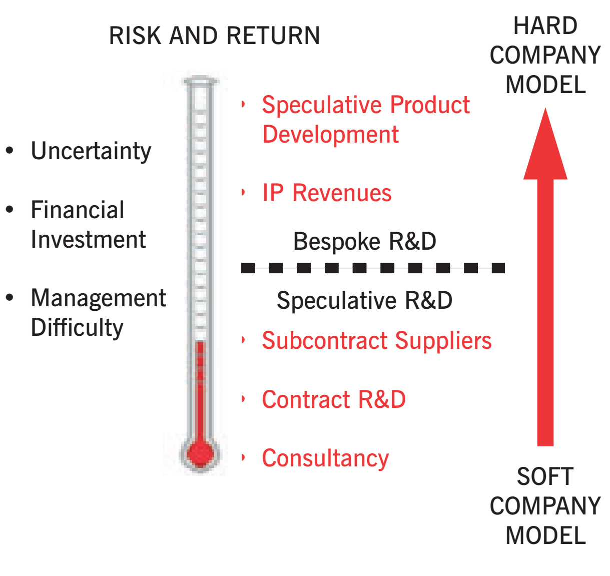
At the simplest (softest) level an individual or group of individuals with specialist technological expertise could sell their time in the form of consultancy projects for customers seeking analysis of specific problems. Early customers might be existing business contacts, or they might result from targeted cold calling or responses to conference papers or articles by founders. It is an activity with low overheads and requiring very little in the way of up-front investment. Very little, if any, specialised equipment is usually required – just a phone, laptop computer and dining table. Marketing expenses are limited to time and travel costs and the only real uncertainty is how long it will take to win the next contract. Fees can be charged monthly against deliverables or even partly in advance, depending on what the client will accept. As a pure consulting company grows, the level of management skills required increases, but remains limited to project management, people management and rudimentary financial management – skills that can pretty much be learned on the job. Success depends on selling 'time' and on delivery of projects to budget.

Sometimes, consulting reports analysing a customer's problem can lead to more tangible R&D contracts and the next notch on the 'riskometer'.

Companies carrying out R&D contracts – i.e. delivering demonstrators, prototypes or 'ready to use' physical deliverables – usually incur both higher costs and higher risks: higher costs, because of the cost of equipment required (although this can sometimes be borrowed in the early days, bought second-hand, or even charged to the customer); and more risky, because of the difficulty in predicting how long it will take to develop the technology or indeed whether the desired outcome can be produced at all. Otherwise, contract R&D is not too different to the kind of consultancy that produces reports. And if the project involves developing a new product, it is the client who has to worry about market risks and competitors.

The terms of trade under which contract R&D companies operate vary. The simplest is monthly invoicing based on time and materials used, just like a legal firm or management consultancy. But up-front

Figure 3: Risks and Returns in Company Start-up Strategies



12 Purists may object to this treatment of risk. In essence it combines the amount of money the founding team and other investors commit to a business and the probability of losing it.

payments to purchase materials and equipment are common, and payments are sometimes linked to milestones such as completion of key stages of the project. Contract R&D companies try to avoid quoting fixed prices in advance, as this means they have to bear the risk of overruns – common in most innovation companies. One way of getting around this is to undertake projects in successive phases of increasing size, so that key uncertainties and risks can be investigated first and quotations (or, better still, 'indicative costs') for later stages refined.

Box 1: Moving up the Soft/Hard Spectrum

"We are often engaged to help anticipate technologies and products our clients are going to need in 3-5 years' time. Occasionally our clients do not have the resources available to address these needs in a timely way. We can take these opportunities back into our shop, create the IP and solutions, incubate it up for a period, and then when our clients are closer to needing it we're ready knocking on their door having achieved proof-of-concept. This situation can result in a licensing and development contract which is likely to lead to a longer-term strategic partnership than a smaller time-and-materials contract."

Ian Rhodes, Member of PA's Management Group

In some sectors a company undertaking contract R&D develops technology to the level of demonstrator or prototype, with the client then taking over responsibility for converting it into the final product and organising manufacturing. Where the final deliverable is software, a single machine, or chemical or biological samples, the contract will typically extend to delivering the final version.

Managing contract R&D companies is somewhat similar to paper-based consulting businesses. Financial success depends on keeping people busy and not overrunning on projects. However, managing technical risk now assumes much greater importance, especially as companies grow and founders become less directly involved in key projects. As a result, managing technology risk is one of the key strengths of successful contract R&D companies. Together with the capacity for innovation which their flexibility and entrepreneurial approach brings, it can make them much more effective at innovative R&D than the established laboratories of the large firms for which they work.

Contract R&D is a viable start-up model in many sectors, from software to electronics to drug discovery. It can also emerge from the pure paper-based consultancy model described earlier, provided founders have the necessary skills. Contract R&D companies may be based around a fairly standard service (e.g. electronics design, chemistry synthesis), although in this case the scope for moving up the value chain is generally limited. Or they may be based around an area of expertise in short supply (microprocessors in the 1970s, wireless telecommunications in the 1990s) that offers higher fees and better long-term potential. Frequently, a highly innovative engineer or scientist is a key driver. And sometimes, soft companies are based around a proprietary technology platform with multiple applications, offering the potential for projects with multiple customers – although here some up-front investment is typically required so that IP can be created and then retained, at least for some applications. Chiroscience (discussed in Chapter 3) and Cambridge Antibody Technology (in Chapter 8) are good examples of the platform-based model.

Companies undertaking contract R&D frequently have the opportunity to move into small volume manufacture on behalf of individual clients, for example because a customer wants half a dozen machines or a continuing supply of chemical reagents. The new management skills that must be acquired or developed – in costing, production management and after-sales service – help support the transition later to the 'hard company' model if the choice is made to develop proprietary products for wider marketing.

Working as a subcontractor, a soft company moves closer to the hard model by taking on sub-assembly work for mission-critical components for an industrial customer or even entire products. At TTP, a broadly-based technology consultancy company, for example, a small industrial design commission for a venture capital-backed customer led on in stages to the creation of a subsidiary company, TTP LabTech, which now develops and manufactures a range of specialised scientific instruments and employs over 80 people (see Box 2).

Box 2: The Transition of LabTech from Contract Development into a Product Development Business

Image courtesy of TTP LabTech Limited

LabTech began when a VC-backed reagents company approached TTP with a technology to detect bacteria in water samples which, it was thought at that stage, just needed some simple industrial design work to take the product to market. While working on the design, TTP discovered problems with the underlying technology for detecting the fluorescent markers used. The small initial contract therefore led on to a sequence of much larger ones to redevelop the instrument from scratch and manufacture it in small volumes for the reagent company. Since the client company's prime business was to supply the reagents used, it did not have the capability to manufacture the instrument itself and LabTech became the manufacturing subcontractor. Over the next few years it learned a great deal about the underlying platform technology through problem-solving and troubleshooting, and it put in place increasingly sophisticated production management and after-sales service on behalf of the client. As a result, LabTech discovered that the technology could also be applied to drug discovery, worked on that application in the lab and eventually put together a small consortium of pharmaceutical companies to fund the development of a product called Acumen Explorer.

It took 10 years from the first small third-party industrial design contract to the launch of the Acumen Explorer, and it was a further four years before it started to achieve significant sales. But this gave LabTech the impetus to develop other proprietary products for its drug discovery customers and by 2009 it employed over 80 people and had revenues of £9.3 million.

As can be seen from the LabTech example, the creation and exploitation of intellectual property around a different application of a technology developed under contract moves the firm 'above the line' on Figure 3's 'riskometer' into more speculative R&D activity. The IP can be exploited in various ways (Box 3), but it is important to manage ownership and commercialisation rights carefully, since the intention is to establish a robust IP package for licensing out or assignment to a new venture.

Box 3: IP Generation and Ownership

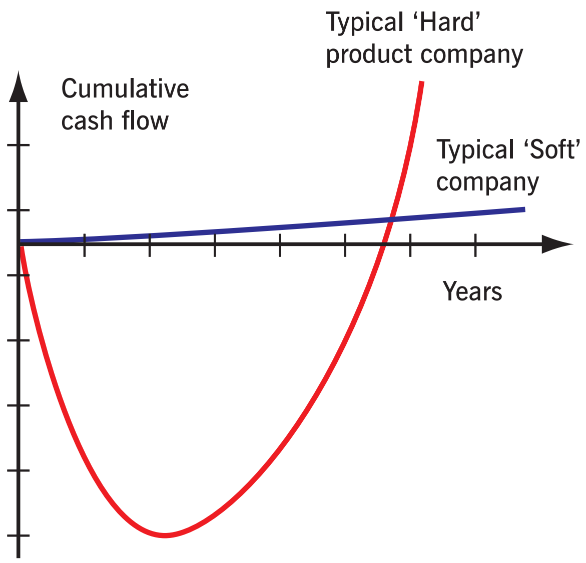
The IP developed in the course of project and contract work can be handled in a variety of ways:

- When developing a product under contract for a client, the consultancy receives fees for the time it spends, discusses what IP the client wants to protect and signs over the IP.
- When developing something for a client around the consultancy's existing technology, the consultancy retains the IP, but grants a licence to the client, as part of the contract, for the purposes of commercially exploiting the work the consultancy is doing.
- The consultancy's self-generated IP can be licensed out exclusively or non-exclusively in return for fees and royalties.
- The consultancy's self-generated IP can form the basis of a new venture, and may be assigned to it if that venture is later spun out as a separate company.

In contrast to soft companies, most businesses established to develop new products on a speculative basis require significant amounts of cash to move from the early phases of development into bringing out a product and scaling up production, sales and marketing. This level of investment is normally only available from venture capital investors, and, for those companies that are successful, growth can be very rapid. For venture capitalists the steepness of this curve is crucial, because it indicates the potential multiple to be made when they sell the business on the basis of future sales prospects. (The faster the growth, the bigger the multiple to sales acquirers will be prepared to pay.)

In the case of a soft company, however, the cash flow curve is far flatter (Figure 4) because there are fewer start-up costs involved and customer revenues can be generated quickly. Some soft start-ups effectively never become cash negative at all. On the other hand, the growth rate once profitable is much slower. Hard product companies need backers prepared to shoulder the risk in order to make the progress necessary to stand a chance of getting to market first. Because of the need to capture market share and gain strength ahead of competitors, speed of execution is critical. As a result a full management team is required, with experience in marketing, sales and distribution management, supply chain management, technical service and possibly production. Financial management and, of course, the job of the CEO are commensurately more demanding. As a result, many of these skills need to be recruited into a hard start-up. There is little time to learn on the job.

Figure 4: Typical Cash Flow Profiles for Successful 'Hard' and 'Soft' Companies



Typical Cash Profiles

	Max Cash Negative	Time to Cumulative Profitability
Soft Company	Up to a few hundred thousand pounds	6-18 months
Hard Company	Ten million pounds plus	5-10 years

The risks associated with hard start-ups are very high, in terms not only of getting the technology to work but also of managing the complexities of putting it into production and getting it out into the marketplace – but so also are the potential returns. However, there are rarely second prizes, and investors in hard start-ups that fail can expect to lose everything.

Finally, the LabTech Acumen example illustrates another key difference between incubating product firms within a soft business environment and a completely product-focused hard start-up firm. For the latter, the gap between first customer engagement and demand at last taking off can be surprisingly long, especially in specialist equipment markets. During this period the hard start-up continues to incur costs rather than revenues and, if venture capital-backed, the founders and management team will suffer strong pressure from investors, heavy dilution and possibly closure. But a soft company environment can enable people to be shifted onto customer-funded projects in other areas during gaps in customer interest in the technology or while the evidence, budgets and political support that is required to make any innovative purchase in most large organisations is being accumulated. This greatly reduces investment costs (possibly even maintaining profitability) and allows the patient accumulation of expertise and market understanding, putting the firm in a far stronger position to fine tune its product and exploit the opportunity once demand finally begins to take off.

Image courtesy of Hermann Hauser

Chapter 3: Early 'Soft' Examples from the 'Cambridge Phenomenon'

The tendency for new science and engineering-based firms to spring up in and around Cambridge over the last 30-40 years has been well recorded.[13] The specific features of the Cambridge environment that made it so conducive to technology start-ups – the liberal attitude in the University towards intellectual property exploitation, labour market dynamics, the foundation of the city's first Science Park on the recommendation of the 1969 Mott Report, etc – were reinforced by changes in the wider industrial environment.

In particular, in the electronics industry the concept of generating revenue from knowledge-intensive services as an initial start-up strategy was beginning to emerge in the 1960s and 1970s, when microprocessors and the falling costs of computing generally opened up myriad new applications in existing industries which small firms could help develop. The Cambridge Computer Group, a 'club' for small IT companies formed at the end of the 1970s, and the strong personal connections between the University's computer lab and (among others) the Acorn 'family' of firms reflect these circumstances. In other industries, such as the life sciences, the soft start-up model emerged later, when technological developments allowed firms in the biotechnology field to create new research tools and platforms they could offer to large incumbent pharmaceutical firms as a stepping stone towards their own 'hard' product/IP offerings. Electronics, including computing, telecommunications and software, and the life sciences have been important new fields of expertise in the region.

A number of firms and research establishments that played a central role in the Cambridge Phenomenon followed a soft business model. Among the earliest examples were Cambridge Consultants, founded in the early 1960s by a group of recent Cambridge graduates, and the MinTech Atlas Centre, a government-funded research institute for computer graphics in engineering design which was set up in the late 1960s as part of the Wilson Government's investment in the 'white heat of technology'. Both of these organisations remain important in the Cambridge region even today – demonstrating the potential for longevity in the soft business model, as well as its adaptability to changing circumstances.

The MinTech Centre, renamed CADCentre in the early 1970s when computer-aided design was coming to the fore, was what we call an Intermediate R&D Institute, that is to say a partly government-funded R&D centre with a medium-term focus and emphasis on getting new technologies into the market, rather than on publications or teaching. CADCentre was largely funded by government with some private sector contracts and, despite some criticism of its operations in the 1980s, has turned out to be enormously important in building Cambridge's CAD (computer-aided design) software cluster. During the 1970s it spun out a series of CAD companies, each pursuing a soft start-up strategy. CADCentre itself went through privatisation in the 1980s, followed by a management buyout and stock exchange listing in the 1990s. Today, as AVEVA, it is an important player in the world market for software tools to design complex, large-scale industrial process facilities. AVEVA has travelled a long way from the early days when it was simply a "*melting pot with government money, equipment and lots of bright people thrown into it*", according to Dick Newell[14], with different industry groups delivering on a few customer contracts (such as an electronic photo-fit system for the police) and working up their own research agendas loosely based around the perceived requirements of the industry (see Case Study 9 in Chapter 4).

13 See, for example, Segal Quince & Partners (1985) The Cambridge Phenomenon: The Growth of High Tech Industry in a University Town; and Segal Quince Wicksteed (2000) The Cambridge Phenomenon Revisited.

14 Dick Newell is a former CADCentre senior engineer and founder of CIS and Smallworld.

Cambridge Consultants became an autonomous subsidiary of Arthur D. Little in the early 1970s and is currently owned by the French consulting/engineering contractor firm Altran. Its genes are to be found in all the other major technology consultancies in the area as well as in several important local product-based spin-out companies. We discuss the case of Cambridge Consultants in greater detail in the first section of Chapter 4.

Other early firms that initially followed the soft model and were crucial to the development of the high tech cluster around Cambridge include Cambridge Processing Unit (CPU), which was the precursor to Acorn Computers and ARM; Chiroscience (in biotechnology); and Symbionics (wireless telecommunications).

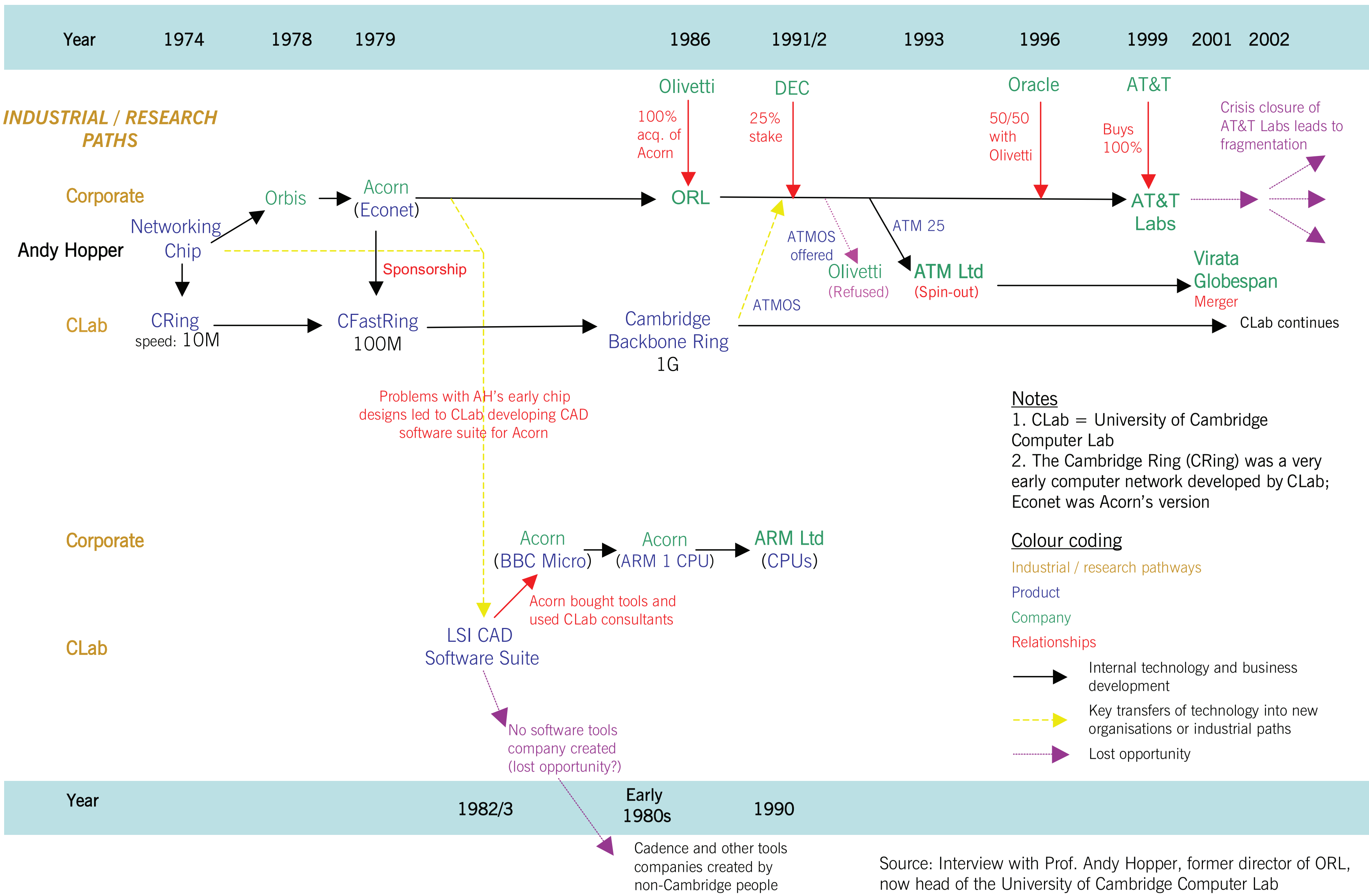
CPU was founded by Hermann Hauser after his PhD and a short period as a post-doc at the Cavendish Laboratory, and Chris Curry who had been working for Clive Sinclair's computer company. The firm started in December 1978 with £100 of capital and with the initial aim of carrying out development contracts for companies wishing to incorporate microprocessors into their products. But the idea of selling computers had been growing in Hauser's mind for some time, and he had already helped with one of Sinclair's products. CPU rapidly won a contract with Ace Coin Equipment in Wales to develop a microprocessor-based controller for its fruit machines, and the profits on this enabled CPU to develop its first computer, the System One, helped by the enthusiasm and creativity of its designers, Steve Furber and Sophie Wilson, who were then still university undergraduates. A new company, Acorn Computers Ltd, was set up to market the System One to computer enthusiasts. By adopting the mail-order model, which was then prevalent for home electronics and computer kits, it was possible to finance working capital through an overdraft with National Westminster Bank, secured against cheques received from customers. The transition to a product-based company was swift and a series of kit-based computers followed, leading to the Acorn Atom which was launched in March 1980 and aimed for the first time at a more mainstream consumer market. An improved design called the Proton was also in preparation. In 1981, when the BBC was looking for a home computer to use in its pioneering computer literacy TV series, Acorn was able to rapidly submit a new design, drawing partly on the Proton, and win the contract.

Winning against much larger and better known companies, this contract, though not bringing funding directly from the BBC, enabled Acorn to build a business which by 1984 had grown to annual revenues of £93 million without raising a penny in venture capital. The BBC contract, coupled with Acorn's status as a nominated supplier to the Department of Industry's Micros for Schools scheme,[15] remains one of the most powerful illustrations of how contracts from public sector customers can help stimulate the development of our high tech industrial base. Acorn's computers were far ahead of their time in terms of file server use and networking capability, and remained an important innovative force for many years. Although Acorn had to be rescued by Olivetti in 1985 when it over-ordered from suppliers and hit cash flow problems, as lead customer it funded the in-house team and the technology that eventually became ARM plc. ARM is arguably one of the biggest success stories in the Cambridge high tech cluster, even though few would recognise it as a company with 'soft' origins.[16] (See Figure 5 for the interactions between Acorn Computers and the Cambridge University Computing Lab on the one hand, and Olivetti Research Labs on the other.)

15 Oxfordshire-based Research Machines, now RM plc, is one of the other major beneficiaries of the policy. Its revenues in 2008 were £289 million.

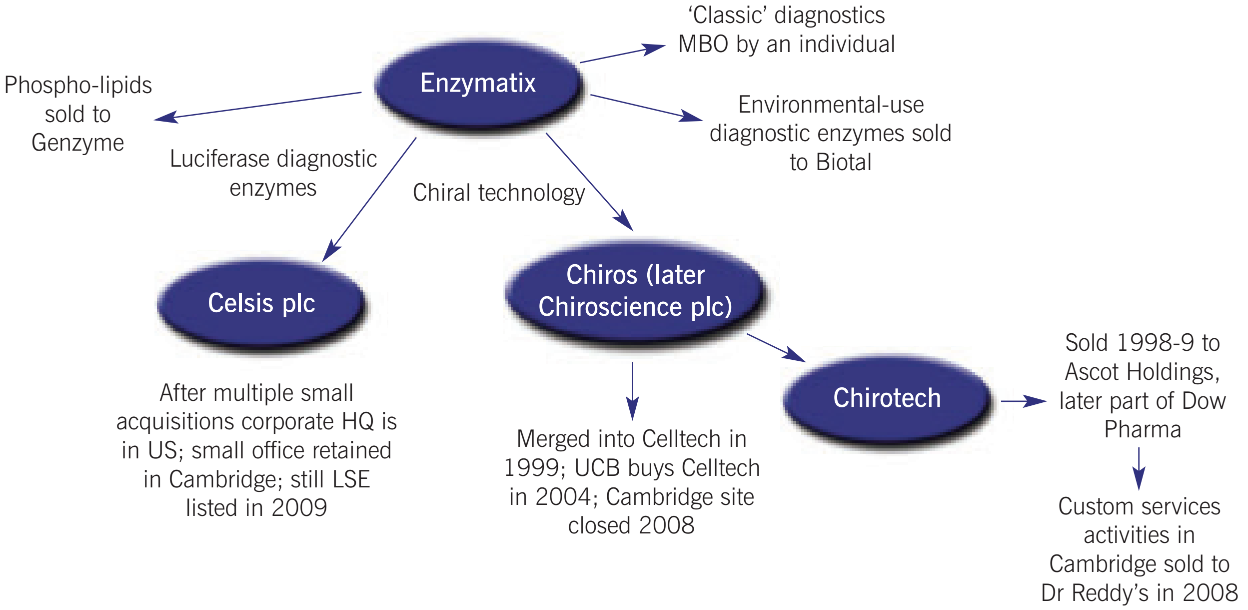
16 In a variant of the standard soft company model, the ARM chip architecture was originally developed as an internal project at Acorn before being spun out as a separate company with investment from Apple. Acorn's internal need for a new microprocessor led to the research team working from scratch on reduced instruction set computing – inspired by reports of Sun's and MIPS' developments in California – to meet particular requirements for its new computers. The first prototype RISC microprocessor was ready in 1984, just as Acorn was entering its financial crisis, but a first attempt to spin out ARM in 1985, shortly after Olivetti rescued Acorn, failed because no working ARM silicon was yet available. The internal design team worked on, and Acorn's Archimedes home computer was launched in 1987 as the first commercial product incorporating an ARM chip (which was manufactured by VLSI).
Apple became interested because only the ARM chip came close to meeting its Newton device's requirements in terms of power consumption and performance, but more development of the basic platform was required to meet the full specification. Apple agreed to fund this through a $1 million investment for 43% of a spin-out venture called ARM Ltd – a stake Apple sold later for $800 million to rescue it from its own financial crisis – but it could equally have simply placed an R&D contract with Acorn. To this extent ARM plc has a strong element of 'softness' in its evolution, with both Acorn itself and Apple as customers and paymasters. The ARM development team thus separated from Acorn, hired an experienced CEO, and developed a business model around licensing its processor architecture to fabless customers, chip foundries and integrated device manufacturers. Additional performance-enhancing modifications made the ARM microprocessor increasingly attractive to potential third-party customers for use in low-cost portable or mobile devices. Like Acorn before it, ARM's growth did not depend on venture capital. The company IPO-ed in 1998.

Figure 5: Development, Evolution and Exploitation of Research by Professor Andy Hopper



Source: Interview with Prof. Andy Hopper, former director of ORL, now head of the University of Cambridge Computer Lab

Figure 6: Enzymatix' Heritage



After Olivetti rescued Acorn, Hermann Hauser became Vice President of Research at Olivetti in Ivrea, in charge of DOR (Direzione Olivetti Ricerca) with seven labs worldwide. One of those labs, Olivetti Research Labs, was created in Cambridge under the leadership of Andy Hopper (who had driven the computer networking development at Acorn). ORL and its later incarnations, though not an independent soft company, had many of the same characteristics as an innovative intermediate R&D institute funded by corporate sponsors.[17] It went on to incubate a variety of technologies and teams, notably the spin-out Virata (DSL semiconductors) in 1993, but also Cambridge Broadband (intelligent packet microwave), Real VNC (remote control software) and Ubisense (real time location systems). In each case, early technology development was effectively funded and/or trialled by the parent company.

Biochemist Chris Evans founded Enzymatix in 1987 with corporate investment from the Berisford Group, owner of British Sugar, to build on his experience working for Genzyme in the US and for its subsidiary in the UK. The business model was to sell both enzyme-based diagnostics products and technology problem-solving services. Although mostly financed by Berisford, the venture also had some contracts. In 1992, when Berisford wanted to dispose of its interest, Enzymatix' technology was parcelled up into five pieces, each with its own revenue stream, and spun off in different directions (see Figure 6).

Chris Evans, together with Andy Richards and Peter Keen, formed Chiroscience from Enzymatix' chiral technology activities. Chiroscience pursued an elegant soft start strategy and went on to become one of the UK's first successful biotechnology companies. In the first year alone it earned £1 million from fee-for-service chemistry and collaborative activity with major pharmaceutical players including Wellcome, Abbot and Menarini. Revenues from fee-for-service chemistry helped to fund the drug discovery activity, supplemented by £3 million raised in the first year from venture capitalists, for whom this revenue-generating activity transformed perceptions of the risk profile. Although fee-for-service revenues covered only around 25% of first year expenditure, it generated far more in terms of contacts, network-building and company credibility.

The soft start worked perfectly, because it allowed the flexible resourcing of work programmes between customer projects and in-house developments. It also enabled Chiroscience to grow an IP position and on the back of it to develop a business model that was more oriented towards proprietary pharmaceutical research. In due course the chemistry business was separated into a wholly-owned subsidiary, Chirotech, both to resolve potential conflicts of interest between chemistry contracts for pharmaceutical company clients and Chiroscience's own drug discovery work, and to overcome resource allocation issues. Chirotech was

17 Olivetti owned the lab outright from 1986 to 1991, when DEC took a 25% stake. By 1994 the lab was again wholly owned by Olivetti, but two years later Oracle invested in a 50% stake thereby doubling ORL's research budget. The lab was sold in its entirety to AT&T for $8 million in 1999 and was shut down suddenly in a crisis move when AT&T got into difficulties in 2002.

sold in 1998-9[18]– by which time it employed 47 people and had revenues of £30 million – but it continued to operate on Cambridge Science Park until 2008.

Chiroscience itself went through various transformations; having started off as a service business it became a single isomer racemic switch company, then a drug discovery company. It later bought a genomics company and eventually merged with Celltech in 1999, having achieved annual sales of £41 million and employment of some 330 people. Although the Chiroscience name then disappeared, over 120 scientists continued its research activity on Granta Park outside Cambridge until the site was closed down in 2008. The founders have gone their separate ways, but remain active in the Cambridge life sciences sector by funding and/or managing other biotechnology start-ups.

In the case of Symbionics, a typical soft-start consulting project model based purely on fees-for-service evolved after 2-3 years into investments in pre-development designs of mobile telecommunications chips that could be out-licensed. Rather than focusing simply on collecting royalty payments, however, the company pioneered the highly successful idea of IP licensing, not as an end in itself, but as a means of leveraging into larger product development contracts to create derivative designs and IP for individual customers – a model subsequently much copied by other high tech firms.

Symbionics was founded in late 1987 by a team of five people from PA Technology Centre's Telecoms Group. The founders wanted to use their experience in contract R&D to build a more scalable and valuable business. Symbionics achieved its position firstly by recognising that as a small start-up it needed to focus on a specific technology, second by having a start-up team with all the requisite functional skills in addition to their technical capabilities, third by settling on a business model that played to Symbionics' strengths without having to involve external investors, and fourth by working closely with its customers. Technologically it stayed ahead of the curve by deliberately getting involved early in European industry discussions on DECT mobile telecommunications technology standardisation. By participating in the meetings (where tiny Symbionics in those days was the only consultancy attending alongside all the major mobile telecoms operators and manufacturers) it could not only align its technology development to the standardisation process, but also influence that process according to the directions its own development activity was taking. From its core ASIC design expertise it developed skills in software design and radio design, enabling it to undertake the design of complete products (except for industrial design, which was mostly dictated by the customer), but chose not to move into product engineering. It moved into other technologies also, including wireless LAN (which was ahead of its time and found no market) and digital video broadcasting, which became a very successful activity.

Throughout the ten years of its independent existence, Symbionics' business model remained that of a product development consultancy leveraging proprietary IP. Recognising the different skills that would be required to integrate forwards into manufacturing, the only standardised product it ever made was separated out into a subsidiary, Symbionics Instruments, which produced highly specialised, very low volume chip-testing equipment.

Symbionics had grown to 140 people with revenues of £12 million when it was taken over in March 1998 by Cadence, which wanted to establish a contract development business as a complement to selling its IC chip design tools. Its growth over this period was totally self-financed, without recourse to venture capital. Although Cadence closed what had been the Symbionics site in 2002 in the wake of the dotcom bust, new firms comprising teams of ex-Symbionics engineers sprang up to capitalise on its expertise, among them Nujira, Fen Technology, Commsonic, Change Management Consultancy, Cellmetric, Qualtra, Cambridge RF, and Sheffield-based Jennic. Symbionics Instruments, which had spun out of Symbionics in 1997, was taken over in 2001 by Tektronix (the North American manufacturer of oscilloscopes and test equipment) and continues to operate as Tektronix Cambridge from its offices in Histon.

In Conclusion

Each of the companies discussed above was founded by talented scientists and engineers who developed distinctive customer-focused – and customer funded – business models to overcome the heavy capital demands of developing proprietary technology. Start-up funding often came from traditional 'bootstrapping' practices, drawing also on personal savings and raising money from family and friends. Where they moved

18 Ascot bought 30% of Chirotech for £30 million in September 1998 (when revenues were £16 million), and a year later bought the remainder for £59 million. Dow Chemical acquired Ascot in 2001.

rapidly towards developing proprietary IP and products, this was supplemented not only by customer consultancy work but in some cases by relationships with the local branches of some of the high street banks. The more astute managers of these banks recognised that firms with the potential to generate revenue streams from consultancy projects or contract R&D work had lower working capital requirements and presented a lesser financial risk than firms seeking bank loans against purely speculative product development. As a result they were able to split out a class of technology firms to whom they could offer overdraft facilities with or without the personal collateral of the founders. Contract R&D debtors with blue chip customers were seen as an asset which could be used as security, enabling these firms to finance growth more easily.

Box 4: Bankable Businesses

"*Soft companies were 'bankable' in a way that hard companies were not: they typically had customers committed to purchase before they did the work; these customers were often high quality, undoubted names, who would pay if the company delivered the project; the project was often based on their previous research expertise. All these factors served to reduce the risk of lending provided we monitored their performance closely. We did a lot of good business on this basis.*"

Matthew Bullock, previously Head of High Technology Finance Team, Barclays Bank

By not involving venture capital at all or, in the case of Chiroscience, not relying on it fully to fund early growth, firms were able to remain in greater control of their destiny and adapt their business model to suit changing circumstances; they were also able to remain locally based for many years rather than being obliged by an acquirer to relocate operations overseas. With firms staying in the area, the region retained its entrepreneurs, scientists, engineers, and specialised technology expertise, even if operations were subsequently run down, and key players re-emerged as serial entrepreneurs, investors or advisors. New entrepreneurial businesses were able to spring up based on that expertise, perhaps funded by local angel investors who had already made money in the Cambridge high tech cluster.

In the next chapter we extend our discussion of soft business models to a variety of different industries, drawing on our interviews with companies throughout the East of England region.

Image courtesy of Argenta Discovery Limited

Chapter 4: How the Soft Model Operates in Different Industries

The early examples of soft businesses discussed in the previous chapter indicate that there are many variants of the soft model in different industries. In the technology development consultancy firms the 'standard' model is relatively easy to apply because the very nature of the business is to work on projects for customers. But development timescales, scientific complexity, capital requirements, industry structures and regulatory regimes drive the way in which the soft model functions in other industries.

The application of the soft model in life sciences, for example, is very different from electronics because of the length of time and the costs involved in bringing a pharmaceutical product through the approval process. The relatively slow shift by established pharmaceutical firms towards outsourcing parts of the research process to specialist firms – at least until the 'biotech revolution' of the early 1970s and 1980s, which enabled the development of research tool and platform technology companies – also stands in marked contrast to the early use of outsourcing in the electronics industry. In other industries such as software, the time required to develop innovative new products may be so short that it can be self-funded and a firm's transition from an initial customised development to hardening that offering into a standardised product may happen within just a few months. In these circumstances, even though venture capital is not involved, only a subset of the characteristics of the 'soft' model is evident.

We discuss below some of these variations in the context of firms in the East of England region. Companies in the following sectors are covered:

- Broadly-based technology development consultancies
- Specialised technology and innovation consultancies
- Drug discovery
- Automotive and aerospace engineering
- Instrumentation and 'research tool' businesses
- Software and ICT
- Intermediate research institutes

4.1 Broadly-based Technology Development Consultancies

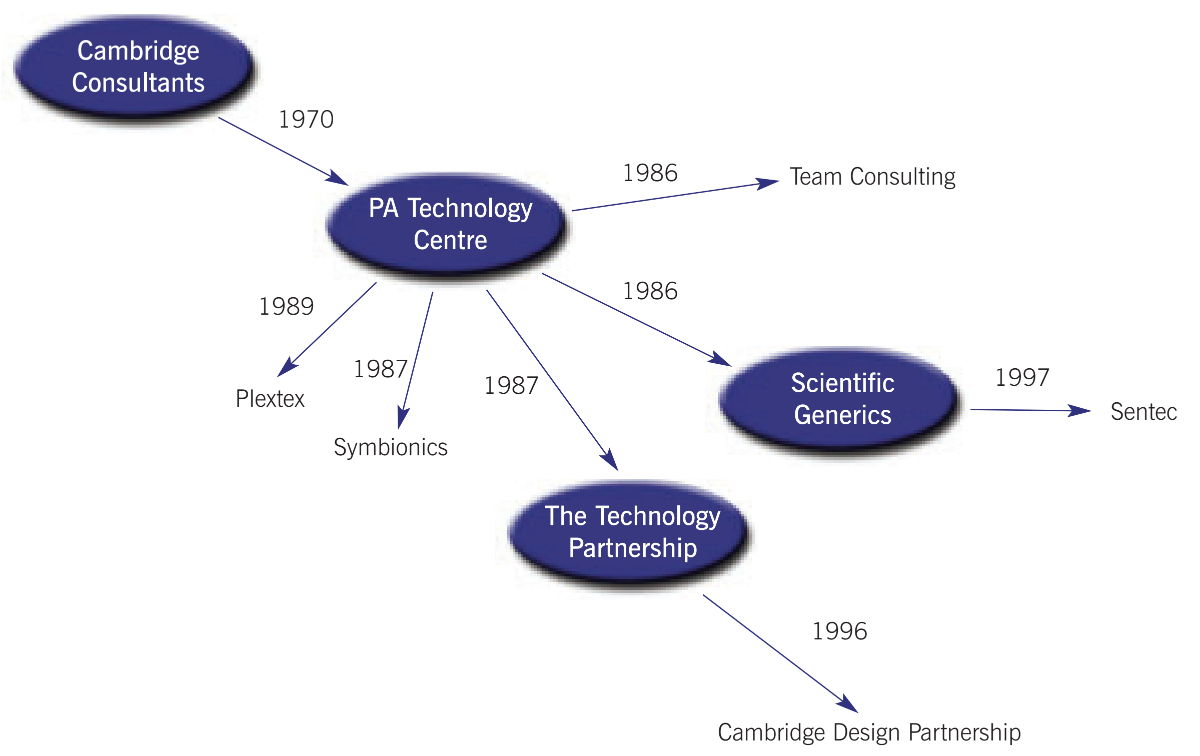
'Standard' soft model: contract R&D involving many science and engineering disciplines for multiple clients in a range of industries fosters an accumulation of know-how and IP that can be productised through licensing arrangements, product-based subsidiaries, or spin-outs (often backed by venture capital).

In the East of England four broadly-based technology development consultancies around Cambridge exemplify the soft business model in its purest form: Cambridge Consultants Ltd, established in the early 1960s; PA Technology, launched after Gordon Edge left Cambridge Consultants in 1970 and persuaded the management consultancy firm PA Consulting to set up a technology group; Sagentia plc (the present name for Scientific Generics[19]), formed when Edge walked out of PA with a dozen or so fellow technology consultants in 1986; and The Technology Partnership (TTP, now TTP Group plc), set up in 1987 after Gerald Avison took another group of consultants out of PA (Figure 7).

The four major technology consultancies have spawned, through walk-outs of staff wanting to run their own business, several smaller, more specialised outfits in the surrounding area. Interestingly, the broadly-based technology consultancy model appears not to be replicated elsewhere in the UK, although

19 Originally called Scientific Generics Ltd, a holding company called Generics Group was established later. In 2006 the name was changed to Sagentia plc.

Figure 7: Cambridge Technology Development Consultancy Heritage: The Consultancy Walk-outs



members of AIRTO (Association of Independent Research and Technology Organisations) share some similarities. Outside the UK the nearest equivalent to technology development consultancies are intermediate research institutes such as the Fraunhofer Institutes in Germany and ITRI in Taiwan, and American firms such as Battelle and TIAX. However, most of the Cambridge firms agree that competition from a customer's in-house R&D team and from firms specialising in narrow technology sectors is much more important than competition from their local rivals.

How they Work

Gathering together scientists and engineers from various disciplines, these consultancies undertake technology development and problem-solving projects for clients in industries as varied as electronics, aerospace, defence, medical devices, printing and telecommunications. The larger firms have extremely well-equipped laboratories and workshops. And by working with manufacturing subcontractors in China and elsewhere they can take a wide range of products right from concept through to volume manufacturing. Because product development is their specialism their employees have far greater – and more diverse – experience than many of their counterparts in client companies. Customers will approach them directly with problems they need solving or new products or processes they need developing. And they will also propose development projects pro-actively to current and potential clients in areas where they have, or are building, expertise and IP.

In the pro-active mode they will typically propose a small feasibility study to a potential client based on some simple experimental results and an economic justification, sometimes supported by a crude mock-up of a new technology application they have spent perhaps a few thousand pounds producing. The application at this stage is likely to be little more than an idea, but if it sits in the right space the client may agree to a first-stage project to examine technical feasibility and elaborate the design further. It could subsequently progress through many further phases, ultimately involving large sums of money, a large team of people and several years of work.

Although the norm is for consultancies to work on a 'time and materials' basis for which they are paid on a monthly or quarterly basis (often also incorporating an up-front payment plus staged payments as agreed milestones are reached), projects are sometimes undertaken on a fixed price basis if the specifications and deliverables can be clearly defined. Where the science is untested or the outcome poorly specified, a wrongly-priced fixed contract can be financially disastrous for the consultancy.

> **Box 5: What the Consultancies do (1)**
>
> *"Companies come to us to provide bespoke technology-based solutions when they can't adequately meet their commercial need with an off-the-shelf product or service. The companies we tend to see are either start-ups that need a novel product to be developed quickly to meet their commercial objectives, or very large multinational companies that need help with a new product development. In all cases, there's a very pressing business need, both because of what's at stake in terms of market share and competitive advantage, but also precisely because there's no off-the-shelf solution."*
>
> Ray Edgson, CTO and Ventures Director, Cambridge Consultants

The range of technology and industry specialisms varies from firm to firm, as does the way firms choose to exploit the intellectual property they generate and their degree of interest in incubating hard product businesses to set up as subsidiaries or to spin out. Common to all, however, is an emphasis on teams and team development, proximity to their customers, and the creation of IP positions around which new businesses can be generated.

> **Box 6: What the Consultancies do (2)**
>
> *"We do more development and less research. We're also very client- and market-focused, and particularly focused on the unmet needs of our clients. Once we've really understood and characterised the unmet need, it often doesn't need fundamental research to solve the problem; it's more likely to be the innovative use of science and engineering already proven in other applications, where you can still get patents. Delivering high quality and reliability is where the effort and a lot of our time go."*
>
> Ian Rhodes, Member of PA's Management Group

A high proportion of revenues is earned in export markets, and has been so since these firms began – not least because in the 1970s and 1980s it was easier to gain access to senior executives in European industrial firms than it was to reach their UK counterparts. In the early days of Sagentia, for example, 90% of its business was outside the UK.[20] Today, a little over half of Sagentia's business derives from the UK.[21] TTP and Cambridge Consultants both earn 65-75% of their revenues (depending on exchange rates and project mix) from overseas markets, not least because some industrial activities are simply not present in the UK. Most of their UK sales come from outside the East of England region, with very few clients being locally based.

The story is similar for the smaller consultancies profiled in the next section, with overseas revenues in the 60-70% range (and growing) for Plextek, Sentec and Cambridge Design Partnership.[22] Team Consulting has experienced the ebb and flow of UK business in its specialist field of medical devices. In the late 1990s UK-based clients who changed employer or relocated to other sites took Team with them, and Team made a concerted effort to win new US clients as well, which also bore fruit. In 2000-2006 only 10% of Team's revenue came from the UK, with the rest evenly split between North America and Scandinavia/northern continental Europe.

The broadly-based technology consultancy model retains its industrial logic even 40 years after it first emerged, because the cost and diversity of R&D technologies keep it completely relevant. Any vertically integrated company by definition lacks the horizontal resources that are probably needed in order for its products or services to move beyond the existing paradigm. To innovate in its market in a technological sense, an industrial company requires access to a wide range of resources that even the consultancies are only able to afford because of their work for many different companies.

A consultancy will invest in (or custom-build) specialist equipment more easily than most industrial companies because it expects to amortise the costs of maintaining its expertise over a number of projects and a variety of companies. And in working for multiple clients in the same technological space, driven by their market

20 Interview with Gordon Edge, founder of PA Technology and of Scientific Generics (Sagentia).
21 Its AIM offer document in 2008 gives the following breakdown for 2007: UK approximately 50%, non-UK Europe 25%, North America 20%, rest of the world 5%.
22 Among our smaller technology consultancy interviewees, 42 Technology has focused on building its UK client base as a first priority, in order to build a business with low cost of sales. International business is growing on the back of this.

needs, it will gradually acquire a unique knowledge base around which an IP position can be established. But for multiple reasons – not least issues around resource allocation, potential conflicts of interest with clients, the different management skills required to run a product business, and the costs of building global marketing and distribution and of tooling up for large scale manufacturing – that IP package can usually only be nurtured within the consultancy to a certain point, beyond which it will be licensed, sold or spun out as a separate venture. Managing the IP they generate and negotiating contracts with customers to retain as much control of it as possible is an essential aspect of technology development consultancies. In addition to the direct economic impact of these firms, then, they have substantial additional value creation effects both for the region and more widely. We return to this point in Chapter 6.

Financing

For all the broadly-based consultancies, start-up funding was limited and breakeven (and even profits) came relatively quickly. Bootstrapping was the order of the day and in their early days these firms would turn their hands to a wide range of projects to bring in revenue before beginning to focus, build IP and specialise. "*In the early days we did anything that was vaguely legal for money*", said one founder we interviewed. Growth has in most cases been self funded, although Cambridge Consultants, which was an early pioneer of the technology consultancy concept and whose finances remained chaotic for several years, suffered a financial crisis in the late 1960s when it set up a subsidiary to develop and manufacture its own products.[23] This ended up by bankrupting the company and led to Cambridge Consultants being taken over by Arthur D. Little in 1971-2. It was an early demonstration that the management skills required for a hard product company are very different from those needed to operate a 'soft' fee-for-service business model, and is a lesson that continues to shape corporate thinking at Cambridge Consultants even today.

Sagentia has operated a slightly different business model to the other three companies, with the incubation of new ventures being more a primary goal of the business. This has caused it to raise a good deal of external equity over its life, in contrast to the other firms – flotation in 2000 raised £46 million, and funding early on came from Rothschild and from Catella of Sweden, which from then onwards was the majority shareholder.

Box 7: Bootstrapped Starts in the Technology Consultancies

Cambridge Consultants: in around 1963 four members of the founding group each managed to obtain an £8,000 unsecured loan from Bankers Trust, which was just setting up in London and understood their aim. "*No other bank would even give us the time of day.*"[24] The loan was repaid about 5 years later.

Scientific Generics: the founders borrowed ~£50,000 each against their homes, raising £200,000-300,000 in total as the founding capital (and added more three years later). The business was profitable in its first year.

TTP: the founding group of 29 consultants negotiated £15,000-£40,000 each in unsecured loans from local banks (Lloyds and Barclays), raising £700,000 plus an additional investment from two Australian investors.[25] This was later supplemented with £500,000 from CinVen in a mixture of ordinary shares and convertible redeemable preference shares – a total of around £2 million. TTP lost money in the first year, more or less broke even in the second, and was very profitable in the third year.

Scale of Business

None of the major technology consultancies since the early Cambridge Consultants experience with electronics has attempted to engage directly in mass market production. But they do assemble and test highly specialised equipment, and they also make small-scale production and assembly equipment and

23 Cambridge Consultants decided to produce itself some instrumentation modules and electronic audio products it had designed "*even though we knew nothing about manufacturing*". The AIM (Advanced Instrumentation Modules) electronics business not only consumed most of Cambridge Consultants' financial resources but also occupied half the time of the consulting team, leaving little scope for generating revenue from elsewhere. Interview with Paul Auton, CEO of Cambridge Consultants 1983-2000. See also Dale, R. (1979) From Ram Yard to Milton Hilton: A History of Cambridge Consultants.

24 Interview with Gordon Edge, who was one of the four; the others were Tim Eiloart, who had originally conceived the idea of Cambridge Consultants, David Southward and George Sassoon. Between 1960 and 1963 Edge, Southward and Sassoon made a gradual transition from part-time to full-time work at Cambridge Consultants. Edge was managing director from 1967 to 1970, when he left to found PA Technology.

25 One was Invetech, formerly PA Technology's Australian subsidiary and managed by ex colleagues of the TTP team. The second was Wilson Technology, an investment company set up by a successful car parking entrepreneur.

help clients prepare for large scale manufacturing. Ian Rhodes[26] describes how this works in PA's technology practice: "*We design and develop equipment that goes into manufacturing facilities. If we develop a first-of-its-kind product, it will have to be manufactured and test inspected within a certain regime to pass through the regulatory approval processes, which may require specialist test methods and automated equipment to carry out those tests. We may well invent, design and develop that automated test equipment. In this instance we are likely to be working very closely on the design of the tooling and the tech transfer of the product to the client's manufacturing partner. We also have a manufacturing practice within PA which can help the client decide which manufacturing partner to work with in the first place, do the due diligence and short-list, and help set up the sourcing agreement. If necessary we can help the client build a new clean room facility and kit it out with equipment. So we do make small runs of specialised equipment and get very close to manufacturing for larger volumes.*"

The absence of any mass manufacturing activity contributes to the relatively small size of technology consultancies. Theirs is not a model associated with large economies of scale, because they depend almost entirely on brain power and work on the basis of a large number of enthusiastic (and relatively inexpensive) junior people doing most of the work, guided by a small number of (expensive) senior people. There appears to be an invisible ceiling of around 200-300 employees, beyond which the management difficulties seem to become too great. "Y*ou need to be able to get your arms around it*", says Gerald Avison, founder of TTP. Other professional services firms in accountancy or law apparently do not face similar scale constraints, perhaps reflecting the difference between a professional service firm based on well defined procedures, and an 'innovation' business, in which culture, multi-disciplinary thinking and managerial judgement play a key role.

Technology consultancies that breach the ceiling seem to experience a shake-out in one form or another, either through a change in the economic environment that forces redundancies or by the departure of a team through an unplanned walk-out or a planned spin-out. When a team of people leaves to start a product-based venture, the core business becomes manageable once again. This 'natural' cap on employment seems to contribute to the self-renewing phenomenon of technology consultancies. In the last economic downturn people left to set up consultancies of their own, perhaps based around technology ideas that customers hadn't quite 'bought into' but which they thought had potential. Table 1 shows the current employment range in the four firms and peak employment in the recent past (around the time of the technology bubble and prior to some important spin-outs).

Up to the natural ceiling of around 250 people there are nevertheless important economies of scale for these kinds of broadly-based technology business. First, size enables them to employ a range of physicists, biologists, mechanical engineers, electronics engineers and software engineers with different industry backgrounds, so they can undertake work for a wide range of companies. Second, by operating many customer contracts in parallel they are more able to ensure sales and marketing activity is maintained at a steady level, avoiding the 'feast to famine' effect that can result from key people working on major projects at the expense of selling new ones. Third, they can invest in proprietary technologies, thereby increasing the margins on customer developments based on them or making it possible to build or spin out 'harder' product businesses. The smaller firms profiled in the following section are more specialised in their activities, giving them the critical mass of expertise in their chosen areas of work that is necessary on credibility grounds if they are to operate at the premium end of the market.

Table 1: Employment in the Major Consultancies

	Cambridge Consultants	PA Technology	Sagentia	TTP Group
Year established	1960	1970	1986	1987
Current employment	263 (2008)	200+ (est.*)	224 (2008)	292 (2009)
(Recent) peak employment	360 (1998)	n/a	224 (2008)	405 (2000)

* Figures for the Global Technology Group in PA Consulting are not normally given separately.

26 Member of PA's Management Group.

Operating the Model

The employment of a range of people with different scientific disciplines enables the formation of multidisciplinary project teams. Implicit levels of communication within such teams, coupled with the non-hierarchical environment typically found in these organisations, encourage innovation and creativity. Multi-tasking is common, with employees working on new project proposals, feasibility studies and development projects in parallel, and providing specialist inputs to other teams. Moreover the ability to move people around between teams gives the flexibility to incubate new technologies and respond to new market opportunities in a way that highly focused, venture-backed businesses usually cannot.

Indeed, the ability to shift people from one project to another is a crucial means of handling gaps in the workload while customers decide whether or not to move from one phase of a project to the next, or when major projects come to an end. And, as described in the TTP LabTech example given in Chapter 2, a gap between initial customer engagement and the take-off of more widespread customer demand for a particular technological application does not normally threaten the very existence of the firm, as would likely be the case for a product-focused company.

Gordon Edge, founder of PA Technology and Sagentia (and a founder of Cambridge Consultants before that), illustrates the diversity of products that can arise from a flexible approach to exploiting platform technologies. He describes how, in the early 1970s, PA Technology assembled a 30-strong team of biologists, physicists, optical scientists and others to develop for a client a recordable compact disc technology that would compete with a programme running in Japan. On the suggestion of a biologist the team examined the physiology of a moth's eye, built a mathematical model to replicate it and constructed what was then the world's largest interferometer. From this the team successfully developed the recordable compact discs for the client. Adapting the technology later for a different application, the team used the same approach to view how changes take place as antibodies bind to pregnancy hormones, and developed a pregnancy testing kit that was introduced to the market by Serono.

The robustness of the broadly-based technology development business model is evident in the way that resources can be allocated to different parts of the business according to the ebb and flow of contracts, as the example of TTP's digital mobile technology demonstrates (Box 8). The TTPCom experience demonstrates not only the flexibility of the model (resources could be redeployed across different divisions as required), but also the cushioning effect of 'softer' activities that fund more speculative technology developments. It also highlights the high levels of confidence exhibited by technologists in selling to customers advanced technology developments that do not yet exist, but which they expect to be able to deliver. The ability to evaluate and manage technology risk is a key skill of all technology consultancies and successful soft businesses. As a result, substantial technology development projects may often be sold to multiple clients on the back of £10,000-15,000 of in-house work to come up with little more than a breadboard mock-up that demonstrates how the technology might work if the customer pays for the development.

The business divisions within these firms are regularly reconfigured, reflecting opportunity and market pull. When a successful part of the business grows beyond an ideal size for a division it will typically be split into two (or part may be spun out, as discussed below). Conversely, as a sector or sub-sector matures and the ability to charge a premium for scarce skills disappears, specialised 'hard' companies begin to take over as suppliers of off-the-shelf technology, leaving no room for profitable contract development activity and pushing the pure soft players into new areas. Twenty years ago all the Cambridge-based consultancies were active on projects to design microelectronics and microprocessors into traditional household and industrial products. Today that technology is mainstream rather than exotic and most engineering companies have the expertise in-house, so product development contracts are simply unavailable at realistic prices.

Once the market loses interest in a technology the consultancies quickly stop selling work in that area and disband the teams involved. Technologists may then move to other groups and recruiting policies change to reflect new commercial or industrial priorities, or consultants are simply 'let go'. Sometimes this provides the opportunity for formation of a 'hard' product company. Indeed, one factor behind the spin-out of CSR from Cambridge Consultants in 1999 was the drop-off in demand for semiconductor design projects. Box 9 describes another such transition.

Box 8: Allocating and Re-allocating Resources – the TTP Communications Story


Image courtesy of TTP Group plc

Early in TTP's life it undertook a small four-month project for the consortium that became Orange to advise on its submission for a spectrum licence for digital mobile technology. This, and earlier work by its founders when they were at PA, gave TTP some early technical insights into the GSM standard. In 1989 it was able to leverage that expertise by winning a major new technology development contract with British Aerospace's Space Systems Division to develop a rural telephony system based on wireless links between homes and ground base stations for customers in Indonesia and elsewhere. This turned into a major contract for TTP's Communications Division, employing some 30 people, and involved designing the silicon chip for the handsets. But in 1991, when BAe got into major financial difficulties, the project was suddenly terminated. This left TTP with a very experienced wireless telecommunications team representing nearly one-third of its total staff, some very expensive CAD equipment and a big hole in its revenue. Attempts to take over the rural telephony concept and spin it off as a new business came to nothing.

TTP was able to overcome this crisis in two ways. First, many of the engineers involved were capable of shifting to other parts of the business to speed up work on other projects. Second, and fortunately for TTP, GSM was just emerging as the new standard for digital mobile telephony in Europe. It was also being adopted by more and more countries internationally. TTP's engineers stepped up efforts to sell telecoms projects to new clients. They discovered that a number of second tier companies across the world wanted to supply handsets for this fast-growing new market, but the standard was complex, the technology was far more difficult than for analogue phones, and it was not possible to buy key components such as semiconductors or operating systems from the Tier One players – Nokia, Ericsson and Motorola. Because TTP's British Aerospace work used a sort of cut-down version of the GSM standard, its telecommunications division was exceptionally well qualified to exploit this opportunity just at the point that it was emerging.

TTP's response was to develop the three key pieces of technology that aspiring GSM handset manufacturers needed to get into business. 'Baseband' chips and radio chips were developed largely at TTP's cost and licensed as designs for fabrication and marketing by Analog Devices and Hitachi, respectively. Protocol software, part-financed by 50% up-front payments (which helped cash flow), was sold directly to the handset companies. So TTP, in conjunction with its semiconductor partners, was able to offer customers a package of technology optimised to work together.

It opted to fund the transition to a hard company model itself, using development contracts with customers and up-front payments to 'soften' the transitional business model, rather than raise venture capital, which would have resulted in loss of control and dilution. This was a risky strategy and technical difficulties at one point led to a six month delay. What had been a very profitable activity during the BAe contract turned into a business with a substantial burn rate requiring subsidy from TTP's other business units. Despite the delay, most customers were retained and by 1997 TTP Communications Ltd was a highly regarded, fast growing and profitable business in its own right. It was progressively able to add other technologies and services to its portfolio and to sell to larger and more established customers – both handset manufacturers and semiconductor companies.

By 1999 it was attracting the attention of possible acquirers. Instead, having achieved three years of profitable growth, the business was de-merged as TTP Communications plc and went public in 2000 at a valuation of £540 million. The business continued to grow rapidly and profitably, signing major deals with Intel, Toshiba and other multinationals. It achieved £60 million revenues at the peak, with 700 employees (compared with 120 at the time of going public). However, an over-ambitious strategy, with developments spread over too many areas, led to TTPCom failing to capture sufficient customers during the transition from GSM to 3G and a sudden collapse in revenues. The company was acquired by Motorola in 2006 for £100 million.

Almost immediately, after itself suffering a severe loss of market share to competitors, Motorola was forced to downsize its operations globally and it closed its Cambridge operations within two years of acquisition. But TTP Communications' legacy lives on in the form of ip.access (its femto base station spin out), Mediatek (which, via Analog Devices, acquired the semiconductor team), Qasara (a fabless wireless silicon business) and Octymo (a management buyout of the operating software team).

Box 9: The Cambridge Consultants Shift Away from Defence-Related Work

Image courtesy of Cambridge Consultants Limited

In the 1970s Cambridge Consultants depended on defence work for as much as two-thirds of its business, spread over around 50 projects in diverse fields, but recognised its vulnerability when the Thatcher Government sought to bring the defence budget under control in the early 1980s. Defence work tapered off when the Ministry of Defence (MOD) shifted to competitive tendering and began requesting contractors to subsidise developments; it made no sense for Cambridge Consultants to agree to this, as it had no production plants to keep functioning. It continued defence work for a while in particular fields such as underwater acoustics and artificial intelligence (AI), in which it had built the UK's largest expert group on the back of MOD contracts and where the MOD had no alternative source of technology. But as defence contracts tapered off, scientists and engineers diverted to other work in the firm (or left to take up academic posts, particularly in AI), turning their expertise to commercial uses e.g. in big industrial laser systems, and in underwater ultrasonics for the oil industry.

A deliberate policy to dilute the share of MOD work led Cambridge Consultants to approach certain industries in a more methodical way in the 1980s, for example by setting up a process engineering division to cater to the UK's manufacturing industry, rather than continuing to organise by technological discipline. But for many years the company's strengths in electronics, silicon chip design (the basis of the CSR spin-out) and software could be traced back to earlier defence work. At least one of Cambridge Consultants' spin-out companies came directly out of capabilities developed during defence-related work: dCS, a high-end stereo company, emerged from the development of sophisticated AD convertors for fighter plane radar systems.

Today, although Cambridge Consultants still has a team of highly specialised engineers and scientists working on defence contracts with clients in the UK and overseas, the majority of its business lies in medical technologies, wireless technologies, products & systems, and innovation management. Each of these four divisions is split into a number of campaigns, each of which focuses on a relatively narrow area of industry. This is one of Cambridge Consultants' mechanisms for renewal. "*Because of the way we are structured, it is easy to set up a campaign in response to an emerging opportunity, or to redefine another if its market moves. We can effectively develop our resource to suit market requirements*", says Ray Edgson (CTO and Ventures Director, Cambridge Consultants). Similarly, Cambridge Consultants' significant strengths in ink jet printing were developed in the 1970s and 1980s within the mechanical engineering division, but none of this activity remains in the company following multiple spin-outs including Domino Printing Sciences, Xaar, Inca Digital and Elmjet (see Chapter 7 for a discussion of the role of public sector contracts in stimulating this area of activity).

Competences

A particular form of on-the-job training takes place in technology development consultancies, in which people are taken from being 'merely' good technologists to possessing both a broad understanding of commercial and business issues and other softer skills that enable them to be successful in the business world. This competence-building approach is variously referred to by the firms as a "*finishing school for engineers" or "boot camp*". New recruits grow their non-technical skills as well as their technical ones. In particular they learn how to sell, and to sell themselves, they learn how to run projects and manage teams, they learn something about marketing and something about finance. According to Richard Archer,[27] "*the kind of training and experience that we had coming from the consulting world is pretty unconventional and it is difficult to replicate.*"

This interaction with customers is fundamentally important as a trigger for innovation, because it is the technologist's role to "*put science and technology in the context of the person sitting opposite you*" and be sensitive to the customer's (sometimes unvoiced) requirements.[28] The consultancies' workplace operates almost as a 'pure market' in skills, with project managers seeking people with technological skills, and those with technological skills trying to find project managers who will employ them to work on a client project. Project teams are constantly being created and dissolved; team leaders become proficient at forming teams quickly and getting them running smoothly; and team members become proficient at joining teams and becoming effective rapidly. But there is constant and intense pressure inside a consultancy business for project managers to deliver on client projects and for the technologists to find a project team and to perform within it. Some people seek a way to escape that pressure by moving into a 'harder' product company (see Box 10).

Box 10: How the Pressures of the Soft Model Lead to Hard Company Spin-outs

"This business has its foundations at the soft end – fee-for-service, time and materials is the business model. It's the origination point that keeps the momentum for a large team of scientific and engineering excellence together. We live to serve our clients' needs in an increasingly competitive, faster-moving world that is more crowded and more specialised, and information is more freely available via the internet. As a result, to be successful in the soft business world you have to continue to find new and better ways to differentiate yourself to continue to justify the premium the big players charge. The good people who come up with the best ideas, see the new business models first, will end up specialising so they can remain leaders in their chosen fields, and valuable and compelling to clients. From time to time our people come across an idea or opportunity: they see another world outside fee-for-service and are motivated to head off into it. It's a lifestyle change. Many of them seek internal support and a few of them get it – which is where the spin-out ventures come from. Some of those that don't get the internal support or funding may leave to pursue their ideas anyway."

Ian Rhodes, Member of PA's Management Group

A core competence that has been highly refined among the Cambridge technology consultancies over the last 35 years is the skill to manage and understand high-risk, rapid product development: the innovation process of moving from market need to finished product, using novel, high-risk technologies to do something that has never been done before. This is a hugely undervalued competence that appears not to exist even in many Silicon Valley firms that have substantial VC backing, let alone in large corporations where projects are broken up and very few people see the 'big picture'. Few successful project managers in large firms have the opportunity to manage an entire engineering project more than once, yet this is what technology development consultancies do for a living. It is not an issue of getting highly creative projects and taking them to market, but of developing a sophisticated understanding of where the risk in a project lies and

27 TTP founding group member and, after its demerger, chief executive of The Automation Partnership.
28 Interview with Gordon Edge, founder of PA Technology and of Scientific Generics (Sagentia).

how to manage it. It requires an intuitive experience-based approach combined with a 'can-do' mindset, a collaborative working atmosphere and a talent for team construction, plus the formal management of projects with very short term goals. Key features of these firms' approach include how people are rewarded for their ideas, how conflicts within and between projects are dealt with and turned into a positive force, and knowing when it is time to be inventive and when it is time to focus on the detail. People brought up in these consultancies understand that process and are not scared by it, but it is difficult to write down and define. "*The term is risk management, not fear of risk.... Customers have been amazed at how we just seem to walk through the problems that these teams get involved with – and it's simply because we're applying this model that we've learned*", says Mike Cane, co-founder, Cambridge Design Partnership.

Because of the economics of their business model only a limited number of people can grow up in consultancy and continue doing it over a long period, since as their fee rate increases it eventually prices them out of the market. Furthermore fee-for-service is a much less complex business model to operate than other 'harder' businesses and it offers few opportunities for people to grow into specialised senior management roles like sales, supply chain management or general management. In a sense, the consultancies train many more rounded technology managers than they are able to use internally. Once people have gained experience and skills, they may wish to move to an environment where these opportunities are more readily available. It makes sense for the consultancies to capture a share in the value the leavers create after they move, and spin-outs can play a role in this process.

Creating New Ventures

All of the large technology consultancies have produced successful 'hard' product-based spin-outs, and the smaller firms have also gone down this route to a greater or lesser extent. However, the four big consultancies display clear differences in strategies and success rates. Arguably the most successful is Cambridge Consultants, certainly in terms of job creation. It has been responsible for two of the region's most successful technology companies, Cambridge Silicon Radio (CSR) and Domino Printing Sciences, and a string of others over the last 25 years. Cambridge Consultants' ventures have been based on IP and/or teams with a long history within the business, but they have been spun out before the development of their product is complete. An injection of venture capital and outside management expertise has generally been used to accelerate commercialisation.

Box 11: The Impetus for Business Venturing

"*What you get when your people are used to working in environments where there are pressing business needs and no existing solutions is a real excitement for venturing. That's why venturing and spinning out new companies is almost second nature for Cambridge Consultants and organisations like us.*"

Ray Edgson, CTO and Ventures Director, Cambridge Consultants

During the 1980s and 1990s PA Consulting Group actively discouraged spin-outs by its technology arm as it regarded avoiding competition with clients as a fundamental priority. It remained firmly at the fee-for-service end of the spectrum for many years. This led to the founders of both Scientific Generics and TTP leaving PA Technology to establish competitor companies where IP creation and exploitation were more central to the business model. Former PA consultants also populated many biotechnology start-ups in the area, reflecting the strong focus of PA in this field. However the business environment has evolved since the early 1990s and PA has subsequently created a number of spin-out businesses under the auspices of PA Ventures, now Ipex Capital. Examples include Meridica and UbiNetics, with others being incubated internally. (Box 12 profiles the Meridica story.)

TTP's approach is rather different. It has nurtured technologies internally for as long as 10-15 years, sometimes with considerable internal investment around the core IP and the creation of fully-fledged revenue-earning businesses, before spinning them out. The GSM technology venture TTPCom had spun out of TTP and IPO-ed in 2000 but its IP, as described in Box 8 above, was built around client projects stretching back to the early 1990s. Similarly, development of TTP's Tonejet digital printing technology has been going on for 14 years at a cost of perhaps £50 million, much of it funded by customer R&D contracts. Over 50 patents have been accumulated over this period. Tonejet is still a subsidiary of TTP Group and announced its first customer installation in 2008.

Box 12: The Meridica Spin-out

Meridica was an internally incubated venture that was created at the turn of this century, in a period when PA Consulting Group was keen to make the group's cash work harder for its shareholders (i.e. the employees of PA). PA identified a basket of IP in the field of advanced drug delivery systems to which it had rights, and three core pieces of founding IP underpinned what became Meridica. After incubation inside PA, the venture was spun out in 2001 as a wholly-owned subsidiary with a substantial cash investment from PA plus the IP package and a small team of engineering and scientific consultants. After a couple of years of development work, Pfizer licensed the rights to a dry powder inhaler for respiratory diseases and it also took a 10% stake in the young company. A year after that, Pfizer acquired the rest of Meridica for $125 million, giving PA a substantial financial return on its initial investment. By the time of its acquisition in November 2004, Meridica had already grown into a company of around 40 employees. Now forming part of the Pfizer Cambridge Research Group, the operation is based on Granta Park.

In complete contrast, Sagentia's approach until 2008 was to give more emphasis to venturing than to the 'soft' consulting activity that generated most of its revenue. This helped to attract bright people who wanted to become entrepreneurs. Sagentia has spun out a very high number of fledgling enterprises – perhaps as many as fifty. Few of its enterprises have generated any significant economic impact so far, the most successful to date being Diomed (a solid state laser treatment company spun out in 1987, in which Sagentia's stake was negligible by the time it listed in the US) and Absolute Sensors (spun out in 1996 and bought in 1999 by Synaptics, which incorporated the technology into its touchpads for laptops).

Ownership

Ownership has an impact on the behaviour of these consultancies. Alone among the Big Four consultancies, TTP Group has kept its shares largely in the hands of current and former employees, giving it great benefits in terms of motivating and retaining staff as well as the independence to take a long-term view of opportunities and risks. Lack of independence from outside investors has caused the others problems. Arthur D. Little (ADL) was regarded as a good hands-off owner when it rescued Cambridge Consultants in 1971-2, allowing it autonomous operation and the resources to grow from the 60 or so people it employed at the time. However, at times, ADL's own financial requirements severely limited Cambridge Consultants' ability to invest in its ventures, forcing the early sale of its shares in several long term venture assets when ADL filed for bankruptcy under Chapter 11 protection in the wake of the bursting technology bubble.

At PA Technology, frustration among the senior management group over their inability to retain the operational independence from PA Consulting built up in its early years led to the departure of swathes of top consultants, yet PA's Technology practice has continued to thrive, if in a less entrepreneurial direction than its founders desired.

At Scientific Generics/Sagentia, where the business model was firmly a combination of consultancy plus value creation through IP licensing and ventures, the decision to float on the stock market has proved problematic. Flotation was intended to raise sufficient working capital to allow the development of technologies that would be spun out as separate VC-backed companies, which is the model that investors bought into. But the integrity of Sagentia's original business model was lost when the consultancy activity, which is an essential aspect of finding and proving markets for technology, became subordinate to the venturing effort and money expended on developing technology in isolation from the market. Large sums were spent on building a substantial IP portfolio, yet few of the start-ups have flourished because the technologies remained largely unproven before their formation.

Summing up this section, the broadly-based technology development consultancies demonstrate the benefits of using 'softer' activities as a profitable core business that, from time to time, generates harder product businesses. These give additional returns to investors and create many more jobs. Start-up costs (of the firm or an initial piece of work) are relatively low and largely funded by customers; technologists learn multiple business- and project-related skills; career progression can be effected through spin-outs (or walk-outs); inter-disciplinary organisation enables significant flexibility in responding to market needs; and the breadth of scientific and engineering disciplines addressed offers both protection against sector maturity or major shifts in market forces and the scope to perform at the leading edge of emergent technologies. Perhaps most important of all, by carrying out R&D contracts for customers and discussing future technology needs these firms are able to operate a sort of continuous real time market research process which helps them remain relevant and identifies opportunities for new areas of project work and new ventures.

4.2 Specialised Technology and Innovation Consultancies

Basic 'soft' model: contract R&D is focused on a relatively narrow range of disciplines or industries, or in a function such as product engineering development or industrial design; firms in this group are less able to generate successful product-based spin-outs and some have adopted an out-licensing strategy.

In addition to the broadly-based consultancies, the East of England region boasts a wide range of specialised technology developers ranging in size from one- or two-man bands up to firms of around 100 people.[29] They vary in technological scope as well, from those with a particular philosophy or aimed at a particular type of project (e.g. Cambridge Design Partnership, which focuses on user-led technology-based innovation projects that are 12-18 months from market and approaches them from the perspective of the customer-user rather than technology) to those with a strong sector or technology orientation (e.g. Sentec, focused on utilities and profiled in Case Study 1 in this section, and Plextek, which has spent years refining its radio and telecommunications technology for automotive and defence use).

As Figure 7 indicated earlier, many of these smaller and specialist firms were spawned by one of the broadly-based consultancies, where their founders would have gained experience in both the project management of risky projects and technology marketing. Still smaller consultancies – many also associated in some way with the big consultancies – include Fen Technology, set up after the Symbionics site was closed by Cadence, Innovia Technology, established by ex-Sagentia consultants, and EG Technology, founded by a former PA Technology consultant. Small groups of people who have left industrial employers are another source of specialised consultancy firm activity (e.g. Hidalgo, founded in 1997 by former engineers and development managers at Philips Telecom PMR). Others are founded by people with a scientific research background and offer services in their specialisation to a range of industries (e.g. Cambridge Ultrasonics, which has been active for over twenty years in modelling and inspection systems primarily for the energy and construction industries).

In economic downturns the major technology consultancies often shake out some of their more senior (and therefore relatively expensive) people, as high-cost projects become harder to sell. Such individuals or teams can usually quickly re-establish themselves, using their reputation and skills to offer services at lower prices to former clients; they may even pick up projects or technologies abandoned by a client at the old firm and decide to develop them further.

But sometimes prior consultancy experience is not long enough to gain a complete understanding of the soft model, and lessons have to be learned 'on the job'. When two electronics engineers decided to leave PA Technology and set up Plextek with a third founder in 1989, not long after a whole tier of their senior managers had walked out to found TTP, their 3-4 years of project work had given them excellent training, but was still incomplete. "*We became a small version of PA's electronics group working out of a back bedroom.*" One as yet unlearned lesson was to demand upfront payments from clients, a condition of engagement that did not occur to them in the first 4-5 years of Plextek's existence: "*Our first large international consulting contract, back in 1994, was with Rockwell – they were scouring the planet for a design house and they picked us – and I spent 8 weeks, 2 hours per day on the phone to California negotiating the contract. But I noticed when we had finished that their paperwork included a standard template for payments, of which the first line was 'down payment' – and ours was nil because I hadn't asked for one! I hadn't been senior enough at PA to learn that sort of thing. One learns by one's mistakes, so now we ask for one and mostly we get one, and if it's a supply contract we ask for a substantial down-payment. We didn't lose money on*

29 The Design Hub, founded by IP advisory firm ip21 Ltd with funding from EEDA, Norfolk County Council and other organisations, has produced a non-exhaustive list of around 20 small product and design consultancies across the East of England region, some of which include technology development within their remit. See http://www.ip21.co.uk/documents/DesignConsultanciesList.pdf.

the Rockwell contract, but it's the structure of when the money arrives and when (or if) you need to borrow money – which we didn't at the time. We were working on fees in arrears like everyone does", explains Colin Smithers, Plextek founder and CEO. At the start the founders were fortunate that two of their PA customers followed them to Plextek with phased contracts worth a couple of hundred thousand pounds during the first year or two. It took only 6-8 months for the business to become cash positive, during which time they drew down only a fraction of the £45,000 overdraft facility arranged with Barclays Bank. The company remains wholly owned by the three founders, who regard retaining control as crucially important to their ability to determine the company's future direction.

The larger specialist consultancies tend to possess a similar understanding of complex risk management in technology projects to that described for the major consultancies above, especially when they are peopled by individuals with prior experience of technology consultancy work. Years of familiarity with the process of taking a product from the early technology problem-solving stage through to putting it into production is often a feature even of a small technology consultancy team, yet it is not uncommon for them to work with a large company client where none of the senior people has ever put a single product into production. When hiring, consultancies have a strong preference for 'doers' with practical skills and a willingness to 'have a go'. Recruits from other technology consultancies tend to simply fit in with the way that work is organised around projects, whereas "*if you recruit someone from industry it always takes them a while to get their mind round [the way we manage projects]*", says Mike Beadman, co-founder of Cambridge Design Partnership.

An alternative used by smaller firms to the direct employment of scientists and engineers is to tap into a network of other small firms and specialist contractors to supply missing skill-sets required for individual projects. At 42 Technology, for example, which has deliberately cultivated a wide network of associates, a core internal team manages a project's delivery and resources the development work according to the competences required. The major broadly-based consultancies also use contractors, but only to smooth temporary peaks in the work flow – and there is the possibility that consultant-employees are assigned to projects simply because they need to be kept busy rather than because their skills are required. Because of the practice of regularly drawing on external associates, the smaller consultancies tend to be both more aware of and more closely linked into the potential of an extended network than their major counterparts.

Spin-outs from the Smaller Technology Consultancies

The ethos of the late 1990s encouraged specialist technology consultancies to exploit their accumulated IP and know-how, in the hope of achieving solid financial returns by spinning out new companies. However, their size and limited financial resources made it necessary to raise outside finance early in this process rather than incubating the businesses with internal funds. Cambridge Design Partnership's (CDP's) experience illustrates the problem. In 1999 it set up a medical device company, Astron Clinica, combining its expertise in building low-cost cameras with skin cancer-screening IP developed by a theoretical physicist at Birmingham University. Astron Clinica's original funding constituted a DTI Smart award and seed funding from angel investors. Further angel funding enabled it to build a prototype machine and embark on a long, but ultimately successful, period of clinical trials nationally. However, medical equipment often takes a considerable time to reach the market owing to regulatory hurdles, and the capital equipment purchasing cycle is relatively long. After two further funding rounds with small VCs totalling approximately £4 million Astron Clinica needed to raise in excess of £12 million to break into the US market, which reduced CDP's equity stake to a depressingly tiny level. Although the product was reported to be selling well in Australia (where the incidence of skin cancer is high), the firm finally went into administration in 2009 despite the time and effort CDP put in to get the business going. Like Sentec (see Case Study 1 overleaf), CDP attempted a couple of other spin-outs before concluding in 2002 that any future venture should have far greater financial backing from CDP itself; since then its strategy has been to grow the consultancy side of the business in order to develop that financial strength.

As the Sentec and CDP examples indicate, the spin-out strategy has so far proved relatively unsuccessful for this group of consultancies because they cannot afford to support their ventures internally for long enough and are heavily diluted by progressive rounds of VC financing. Many spin-out technologies were also rather early stage, based on innovations by individual team members, and it can be argued that more success might have been achieved if they had been taken

Case Study 1: Sentec

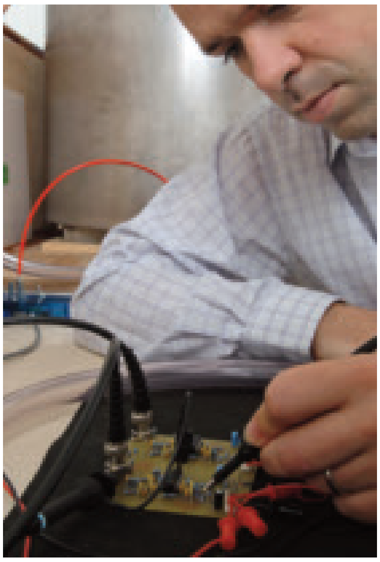


Image courtesy of Sentec Limited

Founded in October 1997, when Andrew Dames and Andrew Howe decided to leave Scientific Generics (now Sagentia) and set up on their own account, Sentec has grown over the last decade into a company with revenues in 2008 of £2.8 million split roughly 70/30 between consultancy and licence income. It has a workforce of around 28 people.

Two former Scientific Generics colleagues, Mark England and Ed Colby, joined a few months after start-up and, like the founders, contributed their savings as working capital for the business; there was no external funding. The business plan envisaged a 50/50 split between Sentec's own R&D activity and technology consultancy work, the latter as a means of financing the development of new technologies. Consultancy developed at first by tapping the founders' network of contacts, and they were soon able to win work by capitalising on their flexibility as a small organisation. On-going consultancy business ranges widely, from cash machines to razors to gas detection sensors, and for clients ranging from local start-ups to multinational companies. The variety of work maintains staff interest, while also keeping them aware of state-of-the-art technology in different industries.

As CEO Mike England describes, the underlying purpose in conducting proprietary R&D was to "*capture the value of [the] founders' clever ideas*" by creating their own IP. In the first few years, despite the firm's small headcount, diverse technology developments were spun out as separate companies with external investors. They included magnetic tags (Holotag, 1998), switches for fibre optic telecommunications (Polatis, 2000), medical diagnostics (Smartbead, 2000); CCTV image processing (Visual Protection Ltd, 2001); TB testing (Rapid Biosensor Systems, 2002), and mesh radio (Casient 2003). But by 2003 it was clear that the spin-out business model was unlikely to deliver the long-term value that the founders had originally anticipated: either the technologies were so far from market that successive rounds of VC funding heavily diluted Sentec's equity stake, or the timing was wrong and the company failed to raise sufficient finance. Either way, this technology exploitation model did not make money for Sentec: returns were too long term and were highly unpredictable. It was also clear that the company's R&D efforts were spread too thinly. This realisation brought a change of strategy: to abandon the spin-out model and instead to develop substantial expertise in a single market area, directly relevant to a specific group of clients, where technologies could be developed to meet specific market needs, and licensed for a substantial technology access fee in addition to royalties. This was a licensing model, best suited to high volume product manufacturing, that Andrew Howe had promoted at Generics. Consensus fell on developing new solid-state sensors for electricity, water and gas utility meters, a market that is long term and has a steady baseline rate at which meters are changed.

The decision to focus on utility meters was reinforced by the success of Sentec's first licence: in 1999 it had mocked up a low cost demonstrator of a new current sensor for electricity metering and showed it to the big meter manufacturers. This revealed shortcomings in its understanding of the market requirements, but its second attempt sparked the immediate interest of a major player. A licensing deal for the sensor technology was signed that conformed to the model Sentec sought: a large up-front exclusivity fee, plus milestone payments dependent on Sentec getting IP granted in key territories. The last of these milestones – which was also the largest – was achieved in summer 2002 when the US patent was granted, nearly three years after the initial filing. In the meantime the costs of product development were also paid for by the client on the normal basis, and the client started shipping the first meters in 2001. Later Sentec renegotiated the agreement to assign the client an exclusive licence for the North American market and a non-exclusive licence for the rest of the world.

The royalties on this deal represent an important and on-going share of Sentec's revenue stream. Since then, Sentec has moved on to tackle both water metering and gas metering using the same basic model and continues to pursue licensing opportunities. Royalties from its own IP (currently around 30% of revenue) are expected to steadily displace consultancy income, and the company's ambition is to move beyond licensing to participate in manufacturing and supply.

further technically and received more market testing prior to spin-out through customer-funded R&D projects.

An alternative – and less costly – way for the technology consultancies to participate in new ventures is to take an occasional stake in a client's project by sacrificing fees for equity. Less than 10% of Plextek's business is done on this basis, for example, and many of its equity stakes have been in businesses that failed, but a major success story was a small stake in Ionica acquired on the back of work on radio propagation and test equipment for the venture.[30] Although Ionica ultimately failed, Plextek was able to make a good return by selling its stake before this happened. CDP has similarly found success with SatMap, a rugged speciality-use global positioning system venture that has grown in three years from a one-man band to a team of 20 people. SatMap's business is focused on marketing and sales, with CDP acting as the development team.

As with the much larger broadly-based consultancies, these specialised technology development businesses perform a variety of services for product-based companies. Whilst their larger counterparts operate in a truly global market place, these smaller firms tend to interact with the local high-tech community in a more intense way, while providing the technologists they employ with an equally demanding and all-round training in managing entrepreneurial technology ventures.

4.3 Drug Discovery

> 'Soft' model: platform technology or fee-for-service business generates a revenue stream through contracts for individual customers that finances proprietary therapeutic drug discovery work to the point where drug molecules can be licensed to, or co-developed with, major pharmaceutical companies.

Since drug discovery is a capital- and IP-intensive industry with very high barriers to entry, significant regulatory development costs, and very long timescales, the general perception is that the whole of life sciences is dominated by venture capital. In actual fact it is far from the case that mainstream VC funds have funded all the top UK publicly-listed biotech firms.[31] The business model generally assumed – that start-ups are based on scientific research undertaken in a university and are financed through several funding rounds by a VC before being IPO-ed or sold – is not in fact particularly prevalent. Unpublished research by biotech entrepreneur Andy Richards in 2008 revealed that fewer than half of the top 30 UK public biotechnology companies have ever received substantial specialist VC money (as opposed to angel funds, hedge funds, university challenge funds, venture capital trusts, IP funds, etc).[32] Clearly, these firms survived and prospered with a different financing model.

The biotechnology 'revolution' of the 1970s[33] ushered in an era of technology proliferation and new firm creation focused either immediately on drug discovery or on the development of platform technologies and research tools to aid the drug discovery process. Whereas the former normally require significant amounts of venture funding, the latter type can earn early revenues by contracting their services to pharmaceutical and other biotechnology companies in the drug discovery business. 'Soft' business models began to emerge in biotech when scientists left major pharmaceutical firms – which are widely recognised as inefficient in the research process – and began to sell their specific expertise back on a research contract basis. These new ventures typically need two or three highly experienced people who can provide scientific leadership at a very senior level to generate credibility with customers, combined with some entrepreneurial understanding.

There are numerous examples where the closure or acquisition of pharmaceutical and biotech company research sites in the East of England region has presented opportunities for soft start-ups in the life sciences as teams of scientists depart. Since 2000 several Big Pharma companies have shut down UK research laboratories in the quest to rationalise facilities and/or therapeutic areas: Aventis (formerly Rhone-Poulenc) in Dagenham, Bayer, Merck (Harlow), GSK

30 Ionica was a fixed radio telephone operator set up in 1991 as a competitor to British Telecom by Nigel Playford, a former PA Technology consultant (who had earlier also founded Cognito, another wireless-based company). Ionica floated in July 1997 at 390p per share, raising £700m, and was briefly valued at over £1 billion based on the huge amounts of cash it raised globally. It went into administration in October 1998 having failed to build its customer base rapidly enough or find a strategic partner to fund future development. The technology, however, survived as the overseas rights were sold to Nortel, which marketed it as Proximity-I until it was bought by Airspan.

31 In the US, in contrast, venture capital has indeed funded all the top public biotech firms.

32 This group included several companies that raised capital via the early AIM market. Mergers and acquisitions since Richards' analysis in the third quarter of 2008 have changed the top 30 list considerably.

33 See e.g. Henderson et al (1999) 'The Pharmaceutical Industry and the Revolution in Molecular Biology: Interactions among Scientific, Institutional and Organizational Change.'

Case Study 2: Argenta Discovery

Argenta Discovery is a highly successful demonstration of the co-existence of soft and hard activities in the drug discovery sector. After the merger of Rhone-Poulenc with Hoechst to form Aventis in 1999, the firm's UK drug discovery group based in Dagenham was closed down and the staff made redundant. In 2000 a group of 20 scientists, together with some academic scientific advisers from Imperial College, raised some £6m of venture capital to found Argenta.


Image courtesy of Argenta Discovery Limited

They acquired a large amount of laboratory equipment from the Rhone-Poulenc research lab at a knock-down price to equip the new company, and in addition negotiated a 3-year contract to supply drug discovery services to their former employer – a revenue stream that attracted the interest and support of the VCs. With this and other contracts Argenta was able to operate close to breakeven right from the start.

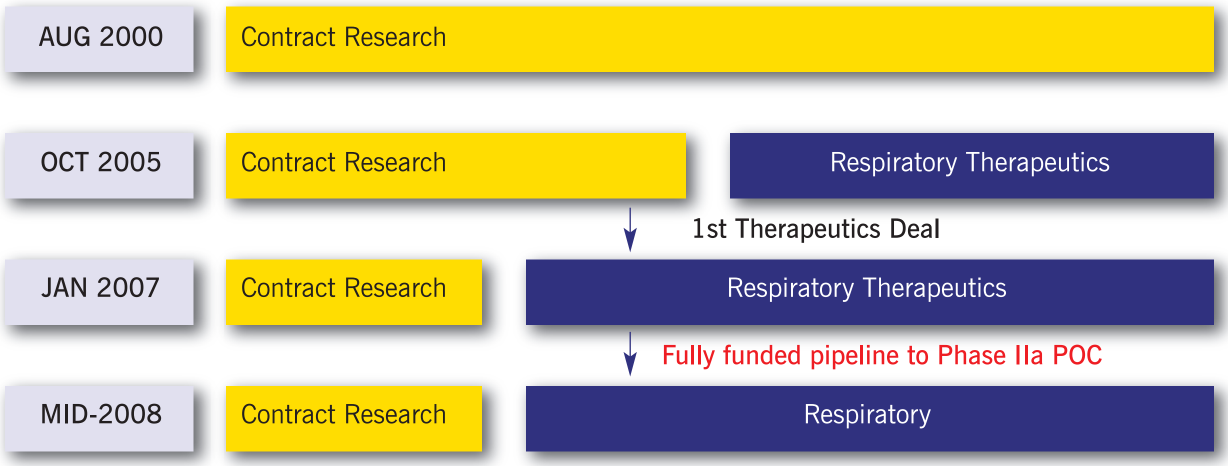
Although a 70/30 mix between contract and proprietary research was planned, in practice only modest proprietary work was done until 2004, when the VCs pushed through a merger with Etiologics. This was another soft start company, based around 15 scientists, led by Dr Mary Fitzgerald, who specialised in chronic obstructive pulmonary disease (COPD). They had been made redundant after Bayer shut down its respiratory disease therapeutics group a couple of years earlier. The Etiologics scientists, like Argenta's, had been able to acquire their equipment for a very nominal sum; they also had a tightly focused pharmacology-based research agenda, but offered R&D services around models of respiratory disease to bring in some contract revenue. Etiologics' CEO, Chris Ashton, had been brought in by its VC investors to lend entrepreneurial experience and credibility to the firm's scientific pedigree, and when the two companies merged he became the CEO of the new Argenta.

By 2004 Argenta thus possessed well equipped laboratories (which it continued to supplement at very low cost as other facilities closed down), an experienced CEO, considerable drug discovery skills and expertise, a profitable contract research activity based around a small number of high value deals with high quality organisations, and a highly focused therapeutics programme in respiratory disease. In due course this led to collaborative agreements with Big Pharma to take Argenta's proprietary programmes forward into clinical trials. With annual contract revenue varying between £6.5 million and £8.5 million per year, by 2007 the company had earned around £50 million, against a total of £17 million invested by VCs: "*the whole point is to run a*

(also Harlow) and Roche (Welwyn). The US firm Millennium Pharmaceuticals acquired Cambridge Discovery Chemistry in 2000 and built a new research facility in Cambridge to house a substantially expanded team. However, it was forced almost immediately by poor results in the US to close down its UK operations in 2003. From the wreckage emerged both Sareum, which brought out the technology it had developed using X-ray crystallography for structure-based drug discovery, and Pharmorphix, which specialised in polymorphism (the relationship between a compound's pharmaceutical activity and the physical form of the chemical). Both were founded by small teams (of 3 people and 4 people, respectively) who had already worked together for many years at Cambridge Discovery Chemistry, and both firms provided services to the pharmaceutical community. Pharmorphix remained a purely soft model focused on R&D services, quickly became profitable, and was sold to Sigma Aldrich within three years. However, Sareum opted for an AIM listing, raising capital to supplement revenue from fees-for-service to fund its proprietary oncology drugs programme.[34]

Argenta Discovery is another instance of redundant scientists leaving established pharmaceutical companies

34 This combination proved difficult to manage and in August 2008 Sareum sold its services activity to BioFocus, based on Chesterford Business Park.



contract research business that is profitable enough to make a contribution to R&D costs… Every time we get £1 million of contract revenue, it's money we haven't had to raise from VCs. That's why this model works", points out Ashton. Argenta is able to bill clients quarterly in advance (compared with the normal monthly-in-arrears billing pattern) for contract business because of the differentiation its combination of chemistry and biology allows and the peer-to-peer respect from Big Pharma for the expertise of the ex-Bayer and ex-Aventis scientists in the respiratory disease area. Argenta calculates that its fully-loaded cost per scientist is only one-third of the real costs incurred by Big Pharma's in-house teams. The contract business brings both delivery focus and the track record needed to impress potential partners of its proprietary respiratory programmes with the quality of its chemistry, biology and pharmacology. This ensures that any proposition gets a serious hearing.

In 2007 Argenta signed an agreement with AstraZeneca for $21 million up front plus downstream milestone payments for one of its proprietary programmes. This was a transformational deal for the company, giving it significant cash reserves to progress its other proprietary programmes over the next 3-4 years whilst continuing its contract R&D business. "*We created IP that AstraZeneca wanted access to; in addition to the licensing deal there is a collaboration agreement where we work together to finish the programme, create more molecules to back up the original work, and get additional milestone payments as the potential drugs go successfully through each phase of clinical development.*" Royalties on sales will follow if one of those molecules reaches the market, making the deal potentially worth over £500 million.

By 2008 the company employed 152 people, its annual revenues were £18 million, there were six drugs at the clinical or pre-clinical stage, and £18 million of cash was sitting on the balance sheet. The graphic above demonstrates how the balance between the two sides of the business has shifted over time. Currently they co-exist very well, but a decision to separate contract and proprietary work later has not been ruled out.

to set up on their own. In this case a team of chemists from Aventis later joined up with a respiratory disease group from Bayer (see Case Study 2). More than a decade earlier Cambridge Antibody Technology (CAT) had followed a somewhat similar path after David Chiswell left Amersham International with a team of 10 antibody researchers when its central research laboratory was shut down in 1989.

CAT was a trailblazer in the biotechnology world (as Chiroscience had been in a different field) for another reason: it was the first UK company to structure partnership deals with major pharmaceutical companies in the form of escalating milestones as successive technological hurdles were passed. This mechanism provides a means for a small biotechnology company to get drug candidates into the clinic (see Case Study 14) without raising significant financial investment and to use the revenues earned to take other proprietary technologies further in the development process. This business model has now become standard practice, but until then UK biotech firms had followed the US West Coast business model, believing they could finance themselves better, and achieve a higher return, by raising large amounts of venture capital to fund development. CAT showed that, even in the expensive drug discovery world, a revenue-generating platform technology model backed by a strong patent position could finance at least the initial stages of the transition to a product company – and that the interaction with Big Pharma during the contract-based work was invaluable in helping such firms gain access for subsequent partnering opportunities. But by the end of the 1990s, gaining access to Big Pharma had become much less of a 'hard sell' because of the desperate shortage of drugs in the development pipeline.

Many biotech firms have found that trying to combine contract and proprietary drug discovery work is a difficult juggling act. The dilemma for firms with a fee-for-service business – where the principal aim is revenue – combined with an intellectual property-based business (whose goal is to invest in its own pharmaceutical product development), is whether to invest the revenue generated in marketing and in growing the revenue-based business or whether to put it into the risky drug discovery side. The challenge, then, is to strike the correct balance between immediate revenues and creating long term value. Also important is to avoid a cultural divide between 'money earners' and 'money spenders' (the latter being the 'glamorous' or 'real' business of in-house research). This is most easily achieved by intentionally switching people between contract and proprietary programmes from time to time. Since contracts are typically several months rather than several years long, opportunities to work on different things in different project teams stimulate both interest and learning, a learning model similar to that found in the specialist consultancy firms. Further, contract work instils a delivery discipline that could be lost if the two sides were separated: monitoring on a daily basis to ensure weekly or monthly targets for customers are met introduces a different style of working to the more cosseted research environment often encountered when customer pressures are small or non-existent and timescales are long.

According to Chris Ashton at Argenta, the contract R&D model in life sciences requires strong financial discipline and realistic ambitions: rather than doubling its headcount following the merger with Etiologics "*we capped the size of the service business and concentrated on getting the right price for the service so that it was profitable*", especially against a background of price attrition at the less complex end of the contract chemistry market.

Whereas Chiroscience solved the balance problem successfully by moving contract work to a separate subsidiary, Chirotech, others have had less success with the model. Royston-based Pharmagene, a supplier of human tissue samples for use in drug research which was also attempting to develop a treatment for cystic fibrosis, was taken over by US firm Asterand in 2005 when its proprietary drug development programme faltered. BioFocus, a chemistry-based company rather like Argenta, was unable to remain independent on the fee-for-service model but continues to offer chemistry services under the auspices of Galapagos NV. At Daniolabs, which aimed to develop assays based on zebra fish, early revenues were generated on contracts to conduct sophisticated disease modelling and safety pharmacology services, but finding the balance as it built up a technology base and an IP position was a constant struggle. It succeeded in winning many small pilot contracts but never managed to capture the larger follow-on contracts that would make ends meet. Eventually the company was sold to a UK competitor, Vastox (now Summit plc), which continues to offer zebra fish-based services combined with its own drug development programme. The balance is particularly difficult to manage in public companies due to the conflicting interests between shareholders who have invested because of the revenue stream and those who have invested for the longer term but higher risk drug discovery potential.

The soft model was undoubtedly very unpopular among life sciences venture capitalists for a long period in the 1990s, even though revenue-generating activities could be seen as partially de-risking the proprietary technology proposition. But a renewed interest in platform technologies may now be altering that negative perception. Investors in the past have sometimes forced the sale of profitable service-based assets that they do not recognise as a valuable component of the business, because they regard fee-for-service activity as slowing down the growth potential. Venture capital-backed drug discovery firms have often faced the problem of UK VCs preferring trade sales – often on the basis of unsolicited bids from Big Pharma – when data on their proprietary research programmes start to come through. This suggests that concern by VCs over the need to finance further rounds of investment (or, alternatively, their fear of dilution) effectively imposes a natural size limit on UK drug discovery firms.

Box 13: Other Examples, Past and Present, of Life Sciences Companies Exhibiting Elements of a Soft Strategy

Acambis: a vaccines company that underwent an opportunistic conversion from hard to soft model when it acquired a US firm that happened to have a manufacturing facility and was well placed to win a US Department of Defense contract to develop a smallpox vaccine in the wake of the World Trade Centre attacks.

Celltech (in Slough): built up a customised mammalian cell culture contract manufacturing business (Celltech Biologics) which was sold off in 1996 to Alusuisse/Lonza for £50 million in order to concentrate on drug discovery. This was the side of Celltech that had commissioned the roller bottle machines from TTP in 1988 (see Case Study 12). Celltech Biologics was highly profitable, had revenues of £16.7 million and 300 employees in the US and in Slough in 1994/5, and was being readied for an IPO in 1997 when the Alusuisse deal came through. The Biologics activity had been separated into a subsidiary in 1991-2, and some investors regarded its specialist manufacturing as too risky if the monoclonal antibody drugs then in various pharmaceutical firms' development pipelines failed in clinical trials and did not reach the manufacturing stage.

Domantis: founded by Greg Winter and Ian Tomlinson, scientists at the MRC's Laboratory of Molecular Biology in Cambridge, in 2000 with seed funding from the MRC's venture fund. Like CAT earlier, which Greg Winter also co-founded, in 2001 it secured a major investment from Peptech (Australia) to enable it to develop single domain antibody therapeutics. Collaborative development deals on several of these therapeutics were signed with major pharmaceutical companies and it raised $54 million from VC investors before the company was bought in 2006 by GSK for £230m.

Geneservice: a spin-out from the MRC of its gene sequencing service and reagent sales activity, which was loss-making and slated for closure. The three founders used their redundancy money plus a tiny amount of angel investment to get the company going. This was essentially a 'free' start-up since the founders were to be made redundant, some assets (equipment) were transferred from the MRC to the new company, and the client list was already in place. The business model was to supply genomic technology services and reagents to research institutes and pharmaceutical companies, a strategy that enabled it to become almost instantly profitable. After two years building revenues, in June 2008 it was sold for £4 million to Nottingham–based Medical Solutions (now Source Biosciences). Geneservice still has an activity on Cambridge Science Park.

Horizon Discovery: founded in 2007 by Chris Torrance (formerly of Vernalis) and backed by loans and a small cash investment from Cambridge Enterprise Seed Funds, Horizon exploits isogenic cell lines developed at the universities of Cambridge and Washington as tools to accelerate the search for personalised drugs. Its Genesis gene-engineering technology platform helps drug discovery researchers understand how cancer manifests itself in patients. Horizon recently announced a 3-year strategic collaboration with Genentech to develop genetically-defined human X-MAN (Mutant and Normal) cancer models for use in Genentech's discovery programmes, for which Horizon is being paid up-front, milestone and renewal fees.

Vivid: was a soft start inhaler company incubated inside Cambridge Consultants by Steve Eason, who had set up the consulting firm's Aspirair dry powder inhaler technology team in 1999. It was earning revenues on a few contracts, trying to do deals and raise venture funding, before being acquired in 2002 by Wiltshire-based Vectura.[35] Now called Vectura Delivery Devices, based on the Cambridge Science Park, it engineers the inhaler devices to fit with Vectura's drug formulation activities.

35 Vectura was founded by former PA biotechnology consultant David Gough.

One of the reasons why the softer model of biotech start-up has functioned relatively well in the East of England region is the involvement of ex-PA Technology scientists. PA established a strong biotechnology group in the 1980s[36] but, unlike academic bio-scientists and people with a background in the large pharmaceutical companies, its members developed their business skills in an environment in which they lived and died by how much work they could sell. They created a valuable pool of expertise and, in times when there was little venture capital available, some important biotech companies in the region employed such individuals in business development roles to access and set up contracts with client companies. Andy Richards, who rounded out scientific skills developed at ICI with several years picking up commercial capabilities as a consultant at PA, is an example of an experienced life sciences business development director (and, more recently, angel investor). Having been instrumental in the growth of Chiroscience until its acquisition by Celltech, he has since been involved in several other biotech start-ups that operate some form of the soft business model.

Proponents of the contract research model in the life sciences industry point to its impact on development and training at all levels of the company: scientists collaborate and interact with their peers in other organisations and all the time have exposure to activities that they would not necessarily experience in a different style of company. Progress through a career at a company like Argenta Discovery is based on the ability to collaborate and communicate. It exposes managers to tough negotiators in major client organisations on a regular basis in a way that proprietary research company managers do not until the moment comes to commercialise a drug. At this point the learning curve is arguably too steep.

4.4 Automotive and Aerospace Engineering

'Soft' model: customer contracts based on proprietary concepts fund costly technological development through substantial up-front fees and milestone payments; Technology Strategy Board-style multi-partner collaborative research projects used by some companies; potential to turn innovations into a product business.

The East of England has a handful of specialist automotive companies including Lotus Engineering (part of Group Lotus) near Norwich, Beru F1 Systems in Diss, Pi Research and Pi Technology in villages outside Cambridge, and, in Cambridge, Tarragon Embedded Technology (now part of Ricardo plc, the Shoreham-based powertrain and vehicle engineering technology consultancy managed by a TTP alumnus). Among the large technology consultancies, Cambridge Consultants has an active automotive group. In each case growth has been based on a 'soft' business model.

Legislation and environmental factors, notably around CO_2 emissions but also around the desire for fuel conservation and safety, drive technology advances in the mainstream automotive industry. They increasingly also drive developments in motorsports, which until recently focused more on speed at any price. The complexity of the electronics, software, composite materials and other aspects of modern vehicles is such that automotive manufacturers must turn to specialist engineering firms to develop advanced systems and materials. Developments in the rarefied world of motor racing may find modified application in the passenger or commercial vehicle market, for example in fuel monitoring systems, and advances in strong but lightweight composite materials for racing cars can be relevant also in the aerospace and marine industries. The Formula 1 world epitomises the notion of continuous design development, with racing car components evolving throughout the season and the next season's car under construction even as the current season's model is racing. In contrast, mainstream automotive vehicle designs must undergo an extensive homologation process to ensure certification for public road use. Since the motorsports industry is a niche market, its suppliers increasingly seek to apply their technologies to broader industries.

Although sports car production is the highest profile aspect of Group Lotus, Lotus Engineering, whose work is mainly for third-party customers, accounts for approximately one-third of the group's overall business (see Case Study 5). Unlike Beru F1, Lotus rarely strays out of the automotive field – on the grounds that the risk, benefit and expense of developing and selling capabilities in different areas are too great to be viable – except where there is sufficient affinity for it to demonstrate its expertise and apply it by thinking laterally to solve engineering problems. For example its aerodynamics skills were brought to bear in the bicycle used in the 1992 Olympics by Chris Boardman, and in GP500cc motorcycle road racing for ex-500cc world

36 According to Gordon Edge, who persuaded PA Consulting to make the investment in the mid-1970s, PA Technology was the first independent consulting company in Europe by quite a long way to establish a biotechnology lab.

Case Study 3: Beru F1 Systems

Beru F1 Systems is an example of a company that began with a fairly hard product model but has more recently shifted to a softer business model that offers better growth and long term prospects.

Diss-based F1 Harness Systems started out in 1993 as a wiring harness company supplying the Formula 1 motor racing sector. In 2001 its product portfolio expanded into electronic systems through the recruitment of a group of electrical engineers from an F1 company, and in 2002 it was acquired by Beru AG, a large OEM supplier of diesel cold start systems and electronics to global car manufacturers. The name changed to Beru F1 Systems and John Bailey – one of the F1 electrical engineers – became managing director. With sales of £6 million and a staff of about 80 in 2008, Beru F1 has drawn on the parent company's product range to expand into electronic tyre pressure monitoring systems for motorsports and niche high-end sports cars, but otherwise operates largely autonomously.

Bailey describes Beru F1 now as a "*pure R&D company*" that engages in almost 100% bespoke activity for its OEM customers. The custom motorsport-related work, together with his own background and contacts in F1, also give him insights into what F1 engineers are looking for. This enables him to undertake a small amount of speculative development, normally as an offshoot or an improvement on something Beru F1 has already produced. The associated costs can rapidly be recouped through the very high margins the company is able to earn.

OEM clients provide a product specification for which Beru F1 quotes a 'take it or leave it' price and sets the terms – usually monthly or quarterly in advance, depending on how costs are incurred. The tyre pressure system it has developed for high-end marques such as Lamborghini, Aston Martin and Tesla is "*quite unique*", since other suppliers do not cater for such low volume markets. "*We are able to equip firms like Lamborghini with a very high spec bespoke system, very quickly – but in return we need to be paid for it, and on our terms.*" The commercial vehicle market is more competitive, but Beru F1 believes it can provide unique application-specific solutions to client problems.

Beru F1's most significant proprietary activity, in development since mid 2006, is its Wire-in-Composite (WiC) technology, which laminates wiring between composite materials to protect the assemblies from damage while also achieving important packaging savings in terms of size, space and weight. Originally developed for use in the harsh F1 engine environment, the technology has the potential for mainstream automotive application as well as in the aerospace sector, where little change in conventional wiring system architectures has been seen for decades. Beru F1 is in negotiations with a number of global players over the application and further development of the technology, likely to be run as collaborative programmes funded by the Technology Strategy Board and under EU Framework Programme 7. Bailey expects that WiC technology will help to transform the company from its current 85% dependence on motorsports. Since Beru F1 has no interest in forward integrating into manufacturing, the technology will be licensed out.

champion Kenny Roberts Senior's GP team. But Lotus Engineering also provides an example of how 'hard' offshoots can emerge from engineering contract work in the automotive sector, when specialised hardware and analytical tools developed in-house are packaged up and sold as a product. Capitalising on its reputation for ride and handling expertise, Lotus sells its proprietary kinematics software and its Suspension Kinematics & Compliance Measurement System (SKCMS). Costing up to £1 million each, depending on specification, these systems have been a modest revenue generator over the years.

Unlike other industries we find little evidence that automotive engineering firms in the East of England region have produced any substantial spin-outs, other than the division of Pi into Pi Research and Pi Technology to serve different markets, where clearly different cultures and revenue models prevailed (see Case Study 4). The Lotus name is linked in sometimes tenuous ways with various racing organisations established by former employees using skills they learned at Hethel; the most famous name among these is Cosworth, whose founders both worked with Colin Chapman. More recent small start-ups by former Lotus Engineering employees include Scion-Sprays and Active Technologies, both located in the Hethel Engineering Centre (see Appendix B). But the volatility of Group Lotus' financial record over the years has left top

Case Study 4: Pi Research

Image courtesy of Cosworth Electronics (formerly Pi Research)

Tony Purnell started Pi Research in 1986 as a consultancy in the basement of his house in central Cambridge, "*without any clue whatsoever about business*", while still a PhD research student. The business was based around a wind tunnel instrumentation and control system he had designed when working for a few months in the US after his Masters degree at MIT, and which was in use at Lola Racing Cars. Through contacts in the industry he proposed an improved version of the system to Penske (the top truck rental company in the US, whose owner also had big motorsport interests) using just a presentation and a rough spreadsheet of costs. The presentation was a success and he won a contract for £60,000, half paid up front and the rest on delivery six months later. Ray Wardell, an experienced operations director (and early investor), handled the business side while Purnell worked on the system. After about three months more clients came along. Purnell remembers, "*They also paid money up front, otherwise how else could I have done the work? It didn't occur to me to do it any other way. I wouldn't have been able to do it if they hadn't given me some money. It wasn't a negotiation. I think we upped the price of the later ones to £80k, but Ray took care of all that.*" By the end of the first year Pi Research had taken on several engineers and was working for over half the Formula 1 teams.

The second development project, an in-car instrumentation system, turned into "*an unmitigated disaster*". Having promised the client delivery in one year of 25 systems for $14,000 each plus development funding of $78,000, it rapidly became clear that the proposed design was unnecessarily sophisticated. Pi delivered one year late and even then was unable to get the software working better than sporadically. "*We were in an engineering crisis because we were being beaten senseless*" by the client, which had promised the system to customers buying its racing cars – yet "*everybody who saw the thing when it occasionally worked just wanted it*". By providing exceptional service, flying an engineer out (usually to the US) whenever there was a problem on a racing car and spending "*every penny the company had*" to resolve the software bugs, the product at last began to work. It was supplied in quantity exclusively to the client in 1989-1990, eventually becoming standard racing car equipment. In 1990 Purnell proposed a re-designed version to a different client and won another development and supply contract, but this time with substantially larger up-front development fees and production charges. Again the product became a huge success despite teething troubles, and supply to the client continued for 5-6 years. Furthermore, the client's exclusivity clause applied only to engines for Indy 500 racing cars, allowing Pi to sell into the Le Mans racing market – and potentially into Formula 1, although here it came up against the spending power of Bosch and Magneti Marelli.

By 1992 the product range had expanded to include wireless telemetry, sensors and customised dashboards, all financed through up-front development fees. The company had earned an excellent reputation for its complete customer orientation and support (at the expense of making money), which far outstripped that of competitors in the embedded technology market. But motor racing is a tiny market and Purnell, with the help of a management consultant, recognised that Pi had become a big fish in the small motorsport pond: to grow it needed to gain a foothold in the mainstream automotive market, as well as diversify into as many aspects of motor racing as possible.

Entry into the mainstream market came through another approach to Penske in 1991, this time by proposing an engine management system for its Detroit Diesel trucks that would contribute towards meeting increasingly stringent emissions controls. Although car companies already had microprocessor engine controllers, no-one was producing them for the harsh environment of the diesel truck market. "*We'd never made an engine controller before, but we probably knew how to*" and Pi was also "*clueless*" about manufacturing. Nevertheless, six weeks after the first approach Purnell gave a presentation of his ideas to Penske and asked for $2.2 million of development funding (a lot of money in those days) for product delivery in two years. Penske agreed and a deal was struck that included royalties on the first 75,000 units and other long-term rights, with manufacturing to be carried out by Pi's selected partner, Motorola.

Breaking into the mainstream automotive market was a major coup. Pi was one of the few companies in those days with the necessary microprocessor skills to produce the controller. But, more importantly, Purnell had the confidence of Penske's chairman, based on the transformational impact of the wind tunnel system he had supplied five years earlier. Pi poured significant resources into the project, hiring a specialist project manager and bringing in the best staff from the motor racing side of the business. With a lot of help from Motorola, who were manufacturing the device in Chicago, the product was delivered on time.

Pi's business was entirely self-funded, without any involvement from venture capitalists, and Purnell owned over 90% of the shares once he had bought out most early individual investors. In around 1992 he made the deliberate decision to shift from being an engineer to being a CEO: "*The truth was I wasn't very good at engineering! I could cope, but I realised that the thing I was good at was identifying the need and then selling an electronics project to mechanical engineers – I could talk the language of a mechanical engineer and I could talk the language of a software engineer or an electronics guy. But I couldn't do what they did.*" When he began to focus on making pitches to senior managers at prospective customers and on the technical sales aspects of the business, leaving a professional managing director to handle the operations side, Pi began to grow.

In 1992 Pi formally split into Pi Research focusing on the motor racing business and Pi Technology to serve volume automotive customers. They were quite different operations in terms of their culture, quality standards and way of working. Pi Research took a gung-ho 'we can do it in 6 months, whatever it takes' attitude; Pi Technology was (necessarily) more bound by the standards, procedures and manuals required to satisfy normal road-use legislation. They operated from the same premises but in separate wings, were treated as separate profit centres, and had their own marketing teams. Pi Technology's US sales office was in Detroit, home of the automotive industry, whereas Pi Research had a sales office in Indianapolis. The Pi Group business plan recognised that motor racing was a tiny market that operated under feast or famine conditions, whereas Pi Technology was a tiny fish in the big automotive pond with scope to grow.

By 1994 Pi Research had the resources to harden the business model and develop its own products and it was no longer working on many customer-paid development contracts. This meant it could sell directly to the motor racing teams rather than via the racing car manufacturers, enabling it to capture better margins and build its own brand, Pi Systems. Meanwhile Pi Technology continued with a softer business model, winning development and supply contracts from various customers over the next several years, while earning royalties on the engine controller for Detroit Diesel as well as continuing to win $1 million development contracts from it. When its software division was appointed Ford's sole preferred embedded code supplier in Europe for car engine controls, Pi Technology saw the prospect of a long term and very reliable business. That led to a 50/50 joint venture between its software division (representing around one-sixth of the company) and Visteon, the Ford auto parts company, for which Visteon paid Pi around $1 million.

The success of the joint venture prompted Purnell to seek out a partner for Pi Research, which was still trying to make a presence in F1 racing despite several costly experiences competing against established players. In the end, Ford's entry into F1 through the purchase of Stewart Grand Prix (renamed Jaguar Racing), coupled with its existing Pi Technology relationship, led the automotive company to buy the entire Pi Group in 1999. By this stage the Group was achieving revenues of around £18 million and employed over 200 people, the large majority on the Pi Research side.

Five years later Ford withdrew from F1 motor racing and the Pi Group was bought by Racepower Holdings. Pi Research, based in Cottenham outside Cambridge, continues to supply the motorsports industry and has extended its activities into marine and aerospace applications. Pi Technology became part of South African-owned Control Systems in 2006 and, renamed Pi Shurlock, continues to engineer automotive electronic environmental products from its base in Milton, near Cambridge.

Case Study 5: Lotus Engineering

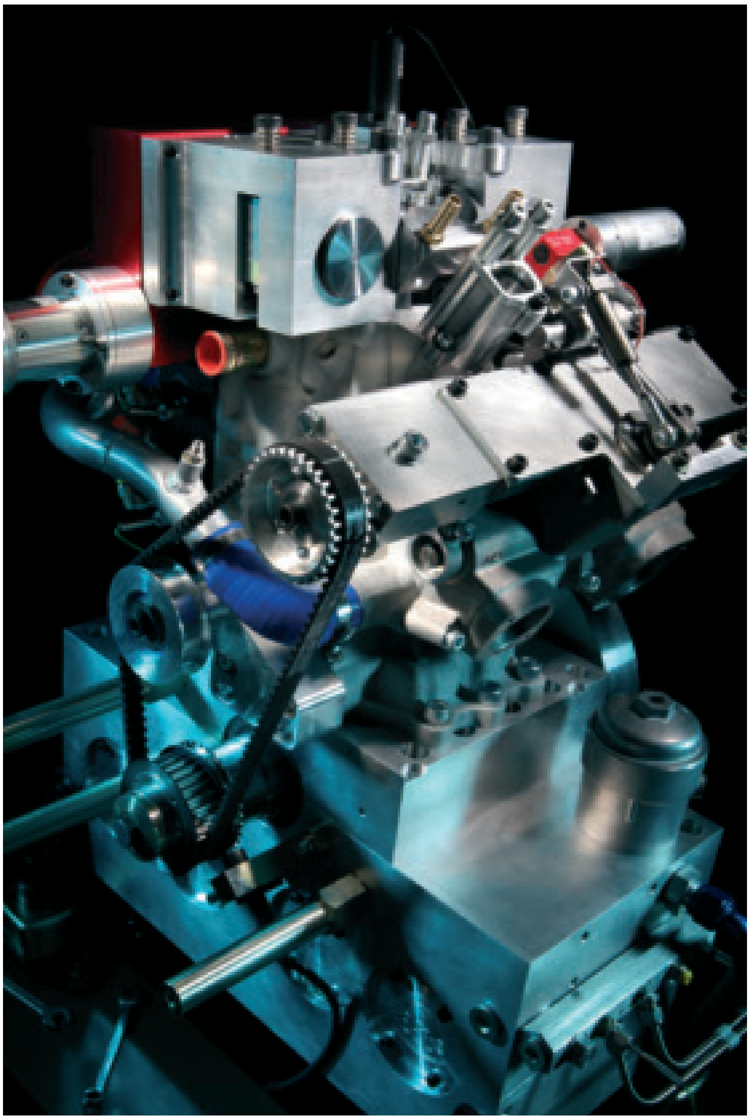


Image courtesy of Group Lotus plc

The sports cars made by Lotus Cars are the best-known part of Group Lotus plc, and yet Lotus Engineering – the original activity of the company set up by Colin Chapman in the 1950s – generates more than one-third of the Group's £110 million turnover and employs around 40% of its 1,353 staff. Lotus Group has been owned since 1996 by Proton (Malaysia), which acquired it from Romano Arteoli, whose Bugatti company had just gone bankrupt; Arteoli had himself bought Lotus in 1993 after General Motors, the owner of the company since 1986, recognised it did not match the GM product portfolio. The Group's history over the last 20 years has been turbulent, with substantial business losses incurred and significant fluctuations in headcount largely tied in with market conditions.

According to Clive Card, Lotus Engineering Project Manager, Lotus Engineering describes itself as a "*whole vehicle engineering consultancy*", with capabilities running from early-stage design schemes through engineering design, vehicle systems engineering, engine design and development, to whole-vehicle projects. The range of work covers the full spectrum from conventional engineering consultancy around well-known technologies through to fundamental research for use both in-house and by collaborative partners. Some applied research performed in its small research group is sold commercially outside the Lotus Group, although the cost implications of taking anything to market – due to the need for certification of road-worthiness – are such that a practical working demonstrator is always required. Proprietary technologies around road noise cancellation, engine order cancellation and vehicle sound synthesis are attracting customer demand and manufacturers have expressed interest in producing the hardware under licence.

Almost since its inception Lotus Engineering has worked for third parties in order to keep its engineers occupied during low points in the Lotus Cars product cycle, and currently 70% of its activity is for external clients. In Colin Chapman's day "*the sale of engineering activity was always there in the background*" since many people wanted a little of the Lotus 'magic'. An early example was the strong connection with Ford that produced the Lotus Cortina in the 1960s. Lotus Engineering has undertaken substantial work on engines for General Motors and at one stage was heavily involved in the design and development of cars for Proton (which previously had been building Mitsubishi Motors cars under licence). Most often, Lotus Engineering finds itself competing against the major OEMs' in-house design and engineering groups.

management with no appetite to move into adjacent markets and spin off product businesses in the way that the technology consultancies have. Government help, in the form of technology procurement contracts (as found in the aerospace industry, for example), would surely lead to better exploitation of these firms' assets and expertise, as well as to further advances in such fields as fuel efficiency and aerodynamics.

Finally, in the aerospace / defence-related industry we should note the activities of the Marshall's of Cambridge Group, notably its Marshall Aerospace subsidiary, and of Lockheed Martin at Ampthill in Bedfordshire. Marshall Aerospace does not really carry out research and development, although its contract business does involve a good element of design work, and to this extent it could be said to be a 'soft' business. For many years Marshall's had design authority for the Lockheed C-130 aircraft used by the RAF and other air forces, and perhaps 300 of its 1,500 employees are classified as designers. Winning the C-130 design authority meant that Marshall's could modify the aircraft as it wished to meet the RAF's evolving requirements. It also enabled Marshall's to work for other countries' air forces and for aircraft manufacturers such as Airbus. The company also has a Special Vehicles subsidiary, producing defence-related equipment including specialised field hospitals, and an aero-testing business used for aviation purposes as well as by motorsport companies. In general the know-how and IP generated by these activities have been rather little exploited outside the core business, although the Group has contributed to the region through the migration of many skilled designers and engineers to other companies. The Ampthill site acquired by Lockheed Martin in 2005 was formerly known as INSYS Group, itself a management buyout in 2001 of the missile defence group Hunting Engineering. Established in the 1950s, its capabilities revolve around weapon and communication systems for the UK, US and other defence industries. Prior to its sale to Lockheed Martin, INSYS employed nearly 500 people across three facilities in the UK. We have been unable to secure any detailed information of this business, but anticipate that it operates a predominantly soft business model supplying the MOD.

4.5 Instrumentation and 'Research Tool' Businesses

'Soft' model: a lengthy and costly technology development and testing phase often necessitates customer-funded contracts, sometimes supplemented by VC funding; contracts with lead customers perform a market research and product evaluation role when the technology platform has multiple potential specialist applications.

Also in the region is a group of instrumentation and 'research tool' companies working on proprietary physics-based technologies, whose markets are often so small they can neither adopt a pure play 'soft start' model based on customer contracts, nor justify a pure VC-financed hard company strategy. A combination of the two is instead required, with development contracts from lead customers playing a key role in proving the value of potential applications, both to investors and to other buyers. Examples are Syrris, which uses flow chemistry and micro-reactor technology to create automated products for research and development chemists; TeraView, an instrumentation company with a unique technology for imaging and spectrometry in the terahertz area of the light spectrum; and Owlstone, which is based around an innovative 'electronic nose' chemical sensing technology, a platform technology with many potential markets and applications. Tiny Hethel Engineering Centre-based Syrinix, which has a means of helping water companies find trunk main leaks, also fits this pattern of needing a lead customer to place a contract in order to finance the development of its technology.

TeraView spun out with VC backing from Toshiba's Cambridge Research Laboratory in 2001, based on eight years of development work on terahertz technology, and is the world's leading company in this important new field.[37] Terahertz is the classic 'platform technology' – or, to use a less flattering phrase, at the time the company was formed it had a 'technology looking for a market'. This is typical of many of the most important breakthroughs in research, both scientifically and commercially. The challenge is to fund a business through the long gestation period while possible applications are identified, tested and exploited. TeraView's business model has been to augment its venture funding via contracts with end

37 Terahertz is a form of light lying between infrared and microwave in the electromagnetic spectrum and has three important properties. First, many common materials are semi-transparent to it, rather like X-rays. Second, it can be used to produce a spectroscopic fingerprint of each element in its 3D field of view; this can be used to determine what chemical or material is present. Third, unlike X-rays, it is completely safe.

Case Study 6: Syrris

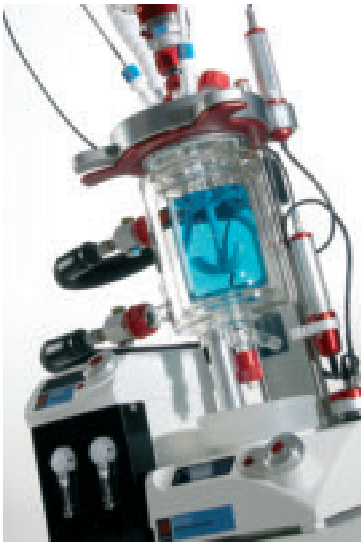


Image courtesy of Syrris Limited

Syrris was founded in 2001 and is of broadly similar size to TeraView: its turnover in the year to December 2008 was £2.2 million and it had 30 staff worldwide, of whom three were US-based and one was in Japan.

Founder Mark Gilligan had worked at TTP on the Myriad project to automate the process of synthesising new chemical entities for pharmaceutical companies, and accompanied Myriad when the project was sold to Mettler-Toledo. Deciding to develop other productivity tools for combinatorial chemistry himself, with co-founder Richard Gray, he brought experienced engineers and chemists from TTP and Mettler-Toledo into Syrris, which started on a shoestring budget.

From inception there was interest in their work on micro flow reactors for chemists from GSK, which recognised the potential to accelerate the medicinal chemistry element of drug discovery. That led to a near 20% equity investment from GSK in 2002-3. Combined with substantial contract funding from the pharmaceutical giant over the following 2-3 years to develop various pieces of flow chemistry equipment, the investment enabled Syrris to hire software engineers and expand from 6 to 17 people. In 2004 Pfizer also started placing flow chemistry development contracts, and has subsequently become Syrris's largest product customer. In addition Syrris partnered with other instrument producers, including MCS (on microfluidics) and Radley's (batch chemistry), to co-develop further products. Another source of funds for Syrris during this early period was a Smart feasibility award of £45,000 in 2002, followed in 2003 by a three-year Smart exceptional award – only the eleventh such grant the DTI had ever made – that the company used for some of the development work on its proprietary Africa product range.

The transition away from a project-led 'soft' business model began in 2005 with the launch of Africa (Automated Flow Reaction, Incubation and Control Apparatus), the company's flagship modular flow chemistry system. This was followed in 2006 by a less expensive and less automated flow chemistry product (FRX) with broader appeal. Syrris subsequently developed in-house its own batch chemistry system (Atlas), launched in 2007. The product business has risen steadily from a 30-40% share of total revenues in 2006 to around 90% in 2008. Crucial to the development of a worldwide customer base was the decision to send a senior Syrris director to establish a US subsidiary in 2005, raising credibility with US customers. The appointment of distributorships in Asia was the next big step, and momentum continued with the founding of subsidiaries in Japan (in 2008) and in India (in 2009, already employing four people).

Further investment was raised in 2006-8 from business angel networks including OION (Oxford Investment Opportunity Network) and GEIF (Great Eastern Investment Forum), and from the Japanese chromatography company, YMC. This funding is primarily to drive the development and working capital requirements of the Atlas product line.

Meanwhile a Syrris subsidiary called Dolomite was established in 2006 as a grant-funded enterprise within the DTI's (now TSB's) Micro Nano Technology (MNT) Network to engage in the design and fabrication of microfluidic devices. Its grant, capped at £3 million, runs until 2011 and tapers off as products and customers emerge.

Although the market for the highly innovative Africa system turned out to be smaller than anticipated, its development enabled Syrris to create relationships with many chemists, who also need more traditional synthesis equipment and are likely to be interested in the next generations of the batch chemistry product. An intimate knowledge of their customers' requirements and a readiness to produce bespoke modules for batch or flow chemistry systems allows Syrris to turn customised work into standard product the following year.

users in different application markets, initially to finance small-scale laboratory studies and, if successful, to fund the construction of application-specific demonstrators and prototypes. These are eventually turned into standard offerings, each built on the company's core 'terahertz engine'.

In its first three years TeraView sold some £2 million of contracts alongside the £3.75 million of venture capital it raised at the start, enabling it to test its technology in applications in drug discovery, security imaging and medical imaging. This mixed model of 'custom' and 'standard' work has continued. In each case TeraView retains any IP, with substantial crossover benefits from one application to another. Today, it has some 50 granted patents and employs 32 people.

In each of these examples, the external validation process of finding a customer prepared to pay for costly development work is a strong indicator of the value of the technology to a market. This is particularly important where markets are highly fragmented and it is not clear where the best opportunities lie. Owlstone, described in Case Study 13 in Chapter 7, provides a good example. Market size also has a bearing on the ability to raise external capital for these expensive technologies: VCs are interested only in large scalable opportunities, not in niche markets (as Syrris's Africa system turned out to be) because the economics simply do not work to give adequate VC returns. Another problem for investors is that rates of business growth are slower. Hence customer contracts can play a crucial role in 'softening' the strategy by bringing in cash for R&D and by helping to test and validate applications.

4.6 Software and ICT

'Soft' model: often a very rapid transition from consultancy or solutions development for a customer to productisation; may not meet all characteristics of the standard soft start-up model if the initial development is aimed at meeting an individual customer requirement, but the customer only commits to purchase on delivery.

Whilst the region has no ICT firms on the scale of the US giants, it has grown a strong group of specialised ICT companies including ARM, Cambridge Silicon Radio (CSR), AVEVA and Autonomy. As in other sectors, spin-outs, walk-outs and serial entrepreneurs have led to the gradual expansion of the sub-cluster as the number of people involved and their expertise and market knowledge has grown.

Though the leading players are all 'hard' companies with a portfolio of standard product offerings, nearly all have their origins in the soft model, either because they were able to use revenues from early one-off projects for individual customers to fund the development of standard products, or because they were spin-outs from companies that were themselves soft businesses or from intermediate (non-university) research institutions undertaking applications-focused development within an environment that bore close similarities to the standard soft company model.

Four organisations have played a particularly important role historically in this process:

- Acorn Computers, whose own history is described in Chapter 3, and whose 'children' include semiconductor companies ARM plc (which employs 1,740 people) and Element-14 (now owned by Broadcom).[38]
- Cambridge Consultants, which spawned Alphamosaic (bought by Broadcom for $123 million in 2004) and CSR (spun out in 1999, it raised a total of $85 million in venture capital funding before listing in 2004; it now employs over 1,000 people). Both of these are fabless semiconductor companies.
- The government-funded CADCentre, which was later privatised and as AVEVA now employs 660 people, and whose earlier walk-out, Cambridge Interactive Systems, went on to spawn Smallworld and Geneva Technology.
- Olivetti Research Labs, which spun off a series of companies including Adaptive Broadband (sold in 2001 to Axxcelera) and Cambridge Broadband Networks, which supplies wireless point-to-multipoint transmission equipment and employs around 100 people.

In the software industry itself the 'soft' business model is often transient, with customisation for different clients representing a shade of grey between bespoke and standard product. A fairly common practice in the UK, and probably elsewhere, is to offer to meet individual customers' requirements for functionality before it is available and do a good deal of development work after winning an order. This has some advantages in the early days but substantial disadvantages as firms become larger, because of the resource requirements

38 See footnote 16 for the ARM story. Some of the Element-14 team were undertaking customer development work for Intel at the time it demerged from Acorn, hence like ARM it has some 'soft' origins even though it rapidly became a hard company.

Case Study 7: Knowledge Solutions

Profits from the sale of an earlier computer training consultancy and share options from a US computer company provided start-up capital for Knowledge Solutions in 1995, supported by very low initial salaries for founders Adrian Palmer-Geaves and Mike Taylor. The consultancy-based business model focused on provision of e-learning and electronic performance support services, with Palmer-Geaves bringing in external contractors as necessary to help them deliver. Turnover of £200,000 in the first year grew steadily thereafter and the firm was profitable from the start – as Palmer-Geaves points out, there's "*no point in doing it otherwise, is there?*"

Three to four years further on, a project on behalf of a life insurance company to reinforce best practice in completing laptop-based insurance application forms led to a development that eventually became Knowledge Solutions' first product: a piece of software that linked the application form to a reference database, with a prompting device in the corner of the screen to encourage the insurance salespeople to seek context-sensitive help in filling the forms in correctly. The client vaguely specified the need for some sort of help function, which Taylor said Knowledge Solutions could deliver and Palmer-Geaves then went about developing. The company's founders saw it at first as a one-off solution for a particular customer, but later recognised the prompting device's potential for a wider market – with the product's development unwittingly paid for by the original client. By this time there were 7-10 people in the company.

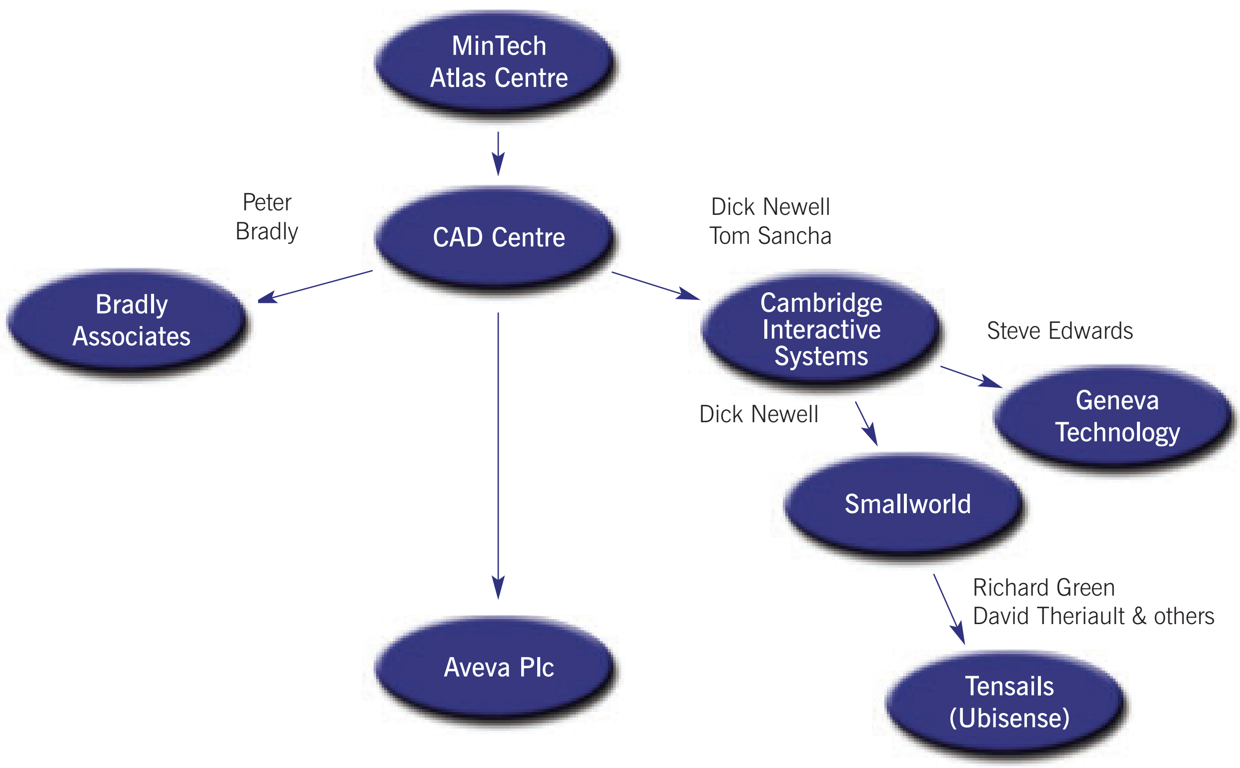
Deciding in 2000 to 'get serious' about developing a more sophisticated but standardised version of the product, they wrote a business plan and attempted to raise money from investors. They did not succeed, "*which was great!*", and then decided they did not need external funding. A newly hired software developer productised the prompting device beyond its original 'string and sticky tape' format, and the product was launched in late 2001. Within 12-18 months Knowledge Solutions was transformed from a 100% services model to 100% product revenues, and turnover jumped to around £700,000.

Since then Knowledge Solutions has built a series of tools and modules to support e-learning and business process training management systems, where the need is to make a large number of people expert in a short space of time on a new procedure or system. Several of the new tools and modules have been developed on the back of enquiries from potential customers, prompting flurries of feverish development activity to build a demo version in the few weeks between the request and a meeting scheduled with the client. Since it was adding new features almost weekly on the basis of taking a beta product to market and continually evolving it, Knowledge Solutions "*shot straight past the competition*". But it also believes it has put more effort than competitors into customer service procedures in order to support its products and address any bugs, leading to further enquiries and the development of additional capabilities. In 2005 Knowledge Solutions invested the company's own funds to re-architect the entire system and integrate its various elements more closely.

By 2007 there were 33 employees and turnover had increased to £1.6 million, of which 74% was product-based and 26% came from services related to product delivery. Product is now normally sold alongside much larger systems implementation projects, achieved through building relationships with systems integrators. Over 50% of revenue derives from public sector purchases of standard product and the company has around 75 active customers.

The acquisition in October 2008 of Enlight AB, a Swedish provider of knowledge-testing software and services, was funded through retained profits and bank lending and, combined with organic growth, boosted revenues to around £5.2 million. It provides an extensive footprint in Scandinavia and partnerships in Switzerland, Austria and Ireland, as well as a further sales operation in the UK. A second acquisition, of BdM Developments in July 2009, added further e-learning and testing products to the portfolio plus some important resources in software development. Revenues are now approaching £6 million.

Figure 8: Software Firms with a CADCentre Heritage



involved and the difficulty in moving towards integrated product architectures. The Case Study of Knowledge Solutions describes how one start-up software firm has managed the transition from a very soft start, via bespoke customer developments, into a standard product offering.

Cambridge Interactive Systems, a walk-out from CADCentre[39] led by Dick Newell and Tom Sancha, also began as a soft business that transitioned into a hard (CAD-based) product model, before going on to spawn further important firms in the software industry (see Figure 8). In all, around 10 computer aided design-related companies are said to have been started by people leaving the Centre – others included NC Graphics and Prosys.[40] These firms formed part of a CAD-related cluster in the region at that time, other notable members being Applied Research of Cambridge (ARC), founded in 1969 by Ed Hoskins of the University's Department of Architecture; Shape Data, which Ian Braid, Alan Grayer and Charles Lang brought out of the Cambridge University Computer Lab in 1974 to exploit their Romulus solid modeller[41]; and Finite Element Graphics System (FEGS), which was established in Leicester in 1978, but moved to Cambridge to be part of the Cambridge CAD 'scene'. Many of these firms exhibited a predominantly 'soft' start-up model. PA also had an active CAD services group in the 1970s, which it still retains.

Cambridge Interactive Systems (CIS) had been founded in 1977 with neither a business plan nor financing, and it relied at first on whatever consulting contracts Newell or Sancha could pick up. The first contract was to link NCR computers at two different second-hand car sales sites – in 1977 a very advanced concept. Newell admitted, "*we knew nothing about NCRs and even less about networking, but decided to do it and wrote a report for which we got £400*". The second contract was for ASEA, a CADCentre customer; and the third was to produce computer graphics to go in a television advertisement for the launch of the Ford Fiesta, for which the advertising company was prepared to pay the enormous sum (in those days) of £10,000 if the work could be done in two weeks. Working 24/7, Newell and Sancha created what may have been the

39 CADCentre is profiled in the following section on intermediate research institutes.
40 Marsh, P. (1985) 'City where dreams come true: high technology in Cambridge'.
41 Shape Data was sold to Evans & Sutherland Computer Corporation in 1981 and in 1988 became part of the Unigraphics division of McDonnell Douglas Information Systems Ltd.

first ever computer graphics used in TV advertising, which led on to a string of advertising commissions for Volkswagen, Philishave and others. But this was a volatile business, with highly lucrative bespoke graphics work for very rapid delivery arriving only every six months or so, and the team decided to shift to a product-based model.

The first reasonably successful product development at CIS was Cablos. This was a drafting system to design printed circuit boards, entirely self-funded from advertising client revenues, and which they thought – correctly – might be interesting to companies such as Pye and GEC. But in 1979, only a couple of years after CIS was founded, they spotted another market in mechanical engineering and developed Medusa, a 2D/3D CAD software system incorporating modelling and parametric design that was far in advance of the multi-million dollar American competition. British mining companies including Dowty Mining were early customers. By 1982 CIS was turning over around £2 million, and the company was bought in 1983 by Computervision, Medusa's US distributor, for approximately $25 million. Medusa ended up accounting for half of the American firm's revenue.

Several key Medusa players left Computervision within a few years to found new software-related companies in the Cambridge region, the most significant of which were formed by a group that coalesced around Dick Newell and another around Steve Edwards (see Figure 8 above). The latter's new company again started with consultancy work, won a contract with telecommunications company Ionica to build a billing system, and went on to become Geneva Technology, a Cambridge-based billing services company bought by US firm Convergys in 2002 for $600 million. By that time it employed around 440 people.

Dick Newell's second important enterprise was Smallworld, established in 1988, floated on NASDAQ in 1996 and sold to GE in 2000 for $210 million. By then it had reached a turnover of £50 million and had a local workforce of more than 150 people. Smallworld was a geographic information system (GIS) business which began with a paid multi-client study to research market requirements and demand for such a product across all industry sectors. With the market intelligence gathered from that report and the £100,000 they extracted from the clients to write it, the team spent two years developing a GIS database and product specifically for the utilities sector – an industry undergoing privatisation that desperately needed to become more efficient.[42] Early versions of Smallworld's GIS were tailored to each individual customer before consolidation into a single product with a proper release cycle.

The latest enterprise in which Newell is involved, this time as investor and board member, is Ubisense. This company was formed from the merger of GIS services business Tensails (founded by Richard Green, previously marketing director and then leader of the telecoms group in Smallworld) with a real time location sensing technology venture that came out of the now-defunct AT&T laboratory (see Chapter 3). The GIS services activity – supplemented by angel investor funding – is financing the development of the location technology. Ubisense is small but growing fast, with around 80 employees and sales of some £8 million.

Other examples of successful software businesses include Red Gate Software, a fast-growing Cambridge company specialising in database and archiving tools, and Neurodynamics, the neural network solutions company that spawned Autonomy. Red Gate, which sells tools for use with SQL database systems, has always been a hard company. But despite this its start up and growth has always been entirely self-funded. Today it employs some 115 people. It illustrates the ability of even hard start-ups in the software industry to manage without venture capital. The story of Autonomy is rather similar (see Case Study 8). Steve Ives, a serial software entrepreneur for over 25 years, left Torus Systems, the local area network software company he had founded in the early 1980s, to establish the largely self-funded Ives & Co software consultancy in Huntingdon in 1989. His more recent ventures – Trigenix (a mobile user interface products and tools developer sold in 2004 to Qualcomm for $36 million) and Cambridge-based Taptu, which is developing a specialist search engine for mobile devices – were launched with venture capital backing.

Clearly the risks entailed and the time scale for developing new software differ significantly from physics or engineering development projects based on untested novel technology. It can be argued that no software company should take more than 6 months to reach a stage of development where at least an intermediate piece of work can be commercialised. Even very large software development projects can –

42 Smallworld's use of a multi-client study to enter a new market is mirrored at TTP, whose study of digital printing technologies led to it identifying the Australian IP on which its Tonejet business is built.

Case Study 8: Neurodynamics and the Creation of Autonomy

Image courtesy of Autonomy Corporation plc

Mike Lynch set up his first company, Neurodynamics, in 1991 from his digs in Cambridge, where he had recently completed a PhD on neural networks. He was unable to find anyone willing to provide financing and the only external funds he could secure for the company was a £2,000 loan from a wealthy eccentric. According to Lynch, the Neurodynamics business model was to find "*people who needed things, say we could do it, work very hard for about four weeks to make what they needed and then deliver it to them*". With the exception of the loan – repaid in six months – the company was entirely self-funded from operating cash flow.

A crucial early piece of work arose from an encounter with an Oracle systems integrator selling to a local police force. The system supported crime records handling, but lacked the ability to deal with fingerprint matching. Lynch set up a meeting with the police force for four weeks later, worked night and day on a self-funded basis, and created a fingerprint-matching product that performed very well in police testing: it could achieve in a few minutes something that was currently taking two people three weeks to do by hand. This was a high value problem for the police and the cost to them of buying the Neurodynamics software was small in relative terms. The software's capabilities were also so far ahead of anything the major incumbents could offer that the start-up company faced none of the competition that would have arisen if the advantage was less clear-cut. Nevertheless, *"if the police force had looked at it and decided not to buy it, we would have had no income for that work. The police bought a product for £100,000, though they probably weren't aware how recently created the product was!*" Very soon Neurodynamics was selling the software to other police forces, and within a couple of years turnover had reached £1 million.

The next product, again self-financed and again targeted at police forces (although this time without a lead customer), was a system for storing 'mug-shots' to simplify the handling of custody photos. Then the company moved into processing text. That was a "*long research project*", with no customer behind it in the early days, and took some five man-years to achieve the first sale, which was into the intelligence community. Like the earlier products it carried a very high margin, generating plenty of cash flow to reinvest in further products.

By 1996 Neurodynamics was a software company selling standard products with gross margins in excess of 90 per cent, and it had activities in a variety of fields – some of which sat ill with the original focus on highly specific information-processing software for the public sector / intelligence community. The decision, then, was to split the company into four entities. Neurodynamics retained its original focus; NeuraScript, which focused on character recognition technology, was bought in 2004 by the listed German software company Dicom; NCorp became a structured data company with VC backing from Apax; and Autonomy spun out with £15 million in replacement funding[43] from Apax and others to specialise in generic unstructured text information processing for enterprises. Having IPO-ed on EASDAQ in 1998 and made a secondary listing on the LSE in 2000, Cambridge-based Autonomy has grown through a business model encompassing product licensing, embedded software in OEM applications, and acquisition into an organisation with a worldwide turnover of £347 million and 1,250 employees in 2008.

43 The term 'replacement funding' (or capital) signifies that a financial investor acquires a stake from another shareholder and the company does not receive additional capital.

and should – be broken up into saleable modules to mitigate the risk of the market moving away from the proposed product during its development. This suggests that venture capital funding may be a distraction to start-up firms in this sector, since readily-available money cushions them from having to interact in an intense commercial manner with customers, and thereby, in effect, from gaining valuable market research data on what customers are prepared to pay for and at what price. Certainly many software companies are entirely self-funded, whether they pursue a soft start-up model based on paid contracts for customers or simply find a way of getting their first product onto the market so quickly that the founders can fund it themselves, or with help from family and friends.

An important feature of the specialised high-tech end of the software industry is that the problems are high value and the solutions to them high margin. A company that can solve a high value problem therefore generates substantial cash flow for reinvestment in its next product. For problem-solving companies such as Neurodynamics and Autonomy, it is possible to build a successful product business without resorting either to venture capital or to customer contracts, as Mike Lynch remarks: "*if when you sell a product you make £1 on 100 you'd have a problem, whereas if you were making £90 on the 100 you can use that money for the next one*".

As the Neurodynamics example demonstrates, the public sector can be an important customer for the software industry, not least because public sector clients are usually less technologically advanced than private sector firms. There can be interesting opportunities for small companies if they can identify a relatively limited or niche problem that they can solve in a demonstrably better way than anything available from the established players to whom risk-averse public sector clients usually look for new systems. Finding that differential gap in performance in the sophisticated commercial market place, in contrast, may well be harder for new software firms.

A very different type of software activity with a reasonably large presence in Cambridge is the game development sector – console, on-line and mobile games development – a legacy of the city's Sinclair and Acorn home computer hardware platforms originally favoured by games publishers.[44] Indeed, Cambridge is said to be one of the largest UK technology clusters for games development alongside Guildford, Brighton and Dundee, with an estimated 800 people directly employed.[45] Leading firms in the local games development ecology are Jagex (over 400 employees), Frontier Developments (over 200 employees), Ninja Theory (over 70 employees), and Sony Studios Cambridge (50 employees). Smaller firms include Zoonami, Geomerics, Short Fuze and Gameware Development as well as a range of freelancers and small specialist sound engineering companies, artists and designers, and other specialist service providers.

Game development companies require substantial financial resources to create new games because of the technology-intensive nature of graphics design and content, and the risks are very high for speculative development of a prototype game that might not interest the publisher. As a result, a very clear 'soft' business model has evolved. The business model for games developers typically involves a development studio pitching to the publisher for a contract to undertake concept development, where delivery of a prototype is likely to be the first milestone. If the concept work is unsuccessful the project will not proceed; if it is successful a larger development contract is awarded – unless the publisher loses interest, which is not uncommon.

As a recent NESTA report[46] describes, however, games studios have typically been forced into what is known as the 'advance recoupment model', whereby the publisher recoups the project's up-front development payments before the originating studio receives any royalties. Rising production costs make this model increasingly unfavourable to game developers. Moreover, the games industry is highly cyclical, based on an approximately five-year cycle of game console launches, while developers targeting mobile phone platforms face significant up-front costs to address the wide array of mobile devices globally and acquire the software development tools required for every mobile platform. This, then, is a business model highly dependent on customer contracts, and in this sense games developers are more similar to the physics-based enterprises discussed earlier than they are to other software firms considered here. According to the NESTA report (p.13), the UK games industry struggles to raise

44 Telephone interview with Jeremy Cooke, founder and CEO, Gameware Development.
45 See www.gameseden.org.
46 Gibson R. and Gibson N. (2008) Raise the Game: The competitiveness of the UK's games development sector and the impact of governmental support in other countries.

external financing for new games development, suggesting that most must rely on development contracts under the unsatisfactory advance recoupment model – and nor are games studios readily eligible to claim R&D tax credits.[47]

Finally, it is the case that many firms in other industry segments also incorporate a software development activity. The technology consultancies often work on development contracts that have an important software component; and leading semiconductor companies such as ARM and CSR depend heavily on their internal software development capabilities. Sometimes the software programmes written for in-house use become significant product businesses in their own right, as noted in the earlier discussion of Lotus Engineering; and in the same automotive engineering sector the core competences of both Pi Research and Pi Technology reside in embedded software systems.[48] The software 'sector', then, is diverse and contains a whole spectrum of business models ranging from very soft consultancy activities through to hard product strategies (such as Autonomy). However, it is mostly characterised by a) opportunities to transition rapidly to standard product if managers are prepared to seize them, and b) a high margin, cash flow-rich activity that often enables significant investment in new product without resorting to external financing.

4.7 Intermediate Research Institutes

'Soft' model: non-academic research organisations with a mission to develop technology for commercial application, but with substantial core funding enabling investment in long-term programmes and/or R&D to support government objectives.

Lying in an intermediate position between the academic world and the commercial world is a whole variety of research institutes and associations that undertake R&D contracts for customers but also have significant on-going funding from (1) government via Research Council or Regional Development Agency grants, or (2) membership fees. One might also include some commercially-owned laboratories where the relationship with the parent firm is rather arm's length and the lab's objective is to generate innovative technologies and new business opportunities, rather than support the parent's existing revenue streams through more incremental developments. Bob John, Chief Executive of TWI, describes the position as follows: "*Inside the intermediate sector is a variety of forms, and there is no such thing as one size fits all. They all have different origins and different models for sitting between on the one hand the generic science base (which is for fundamental research and is sometimes the start point of innovation) and on the other hand industry (which tends to be shorter term and more risk averse).*" Importantly, some mission-driven intermediate R&D organisations are independent of both academia and industry, and are thus completely impartial in their provision of services to third parties.[49]

The types of work these organisations conduct for public and private sector clients include consultancy, applied research, design services, technology development, technology transfer, materials/product/technology validation and evaluation, testing facilities and services, and skills training and certification. Some also engage in early-stage investment in commercial exploitation. Their networking capabilities, their technology research and development activity, and their strategies of trying to license out or spin out the IP they generate make these institutes possible exemplars of various aspects of the soft business model, even if they are not 'soft' companies in the literal sense of our definition.

An example of organisations in the first group is CADCentre in its pre-privatisation days (see Case Study 9). Another is the Institute of Food Research (IFR) in Norwich, which is grant-aided by the Biotechnology and Biological Sciences Research Council. The IFR was created from a number of government-funded research laboratories and consolidated on its present site in 1999. In 2007/8 it had revenues of £17.1 million and employed 247 staff. Like many government-funded laboratories and research associations it has tried to increase the value of contracts for private sector customers and exploit its technology commercially through licences and spin-offs. However these activities are still minimal, with non-government revenues running at only 4% of

47 Telephone interview with Jeremy Cooke.

48 The in-house developed PC tools that accompanied Tony Purnell's Pi software were also highly thought of and, on the racing car side, are still reputed to be the best available.

49 A research association like TWI, for example, cannot, if it is to retain its integrity, favour one member over another, either in doing work for its members or in recommending solutions or providing advice to the community at large on matters of fact.

Case Study 9: CADCentre in the 1970s

Image courtesy of Rutherford Photographic Archive

Around 100 scientists and engineers were employed at CADCentre in the 1970s with the remit to apply advanced computer techniques to engineering design processes to help improve the performance of British industry. Funded entirely by the government (initially the Ministry of Technology) and with no expectation that the organisation would be profitable, contract work covered probably only around 10% of annual running costs. Its various industry groups (civil engineering, mechanical engineering, chemical engineering, electrical engineering, operating systems, graphics, and general applications) devised their own projects and set their own agendas, occasionally coming up with commercially viable products. The mechanical engineering group, for example, cooperated with some external individuals – though never received any funding from industrial partners – to develop what became a very successful numerical control package for milling machines, one of which was sold to General Motors.

An early contract was the development and productisation of a 3D computer graphics input-output package called GINO-F (for Fortran) that had been developed from GINO-3 by Cambridge University's computer lab. Another contract for ASEA involved an electrical design system. One in-house project produced Bugstore, a piece of hardware built to display realistic images produced by a previously implemented software package called Greyscales. At the time, computer graphics was exclusively based upon vector displays. Greyscales was commercialised and sold to General Motors. A short-lived spin-off company called Gems commercialised Bugstore, but CADCentre failed to recognise the enormous potential market for the raster display technology on which it was based.

In 1973 the chemical engineering group proposed development of a software package to represent and design 3D plant layouts; four difficult years later PDMS (Plant Design Management System) emerged, the product that is still the basis of AVEVA, the successor company to CADCentre. The PDMS project was funded by two industrial partners, Akzo (the Netherlands-based chemicals and pharmaceuticals company) and Isopipe, a small Nottingham-based consultancy skilled in producing isometric drawings of pipes. Although the project budget was around £90,000, the shortfall on the total cost of over £300,000 was made up by government funding. The first system was sold in 1977 to Wimpey, by which time it was "*getting to a highly demonstrable and close to shippable state*", according to Dick Newell who, as a CADCentre senior engineer, was also project manager of PDMS.

CADCentre was privatised by the Thatcher Government in 1983 but struggled to become profitable until a management buyout from ICL in 1994. When it was listed on the LSE in 1996 it had around 200 employees in the UK, offices in Europe, US, Japan, Hong Kong and Australia, and sales of £14 million. Twelve years later AVEVA has 663 employees and group sales of £128 million.

turnover, including £111,000 of royalties. In terms of direct engagement with the commercial world, it is therefore at the opposite end of the spectrum from the similarly-sized broadly-based consultancies like TTP and Cambridge Consultants. This raises the question of whether it is a feature of the industry sector or a feature of the culture and business model. If the latter, it suggests that organisations like IFR represent a hidden, and seriously under-exploited, regional asset.

The Welding Institute (TWI) is representative of the membership association form of intermediate research institutes. Case Study 10 describes its origins and how it works with its members. In the commercially-owned laboratories group can be included the now-defunct Olivetti Research Laboratory (ORL), formed from the research activities of Acorn Computers in 1986. CIP Technologies is a government-owned company that is much more closely aligned to our standard 'soft' model than either IFR or CADCentre. This is because it is essentially an EEDA-funded rescue of the photonics activities originating at BT's Martlesham research site.[50] CIP Technologies is described in more detail in the final Case Study in this section.

As the CADCentre case study implies, spinning out companies to capitalise on the IP generated by scientists is not necessarily a priority for intermediate research institutions – perhaps because the focus lies primarily on technical excellence. Often, in the case of paid-for work, the IP belongs to the client. Nevertheless, as with the commercial technology consultancies, know-how or intelligence learned in one sector can be applied in another without violating the customer's rights. CADCentre did not have sales people, so when PDMS was nearing the market Dick Newell had to 'pound the streets' himself. Companies that emerged from CADCentre – of which Newell's Cambridge Interactive Systems (see previous section) was by far the most significant – did so because the engineers wanted to set up their own businesses.

Bob John explains that attempts in the 1990s to create spin-outs and exploitation vehicles at TWI were "*a complete disaster… because of the conflict between the mission-driven model on the one hand and the 'I want to be rich' commercial model on the other*". Its not-for-profit status and need to serve all its members fairly seem to have been important impediments to spin-outs, and none has so far been successful. TWI recognises that "*Cambridge Consultants and TTP are much better placed than we are at taking a patent and an idea to a company and persuading them to pay for it*", because those organisations employ people with the full skill set to do such work whereas TWI focuses only on certain elements. Instead, TWI's focus has switched to getting products to market via wholly-owned subsidiaries (e.g. Plant Integrity) and to capturing the value of its IP through licence fees: "*The beauty is you can generate quite a lot of revenue from that kind of [licensing] activity for relatively small patent costs. Most of it can drop through to the bottom line and the multiplier for members is huge*".

Unlike intermediate research institutes in Europe (e.g. the Fraunhofer Institutes in Germany, TNO in the Netherlands or IMEC in Belgium), or in the US (e.g. the Edison Welding Institute[51]), all of which are partly funded from national, federal or state sources, TWI and similar organisations in the UK receive no government grant funding other than for specific projects. Instead TWI must compete for (mostly European) public money and participate in further-from-market programmes than its industrially-led projects tend to be, in order to "*explore the leading edge*", develop new platform technologies and maintain a world class fully-equipped R&D facility – goals that "*you can't achieve just by being a consultant*", as Bob John puts it. Winning public funding through competitive tender is "*wasteful*" and "*a bit painful*" due to the low success rate – a view shared by CIP Technologies – but TWI aims to achieve a 70/30 balance between industry and publicly-funded programmes.

It is clear that, in some circumstances, intermediate research institutions can play an important role in regional economic development. ORL and CADCentre, both institutions with a relatively limited life, generated important spin-offs and, in the case of CADCentre, itself

50 British Telecom's corporate research campus was drastically reduced in scale after privatisation and its functions were managed by BT Exact Technologies, which also established the Brightstar technology incubator business to capitalise on BT's 13,000 patents and world class researchers. But the number of ventures emerging from Brightstar was small and there were few, if any, significant successes – in part due to the bureaucratic nature of BT, according to some – and parallels could be drawn with the Xerox PARC research facility which also failed to turn its key inventions into commercial success. In 2003 BT spun off Brightstar into a joint venture with New Venture Partners (a technology incubator spin-out from Lucent Technologies) and Coller Capital to give it greater financial muscle. Firms that did emerge include Azure Solutions (revenue assurance; sold to Bangalore-based Subex in 2006), Microwave Photonics (mobile wireless access; sold in 2005 to NextG Networks Inc.), Psytechnics (VoIP voice and video performance management) and io-Global Ltd (recently renamed io-me; location-based technology to monetise digital lifestyle services). All of these businesses required venture capital backing.

51 TWI helped to found the Edison Welding Institute in the early 1980s as a not-for-profit joint venture with Ohio State University. Later, once it had transferred much of its know-how, TWI was squeezed out of the relationship and unwittingly created its own competitor in the US. Today, TWI regards the Edison story as an object lesson in how not to partner with US not-for-profit organisations receiving public funding.

Case Study 10: The Early Cambridge University Spin-out that Became TWI

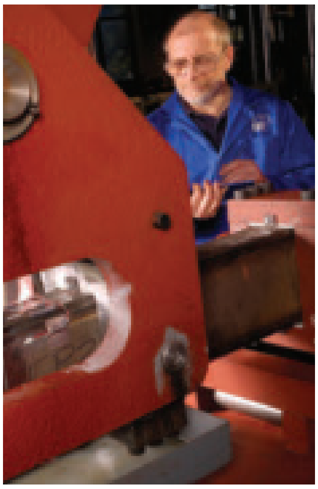


Image courtesy of TWI

In the mid 1940s the leading experts on metal fractures and fatigue – an issue that had assumed prime importance during efforts to raise shipbuilding productivity for the war effort – were Cambridge University academics. Their colleagues' distaste for the noise and dirt their research generated dovetailed neatly with the post-war Government's plan to establish technology research associations to aid economic recovery, and the British Welding Research Association (BWRA) was formed in 1946 by a small number of members of the University outside the city. For £3,000 they acquired Abington Hall, some old sheds and 35 acres of land, and formed a research board composed of industrialists which became the BWRA's governing force. With government providing matching funding, there was no shortage of industrial sponsors for research into the difficult problems around the integrity of structures that the welding industry faced. Since industrialists were paying half the costs and engaging in cooperative research, they drove the work away from an academic perspective into industrial problem solving.

In 1968 the BWRA merged with the London-based Institute of Welding, the industry's learned society with a focus on standard-setting and training, because of overlaps in activity and the need for research and training to progress in parallel. Renamed then as The Welding Institute and established as a company limited by guarantee, in the late 1980s the organisation was rebranded as TWI to reflect the significantly greater number of fabrication processes and wider range of materials on which it conducted research. By its constitution it is both an engineering institute and a research membership organisation, with around 500 UK-based employees. Another 100 staff are spread around the globe, engaged mostly in training and certification.

Current revenue of about £40 million is split between contract work (60-65%), training and examinations (17.5%), membership fees (15%), licence fees (3-4%) plus income from TWI's 20% stake in Granta Park, the science park developed on TWI's 35 acres of land, which acts as a sort of endowment. More than half of the contract income derives from work for individual clients, around one third involves public money (e.g. TSB calls, running the National Composites Network, etc.) and the remainder is multi-client research activity.

Around half of the membership income is invested into a core research programme managed on behalf of the members, i.e. only member organisations (some 3,500 in 50 countries) can benefit from the technology developments achieved through that programme. TWI serves all industry sectors, all engineering fields, and "*every part of the life cycle from invention through brainstorming, prototyping, making it fit for purpose in manufacture, inspecting, troubleshooting repairs, discovering why it goes wrong, right the way through to recycling*".

Unlike other UK industry associations that attempted to transform their operations into commercially driven enterprises, many of which have shrunk significantly in size and scope (or disappeared altogether), TWI has grown from strength to strength. It has done so by maintaining its basic business model whilst internationalising its membership and accessing new forms of finance, such as EU Framework programmes or licence income. TWI regards its core strength as the size and range of its member firms. However, the resulting need to make its technologies and expertise available to all members, coupled with its not-for-profit status, has conflicted with its ability to create successful spin-offs and drives the decision not to exploit its IP aggressively through commercial licensing.

Roughly half of TWI's work is what it describes as 'market pull' – working on projects for its members on a single- or multi-client basis – and the other half involves responding to and investigating unexpected events, such as the failure of joints on a member company's gas pipeline, or supporting completely innovative solutions. It remains mission-driven, in that it plays an important independent role assuring the safety of infrastructure in highly regulated industries such as nuclear power, aerospace, and chemicals, but it also transfers technological innovations from one sector to another, for example proposing to a member textile company the potential of laser welding as a means of joining certain forms of fabric.

Case Study 11: The Formation of CIP Technologies

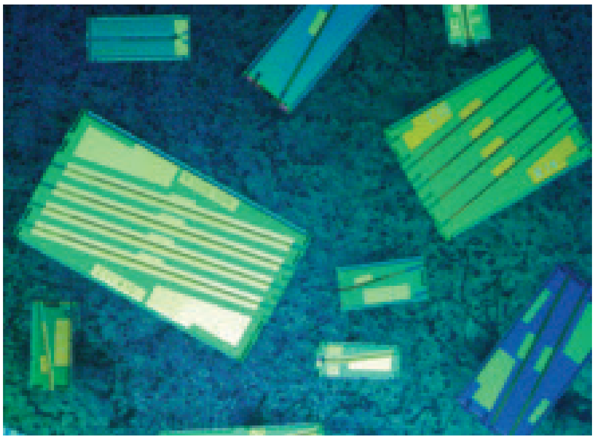


Image courtesy of CIP Technologies

In the mid to late 1970s BT established a photonics technology research group, which conducted world class fundamental research in fibre optics and generated two-thirds of BT's entire patent portfolio. But the technology was far ahead of BT's operational requirements and, as BT shifted from state ownership to being a service provider, photonics research was no longer a central priority. The lab's funding was steadily cut until 2000, when BT saw the opportunity to sell the entire photonics activity to Corning. At that point the lab employed 38 researchers and was conducting purely internal research costing BT some £2 million a year.

Renamed the Corning Research Centre, the lab's funding again came from the central research budget. As a corporate laboratory it worked closely with the Corning business units, developing opto-electronic devices and building prototypes for its captive customers with a focus on making products that could reach the market. Corning invested heavily in the research[52] and the headcount increased to 72 people, but when the telecoms market turned sour in 2002-3, after the technology bubble burst, the laboratory faced closure and all staff faced redundancy.

Not wishing to see the technology dispersed, but equally wanting to avoid the emergence of a competing commercial entity, Corning's technical managers worked with the lab's core scientists to reach a financial arrangement with EEDA, the DTI and the EPSRC that eventually re-established the lab as the Centre for Integrated Photonics (CIP) with the status of a company limited by guarantee. Under this arrangement EEDA took 100% ownership in 2003, and provided a tapering grant for the fabric and activities of the facility that, after five years, has fallen to zero. A key element in securing the initial viability of the centre was a major 15-month EPSRC collaborative research programme won by four universities, for which CIP acted as subcontractor.

When it was first established the Centre for Integrated Photonics played a non-commercial advisory role, funded by the EEDA tapering grant, sitting between universities and industry to aid the transfer of technologies from universities into industrial companies. As time passed the need to secure on-going funding reduced that intermediary role. Today it is a completely commercial entity with, for the first time, marketing & sales departments to complement the client-facing activities of its research scientists. Its expertise is relevant not only to the communications industry but also to defence, aerospace, biotechnology, nanotechnology and other industrial applications. From just six scientists in 2003, CIP Technologies has once more expanded to 42 staff. It achieved a turnover of over £3.5 million in 2008 derived from custom contract work; highly specialised opto-electronic component sales primarily to university researchers; collaborative research activity; and a decreasing amount of technical consultancy.

CIP Technologies has passed through a variety of ownership patterns, shifting from a captive central research-funded lab in a privatised state-owned utility, through an applied corporate research lab, to an independent technology organisation that relies on R&D contracts for one-third of its income and "*lives or dies*" by its IP, according to Michael Robertson, VP Research Programmes. Even though much effort is put into capturing the invention ideas of staff, as a small company it cannot afford to patent them all globally. Although licensing agreements were part of the original business plan, the current preference is to become a product-based company that develops (using customer contracts), manufactures and sells highly specialised indium-phosphide and silica-based components. Its main technology platform integrates these components into modules which are strongly aligned to the strategic direction of the telecoms industry for next generation networks at 1 Gb/sec and above.

52 As much as $20m, according to a contribution from BT to the Lambert Review of Business-University Collaboration.

transitioned into a successful commercial organisation. In contrast, neither TWI nor IFR has generated successful spin-offs, although TWI is undoubtedly a major international success story as a not-for-profit soft business.

Since the advent of Thatcherism, the Government's appetite for directly funding industry-facing intermediate research institutions has waned, with many government laboratories being privatised and no major new institutes being created. The old industry research associations have by and large declined as their members have become less competitive internationally and – unlike TWI – they have often failed to adapt their services to meet their members' technology needs. Government funding has instead focused on universities, where new, more applied R&D centres tend to be anchored. This is in stark contrast to many other successful technology-based economies, including Taiwan, Korea and Germany.

4.8 In Conclusion

This chapter has laid out a variety of ways in which the soft model can be applied in different industries, ranging from the highly transient (as in the software industry) through the 'classical' technology consultancy style to the long-term science-oriented work of the physics-based instrumentation sector. In the following chapter we examine the soft model from a different perspective: its key advantages at different stages of a firm's life.


Image courtesy of Tonejet Limited

Chapter 5: Importance of the Soft Model

Drawing on the discussion in Chapter 4 of the way the soft model is used in different companies and industries, we turn now to an analysis of the benefits it brings to companies at different stages in their development. These are: when a firm is in start-up mode; as a means of growing the firm; as a transition strategy towards a hard product model; and as a mechanism for exploring applications of platform technologies. (Appendix C provides a more academic overview of some of the literature on new firm creation and growth).

5.1 As a Start-up Model

Limited Investment

A key advantage of starting a business with very soft forms of activity, such as paper-based technical consultancy, design studies and problem solving, is that it requires very little initial capital or equipment. These activities often quite naturally lead on to contract development projects, where investment requirements can be minimised by borrowing or renting equipment and facilities, buying second-hand or persuading clients to purchase specialised equipment as part of the project. The biggest costs of the hard start-up – developing products ready to sell and funding a full team while customers decide whether or not to buy – are avoided. And this is helped by the ability of the soft start-up to tackle a wide range of projects. "*You can offer [clients] a lot more in a different, flexible way than in a bigger organisation*", as one interviewee notes.

Many of the companies discussed in the previous chapter began life in someone's back bedroom and the founders often sacrificed several months of salary, took out an additional mortgage, or contributed redundancy money to get their businesses started. Monthly (rather than quarterly) invoicing on contracts helps to keep the cash flowing, and once the firm has established a positive reputation it may even be possible to demand quarterly fees in advance, as Plextek is sometimes able to do.

Ideally the technology should be under-exploited from a market perspective, with growing demand and specialists in short supply: if the technology is nearing maturity it will rapidly become commoditised and there will be too many well-established organisations already occupying the market.

Relatively Easy to Manage

The structure of a soft start-up is generally very simple. It may involve only one or two people, or a couple of dozen, but they will all have a high degree of technical expertise in the chosen technology or group of technologies. All the founders are likely to be involved in every aspect of the business, including technical selling, project management and commercial negotiation as well as the execution of projects. These are basic skills that many experienced scientists and engineers develop during the course of their work in the corporate or academic world. The art for a soft company in approaching clients is to sell the project proposal, starting with just a PowerPoint presentation or, at most, a rough mock-up to illustrate the technology or product idea.

There is little requirement for specialist sales and marketing people, production management or quality control managers. And the simplicity of a business model based on selling and delivering 'time and materials' means that financial management is also relatively straightforward. Management complexity is significantly greater in hard companies where supply chains and distribution networks have to be built and managed, production expenses tracked and product quality controlled, as Cambridge Consultants found to its cost in its early days with its Advanced Instrumentation Modules electronics business. In contrast to soft start-ups, 'hard' product companies require a fully-fledged management team from the start, ideally with practical experience of the target market: when ARM emerged from Acorn to commercialise its

RISC processors an experienced CEO (Robin Saxby, former managing director of European Silicon Structures) was rapidly brought in; and when Cambridge Silicon Radio spun out of Cambridge Consultants, its management comprised a team of experienced engineers and commercial managers who had worked together on a variety of projects inside Cambridge Consultants for over 10 years, again complemented by an experienced CEO head-hunted from the semiconductor industry.

Provides a Means of Accessing a Wide Range of Client Companies

The role of sales and marketing in soft companies is to speak to a wide range of companies who might have problems the firm can help to solve, based on the team's earlier track record, contacts and expertise. This can take place right at the start of the firm's life, with little more than a PowerPoint presentation as collateral. And providing the firm can get the meetings there may be no limitation on the sector, geography, or position of the customer in the value chain.

Talking to potential clients provides an enormous amount of market intelligence very quickly, enabling the firm to refine its offer and refocus on areas where contracts are likely to be sold. As well as maximising the chances of early income, it also helps prevent a business strategy being developed based on misconceptions. Most hard start-ups end up selling products quite different to those originally planned. The soft model avoids the wasted time and investment this entails.

Enables an Unrestricted Product Strategy

A soft business model gives high tech start-ups a significantly greater degree of flexibility in the deployment of employee expertise than is the case in hard start-ups, where the goal is to bring a specific technological innovation to market as rapidly as possible. The soft start firm can take on a range of projects and contracts consistent with its capabilities, led by customer demand for its problem-solving skills. This is technology / innovation 'pull', in which close contact with a variety of customers enables exploratory R&D, i.e. the trying out of new ideas, techniques and solutions in a relatively risk-free manner for both sides: a project can begin small and move through progressive phases as technology targets are met and the client improves its understanding of the benefits or market potential of the development. Importantly, the ultimate responsibility for this role rests solely with the customer rather than the developer – it alone must bear the cost of getting this wrong.

Many soft companies are started with the idea of transitioning into a harder business model based around products or standard offerings, but there are often many potential forms that this could take. Different customers have different requirements, and it becomes possible over time to trial a variety of ideas to see which ones look most promising. And since the client is prepared to pay for an R&D contract, it must believe there is some value in that particular application. A soft company learns through interaction with multiple customers where the market is going, which are the areas of 'new' demand, and which are the skills required to deliver for it.

The risk for the soft company in the start-up phase, however, is that it accepts projects that are far from its core strategy, simply to bring in revenue. An unrestricted product strategy is not the same as an undisciplined 'strategy'. Some degree of focus must emerge if a company is to create a strong brand and benefit from economies of scale in marketing and delivery. Without this, margins and growth rates remain limited.

5.2 As a Growth Model

Allows Gradual Build-up of Capabilities and Market Understanding

New recruits usually bring additional skills or experience, and every new project builds credibility with customers or improved understanding of market needs. This process makes it possible for companies to take on progressively larger and more complex projects and to see bigger and bigger opportunities as their engagement with customers develops. For example, when Pi Research progressed from building wind tunnel instrumentation to continuous real-time in-car instrumentation systems, the technology problems its engineers encountered with the systems led to the company creating a highly-regarded customer service ethic that stood the company in good stead for much more ambitious future contracts. In its early days Symbionics built a strong understanding of the emerging DECT market by participating in European standard-setting meetings; despite its small size, it was able to influence these to its advantage and generate the knowledge base to enable it to move into more demanding technology development activities as the team grew.

Founders and managers also develop their individual capabilities. Tony Purnell, an engineer who was still doing his PhD when he founded Pi, gradually developed the skills necessary to manage a substantial business until its sale to Ford some 12 years later. Successful hard start-ups grow too rapidly for this learning process to take place. Scientists and engineers who found soft businesses frequently become chief executives of highly successful businesses. David Chiswell (CAT), Mike Lynch (Autonomy) and Gerald Avison (TTP Group) are examples from other sectors.

Exploits Creative Talent

A key feature of the soft company model is its ability to exploit to the full the talents of the most creative scientists and technologists. Everyone is creative to some degree and, by exposing scientists and engineers to customer problems, the soft company helps to harness and channel that ability. But in any science or technology company, or indeed in any research organisation, there is a small percentage of individuals – perhaps one in twenty or one in fifty – who are naturally inventive and able to generate far more good ideas than they can handle personally. Such people are often (though by no means always) quite difficult to manage. They may not necessarily be particularly good at presenting their ideas and they may not be particularly interested in the kind of tight project management and close attention to detail required to bring products to market. The soft model provides a way of harnessing the talents of these individuals, both by exposing them to multiple problems and by surrounding them with the complementary skills and resources needed to sell projects to customers and take them forward once funded.

All the major technology consulting firms contain a handful of individuals with these characteristics, and most successful new soft starts include someone who fits this category. A truly great mind (rather than merely a very bright one) is invaluable in exploiting opportunities presented by customers and circumstance. Early growth is often about surrounding these people with pragmatists who can 'get on with the job'. As Dick Newell expressed it, a firm needs to "*find its Michelangelo and then a bunch of people to paint the cherubs*". Tom Sancha was the exceptional mind behind the best innovations in PDMS, GINO-F and Bugstore for CADCentre, and behind Medusa at CIS – successes that enabled the later emergence of Smallworld.[53] But a failure to recognise the need for cherub-painters risks the super-bright scientists (the Michelangelo figures) turning employment interviews into a "*form of torture*" (as one firm recalled) in the attempt to hire more people as brilliant as themselves. All the same, the people who are hired are generally very bright: by one estimate TTP interviewed around 15,000 engineers over the course of two decades, of whom around 1,000 were hired. After ten years of exposure to consultancy work and to clients, only the very best 50 among those hired would have risen to senior management positions.

One way a firm can 'punch above its weight' is to build a network of associates, as 42 Technology has done. Its strategy goes beyond the practice of many soft firms who bring in contractors on a short-term basis to fill particular skill gaps or provide added resource on a specific project. Instead, 42 Technology relies on a range of other individuals and small organisations to complement its in-house staff of 17 people. Howard Biddle, CEO, believes that this approach enables the company to act as "*a conduit to a far broader and more interesting network than [clients] could gain access to on their own efforts*", which provides a "*far richer experience*" as well as enabling the client's contract to be "*resourced based on the skill needs of the project, not on who needs to be kept busy*". The more 'virtual' approach also helps to keep overheads low.

Facilitates Progressively Larger Projects as Resources Increase

There is always some size of project that is consistent with the resources a soft company can bring to bear. As the company grows – in size and reputation – it can gradually take on bigger and bigger contracts. Size also provides the flexibility to accelerate an important project by adding more resources, and clients may be more comfortable giving a sizeable contract to a firm of twenty people than it would to a two-man band. TTP's first projects included advising Lucas on acquisitions strategy, manufacturing consultancy for an IBM plant in Glasgow, and a multi-client project on development trends in ink jet printing. All of the consultants involved shifted from paper-based consulting into managing

53 Tom Sancha died in around 1990 of a brain tumour, diagnosed shortly before Smallworld was founded.

substantial technology development contracts as the team and its credibility increased. Monthly invoicing of fees for time is sometimes not available for larger development projects and it may be necessary to accept milestone payments, perhaps with an initial up-front sum. Growth, providing it is profitable and generates cash to finance working capital, makes it easier to accept these sorts of contracts, often as the stepping stone towards a harder, more scalable business model.

Permits More or Less Self-Funded Growth

Some soft start-ups, like Pi Research, Knowledge Solutions and Plextek, are entirely self-funded. In the IT sector the ability to develop high margin products to solve problems very quickly without up-front customer payments, as in the case of Neurodynamics, achieves the same end. In the case of the technology consultancies, there has usually been some modest level of start-up investment (£2 million spread across a start-up team of 29 in the case of TTP; £100,000 for the team of four who started Sentec). However, growth thereafter is typically funded from retained earnings. The corollary is that venture capital is much less readily available to pure soft companies, so self-funding is more or less essential.

For companies more narrowly focused around a particular technology, or with aspirations to move into product quickly, the range of contract opportunities may not be wide enough to fund a pure soft start, even though raising venture capital on this model is often difficult. Companies using a mixture of venture capital and customer contracts include Syrris in engineering and Argenta in drug discovery. Syrris raised funding from GSK's venture capital arm alongside an equivalently-sized development contract. In the case of Argenta the start-up team of around 20 was able to raise £6 million from venture capitalists. Most of this remained untouched several years into the business, but it nevertheless played a key role in reducing the risk to the founders, providing some cushion against 'feast and famine' cycles, and giving them the confidence to shift some resources into developing proprietary technology.

For firms seeking to exploit a platform technology with multiple applications, like Owlstone or TeraView, a more mixed model may be required. Up-front venture capital is almost essential, as the range of contracts available may simply not be wide enough to support a pure soft start. By 'softening' the business model with application-specific contracts they have been able to reduce the external funding requirement, explore different possible applications in parallel and focus on real market needs. However, it is doubtful – in the UK, at least – that they could have found sufficient contracts to operate an entirely soft model around their highly specialised IP. In the US, though, the SBIR programme and other federal government R&D procurement budgets would have made a completely soft start-up a much more tenable proposition.

Growth rates are slower in a successful soft firm than in a successful product company simply because the latter will enjoy economies of scale that a soft firm cannot. A soft firm grows mainly by adding highly talented people, since its key asset is brainpower – and it is generally recognised that 30% growth in revenues per annum is the maximum sustainable rate that can be achieved. This is not an attractive rate of growth for conventional venture capital funds.

Generates Cash for Limited Investment in IP

The basic soft company model essentially involves selling time, just like an accounting or legal firm. And if its expertise is highly specialised or in short supply, the firm's fee rates can be high. Providing utilisation (the share of total man-hours available that is charged to customers) is high and projects do not overrun, soft businesses can be very profitable. This makes it possible to invest in generating IP so that the hardening process can begin.

But unlike in an accounting or legal firm, even time not charged to customers can be put to good use by developing new product concepts, perhaps in response to discussions with potential customers, or by exploring how technology developed for one application can be applied in another. Even very modest sums can be used to turn these ideas into outline designs, collect basic experimental data, write patent applications and develop the commercial case. This 'evidence' can then be taken to potential customers to persuade them to fund the development. Presenting propositions pro-actively enhances the value of the development expertise offered to customers and can also lead to additional revenue sources through technology access fees, licences, milestone payments and, ultimately, royalties.

IP generated in this way can also form the basis of spin-out companies. But early spin-outs can be problematic, as Cambridge Design Partnership found when it spun out Astron Clinica very early in its history. Mike Cane now categorises internal development projects under three headings: "*ideas that are door-openers for consultancy; ones that could generate IP that could be licensed; and ones that could turn into businesses*".

Enables Technically Oriented Managers to Learn on the Job

When a young engineer or scientist joins a soft company he or she will rapidly become involved in more than just R&D work. Practically everyone is to some extent involved in client-facing activities, whether as a project engineer or scientist during progress meetings with clients, as a project manager concerned with presenting results and negotiating follow-on projects or, at a more senior level, in managing existing 'accounts' and meeting potential new customers.

Project management is itself a core competence of technology consultancies, and of the successful soft businesses in other sectors. Technology projects are highly risky and frequently involve multidisciplinary skills. Identifying key risks early,[54] breaking down the project into stages, efficient costing and managing to tight deadlines are all crucial to profitable operation. Temporary teams are formed time and time again to execute a specific contract, and through repeated experience project managers learn the subtle art of how to assess and deal with these issues across a wide range of situations. Successful contract R&D entails a great deal of uncodified knowledge about how to balance creativity with the need to deliver on a short time-scale.

By working with more experienced peers, people in soft companies – whatever their sector – gradually accumulate the experience to know and sell what is 'just' possible. And the broader the project base, the more enriching is the experience. In the 1980s PA Technology played a particularly powerful role in this regard, involving its scientists in projects ranging from consulting and due diligence studies to long-term technology development. As Richard Archer, founder of The Automation Partnership, puts it, "*you gain the ability to go out and sell something you haven't got, and talk strategically at senior level without feeling embarrassed about it even though you're a spotty engineer*". This gave Archer and many others like him the confidence not just to run bigger projects, but to engage with senior people in customer companies on a wide range of strategic and management issues facing their businesses.

5.3 As a Platform for Transition into Product

Mechanism for On-going Intelligence Gathering about Emerging Customer Needs

The level of on-going engagement between product companies and their customers is often surprisingly sterile, especially once the relationship has been established. Product sales people tend to be very focused on what they can sell in the short term; and buying decisions become routine and are usually made by people without a perspective much broader than their own responsibilities. But outsourcing R&D is rarely an easy decision. So, for soft companies, sales discussions take place at a more senior level in the customer, and the individuals they need to convince – in marketing, operations, or R&D – often have a very strategic view of the challenges facing the organisation and the new directions in which it might go.

Contact with many different potential customers through the fee-for-service business can lead to ideas that might eventually develop into a new product concept. Not all sales meetings result in orders, of course, but even if they do not, they provide the soft company with what Gerald Avison of TTP calls "*a sort of continuous, on-going market research process*". This can alert soft companies to emerging needs very early and help them refine their propositions or develop new ones. If enough companies in a sector mention a problem, it is probably a real one.

Sometimes this can enable multi-client projects to be put together. Myriad, an automated chemical synthesiser developed by TTP, was funded by a consortium of seven major pharmaceutical companies before the business was sold to Mettler-Toledo.

Modest Investments can Create an IP Revenue Stream

Investments to create IP do not need to be large to generate a significant revenue stream if the right business model and target area are selected. After failing to make money out of spin-off companies, Sentec opted to focus its IP creation activities on utility metering as its founders believed the high volume, low cost products required opened up good revenue potential. The key, of course, is the potential value to the customer.

54 It is often assumed that the right first step in any innovation project is to develop a prototype. In fact the first step should be to identify key technical risks and test whether these can be overcome. If not, there is no point in going further. This way of thinking runs in the bloodstream of successful soft companies.

Box 14: Creating an IP Revenue Stream at Sentec

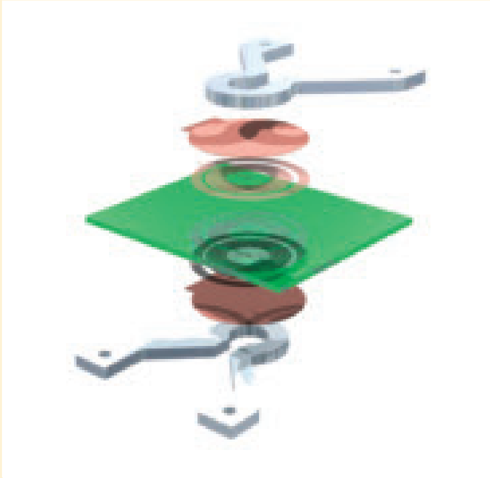


Image courtesy of Sentec Limited

Sentec set about developing a new approach to electricity metering, developing an initial demonstrator at the company's own expense from inexpensive, readily available components. When they showed this to meter manufacturers, it became clear they had misunderstood the target market. However, one company was a keen potential customer, so Sentec engineers persevered and came up with a new, more appropriate sensor design, again producing a demonstrator at the company's own expense and funded by revenues from other contracts. The customer was very attracted by the solution and rapidly signed an option agreement with Sentec. During a delay over the signing of the actual licence agreement (during which Sentec continued to earn option fees), it built a further, more complete prototype, again at its own expense, to win over the customer organisation's engineers. Once the licence was signed (for a fee of several hundred thousand pounds) the customer contracted the actual product development work for the meter to Sentec. Besides development fees, it also earned stage payments against milestones based on patents being awarded in different countries, followed by royalties when the new meter began shipping. A second metering product for water supply, prototyped in-house at an internal cost of £2-300,000 and licensed to the customer in 2005, was expected to start generating additional royalties. Sentec is already generating around 30% of revenues from its own IP, a share that is expected to grow.

Argenta Discovery's business model, although in the completely different industry of drug discovery, is remarkably similar to Sentec's. Originally focused on chemistry-based hit-to-lead and lead optimisation contracts that have allowed it to operate close to breakeven throughout its history, Argenta achieved a much sharper and more informed therapeutic focus for its internal drug discovery portfolio after its merger with pharmacology-based drug discovery company Etiologics, which focused entirely on respiratory diseases. This led within 30 months to a 'transformational' licensing and contract R&D deal with AstraZeneca on one programme that delivered $21 million on signing and potential total revenues from the deal of $500 million. The deal comprises a discovery contract, milestone payments and, if successful, a royalty stream. It has helped Argenta to accelerate investment in other in-house programmes and take some of them further along the development pipeline (creating more value) before partnering, and hence to move towards a 'harder' business model.

Argenta was roughly four times the size of Sentec when it made its first significant investment in developing proprietary IP, and in relation to size the level of investment was probably marginally greater, supported by modest additional investment by the VCs at the time of the merger with Etiologics. But the strategy and business model is essentially the same. Sentec is now interested in supplying products in volume, probably using a subcontractor to manufacture them. It is unlikely, though not impossible, that Argenta will take the next step to becoming a full product marketing company, as the investment entailed would be very large indeed.

Standard 'Products' can Emerge through a Variety of other Mechanisms

Sometimes a one-off bespoke development turns out to be something that can be resold to other customers. Indeed it was just such a project that led over nine years to the creation of The Automation Partnership as a hard company spin out from TTP. The trigger was a £400,000 contract with Celltech to develop a machine to replace a skilled manpower-intensive manufacturing process. Two years later TTP received a repeat order from another customer. Today TAP has sold over 100 similar machines to customers all over the world and developed a family of other products making it the world's leading cell culture automation company (see Case Study 12 in Chapter 6 for a fuller history).

Sometimes opportunities for a specialised product arise from discussions with a number of different companies who would be interested in being customers. If the costs are small it may be possible to finance this from retained profits, as was the case with TTP's Mosquito liquid dispensing system. If they are large, it might be possible to organise funding through a consortium of lead customers who are willing to contribute to design specification and testing, as in the case of TTP's Myriad automated synthesis system.

Many opportunities arise from 'orphan' projects, that is to say, projects for customers who discontinue funding for internal reasons, such as a need to retrench financially or refocus their business. It may then be possible to recover the IP involved and pursue exploitation as an in-house project, or find new customers with whom better IP terms can be negotiated, or move towards a spin-out. This was the impetus for many of Cambridge Consultants' spin-outs. For example, the original funding for its ink jet technology came from projects for ICI, the Post Office and other organisations. But when ICI lost interest, Graeme Minto saw the opportunity to take back the IP and launch a product business, Domino Printing Sciences, backed by venture capital and focused on a simpler application that could be brought to market relatively quickly. He was greatly helped by the emergence of European standards for date labelling of food products (see Box 17 in Chapter 7 for more details). A similar picture emerges from the story of how TTP Communications emerged from TTP Group (see Box 8 in Chapter 4). Hence the combination of capability building and market window is a crucial part of the picture.

5.4 As a Mechanism for Exploring Applications of Platform Technologies

Many of the most important breakthroughs in science and engineering are 'platform technologies' – that is to say, materials, devices, manufacturing technologies, or physical, chemical or biological phenomena with multiple applications. On their own they have no commercial value, but when turned into an instrument, built into a product or used to discover a new drug, they can sometimes open up entirely new business opportunities.

The challenge with platform technologies is to identify the applications that offer a genuine competitive advantage over competing technologies and ways of doing things. Conventional market research and discussions with potential user companies can only go so far; it is easy to express an interest in something that involves no cost. 'This could be really interesting for my company; come back when you are in a position to sell me one' may sound like a buying signal, but it is often just a delaying tactic.[55] A second problem with many platform technologies, especially where new materials, devices or manufacturing processes are involved, is that the time required to scale up manufacture is very long: often longer than originally envisaged or than can be backed within the conventional venture capital model.

The 'hard' company model forces companies to focus on one or two lead applications early. And this is reinforced by the short period in which venture capitalists have to make their return; it is common for VCs to force their investees to focus efforts too early, only to discover later that the strategy has to be changed when initial customer interest fails to turn into a volume market.

The 'soft model', if it can be applied, addresses many of these problems. The best market research a company can have is a contract from a customer to develop a product he needs for his business. The expenditure he commits to means he is far more likely to believe there is a real benefit and he will try far harder to specify all aspects of the functionality the development needs to deliver. This also enables the development team to consider how, and indeed whether, it can meet these goals. Well-defined customer needs give focus to technology projects and provide pointers to the way the market could develop. VC-backed companies exploiting platform technologies, such as Owlstone, often use contracts to augment VC funding and help them to judge where to place their effort.

The larger consulting firms also all have proprietary platform technologies around which they try to sell application development projects. Some have been able to use this model to finance the development of a new product business. TTP's Tonejet (see Chapter 4) is a prime example. Indeed, the ability to spread resources across projects and switch between them, depending

55 Direct intelligence gathering via interactions with clients is also a far better guide to market potential than standard market research methods through inexpert intermediaries, who can sometimes under-estimate the market. TTP's Automation group discovered this when first considering licensing the design of their automated roller bottle machine for cell culture: their proposed partner commissioned classic market researchers to conduct a market study, which revealed interest only at an unfeasibly low price. *"It just tells you that you can't do market research on something that's a bit novel since, as time passed, the market researchers kept encountering customers that told us there was no demand for this stuff, when we had already sold fifteen"* (Richard Archer, founding chief executive of The Automation Partnership).

on which ones are being funded at any one time, makes these broadly-based companies much better able than focused, hard companies to manage long-term platform technology developments.

5.5 In Conclusion

It is clear that the soft model brings benefits at various stages in a company's lifetime. The key requirements for success in the early phase of a soft company are high levels of specialist technical expertise in a technological field that is new or just developing, and individuals with the experience to know and sell what is just possible. The principal advantages of a soft start are the relatively limited financial resources required and an immediate prospect of revenue, without the early – and possibly disastrous – commitment to a specific product and market that a hard start-up typically faces.

In the growth phase the challenges are multiple, not least overcoming the 'feast or famine' problem. Since brainpower is the most important resource of a soft company there is a limit to how many projects can be taken on. It is difficult to juggle the balance of time spent on approaching clients for new work and actually delivering on the contracts that have been signed. And often problems arise when a big contract has been won, since so much effort goes into winning and executing it that there are no new projects waiting once it is over.[56]

Yet these challenges are relatively uncomplicated compared with the financial, production, market and personnel challenges immediately encountered by hard, product-based start-ups. A soft business model enables firms to conduct 'real world' market research, test and refine their technology proposition, build credibility with customers, and develop a robust and competent team of people. This reduces the risk of moving into product and enables more (possibly all) of the associated investment to be provided internally. Besides often leaving founders with greater control than in a pure hard start up, it can also enable more efficient 'execution' once the transition to a hard business model begins and hence an earlier start to product revenues. These factors can have an important impact on the longevity of a firm.

It should be emphasised, however, that the transition into a product business is not without difficulty. It may yet take years to acquire the deep applications knowledge required and the time to develop products is nearly always underestimated. Many smaller firms have fallen into financial difficulties in attempting to shoulder the investment burden themselves. And if scientists and engineers are pulled off customer contracts to work on proprietary product developments, or if management devotes less time to winning new contracts, there is a double setback as internal investment costs rise and revenues collapse. This is what happened when Cambridge Consultants went into receivership in 1970. Its problems were compounded by a weak management accounting system which meant that group management did not realise it was loss-making until it was too late.

Hardening into product also means new management skills are required – in functions such as marketing, finance, operations and general management – and a change of business culture also, as the goal switches from 'innovation' to rapid 'execution' to beat competitors and build global market share. Many soft company employees are not tremendously interested in doing the same things every day. Good product sales people are motivated by targets and a bonus culture that can have no parallel in a soft business. Trying to run the two cultures together, and devise motivation and reward systems appropriate to each, can cause conflicts.

External financing through venture capital and the formation of a spin-out company often play a key role in this transition phase, both in terms of mitigating financial risk and in allowing the creation of a culture and management team more appropriate to a hard business. For the original owners a key goal is to balance the size of the equity stake they retain with the risk reduction, speed of execution and revenue growth that can be achieved through external investment. The further the transition can be taken with internal funds, the larger this stake is likely to be.

Despite these challenges, it is arguable that a soft start-up, followed by a transition into product when resources permit, is much lower risk and more likely to be successful than the equivalent hard start-up.

In the following chapter we look at how the soft company model provides economic benefit to the East of England region.

56 In the enthusiasm to win 'the big project' costs and timescales are frequently underestimated. Surviving 'the big project' is a rite of passage for many soft companies.

Image courtesy of The Automation Partnership Lilimted

Chapter 6: Economic Benefits of the Soft Model

In this chapter we draw together the strands of discussion so far around the contribution of companies pursuing the soft model to the East of England region. In particular we consider employment, revenue generation and new firm creation; we also consider some of the less direct impacts. It is not possible to quantify the overall contributions in a systematic way; however we provide examples to illustrate their importance.[57]

In particular there may be significant job creation across the whole supply chain for a product developed by one of the region's soft companies. Volume manufacturing is not a major part of the economic landscape in the East of England region, and so that employment is largely generated elsewhere (and often overseas). We do not try to identify what portion of these wider economic benefits accrue to the region, or to the UK as a whole.

6.1 Overview of the Region's R&D Activities

The economy of the East of England region as a whole has been one of the fastest-growing in the country. Expenditure on R&D accounts for a higher proportion of economic output than in any other region,[58] with R&D performed by business highly concentrated in pharmaceuticals (25%), aerospace (16%) and computer and related activities (8%).[59] Many multinational companies have established research centres in the region, including several of the top-ranking companies in the Government's annual Innovation Scoreboard. Gross value added per head of £19,599 compares with the UK average of £18,631.[60] The employment rate is high relative to the rest of the country, and is above average in high-tech manufacturing (including medical equipment and electronics) and financial services, as well as in R&D.[61]

A report by PACEC[62] highlighted the relative concentration of the Greater Cambridge sub-regional economy in knowledge-based and high-technology jobs (see Table 2) – which included the manufacturing of sound and vision equipment, scientific instruments, rubber and plastics, and office machinery, in addition to the R&D, pharmaceuticals and computing activities referred to above. The total shown for jobs in the R&D sector excludes university research. Nearly one-third of employment in the Greater Cambridge area, or 115,000 jobs, fell into PACEC's definition of knowledge-based activity, within which it classifies around 46,000 jobs (13% of the total) as high-tech. It found that high-tech activity and employment is concentrated in Cambridge, South Cambridgeshire and Huntingdonshire, which is where most of our interviews took place. Many of the R&D jobs outside greater Cambridge are probably concentrated in large company facilities, which are unlikely to be working with a 'soft' business model as we define it because they will be serving in-house needs.

More recent data for early 2006 from Cambridgeshire County Council,[63] which included Peterborough in its analysis (unlike PACEC), broadly agree with the picture drawn by PACEC of the location, nature and employment of high-tech businesses, although the definitions vary slightly. But the data also show some decline in high-tech jobs since 2002, notably in computer hardware/office machinery – where jobs reverted to early 1990s levels – and even more so in chemicals and instrument manufacturing. The

57 In contrast a recent study by Oxford Economics of the economic contribution of the UK's intermediate research and technology sector estimated both indirect and induced impacts of its activity, in addition to the direct economic impact. It found that the total contribution to UK GDP in 2006 was around £2.4 billion. (See Oxford Economics (2008) Study of the Impact of the Intermediate Research and Technology Sector on the UK Economy.) Note that the study covers innovation centres and some university enterprise units nationally, in addition to the independent laboratories that figure in our research.
58 http://www.goeast.gov.uk/goeast/economy/.
59 Clayton, N. and Morris, K. (2009) East of England Innovation Baseline.
60 http://www.eeda.org.uk/266.asp.
61 Clayton & Morris (2009). Nonetheless, according to the State of the Regional Economy report published by EEDA in 2006, areas of employment and economic deprivation exist in the northern and eastern peripheries of the region. The same report highlights an east-west divide in terms of higher-level skills attainment, with Cambridgeshire, Hertfordshire and Bedfordshire containing some of the most highly-skilled districts in England while residents of Essex, Norfolk and Suffolk are on average far less well qualified.
62 PACEC (2003) The Cambridge Phenomenon – Fulfilling the Potential.
63 Cambridgeshire County Council Research Group (2006) Employment in the Hi-tech "Community".

Table 2: Knowledge-Based Industries and High-Tech Jobs (000s), 2001

	High Technology							Other Knowledge-Based				
	Pharma & other chemicals	Instruments electronics aerospace	Telecoms & electricity	Computing services	R&D	Contract design & testing	SUB-TOTAL	Printing & publishing	Education	Health	SUB-TOTAL	TOTAL
Cambridge	0.5	2	1	4	3	2	12.5	2	23	8	33	45.5
Greater Cambridge	5	11	4	12	7	9	48	6	37	27	70	118
East Region	24	61	40	58	19	37	239	38	196	149	383	622
UK	301	598	365	597	122	399	2,382	365	2,333	1,970	4,668	7,050

Source: PACEC

electronics engineering and biotechnology sectors have both experienced employment declines since 2004, partly due to merger activity that has sometimes led to the closure of local sites.

Large-scale employers in the region include BAE Systems, Ford, Raytheon Systems, Johnson Matthey, MBDA, EADS Astrium (formerly Matra Marconi Space UK), e2v Technologies, Northgate Information Solutions (acquired by KKR in 2008), Fujitsu Services, Kodak (although its Cambridge research facility, which opened in 2005, closed in 2009), GSK, Merck Sharp & Dohme, and Roche. The East of England has been by no means immune to the steady decline in the UK manufacturing base, and its manufacturing sector accounts for a lower proportion of economic output than is the case in most other UK regions.[64]

Work by Drofiak and Garnsey[65] indicates that Cambridge technology firms were attractive acquisition targets during the boom years – and the businesses acquired were vulnerable to job losses. They also found that the rate of high tech start-ups fell (compared with VAT registrations for all new firms) after 2004. In particular the reduced availability of venture capital affected the biotechnology sector. On the other hand the R&D sector continued to grow. New firms active in emerging technology sectors were seen as an important indicator of continued innovation and diversity in the local technology cluster.

The fact that the region's technology firms are attractive to foreign (and especially US) acquirers is by no means a new phenomenon. A speech by Matthew Bullock in 1983[66] emphasised the far greater interest and early involvement shown by American companies than by UK manufacturers in the small firms that had sprung up around the University of Cambridge, and their building of relationships as an acquisitive strategy – first through purchasing arrangements, then through equity participations and finally the acquisition of the entire firm – to gain access to technology while developing a market position. (Interestingly, Bullock also pointed out – over 25 years ago – the greater awareness of the capabilities of the region's technology firms gained by US government agencies, through their visits to the region, than was evident among their UK counterparts.)

Two principal policy issues arise from the above review of the region's overall economic condition. First is the problem of the acquisition of young technology firms by overseas companies, which then simply 'suck out' the acquired firm's technology, product or service into their own business lines and remove all autonomy from the founders who then leave. The acquiring firm may often then decide to close the site owing to lack of interest, a change of strategy, loss of an internal corporate champion or perhaps financial problems. Clearly not all acquisitions suffer this fate. It is nevertheless a common scenario, and in some cases acquisition opens up new opportunities.

How to retain promising young technology firms in the region is not a question that can be answered directly by this research. But the policies we argue for, including public sector procurement-based innovation strategies, could provide substantial growth opportunities and enable these firms to retain their independence for longer.

64 http://www.goeast.gov.uk/goeast/economy/?a=42496.
65 Drofiak, A. and Garnsey, E. (2009) The Cambridge High Tech Cluster: Resilience and Response to Cyclical Trends.
66 Reprinted in 1985 as 'Cohabitation: small research-based firms and the universities' in the journal Technovation,

The second policy question revolves around the diseconomies of scale suffered by large companies in terms of their effectiveness at innovation, and the impact of maturation and declining returns to 'mainstream' technologies: to what extent can young 'soft' firms benefit from these trends? Very large companies are arguably much less efficient at managing the upstream (applied research/discovery) elements of their value chain than smaller flexible firms at the cutting edge of technology, but nevertheless they possess significant resources – in volume manufacturing processes, marketing, distribution and sales, as well as in finance, equipment and people – that small firms generally lack. This often makes large companies better equipped to manage the later stages in the commercialisation of new technology. There are therefore national and regional economic policy arguments for large companies to be encouraged to outsource aspects of technology development to smaller specialist firms and, equally, for large companies to be helped to foster the development of small technology firms around their campuses – a strategy that EEDA is already pursuing with some of the region's large employers.

In the following section we consider the direct contributions that 'soft' companies currently make to the regional economy.

6.2 Employment and Revenue Generation by 'Soft' Businesses

We start in this section by providing data on direct employment and revenue generation in the firms and organisations discussed in Chapters 3 and 4. The data are derived either through interviews or from the publicly available FAME database (Tables 3 – 8). Where organisations no longer exist as independent entities, for example as a result of acquisition or break-up, we give data for the period immediately prior to that event.

Table 3: The Big Four Technology Consultancies

	Founded	Employees	Revenues
Cambridge Consultants	1960	263	£31.0m (2008)
PA Technology*	1970	200+ est.	£40.0m+ est. (2008)
Sagentia Group plc (Generics)	1986	224	£29.1m (2008)
TTP Group plc (The Technology Partnership)	1987	292	£37.8m (2009)

* Estimates based on contribution of PA's technology services to overall PA Consulting Group

Table 4: Smaller Technology and Innovation Consultancies

	Founded	Employees	Revenues
Team Consulting (medical devices)	1986	32	£3.6m (2008)
Symbionics (telecommunications)	1987	140	£12.0m (1997*)
Plextek (telecommunications)	1988	102	£29.0m (2008)
Cambridge Design Partnership (consumer and medical)	1996	43	£3.3m (2008)
Sentec (utility metering)	1997	28	£2.8m (2008)
42 Technology (fluids handling)	1998	17	£2.0m approx

* Last full year before sale to Cadence

Table 5: Drug Discovery / Life Sciences Firms

	Founded	Employees	Revenues
Cambridge Antibody Discovery	1990	284	£194m (2005, sold to AstraZeneca)
Chiroscience*	1992	330	£41m (1999, merged with Celltech)
Biofocus	1996	132	£15m (2005, sold to Galapagos)
Argenta Discovery	2000	144	£18m (2008)
Daniolabs	2001	33	£302,000 (2006, sold to Summit)
Sareum**	2003	33	£1.5m (2008)

* Chirotech Technology, sold before Chiroscience merged with Celltech, employed 47 people and had £30 million in revenues

** Services activity sold in 2008 to Biofocus/Galapagos NV

Table 6: Automotive / Aerospace Engineering

	Founded	Employees	Revenues
Lotus Engineering	1952	530	~£37m†
Pi Research*	1985	141	£11m (1998, sold to Ford)
Beru F1 Systems	1993	80 est.	£6m (2008)
Marshall Aerospace**	1930	~300	£201m (2007)
INSYS Group	1957	~490	£62m (2005, sold to Lockheed Martin)

† Engineering generates over one-third of Group Lotus revenues of £110 million.

* The entire Pi group (including Pi Technology) had revenues of £18.6 million and 228 employees in 1998.

** Estimated number of employees in contract design. Total employment in the subsidiary is 1543. Revenues are for the subsidiary as a whole.

Table 7: Instrumentation Businesses

	Founded	Employees	Revenues
TeraView*	2000	32	£2m (2008)
Syrris	2001	30	£2m (2008)
Owlstone Nanotech*	2004	33	$4m (2008)

* These companies pursue a mixed model.

Table 8: Intermediate Research Institutes and Associations

	Founded	Employees	Revenues
TWI	1946	585	£43m (2008)
CADCentre*	1968	~200	~£14m (1996, pre-IPO)
Olivetti Research Lab / AT&T Lab	1986	~60	n.a. (2002 closure)
CIP Technologies	2003	42	£3m (2008)

* Since IPO, the company (renamed AVEVA in 2001) has expanded to 660 employees and £128m in revenues.

We do not present a table for the software industry for two reasons. First, in 'pure' software firms the consultancy/client contract phase is often so rapid (even if significant in generating the revenue to fund a move to a standardised product model) that inclusion would distort the picture; and second, the data on software activities within firms discussed elsewhere are generally not separately available and have been included with those firms' overall figures. Nevertheless, as noted in Chapter 4, the games developer segment – which does rely heavily on contracts and services – is estimated to employ some 800 people in the region.[67]

The data in the tables above do not represent the complete picture of soft company employment and revenues in the region, since we were unable to collect sufficient responses from our large-scale survey to conduct a meaningful analysis. Nevertheless we are confident that, through interviews, we have captured the largest soft companies currently operating and the most important historical 'soft' players.

We cannot simply add up the figures for employment and revenues shown in the tables, since they refer to different time periods, yet it is clear that substantial direct contributions to the East of England economy have been made over the years by firms following to a greater or lesser extent a soft business model. The 'soft model' firms included in the tables that still exist as separate entities alone employ around 3,525 people and directly generated over £435 million in revenues in the last year. These figures represent the bare minimum contributions of soft model firms to the regional economy. These firms are among the most R&D-intensive in the region and generate significant multiplier effects.

Furthermore, the tables in many cases understate the overall contribution, since they reflect most recent data (or last independent data). Peak activity levels occurred earlier in the cases of several firms that have been acquired or broken up; and acquisition of other firms has apparently sometimes led to higher employment and/or revenue. The absorption of Meridica into Pfizer or Cambridge Antibody Technology into AstraZeneca, for example, does not mean that its operations ceased overnight, simply that a measure of its economic contributions is no longer separately available. Finally, particularly in the case of the technology consultancies, employment may peak shortly before a major spin-out occurs and take some time to regain the previous level (although there are also other economic reasons for falls in employment).

It is to the creation of new 'hard' product-based firms from these soft companies and their role in regional economic development that we turn next.

6.3 New 'Hard' Company Creation

Hard product companies established as spin-outs from soft firms are important contributors to the regional economy, since the successful ones among them often grow into larger businesses than their parent organisations.

'Sponsored' spin-outs from the Big Four technology consultancies employ over 5,000 people (Table 9 shows the latest year for which data are available). While comparisons are extremely difficult, this is almost certainly more than the number of jobs in science and technology spin-outs from the entire University of Cambridge over a longer period (see Chapter 8). Indeed, the major spin-outs from Cambridge Consultants alone directly employ over 3,500 people, well over 10 times the current number of employees in the firm itself, making it by far the most successful organisation in terms of creating businesses and jobs.

Research by Elizabeth Garnsey and Phil Macartney at Cambridge University's Institute for Manufacturing throws further light on spin-out performance, by comparing the level of success achieved by spin-outs from the Big Four consultancies and Cambridge University Engineering Department (CUED). Three of the consultancies (excluding PA whose encouragement of spin-out ventures is relatively new) generated 25 spin-outs over the last four decades, with seven having over 50 employees. In contrast, CUED spun out 68 firms over a 150 year period (including the historically important Cambridge Instruments, formed in 1861). However, only three employed more than 50 people.

Furthermore, there was a significant difference in patenting activity. Only 7% of CUED firms owned more than 15 patents, compared with 30% in the case of consultancy spin-outs.[68]

67 See www.gameseden.co.uk.
68 Comparing Spin-Out Activity from a University Engineering Department and from Commercial Consultancy, A Report by Phil Macartney and Elizabeth Garnsey – Work in Progress, Institute of Manufacturing.

Table 9: Sponsored Spin-outs from the Big Four Consultancies

	Latest Available Year	Employees	Revenues
Cambridge Consultants			
Domino Printing Sciences	2008	2,235	£253m
CSR	2008	1,049	£479m
Xaar	2008	329	£42m
Inca Digital	2009	179	£29m
Alphamosaic*	2007	153	£33m
TTP			
TTP Communications (inc. ip.access)	2006	697	£37m
The Automation Partnership	2008	159	£20m
PA Technology			
Ubinetics	2004	405	£23m
Meridica	2004	40	£3m
Sagentia			
Many small firms, none yet exhibiting sustained success			
TOTAL		5,246	£919m

* When sold to Broadcom in 2004 Alphamosaic had 57 employees and revenues of £13 million.

Excluded from Table 9 are some of the smaller spin-outs or packages of IP sold off to other firms. Among these are:

- Ely-based Kore Technology (analytical instruments), Pelikon (electroluminescent displays, owned by NASDAQ-listed MFLEX) and Vivid Medical (dry powder inhaler technology, now part of Vectura), all of which emerged from Cambridge Consultants;
- Wavedriver (electric vehicle drive system, joint venture ultimately sold to PowerGen) and Myriad (drug screening technology, sold to Mettler-Toledo) from TTP; and
- Imerge (digital servers, sold to US-based Linear), Sphere Medical (advanced medical monitoring equipment, established as a joint venture with Siemens, and which employs 50 people), Atraverda (advanced battery technology, with around 30 employees), and Sensortec (medical sensors, earning £5 million per annum in revenues) from Sagentia.[69]

As noted elsewhere, PA Technology has only in the last 10 years turned its attention to creating spin-outs.

The spin-outs from the major consultancies nearly all have their origins in a significant stream of client projects which have served to build both an in-depth understanding of the technology involved – its potential and its limitations – and a core team capable of exploiting it under a harder business model. This gives them significant advantages compared with university spin outs. The Automation Partnership Case Study illustrates this process.

69 Sagentia retains minority equity stakes in Sphere Medical (7%), Atraverda (7.5%), and Sensortec (9%).

Case Study 12: The Formation of The Automation Partnership

Image courtesy of The Automation Partnership Ltd

When The Technology Partnership was first established as a management walk-out from PA Technology, five of its 29 founder members constituted its Automation Division. Early projects were worth only £10,000 or £20,000 each but, in conjunction with Rosemary Drake, TTP's sole bio-scientist, they approached Celltech to see how they could help. Celltech had just won a contract to manufacture erythropoietin on behalf of Johnson & Johnson and because the approved manufacturing method was based on 'roller bottles' – a lab-based manual method of bio-processing – it faced recruiting dozens of degree-qualified bio-scientists to deliver the volume contracted. Conversion to the more normal bio-reactor manufacturing technology would have entailed years of delay whilst regulatory approval was obtained. Living cells are fragile organisms, but the TTP team was able to develop a precise automated version of the manual process. Indeed, because the process was now under software rather than manual control, it was possible to optimise it further.

The four automated cell culture machines TTP supplied turned out to be highly successful, yet conventional market research subsequently commissioned by TTP indicated that there was no wider market for them, at least not at an economic price. In fact it was not until some months later, when a Celltech employee attending a conference bumped into a scientist with US pharmaceutical giant Merck, that a repeat opportunity arose. Like Celltech, Merck had a big opportunity and an impossible scale-up challenge, this time to supply chickenpox vaccine for all US children. Celltech was happy to make the introduction to TTP and take a small fee. This led to a £3 million order for 11 machines, by far the biggest piece of business in TTP's history at the time.

Over its first five years TTP's Automation Division worked on custom projects in aerospace, packaging and electronics assembly, but it progressively focused its business on standard products for the pharmaceutical industry. This was helped by the close relationship built with Merck following the initial contract and for a period the TTP team was acting essentially as its new process technology development function, with up to 16 projects running simultaneously. All of those projects turned out to be one-offs, but they provided fee revenue and, by essentially creating a test bed, allowed TTP's Automation Division to expand its team, acquire new skills and explore new technological areas. It was also able to exploit these technologies elsewhere, if Merck was not interested in implementing them. Moreover, working with Merck – then the most respected company in the US – endowed its work with enormous credibility in the eyes of other clients. As Richard Archer, later TAP's chief executive, recalls "*There was all sorts of value in the relationship with Merck, and we were creating a variety of opportunities through that channel in terms of hidden market research and effectively free product development.*"

Another one-off contract from Wellcome for a large drug screening compound store opened up opportunities in another pharmaceutical application and revenues increased significantly from sales of similar systems to other major pharmaceutical companies.

As with other soft companies, the transition to products demanded quite different kinds of employees and raised difficult management challenges. Richard Archer continues: "*We needed workshop technicians, and dedicated sales guys who didn't do anything other than go out and sell [our products] although they weren't the people who invented the thing*" – these were people who could move the work from "*heroic one-off projects*" into a scalable (product) proposition. Establishing a different, more manufacturing orientated culture was one of the reasons for separating the business from its parent.

In 1998 TTP's Automation Division demerged from TTP Group to form a separate 'hard' company called The Automation Partnership (TAP) – initially with the same shareholders. Today it employs some 150 people, with annual sales peaking at £25 million, and is the world's leading cell biology automation company. The Cellmate product that gave TAP its original lucky break has gone through five redesigns and, with sales now approaching 100 units, is an industry standard. Over the years that product has been joined by a range of other products nearly all developed, rather like Cellmate but in a somewhat more planned fashion, with funding from one lead customer or occasionally a consortium.

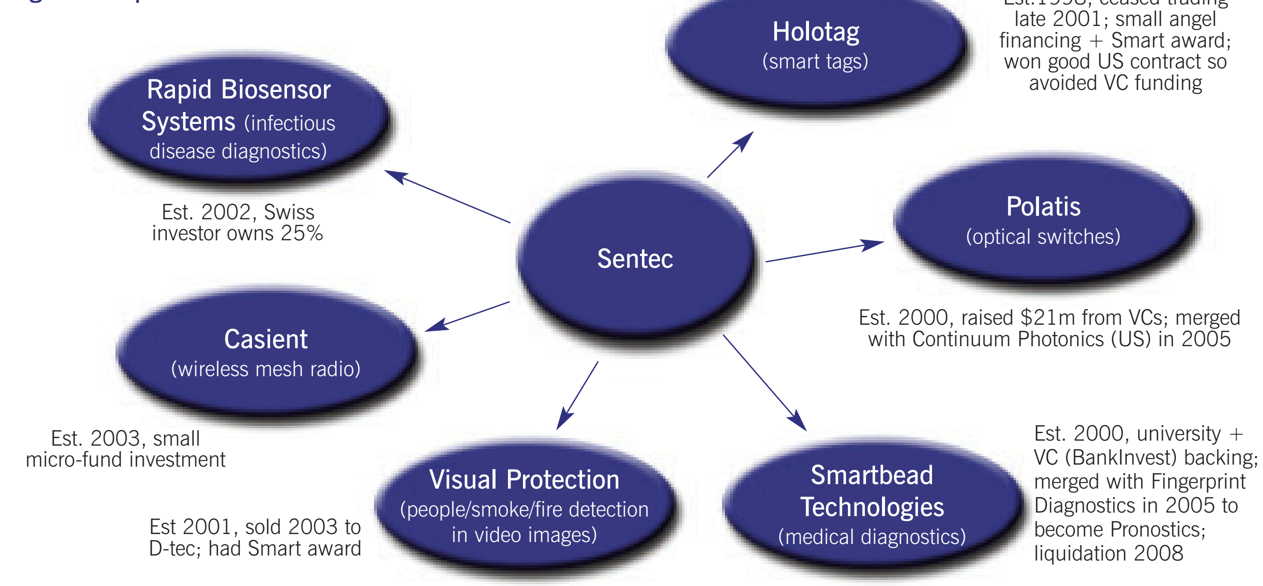
The more specialised consultancies also started to generate sponsored spin-outs, particularly in the late 1990s when venture capital was relatively easy to obtain and it was 'the thing to do'. But profits from these ventures have been elusive, and equity dilution means that the financial returns to the parent companies have been, or will be, very small. Some admit also that their technology was not sufficiently well developed before the new venture was set up and external funding sought. Many had probably not progressed much beyond a bright idea and a patent. During the early stage of these spin-outs, VC funding was used to develop the idea further, with the technology consultancy company typically acting as contractor to the spin-out venture.

Often key people leave with a spin-out. This happens also in the large consultancies, but the departure of a 3-4 man team is potentially much more damaging for a company of 20-30 people. Hence most of the smaller consultancies have now adopted a more restrained approach to packaging up and spinning out IP, preferring instead to develop the technology further with their own funds and then use a licence alongside a development contract or slowly build an in-house hard business to commercialise it.

Plextek, for example, began to incubate internally a telecommunications infrastructure business, Radiant Networks, in 1997 and then took VC backing – "*an extraordinarily painful experience*" that ended up with the venture being "*wrecked*" in 2001-2, in the view of Colin Smithers, Plextek's CEO. Its newer venture, Telensa (telemetry for automated electricity meter reading and for controlled street lighting) is being nurtured as a subsidiary and remains entirely self-funded. Sentec has similarly concluded that the risk/reward ratio for VC-backed spin-outs is not in its favour. Says Mark England, CEO: "*The dilution that we've seen from our spin-out companies that are still on the go has basically persuaded us that unless we can find some way of leveraging our position in the companies when they go through funding rounds it's not a very good way for us to make money*". Figure 9 indicates new firm creation at Sentec, showing no further activity since 2003. Two of its ventures were jointly owned with the University of Cambridge, with the University contributing facilities and staff to help with early development for its 25% share. Although spin-outs are seen to generate publicity for the parent firm, the low success rate and length of time it takes to generate a return are major disincentives for these firms.

Figure 6 (Chapter 3) and Figure 8 (Chapter 4) show the various ventures that came out of Enzymatix and Cambridge Interactive Systems (itself a walk-out from CADCentre), respectively. Symbionics also created several spin-out ventures, notably Symbionics Instruments (now owned by Tektronix), Accelerix (a joint venture bought out by MOSAID of Canada) and InTalk (ultimately sold to Nokia). After Cadence bought and then shut down Symbionics, some Symbionics engineers went on to found companies such as Nujira, Fen Technology, Cambridge RF, Commsonic and Ovus, all in the East of England region. As noted in Chapter 4, Steve Ives, founder of Huntingdon-based software consultancy Ives & Co, subsequently founded Trigenix (sold to Qualcomm in 2004) and, more recently, the mobile search provider Taptu.

Figure 9: Spin-outs from Sentec



Acorn Computers was the source of a very important firm in the local science and technology community, ARM plc, which grew from an internal project into a spin-out in 1990 and now employs over 1,700 people (see footnote 16 in Chapter 3 for further details). And in 1999 the rump of Acorn became Element 14, set up by Stan Boland and Simon Knowles with VC backing to develop and sell semiconductors for ADSL; by the time it was sold to Broadcom 15 months later for $540 million, Element 14 still employed just 68 people. After a couple of years at Broadcom, Boland and Knowles founded Icera Semiconductor, a fabless semiconductor company which is headquartered in Bristol, but has a design team in Cambridge (as well as teams in France and North America).

The Olivetti Research Lab (ORL), also originating from Acorn and set up after its acquisition by Olivetti, has generated several important companies for the region with VC backing. The biggest success was Virata, spun out in 1993 (although its acquirer, Conexant, closed the Cambridge site, shedding 80-90 people, and transferred its activities to India in 2004-5). Other ventures originating in ORL include IPV (video management software), Adaptive Broadband (broadband wireless, now owned by California Microwave), and Cambridge Broadband Networks (intelligent packet microwave). When AT&T closed the lab previously known as ORL practically overnight in 2002, ventures such as RealVNC, Level 5 Networks (now called Solarflare Communications) and Ubisense emerged. As discussed in Chapter 4, Ubisense joined forces with Tensails, set up by Richard Green and others from Smallworld, and now employs around 80 people.

Table 10 provides summary details of some of these spin-outs. The names of associated companies, i.e. not true spin-outs, but ventures created by former employees of a company, are shown in italics.

6.4 Other Direct Economic Benefits

As Table 10 suggests, East of England region firms have sometimes been acquired for high prices, and part of that wealth has remained in the local economy. Box 15 indicates the multiple economic benefits derived from Cambridge Consultants' spin-out companies alone. Of its 16 sponsored spin-outs, only two have failed – a very high success rate. Moreover, the internal rate of return on its latest batch of seven spin-outs was more than 50%, putting it among the star performers of early-stage venture backers.

Box 15: Economic Impact Generated by Spin-outs from Cambridge Consultants (as of 2006)

5 LSE-listed IPOs

3 high value trade sales

A combined market value in excess of £1.5bn

More than 2000 new jobs

At least 20 millionaires

Source: "Secrets of Successful Corporate Venturing", presentation by Ray Edgson, 13 November 2006.

In addition to the sponsored and less voluntary spin-outs we should also consider the impact of walk-outs. Among these is a team led by Nigel Playford, who left technology consultancy Generics to found first Cognito in the late 1980s, followed in 1991 by Ionica. The latter employed over 1,000 people at its peak and commissioned development work from a variety of technology consultancy companies in the region, including Symbionics and Plextek.[70] Having raised substantial sums of money globally and done an IPO in July 1997, Ionica briefly became Cambridge's first $1 billion company before crashing spectacularly in 1998 owing largely to failures of strategy and marketing rather than technology.

Numerous other examples of walk-outs from soft companies exist, many from the technology consultancy world, but also from intermediate research institutes such as CADCentre and even from industrial firms such as Lotus Engineering (from which small start-ups Scion-Sprays and Active Technologies have emerged).

6.5 Indirect Impacts

Our third category for consideration covers a diverse range of indirect economic benefits that the soft company model brings to the region.

Any attempt to estimate the overall value-added economic contribution for the technology consultancies is open to very large uncertainties; furthermore a high proportion of their clients (and the revenues of their UK clients) are outside the UK and therefore beyond the scope of the report. Nevertheless, a commonly-held

70 Plextek opted to forego part of its fees in exchange for an equity stake in Ionica and, not being 'locked in', was able to make a good exit when its client listed. Symbionics also provided some seed funding.

Table 10: Spin-outs from Firms with Soft Company Origins or Characteristics

	Founded	Employees	Notes
Enzymatix			
Celsis	1992	262 (2008)	Life science products and laboratory services supplier. LSE listed since 1993; HQ in Chicago following multiple acquisitions. Tiny East of England presence now.
Chiroscience Group		330 (1992)	Revenues £41m in 1999 before merging with Celltech.
Chirotech	1991	32 (2007)	Sold in 1999 for £89m to Ascot Holdings (part of Dow Pharma since 2001) and then to Dr Reddy's in 2008. In 1999: £30m revenues, 47 employees.
CAD Centre			
Bradly Associates	1973	n/a	GINO (graphic input-output) package commercialisation.
Cambridge Interactive Systems	1977	n/a	Sold in 1983 to Computervision for $25m; revenues were ~£2m.
Smallworld	1988	392 (2000)	Floated on NASDAQ 1996, sold to GE in 2000 for $210m.
Geneva Technology	1989	~440 (2002)	Sold to Convergys in 2002 for $600m.
Tensails/Ubisense	2002	78 (2007)	Merged GIS business into Ubisense (ex-ORL) in 2006.
Acorn Computers			
Active Book	1988	n/a	Hard start-up with funding from AT&T and Kleiner Perkins; pen-based computer to rival Apple's Newton. Bought by AT&T in 1991 for $40m.
ARM	1990	1,771(2008)	Revenues of £299m in 2008. Listed on LSE in 1998.
Element 14	1999	68 (2000)	Rump of Acorn. VCs invested $13m; high end ADSL microprocessors; sold to Broadcom in 2000 for $540m.
ORL/AT&T Labs			
Virata (original name ATM Ltd)	1993	92 (2001)	5 VC rounds raised $71m, NASDAQ IPO in 1999. Merged with Globespan in 2002, then with Conexant in 2004. Revenues were £30m in 2001. Cambridge site closed early 2005.
Adaptive Broadband Ltd	1998	49 (2000)	Bought in 2001 by Axxcelera (which was itself then bought by California Microwave). Fixed wireless equipment.
Cambridge Broadband Networks	1999	93 (2007)	Point-to-multipoint microwave for mobile broadband. VC backing, incl. $7.5m in Feb 2009.
Real VNC Ltd	2002	n/a	Remote control software/remote systems administration, sold under licence worldwide.
Adventiq	2005	n/a	System-on-a-chip for use with VNC software.
Symbionics			
Adherent Systems (original name Symbionics Instruments)	1994	43 (2001)	Digital video broadcasting test equipment. Spun out of Symbionics in 1996, bought in 2001 by Tektronix; still operates in Histon as Tektronix Cambridge.
Accelerix	1994	n/a	Systems-on-a-chip company. Originally 50/50 JV with MOSAID Technologies (Canada). Sold out of JV in 1999.
InTalk Inc.	1996	n/a	Prior to spin-out known as Symbionics Networks; wireless LAN components. California HQ. Bought by Nokia in 1999.
Nujira	2002	n/a	Founded by ex-Symbionics engineers; develops low-power amplifiers for wireless communications. Raised $18m in Series C funding in 2008.
Fen Technology	2002	n/a	Electronic design services for consumer, industrial, medical and automotive products.
Cambridge RF	2003	n/a	Design services and consulting to wireless communications and microwave industry.
Plextek			
Radiant Networks	1997	n/a	Mesh radio network. Angel funding then VC backing. Business failed.
Telensa	2002	2 (2007)	Tele-management systems for street lighting industry. Majority-owned by Plextek. £9m revenues in 2007.

view among the Cambridge technology firms is that the "*role of the technology consultants and the value they bring to the economy are not properly understood*".[71] Certainly when measured by the added value they create through ideas, concepts and designs for their customers' end products, their overall economic impact is far greater than the employment and revenue they generate directly combined with those of the spin-out firms they have incubated.

One example of the added value comes from the TTP Automation Division's delivery of four automated cell culture machines to help Celltech deliver on its manufacturing contract to produce the very expensive drug, EPO. Richard Archer recalls that their calculations showed that "*they were adding value at £40,000 per minute – better than Longbridge!*"

Other examples include the work on nanostructures done by PA Technology during the 1970s and 1980s, which led to the creation of companies such as Biacore in Sweden (which was bought by GE in 2006), and the work Sagentia did with AstraZeneca which is believed to have prolonged the life of the pharmaceutical firm's anaesthetic drug by nearly a decade.[72] Meanwhile, according to Bob John, CEO of TWI, the organisation's services and technology generate value added for its customers of the order of £1 billion per annum, compared with TWI's annual turnover of approximately £40 million.

These sorts of calculations are highly problematic. And specific examples of downstream added value must also be treated with care as there are usually a variety of factors at work and the development project itself may have had only a modest incremental effect. Furthermore, much of the downstream economic benefit frequently accrues outside the UK.

Nevertheless, it is clear that these 'soft' companies 'punch well above their weight' when it comes to the overall economic impact on the industries which they serve.

In sectors such as pharmaceuticals, aerospace and defence, where the UK is relatively strong, their contribution to the broader national economy is likely to be significant, even if it cannot be easily measured; for example, through the provision of specialist chemistry and biology services to established pharmaceutical companies that increase their effectiveness in discovering new drugs and bringing them to market.

Soft companies also play a key role within the 'cluster' as a whole, by helping other high technology start-ups access experienced development teams which they might not otherwise be able to afford or recruit quickly enough. Examples include Plextek's and Symbionics' work for Ionica, and Sentec's work for Owlstone.

Spin-out ventures also undoubtedly go on to create further jobs and value added among their suppliers and customers, even if their direct employment is relatively low. For example, as a fabless semiconductor company Cambridge Silicon Radio (CSR), the spin-out from Cambridge Consultants, has grown into a company of around 1,000 people. But many further silicon fabrication jobs are located in Asia, and even more in the many companies – nearly all of them foreign – that build CSR chips into their products. The same argument can be made for ARM, which emerged from Acorn: its turnover (£299m in 2008) is entirely based on royalties earned from licences for the chips that power the Apple i-phone, mobile phones, digital cameras, computers, set-top boxes and a host of other devices produced worldwide.

The virtual disappearance of sophisticated electronics and telecommunications manufacturing from the UK means that in these sectors most upstream and downstream jobs are being created overseas. But it shows that the power of the soft company model in rejuvenating the manufacturing sector and creating jobs in the UK could potentially be very much greater than the purely direct effects.

It is certainly apparent that over the last fifty years these companies have been able to reconfigure their skills base and strategies to take advantage of new waves of technology and pioneer developments in new industries as they emerge. But this raises two important policy questions. First, could more be done to encourage the location of commercially viable downstream manufacturing and assembly operations in the UK? And second, are there specific sectors in which the soft model could lead to these activities being more likely to be located in the UK? In particular, could R&D contracts for public sector customers play a role in this regard, in the same way that contracts from private sector customers have clearly done?

71 Interview with Ray Edgson, CTO and Ventures Director, Cambridge Consultants.
72 Communication from Gordon Edge, founder of PA Technology and of Scientific Generics (Sagentia).

6.6 Building Social Capital in the Region

Besides the direct and indirect economic benefits that derive from employment, there are several other important ways in which soft companies (as opposed to other forms of enterprise) contribute to the region's capacity for economic development.

The first is their contribution to developing a pool of technology entrepreneurs and senior managers. This is most noticeable in the technology consultancies, where the work load is both demanding and highly varied, and where the most creative people can flourish. These firms effectively act as what Ray Edgson of Cambridge Consultants calls "*a finishing school for engineers*", providing skilled technologists with the training that some of them will choose to use in a spin-out venture, where they will be standing on their own feet rather than surrounded by the infrastructure and specialists provided in a big company. De-risking the technology, building team skills, and working together over several years are crucial aspects of that preparation. The very nature of technology contract work provides opportunities for individuals to sort themselves into those who are content to remain technologists and those who want to be technology-entrepreneurs.

Because technology consultancies are able to get other people to pay them to solve difficult technological problems, their people are also rather competent. "*These are all great ingredients when you're looking for a venture",* says Edgson. *"You are ticking the due diligence boxes in some of the most tricky areas that you face within an early stage spin-out: there is evidence of commercial need, because a client is coming to us to provide a relatively expensive bespoke solution having found there to be no off-the-shelf option; and you have people who know enough about it that they are managing to sell their time to help somebody else solve the problem.*" But those who do go with a spin-out team self-select; it does not work if they are forced to join. And what a venture capital backer looks for is a complete, or nearly complete, team which usually comes pre-assembled in a soft company spin-out.

Moreover, evidence of successful previous spin-outs helps to attract to the originating company new, bright and motivated recruits who want to work in a dynamic commercially-oriented environment. So, even though the founders of spin-outs may not return, a virtuous circle around entrepreneurial activity is created.[73]

Besides providing an environment in which to grow the management of their own ventures, soft companies are also an important source of talent for other new ventures, providing many key players throughout the Cambridge cluster and beyond. The larger consultancies also operate their own venture funds, which invest in external companies or provide partial backing for selected in-house ventures. And they have spun off independent funds (like Prelude, from Cambridge Consultants) and provided many of the key staff for others.

It can also be argued that the soft start model leads to greater longevity. Clearly the technology consultancies and intermediate research institutes like TWI have been in existence for many years – nearly half a century in the case of Cambridge Consultants, for example, with its business model largely unchanged, but evolving and spinning off businesses steadily. But many of the harder businesses spun off from these firms have also been around for many years. Domino Printing, spun out of Cambridge Consultants in 1978, is a prime example. There is also evidence that hard companies built through a soft start model have been able to develop further and last longer than most VC-backed start-ups. Examples include ARM, Pi Research and Autonomy.

The comparison with VC backed firms, usually focused on a trade-sale exit to a much larger international company, is important. Once a business is sold, there may be little rationale for the acquirer to invest in further development locally, other than incremental development of the product line it has bought. And the opportunity for the local company to spot and exploit new opportunities entrepreneurially from its engagement with customers may largely disappear as decision-making moves to the acquirer. As a result, founders usually move on after completing their one or two year lock-in period. Closures as a consequence of poor results, loss of interest, or a change in strategy by the acquirer are common.

Many of the founders and employee shareholders in successful new ventures often become angel investors in new enterprises once their own business has been sold or has IPO-ed.[74] The advantage of the soft model is that it minimises the dilution of founders' shareholdings; even if a company needs to raise venture capital, the pre-existence of a revenue stream

73 On a more problematic note, jealousies can emerge when some people in a team are left behind.

74 Cambridge has a vibrant community of angel investors, of whom many with a high-tech background also lend their experience as advisors or non-executive directors.

and reference customers means the valuation can be higher, and on-going contract revenues reduce the amount of capital that needs to be raised. The major angel investors in the Cambridge technology community have nearly all managed to build their business with little or no venture capital, often using some form of soft model.[75]

6.7 In Conclusion

Soft companies are essentially about earning a living from R&D. Their primary income source is commercial customers with some form of innovation need. But their contribution to the regional economy really becomes significant through the scalable product businesses they spin-out or transition into. The ability to fund some of their own R&D and retain IP ownership is critical to this process, and it is therefore important to understand the role that government plays – or could play – in supporting these transitions. If, as we have argued, soft businesses and soft start-up models are highly effective at creating economic growth, it is vital that government policies be designed to support them.

From the above it can be seen that firms pursuing a soft business model contribute to economic growth and development in multiple ways. Consultancy and contract development companies provide an ideal environment in which to incubate and exploit new product opportunities, including those that are too small or too long-term for venture capital alone. They also represent a resource for early-stage product companies that need to subcontract development activity, as well as for the well-established local and multinational companies requiring innovative solutions to tricky technological problems.

And we see many of the same benefits arising in more focused companies – such as Pi Research in automotive, Cambridge Antibody Technology and Chiroscience in drug discovery, and Cambridge Interactive Systems in software – where the soft approach has brought multiple strategic benefits, as well as generating for their founders sufficient wealth to be able to play a continuing role in founding, funding and advising further businesses.

In the following chapter we consider different sources of government funding for technology development and discuss how the firms we interviewed regard them.

75 In contrast, the scientists and engineers who found hard start-ups may end up ‘well off’ when their businesses are sold, but the stakes they own are rarely sufficient to make them wealthy enough to become big angel investors. This is because of the punitive dilution resulting from significant VC involvement and the prevalence of ‘down rounds’ in science-based companies with long gestation periods.

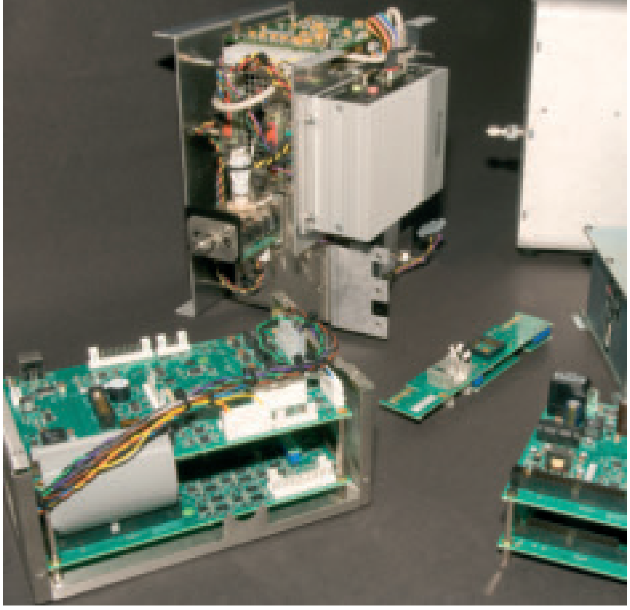


Image courtesy of Owlstone Nanotech Limited

Chapter 7: Government Funding for R&D in Firms

This report is primarily concerned with R&D contracts carried out by businesses for other, usually larger, corporate customers. As a business model this has in the past played, and continues to play, a critical role in the success of the Cambridge technology cluster, and it is also widely used by science- and engineering-based companies elsewhere in the region. But, as we have seen, the biggest potential that soft companies have for job creation is through the establishment of harder, product-based spin-outs constructed around proprietary concepts and IP incubated within the parent businesses.

At the same time, the extent to which soft companies have been able to make these transitions varies considerably. Some IT businesses like Acorn and Autonomy were able to move through the soft phase and develop proprietary products very quickly and with minimal investment in IP. Cambridge Consultants, TTP and PA Technology have all been able to spin out separate businesses on the back of orphan projects for customers and/or re-investment of profits generated from the core soft business. Usually this process has taken several years as technical competence and market understanding is built up through customer projects. On the other hand, the smaller consultancies, lacking the profits to invest in in-house R&D, have found it much more difficult to create successful product spin-offs. And some of the largest soft businesses in the region – Lotus Engineering and TWI – have also failed to generate significant spin-outs at any time in their history.

For all of these businesses, the trigger for beginning the transition from a soft to a hard business is the ability to retain IP and fund the development of proprietary products. We have therefore tried to examine the extent to which government policies support this process.

In this chapter, following an overview of current policies, we look first at the use that the firms in our study make of single-company government R&D grants, which are currently administered through the regional development agencies; second, we discuss firms' participation in collaborative research programmes such as those operated by the Technology Strategy Board; third, we explore the availability of government R&D contracts; and finally we assess briefly the role of R&D tax credits in encouraging R&D activity.

7.1 Current Government Programmes to Fund R&D in Companies

There are five principal ways in which government supports R&D projects financially.

(i) R&D Tax Credits: these enable any firm to offset a multiple (currently 1.75 for SMEs) of all R&D costs against corporation tax or (for firms not yet generating profits and therefore not paying tax) to claim most of this as a cash payment at the end of the financial year. The scheme costs HM Treasury over £600 million per year, roughly one third of which goes to SMEs,[76] and is therefore by far the most significant source of R&D funding in aggregate terms.

(ii) Single-company Grants for R&D: these have existed for many years and since 2003 have been administered by the Regional Development Agencies, rather than nationally. They are awarded competitively against project proposals and in England and Wales currently cover up to 45% of costs for Micro projects up to £20,000 (for businesses with fewer than 10 employees), up to 60% of costs for Research projects up to £100,000 (for businesses with fewer than 50 employees), and up to 40% of costs for Development projects up to a maximum of £250,000 (for businesses with fewer than 50 employees, or up to 35% of costs for businesses with 50-249 employees).[77]

76 See www.hmrc.gov.uk/stats/corporate_tax/rd-accrualsbasis.pdf.
77 The much more recently introduced Proof of Concept grants are related but different, in that they mainly fund market research rather than product development. These awards cover up to 75% of costs for projects up to £20,000.

Since April 2003 £130 million of grant funding has been awarded to nearly 1,700 SMEs. Total government expenditure in the 2007-8 financial year on R&D grants in England was around £25 million. Of that total, some £2.7 million was awarded within the EEDA region.

(iii) UK Collaborative R&D Grants: collaborative R&D programmes have also been in existence for many years. Previously known as LINK projects and administered by the DTI, they are now managed by the Technology Strategy Board (TSB). Competitions and specific themes are announced at intervals during the year and awardees have to be consortia, typically including both companies and universities. UK collaborative grants typically limit the proportion of overall project costs funded to 50%, varying from 25% for 'experimental development' (i.e. relatively close-to-market projects) involving industry and academic partners, up to 75% for 'basic research'. Within this, universities are 100% funded and SMEs for up to 60% of their eligible project costs, so larger companies typically receive a lower proportion. Between 2004 and June 2007 in excess of £1 billion in combined business and government investment was spent on a portfolio of over 600 collaborative projects.

(iv) EU Framework Programmes: these mainly fund 'pre-competitive' collaborative projects involving big consortia of partners from different countries. The competitive model is similar to TSB programmes, but more complex. The funding rules for universities and companies have tended to be broadly the same, with more generous terms for SMEs in the most recent round of competition. The FP7 programme has a total budget of €50.5 billion over its 2007-2013 life. In 2007 some €753 million of EU funds were awarded to (multi-year) collaborative R&D projects in the UK, equivalent to 14.5% of all awards to EU members. Around 19% of SME applicants from the UK were successful, and they collectively received 18% of the requested EU contribution.

(v) Public Sector R&D Contracts and the Small Business Research Initiative: For many years the UK Government has advocated the role of public procurement in stimulating innovation, a call echoed at EU level. The main mechanism for achieving this is the Small Business Research Initiative (SBRI), which was introduced towards the end of our research.

7.2 Evolution of the UK's SBRI Programme

The UK SBRI was launched in 2001 by the DTI with the aim of encouraging UK government departments to award R&D contracts to small firms. It was designed as a procurement-based programme giving 100% funding of developments, rather than as a grant initiative giving partial funding. However, few government departments participated (the most noticeable was the Biotechnology and Biological Sciences Research Council), the total value of contracts reported never exceeded around £2 million per annum and, with the exception of the BBSRC, few if any were for technology development – as opposed to policy research, for example.

Following a campaign launched in 2004 for the UK Government to introduce a more effective programme based on the highly successful US Small Business Innovation Research (SBIR) programme,[78] a commitment to provide £100 million per annum to SMEs through the UK SBRI (Mark 2) was announced in the March 2005 budget, and spending departments were set expenditure targets of 2.5% of their external R&D budgets.[79] (Box 16 outlines the main features of the SBIR programme in the US and Case Study 13 highlights how Owlstone has used it.)

Between 2006 and 2008 roughly 200 SBRI contracts were advertised on the Supply2.gov.uk web site, with topics ranging from university research calls (for which companies were ineligible) to lawnmower maintenance. Few, if any, were for technology development contracts with firms. The well regarded BBSRC programme was axed in 2006 in favour of a new 'Small Business Research' initiative covering all Research Councils. Although this was promoted on web sites and in publications, it appears that no projects have ever been advertised or placed under the scheme.

One reason for this disappointing response is that the 2.5% target was interpreted by DTI as a target for the percentage of all external R&D expenditure to be spent with SMEs, rather than the value of development contracts placed through the SBRI scheme. Based on US experience an appropriate target for the former figure would be very much larger than 2.5%, probably

78 The campaign was launched by David Connell, one of the authors of the current report, and Anne Campbell, then MP for Cambridge. See Connell, D. (2004) Exploiting the UK's Science and Technology Base: How to Fill the Gaping Hole in UK Government Policy, which has a Foreword by Anne Campbell MP.

79 This is the same formula as used to set the US SBIR budget. However, the SBIR is run as a ring-fenced seed fund rather than as a targeting process. Furthermore, SBIR is just one of many ways in which federal R&D contracts are awarded to small US businesses, and is designed to help them get onto the first rung of the federal procurement ladder. The total value of R&D contracts awarded to small US firms is several times higher.

Case Study 13: Owlstone Nanotech

Image courtesy of Owlstone Nanotech Limited

In the case of Owlstone an American PhD student in Cambridge, Andrew Koehl, was determined to start a business likely to be fundable through the US SBIR programme and, with fellow electronics engineering colleagues Billy Boyle and David Ruiz-Alonso, sought out a suitable technology. In the post 9/11 era they settled on the idea of an electronic nose to undertake chemical detection for homeland security. Based on Koehl's invention of a way to miniaturise field-asymmetric ion mobility spectroscopy, he began submitting SBIR proposals with the intention of setting up a business in the US after his PhD. At the third attempt he won a Phase 1 SBIR award worth $100,000, but by that time the three of them were already runners-up in the 2003/4 Cambridge University Enterprise business plan competition using feedback from the failed SBIR attempts to help refine their proposition. That success led to meetings with VCs and in May 2004, after a chance encounter in a college bar with the young CEO of a new VC fund, to a $2 million investment from Advanced Nanotech, which was just raising a fund and needed a first investment for its portfolio.

Advanced Nanotech was a small but unusual fund in that it was interested in investing at a much earlier stage than conventional VCs, including in university projects. Although its other investments have been largely unsuccessful this was a stroke of luck for Owlstone, as it immediately gave the young company access to the kind of funding needed to progress its start-up plans.

Owlstone decided to stay in the UK, and so was unable to take up the SBIR funding. Over the next two years the team worked to validate the technology, file patents and build the team. Some early electronics development was outsourced to Sentec, but as the team increased in size it became progressively self-reliant.

It was evident that there were many potential applications of the technology and Owlstone attempted to soften the strategy by securing development contracts with industrial customers. This was initially unsuccessful as the companies targeted were more used to buying already-developed boxed solutions, so it had to continue to rely on venture capital and US private investors for funding. By 2008 it had raised over $9 million. However it also started again to apply for SBIR contracts, helped by its unusual, predominantly US ownership structure and, to some extent, by the decision to establish a Delaware holding company so that the company could be floated more easily on a US stock exchange at a later date. In 2005 and 2006 Owlstone won two Phase 1 SBIR contracts (e.g. from the US Air Force for air quality monitoring in jet fighter cockpits) and also began working with prime defence contractor SELEX Galileo, which was looking for a sensing technology provider. Over the period 2006-8 SELEX paid Owlstone over $1 million in contract development funding. In 2006-7 Owlstone began shifting towards a sales-based business with three revenue streams: instrument sales, contract development, and sales of sensors to third parties. It also in late 2007 won its largest development contract to date with the US Defense Threat Reduction Agency, worth $3.7 million over three years.

Since Owlstone's sensors can be used in many different applications and the sector-specific knowledge for each is so different this has, interestingly, pushed Owlstone towards a softer model: *"We now only work with a lead customer prepared to fund application R&D, as this is the key test of whether there is a real market opportunity"*, comments co-founder Billy Boyle. By 2008 Owlstone's team of 33 people (including three in the US) were generating $4 million in revenues, of which half derives from R&D contracts.

Box 16: The US SBIR Programme[80]

Ever since the Second World War, the US government has played a major role in funding the development of new technologies in companies through procurement contracts. US pre-eminence in semiconductors, computers and many other technologies is in large measure due to this policy. The Small Business Innovation Research programme was launched in 1982 to ensure that start-ups and small companies get the opportunity to participate in this process.

Underwritten by legislation, the SBIR programme requires all larger federal agencies to spend 2.5% of their external R&D budgets with small firms through a highly transparent competitive process. Under this programme each agency announces its requirements as topic solicitations at set times in the year. Successful bids initially win a $100,000 Phase 1 feasibility study. Roughly half of these go on to win a Phase 2 award, typically worth $750,000, aimed at taking the project to demonstrator or prototype stage. Companies are paid 100% of their project costs plus a small profit element, and they keep any intellectual property developed. Multiple awards are common.

The SBIR programme is worth over $2 billion annually and makes over 4,000 awards each year. All larger US government agencies participate, from the Department of Defense to the National Institutes of Health and the National Science Foundation (equivalent to the UK Research Councils), so most small companies can expect to find a topic advertised by one of the federal agencies that they could use to fund the development and trialling of their technologies. Awards are linked to public sector customer requirements, and details of the topic, awardee, and awarded amount are published on the internet.

The SBIR programme has become known as 'the world's largest seed capital fund' and is probably more important than venture capital in funding very early-stage technology companies in the United States.

However, SBIR is just one way in which early-stage firms can win R&D contracts for the US government. More substantial contracts are available through Broad Area Announcements, SBIR Phase 3 follow-on projects (not included in the $2 billion SBIR budget) and unsolicited proposals. The SBIR programme is designed to provide just the first step on the procurement ladder.

by four or five times. Between 2006 and 2008 the DTI, and later BERR, published statistics indicating that, on average across departments, the value of R&D contracts awarded by government to SMEs exceeded the 2.5% 'target' by a considerable margin. However, the basis of the figures was never adequately described and their credibility was further called into question as the total reported figure fell steadily from £509 million in 2003-4 to £137 million in 2006-7. One aim of this research project was to shed some light on the real value.

In the meantime, after further lobbying, the failure of SBRI Mark 2 was acknowledged in Lord Sainsbury's review of science and innovation policy[81] and a revitalised SBRI (Mark 3) was announced simultaneously by the Treasury, DIUS and BERR in April 2008. The new programme is closely modelled on proposals made by David Connell[82], but without either an explicit ring-fenced budget or Treasury guidance to individual spending departments on the appropriate size of their financial commitments. The Technology Strategy Board was made responsible for championing SBRI and for coordinating its introduction across spending departments.

By October 2009, there had been 17 SBRI competitions, 956 applications from companies, and 269 Phase 1 contracts awarded with a total value of £8.8m (and with more contracts in the pipeline from closed competitions). However, with the exception of one or two pilots, all of these competitions took place after our interviews with companies.

The number of SBRI awards made to date is highly skewed by a number of very small awards (around £10,000 each) for Phase 1 demonstrator projects to reduce CO_2 by retro-fitting social housing, as well as some other low value competitions. Furthermore a number of important government departments are not yet using SBRI, including the Department of Business,

80 For more details, see Connell, D. (2006) "Secrets" of the World's Largest Seed Capital Fund.
81 Lord Sainsbury of Turville (2007) The Race to the Top, A Review of Government's Science and Innovation Policies.
82 Connell, D. (2006) "Secrets" of the World's Largest Seed Capital Fund.

Innovation and Skills (which through the Research Councils could play a key role in funding the development of innovative research tools), and the Department for Energy and Climate Change. The level of commitment from some other departments for whom SBRI should be highly relevant, such as Transport and the Home Office, has been very small.

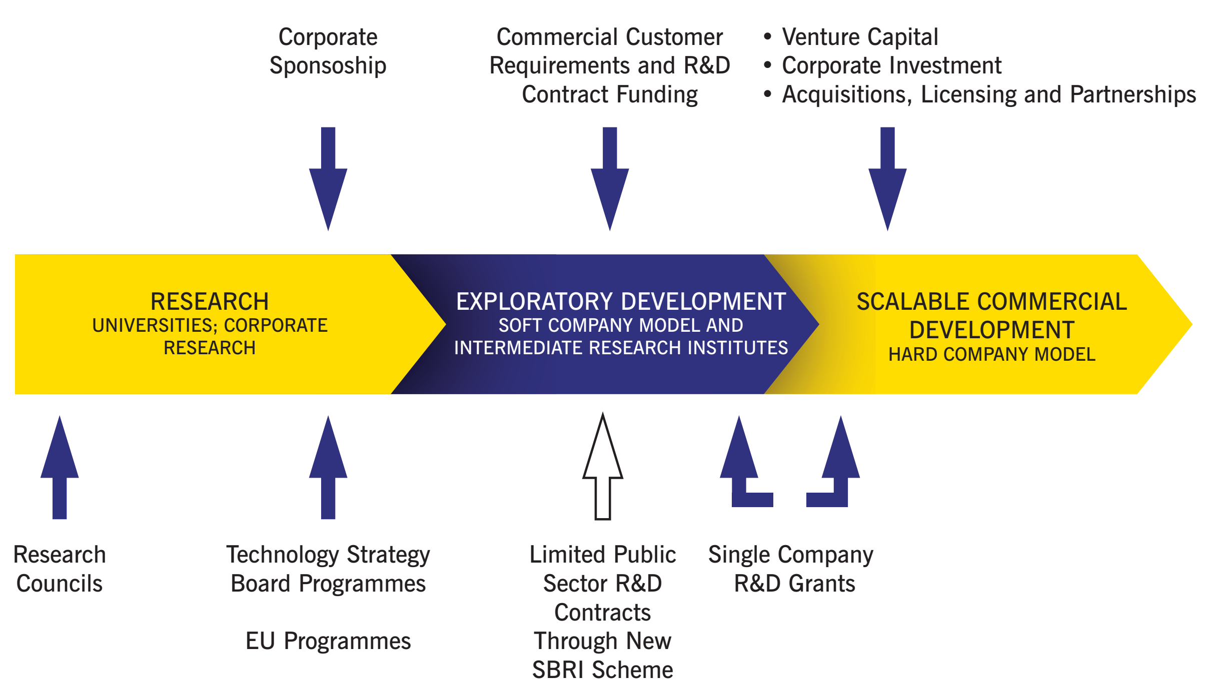
So whilst there have been some very effective competitions, like that run by NHS East in conjunction with EEDA (see Box 18 in Chapter 9), there remains a major question mark over how participation is to be achieved across government and how competitions are to be funded.

7.3 How Government R&D Funding Policies Relate to the Overall Innovation Process

It is important to consider how UK government R&D support mechanisms relate to other funding sources at different stages in the commercialisation of new science and technology concepts. Two factors are important. The first is where the kind of R&D supported by a particular programme sits in the process. For example, EU Framework Programmes generally fund pre-competitive commercialisation R&D and are far from market, whereas Small Business Research Initiative (SBRI) contracts are ideally suited for prototype development and lead-customer trials during the exploratory development phase. In Figure 10 we superimpose the principal funding sources – public and private – on the exploitation process diagram we introduced in Chapter 1. Venture capital is really designed for the third stage in the process, when a clear application market has been identified, technology risk is minimal and the key challenge is fast and efficient execution. Although VC funds, especially those with an early-stage remit, do sometimes get involved earlier, the chances of delivering adequate financial returns are very low, even if the technology is successfully commercialised – as data on the financial returns delivered by VC funds show (see also Chapter 9).

A second – and closely related – factor is how easy it is for firms to make use of a particular source of funding and how much additionality it brings. For example, larger single-company grants only cover 35% of project costs, which means the other 65% must come from the firm's own reserves or from investment. This presents small firms with a real challenge even if they are profitable, and is a problem aggravated by the difficulty of raising venture capital for the exploratory development phase. The need to provide matching funding presents a similar challenge for SMEs in relation to collaborative R&D grants.

Figure 10: R&D Funding Sources for Technology Firms



These different funding mechanisms have very different strengths and weaknesses. However, few companies have a detailed grasp of the differences between them, and experience with the bureaucracy associated with some grants can lead to some entrepreneurs tarring them all with the same brush. We have therefore tried hard to ensure that comments on experience are clearly related to the type of award and the detailed circumstances.

In general our research shows that the larger, more established soft companies make less use of grants and, if they use them at all, will tend to focus on collaborative projects purely because larger projects are involved. Single company grants tend to be more appropriate for smaller companies (and in any case there are upper limits on the number of employees allowed in applicant firms).

7.4 Research Approach and Findings

To examine the evidence, in addition to our in-depth interview data (Module 1), we draw on the responses from 22 firms to our survey of companies that recently received a single company R&D grant (Module 2). In contrast to Module 1 interviews, which were mainly with entrepreneurs whose firms had already achieved considerable success, the Module 2 survey recipients were all much smaller firms, and most had not yet achieved profitability.[83] Unlike Module 1 firms, the Module 2 sample was not selected on the basis of business model. The questions in the survey were primarily designed to establish the prevalence and role of different types of funding, including grants, venture capital and contract revenue funding from the private and public sector. We also asked about recent efforts to secure external financing and revenues, and elicited basic information about the firm to establish whether it should be regarded as following a hard or a soft business model. (Note that we include the hard model Module 2 firms – who were in the majority among our respondents – in our discussion, since we are interested here in general access to R&D funding sources.) Further information was collected through telephone interviews with sixteen of the survey respondents.

Single-Company R&D Grants

Various R&D grants, all requiring some degree of matching funding, are targeted at firms in different stages of technology development. By far the most frequently used research-related grants by our Module 2 firms were the Grants for R&D (GRAD) for Micro, Research or Development projects (Table 11) – no surprise, since the firms selected as survey targets were drawn from an EEDA-supplied list of GRAD winners. EEDA made no Exceptional GRAD awards (worth up to £500,000) during the period of our study; Proof of Concept grants, essentially to test the market rather than prove the technology, were launched only in 2007 and relatively few of the firms in either Module had applied for them. The GRAD awards are seen by Module 2 firms to be crucial, or at least beneficial, to their business. Typical comments associated with winning a grant were:

- *"enhances credibility with customers";*
- *"it helped us develop a potential product and extend our industry contacts";*
- *"we did not commercialise, but learned about the technology and used it to develop our business";* and

Table 11: Use of GRAD Awards by Module 2 Firms

	Number of Applicant Firms	Number of Successful Applications*	Total Value of Grants Awarded in Last 3 years	Average Value of Grant Awarded
Micro	5	6	£81,700	£13,600
Research	14	17	£1.1m	£64,700
Development	8	9	£1.35m	£150,000
Proof of Concept	5	4	£93,000	£23,250

* Some firms made more than one application for a particular type of grant

83 The respondent firms ranged in size from one-man bands to firms employing 25-30 people; they ranged in age from one year to over 30 years old, with a heavy weighting towards those formed in 2000 or later (15 firms); one firm was still pre-revenue, six had revenues in excess of £1 million and the remainder lay in between. Activities covered a wide range of business / industry sectors, but all involved some form of technology research or development in order to qualify for the grant.

- *"it enabled us to bring the project forward more quickly than we might have been able to with our own small resources".*

As far as our Module 2 firms are concerned, these schemes clearly 'tick the right boxes' with respect to opening doors to potential customers, providing credibility and legitimation, validating the technology, and learning effects. Some commentators[84] have raised concerns that government support as a whole for 'innovation' in fact tends to encourage invention (the development of ideas) rather than the production of commercially relevant innovations. Nevertheless, Module 2 firms pointed to positive outcomes from winning grants, such as "*investors seeing the added value in grant income without loss of additional equity*" and "*new technology attracting private investor and business opportunities*".[85] One firm was applying for a Development grant to support the development of technology it was spinning out into a new venture, specifically because the VC backing the new venture wanted grant funding to run alongside its financing. Another had won two Development grants, which had "*helped at critical points in the business*", enabling it to get further than would otherwise have been possible. Some firms (though only one or two among our Module 2 firms) owe their survival to R&D grants.[86]

In contrast to the Module 2 finding, single-company grant programmes are now used little, if at all, by the larger or more well-established soft companies amongst our Module 1 firms – not least because the Micro and Research grants are restricted to firms with fewer than 10 or 50 employees, respectively; the Development grants are targeted at firms with up to 200 employees. But many of our Module 1 firms when they were younger had made use of the DTI-administered equivalent scheme, Smart (and sometimes the follow-on Spur award),[87] either for their core business, or for early-stage spin-out ventures. At Enzymatix in the late 1980s, Chris Evans was a skilful grant proposal writer and won many Smart awards for the company; in the early days of Chiroscience he did the same, but after the IPO the company would probably not have been eligible. Also in the biotech industry, by 1993 CAT had won 2 Smart awards, of which one at least turned into a Spur second stage award that doubled the amount of money it received.

In the late 1990s, within the first few months of its life, Sentec wrote a proposal for (and won) a Smart award for its early spin-out, Holotag; and a second in 1999 for in-house development of the multiplexed diagnostics technology that eventually spun out as Smartbead. A third spin-out company, Visual Protection, won a Smart award in 2002, while Sentec itself won an award in 2004 to develop its water meter technology. The award for Smartbead in particular was seen to provide endorsement to secure further funding for the venture.

Another firm to benefit from Smart awards was Syrris, which was able to leverage a feasibility study in 2002 into an Exceptional Smart award worth £400,000 in 2003-5 to help fund the development of its flagship modular flow chemistry system.

But some firms were more sceptical of the value of government grants to their businesses. One specialist technology firm commented on the need for "*imagination*" and a "*market-oriented mind*" in writing proposals, concluding that they were "*barely worth the effort*" since the percentage of funding given was not very high. Moreover, using government grant money made it difficult to claim under other schemes, such as R&D tax credits, for subsequent (and much more significant) technology expenditure. A different specialist technology firm regarded research grants as "*massively annoying*", since the overhead on running a small (£40,000) R&D grant is "*enormous*". On the other hand this firm had a very positive view of Proof of Concept grants, which were far easier to apply for and the requirement to use an external consultant was "*handy because we are good at the technology but weak at the customer side. If we had an idea it was an opportunity to get someone in to produce some serious work identifying customers and getting us in front of them*".

84 See, for example, Gill, D., Minshall, T., Pickering, C. and Rigby, M. (2007) Funding Technology: Britain Forty Years On.

85 More negative perceptions of the grants' impact tended to revolve around the perceived administrative burden that grants entail. One respondent in particular regretted that the current emphasis lies on paper-based reporting rather than the 'hands-on' project monitoring encountered before, which had permitted both knowledge exchange and physical oversight of what the grant-awarding body's money had achieved. Another criticised the requirement that a Research grant be completed before an application could be made for a Development grant for the same technology, leading to a funding gap for this firm.

86 Some firms do not survive, but it is within the remit of EEDA and other regional development agencies to take risks on the enterprises and projects they choose to grant fund. The requirement for applicant firms to provide some level of matching funding is seen as guarding against applications for a grant to research or develop something the firm would do anyway. There are complex issues, beyond the remit of this research, around the extent to which these schemes actually achieve the desired additionality.

87 The Smart (Small Firms Merit Award for Research and Technology) scheme was piloted in 1986 and rolled out across the UK in 1988. Like the current range of GRAD awards, Smart provided funding for feasibility studies (75% of project costs, maximum grant £45,000 for firms of <50 employees) and development projects (30% of project costs, maximum grant £200,000 including any feasibility study, for firms of <250 employees) as well as for a few exceptional projects (support as for development projects) deemed to be 'strategic' in nature. Spur awards were introduced in 1991 for firms with up to 500 employees (reduced in 1994 to 250 employees); they were incorporated into a single overarching Smart scheme in 1997.

The ability of government agencies to identify the right projects to fund is also questioned: Mike Lynch, founder of Autonomy, recalled that his company had tried unsuccessfully on several occasions to win Smart-type awards and found that "*they were a classic failure of government bodies to be able to understand the technology world. The hilarious thing was tracking the winners over the years and what happened to them. Basically if you were very good at filling in forms you would get them, but if you had any decent technology and wanted to exploit it you had no chance of winning*".

The lack of commercial focus was also a criticism levelled at collaborative R&D programmes, discussed in the following section.

Collaborative R&D Programmes

We found little use of (or appetite for) collaborative research funding programmes, whether UK-based and run by the DTI / Technology Strategy Board (TSB) or under the EU Framework Programmes. Typical comments were: "*dysfunctional*", "*takes our researchers further from the market*", and "*time scales are too long*".

Only three of the twenty-two Module 2 companies had successfully applied for a TSB Grant for Collaborative R&D, one of which – a small biotech firm – had won four grants worth a total of £90,000. Its experience with these collaborations was very mixed, whether from a funding, technical or partnership perspective. Funding ranged from 20% of internal costs, which was an insufficient return on the effort (and caused subsequent problems in claiming R&D tax credits), to 40+%, ~50% and ~60%, all of which were regarded as "*reasonable*". Technologically, one was "*not successful*", one was "*okay*" and two were "*good*". Partnering worked well on one (involving a university and a manufacturer), was "*difficult*" on another (involving a similar company) because the science was hard, and "*frustrating*" on the other two because the university partners made slow progress or had a different focus and direction.

But one highly enthusiastic Module 2 participant in collaborative funding programmes (with the TSB and, prior to that, the DTI) commented on the benefits to the company: "*you can appear slightly bigger than you are, you can achieve more. It's very important for a small company to appear capable of taking on a whole lot more than it actually does*". Collaboration also allowed this company to talk about its networks and "*appear very knowledgeable across a much wider base*" than would otherwise be possible. No other Module 2 firm expressed such whole-hearted approval for the collaborative mode of research.

Module 2 companies regarded EU collaborative programmes as "*too bureaucratic*" and the paperwork "*very demanding*", particularly for small companies that lacked the internal resources to deal with it. The few firms that were involved tended mostly to act as subcontractors, which eased the administrative burdens and allowed them to receive 100% funding for their input.

As for our Module 1 interviewees, the only organisations expressing any appetite for collaborative research were the intermediate research institutes.[88] Collaborative R&D programmes for these bodies can be an important part of their activity although, like everyone else, the research institutes bemoan the lack of fully-funded projects in the UK. Bob John, CEO of TWI notes: "*we don't get 100% funding when we're doing work for the TSB. We'd be better off under current funding rules if we were a university. There's no national money going in [as core funding to the TWI]. In our arena, there's lots of public money going into the various institutes in the rest of the world, like Fraunhofer and so on. They've always got that money to add to whatever funding they get, so it's not a level playing field. We only get public support if we're in competitively funded projects, which is a bit wasteful because the success rate on those is pitiful. It might not seem to matter to UK plc, but technology adoption resources for companies need to be national*" rather than made internationally available.

EEDA-backed CIP Technologies is well known in Europe for the strength of its research, despite its small size, and in the last FP7 photonics call received invitations from possible partners to participate in more than 40 proposals. Previously CIP had been party to 10 FP6 proposals and won seven – an admirably high success rate, but one which left it with the challenge of fulfilling the requirements of all seven projects – so this time it was far more selective. Disappointingly, of the four applications it chose to join only one was successful – although this was a better strike rate than the 10% of proposals that finally received funding. Given that CIP Technologies employs only around 40 people Michael

88 We are aware of some soft companies that participated historically in UK collaborative R&D projects. But the current perception is overwhelmingly that multi-partner R&D grants are irrelevant to their business.

Robertson, VP Research Programmes, points out that the effort involved in all the proposal writing and in shepherding the proposals through the referee process (for which applicants are not paid) represented "*a significant waste of manpower*".

Small companies can find it hard to raise the matching funding to participate in TSB and EU collaborative projects. Strategically CIP Technologies would prefer to participate in EU FP7 projects, which pay SMEs 75% of costs, than in TSB programmes, where the maximum cost contribution is 60% – or as little as 50% for relatively small-scale DTI projects on which it has worked. CIP funds its share of collaborative project costs from commercial income and tries to ensure that, although collaborative programmes must be pre-competitive, the ones it joins are well aligned with its commercial purposes. One advantage it sees in doing collaborative work is that it allows CIP to work with potential customers as partners on the project. But there is also a need, as a smaller company, for it to avoid being exploited by heavyweight partners. This means being highly attuned to the risks and being selective from the very beginning in its choice of partners for projects.

The reaction among the technology consultancies to collaborative R&D work funded by the UK government or the EU is uniformly negative. One of the broadly-based firms commented: "*some of the grants in the UK are often much more nebulous [than the US ones] and more researchy, and we don't feel that's the right place for us to be competing*". Cambridge Consultants did participate in a couple of collaborative programmes a long time ago and CTO and Ventures Director Ray Edgson sums up the general attitude: "*We have not found them to be beneficial. One reason is that they are very long term – for us, three years is a long time. In the time it might take to get one collaborative research project done, we might expect to get three or four products onto the market. Given that we're trying to stay commercially lean and fit and aware, something that takes people out and slows them down to the pace of these collaborative programmes is not a very appealing prospect for us… Collaborative programmes are too slow, too far from market, and they also don't bring in useful amounts of money. Basically we are expected at best to do things at marginal cost, and may also be required to put in matching funds as well. So we are left then with a choice: do we do this slowly, with a bunch of collaborators with difficult IP terms and actually not much money for the trouble of going through all the administration and stuff, or do we just get on and do something entirely on our own? We usually choose the latter: it's quicker, it involves much less admin, and we own the IP.*"

From the perspective of the consultancies, government R&D money tends to lower the commercial 'tone' and dilute the profit motivation. Commercial activity should dominate the work environment and drive the enterprise forward. It is this commercial orientation that develops the broader skills of staff; that differentiates the consultancies from research institutions and similar organisations (which are seen to be weaker on project management and further away from the market); and that enables them to demonstrate a world class ability to commercialise and exploit technology, as part of the chain running from research to the marketing activity of their sophisticated multinational clients. "*If there is to be public money invested in the commercial technology sector, and in consultancies like us in particular, I think that UK plc should expect to benefit most from our strengths in commercialising novel technologies. So if there were government money coming in I'd want it to be somehow tapping into that ability to build industry and create jobs and improve competitiveness. I wouldn't want it to be spent on research. That's not what we do best*", remarks Roy Edgson at Cambridge Consultants.

As a smaller specialist consultancy, 42 Technology recognises the potential for fruitful use of a TSB-style collaborative programme with selected partners if there were a particular expertise and a demonstrable capability it wanted to develop. But the issue is whether collaboration would be a distraction from winning fully-funded work: it would have to "*bring real added value to the business, rather than simply being a means in itself*", according to CEO Howard Biddle. As for Team Consulting, CEO Jerry Turner says "*we look at the application process and think it's too much hassle and we've got other things to do, even for the UK ones*". Sentec did, however, make use of collaborative DTI funding in 2005 for work on dual fuel smart meters.

In other industrial sectors, Cambridge Antibody Technology participated in one EU collaborative grant with various partners but founder David Chiswell was scathing about the value it brought to the business and refused to work on others. "*All you do is spend all your time getting a little bit of money and working with* *disparate partners*" and, with EU programmes requiring the involvement of several labs, "*you have all the bureaucracy, all the bargaining over IP*". But in the aerospace and automotive sector enormous development costs (and a sharp squeeze on the profit margins on cars) encourage firms to take a more positive view of collaboration. Lotus Engineering has participated in a variety of programmes funded by the EU, the TSB, DEFRA and organisations such as the Energy Savings Trust, some of which have generated positive PR for the company, interest from clients in the technology, and some engineering work. As Clive Card, Lotus Engineering Project Manager, explains, "*The strategic impetus of our collaborations is not to cover some costs but as a way to expand our existing knowledge … getting collaborative funding helps us to do stuff we really want to do.*"

Finally, firms pointed to potential difficulties in managing the IP position with respect to collaborative research. IP ownership has to be kept clear all along the value chain. A participant developing a technology platform, for example, must own the IP for manufacturing it, but a consortium member who develops ways of measuring it or using it should own the IP for that aspect.

Summing up this section, then, we find that many firms regard multi-partner collaborative projects as too slow, too far from market and the realities of the commercial world, too difficult in terms of IP management, and a distraction from profit motivation. Exceptions are the intermediate research institutes, such as TWI, that are positioned between academia and big business and help industry to translate research into production[89], and mature, heavily capital-intensive industries with complex and well-established supply chains, such as automotive and aerospace. Both of these see some role for collaborative projects. Very small firms that get involved need to be nimble to capture the network advantages by establishing their credibility and forging strong links with potential future partners, but they also risk being exploited by large collaborators. Their alternative is to work as subcontractors to project partners, which also shields them from the bureaucratic burden, particularly of EU projects, that is seen to be "*a nightmare*".

Public Sector R&D Contracts and the Small Business Research Initiative

When we turn to R&D contracts (as opposed to grants) funded by the public sector, we find little or no recent involvement by either Module 1 or Module 2 firms.

Once again we start with Module 2 firms, where survey data allow us to present comparative figures for the private and public sector contracts won in the most recent year (Table 12). Private sector customers dominate, in both number and value terms; three years earlier the difference was even more stark, since there were no firms with public sector customers at all compared with eight undertaking contracts from the private sector.

The small sample size means that quantitative comparisons must be treated with care, but a crude comparison of public sector contract revenues (£173,000) with single-company R&D grants won by our Module 2 firms (£875,000) suggests that the value of contracts awarded is just under one-fifth that of grants income. Grossing the figure up for the whole of England, on the assumption that the pattern will be broadly similar across regions, a very approximate value for total public sector R&D contracts per annum placed with small companies is a minuscule £5 million. The US annual spend on SBIR awards alone is $2 billion.

Moreover, the public sector contract funding shown in Table 12 for the most recent year is dominated by a single SBRI award by the BBSRC. As discussed earlier, this programme is no longer in operation. The recipient

Table 12: Private and Public Sector R&D Contracts Among Module 2 Firms

	Private Sector Customers	Public Sector Customers
Number of Module 2 companies undertaking R&D contracts in last year (n=22)	9	2
Revenues from R&D contracts in last year	£2.2m	£173,000

89 In the 4-6 levels of NASA's Technology Readiness Levels, according to Bob John of TWI. See also the Oxford Economics report on the Intermediate Research and Technology sector.

found the contract to be too academically oriented, geared towards enabling activity rather than direct development activity. In fact he felt that in practice the BBSRC appeared to be furthering its goals of encouraging academic excellence by subcontracting to a company rather than to universities. While the 100% research funding was welcome at the time and the firm developed expertise, the contract did not help to further its mainstream objectives and "*we wouldn't do it again unless it was really for us*". The SBRI programme was seen to be much less flexible than the US SBIR, where it was possible to go for directly relevant contracts.

Among our Module 1 interviewees there were several historical examples of public sector contracts that had played an important role, notably for the BBC Micro (developed by Acorn Computers), and Post Office and Bank of England contracts for ink jet printing development with Cambridge Consultants (see Box 17). There were also some defence contracts, especially with Cambridge Consultants during the 1970s and early 1980s until the Thatcher Government cut the defence budget and procurement rules were changed, making it more difficult for SMEs to participate.

The privatisation of MOD R&D laboratories and changes in government procurement practices over the last 25 years have substantially reduced the opportunities for smaller firms to win public sector-funded technology contracts, especially on reasonable terms. Although the Department of Health would appear to be a prime candidate for commissioning medical equipment

Box 17: Developing an Ink Jet Printing Capability at Cambridge Consultants


Image courtesy of Domino Printing Sciences plc

In the late 1960s the Post Office contracted Cambridge Consultants to work on developing envelope-franking technology. The mechanical engineering group began doing experiments based on original continuous ink-jet printing patents that were owned by a US company, AB Dick, but which were about to expire. This work formed the basis for developing Cambridge Consultants' expertise and the beginning of a patent portfolio.

ICI's Dyestuffs Division was attracted by the possibilities of ink jet printing on textiles. The project became Cambridge Consultants' largest, accounting for perhaps one-third of its revenue for a couple of years. But ICI lost interest in around 1974, phased out the work and sold its single nozzle patents back to the company for £10,000. This patent portfolio complemented the many nozzle array patents Cambridge Consultants had taken out in the meantime.

The EU directive on date labelling provided a market opportunity in 1978 for Graham Minto to spin out Domino Printing Sciences with the orphaned single nozzle ink jet technology. He later bought out Cambridge Consultants' shares in three tranches of £1m[90] and listed the company on the London Stock Exchange in 1985. By 2007 Domino's sales had reached £232 million and it employed nearly 2,100 people.

Meanwhile ink jet work continued inside Cambridge Consultants on many large projects, including a variety of projects to develop banknote security features for the Bank of England. Only some of the techniques were implemented, but the company developed a lot more technology. A lull in demand for ink jet projects in the mid-1980s left Cambridge Consultants with more orphan technology which it packaged up and spun out as Elmjet, specialising in array printing. A few years later Elmjet was bought by an OEM customer.

Xaar was spun out in 1990, based on IP developed around a very large actuator project for an American ink company and improvements in Cambridge Consultants' original single nozzle technology. With employment of 318, Xaar's annual sales in 2007 were £48 million.

Continuing customer interest led to internally-funded work by Cambridge Consultants' mechanical engineers on flatbed plotters for the screen-printing industry. That work led to the spin-out of Inca Digital Printing in 2000 and its aquisition by Dainippon Printing in 2005.

90 Cambridge Consultants' annual turnover was around £3 million at the time.

developments, in practice we found very little activity despite the apparent size of its research budget.[91] Initiatives such as Health Enterprise East[92] may eventually bear fruit, but there is little evidence so far of much market pull into the nation's hospitals. "*We see adoption by the NHS as a major issue*", says Jerry Turner, CEO of Team Consulting. Even for straight product procurement the NHS is "*so slow to adopt innovations*": Ophthalmos, a company in which Team Consulting is an investor, has been unable to get its lens-free ophthalmoscope, which can be used as a diagnostic tool for the detection of diabetes and other serious illnesses, onto the standard NHS procurement list despite "*all kinds of positive citations from professors, consultants and doctors*".

Most of the firms we spoke to either ignored or had more-or-less written off the public sector as a customer for technology development, except for PA which continues to support a range of technology-enabled public sector programmes, perhaps because its much larger management consulting division helps to enable access. Defence procurement remains the main source of public sector technology development projects, but is generally at a very modest level except in the case of PA, which still has a significant defence and security business. Cambridge Consultants also retains some involvement, but on a significantly smaller scale than before the Thatcher reforms (see Chapter 4). Other, smaller firms in the East of England generally express frustration over the difficulties of getting effective access to the Ministry of Defence. One firm "*found it quite difficult to get on their lists for procurement calls*".

Another company made several unsuccessful proposals into the annual calls from the Defence Technology Centres,[93] which offered fully-funded terms although with no guarantee of a future market for the research. In addition to the 100% funding the terms are attractive since the DTC does not expect to claim the IP itself and it appears to be relaxed about where the technology can be sold. Despite considerable success in submitting EU proposals, this firm has given up trying with the DTC and feels "*it's an old boys' network of big defence companies*" where the thinking is particularly closed.

We should note that since the interviews for this report, a new MOD unit, the Centre for Defence Enterprise, has started operations with the aim of engaging with non-traditional suppliers of technology, including SMEs. This is now running regular competitions using something close to the SBRI model and appears to be much more SME-friendly.[94]

Plextek took a roundabout route into the MOD, having failed with an earlier attempt to win a contract. It took a mock-up of its radar system to the 2003 Paris Air Show, where the systems integrators homed in "*like bees round a honey pot*", as founder Colin Smithers puts it. Encouraged by the level of interest it built a working prototype at its own expense and after two years succeeded in selling ten of them to seven different systems integrators.

Plextek continued to evolve the product and provide upgrades and eventually, with several integrators demonstrating to the MOD systems that incorporated Plextek's high-end sensor, the MOD 'got the message' that Plextek had the technology for a radar system. It won its first MOD contract worth £1.73 million in 2008 for its Blighter ground surveillance radars – but as a commercial off-the-shelf supplier, Plextek has the rights to all its IP and to sell the system wherever it wishes. Under a standard MOD research procurement programme, the MOD would have funded the research, but would ultimately have owned the IP. It would also have limited the profit margin on work done, and it could have put out a tender for any other supplier to manufacture the system. "*It's a very, very significant factor in why we did it that way.*"

Other firms have also been deterred even from working as subcontractors to MOD suppliers. Cambridge Design Partnership, for example, gave up on an opportunity to be a "*subcontractor to a subcontractor*" for military robotics because "t*he terms were beyond belief*", according to Mike Cane. It refused to take on another aircraft-related contract it described as "*sickeningly simple*" because it involved "*£10,000 of work, £90,000 of paperwork and probably another £90,000 of insurance to support it for the next 15 years*", which

91 According to official DIUS statistics, the Department of Health spends £734 million per annum on R&D. However, less than 10% of this has been managed centrally and much of the rest has been used to fund general (rather than R&D) expenditure.

92 Health Enterprise East is the Innovation Hub for Healthcare in the East of England, to which NHS staff can bring their ideas for technical devices, therapeutics, computer software, etc. and receive help with protecting the intellectual property as well as an assessment of its value. EEDA is a major contributor to its funding. Since we carried out our interviews it has managed a very well received SBRI programme co-funded with EEDA (see Chapter 9).

93 These are collaborative consortia of industry and academia, working on behalf of MOD, that act as virtual centres of excellence in broad technology areas relevant to defence. Each consortium has a major defence supplier as prime contractor and typically includes several other major suppliers, all of whom work on a 50%-funded basis. Participating universities, research institutes and SMEs – the 'science providers' – act as subcontractors, hence are100%-funded and retain their IP. Approximately 30% of DTC resources are targeted at SMEs and universities.

94 It is too early to say whether the Centre for Defence Enterprise has a sufficient budget to make a real impact on the level of MOD contract funding awarded for the development of innovative technology in SMEs.

is a requirement for an MOD aircraft instrument.

The contrast with one UK company's experience with the US Department of Defense is striking. As described in Case Study 13, Owlstone works through a prime defence contractor to bring its gas detection systems into the defence market. But, as a majority US-owned company, it has also applied for – and won – Phase 1 SBIR contracts. These have helped it get a foot on the first rung of the Department of Defense procurement ladder and brought it to the attention of people with bigger R&D budgets. Since then it has won a $3.7 million DOD project through an unsolicited bid, seen as generating a higher level of commitment to eventual purchase of the technology at the end of the contract. Around 80% of US R&D contract funding is believed to be distributed through unsolicited bids.[95] On the other hand, the standardised application process for SBIRs across all US government agencies means that an application is both quick and easy to submit, with SBIR contracts then connecting a company into wider development and procurement networks.

In sum, the UK picture for public sector R&D procurement is not encouraging for small and medium-sized technology firms and rather few recent contracts have materialised, even for our Module 1 firms. In stark contrast to the statistics published by DTI and BERR, few contracts seem to be awarded each year and all the firms we interviewed had effectively discounted the UK public sector as a customer for innovation, despite the major benefits for UK plc that derive from private sector-funded technology contracts.

R&D Tax Credits

In contrast, the R&D tax credit is a government innovation support scheme, introduced for SMEs in 2000, that is both widely used and highly appreciated.

Our Module 1 firms were enthusiastic – "*The one really, really good scheme is the R&D tax credit*", says Colin Smithers of Plextek – although not all firms were as skilled in their understanding of the rules as Cambridge Design Partnership: "*We're the experts on it*", managing to claim tax credits on over 50% of their R&D costs.

Some technology consultancies laboured under the misapprehension that they were unable to claim on any research contract work done for external clients, yet this is true only for work done on behalf of SMEs (which claim the tax credit themselves). For contracts on behalf of large clients, the technology developer is able to claim as though it is the large company; and another formula for R&D cost reimbursement takes care of work for international clients.

However, in line with the view of sceptics that the R&D would be done anyway,[96] among the 13 Module 2 firms that claimed the credit only three said that the scheme increased their R&D expenditure to a great extent; one admitted that the availability of the credit made no difference to its R&D expenditure.

R&D tax credits generate roughly 17p for each £1 spent on R&D by small firms, paid in cash after the end of the tax year. Whether the credits are all used to fund extra R&D is questionable; it seems far more likely that they are spread across the full range of R&D and non-R&D expenditure categories. And it is arguable that the enthusiasm for R&D tax credits reflects rather the many problems seen with other sources of government R&D funding, especially the high levels of bureaucracy involved. In contrast, R&D tax credits are highly predictable and easy to apply for. The question is whether the £600m plus involved (of which roughly one-third goes to SMEs) could be more effectively spent.

7.5 In Conclusion

The picture from our research, then, on the usefulness of programmes to fund R&D in firms is decidedly mixed at best.[97] And there are strong arguments for trying to make them more relevant to the kinds of firms described in this report. We make some proposals on how this might be achieved in Chapter 9.

In the following chapter, we look at the relationships that firms forge with the academic sector, another of the pillars on which government science and innovation policy is built.

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95 Interview with Billy Boyle, co-founder, Owlstone Nanotech.

96 Other research at the Centre for Business Research found that around half of the surveyed SMEs that used the R&D tax credit scheme did not increase their R&D expenditure, and around a further one-third felt it only increased their R&D spend to a limited extent. See: Cosh, A. and Hughes, H. (2007) British enterprise: surviving or thriving? p.45. There is also a lot of anecdotal evidence from both large and small companies that decisions on R&D investments in the UK are generally made without regard to R&D tax credits.

97 Appendix B briefly examines a different form of support for innovative businesses, organised at the regional level: the role of science parks and enterprise hubs.

Image courtesy of Cambridge Design Partnership Limited

Chapter 8

Chapter 8: Relationships with Universities

The university sector has been seen by successive UK governments as playing a key role in supporting innovation. And a variety of initiatives over the past 15 years has added a ‘third mission’ to their traditional research and teaching activities.[98] The increasingly commercial roles universities are expected to play are illustrated by the metrics regularly monitored by the Higher Education Statistics Agency on behalf of the Higher Education Funding Council for England and Wales, which cover collaboration and contract revenues, consultancy, patents, spin-out companies created and IP income.[99] What does our research tell us about the impact of this policy on economic development in the East of England region? And how do the firms we have investigated interact with universities?

8.1 “People Assume a Connection”

One might intuitively expect to find close relationships between technology-based companies in the East of England region and the many world-class research groups in its universities.

But in our research for this report, we found that direct IP relationships with universities were rare, in the case of both Module 1 and Module 2 firms. The few cases where academic IP was important were, almost without exception, Module 2 firms usually led by PhDs in the field of electronics or biotechnology trying to commercialise their own research. None of our Module 1 firms, with the exception of CAT which was built with the aid of technology from the MRC Laboratory for Molecular Biology, had made significant use of academic IP in their core business (see Case Study 14). Nor did they appear to expect future innovations to come from this source. At the same time, some of the technology consultancies had provided R&D services to new ventures (predominantly, if not totally, hard start-ups) established to commercialise university IP, sometimes partly in exchange for equity. But these relationships were essentially similar to other customer relationships. Furthermore there were few, if any, success stories.

At least one of the broadly-based technology consultancies had tried more systematically to build a closer relationship with two of the region’s universities, again with disappointing results.

We should note that most of the companies in our study were physics-, engineering- and ITC-based. There are prima facie reasons for believing that university IP is rather more important for drug discovery and other biotechnology-based companies, and other evidence points to this.[100]

However, the message amongst the firms we studied was unambiguous.

Whilst conceding that the first of the broadly-based technology consultancies was originally established in Cambridge because of the scientific and engineering capabilities of the university, Cambridge-based entrepreneurs take the view that the consultancies themselves have been more directly responsible for the emergence of the Cambridge high-tech cluster. Entrepreneurs see academics – at least until recently – as being too focused on their own scientific disciplines and lacking in the commercial skills necessary for fruitful entrepreneurial interaction. Outside the biotechnology sector, we found no instances where the firms we studied had pro-actively sought and successfully identified technology from the university science base to transfer into their core business. The

98 See, for example, Gill, D., Minshall, T., Pickering, C. and Rigby, M. (2007) Funding Technology: Britain Forty Years On.
99 See HEFCE (2007), Higher Education–Business and Community Interactions Survey.
100 Allott, S. (2006) From Science to Growth. See also Mayer, H. (2005) “Taking Root in the Silicon Forest: High-Technology Firms as Surrogate Universities in Portland, Oregon”; and Zucker et al (1998) “Intellectual Human Capital and the Birth of US Biotechnology Enterprises”.

Case Study 14: Cambridge Antibody Technology

Cambridge Antibody Technology is a classic example of a soft start company. Its founding chief executive was David Chiswell, who had been made redundant from his job as a research department head at Amersham International when it closed its central research laboratory in 1989. Chiswell was responsible for looking at molecular biology futures at Amersham and had already been doing some lab research on humanising antibodies. Greg Winter, a leading academic expert in the field at the Medical Research Council Laboratory of Molecular Biology in Cambridge, was one of Chiswell's consultants. He held several patents for single domain antibodies and much of the base IP to the MRC's antibody gene library and when Chiswell sought his advice on setting up a company the two of them decided to team up together.

The initial team of four was largely funded from the Amersham redundancy pay and for some months the only lab work was in a borrowed "tray" in Greg Winter's lab at the LMB. Chiswell tried for 6 months to raise venture capital, but "antibody engineering" was not something in which VCs were interested at the time. Instead CAT received some modest start-up funding – £750,000 – from an Australian company, Peptech[101], which already had a relationship with Greg Winter and had previously tried to recruit him to head up its research. A Smart award of £45,000 in April 1990 enabled the team to be expanded to five and there was another Smart award later. However revenue funding from R&D contracts became increasingly important and by 1993, when CAT employed 15 people, the company was operating profitably.

In the first couple of years CAT relied heavily on the laboratory resources of the MRC and was able to draw in a rather informal way on the expertise of LMB scientists. It filed a patent on phage display of proteins in mid-1990 and got itself noticed in the scientific world with an important paper in the journal Nature at the end of that year. While advancing the phage display science, Chiswell approached Pharmacia to suggest making research kits based on CAT's technology. The terms of that first deal – for what was essentially CAT's first product – was worth one or two hundred thousand pounds in 1991 alone, in the form of an up-front payment and a research and development agreement to design and assemble the kits. David Chiswell noted this was "*a fantastic deal for us, because it was more than we could spend*", generating most of CAT's revenue that year and the next.

Having moved the basic technology forward to demonstrate it could actually isolate useful proteins, in late 1992 CAT began working on deals with pharmaceutical firms to produce antibodies against specified targets using the proprietary technology it had accumulated and developed, at first for a small up-front fee and expenses plus milestones and eventually royalties. The first deal was with BASF in 1993, to produce an anti-TNF antibody, two

technology links between the large consultancies and the University of Cambridge seem particularly weak, despite attempts from time to time to work together. One interviewee's description of the University as being "*over there somewhere*" sums up the general attitude.

Instead, the main contribution of universities to our firms is through the recruitment of science and engineering graduates and post-graduates – part of what Allott (2006) refers to as the people-centric approach to the innovation process.[102] This transfer of people, and especially of PhDs, is important in bringing leading-edge science into the industrial technology base, as PhD-trained recruits in particular tend to retain strong links with their professors and contemporaries, and with their professional academic field.

Other links between our firms and universities come in the form of firms hosting student projects and providing summer internships. Some individuals within firms play (or have in the past played) a role as guest lecturer or student mentor in a university department. In a few cases small firms, mostly in our Module 2 group, were able to arrange to use specialised university equipment or else they commissioned very specific pieces of work from a university laboratory. Knowledge Transfer Partnerships had also been a source of technological expertise for one or two Module 2 firms and in the best

101 Sydney-based Peptide Technology Ltd (Peptech, renamed Arana Therapeutics in 2007) was founded in 1985 by Dr Geoff Grigg, who was head of molecular biology at Australia's CSIRO (Commonwealth Scientific and Industrial Research Organisation). He had done his PhD in microbial genetics at the University of Cambridge and a post-doctorate with Fred Sanger, during which time he got to know Greg Winter. Peptech became one of Australia's first listed biotechnology companies and holds a number of antibody technology and anti-Tumour Necrosis Factor (TNF) patents, enabling it to earn royalties on several important antibody drugs.

102 According to Allott (2006), the people-centric approach takes customer demand as the source of business ideas. He contrasts this with what he calls the idea-centric approach adopted by policymakers: a linear transfer of ideas from academic research, via a search for practical application, into the commercial world.

additional specified targets and 2-3 as yet unspecified targets over a three-year period, in return for £100,000 upfront, £1 million when CAT delivered a candidate antibody, £1 million when BASF developed it to the next stage, and so on. CAT put six of its twenty staff to work on that project. There was very little precedent at that time for a deal structure in which CAT covered its costs but only made profits if it successfully produced suitable antibodies. *"We could never get a profitable FTE return unless we took on some of the risk of achieving what the client wanted."* But this was a managed risk, staged over intermediate milestones, each of relatively low risk but carrying a significant premium. The first milestone was usually to produce a relatively small number (~5-6) of antibodies that bound to the target, but with a low specificity hurdle; over the next 3-4 milestones (which could be less than six months apart) the deal might specify 1-2 antibodies with a higher affinity, then one that would be neutralised, and then one candidate that to be useful in the clinic would need a given affinity and given specificity. Although CAT's first deals with Big Pharma were struck under uncertainty over whether its technology could deliver, success gave it confidence and over the following 3-4 years the up-front access fee on each deal rose from a few thousand pounds to £5 million.

Work on proprietary products commenced in 1995, a year in which CAT struggled for finance (owing to its expansion to over 20 people plus the high cost of clinical work). £3 million of additional equity had been raised in 1993, but VC funds still showed no interest in antibodies. However, major contract deals that year with Genentech, Lilly and Pfizer put the company in a position to raise £12.75 million in a pre- IPO round in 1996 and do an IPO in 1997. Until 1996, two thirds of the total £12.25 million of funding raised had come from customer revenues; CAT more or less broke even from 1993 to 1995, by when it employed 32 people.

The pre-IPO and IPO rounds allowed CAT to invest more in its own programmes and increase head count rapidly – to £27m and 200 respectively by 2001. From then onwards the mixed model continued on a roughly 50/50 basis: if CAT started to run out of money for clinical work it did more contract deals, although the obligation to meet deadlines on contracts always risked sucking resources away from the proprietary work. By 2004, when CAT was acquired by AstraZeneca, it had 3-4 development programmes that were entirely its own, another 2-3 programmes partnered on a 50/50 basis, and a further 7-8 funded by other companies, all at various stages of clinical development. Hence it was a mixed portfolio, demonstrating CAT's move up the value chain and a gradual 'hardening' of its business model.

CAT was taken over during a 'buyout frenzy', when AstraZeneca's offer of £13 against a share price of £7 gave the board no choice but to accept. It acquired a firm that had grown over the course of 14 years to 284 employees and revenues of £294 million.

cases the researchers provided useful access to their academic groups. Finally, a few firms interacted with universities by working as subcontractors on Research Council-funded collaborative programmes.

Where companies formed relationships with academics, they were with individuals whom they knew and respected rather than with their institutions. Relationships were as likely to be established with academics outside the region, including outside the UK. Expertise is more important than proximity, and successful technology companies act and think globally to find the best partners and suppliers they can. Therefore it is not surprising that the contacts maintained by our Module 1 and Module 2 firms are geographically diverse, even though these firms are based in a region boasting scientifically strong academic institutions.

While acknowledging the depth of scientific expertise to be found in universities, firms were critical of the university sector's ability to interact with business on several grounds, most importantly with respect to the market readiness of and valuation put on academic IP, and urgency in the pace of collaborative work.

According to one of our interviewees, "*tension over what's good for the university prejudices UK plc big time. Most universities lock down the IPR so that firms have to negotiate all contracts through the technology transfer office, which is charged with maximising income to the university, and you end up with weird behaviour from the universities asking for too much. It's total sub-optimisation [of the industry-university relationship].*"

Many university technology transfer offices were regarded as having unrealistically optimistic expectations of the commercial value of their IP as a licensing opportunity. In a rare case among our Module 1 sample of an attempt by a specialist consultancy to license university technology from two different universities, it found that both institutions vastly over-inflated the value of their patents because of their desire to earn a return and their under-estimation of how much further work was required to bring the technology to market. The consultancy abandoned negotiations with one university because its requirements were "*so outrageous*". Another firm suggested that in a university's view, simply having the idea means it is 90% of the way towards commercial realisation. In reality the research done to create an idea represents at best 10% of the work. (It is unclear whether this comment applied to the academic researcher or to the technology transfer office involved.)

In the view of the technology consultancies in particular, the speed of academic science is too slow and not closely enough attuned to what the market might need – echoing the Lambert Report[103], which noted that commercial organisations and universities "*work on different time scales towards different objectives under different management systems*". The perceived lack of sense of urgency in university work clearly has a detrimental impact on commercial enterprises' desire to engage with the sector, whatever policymakers might hope for. One firm commented, "*the pace a university works at is quite low. It's fine for policymakers to wish [industry] to get and maintain involvement with universities, but that's different from saying universities are causal in the success of businesses like ours on a daily basis*". Time scales can be an issue even in subcontract work: one firm noted specifically that, since a university is not allowed to employ a researcher until the project receives its grant funding, there can be a 6 month delay getting someone into post. In this case it hindered the design work that was mainly the university's responsibility, and meant the subcontractor was unable to start on the fabrication. Problems of this kind made it easy to lose the first year of a 3-year project entirely.

Firms also said that frictions between universities and potential commercial partners could arise around IP ownership because of inexpert negotiations over licensing agreements. The situation is not helped by aggressive IP departments or technology transfer offices (in some universities) that are staffed by non-scientific and/or non-commercial people who do not understand the complexities of the science and/or commercial situation. Lack of experience often means that the IP 'trail' was often not sufficiently clear-cut for proper licensing arrangements to be made. Firms working in a subcontracting role had also found themselves under pressure from IP departments to give away detailed process knowledge acquired over many years, even though this was valuable but non-patentable know-how that had to be kept secret even from (university) contractors.

Contractual ownership issues over IP, plus the limited experience of spin-out teams and – particularly in the case of platform technology ventures – a lack of market readiness, make it hard for universities to create robust spin-out opportunities. The founder of one tiny spin-out firm (a Module 2 company) based around doctoral research freely admits to a complete lack of prior commercial experience and even admits that, had he been more aware of commercial realities, he would not have gambled on establishing a business; R&D grants have ensured his survival.

Finally, our firms were somewhat critical of the Research Councils' apparent unwillingness to fund businesses or intermediate research institutes directly. As one interviewee commented, "*there is nothing in the EPSRC charter that prevents them [from funding us], but universities regard it as their money*". Firms do sometimes work as subcontractors to Research Council-funded projects, but are generally not enthusiastic because the relationship turns them into 'second class citizens' even where they are contributing important science. More positively, however, subcontractors are paid for their work at the full rate because they are not seen to be part of a collaborative project (on which only partial funding is payable, c.f. Chapter 7), and this can be helpful to younger and smaller firms.

Despite these issues many believe there should be greater scope for the technology consultancy firms and the intermediate research institutes in particular to act as a bridging mechanism between academia and industry. Ian Rhodes of PA, for example, notes: "*there is the need for someone like ourselves, as a broker in the middle who is deep in certain areas and sectors, e.g. in certain aspects of med-tech that we know well, who is able to go to the university and say 'these are some of the problems we think you should be working on and*

103 HM Treasury (2003), Lambert Review of Business-University Collaboration: Final report.

coming up with the solutions to if only this or that could be done, and we can put a lot more detail on that in terms of either the scientific characterisation or some of the business or commercial constraints that we know would apply if you wanted to make it a commercial success'." The scope to play the role of technology broker tends to be greatest where platform technologies with the potential for application in many industries are involved, as a means of encouraging the diffusion of knowledge across different commercial settings and of shaping the way that the university engages with potential partners.

8.2 University of Cambridge Spin-outs and their Contribution to the Economic Base

The companies in our research were selected because they were examples of the soft model. But it turns out that these companies, and their hard company successors and spin-outs, constitute a high proportion of Cambridge's most successful firms measured in terms of employment. We know also that very few University of Cambridge spin-outs over the last thirty years have grown to employ more than one hundred people. It makes sense, therefore, to examine the university spin-out picture in a little more detail and to consider what policy lessons we can draw from the contrast with the success of the soft company sector.

Of course, it can be argued that the University of Cambridge has made a substantial contribution to the development of technology-based firms in the region through its relaxed stance, until fairly recently, to the transfer of employee-generated IP into a commercial setting. Not least was the foundation of Cambridge Science Park (in 1970) and St John's Innovation Centre (in 1987), both of which have provided the facilities for academics to pursue the development of their own innovations.[104] Nevertheless the University put little direct resource behind licensing or spin-out activities until the late 1990s, when it adopted a more pro-active approach to harnessing the entrepreneurial spirit of its staff through the establishment of what is now Cambridge Enterprise and instituted the gradual formalisation of IP policy.[105]

As a result of the University's hitherto relaxed approach to technology transfer, it is difficult to establish with any degree of certainty how many ventures can genuinely be traced back to the University. Among the earliest examples of venture creation are the Cambridge Scientific Instrument Company in 1881, the Pye Group in 1886[106] and The Welding Institute (TWI), profiled in Case Study 10, in 1946. Of these three, only TWI continues. The distinction has to be made between university spin-outs (ventures created by University members based on University-owned IP and in which the University holds an equity stake) and university start-ups, where the definition is more broadly drawn to encompass ventures created by researchers or students within five years of their time at the University and for which the knowledge gained from the University is crucial to the success of the business.[107]

A list of firms generated by the Institute for Manufacturing in 2005 numbers some 300 businesses, dead and alive, that had backing from the university or university academics.[108] Total employment among these firms was 8,800 people (including 1,679 at UCLES, the University local examination syndicate). Only 42 of the 252 firms still trading in 2005 were spin-outs based on IP owned by the University; the rest included start-ups by PhD students (like Owlstone), spin-outs from local corporate laboratories with some form of university affiliation (such as TeraView, from Toshiba), and some firms whose relationships are more distant, for example ARM plc, which emerged from Acorn Computers twenty years after PhD graduate Hermann Hauser first went into business. Nevertheless, the paper shows just how long the University of Cambridge has been pioneering new technology – it includes Cambridge University Press, founded in 1534 and the internet start-up of its age!

A report in 2000 by Segal Quince Wicksteed[109] found that the proportion of high-tech companies established since 1990 with a founder from Cambridge University or a Cambridge research centre had fallen to 17% from the 25% of firms in 1984 that they identified in their original Cambridge Phenomenon study. They attribute this decline in part to increased corporate venturing, i.e.

104 Business incubation centres and science parks established by universities alone or in collaboration with the regional development agency represent a potentially important form of contribution to economic development. See Appendix B for a summary of EEDA-sponsored science parks and enterprise hubs, some of which are university-based.

105 The new policy adopted in December 2005 provides that the University has first rights over inventions made during the course of research by academics and staff.

106 Segal Quince & Partners (1985) The Cambridge Phenomenon: The Growth of High Tech Industry in a University Town.

107 Hiscocks, P. (2005) Performance of New Business Ventures from the University of Cambridge.

108 See www.ifm.eng.cam.ac.uk/ctm/teg/documents/CambridgeUniversityspin-outsandstartups200905. pdf. The list has not been updated because of the difficulty in drawing suitable definitional boundaries.

109 Segal Quince Wicksteed (2000) The Cambridge Phenomenon Revisited.

greater numbers of spin-outs from existing firms, as well as the establishment of research centres in Cambridge by large multinationals.

Nonetheless, a number of important contributors to the region, some of them highlighted earlier in this report, have emerged from the University.[110] In the computer-aided design world, for example, firms such as Shape Data (and later Three-Space Ltd) from the Computer Lab, and Applied Research of Cambridge from the Department of Architecture were an important part of the cluster that included CADCentre and its associated firms. More recent examples of potentially important start-ups from the University include Cambridge Semiconductor, Plastic Logic,[111] and Light Blue Optics, all still loss-making. The case of Owlstone, profiled in Chapter 7 similarly fits here.

Cambridge Display Technology, which spun out of the Cavendish Laboratory in 1992 and now employs approximately 160 people, was a 'classic' hard start-up. It raised some $140 million from VCs and its NASDAQ floatation before being sold to Sumitomo Chemical in 2007 for $285 million.

Not-for-profit research laboratories with a close relationship to the university have also played an important role in biotechnology start-ups. In monoclonal antibodies, Greg Winter of the MRC Laboratory of Molecular Biology created CAT with David Chiswell (see Case Study 14 in this Chapter), before going on to found the domain antibody company Domantis a few years later. Backed by £42 million in venture capital, Domantis employed around 60 people and achieved sales of around £2 million before being bought in 2006 by GSK for £230 million. Another venture capital-backed biotechnology business was KuDOS Pharmaceuticals, which spun out of the CRC Institute of Cancer in 1997 and raised £43 million in three rounds of VC financing before being bought for $210 million by AstraZeneca in 2006. By then it employed 75 people but its annual revenues were still under £1 million.

Data from Library House[112] indicate that University of Cambridge spin-outs have been second only to those from Stanford University in attracting venture capital backing, with £140 million raised in the period 2001-6.

However, there is plenty of evidence to suggest that neither their academic founders nor the University (through its various seed funds) are always able to reap the financial rewards, even if the business is eventually successful. The technology in academic new ventures is often too far from market for the founding team to retain a significant degree of control in bringing their idea through lengthy development and into manufacturing and finally the marketplace. The distribution of returns delivered by Solexa, one of the most successful companies to be seed-funded by Cambridge Enterprise, the University's technology transfer business, illustrates the point. Solexa was founded in 1998 to exploit IP developed by Cambridge scientists to rapidly read individual genomes, and after many rounds of venture capital it was sold to Illumina in 2007 for $600 million. The University venture fund reportedly received 1.63 times its investment; later investors (including those who did not invest until 2004) received 9-10 times their investment. But the academic founders are reputed to have received just $2 million (0.3% of the proceeds) between them.

Just as we have seen in the case of the large technology consultancies but also in other industries, spin-outs themselves sometimes spawn new ventures. This has undoubtedly also been the case historically with spin-outs from Cambridge University, with progressively weaker and less direct relationships occurring in later 'generations'. Hence although firms remain in – or indeed are attracted to – the Cambridge area because of the presence of the University, the exact nature of their relationship is probably significantly less clear than policymakers may imagine. In tracing local firms' progeny created either voluntarily or involuntarily (e.g. following takeover of the 'parent' firm, with or without subsequent closure by the acquirer), we found that many founders chose to locate their new venture in or around Cambridge, irrespective of links to the University. The fact that entrepreneurs remain embedded locally (and are engaged in business angel networks) seems an important factor in the continuation of the Cambridge 'phenomenon' and in the economic growth of the region.

8.3 In Conclusion

The relationships between universities and the companies we have researched provide an

110 Elizabeth Garnsey in the University's Engineering Department has tracked trends in technology-based companies around Cambridge for the past two decades.
111 Plastic Logic has raised over $200 million to exploit plastic electronics technology developed in the Cavendish Laboratory but, as it is still pre-revenue, it is too early to say whether it will be successful.
112 Library House (2007) Looking Inwards, Reaching Outwards: The Cambridge Cluster Report 2007.

independent, but for some probably troubling, perspective on how academic science and technology contribute to regional economic growth.

But for many in the technology business and investment communities, these findings may not be too surprising. Universities are undoubtedly important contributors to the wealth of the region, but the relationship with technology-based firms is often less direct than is assumed by government policymakers. And academic research departments tend to be poorly equipped to develop an innovative technology to the point at which it can be exploited commercially through a spin-out company, certainly with a hard, product-focused business model. Unlike the technology consultancies, they do not accumulate expertise through repeated commercial contracts. And the short-term, project-based contracts through which academic research is funded can make it difficult to build spin-out teams with critical mass. Lack of experience of commercial negotiations and commercial project management is a further weakness.

Soft start-ups, based around areas of academic expertise and platform technologies, could provide a way of dealing with these limitations, providing sufficient R&D contracts were available. This might allow teams and commercial abilities to be built gradually, before a transition into a harder business model is made from a position of strength. However, an overly romantic view of the investment readiness of academic science has probably led to too much emphasis on the hard start-up model, with many disappointed academics and investors as a result.

It is clear that the Cambridge cluster of private sector companies, and in particular soft companies, are a more important source of ideas for new businesses than the University of Cambridge itself – at least in terms of job creation.

Equally we find that IP licensing and other forms of hard technology transfer from the University are also relatively unimportant locally in terms of job creation. Rather than direct IP relationships between our 'soft' firms and the academic world, we find that relationships between the two revolve primarily around people: through recruitment from universities, and through personal contacts between experts across a wide geographical base. We return to this argument in our concluding chapter on policy implications for innovation, growth and economic development.

Image courtesy of TTP Group plc

Chapter 9: Policy Implications and Recommendations

In Chapters 3-8 we reviewed different aspects of the soft business model, discussed how firms with this model contribute to economic growth in the East of England region, and examined how they interact with government policies on science and innovation. The research shows that many of the largest and most successful science and technology businesses in the region owe their origins to the 'soft' business model.

- Firms use the soft model in different ways, depending on how innovation works in their industry and also depending on their phase of business development.
- Some organisations retain the soft model as a core mode of operation throughout their lives; others traverse the soft phase rapidly, using it as a stepping stone to product sales; still others spend years fostering proprietary technology and investigating different potential applications within the protective umbrella of a soft business before making the transition into a product company or spinning out a separate venture.
- Soft companies exploit their intellectual property in different ways too: by patenting and licensing it in return for royalties; by patenting and exploiting it through funded product development, perhaps receiving additional payments alongside basic fee rates; by packaging up a specialist team and/or bundle of IP and spinning it out as a separate enterprise; or by keeping and exploiting technical know-how (which is often process-oriented and therefore not patentable) in-house, in work for external clients.
- They are also financed in different ways: often with a bootstrapped start (salary sacrifice, personal bank loans, loans from friends and family) until revenue from consultancy projects or fees-for-service kick in; more substantially through customer contracts bringing up-front payments, milestone payments and sometimes royalties; sometimes with a mixed model of contracts and products; but only rarely with venture capital funding except for product-based spin-outs from the parent firm.
- Their use of, and attitude to, government policies to support innovation also varies widely from scheme to scheme:
  - a generally positive view of single company R&D grants, especially in the early stages of a firm's life;
  - a mostly unenthusiastic attitude to the value of collaborative research programmes;
  - very limited experience of, and a sceptical view with respect to, government R&D procurement contracts; and
  - an informal approach to interaction with universities, with university IP playing only a limited role as a basis for innovation within firms.
- Finally, even where firms have been established as 'hard' businesses, with backing from venture capital to develop a focused range of products, development contracts with customers often play a critical role in 'softening' the business model to reduce risks, augment funding and ensure effective engagement with lead customers.

9.1 Exploding the Myths

Soft companies and R&D contracts with customers play a critical role in the region's innovation economy. They facilitate the 'natural' innovation process by which solving user problems leads on to the creation of new and better products, and they have enabled the formation and growth of many of the region's most successful science and technology companies. It is therefore essential that government policies – at national and regional level – are well enough configured to foster and support this business model. The analysis in Chapter 7 suggests that this is currently not the case.

Furthermore, we contend that this is a reflection of three important, but largely erroneous, assumptions that have underpinned government policy thinking for decades:

- that university research is the economy's key source of technology and innovation;
- that venture capital funding is the primary financial resource for technology-based start-ups; and
- that co-funding multi-partner collaborative research programmes is the best way for government to support technology development projects.

We address each of these beliefs in turn.

Myth Number One... that University Research is the Key Source of Technology and Innovation

The UK's universities account for a high proportion of government funding for research and development, and there is an implicit assumption underlying many utterances on science and innovation policy by government ministers and officials that much of their research output is ripe for commercial exploitation through university spin-outs and technology transfer to established firms.

Clearly university IP can and does play a role in economic development, both locally and nationally, and we have no doubt that its economic impact could be greater. However, as this study shows, the effect is actually quite modest – at least over the short to medium term. Cambridge and its environs have the strongest academic research infrastructure in the region and in the UK, together with a vibrant community of science and technology companies. Yet despite this, in the main these companies rely on the inventiveness of their own people to create new technology, rather than on IP from partnerships with universities. To the extent that they are looking for new technologies to solve problems, the search is global and covers all sources – academic and industrial. As David Chiswell, founder of CAT, notes, "*Policymakers assume all the best people are in academia, but a lot of company people are excellent scientists and drive forward the research*". It is also clear that customer problems provide the stimulus for much innovative technology development.

Equally there are few, if any, really successful science and technology companies that have been formally spun out around Cambridge University IP in the last 30 years. In the physics and engineering arena, for example, the most successful to date is probably Cambridge Display Technology (CDT), which was sold to Sumitomo Chemical for $285 million. CDT's achievements should not be ignored, but the total returns over that time scale were too small to meet the expectations of conventional VC investors.

It is clear also that success tends to mean acquisition and, especially in life sciences, often limited further growth beyond the R&D team. We also saw in Chapter 8 how the returns to seed investments by the university and to founders from the sale of successful university spin-outs have frequently been woefully inadequate.

Far more important from the perspective of jobs are the companies set up by 'twenty-something' Cambridge graduates and PhDs to exploit skills or inventions independently of the university. These include Cambridge Consultants, founded by a group of science and engineering graduates; Cambridge Processor Unit and Acorn Computing, founded by Herman Hauser after finishing his PhD in physics; Autonomy, founded by Mike Lynch after his PhD research on neural networks; Pi Research, founded by Tony Purnell during his PhD in engineering (which he never finished); and Owlstone, set up by two PhD students and a young Research Fellow in electrical engineering. In every case it was the entrepreneurial drive of the young founder that was the key to getting the business started, and there was no formal university role. In all but the last case it was the founders, customers, and some bank lending that funded the business.

Our examples tend to focus on engineering– and physics–based businesses and our coverage of the biotech sector in this report is rather weaker. There are also prima facie reasons to expect that life sciences IP developed in academia would be more readily transferred out for commercial exploitation. However, even in life sciences it is clear that spin-outs from existing companies play a very important role in the sector's development.

These conclusions are not to undermine the importance of fuelling the economy with longer-term research and trained engineers and scientists. However, they point to a need to 'de-glamorise' the role of the university boffin in creating the new science- and technology-based companies required to rebuild the UK's industrial base, and to ensure that greater policy attention – and more money – is devoted to helping all entrepreneurial start-ups and especially spin-outs from research intensive companies.

We believe they point also to the need for a fundamental rethink of how effective universities can ever be at commercialising academic IP, given the way that they are structured, staffed, incentivised and financed. We return to this issue later and suggest some possible policy solutions.

Myth Number Two... that Venture Capital Funding is the Primary Financial Resource for Technology-Based Start-ups

The 'Silicon Valley model', with its focus on fast-growing, 'hard' product companies, is glamorous and seductive. There are some spectacular examples of venture capital-backed success stories in the US, and its advocates are articulate, well-funded and persuasive. Successive governments over a quarter of a century have argued for the UK to look to Silicon Valley as a role model for financing new science and technology firms.

Yet the picture in the UK seems to be very different. The average returns to early stage science and technology VC investors in the UK (as across Europe) have been consistently too low to attract institutional investors[113] and even before the credit crunch the Government and European Investment Bank have increasingly had to play the lead role in getting new funds established.

Furthermore, research by the CBR has demonstrated that only a tiny minority of SMEs (4% of those surveyed) pursues external equity financing – although those that do look for VC funding regard it as an important source of finance.[114] As this report shows, a high proportion of the region's most successful science and technology companies have their origin in a 'soft' start, either directly or because they have been incubated in a soft company prior to spin-out. And recent research from the US suggests that the role of venture capital there may also have been overstated, with fewer than one in five of the fastest-growing and most successful companies having had venture investors.[115]

There is also reason to believe that soft start-ups, being controlled by their founders, are likely to survive longer as independent entities, and lead to greater returns to founders and ultimately to more money being reinvested in the region by business angels.

We would argue that the way that standard venture capital funds operate is directly responsible for the different trajectory taken by many hard start-up businesses. VC investors expect to see very high returns (to compensate for the increased risk and illiquid nature of their investments), and so VCs must invest in scalable businesses with a standard product. Nearly all funds have a ten-year fixed life, which in practice means VCs need to be able to exit their investments in around seven years. Stock markets are only intermittently open for IPOs, and there is a minimum market capitalisation at which an IPO gives sufficient liquidity for investors. This forces VCs to focus on finding trade buyers for their portfolio companies and on investments that create a single new product line that can be slotted into an acquirer's existing distribution system. It also saves the extra investment required in building a portfolio company's own sales, distribution and customer support infrastructure once some initial market success has been achieved. An early trade sale – and a safe return today, rather than a possibly larger, but less certain one in a few years' time – is therefore nearly always preferable.[116]

In contrast, the soft model allows the entrepreneurial process to continue for much longer and enables the creation of fully-rounded businesses with their own international sales, distribution and support activities, and with the drive to continue to grow and develop the business. The way that the soft model allows entrepreneurial founders to develop their own skills gradually, and to remain at the helm, is no small part of the picture. Most entrepreneurs are 'unbackable' when they start their first business before gradually bootstrapping their way into the Sunday Times Rich List. The paths taken by Richard Branson and Alan Sugar are in many ways relevant to technology entrepreneurs.

113 According to the British Venture Capital Association's Private Equity and Venture Capital Performance Measurement Survey 2008, the average internal rate of return for all funds over the last ten years was 15.4%. However, the average return from venture funds was minus 1.6% and for technology funds was minus 2.0%. Whilst the tech boom and current recession may have had a particularly adverse effect in the latest returns, the pattern of poor performance is systemic. The picture has been unchanged for 20 years. Several reasons have been discussed for the discrepancy between US and UK returns. The most likely, in the authors' view, is the much greater investment return on the one or two 'home runs' on which VC funds depend. This reflects the ability to scale a business faster and further within the US market, a resulting ease of access to the public markets through IPOs, and the focus of some funds on IT-based businesses with relatively little technical risk and short lead times.

114 Cosh, A. and Hughes, A. (Eds.) (2007) British Enterprise: Surviving or Thriving? SME Growth and Public Policy 2001-2004.

115 Kedrosky, P. (2009) Right-sizing the US Venture Capital Industry.

116 Two semiconductor spin-outs from Cambridge Consultants illustrate this point. CSR's investors decided to invest more and IPO the business. Alphamosaic's investors opted for an earlier trade sale exit and achieved a lower, but safer, return.

The pressures on VCs discussed above also have an impact on platform technology companies pursuing a mixed funding model, with venture capital supplemented by development contracts from customers to explore different applications. VCs do not like 'unfocused' companies and, where lack of focus occurs alongside lack of customers, this is understandable. However, it is also common to find VCs urging companies to drop lines of customer-funded development to concentrate on applications where some customer traction has just started, in the hope that this will deliver the scalable fast-growth model they need. But often they discover that the push to focus was premature and that there is little demand for a standard product based on one or two similar contracts with lead customers. The outcome is usually financially and organisationally damaging, and brings a major loss of investor confidence. In these situations, a slower, softer, and more exploratory strategy, with investment spread over a longer period, might well have been far more effective, but unfortunately it is not one that fits the 10-year fixed-life model of most VC funds.

Venture capital will always be important to certain kinds of company at some stage in their development, and because of the consistently poor financial returns to investors it is likely to require more government support rather than less. However, the implication of our research is that to maximise the economic potential of the business model that does work well within the UK (at least judging by the evidence from the East of England region), the Government should devote at least as much attention to encouraging the customer R&D contracts on which the soft model depends.

Myth Number Three... that Co-funding Multi-Partner Collaborative Research is the Best Way to Support Technology Development

The third implicit assumption underpinning government policy is that the best way to support technology development projects directly in firms is through collaborative research and development grants involving multiple partners, including companies and universities. The amounts available – in total and per project – are much larger than through the single company R&D grant schemes.[117]

But as our research shows, the majority of the region's most successful soft companies have made little or no use of collaborative R&D grants. This strikes us as a serious indictment of the policy model. All the successful soft companies we interviewed were looking for opportunities to create IP in order to increase value creation and accelerate their growth. Their ability to do so is restricted in their normal contract R&D business, as the client normally owns the IP and the amount of money available for in-house investment in IP is restricted. One might expect prima facie, therefore, that government-financed collaborative projects would provide an ideal mechanism to enable these firms to leverage their own investment where they want to build and retain IP, perhaps leading on to a spin-out business. Instead, most regard collaborative R&D as irrelevant. Those that do participate, such as Lotus Engineering, have failed to turn projects into significant product revenues or successful spin-outs.

The failure to design our most important policy for funding R&D to make it attractive to these companies represents a major missed opportunity. It is a failure that reflects two accidents of history and one of vocabulary. The accidents of history stem from the economic and political climate leading to the European Commission's early forays into science and technology policy in the early 1980s.

First, technology policy thinking in both the US and Europe was greatly influenced at this time by the role ascribed to Japan's Very Large Scale Integration project in semiconductors, which took place between 1976 and 1980. This was seen as catapulting Japanese companies from nowhere to almost total dominance of the world memory chip market and, at the time, Japan's Ministry of International Trade and Industry seemed set to repeat the trick through its collaborative Fifth Generation Computing programme. The US and Europe wanted some of the same magic. In the UK this led to the Alvey Programme for computing research in the period 1983 to 1988.

Second, part of the background to the Esprit programme, which ran from 1984 to 1988, was a European industry characterised by competing national champions such as ICL and Bull in computers. The ideas of Viscount Davignon, the EC Industry Commissioner, for pan-European mergers had earlier been rejected, but pre-competitive collaborative R&D programmes became a substitute as well as a way to encourage European integration more generally. The pre-competitive focus and the state aid rules that underpinned it were designed to prevent anti-competitive practices, limit subsidies to national firms,

117 The total cost to the Government of R&D tax credits is even greater than collaborative R&D grants, but evidence suggests (as indicated in Chapter 7) that it has little impact on firms' total R&D expenditure.

and build economies of scale across companies.[118] Twenty-five years later, these rules persist largely unchanged and severely limit how national governments within the EU can make R&D grants to companies. Collaborative R&D has come to be seen as the only legal way in which the UK government can fund sizeable R&D projects in companies, and its rationale is underpinned by the (in our view over-stated) role ascribed to universities as sources of IP and scientific expertise on which companies should draw.

The accident of vocabulary relates to the way that technologists, managers and entrepreneurs use the word 'collaboration' to present a contractual relationship with a customer as more of a 'partnership between equals' than a contract between a buyer and a seller. This usage has led to the idea that any kind of loose 'collaboration' is a good way of developing new technologies for commercialisation. This report shows that tightly specified, single customer-contractor relationships with clear phases and milestones play a crucial role in driving innovation through to real products. The multi-partner collaborations funded under TSB or EU programmes are very different in terms of structure and management, with much less well defined project leadership, multiple – and often divergent – objectives and a lack of hard intermediate milestones. Projects are required to be pre-competitive and the closer they are to commercial exploitation, the greater the funding required from participating companies. Added to this are major problems regarding IP ownership.

Whilst providing a viable way for large corporate laboratories to subsidise their long-term programmes, collaborative R&D projects of this kind are ill suited to SMEs. EU programmes, with multiple partners spread across the EU, are particularly problematic.[119]

As one respondent remarked, "*I see a lot of activity going on where programmes are put together and optimised to meet the collaborative rules, rather than optimised in terms of what makes the best research or the best commercial return*".

For those SMEs that do participate (and these were not generally amongst the most successful firms we interviewed) it can be argued that firms are pushed in the direction of expensive, slow, collaborative research and away from the tight, customer-focused developments where they should concentrate.

Whilst we have no doubt that multi-partner collaborative R&D has a role in government innovation policy – where standards, complex supply chains and early-stage work to address new technological or societal challenges are required – we believe that a fundamental rethink is necessary and that new policy models should be designed to ensure that the money currently spent on collaborative R&D is available in a manner more relevant to SMEs.

9.2 Recommendations

This report shows that 'soft' companies with R&D contracts for customers have played a critical role in the growth of entrepreneurial science and technology companies and in the economic development of the region. Whilst our concern is with East of England region companies, we have every reason to believe the lessons are relevant nationally.

We believe that government innovation policies need to undergo a fundamental rethink to ensure programmes are in place – and adequately funded – to support and encourage these ways of doing business and to 'play to the grain' of the innovation process. Our recommendations focus on four areas:

- government technology procurement
- private sector R&D contracts
- venture capital
- intermediate R&D institutes

Recommendation 1. Enhance Government Technology Procurement Programmes

Our research shows that R&D contracts from customers play a key part in the development of new businesses and job creation. Today these contracts come almost entirely from the private sector although, historically, the public sector has also occasionally played a role, for example through the BBC microcomputer programme. It is also clear that, in the US, government R&D contracts have been the driving force behind the development of entire new high technology industries like semiconductors and supercomputers.

In the UK, government procurement plays a major role in the overall economy. It is responsible for 55% of all

118 Teaming Up for the 1990s: A Guide to International Joint Ventures and Strategic Alliances. (This book was written by David Connell when he was a consultant at Deloitte Haskins & Sells. A merger of the firm's US practice with Touche Ross in 1989 resulted in the transfer of the IP to the new firm, and on publication authorship was attributed to T.M. Collins and T.L. Doorley, two of the firm's partners.)

119 The administrative burden of applying for and managing such collaborative funding is widely regarded as onerous. Small firms in particular find proposal writing a heavy (and uncompensated) drain on resources, and bemoan constant changes in the application process that reduce the potential to improve their efficiency in applying.

purchases of IT goods and services, for example,[120] and is the dominant customer for healthcare and medical products. In many sectors such as security, transport, energy and the environment, where the government is not a direct purchaser, it has a major influence either as a specifier or through general policy. If it were to fund some of the new technology it needs in the future and were to participate in a more active way by specifying requirements, evaluating prototypes and acting as a lead customer for trials, much more of its mainstream procurements would end up being supplied by UK companies. Furthermore, those companies would be far better positioned to sell globally and ahead of competitors. By participating actively at this early stage, it is also likely that the efficiency of government services would be improved, major policy goals achieved earlier, and the probability of making major procurement mistakes reduced.

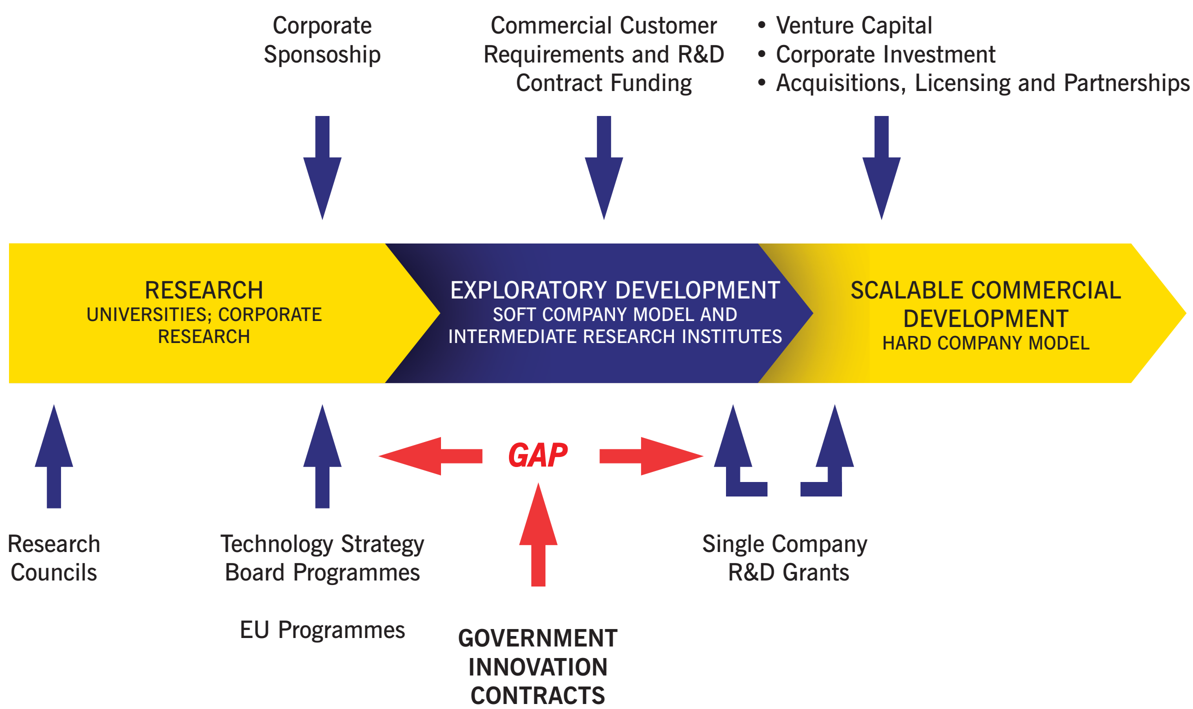
These arguments are widely accepted by Government and form the basis of numerous policy announcements.

Our research shows that, despite this, the UK government is virtually absent as a lead customer for new technology in terms of either R&D contracts or demonstrator and prototype purchases (see Figure 11). This is in spite of attempts over many years to encourage government departments to operate as lead customers, most recently through the requirement for them to prepare annual Procurement Innovation Plans. We believe this is a major missed opportunity.

The most tangible government programme is the Small Business Research Initiative (SBRI), and the new mechanisms put in place by the Technology Strategy Board since April 2008 to implement it are well designed and managed. However, the fragmentation of budgets and innovation management responsibilities within individual spending departments has meant that participation across government and the value of SBRI competitions announced so far have fallen well behind the commitment made in the March 2008 Budget and reiterated in April 2009 by BERR and in the Budget report.[121]

Principal responsibility for implementing these policies lies with the TSB (as coordinator) and central government spending departments. Nevertheless EEDA has already played an important catalytic role, and the regional SBRI it has initiated with NHS East of England is one of the most significant pilot programmes to date (see Box 18).

Figure 11: The Innovation Funding Gap



120 DTI (2003) Competing in the Global Economy: The Innovation Challenge.
121 BERR (2009) New Industries, New Jobs; HM Treasury (2009) Budget 2009: Building Britain's Future.

Box 18: A Regional SBRI Programme

In April 2009 the East of England launched a Small Business Research Initiative competition in the health sector to help industry bring new technologies to support the achievement of regional health priorities and increase the possibility of adoption in the NHS. The competition was open to all companies, including those not currently engaged in the health sector.

The programme was funded by the NHS East of England and the East of England Development Agency (EEDA), together with the Technology Strategy Board (TSB) and the European Regional Development Fund.

The competition covered three topics:

- Managing Long-term Conditions – remote monitoring
- Patient Safety – improving health outcomes
- Keeping Children Active

Like all SBRI competitions, it operated as a procurement process aimed at developing the new technologies the NHS needs. So awards take the form of contracts rather than grants, and developments are 100% funded.

Projects were selected through an open competitive process in two phases, and the selection panels for each topic included senior clinicians and experienced technology developers. Winners are first awarded Phase 1 contracts to investigate project feasibility and undertake preliminary design work. These are for up to 6 months and £100k. Companies that successfully complete Phase 1 are then eligible to compete for Phase 2 funding of £250k – £750k for up to 2 years to take their technology to demonstrator or prototype stage, and possibly to enable user trials. All firms retain the rights to any IP generated from the project, with certain limited rights of use retained by the NHS.

The competition attracted 177 proposals and eleven companies, mostly start-ups or early stage companies, have been awarded Phase 1 contracts. It is expected that roughly 50% will go on to receive Phase 2 awards. Examples of Phase 1 contracts include:

Eykona Technologies Ltd	3D imaging systems for objective measurement and characterization of ulcers
Exhalation Technologies Ltd	Device for assessment of lung inflammation in exhaled breath for asthma-prone children
Sonovia Ltd	Ultrasonic patch for targeted delivery of drugs for patients suffering from chronic musculoskeletal conditions such as arthritis
Docobo Ltd	Remote monitoring telehealth system to enable individualized interactive chronic disease management in the home
Oxford BioSignals Ltd	Monitoring cardiac and other vital signs in hospitals
Anaxsys Technology Ltd	Respiratory rate monitor for use by paramedics in ambulances

We propose four measures to accelerate and extend the take-up of SBRI and related procurement-based innovation policies:

(i) that central government allocates a fixed annual budget to the TSB of £75 million to enable it to match-fund departmental SBRI programmes and encourage their expansion;

(ii) that the use of SBRI at regional and local government level be promoted;

(iii) that an annual, quantified, independent review of progress with SBRI and related procurement-based innovation programmes be published by an organisation such as NESTA or an appropriate House of Commons Select Committee;

(iv) that a substantial component of the next European Framework Programme (FP8) – we propose €800 million per year – be directed to co-funding innovation procurement programmes in member states that are compliant with guidelines based on the US SBIR and UK SBRI models.[122, 123]

122 During the last two to three years the European Commission has promoted a concept known as “Pre-commercial Procurement”, which allows EU public sector organisations to place 100% R&D contracts with firms. This has led to a useful clarification of EU procurement rules, which legitimises SBIR-type programmes. However, beyond this the PCP initiative is effectively unfunded.

123 More detailed proposals have been made to the European Commission.

Recommendation 2. Revise TSB Collaborative R&D Programmes to Encourage Bilateral Contracts with Lead Customers

The soft company model is at present dependent on R&D contracts from the private sector, but not all private companies are used to placing R&D contracts with other companies and budgets are limited. So there are good reasons to make this practice more widespread through grants.

The multi-partner collaborative grant model which dominates the Technology Strategy Board's tool-kit is a legacy of its days as a part of the DTI. Significant changes have been made since its change to Agency status and the appointment of a vigorous, more business-orientated management team. We believe it is now timely to undertake a 'zero-based' review of the collaborative grant model to examine the impact of past projects and establish for what sorts of firms, technology projects and industries different variants are appropriate.

In particular we propose that more bilateral contracts should be funded between private sector customers and suppliers, especially small, specialist technology companies. Such projects have traditionally been a rarity within the TSB portfolio, and the percentage of supplier costs covered has generally been small as they have typically been regarded as close to market. Larger, longer-term collaborative programmes have been dominant, partly driven by perceptions of EU rules.

Recent changes to EU State Aid rules suggest that an attractive programme could be devised to encourage bilateral projects involving lead customers and innovative SME suppliers, with up to 75% of the cost of developing pre-commercial prototypes covered in the supplier (80% if it employs fewer than 50 people) and 60% in a large company customer. We propose that these new rules should be used to construct such a programme, perhaps using a phased approach similar to the SBRI programme.

We believe that bilateral contracts involving private sector customers and SME suppliers should account for 50% of TSB expenditure on collaborative R&D.[124]

Recommendation 3. Revisit the Venture Capital Funding Model

Many soft companies have provided excellent returns for their founders and other investors, but their timescales are too long and their strategies too uncertain to attract venture capital. It could also be argued that some firms that have raised venture capital were encouraged by their investors to adopt a 'hard' product-oriented strategy too early in the development of their technology in order to deliver an exit within VC timescales, whereas a softer strategy and slower 'burn rate' might have been more successful. Platform technology companies, in particular those whose potential markets are highly fragmented, often need to soften their strategies by working with customers to test applications and therefore need longer-term financing.

As noted earlier, the average returns to venture capital have for many years been too low to attract investors into UK funds. Early stage technology funds are particularly problematic. The withdrawal from venture capital of 3i, the largest and most experienced investor in the sector, underlines the problem. There are many problems with the VC model in the UK and strong arguments can be made for the creation of an up-to-date version of the Industrial and Commercial Finance Corporation (ICFC) to replace 3i. A longer time horizon, an evergreen model, and greater sectoral focus by individual funds are three of the desirable changes.

The science-based focus of early-stage companies in the EEDA region requires venture capital funds with an investment model that enables them to engage with soft start-ups and platform technology companies operating a mixed model, probably using small scale investments, over a longer term, and with a more hands-off approach than would be advocated by conventional VC wisdom. Convertible loans probably also have a role to play with this kind of business.

We believe that both central government and the regional development agencies like EEDA have a role to play in encouraging the development of new investment models along these lines which are more appropriate for the kind of science and technology businesses that start within the region.

Recommendation 4. Establish Focused, Fixed-Term Intermediate R&D Institutes

In this report, we have also discussed the role of intermediate research institutes which, though not profit-oriented companies in their own right, have a mission-driven role to develop technology for commercialisation that is uncompromised by the conflicting requirements for academic research

124 Bilateral contracts could still involve other companies or universities, but as subcontractors, and only at the choice of the two principal parties concerned.

publications and teaching seen in university departments. As such they have some features of the true commercial soft company. Some – like CADCentre and ORL – have transitioned into, or spun off, important product businesses. In contrast TWI has been notably less successful in terms of product-based spin-outs, although it has been highly successful globally as a service business.

An important question remains regarding whether intermediate research laboratories focused on emerging technology areas, with some core funding from government, flexible full-time staff and senior staff motivated towards commercialisation rather than academic publications and teaching, could help to catalyse the exploitation of the region's science base.

Earlier we commented on the relative lack of companies based on Cambridge University IP amongst Cambridge's larger science and technology firms. The experience of venture capitalists investing in start-up companies points to a series of problems with exploiting university IP.[125] Many of these problems derive from the nature of the exploratory development stage typical of the exploitation process for any major new platform technology, as described in Chapter 4. This stage must be carried out in a very mission-driven environment geared to rapid delivery, but is rarely well enough defined or close enough to market to be appropriate for VC funding alone. Attempting in a conventional university research department to bring a proposition to the point at which a potential spin-out is genuinely VC-ready is fraught with problems:

- it is difficult to build the teams of 5-20 people required as the core of any major spin-out business;
- development is progressed in fits and starts as academics have conflicting time pressures to publish and teach;
- research staff are funded to work on specific projects; it is therefore difficult to switch resources to accelerate work on a temporary basis to service 'customers' or on a more permanent basis when the pace of R&D needs to quicken;
- IP is not captured on a regular basis or approached strategically during projects; there is a great deal of IP leakage as researchers come and go, increasingly outside the UK; and
- collaborations with corporate partners are not approached with the 'hard nose' and degree of commercial sophistication needed to maximise economic potential within the UK, for example by segmenting IP rights by field and charging sufficiently to build up cash reserves to enable later spin-outs.

Whilst most senior academics do not want to move out of academia into industry, the point is that in many disciplines there is no 'halfway house' in which they can take their technology further commercially whilst staying in research. The intermediate research laboratory concept – partly core funded by government, and partly funded through R&D contracts, with engineers and scientists supported and funded to focus on physical deliverables rather than on publications and teaching – could play that role for some areas of science.[126]

Apart from through intermediate research institutes there are two other ways in which the soft company model could be brought to bear on the 'policy challenge' shown in Figure 11 above. The first is through the formation of soft company spin-outs from university research programmes, and the second is through partnerships with existing soft companies. Top Express, initially formed in 1978 by Professor Ffowcs Williams to exploit noise reduction technology, is an example of the former. A partnership between The Technology Partnership (TTP) and the Cavendish Laboratory to commercialise polymer solar cells technology is an example of the latter.

The initiative for both of these must lie with entrepreneurs and the private sector.

We believe a fresh look and some experiments are required to see whether some form of intermediate institute or soft company structure, twinned with a major academic research department, could assist the commercial exploitation of academic IP. The Centre for Business Research has already made a start on this research through another project.

125 A separate project is being undertaken by the CBR to examine the processes by which university IP is exploited and the role of intermediate research institutions in national innovation systems, as part of the EPSRC-funded Cambridge Integrated Knowledge Centre (CIKC).

126 The role of intermediate research laboratories is being examined as part of the CIKC project and different models have already been studied in Germany, South Korea and Taiwan. It is clear that very large government research organisations can become moribund, but preliminary indications from this research suggest that smaller intermediate research institutes could play a useful role as time-limited incubators for areas of science and technology whose timescales are too long for either private sector soft companies or venture capital. Our initial view is that, to work effectively and avoid the risk of ossification that such institutes typically endure, a complement of 30-150 researchers should take forward R&D programmes for up to 10 years prior to privatisation.

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Appendix A: Interviewees

Corporates

42 Technology	Howard Biddle	CEO
(Acorn)	Hermann Hauser	Founder
AIC	Matthew Jones	Head of Projects & Innovation
Argenta Discovery	Chris Ashton, Colin Knox	CEO, Finance Director
Autonomy	Mike Lynch	Founder
Beru F1 Systems	John Bailey	Managing Director
CADCentre	Dick Newell	Senior Engineer
(Cambridge Antibody Technology)	David Chiswell	Founder
Cambridge Consultants	Paul Auton	Former CEO
Cambridge Consultants	Ray Edgson	CTO/Ventures Director
Cambridge Design Partnership	Mike Beadman, Mike Cane	Founders
Cambridge Magnetic Refrigeration	Kurt Hasselwimmer	Founder
(Chiroscience)	Andy Richards	Founder and Business Angel
CIP Technologies	Michael Robertson	VP Research Programmes
Knowledge Solutions	Adrian Palmer-Geaves	Founder
Lotus Engineering	Clive Card	Project Manager, Research
Marshall of Cambridge	Michael Marshall	Chairman
(Olivetti Research Labs)	Andy Hopper	Director
Owlstone	Billy Boyle	Founder
PA Technology Centre	Ian Rhodes	Member of PA's Management Group
PA Technology Centre	Paul Ruskin	Member of PA's Management Group
(Pi Research)	Tony Purnell	Founder
Plextek	Colin Smithers	Founder
Real Time Content	Martin Russ	CTO
Sagentia	Alistair Brown	CEO
Sagentia	Gordon Edge	Founder
Scion-Sprays	Gavin Farmer, Jeff Allen	Managing Director, Director
Sentec	Mark England	CEO
Serentis	Peter Keen	Finance Director
Sonar Link	H-K Yeo	Founder
(Symbionics)	Henk Koopmans	
Syrinix	Paul Linford	Founder
Syrris	Nick Tait	Finance Director
Team Consulting	Jerry Turner	CEO
The Automation Partnership	Richard Archer	Founder
TTP Group	Gerald Avison	Founder
TWI	Bob John	CEO

Intermediaries

Babraham Bioscience Technologies	David Hardman, Derek Jones	CEO, Chief Business Officer
Beacon Innovation Centre / Orbis Energy	John Balch	Director
BioPark Welwyn	Steven Read	
Centre for Sustainable Engineering	Phil Shephard	
Colworth Park	Sally Ann Forsyth	
Health Enterprise East	Phil Seabright	
Herts BIC	Phil Lines	
Hethel Engineering Centre	Damian Hindmarsh, Simon Coward	
Norwich Research Park	Robin Daniels	
St John's Innovation Centre	Walter Herriot	Chief Executive
(Barclays Bank)	Matthew Bullock	Chief Executive, Norwich and Peterborough Building Society
Coller Capital	Stuart Davies	
New Venture Partners (BT Brightstar)	Chris Winter	Partner
Cambridge Network	Peter Hewkin	Chief Executive
East of England International	Roger Moore	

Appendix B: Enterprise Hubs and Science Parks

A key instrument of public support for innovation at the regional level is the 'enterprise hub', which typically brings together a variety of independent support activities around a particular theme or industry sector, and encourages networking activity and knowledge transfer.

In the East of England, EEDA supports the development of several enterprise hubs in the form of incubators, innovation centres and science parks. Several are based around the life sciences and healthcare, including Babraham Biosciences (profiled below), Health Enterprise East at Papworth, Norwich Research Park (health, food, plant and microbial sciences, environmental sciences, and chemistry and materials) and BioPark Welwyn (biosciences and health technology). This last facility is based at the former Roche pharmaceutical research laboratories, which closed a few years ago and was acquired by EEDA and the University of Hertfordshire. It has 15-20 tenants in the biosciences field (including one of our Module 1 firms, Argenta Discovery, and a Module 2 survey respondent).

A second group of enterprise hub facilities focuses on energy and environment. It includes Orbis Energy (recently established in Lowestoft to foster offshore renewable development) and Environment East (based in Peterborough and associated with the Centre for Sustainable Engineering).

A third group covers a range of sectors, and includes long-established facilities such as the St John's Innovation Centre in Cambridge (arguably at the foundation of the Cambridge Phenomenon), Hethel Engineering Centre (profiled below) and Herts-BIC (profiled overleaf).

Profile: The Babraham Site

- Comprises Babraham Institute (funded by BBSRC, world-leading research in bio-medicine), Babraham Bioscience Technologies (BBT) and Babraham Research Campus
- BBT fulfils the Institute's knowledge transfer remit, manages its patents, runs the Research Campus, operates Aitua
- Aitua is a technology accelerator: promotes and invests in commercial development of biomedical IP from the Institute, companies on the Research Campus, and externally
- Research Campus incubates start-up and early-stage firms in the human biomedical field only:
  - no service firms or animal health ventures
  - current tenants range in size from 1-35 people; some but not all originate from the Cambridge biotech cluster
  - oldest tenant is ImmBio (established 1999)
  - some tenants have a 'soft' revenue stream in parallel to proprietary research (e.g. Horizon Discovery)
  - won a £300k Capital Equipment Competition (EEDA) for bio-processing facilities
  - tenants also have access to the Institute's facilities

Profile: Hethel Engineering Centre

- Located next to Lotus Group (Cars/Engineering) outside Norwich
- Focus on high performance engineering and manufacturing
- Incubator for several pre-product start-ups, plus service firms
- On-site rapid prototyping equipment is available for tenant use
- Some additional facilities at Lotus are available to Hethel tenants
- Two tenants (Scion-Sprays, Active Technologies) are 'walk-outs' from Lotus
- Other tenants include:
  - Syrinix (trunk water main leak detection) – customer-funded R&D
  - Sonar Link (underwater acoustics) – pre-revenue, competing for oil industry R&D funding from ITF[127]
  - AIC/Redox Biofuels (electrochemistry) – SBIR applicant

127 ITF is a not-for-profit organisation owned by major global oil and gas industry operators and service companies that aims to "identify technology needs, foster innovation and facilitate the development and implementation of new technologies". See www.oil-itf.com/index/about.

Profile: Hertfordshire Business Incubation Centre

- Designated the first EEDA Enterprise Hub, funded by EEDA and Stevenage Borough Council
- Focus on support to aerospace/defence; biotech; ICT industries
- Stated aim is to *"facilitate the incubation and rapid growth of knowledge based businesses"* in Stevenage, Hertfordshire and the EE region
- Works with local large employers, including EADS Astrium, MBDA and GSK, to establish links with small businesses
- Runs the European Satellite Navigation Challenge (Galileo Masters) to encourage the development of ideas involving satellite positioning technology

Appendix C: Overview of Relevant Academic Literature

The entrepreneurship literature has examined entrepreneurship and new firm creation from a variety of angles e.g. how entrepreneurial activity takes place (Stevenson & Jarillo, 1990), how competences are created through problem-solving (Hugo & Garnsey, 2005), internationalisation processes (Bürgel, Murray, Fier & Licht, 2001), employment creation (Tether & Massini, 1998), etc.

One of the most widely applied models to explain the process of new firm development and growth is the stage-model (or lifecycle) approach. Churchill & Lewis (1983) were among the first to map out the phases of new firm development, beginning with 'existence' and, as problems are resolved or milestones are reached, moving progressively through phases of survival, success, take-off and, finally, maturity. Other stage-model researchers adopt different terminology and may have a different number of stages, e.g. conception, commercialisation, growth and stability (Kazanjian & Drazin, 1990). Churchill & Lewis (1983) recognise that progress may not always be linear, i.e. firms may fall back to an earlier stage of growth (rather than go out of business entirely) if the problems at a transition point cannot be overcome – although back-tracking is an aspect of business experience that is frequently under-played in much of the lifecycle literature.

Garnsey (1996), however, emphasises the dynamic processes of early firm growth and the fact that steady, rapid growth through to maturity is the exception rather than the rule. Compellingly, she argues that start-up firms suffer from an "*asymmetric information problem*" – otherwise known as the 'liability of newness' – during a phase of development that she refers to as resource mobilisation; and she further points out that the different possible outcomes at each stage of development mean that member firms of any one cohort will follow quite different trajectories. The growth phases she identifies – 1) access resources, 2) mobilise resources 3) generate resources 4) growth reinforcement 5) growth reversal 6) accumulation 7) maturity – map well onto the symptoms and growth processes seen in companies following a soft model and capture the dynamic nature of their progress. In this and other papers (e.g. Hugo & Garnsey, 2005) she adopts a resource-based perspective to suggest that a firm's ability to overcome setbacks is shaped by internal feedback loops between obstacle, innovative response and the further outcome. In other words important learning will flow from effective exploration and experimentation to overcome setbacks. We would argue that this is precisely the way in which a 'soft' company develops its competences and capabilities.

Firms have been shown to be important catalysts in the economic development of high-tech regions. Sturgeon (2000) argues that the roots of Silicon Valley can be traced back to companies in the field of radio technology that spun out from the Federal Telegraph Corporation in the early years of the twentieth century. Others have traced the significance of Fairchild Corporation as the source of much technology and many of the firms that established the foundations of Silicon Valley (Mayer, 2005). Both of these developments pre-dated by far the efforts of Stanford University to establish itself as an incubator of high-tech firms. Universities react to the emergence of entrepreneurial clusters by running programmes to educate budding entrepreneurs, and regional development agencies may introduce specialised support services or other targeted incentives, but these activities generally lag the establishment of a vibrant high-tech community. As Feldman (2001) points out, the locational characteristics that are typically associated with an entrepreneurial environment – supportive social capital, availability of venture capital, and access to entrepreneurial support services – are generally built upon the actions of pioneering individuals and firms rather than on the presence of a world-class research university.[128]

Mayer (2005) introduces the notion of firms as 'surrogate universities', in the sense that some R&D-intensive companies act as business incubators by providing the conditions in which entrepreneurial activity can be fostered: a highly specialised pool of scientists and engineers and a supportive environment in which to develop new skills and expertise. During economic downturns, financial retrenchment at or restructuring of the parent firm, or as a result of internal entrepreneurial activity, experienced teams spin out new businesses which themselves over time may grow into important players. Sponsored spin-outs, i.e. new

128 The mere fact that a region has a world class higher education infrastructure does not necessarily mean that a high-tech industry will develop around it. Moreover, the commercialisation of academic research may occur more readily in some sectors than in others. Zucker et al (1998) explore how the biotechnology industry emerged from the university base.

ventures set up with the active involvement of the parent firm in the form of financial, technological or other contributions, can represent an important mechanism for industrial growth and change, since they tend to cluster in knowledge-intensive industries (Wallin & Dahlstrand, 2006). Internal firm processes, then, determine the resources and capabilities available to potential technology spin-out teams.

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