High Value Manufacturing in the East of England

Report 2002

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For

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Executive Summary

Introduction

Invest East of England, the main sponsor of this research, is an inward investment agency established in 1997, as a sister organisation of EEDA, the regional development agency for the east of England. Invest East of England is based in Cambridge and covers the six counties of Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Norfolk and Suffolk. Local businesses, the UK Government, local government and a wide range of business partners fund Invest East of England.

Invest East of England's aim is to:

- To support companies considering investment in the East of England;
- To work with investors to ensure they grow profitably in the region.

Within this context the consultant Dr. Justin Hayward of Cambridge Investment Research Ltd was asked to undertake an analysis of high value manufacturing and its connection to research and development, following a proposal his company made to Invest East of England on a related topic.

Initial observations and conversations noted that there are several important clusters of high technology R&D companies in the region, especially around Cambridge, and that there are also several sophisticated manufacturing companies of medium-size, dotted around the region, which may or may not be connecting with local R&D companies with manufacturing ambitions. It was also noted that manufacturing in other higher cost clusters has continued to thrive. Comments concerning these subjects brought together in the final recommendations.

A Summary of the Government's Manufacturing Strategy

This paragraph writes down what the UK government's stance is, giving the private sector business an idea of its intentions for the medium term. The government's manufacturing strategy document is available online, and is about 60 pages long. The strategy is based on "seven pillars": economic stability, investment, science & innovation, best practice, skills, infrastructure and market. The government states that it is for free trade.

Since manufacturing represents just under 20% of UK GDP and 60% of our exports, it is a crucial sector for UK wealth. The weak €/£ exchange rate, the collapse in the TMT markets and "911" have made conditions tougher. The report notes that UK manufacturing profits have decreased to 4%, and that, parallel with the US, 6.7% of jobs were lost in 2001. The UK is much less productive than the US, Germany and France. The government believes that the UK can match the best in new product development, processes, and marketing and sales. But we lack investment per hour worked, skills, and R&D and innovation relative to our competitor nations; this is a significant factor in our productivity lag. Since capital continues to flow globally, and tariff barriers come down, lower wage areas have been able to compete better. The government thus aims to help UK business move into high-skilled, “value-added”, knowledge-intensive manufacturing. It notes cases such as Swiss textiles, and Japan generally versus Korea, where higher capital and knowledge-intense manufacturing is successful against the lower wage countries. It notes that lower investment levels in skills, innovation and R&D make the UK less attractive to further investment. The UK does still attract more foreign direct investment than the rest of Europe.

And it believes large companies moving into the UK makes the UK better off, though CIR notes that there an be problems of integration with communities and lack of staying power in foreign, locally-installed companies. Reducing bureaucracy and tax help these entrants, and help the UK to carry out the “government’s” strategy of moving “up the value chain” to “knowledge-intensive, high value-added, high-skilled, innovative” manufacturing.

This type of manufacturing, from a regional perspective, is the subject of the CIR High Value Manufacture East 2002 Conference. It also offers a partial definition of High Value Manufacture; though see below[1] for more comments.

Relevant points taken from the July 19, 2002 IfM “Manufacturing Matters” conference

According to Professor Rob Rowthorn, for the period 1990-2001, the UK was “strongly competitive” in:

1. Machinery & equipment,
2. Chemical products,
3. “Other transport” (aircraft/defence)

It is also “competitive” in the sectors of:

1. Electrical machinery,
2. Precision instruments,
3. Rubber & plastics,
4. Non-metallic minerals.

The Government’s Manufacturing Strategy presents DTI and ONS data showing that the above areas where we are “strongly competitive” also correspond to the sectors where the highest percentage of employees are trained at degree level. To note an exception to this “trend” we see that computer manufacture is a “weakly competitive” sector, though it is one where the workforce is highly qualified.

More highly productive EC countries tend to respect training and vocational skills more, and use them more widely across the workforce.

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[1] Manufacturing may be “high value” where the: Market is “emerging”, “immature”, “niche”, “being disrupted”, so non-existent” or “for custom product”, but not usually “commodity”; Market is for technical or complicated products; Processes are not familiar, or widely well-tried and tested; Products are high margin; Products need above average at-hand expertise; Product follows from hard R&D.

Professor Ron Martin gave some regional manufacturing perspectives. He noted the growing emphasis on geographic sectoral business clusters. But how important is clustering and geographic proximity? Our interviewees on the front line gave some insights. Geography is secondary to harder aspects such as price (tax, , labour, distribution and materials costs) and quality (conformity, turnaround time). But all else being about equal, there is no substitute for in-person relationships and face-to-face meetings. And more so when it comes to technical products needing high expertise.

ONS data showed that regional manufacturing growth was correlated positively with total output growth. Ron Martin also noted that the Eastern region got a high increase in overall output from increases in industrial output relative to other regions of the UK.

In the UK, there is a general trend to decreasing employment as productivity increases. Overall, output rises. But EEDA, Cambridge Econometrics and Ernst & Young predicted a 14% reduction in Eastern region manufacturing employment by 2010, for an absolute total of 323,000. If high tech[2] manufacturing remains at the same proportion, this implies an Eastern Region high tech manufacturing workforce of 220,000 in 2010. [See the Business Weekly figures provided by EEDA and IfM].

Ron Martin also presented a regression showing that where industrial output growth was highest, service growth was highest. He went on to say that this service-manufacturing pairing can become a positive or a negative feedback loop, and that certain regions were undergoing negative loops, and others, like the South East and the Eastern Regions, were experiencing positive feedback loops.

It was noted also that the South East and East of England owned 40% of the patents filed for only 23% of the population. The East of England had in 1999 the highest ratio of R&D expenditure per unit GDP output and per employee, at 3.25% where London has a spend of less than 1.5% of a (much higher) GDP. But the 2000 figures for high tech manufacture employment showed the East of England in regional 5th position, with 4.75% of the workforce, well below the leaders at over 6.5%. But it still had the 4th highest "clustering" density of high tech manufacturing jobs, which according to the data presented, numbered 116,000. This all suggests that innovation rates and R&D spend (per GDP or employee) for the East of England (top of the regions) are not matched by the manufacturing of those innovative developments. The UK is the 4th most innovative (patents per person) country in the world, according to the WEF Global Competitiveness Report 2001-2.

Perceptions of Manufacturing in the UK and East of England

High value manufacturing in the East of England clearly comes under the general heading of manufacturing. Manufacturing in the UK seems to have been on the decline since the 1960s. Productivity gaps have widened. The industry size and employment have gone down. In global terms, if not Western European and US, the UK is a high cost region. The UK government is trying to do something about all this. As summarised above, there has been a dedicated "Government Manufacturing Strategy" document published, and the DTI has done work, over

[2] Biotech, pharmaceuticals, ICT, other high tech.

the last three years, enumerating and quantifying “clusters” around the UK, using the national average density of activity as a way to benchmark these concentrations of activity. For the East of England, these clusters were: Agriculture/Food processing, Furniture Manufacture, Financial Services, Tourism, Software development, Marine Technology, Pharmaceuticals/biotechnology, printing and paper (where we are highly competitive), R&D activity, Automotive assembly, ICT/electronics, and Instrumentation. For reasons of resources, we focused on the last seven of these, in particular, industrial inkjet printing, biotech, microsystems/electronics. The government manufacturing strategy singles out motorsport/automotive, electronics, and pharmaceuticals as “bright” case studies.

Since manufacturing has been on the decline, inventors may find they need to go abroad to realise their invention. High patenting costs and renewal fees, and bureaucracy do not help smaller inventors. There seems to be a lack of interest from stakeholders in engineering. Losing a technical skill can be irreversible; having allowed the skill to disappear, it is hard to replace it competitively. We also note that there is a perception in Western Europe and the US that China, a vast, inexpensive country that is embracing capitalism, is surging forward in manufacturing ability; that outsiders must understand what China will offer.

The Economist magazine has researched manufacturing data from 1989-1994 and seen how company turnover was 22% and 17% of all companies per annum in the UK and the US respectively. But net two-year employment gains of surviving companies in manufacturing were 5% and 130% in the UK and US respectively. Why the enormous difference? Lower non-wage labour costs (lower job protection laws), lower bureaucracy, a bigger domestic market allow more, smaller startups to test market demand and grow faster than in the UK. In the end, this leaves fewer opportunities unexamined, and so leads to higher reemployment.

High tech manufacturing itself has trends. There are trends toward “more models” or “mass customisation”, and a shorter time between models. There are higher needs for sales to new markets and niches, which implies in many cases the need for language skills. Against these trends there are higher workloads and a need for more staff. This is tempered with increasing productivity and efficiency. Only on a sectoral case-by-case analysis could one say exactly which trends dominate, though we’ll see figures forecasting lower employment numbers in tech manufacturing in the East or England by 2010, a very long-term prediction by a consortium.

High tech manufacturing must not be confused with industries that pollute heavily, or that use large factories that some might consider ugly. Lower volume runs in efficient lines using new methods will often be making advances in environmental aspects as well as production efficiencies.

Another perception is that private capital finds it hard to invest in manufacturing (though the British Venture Capital Association lists over 100 separate funds that say they are interested in the sector). As CIR has discovered in its direct research, venture capitalists hold “return in a reasonable period” as one of the most important factors for investment. But manufacturing returns are often longer term. So there is a mismatch. What is needed is to show that the transaction-makers, the financiers are there and are able to ensure that venture capital investment can find exits within the limits of the typical ten-year fund cycle. Corporate venture capital funds are less numerous in the UK than they are in the US: our market is smaller, and so are our companies. Larger companies are more likely to have a dedicated, sophisticated fund in place for investing in other companies not just for financial returns, but for acquisition of relevant know-how.

There is a perception that the British entrepreneur lacks “killer instinct” in business, and that there are anti-winner cultural influences that brake the entrepreneurs ambitions, even though we are so close to the world’s finest and most sophisticated financial centre, which incidentally, is also the British industry with the highest export-import ratio, by a large margin: the City of London.

Related to this lack of killer instinct is a lack of ability to market and sell to customers. There are “creators” and “transactors”. Creators are inventors of technology, innovators, designers, often those within the core of a technology business. They often are not good at or interested in selling. The transactors are the service providers who live by making deals happen. They are for example financiers and sales people. The creators are overweight in this subregion. The creators have a suspicion toward the transactors. Sometimes they do not value their services or roles. The transactors respect the creators’ abilities, but have different motivations and find it hard to engage them.

Entrepreneurs are not valued in the UK. Is it trite to note that Richard Branson, with his Virgin enterprises, the stereotype, risk-taking entrepreneur, who made his first million at 21, was the only entrepreneur in the BBC’s much-touted all-time top 100 Great Britons?

In this report, we look at a subset of the UK manufacturing activity. First we consider only the East of England, a region that generates about 7.5% of the nation’s GDP. We then focus on manufacturing in the context of higher technology or technical sectors. This is a less well-defined niche. By it, as we’ve suggested, we mean manufacturing that follows on from scientific analysis or technical and product know-how, and above average design and development and processing work.

We are guilty of interviewing a sample of company managers who are overweight Cambridge subregion connections. We put this down to our own geographic location and biases in networks that arise from it, over and above any regional leadership position that Cambridge may have in research and development, technology or manufacturing. We and our sponsors did try to engage and interview companies from further afield. We found them a little harder to engage in the process than companies in the Cambridge subregion. Given that the project first arose from a Cambridge-centric network meeting and a Cambridge-centric proposal based on this meeting’s content, it is not surprising that the report and publication the report are also Cambridge-centric. The particular sense in which there is Cambridge-centricity is that the connections sought were between Cambridge subregional research and development companies and external manufacturing companies, as opposed to East England R&D and manufacturing companies which is not a Cambridge-centric starting point.

In this light, this report might be the first of a group of reports written in which a target regional subcluster of R&D companies is linked to the rest of the region. Or it could be a section of a larger piece of work that removes the Cambridge-centricity and runs the project against all R&D companies and all high value manufacturing companies. The chosen subclusters of businesses for the report also led to some Cambridge-centricity, simply as most of those subclusters’ companies are based in this subregion. For example, if one had taken the specialist or formula one automotive subcluster, or the plant sciences subcluster, one would have had a less Cambridge-centric group of companies to work with.

There are also reasons of project size and scope that lead to this effect.

Our perceptions of the region before the project were that, centred on Cambridge, there is a well-known group of clusters of largely loss-making, small research and development companies, fewer than 10% of which were funded by institutional money. This subregion is connected to, but not dominated by the renowned University there, with perhaps 10% of those companies being identified as having come directly from the University. While we were working on the project, the University announced changes to the rules on how ideas of value coming from within its walls are commercialised. We await the effects of this. As regards the other parts of the East of England, we were much less aware of activity in either R&D or manufacturing, and believed that it was not so noteworthy in the sense developed by the DTI as we mentioned above. Outside of the many medium-sized market towns there is "space", mainly in agricultural use, and taking this together with the R&D activity, we understood the regional branding by the EEDA of "space for ideas". We also perceived difficult relations between those who live and work outside the Cambridge subregion, and those within it, who are associated with the term "Cambridge Phenomenon", coined by SQW Ltd in a report first released in 1984.

Some local leaders in financial services believe that there is too much hype around Cambridge. They hold that we should not sell out to foreign interests at the first opportunity. They consider that we in the UK are not good at "services". And they remind us that Universities are not there to develop commercialisable technology in the first instance.

Others say that government policy is a complex "nexus". That Cambridge and the region need to build "lighthouse companies" that highlight the region's successes and characterise it. They believe that there can be big wins from linking to other towns with complementary skills.

Our perceptions were modified by this project.

The feedback from the interviews showed that there is a great deal of (vested) interest in ensuring that we as a region work together to define where we are competitive, or what are our competences and strengths in high value manufacturing. This depends on sector, of course. There was also interest in working out where we are missing connections between different parts of the value chain corresponding to those strengths, and how to build bigger businesses that are profitable and that can be welcome in the region through their engagement with those who live here.

Recommendation and Actions

- Each manufacturing company has a different positioning, and may have different strategies for different product lines. Most are not part of a regional sectoral cluster, but do benefit from pools of skills. These points favour detailed analysis of cases, rather than attempts to generalise.

- Higher labour cost regions should not assume that manufacturing is not possible there. Each case must be looked at on its own merits.

- A cursory sectoral and competitive analysis shows that precision instruments, machinery, devices, pharmaceuticals, industrial inkjet and materials, displays and microelectronics application, along with some software engineering skills all appear to be strengths at several levels (UK, East England, sub-regional, & niche markets) that should be developed and applied to commercial success.

- The ambition of a given CEO or management team is the key driver in building bigger businesses. This is what they are paid for. The best CEOs have a vision bigger than themselves, don't get too hung up on failure, and never give up; We must seek CEOs with competence and ambition. The junior chamber in Cambridge is an interesting initiative. But experience in running bigger companies is also needed. Homegrown, long-term managers are ideal, but if not available, then we do need to import this desire and knowledge. This means selling to successful people: the benefits, brand and kudos of living and working and in the region.

- Infrastructure takes time to change. There can be conformity for conformity's sake among political organisations, that hinders progress;

    - Buildings containing different types of cleanroom and technical manufacturing space are needed: "The most pressing infrastructure issue short-term issue is cleanroom space".

    - There should be no local residential fear of ugliness and "industry". We are not talking about the types of activity that produce immense clouds of smoke pollution. Factories will not be large. They will often be more environmentally harmonious than the current method. Local resistance to manufacturing has given way to an open-minded view that high value manufacturing can and should be done in the region where it is embedded in a range of strengths. We want to allow for line experimentation at lower volumes for small or not yet existent markets. Here, demonstrations and prototypes for distribution outlets are made.

    - Broadly speaking, for technical manufacturing companies, there is an optimum seam of location to the South of Cambridge where rents are lower than in Cambridge, but where there is access to highly-skilled engineers and scientists, but also access to technicians and salespeople to the south. There are certainly other "ideal" locations, but we haven't performed this kind of workforce analysis to identify them thoroughly across the region.

    - The East of England wants bigger businesses that act as examples of success, in the same way that early stage entrepreneurs have been successful and produced inspired many new small businesses. Entrepreneurship, at least in the Cambridge region, has come to mean setting up a small technology business and selling it when it reaches 15 employees. There are other types of company that are important. And there is no company in the region that doesn't need "entrepreneurship" to take it to the next stage, including companies approaching 300-500 or more employees.

- The private sector must engage with capital providers and schools and colleges, e.g. by going there and talking to students, and inviting them back to plants/offices. Can they sell the idea of manufacturing to the new generations?

- Government can be helpful in creating forums for discussion and networking among R&D companies, high value manufacturers, subcontractors and individuals with skills, and in setting up workspace, but can the government agencies sell their offerings successfully to the private sector entities and people involved?

- Rather than positive feedback relationships between service and manufacturing economies, we have focused on the value chain or value network, and on R&D and "innovation" connecting to development and making of products. The decision to manufacture (and where to do it) involves investment, and therefore either public sector or private or public capital markets, whose timeframes for investment returns are short, and also involves a range of other factors: trade restrictions, equipment, labour, materials, distribution costs and tax issues. Then there are more problems: The make or buy decision theory is well-known as a matrix relating the importance of the technology to the business and the technology's competitiveness. Many local R&D licensing companies don't face these tough questions. We need a flow of knowledge to encourage and equip them to do so, where it may be right.

- People believe that moving along the supply chain results in a stronger market position, through protection of IPR in practice, company size and weight, and better connection with markets. The Cambridge region has been described as disconnected from markets. This is a chicken and egg problem. But there are benefits to manufacturing locally. "Lighthouse" firms can lead the way.

- There is an argument that building factories near large markets, such as in China and the US is the only way to "get closer to markets". But much more could be done locally in prototype, demonstration and early-adopter manufacture, and through "transactors" to strengthen and build companies here.

- Accessing and communicating with markets and customers and thinking about benefits rather than technology continues to be a problem that can be attacked by bringing together "transactors" and "creators" to talk and understand each other better.

Conclusion

Knowledge and high skills are present in many sectors, and attainable in others with some coordination, in this region. CIR's report discusses some of these here, using a "listening" approach. We have seen how the region has innovation above average or leading in the UK. But the "government's" strategy of moving "up the value chain" to "high value-added" manufacturing involves having a connection to the market's needs. Customer benefits. It cannot be argued that this region is strongly competitive in the area of understanding customers. This is probably due partly to the market being small in the region, and to the UK domestic market being still just medium-sized.

But this integral part of the government's and other's strategy for manufacturing remains the problem. It is one thing to manufacture technical products. It is another to do high-value manufacturing. This latter needs a strong connection to markets and individual customers. Tieing up with the idea that the ambition of the CEO is important, we believe that that CEO must ensure that sufficient high-level sales activities are allowed for and carried out by an aspiring, skilled, innovative medium-sized company looking to climb the value chain.

Given the goal of climbing the value chain in high-value, niche technical applications in this higher cost, small domestic market area, those "transactor" sales people must be skilled adventurers, listeners, negotiators and sellers. Will we in the East of England and Cambridge begin to value these attributes more?

1. Introduction

1.1 Background and Context

Invest East of England is an inward investment agency established in 1997, as a sister organisation of EEDA, the regional development agency for the east of England. Invest East of England is based in Cambridge and covers the six counties of Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Norfolk and Suffolk. Local businesses, the UK Government, local government and a wide range of business partners fund Invest East of England.

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1.2 Structure of CIR Research Report

This report covers key data on regional high value manufacturing from the Business Links and County Councils of the East of England. From this data, key clusters of high tech R&D and potential manufacturing activity are identified. It then presents key points taken from interviews made with senior managers at R&D and manufacturing companies in the region. There is a case studied example of the key 10-year-old company, Cambridge Display Technology, which has over 100 employees, has raised more than $75m in capital, and which has a low volume manufacturing facilitation plant in the region. There is also a full transcript of an interview with a senior director at Xaar PLC a leading industrial inkjet technology company. From this example and the other interviews, we analyse perceptions and make key conclusions and suggested recommendations. Further information is given in the Appendices.

1.3 Project Scope and Methods

The scope of this project was to assess and evaluate High Value Manufacturing in the East of England, within key markets, and to see to what extent it connects with regional commercial research and development. Given this, the project focused on:

- Cambridge subregional R&D companies;
- East of England technology manufacturing companies;
- an assessment of these companies in aggregate and the relative regional opportunities for growth.

Interviews were conducted with managing director, finance director, or business development director of companies in various sectors to gauge perceptions, attitudes, demand and supply. All interviews were documented, though several were only possible under strict confidentiality of any particular or attributable, sensitive part of the scripts. Materials were found through web searches and information drawn from consultancy and company reports, IPO prospectuses, trade journals and professional body and governmental publications. Established marketing and strategy analysis techniques were deployed to assess and evaluate the raw data and conclusions drawn from this.

The geographical scope for this study is the East of England. This comprises Essex, Suffolk, Norfolk, Cambridgeshire, Bedfordshire and Hertfordshire. The general scope of the work is to understand R & D and manufacturing companies in the region: their business models and interconnectivity, and under what market conditions they are competitive and have potential to grow and flourish.

2. General overview of high value manufacturing in the East of England

A list of larger research and development organisations based in the East of England is given in the Appendices. These organisations cover a range of sectors: automotive, agriculture, bioinformatics, biotechnology, botany, chemicals, computing, communications, (micro/nano)-electronics, engineering, food, materials, medical science, plant breeding and science, pharmaceuticals, printing technologies.

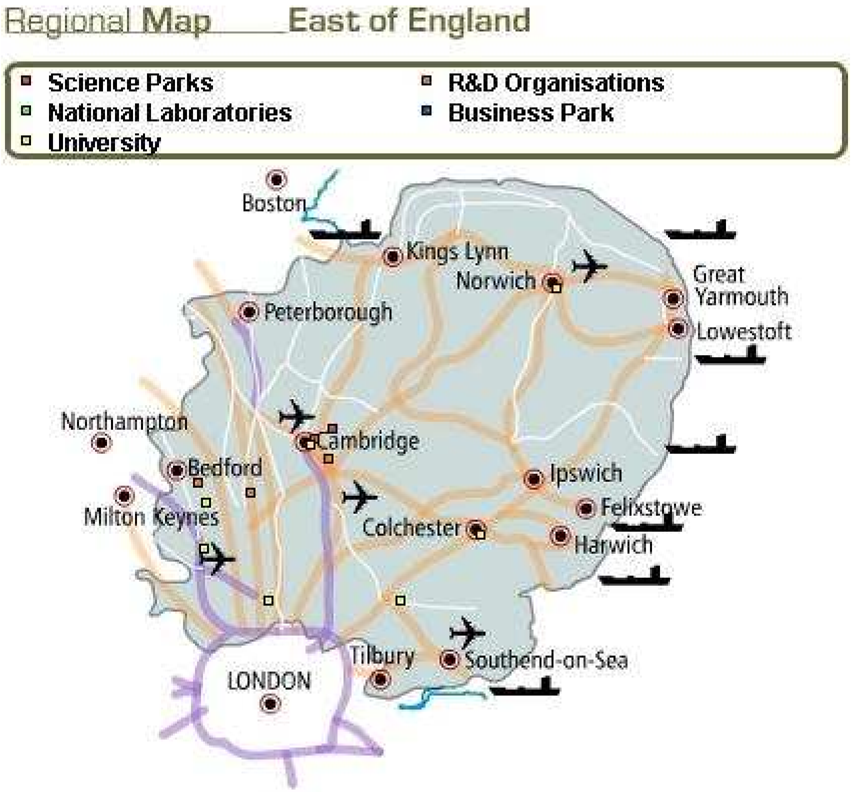

Figure 1: East of England R&D centres (Source: Invest UK)

The above and smaller company research makes the region what it is: The region that spends more on R&D and innovation per unit GDP and per employee than any other UK region.

2.1 Clusters of commercial activity in the East of England

From the databases and other sources of information, we established that the most competitive or groundbreaking sectors for the East of England were: Industrial inkjet, pharmaceuticals, diagnostics (drug discovery), medical devices, materials, microsystems/nanosystems, polymer microchips, semiconductors, aerospace, wireless communications & tagging systems, niche automotive & Formula One, plant sciences, and photonics/optoelectronics. Instrumentation, testing equipment, electronics, hardware & engineering, software engineering are known “traditional” Cambridge regional subclusters.

Generally, engineering is strong to the South of Cambridge in Essex, Bedfordshire and Hertfordshire.

2.2 Statistical presentation for East of England

There are about 190,000 firms in the East of England. About 7.4% of these are manufacturing companies, or 14,120. Those manufacturing companies employ about 22 people each on average. There are about 2000 high tech manufacturing firms. A further 3000 firms are in "high value manufacturing" where significant technical expertise is required, such as in chemical products, precision instruments, and electrical machinery, corresponding to sectors where we as a nation as "strongly competitive" or "competitive".

County	*More than 1000 employees*	*More than 750 employees*
Beds	IBC Vehicles Ltd/Vauxhall	Insys Ltd
Cambs.	Marshall Group	Napp Pharmaceuticals
Essex	BAE Systems Avionics, E2V Technologies, FLS Aerospace Ltd, Danbury Electronics	None
Herts	MBDA (UK) Ltd, Polaroid (UK) Ltd	None
Norfolk	Group Lotus Ltd	None
Suffolk	None	Delphi Diesel Systems Ltd

Table 1: Medium-sized high tech manufacturing companies

There are no manufacturing companies employing more than 3000 people in the eastern region. 9 companies employ more than 1000, and just three more employ more than 750. But there are many companies that are manufacturing on a smaller scale. The Cambridge subregion doesn't have any other commercial high tech companies, manufacturing or not, above 1000 employees either. By global measures, the term "SME", when referring to East of England, is redundant.

	All companies	*HighTech companies*	*HighTech Manufacturing*	*All Manufacturing*
Beds	20300	920	160	1450
Cambs	27400	1630	490	1910
Essex	55500	2720	510	4480
Herts	37900	2300	390	2870
Norfolk	27400	810	200	1880
Suffolk	21900	850	270	1610
Total Companies	190000	9220	2020	14190

Table 2: Chart of Eastern Counties Companies Sources: Dun and Bradstreet, IfM, CountyWeb, Business Links, Chambers of Commerce, County Councils

2.2.1 Cambridge Subregion

The data for this region is more reliable than for the rest of the region, as CIR has a database of its own that acts as a significant, first-hand verified sample for the full list, obtained from government sources with a cash payment.

Total companies in Cambs	*27400*	
All high tech	1630	6%
High tech R&D	445	27%
High tech manufacturing	490	30%
High tech manfacture and R&D	170	10%

Table 3: Breakdown of high tech and manufacturing activity Cambridge subregion

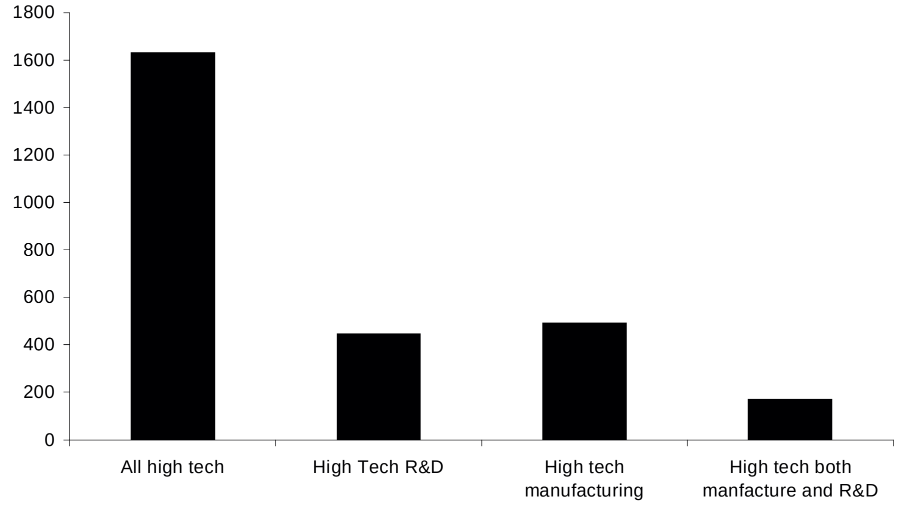

Figure 2: Cambridge Subregion R&D and manufacturing

The figure below shows how few large companies there are in Cambridgeshire. But there are a significant number of companies moving into exciting phases. 83 companies have more than 100 employees, and many of these are strong innovators.

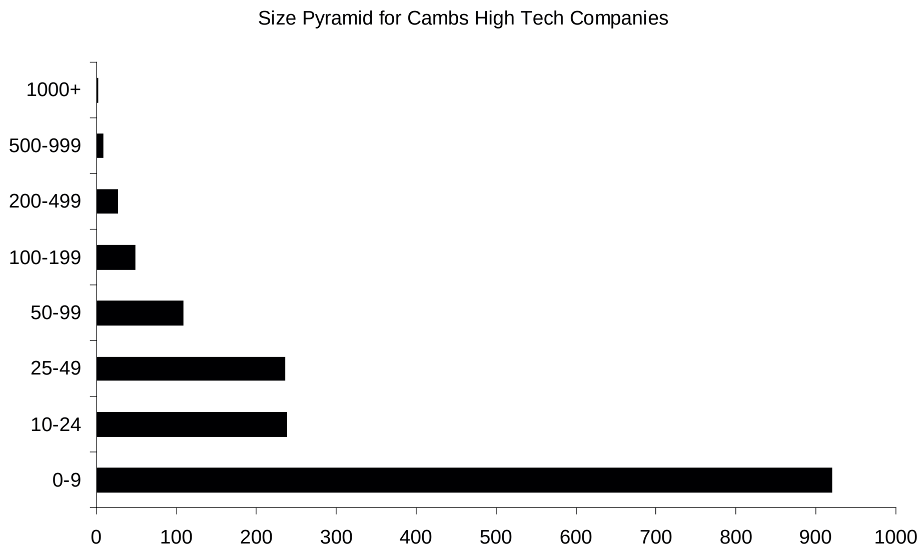

Figure 3: Cambridge region company sizes in 2001/2

In Cambridgeshire, including Peterborough and Huntingdon, there are 1631 tech companies of which 47 are public entities, the majority in R&D, that make up 18% of total employment. Its 1631 technology companies employ a maximum of 48,000 people and a minimum of 38,000 people. Only one high tech firm has more than 1000 employees (Marshalls, 2750). 920 or 56% have less than 10 employees. 83 tech companies, or 5.0% have more than 100 employees. 444 or 27% of companies are doing research and/or development. 169 or 10% of all tech companies say they do research and/or development and manufacturing. This represents 38% of the companies who do research and/or development. 488 or 30% of the tech companies do manufacturing.

By taking the headcount range data for each company or institution, we estimate that up to 48000 people are employed at these 1631 companies. But the number could be as low as 38,000, given uncertainties in the real average for the lowest size of company, for full-time equivalent employee numbers and for "downturn shrinkage". This implies an average of about 24-30 people at each company.

Though R&D and manufacturing companies in the sub-region often advertise across the UK or beyond for staff, they do value and respect the people coming from engineering and other science and technology departments of Cambridge University. They said these people often outgrew the company and were too good to be held on to. They said that being based South of Cambridge was excellent for getting technicians and shop-floor people (from Herts and Essex) and also the highly skilled engineers.

A codification of interesting activities being undertaken in this region is given in Appendix A.

2.2.2 Suffolk

Suffolk technology or manufacturing clusters are in telecommunications (65 companies employ 4900, of which BT Plc 4500 people), manufacture of agricultural and forestry machinery (36 companies employing 2600), making electronics products (56 companies employing 1440 people), and pharmaceuticals (13 companies employing 395).

2.2.3 Norfolk

Norfolk is home to the 1700 employee Lotus Group operation.

Plant science, crop science and genetics at the John Innes Centre, Norwich, a registered charity limited by guarantee, government supported, employs around 950 people.

Bespak Europe, Kings Kynn, in drug discovery products (up to 600 employees); Baxter Heathcare's disposable medical products (560); C-Mac Microcircuits (parent company Solectron) electronics components in Great Yarmouth (350) and Multitone Electronics in Kings Lynn, specialising in wireless communications RF base station devices (300), are the leading high tech manufacturing entities. These each may have significant potential directly to help, or to advise regional R&D companies in similar sectors. Their stance is generally that selling to smaller R&D companies should not take up large amounts of resources from current accounts, but that such diversification of risk for the medium term can be healthy. Relationships in particular with Cambridge companies are in early stage or not yet broached.

2.2.4 Bedfordshire

Unipath, Bedford, (410 employees on site) is a market leader in 30 countries, and second in a further 15-20, in vitro diagnostic products: the end users are women. Huntleigh Healthcare (400-500) produces medical devices for hospitals. Pneupac Ltd (c175 employees), owned by Smiths Medical), Luton, is a medical equipment manufacturer.

Insys Ltd (750-1000) is a supplier to the MOD of light engineering designs (metals and composites, fibres).

Apart from these medium-sized diagnostic and medical device and equipment manufacturers and engineers, Bedfordshire also has significant numbers of companies in computers and security equipment.

2.2.5 Hertfordshire

Herts is the second largest county in the region, after Essex. CIR was able to examine a sample of just 55 high tech manufacturing companies in the county, supplied by the county's business link agency.

Ferraris Medical Plc, Hertford, (450) precision medical and industrial instruments, well-known as a member of the Mid-Anglia index, turned over £57 million globally in 2001, according to its website. Graseby Medical Ltd (180) is a medical equipment manufacturer.

Herts has a printed circuit board manufacture subcluster of more than 10 companies, and another 30 companies in electronics components manufacture generally. It also has up to 150 companies in network and data communications. It is also strong in mechanical engineering in areas such as fabricated metals and industrial process control precision instruments.

2.2.6 Essex

Essex is twice as big as Cambridgeshire in terms of working population. It has nearly 5000 manufacturing companies across sectors. CIR was allowed access to a subset consisting of 975 high value manufacture companies, by the private company keeping data for Essex business link. 11% of those were high tech manufacturing companies. Within this subgroup, nearly half are within the category of security equipment, and about 30% are in computers. There are significant precision instruments, electrical and non-electrical machinery clusters. Other than the companies singled out below, there are some 230 companies in various types of engineering, employing up to 4000 people.

BAE Systems Avionics (1500), Basildon, navigation equipment; Danbury Electronics (1350), Chelmsford; electrical equipment; E2V Technologies Ltd (1350, separated from Marconi), electronics; FLS Aerospace (Danish parent) (1000), Stansted; KeyMed Ltd (680), Southend, medical equipment; and Marconi Mobile, Chelmsford (500) are among the leading companies in high tech manufacture in Essex.

2. East of England Manufacturing and R&D

2.1. The ARM Model: Licensing technology[3]

ARM has a CPU IP licensing model. ARM is a pure IP company. It only makes a few development systems; or what you need to enable people who develop products and who have physical systems. ARM sells software tools. Development systems revenues amount to 15% of turnover. Most people there that develop IP or develop systems are engineers: the majority are hardware (soft-hardware), the rest are in software. These staff break down about 4:1 hardware:software. ARM’s market share is 85% in the mobile phone sector. In networking embedded devices ARM has over 50% of the market.

ARM’s website states that:

“ARM is the industry's leading provider of 16/32-bit embedded RISC microprocessor solutions. The company licenses its high-performance, low-cost, power-efficient RISC processors, peripherals, and system-chip designs to leading international electronics companies. ARM also provides comprehensive support required in developing a complete system. ARM's microprocessor cores are rapidly becoming a volume RISC standard in such markets as portable communications, hand-held computing, multimedia digital consumer and embedded solutions. ARM is an intellectual property company whose assets are its people, design methods and experience. ARM designs and licenses microprocessors and systems to electronics companies in return for a license fee and royalties. We do not manufacture chips, but focus on the creation of ideas and designs. Our goal is to establish ARM as the architecture-of-choice for the Digital World, through continuous collaboration with our global network of partners. At present, around 50% of our revenues come from license fees, 20% from royalties, which are charged on each ARM microprocessor shipped by our partner licensees and about 16% from development boards and software toolkits, which are used to design applications around the ARM core. 14% of revenues comes from consulting services, support, maintenance and training. In 2001, our partners shipped over 400 million units of microprocessors using our technology and our cumulative shipments now total more than 1 billion units.”

ARM is not planning to change. It is business oriented, and considers that this strategy is the best strategy.

As above, ARM doesn’t do much consulting: There are Bluetooth and consulting groups, and a third party IP group. Certain IP ARM doesn’t want to develop itself, but must access it. Deals are done with providers of IP.

These are mainly global companies that may be large or small. A supply chain for ARM might look like:

ARM → IP components to ASIC designer level → built by silicon partner global semi conductor manufacturer e.g. TI → handset producer e.g. Nokia → end user (you and I)

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[3] Disclaimer: This section is CIR’s understanding of ARM and is the result of using public domain information and conversations with people close to but not representing ARM.

Figure 4: ARM example supply chain

ARM's strengths are its commercial-mindedness and its clever business model. It has locked into the points in the demand and deployment chains where it can extract best value.

Weaknesses are that ARM is basically a single product company. It sells "RISC"s. But it does have diversified global customers who are physically and sectorially diverse. ARM on average gets 5-10% of the value of the ASIC. These are expensive items within a system that goes into the handset. But this is no more than 5-10% of value again of handset. So ARM is taking 5-10% squared of the value of the "handset" market: i.e. ¼-1%. ARM licensees ship around 400million units a year. Mobile phones and PDAs are not cheap to the end-user. But ARM's 2001 revenues were £146 million.

External threats to ARM are not thought to be high: Competitors are technically not special. And their business models are not as good. There are cloners. One big problem for ARM at present is the market's weakness. Bad news causes big selling. ARM has recently shown bad news to the market on revenues, and has downsized its workforce strongly. There is saturation in some segments. Mobile markets are not growing in current downturn. Most analysts forecast zero to slight growth. Opportunities are that ARM's IP is maturing; it is the standard in embedded 32-bit RISC.

ARM is not ushering in anything completely new. Its technology is not "disruptive". There are no quantum leaps. It is not so easy for a developer to use from any source. But it is changing worlds gradually. Mobiles are so feature rich because of the ARM strands of technology IP.

As an analogy, ARM "manufactures" IP. There is a good supply of "IP manufacturing" skills locally. The UK as a whole needs more of these skills. Expertise is moderately available in UK, but it is not as good as it could be.

ARM is unique. Cambridge is a good, small R&D area. But in "business" it is way behind many places, such as the US, France and Japan. Cambridge is focused on "entrepreneurship" and is too tied to technology than to business.

Generally, ARM works with small, individual contractors, usually in the UK. It works with larger Indian subcontracting companies. In the UK, we are starting to stifle labour markets. In India ARM can subcontract IP development for a quarter of the cost in the UK. But there are locally available development services that ARM works with. These are smaller than the tech consultancies here. ARM wants to have control over the IP. Larger organisations contaminate it. They bring IP to the table themselves and say "what we've done for you will mean we should be cross licensing". That means other companies start wanting royalties as well.

It's a pure fluke that ARM has a presence in Cambridge. ARM came out of Acorn. That started many years ago because of the University. ARM has never been HQed in Cambridge. The dynamo is in Maidenhead. There are no sales out of Cambridge. Even though ARM is a Cambridge success story it is still rather really an M4 corridor success.

ARM is in a subcluster in a loose sense. There are lots of tech and IP businesses in Cambridge. But in terms of successful businesses, there are very few. There are no other CPU IP licensing companies. Many, like Cambridge Silicon Radio, are involved in moving a physical product in one vertical market. There is no similarity. Loosely, all those companies may be grouped in semiconductors, but the business models are different. There is a cluster of fabless semiconductor product companies but ARM is not part of it. Companies, like Virata, ARTVPS, Alphamosaic, CSR and Cyan are about physical semiconductor products.

It is of no importance at all to ARM's research and development base, that manufacturing of products based on this research and development happen nearby. Since in reality in the UK, no-one except Globespan manufactures our products in the UK. (And they may not actually do much here). ARM's customers are in the US and Asia, close to big markets.

The ARM business model, though cute as we have seen above, does not lead to a significant share of the value chain and therefore the market. Even a dominant market share in the some of the world's biggest markets lead to a company with hundreds of employees only.

2.2 Senior Management Interviews

This part of the project approached high value manufacturing from the company senior manager or director's perspective. To gain a clear and structured understanding of different company approaches, CIR interviewed SME companies within various sectors including industrial inkjet, medical devices, semiconductors, biopharmaceuticals, and electronics. The goal was to secure interviews with as many senior managers as possible. The interview questions are in Appendix N. Interviews were conducted by telephone and in person and raw transcripts were edited afterwards by email. We asked for the frank opinions of the executive directors questioned. A total of 14 people from separate organisations were interviewed, many more were approached, but were not able or willing to take part. The table below records this:

Category	**Interviews**
ICT	10
Life Sciences	5
Microsystems	6
Industrial Inkjet	3
Devices	2
Hardware	11
TOTAL	15

Table 4: High value manufacturing in-depth interviews (senior directors)

2.3 Key points from the business leaders

The big difference is the labour rate, not the purchase ledger

One key manufacturing managing director summed up clearly the situation for many UK manufacturers:

"Traditionally, it was a fair proposition for high volume, low cost manufacture to be done in the UK. What happens now is that offshore manufacturers are marketing themselves aggressively in the UK. The materials buying content side offers little advantage to the foreign companies. They buy from same sources as we in the UK do. The big difference is the labour rate of around $0.625/hour against our rate at $37.50/hour. £20-25 per hour in the UK is typical (all figures in 2002). We have to be realistic. Many of the high volume, low value products will move out of the UK. Take people who make high value, low volume products where you typically need a high level of skill, and in those areas, those [the offshore manufacturers] are not the kind of products that they are interesting themselves in, as they are set up for high volume.

"For us, it is a matter of thinking through whom we are trying to sell to. We've done reasonably well with people who make low volume products."

This paragraph confirms the enormous differences in labour costs between low cost and high cost regions of the world. It is interesting that the effect of global markets means that there is less difference on the materials buying side. Flow of "labour" is less global, one factor that keeps in place large differences in labour costs. The conclusion of this practitioner is that where you need high levels of skill and expertise, so that the products are lower volume and possibly higher margin, this region can remain competitive. In conjunction with another interviewee's comments that you can seek out "large niches" by pre-empting where an industry's needs will be and exploiting this detailed knowledge, companies in high value manufacturing in this region can be both competitive and significant in size and influence.

"Take for example, a flat metal plate with a rectangular hole in it. In UK, this costs £2.40. You can buy the same from Sweden for 40p. The difference is that when that when the Swedish manufacturer makes something, he will only do it on batch, say, 3-4 months worth of product. This looks good on P/L but bad on cashflow accounts. People have to look at the economics of this.

People who make in lower volume find UK suppliers better to work with: costs are higher, but you can buy from them at monthly volumes. This adds to the cost of manufacture, but in manufacture of high value items it doesn't matter so much."

This is a tactical, service style point, which can be quite important in keeping UK manufacturing of components for complex high value products healthy.

Good practice can also be a source of competitiveness or advantage to younger SME manufacturers in the region:

"Being new on the market we have a flexible approach. Access to the managing director and products engineers is easy with us. Potential clients can come to factory and see things being made: they need to see enthusiasm. The customer involvement with us is very high. They don't want to see reluctance to try and do something [new]. New customers only have to pick up phone to get through to managing director. So this is a double-edged sword."

Market conditions for manufacturing have been depressed since the "bubble" in telecoms manufacturing industry burst two years ago. One manufacturer said: "Things are now [late 2002] as bad as they can get. The market has bottomed out. All are quoting with gross margins that at other times they wouldn't have considered. It is a buyers market.

"The biggest factor [in this UK 'depressed manufacturing marketplace'] is lack of faith in investment.

"In difficult circumstances, there are always hard decisions to make about buying new capital machinery. Manufacturers often must do so, to meet customer requirements. It is hard to go in and invest when times are hard."

Value chain climb

We venture a "two by two" matrix:

High cost region	Academic papers suggest possible?	East of England, Silicon Valley
Low cost region	South East Asia China →	→ ?
	Low value Products	**High value products**

Figure 5: High cost region vs value of products

South East Asia and China have been lower cost regions by comparison with the US, the UK and the rest of Western Europe. But as mentioned above, they have also been geared up toward high volume, commodity manufacturing of simple products. We see that East of England strengths correspond to activities that require a good deal of expertise, knowledge and value-add in product manufacture, such as in putting together sound systems, inkjet printers, medical devices or automation machines that have many thousands of components and involve significant software as well as hardware input. This comes as no surprise to most. But there do exist academic papers that suggest, say, Cambridge can make low value products. And the big threat to other high cost regions is that ambitious countries such as China will venture into many areas of high value manufacturing with competence.

We have noted that the East of England is highly competitive in its R&D spend and in measures of innovation. We have also shown that it has significant manufacturing capabilities and that certain companies are looking at how success in licensing pushes them toward manufacturing or at least preparing the market for it. Further, we have seen that there is a perception that licensing models are "cute" and make for robust business models; ARM is a "lighthouse company" that certainly propagates this point of view. This acts as a retarder upon value chain climbing that will build bigger businesses in the region, where they are selected and invested in wisely according to strengths. There have been of course other localised retarding factors such as groups against building on Green Belt, building in "my back garden", or building at all.

Another senior manager said that:

"As we mature, growing emphasis is being placed on scale-up of technology and manufacturing."

The quote above means that as companies reach a certain size, say 75-100 employees, they may need to be more proactive in preparing the market for the arrival and the manufacture of goods based on its technologies. Where the technology is "disruptive", such as for lighting or displays based on light-emitting diodes, this is especially so. The question is how best to do this, and what to do with smaller demonstration lines after they've been built and proven.

"We sell "licenses of *process* IP".

When building factories to demonstrate *processes* to major manufacturers who buy the template of how to do it, not just the technical, written details of the IP, you open up opportunities to make more of your product, and to help sell it into distributors who are taking away much value in the chain. Further, "potential manufacturers and licensees see a working line in operation, which builds confidence in the manufacturability of technical products. And we have Joint Development Agreements aimed at filling gaps in the supply chain."

"We'd like to sell the 'razors as well as the blades'", said another senior director. The Cambridge subregion, where it is delivering product, often delivers machines but not technical consumables that can add a lot of value to the business. This is perhaps taking more from one part the value chain rather than climbing along it. But it is another point well made, that making the machines enables a company to extend its portion of the supply chain.

The US Fabless chip model, over here

One senior manager said: "We have a factory-less 'fabless' semi-conductor business model. This is well known in the US. We design, have made, and sell chips. We research, develop; prototype but we do not make the chip. For that, you need a fabrication plant priced at $1bn. We contract this part out." This kind of capital investment for manufacture is just not there for the UK, and probably not wise in this case.

A cluster of companies, like GlobespanVirata, ARTVPS, Alphamosaic, Cambridge Silicon Radio and Cyan make physical semiconductor products, but not here (exception possibly Virata).

The generic supply chain looks like:

Designer of chip → Silicon foundry (make) → ship to customer directly e.g. mobile phone/PDA company

This model uses the region's strengths well in IP design and development, but also enables value to be got from selling product. This product is made offshore however.

Other companies see manufacturing here as impossible, for their case, and baulk at the effort required to work with manufacturers outside of the UK: "Our technology is more manufacturable, than ARM's. We are not intending to but we could [manufacture]. We'd have to do it offshore, and that means problems. But to blindly use [the ARM business model] is not right thing to do."

Technology consultancy companies as channel from R&D to manufacturer

Repeatedly, Cambridge subregional companies said they: "work with tech consultancies like Plextek, TTP, CCL and Generics as design and development partners in order to support …customers."

This is a well-developed channel that could apply wider in the region. There is a strong cluster of technical consultancies in the subregion. There were manufacturing interviewees that saw this as a way to expand their businesses, but who hadn't found the resources or the opportunity yet to exploit the notion. Manufacturing companies could also approach the tech consultancies as a channel to find R&D and innovation that needs prototyping and low volume manufacturing.

Benefits of working with local companies nearby and clustering

This positive comment came from a manufacturer in electronic, high value components.

"We worked with [a Cambridge technology consultancy]. Often their clients are on compressed timescales. But they can come and see us at short notice. They can look at a similar product going through a real process. We can then sit round a table and thrash through it. We can actually get in a car, drive to [this Cambridge technology consultancy] and go and sort out the problem. There is a high quality of communication when you are working locally. You can't match a conversation across a table with emails or phone calls. We've learnt hard lessons on that. I am discussing a new product introduction. It is so essential to get communications right so that the client understands quickly what they must do. You only need a slight misunderstanding for wasted time and cost, especially when timescales are extremely compressed."

It is this solid basis, along with underlying social, lifestyle and economic benefits that have meant that businesses continue to cluster rather than separate out in a "heat death" arising from superb telecommunications.

However, on clustering in the academic sense of Porter, another manufacturing business leader said: "If this [clustering effect] applied to us, we would work for local companies on new machines and then sell them to the US later. In our case the complete inverse applies. [We want to break into the local market having sold externally to get to where we are now]."

So not all are in the same mode as regards the benefits of geographic closeness.

"Individual companies make individual decisions," was the final analysis of a senior technology consultant.

Strategies, tactics and pitfalls of East of England tech manufacturing companies in "adding value"

The following are a set of anonymous quotes from business leaders interviewed, about their business models.

1. "We are looking for emerging niche opportunities in early stage [new markets]. We are anticipating the industry's commercial and scientific objectives, investing in new technologies and putting in place the resources and people to address them."

By doing this, the company can access markets with low competition and high barriers to entry. They can then make a good margin on their product manufacturing. This strategy means good market communications.

2. "When a product company offers consulting, this can send the wrong signals to the market."

There is a balance between those who seek to sell product only, and be seen to be doing only that, and those who wish to run a smoother revenue servicing model, where products sold at low profit are supported with consumables or software, or accessories. For public or imminently public companies, there may be a financial-ratios (PE) "penalty" however, for being seen as a consultancy compared to selling product, though this has reduced since the market crash. On the other hand there may be solid reasons for doing it. CIR saw both models being applied by local companies.

3. "We outsource [components] and build to order, like a JIT or Dell Online model. There is high customisation."

Customisation was a common theme. It means companies may be making low volumes of each type of product, and will need to be using techniques of operation that can cope. Return on capital can be increased when profits remain constant but less capital is used [in building a facility, line or on equipment]. It is this improvement in efficiency that makes some types of manufacturing more likely in the region.

4. When a company "has a long purchasing ledger, and a short sales ledger", as the product is large and complex, it may well be adding a lot of value and gaining good margins.

Many of the region's companies are making complex products, and though they can work to high margins if they are ready for niche market demand, and they face complications in buying. This means there can be opportunities for slick low volume suppliers: "We are positioned as a contract manufacturer of electronic security products. And we are actively marketing to Cambridge-area companies"; "We need to re-evaluate, but we are manufacturers, mainly. If a customer came and said he had a product, say, as an electronic circuit diagram, but none of data needed to translate it into hardware. Then we can facilitate for people doing CAD layout and design, to the necessaries for the product's hardware." This specialisation of services to R&D companies, along with the openness of R&D companies to trade, would enrich the region's clusters.

5. "Technology gurus tend to dream up the impossible. We must have our feet on the ground, staying nearest to real opportunities. The marketing route is not always the sales route. We should concentrate on account-managed customers, building along the value chain."

This sophisticated manufacturing operations chief was sceptical about the idea of working with small, exciting, deep technology R&D companies. His opinion is clear from the above. Keep good relationships with current accounts and try to offer more and more to them: more complete manufacturing “solutions”. This may not exclude working with larger technology consultancies, however.

Skills: education has a lower prestige

“The evidence seems to be that we don’t train enough. I am in contact with some German companies. German qualifications go much further through. Even in the Phillipines, they now have state-of-the-art facilities where in the workforce, the proportion of graduates is high. When recruiting in UK it is not uncommon to find to shortcomings in basic education. They can’t read drawings. Education has a lower prestige here.” The government manufacturing survey statistics clearly show how German education among the workforce is much higher than in the UK. We are familiar with the German use of academic title or letters used. And our interviewee went on: “Given what is now available [in the UK, due to dropping standards], a company has to be prepared to invest in training.”

Particular sectors may have more reserves of skills than others, which affects competitiveness: “There is no indigenous automation industry in the UK, as there is in micro processing, for example. You have to buy the core skills, which *are* available locally, and then train.” The extent to which this is a problem depends on the ability of private companies to train people, and on the generic skills people gain from the education system.

“While we can hire locally the market has tightened up for the “right” knowledge workers. We go to US to get some of the specialist workers. On work permits: it is incumbent on the DTI to see that it is an important enabler. There is a normal, natural degree of challenge against bringing in foreign experts. We need to go beyond that. The right expertise can be tremendously important for our local commercial success.”

This is an example of one manufacturing CEO’s frustrations about getting the right team. *He doesn’t feel that bringing in skills from abroad is a bad thing*, and that it should be made easier to do by the government.

Manufacturing sentiment at a Low

East of England “pride in manufacturing skills is at a low” was the message of one seasoned executive.

But can contract manufacturers build in the region?

“Yes, [there are companies in the region we can contract manufacture for]. Opportunities exist both with those doing R&D and with consultants.” Decisions on investment are tough when others nearby are disappearing or faltering.

Above, we gave several examples of high value manufacturing companies that are here in the region, including Marshalls. Here is what one person we interviewed had to say about this important company:

“Marshalls of Cambridge employ 2750 people. ARM employs less than 400 in Cambridge. Yet Marshalls is seen as dispensable. In reality, Marshalls creates more wealth locally. Relative to Cambridge, ARM is a success, but not in global comparative terms."

But ARM has found a robust model for itself. CIR found that many others don't share their model, and could well lead to larger companies bringing wealth to the region in the future.

On the attraction of Cambridge

"Our engineering staff are often Cambridge graduates, but often hired from elsewhere. The people who studied here often want to come back. They have pleasant feelings about coming back. So being near Cambridge is good. We can't always keep hold of them, though."

But it is not just that people like to come back. There is an intangible asset value associated with being located in "Greater Cambridge". A premium for your company. This is what marketing types call "brand". Rents go up accordingly as you approach the town itself. House prices have experienced the same sort of effect that means that the "workers" in restaurants and bars in Aspen, Colorado, must live across the valley in another town. It is surprising that this should happen in such a small town of just 110,000 people with a moat called "the Green Belt". The community is so small that real clustering, networking effects apply to entrepreneurs, whose ideas are known quickly by all. There are only, say, two, not six, links needed to connect any two people. And there can be a scarcity rather than an abundance mentality as a result of this connectivity and smallness. People sometimes act as thought they don't feel there is enough to go round. Another expression of this is when people say: "it's very 'political' here. CIR believes that there are "private sector-university sector" complications and conflicts of interest now rife that increase political behaviour.

Another executive said: "The advantage of being established in Cambridge is the high tech aspect. There is highly advantageous access to workforce, and there are other groups that we could benefit from interacting with more. But we are now global in terms of markets and projects we take on. We are diversifying geographic risks. Our focus is external to the region."

Finally, one senior consultant said: "Luton is more important in UK terms. GNP from Cambridge is lower than Luton, which has more beneficial exporting. Cambridge may be misleading itself."

Problems of workspace facilities

"You can't rent space that is 50% workshop, 50% office. Either it is 95% workshop (South of Royston) or 95% office/lab (Cambridge area). So we had to get a purpose-built office."

The problem of workspace is being addressed by various public sector initiatives, for certain sectors (see below). But are there private sector or public market solutions available, using consortia and capital markets?

Mismatch between the aims of private equity investors and manufacturing companies

"The DTI was astonished at how little business we are doing locally. It is impossible to pitch into the local community. This is due to a bad fit with the VC and biotech funding models; there is a mismatch in the favoured and actual time to exit or returns."

Cambridge Investment Research Ltd has written a report on private equity processes, based in part on a component of direct market researching with over 30 players in private equity. Venture capitalists responded clearly. “Return within a reasonable period” was one of the most important investment criteria, even though hundreds of UK private equity funds mention manufacturing as an investment sector they consider. But manufacturing development must be a longer-term investment. So there is a risk profile mismatch, and manufacturing companies, or those with ambition to manufacture, must use other forms of capital or strategies.

Connecting R&D with manufacturing

Connecting R&D with manufacturing is not straightforward. Research and development implies new technology, and most likely, different end-product applications. What must be offered to smaller R&D companies with little or no resource in terms of manufacturing engineering is design for manufacture (DSM). This design for manufacture is now very common. Who will manufacture the R&D prototype or make it really ready for manufacturers to start from? There are companies in the region that are able to offer this hands-on service. This is an important building block for R&D companies to connect with the value networks. This is not the same as the channel to manufacturing through technology consultants who cluster in the Cambridge area.

Getting close to the markets

The following “rant” is typical of what people say about businesses in the Cambridge subregion:

“I’ve been in Cambridge for decades. The bulk of companies fail: why? As they do not get close to the markets. They are too technology-focused not benefits-focused. It is technology for its own sake. Who will buy? This flummoxes many local CEOs.”

But many believe that manufacturing brings companies closer to markets. Even when you manufacture, though, there is still more to do than meets the eye: “Even though we have a distributor, a lot of the selling has to be done by us.” This CEO got involved in selling to a large institution and many specialists, alongside the distributor.

2.4 East of England Manufacturing: New Initiatives

1. National Microsystems Centre
    a. factory and cleanroom space
    b. employ approximately 2000 staff

This centre will not automatically be built here in the East of England.

2. Regional Centre for Manufacturing Excellence

The Government has set up a Manufacturing Advisory Service including ten regional centres of manufacturing excellence (RCMEs), which will help companies directly and act as gateways to national centres of expertise.

3. Manufacture East

More information these initiatives will be made available by EEDA.

3. Comments on Industries for the East of England

3.1 Semiconductor design and electronics

UK Invest, whose aim is to sell the UK's prowess, states that: "The UK has the world's fifth largest electronics industry, with over 9,000 electronics companies employing some 400,000 people in manufacturing, plus 130,000 in the software and services sector, and it also has Europe's largest semiconductor design industry. Over half the market in integrated circuit applications design is based in the UK, including 60 of the European total of 140 design houses. Britain has a wealth of designers with experience of OEMs, silicon vendors, IP providers, EDA tool vendors and independent design houses. It is expert in all kinds of application and device design activity, from system-on-chip, DSP, analogue, to EDA tools and devices.

"Semiconductor design companies worldwide choose the UK because of its advanced high technology infrastructure. Including its telecommunications, excellent record of R&D and strong science base. The UK can also offer a large and well respected academic community for joint research and development (over 70 universities are involved in semiconductor design) and highly qualified graduates as potential recruits.

"The world's leading information technology companies have chosen the UK as their European operations hub, and many inward investors manufacture complete products or components here. This continuous investment by overseas manufacturers has ensured that the UK is a world leader in many key areas of electronics development and application. For OEMs, the UK market for electronic equipment, with sales of $13 billion a year from domestic production provides a solid base for expansion into exports.

"Supporting services for the electronics industry in the UK are outstanding. The UK has a long history of engineering innovation, and the well-established technical support networks reflect this history. Components suppliers work to the highest standards of quality assurance and guaranteed delivery, while specialist high-tech companies have developed from the UK's defence sector. Major electronics companies with UK manufacturing plants include Compaq, Ericsson, Fujitsu, Samsung, Sharp, Sony and Toshiba."

CIR notes that the electronics industry may have its status quo changed as companies go beyond the limits of Silicon with "large molecular electronics" at the nano-scale (one billionth of a metre). Hewlett Packard has released news of its plastic "Millipede" project. Cambridge itself has Plastic Logic and partners working in a related sector. The cost of fabrication plants in Silicon has gone through $1 billion, but with the new technology, capital requirements may be much lower in newly arranged and designed plants based on the different materials. This is an area where the region can build.

3.2 Medical systems and devices

Hardware and software engineering meet in this sector.

UK Invest states that: "The UK's medical systems industry is a highly competitive one, delivering leading edge design, development and manufacturing. This has attracted extensive investment from foreign companies, especially those who have seen the UK as a natural entry point to the European market. Up to half of medical systems production is exported from the UK. Over half of the larger companies in this sector represent investment by an overseas parent company and contribute more than 40 per cent of the total UK production.

"The choice of the UK by overseas companies as an inward investment location and subsequent success in medical systems markets is due to the support of its strong scientific and technological traditions in areas such as information technology, materials science and biotechnology. Our worldclass clinical expertise has developed in areas where there are many hospitals and clinicians, and collaboration between industry and the clinical community is highly effective. Both the UK Government and industry plan significant investment in the telematics, materials, biotechnology and orthopaedic areas, ensuring continued innovation and products in this sector in future years."

Medical Devices

Eastern Region business leaders interviewed did not say they were part of a cluster. But there is certainly a good deal of activity in diverse parts of this market, which is a competitive sector for the UK. Pharmaceuticals is also a competitive industry in the UK and across Europe, which the medical devices sector serves, in part. This combination, along with the informatics "boom" that derives from burgeoning biodata to be handled are sectors where the region is in place to do well.

Life Sciences generally has activity in the following areas (courtesy of ERBI website):

Biotech companies:
- 30% develop (bio)pharmaceutical products
- 28% develop pharma services, eg discovery tools, bio-informatics, CROs etc
- 15% develop diagnostics and reagent supplies
- 11% involved with agbio development
- 12% develop biotech instrumentation and equipment

Specialist service provider offerings:
- 40% technical services
- 9% financial services, total or major biotech offerings
- 5% legal services
- 15% consulting services, 100% dedicated to pharma/biotech industries
- 31% other business services, offering a local biotech centre of excellence

3.3 Displays

This is an exciting market that is forecast to flourish over the next decade, with organic light emitting diodes being a new technology basis for lighting and displays. See Appendix 3 interview for much detail from the point of view of one strong licensing company in the sector, Cambridge Display Technology.

3.4 Industrial inkjet printing

See Appendix 3 for another indepth interview serving as a good introduction to this sector. For the medium term, "inkjet printing is seen as being very important in achieving low manufacturing costs". This is because the technology can be developed to enable complex organic or polymer (large molecule) chips to be printed and because this reduces the cost of capital equipment.

Cambridge is the centre of a cluster of companies that are involved in industrial inkjet printing manufacturing and R&D. As a cluster, the group of companies leads certain markets. This was the only real "cluster" that interviewees regularly mentioned. It is held, locally, to be a world-leading cluster by various measures.

3.5 Wireless Communications

Wireless is still more on the lips of venture capitalists in the region than any other sector. The industry has obviously had many set backs. But as we stated above, there are clusters of companies driven by BT in Suffolk, Marconi Mobile in Essex and by many smaller companies in the Cambridge subregion.

3.6 East England Value Proposition

3.6.1Eastern Region strengths-weaknesses-opportunities-threats analysis

The "SWOT" analysis highlights some of the challenges facing companies in the East of England:

Strengths	**Weaknesses**
Relative to much of Europe, manufacturing costs are lower, but very high relative to regions such as South East Asia. Relative to the rest of the UK, Eastern R&D and innovation leads by a number of measures. Various technology R&D and high level engineering expertise: in particular: micro-, nano-electronics, materials, industrial inkjet printing, technical machinery, high end automotive (motorsport), and pharmaceuticals. In manufacturing, as a nation, the UK has been "strongly competitive" in: machinery & equipment, chemical products, "other transport" or aircraft & defence. It is also "competitive" in the sectors of electrical machinery, precision instruments, rubber & plastics, and non-metallic minerals. Basic engineering and technician skills in some areas. Programming and software engineers. Deep technology generation.	Access to markets. Communications with markets. Sales and marketing understanding. People and company population density and numbers Lack of "Lighthouse" companies above 1000/10000 employees. Modesty, lack of killer instinct Management resources, and trust in managers/salespeople "transactors" by technologists "creators" Political, geographic, informational disconnect across counties and market towns Culture clashes: creators vs transactors; London vs provinces; Cambridge vs region; Cambridge vs London. Company size base is small, "adventure" needed (cf Jeff Bezos, Bill Gates, Michael Dell), or import of experience Distortion of specialist services economy by HEIs.

Opportunities	**Threats**
To climb up the value chain in mature and emerging deep technologies, building on national and local strengths. FDI investment in manufacturing increases. Large companies no longer get turned away and choose to develop here. Functioning, productive networks across market towns and districts. M&A or growth results in a coherent, ground-breaking "lighthouse" company of some size that generates interest in region.	Predatory buyers of technology relocate it. Foreign companies let communities down by leaving when the going gets tough, or do not connect with local people well. Insularity kills opportunities. Internal failure to connect across the region at the levels of infrastructure, virtual and physical networks, and in subcontracting or workforce base. Physical infrastructure doesn't improve a lot, firms move China manufacturing of high value products longer term

Figure 6: East of England high value manufacturing strengths, weaknesses, opportunities, threats.

3.6.2 Notes on business models for technology companies

There are several key sources of revenue including design, product, and process licenses, maintenance, consumable supplies, consultancy and: selling of products. Licensing normally means being at the left of the supply chain and giving up from 99% to 99.9% of the value in the chain. But it should also be accompanied by process licensing that pulls a company along the value chain, getting involved in facilitating technology for manufacturers. Finally, those who do R&D and make products, and selling to end-users or distributors are capturing all or a good percentage of the value chain.

One company, apparently resistant to venturing up the value chain, had the following experience:

"We are a licensing and development company, with a need to demonstrate to quite a few people, rather than being a manufacturing competent company. [Our product] has 2-3000 electronic components. We have been dragged into the manufacturing side just to meet the needs of our customer licensees in and outside the UK. We need to make demonstration units to enable licensing. We make these demos, through subcontracting. This is mainly done in East Anglia. We sell to the suppliers of the [complex parts] that go into PCs. Every licensee wants a different product. The information needs of licensees [about new technology] are higher than we thought. If you are licensing to a big company in Korea, and if 1% of their workforce sends you emails asking questions, you are going to need staff to cover this."

This is key. Even to sell licenses you need some manufacturing. For selling, the more units you can demonstrate the better. Toys are good. Some people, not necessarily key customers, will buy these demonstration products at high prices, and this is what exploiting disruptive technology is about. Embracing the needs of the market may lead to a bigger more successful business with a higher bargaining power, or stronger market position.

3.6.3 Supply chains seen in high value manufacturing

The market structure has varying numbers of links in the chain to the end-user:

R&D and Manufacturing Company → End-user
e.g. R&D, and Manufacturer of device (one firm) → R&D institution
R&D Company → Integrated Manufacturer → End-User (few)
R&D Company → Manufacturer → Distributor → End-User (many)
R&D Company → Component Manufacturers → Complex Product Manufacture → VAR & Distributor → End-User
e.g. Demo/cmpt subcontractors → R&D company → complex component manufacturers → PC makers → Consumers of PCs

Table 5: Example value chains encountered in this study in high value manufacturing

The number of customers, and information and reach of the company will determine whether a reseller or distributor is used. Some R&D companies manufacture and ship products. This is a minority. The last example is the most common case.

3.6.4 Evaluation of key success factors

The key success factors arising from the above analysis are that:

- Assessing, accessing, and communicating with many, large niche markets must be done well;
- Regional value networks are not being tapped. Policy nexus, parochialism and effective distance means subregions act independently;
- Ambition as well as ability of the business leaders of companies and clusters are key;
- Creators (people doing technology and operations in product companies) must work with transactors (salespeople, financiers) to move product and make capital flow;
- Without selling a viable, exciting industry to young people with energy and skills, it may be hard to support high value manufacturing in the region long term.

The key value proposition for the region is one of advanced, specialist, technical, expertise-dependent, lower-volume, highly iterative, experimental, process-demonstrational, higher margin, emerging market, and niche sector manufacturing, supporting strong R&D generation.

3.7 Case: How does Silicon Valley support advanced manufacturing people?

The following passage encapsulates how important "advanced manufacturing" remains in the Silicon Valley cluster:

"Manufacturing remains a dominant industry in Silicon Valley. The stunning growth of semiconductor manufacturers and suppliers like Intel, AMD, National Semiconductor, Applied Materials have caused workforce shortages that can only be met locally if the education programs are relevant to the demands of advancing rigor and technology. The industry is meeting global competition by employing high-tech, high-value added processes in its local design and manufacturing operations, while moving low-skill, low-wage work offshore. Because of these global changes, tremendous opportunities exist for young people with the sophisticated computer-aided design and manufacturing skills needed to meet industry needs. Simply put, Silicon Valley has labour force needs and wants to expand opportunities for high-skill, high-wage employment for its youth."

We notice in the above, something not often mentioned in the UK: "high wage". There is a keen understanding of the market dynamics of labour in the text. They know that making sure the skilled workforce is happy financially is an important message to get over.

The UK's Eastern Region doesn't have the same problem of large, successful manufacturers rapidly depleting workforces, but the issues of higher cost and the deferring of low cost, high volume commodity manufacturing offshore is the same of both regions. How is Silicon Valley addressing these issues? Silicon Valley has an organisation called: Workforce Silicon Valley: WSV is organized around six learning collaboratives (organizational structures designed to foster collaboration between industry, high schools, and higher education around the common goal of preparing students for high-skill, high wage work), which represent high-growth, high-employment industry clusters. They unite industry, high schools, and higher education around the common goal of preparing students.

The Eastern Region might have a number of "Learning Collaboratives" to work with people and organisations with an interest in economic growth through building bigger businesses, retaining and nurturing high-value manufacturing skills, and understanding strengths. Benefits of such initiatives according to WSV are:

For Business

- Facilitate networking between industry partners, high school and higher education
- Strengthen educational partnerships with industry
- Enhance opportunities for student and faculty internships at local businesses and organizations
- Identify industry workforce needs and skill levels for integration into project-based learning at schools.

For Educators

- Facilitate networking between high school and higher education, and industry partners
- Allow partners to share curriculum, career pathway development plans, and project-based learning units
- Assist partners in developing the articulation process between high schools and community colleges
- Promote student educational plans among high schools and community colleges for workforce preparedness
- Create partnerships for grant-writing opportunities

If the above is in place, then this will instil more confidence in investors in a given region.

Given the political and informational separation of the counties and economic clusters in the region, there may need to be more than one collaborative here in the East of England. In the Cambridge subregion, these might be brought under the umbrella of "Workforce Plastic/Wet Fen"… however, Cambridge Investment Research Ltd also recommends direct interaction and involvement of private companies with the communities and schools of the "workforces", as was done by entrepreneurs both before and since the introduction of welfare state systems of allocation of public money, though in different levels of labour costs and competitiveness. UK engineering companies used to provide many services for whole communities, even houses and hospitals! This may now be out of reach given the nature (speed and uncertainty) of global markets. According to one of CIR's managing director interviewees, as late as the 1960s and 1970s, those in schools in the East of England would be well aware of the activities of many private companies who would engage with them well before they left school.

4. Recommendations

Each manufacturing company has a different positioning, and may have different strategies for different product lines. Most are not part of a regional sectoral cluster, but do benefit from pools of skills. These points favour detailed analysis of cases, rather than attempts to generalise.

Ambition and competence of CEOs is important; Homegrown, long-term managers are ideal, but if not available, then we do need to import this desire and knowledge. This means selling to successful people: the benefits, brand and kudos of living and working and in the region

The East of England wants bigger businesses that act as examples of success, in the same way that early stage entrepreneurs have been successful and produced inspired many new small businesses.

Entrepreneurship, at least in the Cambridge region, has come to mean setting up a small technology business and selling it when it reaches 15 employees. There are other types of company that are important. And there is no company in the region that doesn't need "entrepreneurship" to take it to the next stage, including companies approaching 300-500 or more employees.

The private sector must engage with capital providers and schools and colleges, e.g. by going there and talking to students, and inviting them back to plants/offices. Can they sell the idea of manufacturing to the new generations?

Government can be helpful in creating forums for discussion and networking among R&D companies, high value manufacturers, subcontractors and individuals with skills, and in setting up workspace, but can the government agencies sell their offerings successfully to the private sector entities and people involved?

Accessing and communicating with markets and customers and thinking about benefits rather than technology continues to be a problem that can be attacked by bringing together "transactors" and "creators" to talk and understand each other better.

There is an argument that building factories near large markets, such as in China and the US is the only way to "get closer to markets". But much more could be done locally in prototype, demonstration and early-adopter manufacture, and through "transactors" to strengthen and build companies here.

Precision instruments, machinery, devices, pharmaceuticals, industrial inkjet and deep materials, displays and microelectronics application, along with some software engineering skills all appear to be strengths at several levels that should be developed and applied to commercial success.

5. Conclusion

CIR's consultancy assessed and evaluated East of England High Value Manufacturing, in a Cambridge-centric way, in certain clusters. It was not meant to be complete or final. It is, rather, the first, rapid iteration in an effort to understand the region's advanced manufacturing and R&D as a whole and in some of its particulars: What its strengths are, and how it can build bigger businesses and prosper: How it can prosper in a way that is not based on a centre and radial links, that leaves out important sectors and areas, but rather an irregular network across the region.

Common themes were that certain sectors are strongly competitive, innovative, and complementary; that information could flow better and relationships could be developed where they are early stage or non-existent; that the ambition of the people at the helms is key; this needs to be grown and sometimes supported by external management talent; manufacturing brings more value to companies, makes them stronger and brings them closer to the markets up to now hard to access and communicate with; Culturally, technologists and deal-makers of all kinds, and people on both sides of certain geographic dividing lines must be able to work together, in a sophisticated business society that is stratified and specialised to create advantage; Finally, that it will be hard to sell manufacturing to the young, who must be trained better and have the will to train, and that longer-term need is in the hands of private and public groups.

Knowledge and high skills are present in many sectors, and attainable in others with some coordination, in this region. CIR's report discusses some of these here, using a "listening" approach. We have seen how the region has innovation above average or leading in the UK. But the "government's" strategy of moving "up the value chain" to "high value-added" manufacturing involves having a connection to the market's needs. Customer benefits. It cannot be argued that this region is strongly competitive in the area of understanding customers. This is probably due simply to the fact that the market is small in the region, and the UK domestic market is still just medium-sized.

But this integral part of the government's strategy for manufacturing remains the problem. It is one thing to manufacture technical products. It is another to do high-value manufacturing. This latter needs a strong connection to markets and individual customers. Tieing this up with the idea that the ambition of the CEO is important, we believe that that CEO must ensure that sufficient high-level sales activities are allowed for and carried out by an aspiring, skilled, innovative medium-sized company looking to climb the value chain.

There is much to celebrate in high value manufacturing in this region. Manufacturing that works with or directly builds strong, innovative companies. But many want to do rather than celebrate. As well as supporting new companies, the message has been that the Eastern Region must now build upon its base of good high value manufacturing and R&D companies.

Appendix A: East of England Research Groups

Research Laboratories

1. Microsoft Research (Roger Needham, Andrew Herbert)
2. Schlumberger Cambridge Research Ltd (geomechanics, physical chemistry, fluid mechanics and seismics)
3. NI Agricultural Botany
4. Plant Breeding Insitute
5. Babraham Institute
6. Institute of Food Research
7. CU Computer Laboratories (Stephen Allott)
8. CU Cavendish Labs/Nanoscale Labs (Richard Friend)
9. AT&T (Andy Hopper)
10. Marconi
11. Generics (Gordon Edge)
12. TTP (Gerald Avison)
13. Analysys (David Cleevely)
14. Plextek
15. PA Consulting
16. ADLittle / Cambridge Consultants (Brian Moon)
17. The Welding Institute
18. Building Research Establishment
19. ARM (Warren East)
20. BP Amoco
21. Wellcome Trust Genome Campus
    a. Sanger Centre
    b. European Bioinformatics Institute
22. GlaxoSmithKline Research & Development
23. Nokia
24. Philips
25. Epson-Seiko
26. Toshiba
27. Hitachi
28. Rank Xerox
29. Agilent Technologies
30. Adobe Systems Engineering
31. Raytheon
32. Medical Research Centre (Addenbrookes)
    a. Biostatistics Unit
    b. Cancer Cell Unit
    c. Cognition and Brain Sciences Unit (formerly Applied Psychology Unit)
    d. Dunn Human Nutrition Unit
    e. Resource Centre for Human Nutrition Research
    f. UK Human Genome Mapping Project Resource Centre
    g. Laboratory of Molecular Biology (LMB)
    h. Centre for Protein Engineering
33. CU Dept of Chemistry
34. CU Dept of Engineering (Andy Hopper)
35. Institute for Manufacturing (Mike Gregory)
36. CU Dept of Material Science & Metallurgy
37. Agrevo
38. BT Research Labs
39. BHR Group Limited
40. Ford
41. Nissan
42. Vauxhall
43. Smith Kline Beecham
44. Unilever
45. Schering Plough (Pharmaceuticals)
46. Institute of Food Research
47. John Innes Centre (plant and microbial science)
48. Materials Engineering Research Laboratory
49. Merck Sharp & Dohme Research Laboratories (Biotech, immunology)

East of England Universities

1. Anglia Polytechnic University
2. University of Cambridge
3. Cranfield University
4. De Montford University
5. University of East Anglia
6. University of Essex
7. University of Hertfordshire
8. University of Luton

Appendix B: Activities supported in the Cambridge subregion[4]

Electronics, IT and telecomms

1.1. Electronics, Microelectronics
- 1.1.1. Automation Systems
- 1.1.2. Digital Systems
- 1.1.3. Electronic circuits, components and equipment / electronic engineering
- 1.1.4. Superconducting materials/devices
- 1.1.5. Microengineering, Micromachining
- 1.1.6. Printed circuits and integrated circuits
- 1.1.7. Semiconductors

1.2. **Information Processing, Information Systems**
- 1.2.1. Artificial Intelligence (AI)
- 1.2.2. Computer Software
- 1.2.3. Computer Technology/Graphics, Meta Computing
- 1.2.4. Data Processing / Interchange
- 1.2.5. Data Protection, Storage Technology, Cryptography
- 1.2.6. Databases, Database Management, Data Mining
- 1.2.7. Electronic Commerce, Electronic Payment, Electronic Signature
- 1.2.8. Imaging, Image Processing
- 1.2.9. Information Technology/(bio)informatics
- 1.2.10. Internet Technologies
- 1.2.11. Peripherals Technologies (Mass Data Storage, Display Technologies)

1.3. Telecommunications
- 1.3.1. Audiovisual Equipment and Communication
- 1.3.2. Broadband Technologies
- 1.3.3. Mobile Communications
- 1.3.4. Narrow Band Technologies
- 1.3.5. Network Technology, Network Security
- 1.3.6. Satellite Technology / Systems / Positioning / Communication

Industrial manufacturing, material and transport technologies

1.4. Industrial Manufacture
- 1.4.1. Industrial Inkjet Printer manufacture
- 1.4.2. Medical Devices/machines
- 1.4.3. Design and Modelling / Prototypes
- 1.4.4. Industrial Engineering / Processes / Manufacturing Techniques
- 1.4.5. Machine Tools
- 1.4.6. Packaging / Handling

1.5. Materials Technology
- 1.5.1. Adhesives
- 1.5.2. Ceramic Materials and Powders
- 1.5.3. Coats and Surface Treatment
- 1.5.4. Dyes and Inks
- 1.5.5. Optical Materials
- 1.5.6. Plastics, Polymers and Composite Materials

1.6. **Transport/Automotive**
- 1.6.1. Design and Technology of Vehicles (wider region)

1.7. Aerospace Technology
- 1.7.1. Aeronautical technology / Avionics (wider region)
- 1.7.2. Aircraft, Helicopter (wider region)

[4] Using classifications developed by the Innovation Relay Centre, Cambridge

Other industrial technologies

1.8. Other Industrial Technologies
- 1.8.1. Chemical Technology and Engineering
- 1.8.2. Electrical Engineering and Technology / Electrical Equipment
- 1.8.3. Laser Technology
- 1.8.4. Sensory/Multisensory Technology, Instrumentation
- 1.8.5. Simulation, Simulation Engineering
- 1.8.6. (Digital) Sound Engineering/Technology
- 1.8.7. Speech Processing/Technology
- 1.8.8. Vacuum/ High Vacuum Technology

Biological sciences

1.9. **Medicine, Human Health**
- 1.9.1. Clinical Research, Trials, Medical Research
- 1.9.2. Diagnostics
- 1.9.3. Diseases
- 1.9.4. Gene - DNA Therapy
- 1.9.5. Medical Instrumentation, Medical Imaging, Radiology
- 1.9.6. Medical Technology / Biomedical Engineering
- 1.9.7. Medical devices
- 1.9.8. Pharmaceutical Products / Drugs

1.10. Biology / Biotechnology
- 1.10.1. Cellular and Molecular Biology
- 1.10.2. Enzymology / Protein Engineering / Fermentation
- 1.10.3. Genetic Engineering
- 1.10.4. Microbiology
- 1.10.5. In vitro Testing, Trials

1.11. **Life Sciences**
- 1.11.1. Genetics

Measurements and standards

1.12. Measurement Methods
- 1.12.1. Analyses / Test Facilities and Methods
- **1.12.2.** Recording Devices

1.13. Standards
- 1.13.1. Technical Standards
- 1.13.2. Quality Standards

Appendix C: Questionnaires

Framework for Interview

Sector and activities: What does your company:

- research?
- develop?
- make, as prototype?
- make, more than single or a few units of?

Business analysis: In a nutshell, what is your business model?

If early stage, do you intend to manufacture, or develop / prototype your research?

How do you describe your market and supply chain qualitatively? Where do you fit in? How much consulting and servicing vs selling of product?

What are your relative strengths and weaknesses? (expect "selection bias" here!)

What are the external opportunities and threats?

Does your technology, product or business model change the supply chain's structure at all? (cf digital cameras, DVD, Amazon e-commerce, etc)

If you don't manufacture, why not? What is needed?

Company manufacturing capability: How many units can you make a week now?

Demand: How many units are there in your market now, a year?

Forecasts: What are your management/the analysts forecasts for your market in 1,3,5 years?

Supply: What is needed in the region to support manufacture to this level?

- Capital/investors persuaded?
- Expertise in manufacturing?
- Infrastructure? Outsourcing of suppliers (tools, cmpts), services, subassembly & other subcontactors, workforce
- Are these external elements locally available? Where are they based? Does it matter if they are not?
- Other? (intangible, cultural, etc)

Location: Why are you based

- in the East of England?
- exactly where you are?

Are you are part of a geographical and sectoral "**subcluster**" of companies/institutions?

If yes, who are the other regional companies in the region doing something related to what you do, or who are involved in the supply chain in any direction from you?

Where else in the UK do you have buyers, suppliers, competitors (esp. manufacturers)?

What are the relative strengths and weaknesses of this subcluster vs others (please name them)?

How important is it to your research and development base, that manufacturing of products based on this research and development happen nearby?

Leadership: Does this regional subcluster or your company "lead" others or the world?

Framework for contract or product manufacturing companies

1. What are the resources / assets / competences of your factory/plant/line/workshop?
2. Which regional companies (give description if not public domain) are you partners with, customers of, or suppliers of products or giving consultancy to?
3. How many employees (fulltime equivalents) do you have? Roughly what do you turnover annually?
4. Tell me about the industry and markets you are in or rely on.
5. Give me a clear picture of the supply chain and how your company fits into this.
6. What competition do you have? Where is it?
7. What are your strength, weaknesses internally, and the opportunities and threats externally to you?
8. If you use financing, can you name investors whose investment criteria are a fit with your company?
9. Where do you have links into R&D seeking manufacturing in the Eastern Region?
10. Do you believe there are companies that you could connect with?
11. Are there any other reasons why you do not connect?

Appendix B: Displays, Ink-jet and other interviews

Since the material in the interviews was generally of a sensitive nature, the interviews have been summarised and aggregated so as to hide the speaker's identity. We retain key points. However, the following two interviews are available as in full.

Cambridge Display Technology: Interview[5] with Dr. Scott Brown (CDT R& D Director)

Full Interview Transcript, as screened by CDT

Sector and activities: What does your company

- research?
- develop?
- make, as prototype?
- make, more than single or a few units of?

We do all of those things to a greater or lesser extent. At this stage in our company's history, the emphasis is still mainly research and development, although as we mature, growing emphasis is being placed on scale-up of technology and manufacturing.

CDT was founded in 1992. It was originally a research organisation studying LEP materials for use in OLED displays. It was a spinout from Cambridge University's Cavendish Lab[6].

Brief history of CDT

1989: Light emitting polymer (LEP) discovered in Cambridge University's Cavendish Laboratory and fundamental patents filed. **1992:** CDT formed to commercialise technology. It was funded by UK venture capital, Cambridge University and colleges and private individuals/angels. University IP granted via "LEP technology deed". **1996:** First licenses granted. Technology deed extended to end 2000. **1999:** US firms Kelso & Company and Hillman capital acquire 75% of shares and inject capital. **2000/2001:** Management team built, new capital raised, Godmanchester project starts, comprehensive licensing program begins. New university "deed" signed. **2002:** Licensees launch first commercial products using LEPs. Godmanchester starts up (see below).

FINANCING: $78 million was raised to support technology development in the period 1999-2002.

EMPLOYMENT: In 2002, we have 120 people working at CDT, comprised as follows:

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[5] This interview has in it technical as well as business model information.
[6] Other displays partnerships are listed at http://flatnet.phy.cam.ac.uk/partners.htm

- 25 in support functions, e.g. Administration/Management/HR/IT/Finance. Most are degree level employees.
- 35 are in Godmanchester, where we have a 14” substrate line to demonstrate manufacturability of Polymer OLEDs. We intend to sell small volume of niche displays from this facility as well as process technology packages and technical services. Staff at Godmanchester are mostly engineers, although we have just recruited an additional shift crew.
- 60 R&D staff working on material synthesis (12), material science (6), device physics (8), device development (20), device testing (5) and Ink jet printing (10). They all have a degree or PhD. Operators all have degrees.
- 3-4 in IP strategy development and patent filing.
- In addition to the above, CDT acquired Litrex in the USA, an ink jet printing start-up company. There are 35 employees at Litrex developing ink jet printing equipment for the electronics industry.

How is LEP technology “disruptive[7]”?

LEP technology is considered at CDT to be a technology dislocation in the display industry. Light emitting polymers produce light when current is passed through them. A wide range of colours is available. They only consume power when lit, have high brightness, extremely good viewing angle and fast switching speeds. These are considered to be advantages over current LCD displays. With the development of ink jet printing of LEPs, low cost manufacturing becomes possible. Polymer OLED displays can be lightweight, thin and have low power requirements, making them ideally suited for portable applications. Good viewing angles and fast switching make them equally suitable for TV but LEP lifetimes will need to improve. This is the current focus of on-going R&D at CDT.

We have found that to be successful, we need a combination of material science and device physics. It is extremely important to understand the relationships between LEP structure and performance in an actual device. For this reason, we have invested in clean room facilities and 6” processes and equipment so that materials can be tested in prototype displays.

The devices made initially were crude. Over time, the device development activities at CDT have become more and more sophisticated and a number of important discoveries have been made either in the processes used to make OLED displays or in the design of the device itself. Novel cathode materials have been developed to enhance LEP lifetime for example. LEPs are sensitive to oxygen and moisture and for this reason, the way a device is encapsulated or hermetically sealed is important. We have developed processes that produce good encapsulated devices. As mentioned above, we have also been seeking low cost manufacturing processes that

[7] “Disruptive technology” is often misused. Christensen means: It doesn’t promise higher margins. Key, larger customers do not want it. Performance may be lower than what is already available. Its end markets may not exist. It sounds pretty awful to the business student. But the point is that there will niche customer benefits rather than product features that usher in the new market. To exploit it, large companies or institutions, where it most often arises, must be willing to set up smaller “spin-outs” armed with the technology, that can get excited about these smaller, riskier opportunities. Those opportunities can increase rapidly as the technology iterates and develops.

will enable large volume displays to be made cheaper and efficiently. A significant amount of material is wasted in a traditional spin-on manufacturing process. CDT have been developing LEP ink jet formulations and hardware (in conjunction with Litrex, a wholly owned subsidiary of CDT) in order to be able to offer display manufacturers a low cost alternative to spin processing.

Small molecule OLEDs have been developed by Kodak and are also currently being commercialised. Small molecules offer many of the same advantages of LEPs developed by CDT when compared to LCDs. However, one important difference between small molecule and polymer OLED materials is found in the way each is deposited. As mentioned above, polymers are solution processable and are therefore amenable to an ink jet printing approach. Small molecules, on the other hand, are deposited by evaporation through a finely patterned mask. The cost of these mask is a significant factor, especially as display size is increased. Furthermore, the manufacturing process becomes complex at large scale, as large mask sets need to be held at precise distances from the display substrate and cleaned at regular intervals.

Looking ahead, CDT see LEP based technology finding its way into many application areas, including large area displays, signage, lighting and photovoltaics. Work is already underway on developing flexible substrates. Developments in this area will ultimately lead to conformal and flexible plastic displays. CDT have also demonstrated that LEP materials can be operated in reverse, i.e. instead of passing current through them to produce light, LEP materials will also produce electricity when exposed to light.

Godmanchester Project

The aim of the Godmanchester facility is to demonstrate LEP device fabrication at a manufacturing scale. The facility is semi-continuous and handles 14” glass substrates. It is a $30million investment and includes all essential unit operations you would expect to find in an OLED manufacturing line, e.g. ITO patterning, substrate cleaning and inspection, spin processing, cathode deposition, encapsulation, scribe and break, TAB bonding and device testing. 4 integrated Litrex ink jet printers will be installed before the end of the year. CDT intends to develop processes, know how and related IP at this facility and revenues are expected based on:

1. Transfer of manufacturing process packages
2. Sale of limited volumes of “niche” displays
3. License of process IP
4. Technical service and support

The Godmanchester line allows potential manufacturers and licensees to see a working line in operation, builds confidence in the manufacturability of OLED devices and reduces the business risk associated with capital investment.

Business analysis: In a nutshell, what is your business model?

CDT is an IP licensing company and is reliant upon the technology it develops. Some revenues will come from the sale of displays made at Godmanchester but this is expected to be a small part of total revenues. CDT has developed IP in all key areas of Polymer OLED displays. The table below summarises CDT’s IP portfolio. New patents are being filed on an on-going basis.

Technology	*Granted/Pending Applications*
Device	14
Materials	27
Processes	11
Electrode/Charge transport layers	16
Display Architecture/Applications	8
Electronics and drivers	9
Optics	7
Ink jet	6
Flexibles	3
Photovoltaic and photodetector	6

Table 6: CDT Technology Breakdown of Worldwide Granted and Pending Applications

Company	*License Type*
Covion	Materials
Bayer	Materials
Dow Chemical	Materials
Sumitomo	Materials
Delta Optoelectronics	Manufacturing
DuPont Displays	Manufacturing
MicroEmissive Displays	Manufacturing
Osram Opto Semiconductors	Manufacturing
Philips	Manufacturing
Seiko Epson Corporation	Manufacturing
Plastic Logic	AuxiliaryComponents
ST Microelectronics	Auxiliary Components

Table 7: Current licensees of CDT Intellectual Property

CDT recognises that OLEDs are new and that a well-developed supply chain does not yet exist. CDT's approach differs from most IP companies in that it is active in developing the supply chain for OLEDs.

Activities in this area take several different forms:

1. CDT have a number of Joint Development Agreements aimed at filling gaps in the supply chain. An example of this would be the JDA we have with ST Microelectronics. To optimise OLED device performance, new driver chips may be required. Together CDT and ST Microelectronics will develop these and ST Microlectronics will supply these to the OLED industry.

2. Where it is seen as beneficial, CDT will acquire IP and sub-license to its licensees to enable uptake of the technology. CDT will also facilitate cross-licensing of IPR, where appropriate and possible.

3. CDT may also make acquisitions or form JVs to develop critical parts of the supply chain. For example, ink jet printing is seen as being very important in achieving low manufacturing costs and, thereby, differentiating polymer OLEDs from those made with small molecules. There was no viable ink jet printing technology available to potential display manufacturers. CDT acquired Litrex to develop this technology. CDT also worked closely with Seiko Epsom to develop their printing technology for OLEDs. CDT and Seiko Epsom recently announced a joint venture, Polyink, to provide a fully serviced ink jet printer and ink formulation option to customers.

Exploitation Strategy of CDT

The markets accessible to LEPs will increase over time as the technology matures. Early target markets (comprising segmented and alpha-numeric displays and dot matrix displays) total over $4bn pa at OEM prices in 2005. The characteristics of LEP products will also enable new concepts and designs in information display and lighting which are not available with current technologies; composite products (combining backlights, seven segment, alpha-numeric and dot matrix displays) are examples of this. The longer-term objective is to enter mainstream flat panel graphics display markets, currently valued at over $30 billion (2005).

CDT's exploitation route for the technology is through licensing and technology transfer, coupled with corporate partnerships, joint ventures and developments, and device manufacturing. CDT’s LEP technology leadership will allow the company to leverage developed manufacturing skills that are essential to be a world-class display manufacturer. Through technology development, technology transfer, licensing and licensing services, manufacturing licensees will have immediate access to the state of the art in LEPs. This will allow rapid development of display products targeted for strategic markets.

Partnerships with corporations who will develop LEPs for high information content graphics displays and flexible substrates is a high priority. CDT's model is to be the centre of a close technology development network that provides the technology and IP needed to advance the commercialisation of LEPs.

To this end, commercial agreements with Philips, Dupont, Osram, Delta Electronics, and Seiko Epson, have been formed, with more under development.

The strategy involves infrastructure development for the emerging industry, including development of commercial material systems, production techniques and capital equipment such as ink-jet printing and tuned polymer formulations. Central to this strategy also is the creation of a supply of the highest quality LEP materials.

CDT is strategically positioned at the center of activity for the next wave of display technologies that is light emitting polymers. Having unique expertise in all aspects of LEP technology including novel material design, synthesis, materials systems, device architectures and production scale-up, CDT will offer to its partners and licensees the chance to participate in the realization of the full potential of this truly unique technology.

IP licensing

CDT usually asks for an upfront payment for the licence and a royalty stream from devices made later. Commercial products are now entering the market. Philips have launched an electric razor incorporating a monochrome polymer OLED display. Delta Electronics have also commercialised an MP3 player with a monochrome display. More sophisticated products are expected to quickly follow.

Early target markets comprise segmented and alphanumeric displays and dot matrix displays. The longer-term objective is to enter full colour, flat panel display markets, valued at over $30 billion (2005).

How do you describe your market and supply chain qualitatively? Where do you fit in? How much consulting and servicing vs selling of product?

CDT have licensed LEP material production to 3 material suppliers, namely Covion, Dow Chemicals and Sumitomo. Technology relating to PEDOT, a hole transport material, has also been licensed to Bayer. CDT has no ambition to become a materials supplier itself. Royalties are paid to CDT based on material sales. CDT has deliberately limited the number of material licensees. Our intention here is to ensure that the display manufacturer has a choice of reliable suppliers but to avoid a proliferation of suppliers. This is seen as important if material suppliers are to be encouraged to invest in development and manufacturing plant (the total volume of LEP required on an annual basis is not very high). Display licenses have been sold to Philips, Delta Electronics, Osram and Dupont. While a small number of displays will be sold from CDT's Godmanchester facility, CDT does not intend to become a large scale display supplier.

The supply chain will differ case by case.

For example, Philips are able to buy LEP materials from Dow, Sumitomo or Covion, made display modules themselves on their own manufacturing lines and integrate these into their own consumer electronic products. Other companies, like Delta Electronics, are likely to make and sell display modules to others who are then able to incorporate these into their appliances. An early application for OLED displays is in mobile phones. Companies like Motorola, Nokia, and Eriksson are likely to sub contract assembly and will source display modules from a display manufacturer.

Litrex is a special case. While CDT business model centres on IP and IP licensing, Litrex (a wholly owned subsidiary of CDT) is in the business of developing, manufacturing and selling ink jet printing equipment. This is available to any display manufacturer who wants to buy one. Other equipment required to manufacture OLED displays is readily available from suppliers to the electronics industry.

Displays are currently made on ITO coated glass substrate. The substrate used is standard in the LCD display industry and the user has the choice of several suppliers. Development work at CDT is showing that some substrate is better than others for use in OLED displays. CDT is presenting data to suppliers so that if a special grade of substrate is required it is readily available.

While most of the electronics associated with a passive matrix device are standard, unique driving chips may offer benefits to the OLED display user. These benefits may include better power consumption, grayscale or LEP lifetime. As mentioned previously, CDT is working under JDA with ST Microelectronics to develop chip sets for OLED applications. As display sizes increase, we will see a move from passive matrix to active matrix backplanes. LEP lifetimes are typically much longer when driven by constant current, making them uniquely suitable for use in active matrix systems. However, current, active matrix substrates utilise voltage driven TFTs and since OLEDs are current driven devices, more development work is required on the TFTs themselves. CDT is working with potential backplane suppliers to ensure that active matrix substrates are ready for when the market needs them.

As this technology evolves, we will increase our development effort on plastic substrates. While proof of concept has been demonstrated, it will require significant development work before a roll-to-roll continuous process is available.

What are your relative strengths and weaknesses?

Strengths

We have created a strong technical foundation and robust IP portfolio. This is regarded as being a key strength and because of this we continue to enjoy a high level of support from our share holders and god ratings from analysts. We have a robust portfolio relating to LEPs and this has been extended to devices. We have a skilled set of employees and close relationships with the Cavendish and Melville laboratories of Cambridge University. There has been significant capital investment to demonstrate the viability of the technology and we have shown that LEP technology is extendible. We have proof of concept on lighting and photovoltaic applications and we are continually adding to our IP portfolio. We have a number of strategic Joint Development Activities underway with key players in the display and lighting industry. Our technology offers a low cost manufacture route to OLED displays. We have excellent name recognition and credibility in the display field. We are often approached by others to work with them.

Weaknesses

We are a small start-up company and that does bring with it some resourcing issues. On the positive side, we do have many more opportunities than resources to pursue them. We still have work to do on LEP lifetimes, in particular with blue materials.

What are the external opportunities and threats?

As mentioned before, within the OLED display arena there are two technical options, one being polymers and the other being small molecules. Small molecules have been under development for longer. At small display sizes, competition between the two technologies is likely to be fierce. At higher substrate sizes, CDT believes that polymers will be the materials of choice. There is the potential that small molecules overcome the issues associated with manufacturing at large scale. Looking more broadly, however, OLEDs, whether small molecule or polymer based will compete with LCD displays. The biggest threat to the emerging OLED industry is that LCDs continue to improve and the benefits offered by OLED displays are eroded.

For CDT, in particular, we have a good relationship with display manufacturers. It is naïve to think that they are not doing their own development in the OLED area. As the Industry takes off, it will become increasingly difficult for CDT to maintain a leadership position in OLED IP. Inevitably there will be more IP sharing and cross-licensing. To sustain itself as an IP company, CDT will have to eveolve its technology into new areas. This is already starting as we demonstrate the use of CDT polymers in photovoltaic applications, for example.

Does your technology, product or business model change the supply chain's structure at all?

We believe that LEP technology will cause disruption in the display industry and that there will indeed be winners and losers. New material and equipment suppliers will emerge. New products and new applications will be born. We have tried enable the supply chain, thus far, by supplying the new licences on materials, display designs and manufacturing processes. We will continue to do this.

Some examples:

Covion and Dow were not in LCD material supply but they will be important material suppliers to the OLED display market. As OLEDs make their way into consumer electronics, they will take market share from LCD displays. For some companies this will have no net effect. Some of their LCD lines may convert to OLED lines. For LCD module producers or LCD material suppliers there is unlikely to be a loss of existing business. I see OLEDs affecting more their future growth potential rather than stealing their existing business, since the total display market continues to grow as a whole.

CDT expects that LEP technology will be used in current product markets like mobile communications, computers, and consumer electronics. Ultimately, LEPs also have the potential to be an alternative to the cathode ray tube - the display technology used in conventional televisions and computer monitors. LEPs will also enable new products that require thin, lightweight, conformal or flexible displays.

Company manufacturing capability: How many units can you make a week now?

We can handle around 50 6" substrates per week on our research and development line. At our pilot line in Godmanchester, we currently process around 5 14" substrates an hour. The process is not optimised for throughput at this time, nor are we running shifts.

Demand: How many units are there in your market now, a year?

See sheets faxed over. (Ed. The markets are well-covered by analysts in the City.)

Supply: What is needed in the region to support manufacture to this level?

- Capital/investors persuaded?

Cambridge University was one of CDT's founder shareholders. This was a pioneering step for the university to invest in the commercial exploitation of research. Other founder shareholders were Cambridge Research and Innovation Ltd and the academic inventors who discovered the technology.

The company's early funding came partly through investments from diverse shareholders, including the Genesis rock group and its manager; the Sculley Brothers; the Generics Group plc; Hermann Hauser, a founding director of Acorn Computer, Steve Kahng, president of Power Computing Corporation; and Esther Dyson, president of Edventure Holdings, of New York.

In September 1997, this group was supplemented by an investment of approx. $10 million by a financial group headed by Lord Young of Graffham, former Secretary of State for Trade and Industry in the UK government who also became Chairman. Later in the year, Intel, the semiconductor manufacturer, also invested in CDT.

In July 1999, Kelso Investment Associates and Hillman Capital acquired a majority interest in the company, for a total of $133m. Kelso and Hillman are both private equity funds, based in New York, USA. A new parent company was established for the group, also based in the USA.

As part of their acquisition, Kelso and Hillman provided additional funding of $16m directly to the company to finance ongoing research and development activities.

In March 2001, a further $28m was raised from shareholders. These funds were raised partly to finance construction of a new $25m facility dedicated to developing commercial scale production techniques and know-how for LEP technology, in order to assist licensees in developing their own manufacturing operations.

- Expertise in manufacturing?
- Infrastructure? Outsourcing of suppliers (tools, cmpts), services, subassembly & other subcontactors, workforce
- Are these external elements locally available? Where are they based? Does it matter if they are not?
- Other? (intangible, cultural, etc)

The most pressing infrastructure issue short-term issue is cleanroom space. We grew out of Cambridge University and lease space at Greenwich House on Madingley road. We have grown to a size where we have to start planning for further expansion. There are no problems recruiting people.

We do subcontract some or our activities. We have our mask sets made externally and some of our substrate patterning is done by Qudos in Oxford. We also work with a number of UK universities.

Forecasts: What are your management/the analysts forecasts for your market in 1,3,5 years?

The lighting industry is worth $40 billion. The technology CDT has is forecast to take strong market share within ten years, with its OLED chips that glow when current passes through them. CDTs direct markets for OLEDs in phones, notebooks, toys, PDAs, cars, cameras, TVs, etc, are forecast to be worth $2.5 billion by 2007.

The longer-term objective is to enter mainstream flat panel graphics display markets, currently valued at over $30 billion (2005).

Location: Why are you based in the East of England? exactly where you are?

Our Cambridge location is historical.

Are you are part of a geographical and sectoral "subcluster" of companies/institutions?

Discussions are underway on setting up a regional cluster focussed on inkjet printing.

CDT, Linx, Domino, Xaar, and others are involved. (Inca Digital, Xennia, Videojet, Epson-Seiko, TTP are also in the sector and in the region).

In addition, we are aware that the EEDA wants to develop a National Microsystems Centre in the area that would include factory and cleanroom space and employ approximately 2000 staff. EEDA came and visited us about this. We would be interested this, either leasing clean room space or paying for specialised analytical services.

Xaar PLC: Interview[8] with Steve Temple (Xaar Technical Director)

Sector and activities: What does your company:

- research?
- develop?
- make, as prototype?
- make, more than single or a few units of?

We make inkjet printheads. We research into the next generation of this product. Basically, the object is to improve digital printers. So we do research, development, small scale and somewhat higher volume manufacture. We do this not only as general but also as individual products. We make as prototype in Cambridge, and then lots of units in Sweden: we make average above 100000 a year selling in a range up to GBP£2000 a unit. The same product sells at different prices depending on quantity and history. Across products, the smallest is 64 channels, now a dying breed. The biggest volume is in 128 channels. The revenue gap with the next generation is closing. The 128-channel still dominates. We are introducing the Leopard – made by one of our licensees. It takes 2 years to integrate to new printers – so quantities will be small for a couple of years.

There is cross-hiring going on. There is a link to organic chips that I can't detail here. We are taking standard products and adapting them. That will change to specific prods being made. Requirements are so different from paper. It is driven by market being paper printing (textiles), not electronic or biotech materials yet. There is no incentive to dive into this yet. It is a doubly risky market. You take risk on your partners. We frequently see requirements from all sorts of applications. Individual development would require a lot of work and forces you to judge someone else's business. For example, for printing polyester instead of vinyl. We can handle different materials and we know the print environment.

Xaar is a leading developer and provider of innovative piezo inkjet technology. Xaar is a specialist manufacturer of highest quality digital printheads, inks and peripheral equipment.

Brief History of Xaar

The founders have a broad background. A group of 4 ex-CCL people and 2 from the US. Core Xaar IPR was invented in 1987. There is also longer history of inkjet. The Xaar IPR was developed under a US company that withdrew. Bob Hook bought the technology rights. He set up Xaar. He was MD and Chairman, and developed a strategy and structure for the company. This was before the success of ARM. He had licensing ideas. The targets were Japan and Epson, and others. We didn't have access to Canon technology. But we succeeded. "Brother" was the first licensee, an electronics company in Japan. We then built on the licensing strategy. At that time, Graham Wiley was MD. We continued the licensing strategy until 92-93. We wanted to form a manufacturing branch. In 1993, IBM Sweden licensed from us. They have a printer plant in Stockholm. They bought a Xaar

[8] This interview has in it technical as well as business model information.

licence as a kickstart. Then they proceeded to spin out. IBM Sweden transferred to another company, and then carried on on its own. In 1996-97 Xaar had 5 or 6 licensees, and set up its own manufacturing. Then it IPOed in 1997. This provided funds for facilities on the science park for making print heads. It didn't go well at first. There were problems converting from R&D to manufacture. In 1999 the Swedish licensee got into trouble. Its owner went bust. The spin off was bought back by Xaar. That is what is now the plant in Sweden, inherited from IBM, at less than the original price. But it is thriving now. At the time it was a difficult decision. The firm had had a chequered history, with 3 owners, and problems with customers. There were 2 customers worth 80% of the firm's business, and doing business in Sweden was tough. All this made it hard. In the end, it was the only way to demonstrate confidence in our technology. Xaar was giving up. But the Swedish manufacturing plant had the potential to be the answer to Graham Wiley's objections. In the end it was successful. Now, all manufacturing was transferred to Sweden, and Cambridge did the R&D.

We also have done interesting things recently. We have 7-8 Japanese licensees. We did a deal with one, and one other to act as agents to sell their printheads. "Leopard" was built by one of the licensees. If we know the licensee is making something close to our product, we would work with them to produce a version for the end user. We are doing it on our own behalf, but customised for a particular application. We would certainly go directly to licensees. This is potentially a fascinating way of doing business, extending the licences with our manufacturing base. The idea was cooked up by our sales director.

Strategic Options

We are thinking through the strategy. You can take two opposing views.

1. We remain a licensing company
2. We extend the manufacturing base.

For example, we have expertise in industrial print head and the licensee's is not suitable. We interface. We customise their head for us, based on our expertise selling into this market. They also sell into independent markets. If we did run off, then they can revert to a royalty model. Up to a certain volume we handle as their agents. If high volume, then we pass back to licensee and get commissions, which are smaller on higher volumes. The danger will be that the licensee competed with each other and us. This would upset balances. But we are aiming at different sectors with different products so there is no real danger. If two licensees made an identical product, then if we handled both, we would refuse to enter into agreement with the second. It doesn't make this problem go away as we are still left with a competing product.

Business analysis: In a nutshell, what is your business model?

Our primary business model is manufacturing. We moved away from licensing to mixed licensing and manufacturing. The bit that can grow is the manufacturing part. We amalgamate the two businesses by working with licensees. We are supplying component manufacturing to OEMs. Then they make the print engine, they sell that to the printers. All supply the consumable ink.

How do you describe your market and supply chain qualitatively? Where do you fit in? How much

consulting and servicing vs selling of product?

“Because Xaar is a technology company, we have the expertise to marry with your business objectives to create bespoke digital inkjet solutions.”

We swap royalty for commissions. This is extended to the group of licencee representatives.

Our consulting is small compared to selling of products. We work with application product manufacturers. When someone conceives of a new application, we sit with him or her and once we’ve or they have chosen the engine, we then get the printhead chosen. Speed increases the price. Then we sell a development kit, together with electronic supplies and 1-2 personyears work on application support and to develop their product. We hope this will be a success. Then the volume of sales of that application into that market should increase. Then they sell units.

Contractors that work for us on printheads are Welwyn Electronics. They used to be here, now in Northumberland. Could have been one of a dozen. They do raw materials and electronic components, and mouldings. All expected in such an electronics package. There are not 100s of choices, a few are selected and they are usually big. We get chips from NEC, Japan.

For ink: we have 30 ink suppliers. A lot of the time they sell through us on a commission basis. The key thing is to offer warranties. If customers use rogue ink, we withdraw. We have two ink licences that use Xaar patents. To make a formulation from us you need both licensee and supplier agreements. One is British, the other Japanese. 3rd party suppliers of ink are global: 2 in the UK, 1 in the US 1 from Japan.

The main driver is whom the printers already work with. They like to get ink from a common source. That is nice as it splits up the market a bit. There are 100s of different sectors in printing. Many groups turn to particular suppliers. They turn to expertise in a particular sector. They want to go to same ink suppliers and get the same ink from them.

No one is doing both (ink and printers?). They all want a position in the market. A lot of revenues are ongoing. In office printing, the revenues are 5:1 consumables:printers so you can buy printers at less than cost. This model for office printing is not the model in the industrial printing world. You get ink from Joe Bloggs. The printer equipment maker needs to take profit from the machine. In the inkjet market it is hybrid. But you take some slice out of supply chain. It will be 10-15% rather than 500%. The price of ink in the office market is $1000/litre. Ink prices in the industrial world are $100 a litre. They sell by the tonne not the litre. We sell 50 tonnes every 6 months.

What are your relative strengths and weaknesses?

Our main strength is the technical base: our patent portfolio. No one has succeeded to get round it. Now manufacture has become a strength. (I’m not sure what I was trying to say here!).

We combine technology and manufacture. This is unusual, and not like ARM. We are vulnerable to better technology. If you have a big installed base, then you are stronger. It is a process of building. Early on, in a new market, whoever gets it right will take the market.

What are the external opportunities and threats?

There are two obvious threats from other printhead manufacturers, one a major US firm, and then Epson. There is a longer-term threat from display technology. I don't think that will ever happen. We might be in there printing the displays.

Electronic printing is an opportunity. Digital printing and textile market are too. Both want to shove acids through our heads: technical problems have not been overcome yet. The market is yet untapped: some have been done, but by transfer printing, where you iron on like t-shirts.

Does your technology, product or business model change the supply chain's structure at all? (cf digital cameras, DVD, Amazon electronics commerce, etc)

We grafted onto an existing supply chain. This is the key for textiles. Get into bed with textiles ink manufacturers. We are exploiting it rather than disrupting.

There is a slightly different model though. Any form of digital printing will be closely integrated within the current supply chain. It is a statement of immaturity. No one working on the machinery for paper has any rights to technology. The business is free for all in terms and supply. Digital printing is not settled yet. In 50 years, there may not be a relationship between printhead manu and ink supplier. Next 20-30yrs. Not new suppliers, not new way of doing.

Company manufacturing capability: How many units can you make a week now?

We make about 8,000 a month. There is a mixture of sizes and values.

Demand: How many units are there in your market now, a year?

No one can answer this. We are one of the major manufacturers here. We exclude the office market run by Canon, HP, Xerox and Epson. In the industrial market, Xaar is one of the major suppliers. There is a new market for this type of printing which is huge.

We look at the market for print, the final value of printed material, simply as a way of estimating value to us. Printers are related to productivity. The potential number of print heads is a "telephone book" number. It doesn't tell you what sectors will go digital. We are doing detailed market research now, and are taking this serious these days. Xaar will be a large company if it gets a dominant share.

Supply: What is needed in the region to support manufacture to this level?

- Capital/investors persuaded?
- Expertise in manufacturing?
- Infrastructure? Outsourcing of suppliers (tools, cmpts), services, subassembly & other subcontractors,

workforce

- Are these external elements locally available? Where are they based? Does it matter if they are not?
- Other? (intangible, cultural, etc)

Since IPO we have not needed more capital. We have £10m in the bank.

At the moment, financing is not an issue. When we bought the Swedish company, we did a good deal on capital equipment. We bought capital equipment for $5m, worth $30m on the open market. If we had gone it alone then capital would have been a serious issue. People are not keen to buy into new manufacturing ventures. Initially, we began as a licensing business.

For us, we just need to top it up to extend to capacity at modest rates of expenditure, and replace kit; neither of these costs are massive amounts, so we have a happy position. IBM helped. IBM bequeathed us its subsidiary. It gave capital to set up manufacturing.

Manufacturing is critical and not very available in this area. All expert people have come from outside Cambridge area. There are 100 in Stockholm. Where we have topped up, we have not recruited locally.

Infrastructure is not an issue. It is easier to get line workers than management operations guys. But none are a big limitation.

We can't easily get manufacturing operations expertise here because the cultural ambience in the Cambridge subregion is about R&D,

If we look at Peterborough, or go to a 50-mile radius then would find quite a few. In a 20 mile radius there is nothing. Only the PCBs manufacturers we use are in east of England.

Forecasts: What are your management/the analysts forecasts for your market in 1,3,5 years?

If you read the analysts forecasts, you wont find very specific market information. Digital printing is a new market. We are having to go and commission specific studies. And it is highly segmented. We are buying this at the moment. We went to a market expert and spent good money on the reports.

Location: Why are you based

- in the East of England?
- exactly where you are?

We are here for the same reasons as rest of inkjet cluster. CCL and the Cambridge Science Park have been important.

Are you are part of a geographical and sectoral "subcluster" of companies/institutions?

There are perhaps five companies: Domino, Linx, Willett, (3 continuous inkjet companies) (Videojet discontinued here), Inca (associated with Xaar, also from CCL, and acting as integrators for us)..

We supply (printheads) to Domino and Inca, and Willett. See all as potential buyers of our technology. Those that have continuous inkjet printing are not old hat –it's a different market. They are not competitors.

If yes, who are the other regional companies in the region doing something related to what you do, or who are involved in the supply chain in any direction from you?

Where else in the UK do you have buyers, suppliers, competitors (esp. manufacturers)?

We buy globally, and in UK like Inca Digital. There are 3 or 4 different suppliers. They are the same ilk as Inca.

Suppliers: Welwyn Electronics as a contractor. They have no competitors in the UK. Then they come from US and Japan.

What are the relative strengths and weaknesses of this subcluster vs others (please name them)?

I am not aware of another cluster.

How important is it to your research and development base, that manufacturing of products based on this research and development happen nearby?

I can say that we need a better understanding of manufacturing as well as an R&D base. This lack of skill locally is a serious problem. You can't go to someone and ask what is the best way to make this. So I am likely to make something weird. This is a serious problem.

Leadership: Does this regional subcluster or your company "lead" others or the world?

Others are Canon, HP and Epson. They dominate the office market. The Cambridge subcluster is industrial, not office. Some of our licensees have ambitions in this area, like Brother. The regional subcluster does lead the world on industrial and commercial inkjet printing.

It is a sector thing. Another sector is the utility company-billing sector. They print at a rate of 100ft a minute. Scitex dominates that market: an Israeli company with US technology. They print more area of print than the whole of the Cambridge subcluster. But they cover just 0.01% of the area, we cover 30%.

As a group, in this particular sector, we are definitely the leader.

Appendix C: Questions A-Z: themes and topics evolved from project

a. How can we build bigger businesses in the region?
b. How important is it, that high value manufacturing happens in or near to the region, to the long-term development of the research base?
c. How do we encourage corporate investment in manufacturing?
d. In what stages of the value-chain and under what stages of market maturity and competition is the region competitive or leading
    i. How good are Regional/Cambridge companies at selling and connecting with the market?
e. Where is there still lack of information flow across the region?
    i. On manufacturing principles and skills generally
    ii. Between companies that could be working together
    iii. In the use of marketing by manufacturing companies
f. What are the perceptions of companies outside the so-called "Cambridge Phenomenon" from within? And vice-versa?
g. How indifferent are companies to subcontractor/partner location? How does this relate to the product/component complexity?
h. When should a local company adopt local manufacture of my products (and the corollary, when should I be prepared to go offshore?)
i. How can we improve connections between sophisticated manufacturing plants in the East and R&D companies in the region?
j. How can we create clusters of suppliers to improve our competitiveness?
k. How valuable is the IPR only model today?
l. Where do we have disruptive technology and what are we doing to execute that disruptiveness in the market?
m. What kinds of manufacturing processing and supply chain management do the licensing companies engage in?
n. How can companies facilitate manufacturing technology?
o. What aspects of biotech manufacturing viability are different from ICT?
p. Where are the strengths in the region in the life sciences sector?
q. How can the East of England build bigger businesses?
r. Where does the manufacturing ability in the region support and not support the needs of the R & D teams producing deep tech?
    i. What is needed to support manufacture generally?
    ii. What research and teaching is required to encourage manufacture?
s. What practical, specific actions must be taken at the level of infrastructure, to encourage value manufacturing in the areas we have seen to be competitive for the region?
t. How can we encourage manufacturing companies to think about achieving Marshall's levels and higher levels of employment?
u. What can private manufacturing companies be doing to encourage younger people to engage and become interested in tech manufacturing?
v. What can be done to ensure the best message about the region is being transmitted to London, the UK and beyond?
w. What infrastructure is needed?
x. What government tax incentives can be offered to encourage manufacture?
y. How can we make the process of manufacturing exothermic? (instead of constantly needing to be fuelled)
z. Review:
    1. How can distinct market towns/regions in the East of England connect better to build more value in the region?
    2. How and under what conditions can higher-cost regions compete in tech manufacturing?

Appendix D: Databases used & references

Cambridge County Council (1631 rows); Suffolk, Norfolk, Bedfordshire (full Business Link county database of regional company data); Hertfordshire and Essex (Business Link or Database contractor on their behalf supplied selection of high tech manufacturing companies only); Applegate, Dun & Bradstreet and County Web (Free company databases); ONS, DTI, WEF data.

Sample work made available by industrial research fellows Vanessa McNiven and Derek Ford at the Institute for Manufacture in Cambridge.

The Economist and Business Week, web archives and print editions.

The Internet.

But the bulk of the data was taken from in-depth interviews with 15 R&D and manufacturing executive directors in the region, and 10-15 informal conversations with other business leaders. We are grateful to all who spared their time to take part.

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