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NESTA Making Innovation Flourish

Chips with everything

Lessons for effective government support for clusters from the South West semiconductor industry

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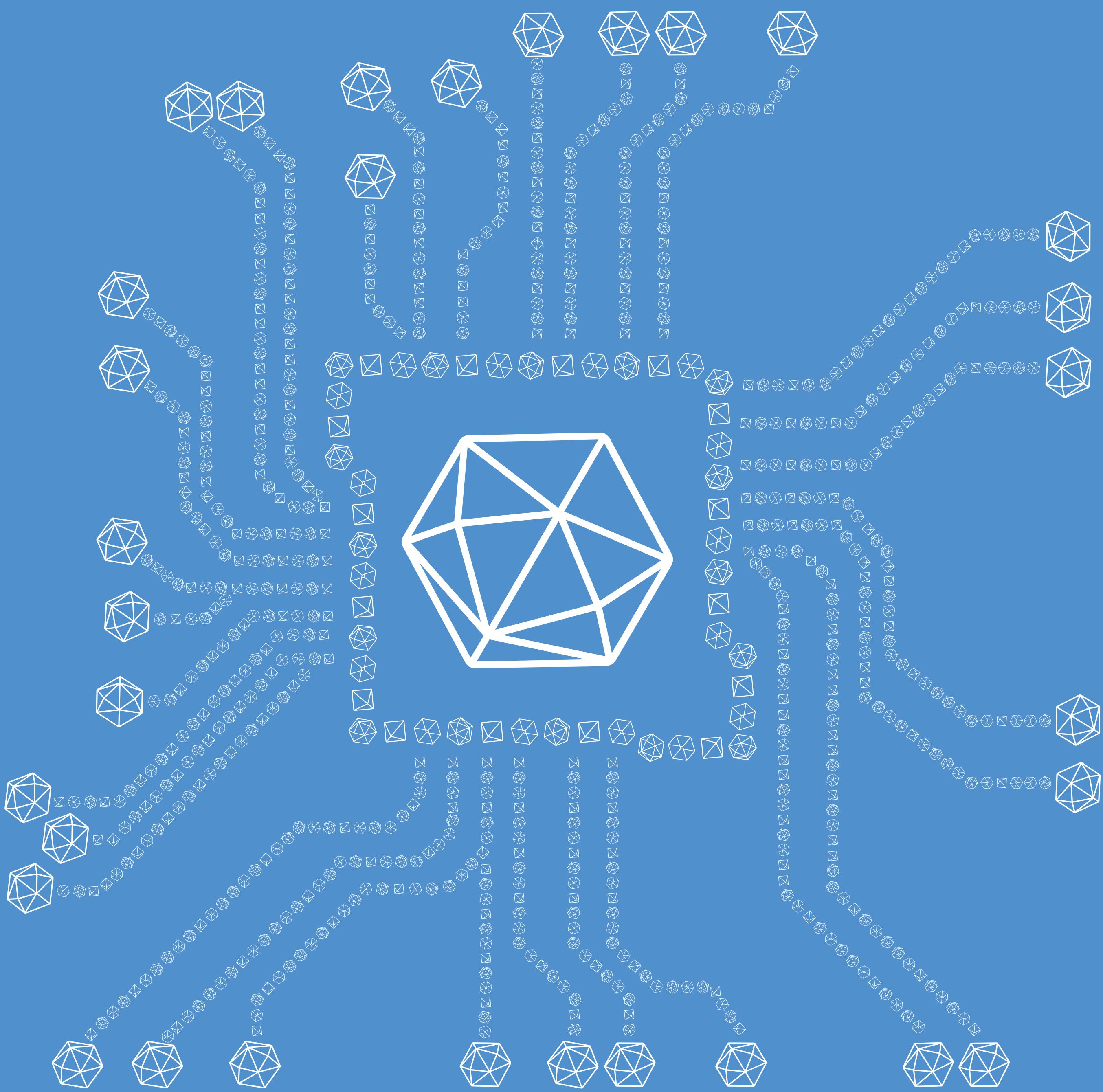

Executive summary

Modern life pulses to the rhythm set by semiconductors. They are in a staggering array of products, from mobile phones and laptops, to traffic lights and trainers. Their ubiquitous nature makes them big business.

The UK has a vibrant semiconductor industry. UK companies compete in global semiconductor markets by combining technological innovation with business model innovation. In doing so, these companies make an important contribution towards the UK's economic success, with the UK semiconductor market worth $6 billion in 2009 – third in Europe, behind France and Germany. Equally the industry has an important impact at the regional level, and the South West semiconductor cluster is one of the largest silicon design clusters in the world.

NESTA's 'Rebalancing Act' highlights how the continuing success of innovative companies will be important to the UK economy. A starting point for government in considering how to support innovative, high-tech companies and regional clusters is to understand the challenges facing these industries. This report examines the semiconductor industry in the UK, particularly in the South West, to identify how this cluster has grown over the past 30 years and how government, with very limited resources, can effectively support regional clusters.

The South West cluster has grown because of a combination of factors. Large semiconductor companies present in the region in the 1970s and 1980s, such as Inmos and Plessey, have endowed the region with a highly skilled workforce and contributed to attracting entrepreneurs, companies and investors to the region. This has been supplemented by intelligent, targeted support from local universities.

Many challenges facing the semiconductor industry reflect problems common to many industries: difficulties in recruiting good quality graduates (currently only one in five electrical engineering post-graduates are from the UK), adequate access to finance for start-ups and creating incentives for growing large companies in the UK. The industry is not waiting on government to deliver all the answers, and has created a number of skills and research initiatives through bodies such as Silicon South West and the National Microelectronics Institute, as well as establishing the European Micro-Electronics Academy to try to reduce costs for start-ups and inspire new entrepreneurs.

But there are some issues which fall to government to resolve. Government has signalled its intentions to address start-up and growth barriers through reviews on access to finance and taxation of Intellectual Property. With the university system in flux, the industry is keen to see how government seeks to improve the quality of graduates.

Finally, with government considering how to help existing regional clusters, it is worth drawing out two important lessons from the emergence of the South West semiconductor cluster. Both are relatively low cost and seek to work with private sector networks, rather than replacing them with public sector delivery agents.

- First, investment in networks, whether university or private sector-led, can help grow clusters by introducing customers and suppliers, providing mentoring and sharing resources.

- Second, incubation models, embodied by the SETsquared partnership in the South West, can work to promote growth of new companies in these regions and highlights how universities can effectively pool their resources to support these companies.

The ongoing success of these interventions is dependent on sustaining the small base funding that supports such networks and incubators, separate from research or company funding. It provides early-stage funding from which private sector funds can be leveraged. This approach will not be suitable to all industries or regions but offers an example of how a blended approach can help private sector investment in innovation and consequently contribute to economic growth in the region.

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Part 1: Introduction

Semiconductors are an invisible part of the fabric of modern life

Semiconductors are ubiquitous in modern life, encountered in a huge array of products: from the alarm clock, to the fridge, the family car (a recent model will have 50 processors), the traffic lights on the way to work – and of course, every computer and mobile phone. Their presence in the very fabric of modern life has only come about due to remarkable advances in science, technology, software and manufacturing.

The semiconductor industry has been intimately connected to the story of technological progress over the past half a century. The early years of the industry in California are credited with the birth of Silicon Valley,[1] and saw the first venture capital investments.[2] In the past couple of decades, virtually every aspect of technological progress – including the spread of personal computers, the internet, digital cameras and mobile phones – has been driven by innovation and competition in the semiconductor industry.

As semiconductors become an essential part of an ever wider range of goods, standard designs in areas like memory chips have emerged to serve large parts of the market, and this part of the industry behaves somewhat like a commodity industry, with fierce price competition and a focus on process innovation. At the other end of the industry, demanding customers such as smartphone manufacturers drive constant product innovation, and pressure to incorporate the latest technology advances.

Future technological and economic progress also appears to be dependent on improvements in semiconductor technology. The cost of a transistor has fallen, on average, by 35 per cent every year over the past 50 years (when adjusted for inflation).[3] Moore's Law (taken from a statement made by Gordon E. Moore[4] in 1965) states that the number of transistors that can fit into an integrated circuit at minimum cost doubles every two years. This predicts exponential growth for the number of transistors in a circuit, with knock-on implications for the increasing speed and power of those circuits, and decreasing costs. Moore's Law is part prediction, and partly an expected innovation target for the industry to meet.

It has been speculated that the limits of this law will be reached, as the transistors approach atomic levels, but a great deal of research is underway into technologies that would take Moore's Law beyond its current limits. A common way of categorising research in the sector is to divide it into 'More Moore': scaling processes and components to ever smaller levels; and 'More than Moore', focused on integrating existing components in new ways with such areas as human biomedical sensors and photovoltaics. While the end of Moore's law has been pronounced many times, it has remained true for decades, and in a testament to innovation within the industry, with each new obstacle, a new technical solution has been found.

The ubiquity of semiconductors makes them big business

The global market for semiconductors had sales of $226 billion in 2009 with 28-30 per cent growth forecast for 2010.[5] The semiconductor industry is almost unique in its rate of unit

1. William Shockley moved to Mountain View, California in 1956 and founded Shockley Semiconductor Laboratory, whose alumni went on to found Fairchild Semiconductor and Intel.
2. Fairchild Semiconductor is commonly referred to as the first venture-backed start-up, first funded in 1959.
3. Mentor Graphics, adjusted for inflation – presentation to Semicon-West, July 2009. Data from Mentor Graphics, SIA, Woodrow Federal Reserve Bank. Available at: http://www.semiconwest.org/cms/groups/public/documents/web_content/ctr_030755.pdf
4. Gordon E. Moore is the co-founder of Intel Corporation, and was a founding member of Fairchild Semiconductor.
5. Future Horizons forecast, 2010.

What is a semiconductor?

A semiconductor is a material that has an electrical conductivity between that of a conductor and an insulator. What makes them so useful is that the behaviour of the material can be easily manipulated. The pure silicon crystals are 'doped' with impurities. Then by introducing an electric field, a current can flow. Semiconductors can also react to exposure to light, pressure and heat. These properties allow current to flow only under certain conditions, creating the capacity for a switch that acts as a logic gate or for a sensor. Electronic components made from semiconductor materials include transistors, solar cells, many types of diode, including light-emitting diodes (LEDs) and digital and analogue integrated circuits (ICs). Silicon is used to create most semiconductors, and a very high level of chemical purity is required to avoid defects.

In most mass production processes, silicon crystals are grown as cylinders between 100mm and 300mm in diameter, and these are sliced into very thin wafers. Wafers are usually manufactured in areas with very low energy costs, because of the large energy consumption needed to work with molten silicon.[6] Large amounts of pure water are also needed. The wafers are then shipped to semiconductor manufacturers for processing into chips. These do not need to be located close by, because shipping the thin wafers is relatively cheap. They are likely to be located in places with skilled but relatively low cost labour.

growth, shipping almost 50 per cent more transistors and 11 per cent more chips year on year for the last ten years. This compares to 0.1 per cent annual growth for the automotive sector and 9.3 per cent for computers.[7] Underlying this growth trend, the industry is highly cyclical, with boom and bust phases. The top companies in the industry have changed places as the industry has evolved, and new waves of innovation appear. The industry now seems to have entered a more stable phase: Intel has dominated the industry for some years, and creates significantly more value than others in the sector.[8]

The industry is global in nature – the supply chain is vast, spanning many different countries and companies, and manufacturing occurs mainly in South East Asia, with design activities spread across the globe, including the UK. Vertical integration from the raw wafer through to packaged and tested chips, incorporating design, manufacturing and testing was once the norm. A few Integrated Device Manufacturers (IDMs) still exist – Intel still operates as an IDM – but in a highly competitive industry, the advantages and flexibility from breaking this value chain into separate specialist companies has helped to drive improvements, and has changed the nature of the industry.

A landmark event occurred in 1987 when Taiwan Semiconductor Manufacturing Company (TSMC) was spun out of a public research institute to become the world's first semiconductor 'foundry', specialising only in the manufacture of other company's chip designs. This consolidation and relentless focus on improving manufacturing processes proved successful, and opened the way for design-only companies, who could now easily contract the manufacture of their products out to foundries.

This business model is known as a 'fabless' semiconductor company of which Qualcomm is a good example. With a foundry company to take care of the manufacturing, it was possible to set up a semiconductor company that concentrated on design, outsourcing manufacturing and no longer needed to own fabrication plants (fabs) for their chips. The general trend towards disaggregating research and development, as with other industries, can benefit small start-ups. It is cheaper and easier to start a company without the need to manufacture, and small companies are able to supply the innovative ideas that are in demand.

This disaggregation of the value chain into specialist companies has continued. Rapid unit growth and intense competition means that every improvement is valuable, and drives innovation and specialisation in the sector. Some, such as the UK's ARM, specialise only

6. See http://www.solarbuzz.com/Plants.htm
7. Walden Rhines, Mentor Graphics. Available at: http://www.eetimes.com/electronics-news/4088277/Viewpoint-Is-semiconductor-industry-consolidation-inevitable-
8. McKinsey & Company (2007) 'Creating Value in the Semiconductor Industry.' 2007 Working Paper.

in design, licensing IP to other companies who then manufacture chips with the design company collecting royalties. Other new companies, especially in South-East Asia, specialise in testing and packaging the manufactured output from foundries and other plants. Many integrated device manufacturers have become 'fab-lite' by continuing to manufacture some products in-house, while working with partners to produce more specialist or advanced products. In addition, the trend towards open innovation across the technology sector has made firms more receptive to the ideas and expertise offered by smaller companies.

The industry trends toward *specialisation* in the different stages of the process, as they become more complex and expensive, and *consolidation* across each stage, to generate economies of scale that allow continued investment in plant and tools.

UK semiconductor companies innovate to stay ahead of the game

The UK has had a long presence in the semiconductor industry, beginning with defence and electronics companies such as Plessey, and including names such as Inmos, Acorn, Imagination Technologies and Cambridge Silicon Radio.

The UK is a genuine centre of expertise for analogue and mixed signal capabilities, that are needed for radio functionality, including Bluetooth and Wi-fi as well as fibre optic technologies. As the industry evolved, companies in the UK were quick to seize on opportunities offered by foundries, and moved up the value chain to focus on high-value design. UK companies also have a reputation for being better at constructing products that work as part of an integrated system, rather than isolated chip designs, an increasingly important skill.[9]

The UK has a small share of the global semiconductor market (around 2.7 per cent, representing 20 per cent of the European market),[10] but it is the third biggest player in Europe (after Germany and France) creating high value jobs and significant wealth.[11] UK companies have developed good market share in specialist areas, like design, with the largest concentration of semiconductor designers in Europe based in the South West.[12]

In 2009, the UK semiconductor market was worth $6.0 billion USD, the European market $29.9 billion USD and the global market $226.3 billion USD.[13] The UK hosts the operations of more than 500 semiconductor firms, 80 per cent of which are foreign-owned. These employ around 8,000 engineering staff.[14] The firms are concentrated in clusters in Cambridge, the South West, Thames Valley and 'Silicon Glen' in Scotland. The South West has a real international reputation for expertise in design and communication technologies, as well as perhaps the most vibrant start-up community. It also forms part of the wider UK electronics industry worth £23 billion and employing 250,000 people both directly and indirectly.[15]

How can government policy help high-tech semiconductor companies?

NESTA's 'Rebalancing Act' highlighted how future growth could be spurred by high-tech companies, such as semiconductor enterprises.[16] However the role of government in developing high-tech sectors is patchy if not poor. Striking a balance between active investment in certain companies ('picking winners') and promoting the right policy framework for high-tech sectors is a difficult one.

In this report, we examine the growth of the semiconductor industry in the UK, particularly in the South West, to identify how this cluster has grown over the past 30 years and the role of government in fostering this growth. This study on the South West semiconductor cluster examines how the cluster has grown, the challenges it faces and how policy impedes or facilitates the growth of these companies. As part of this project, NESTA interviewed founders and managers of companies at different stages of growth to understand what drove them to establish their companies, locate in the South West and how they have grown and expanded.

9. Reference: NESTA interviews.
10. Future Horizons – semiconductor consumption figure.
11. Department for Business, Innovation and Skills (2009) 'Advanced Manufacturing Strategy.' London: Department for Business, Innovation and Skills.
12. See 'Key Industries' on the South West England Regional Development Agency website. Available at: http://www.southwestengland.co.uk/key_industries/ict.aspx
13. Future Horizons.
14. UKTI Semiconductor Design fact sheet, Aug 2010 http://www.ukti.gov.uk/uktihome/aboutukti/localisation/116366.html
15. NMI Yearbook 2009-10, http://www.nmi.org.uk/assets/files/annual-reports/NMI%20Yearbook%202009-10%201_1.pdf
16. NESTA (2010) 'Rebalancing Act.' London: NESTA.

Part 2: The South West semiconductor cluster

The semiconductor design industry forms an important part of the electronics industry, and the South West is its hub in the UK. The cluster contains around 50 companies and directly employs in the region of 5,000 people.[17] The region around Bristol and Bath is home to one of the biggest silicon design clusters anywhere in the world outside Silicon Valley.[18] It is double the size of its nearest UK competitor, Cambridge. In the last decade, start-ups in the South West have attracted more than $550 million in investment and returned more than $800 million to shareholders. This section explores the birth and growth of the semiconductor industry in the South West.

Historical background

As with all clusters, the foundations of the South West cluster can be traced to a few key decisions and factors, including:

- The decision of Silicon Valley company Fairchild Semiconductor to locate a design office in Bristol in 1972. Ironically, the location was chosen partly because there was no cluster present: Fairchild reasoned that it could retain engineers better by opening offices in locations where there were few similar companies around. One of the original office members would go on to work for Inmos, a government-backed company founded in 1978 which became a critical training ground for many engineers in the area.

- The recognition by councillors in Swindon that, with the railway industry in decline, other industries would be needed in the area, especially those that would employ engineers, as well as having semi-skilled roles to boost female employment. This led to the location of Plessey Semiconductors to Swindon, providing training for engineers in a wide range of semiconductor skills. At the time: "Pressed Steel offered more pay, but apprenticeships at Plessey were reckoned to be better because of the variety of skills that were learned".[19]

- The universities in Bath and Bristol and easy access to Heathrow airport for flights to the United States also contributed to location decisions of semiconductor companies.

These factors led to the location of both Plessey Semiconductors and Inmos in the South West, in Swindon and Bristol respectively. These have been the two most influential companies in the history of the cluster, creating a legacy of skilled people that have remained in the area.

Growth of the cluster

Growth of the cluster since these early pioneer companies can be traced back to the convergence of several factors, including:

- A highly skilled work force with excellent sector expertise: The South West has a wealth of talented, highly skilled electronics engineers. In part, this has been a factor of the rise and fall of the two major players, Plessey and Inmos. Those who moved to the area were frequently reluctant to leave, perhaps reflecting the high quality of life and attractive surroundings of the South West.

17. Silicon South West (2009).
18. See http://www.southwestengland.co.uk/key_industries/ict.aspx
19. See http://www.swindonweb.com/?m=8&s=116&ss=396&c=1327&t=Plessey+is+back...

Plessey, Inmos and the South West

Plessey was a key driving force for electronics in the UK from the earliest days of the industry, originally making radio sets for Marconi, and later supplying the Post Office and defence communications. Its electronics division was formed in 1951, and the first silicon plant in Europe was opened in 1952. Plessey Semiconductors opened its plant in Swindon in 1957 (the same year that Fairchild Semiconductor, the original Silicon Valley company, was started in California). Plessey became the largest employer in Swindon by 1960, replacing jobs lost with the decline of the rail industry. As a large, vertically integrated company, Plessey trained hundreds of engineers, taking in many new graduates and apprentices. It had a small plant in Swindon, and in 1985 opened a leading-edge plant near Plymouth, creating a cluster of skills in silicon design and CMOS manufacturing there.

In 1989, Plessey was acquired by GEC and Siemens, with GEC taking the semiconductor business and Siemens the research centre. The resulting GEC Plessey Semiconductors (GPS) continued the company, but lacked investment, and the plant technology gradually fell behind the rest of the world, where places like Taiwan were making significant investments. Although Plessey did not generate any notable spin-offs of its own, it played a critical role in training a generation of designers and engineers who went on to work for other companies in the South West. After a series of acquisitions, the company was divested and the remnants of the company were re-acquired and re-named Plessey Semiconductors in 2010, and the new company aims to make use of the Plymouth facility again.

Inmos was founded in 1978 by three entrepreneurs from the UK and US and funded with an initial investment of £25 million from the UK government as a national champion for microelectronics through the National Enterprise Board (NEB). The UK company aimed to develop a new generation of microprocessors, which put the memory on the same chip as the processors – dubbed the 'transputer'.

The company was established in Bristol, with additional design expertise in a Colorado office, while a manufacturing plant ('fab') was constructed in Newport in South Wales. The company received a total of £211 million from the government over six years, and was sold in 1984 to Thorn EMI for £192 million, before it had become profitable. While the impact of direct government funding is debatable, Inmos has undoubtedly proved to be a fertile training ground for hundreds of engineers in the cluster, with many former Inmos employees remaining in the South West and sustaining the cluster. Spin-offs and companies founded by Inmos alumni include Meiko, Division, PixelFusion, XMOS and Motion Media Technology. Inmos was eventually absorbed into ST Microelectronics in 1994, with the brand name being discontinued.

- The rise of the semiconductor serial entrepreneur: A virtuous circle has been created by entrepreneurs who have a successful company exit and then start again, often investing their own cash, in new semiconductor companies.

- Financing new start-ups: Successful entrepreneurs attract venture capital, and vice versa. The South West now is a magnet for venture capital funds seeking to find start-ups.

- Broader network support: Private sector-led networks have developed organically and facilitate the exchange of ideas, and act as a focal point of the semiconductor industry. This is reinforced with farsighted local universities, and an innovative approach to incubation of the start-ups.

These factors are explored in more detail in the following section.

A highly skilled work force with excellent sector expertise

The South West now has the dual advantage of a supportive ecosystem and a highly skilled workforce with good semiconductor experience. Critically this provides a ready stream of both semiconductor entrepreneurs and a locally based, well trained workforce for both start-ups and corporations seeking to locate or expand in the region.

This workforce comes partly from the local universities, although many recruit globally. However, just as in Silicon Valley, companies within the area are also important sources of trained employees. In particular Plessey and Inmos are cited as the source of the South West's highly skilled workforce and served to seed the area with sector expertise.

Plessey was attracted to the area, partly by Swindon Town council who were well aware that the railways were in decline and they needed to attract new employers to the area.

For Inmos, easy access to trans-Atlantic flights from Heathrow, in order to visit customers and the company's Colorado Springs research facility, was an important factor. Inmos may also have been attracted in part by the presence of the Fairchild Semiconductor design office in Bristol, which was established in 1972. The Design Manager at Inmos, Peter Cavill, was recruited from Fairchild, where he was one of the founding members of the Bristol office. Other factors in the location may have included the existing industries of the South West: a specialisation in defence companies and research.

New companies starting up in the 1990s and 2000s could draw on engineers who had located into the region to work at both companies. Equally, foreign companies seeking to locate new R&D labs or design centres identify expertise in the area as a key driver of investment decisions. This has undoubtedly been a fundamental factor in the growth of the cluster, as the family tree of semiconductor companies in the South West highlights (see p.12). Other international corporations such as Intel, Dolby and National Semiconductor recognised the growing importance of the South West by locating their sales offices there.

The rise of the semiconductor serial entrepreneur

One of the main residual effects of Inmos, Plessey and other companies is the creation of a new set of entrepreneurs. For example, Hossein Yassaie established Imagination Technologies, a mobile graphics and microprocessor chip company, after initially moving to the area to join Inmos in the late 1970s.

Equally other companies have spurred semiconductor entrepreneurs who have established companies in the cluster. Stan Boland, Peter Claydon and Gary Steele were all attracted to work at companies with no direct links to Inmos and Plessey. With the exception of Simon Knowles, who worked for Inmos and then STM before co-founding Element 14, an independent fabless chip company, with Stan Boland, none of these new companies had direct links to Inmos or Plessey.

Boland, Claydon and Steele are all examples of the South West's serial entrepreneurs, using management expertise gained in their starting companies to found new ones. Each entrepreneur keeps coming back for more, but each is motivated in different ways.

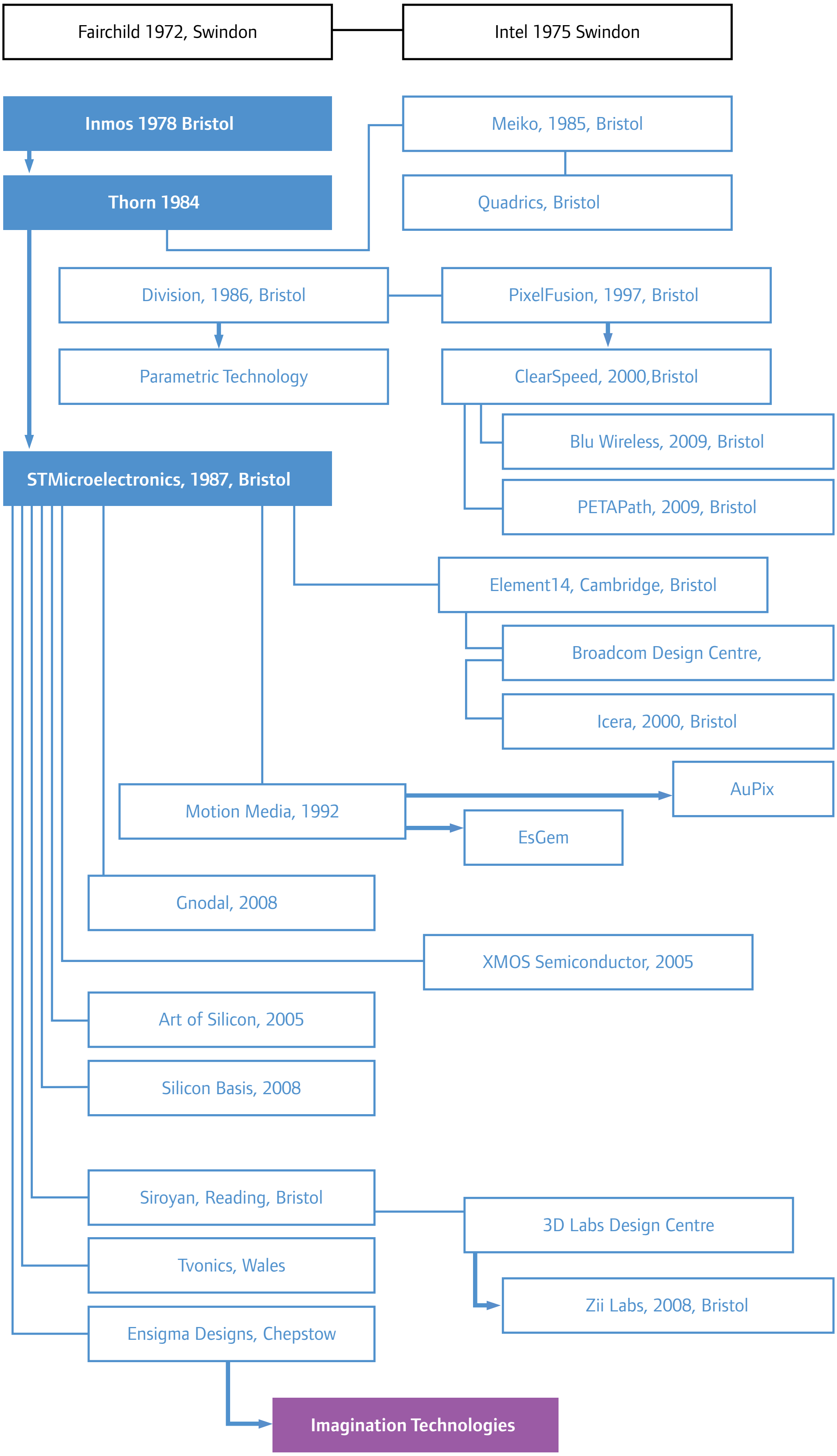
All these founders had many reasons for establishing their companies in the South West. As highlighted above, a highly skilled workforce is a critical factor. Quality of life, well established networks among individuals and companies and the research expertise of nearby universities are cited as other key factors in location decisions.

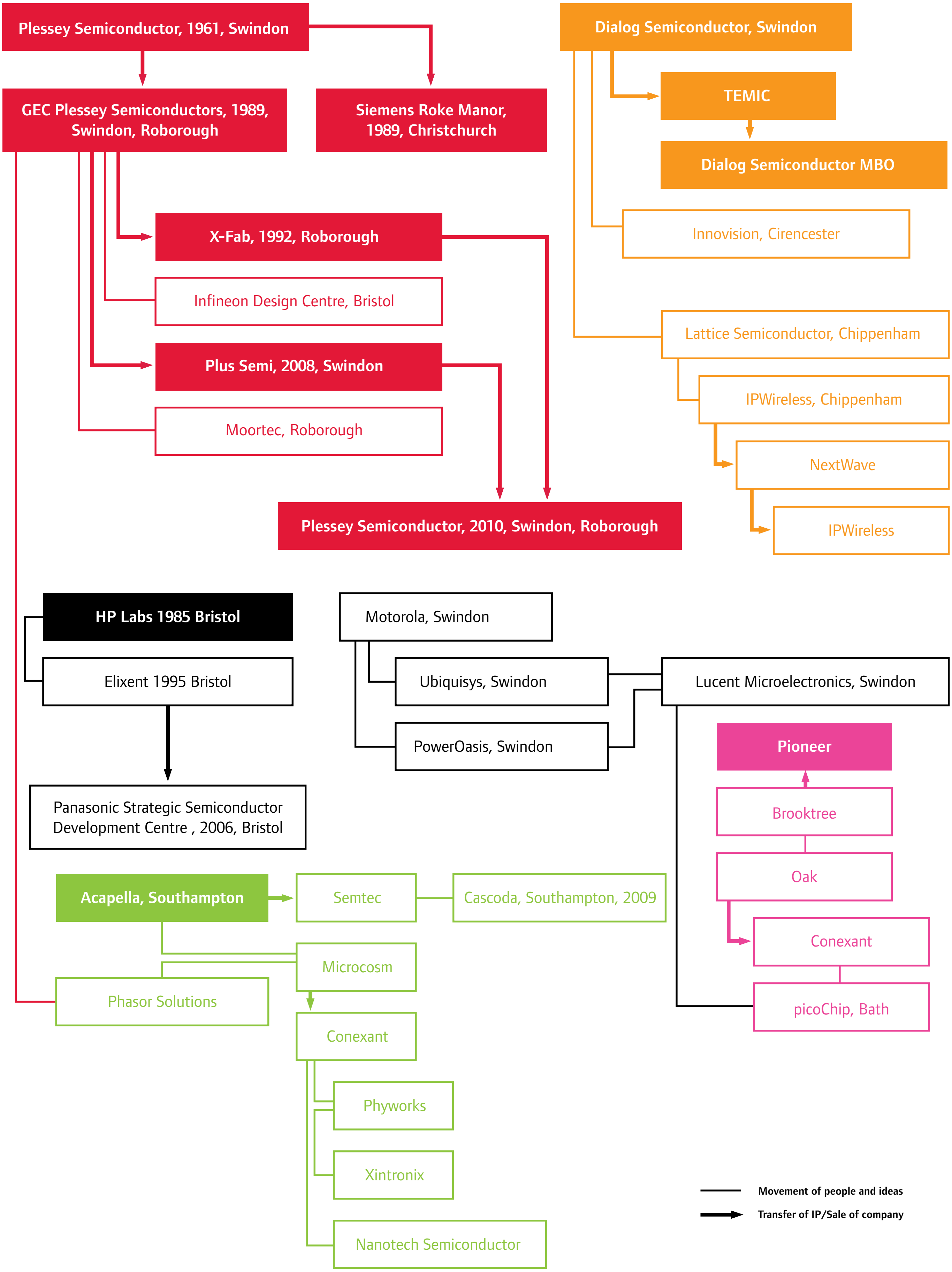
These entrepreneurs, though located in the South West, are focused internationally. That's where their customers are, and that's where growth for their companies will arise; there is no local market for these products. Therefore easy access to international companies, via nearby Bristol and London airports, influences their location decisions.

Where successful entrepreneurs reinvest, there are a number of factors involved. Partly it is a matter of professional pride: proving they can do it again, and that it wasn't just a matter of luck the first time.[20] It is also a matter of opportunity: a successful exit provides many venture capital firms with the confidence that success can be replicated in another technological area. Investing in a proven manager helps to lower their risk, so this gives these serial entrepreneurs a relatively accessible audience for any new ideas they have.

20. Why Peter Claydon set up picoChip: "I don't want money, but I want commercial success because that's how an engineer measures success. I tell the VCs I want money, because that's what they want to hear, but it's not money, it's the success of the company in commercial terms that I want." Source: Electronics Weekly 27 November 2009, http://www.electronicsweekly.com/Articles/2010/06/01/47541/picochip-loses-its-soul.htm

Figure 1: Family tree of semiconductor companies in the South West





Plessey Semiconductor, 1961, Swindon
GEC Plessey Semiconductors, 1989, Swindon, Roborough
Siemens Roke Manor, 1989, Christchurch
X-Fab, 1992, Roborough
Infineon Design Centre, Bristol
Plus Semi, 2008, Swindon
Moortec, Roborough
Plessey Semiconductor, 2010, Swindon, Roborough
Dialog Semiconductor, Swindon
TEMIC
Dialog Semiconductor MBO
Innovision, Cirencester
Lattice Semiconductor, Chippenham
IPWireless, Chippenham
NextWave
IPWireless
HP Labs 1985 Bristol
Elixent 1995 Bristol
Panasonic Strategic Semiconductor Development Centre , 2006, Bristol
Motorola, Swindon
Ubiquisys, Swindon
PowerOasis, Swindon
Lucent Microelectronics, Swindon
Pioneer
Brooktree
Oak
Conexant
picoChip, Bath
Acapella, Southampton
Semtec
Cascoda, Southampton, 2009
Microcosm
Phasor Solutions
Conexant
Phyworks
Xintronix
Nanotech Semiconductor
Movement of people and ideas
Transfer of IP/Sale of company

The rise of the South West Serial Entrepreneurs

Serial entrepreneurs have played an important role in the growth of the semiconductor cluster. The experiences of Stan Boland, Peter Claydon and Gary Steele are highlighted below as example entrepreneurs. Obviously, there are many others.

Stan Boland

Stan Boland joined **Acorn** computers in 1997 as Financial Director, having worked at Rolls-Royce and ICL. He became CEO of Acorn, and proceeded to reorganise the company to focus on its chip design technology. With Acorn colleagues including Sophie Wilson and Simon Knowles from STM and Inmos, he created **Element 14** initially as a division of Acorn, and then spun it out. He became CEO and in 1999 they raised £8.1 million in first round funding. Even this amount was a challenge – Stan met with nearly 40 funds, and made 77 presentations to raise this amount. Element 14 was bought by Broadcom at the height of the internet boom in 2000 for $640 million, before the launch of the first product.

Many engineers stayed with Broadcom, but Boland, along with Simon Knowles, who had co-founded Element 14, Steve Allpress and Nigel Toon went on to found **Icera** in 2002 with the aim of developing a new generation of chipsets for mobile broadband cellular communications. They shipped their first products in 2007, and have also raised around $250 million in investment. They bought Canadian company Sirific Wireless in 2008 and are reported to be considering floating on the London Stock Exchange. Nigel Toon left to become CEO of Picochip in 2008.

Peter Claydon

Peter Claydon worked at the Bristol design centre of Silicon Valley chip designer, Brooktree, which was sold to Pioneer in 1992. The Pioneer Digital Design centre closed in 1997 and Peter become general manager at the broadband business unit at Oak Technology, another Silicon Valley company with an office in Bristol. The Oak business unit was bought out in 2000, and Peter Claydon stayed on until the unit was wound up. In 2000, he founded **picoChip** with Doug Pulley, who had also worked at Oak and then Conexant. The aim was to put together a massively parallel programmable multicore device for digital signal processing.

Early conversations with venture capital company Pond Venture Partners helped to narrow down the target market to wireless and femtocell products, and they invested to generate funding of $7 million with the founders. When the first devices launched in 2003, an additional $17 million was raised from existing and new investors. The firm now has a total of $112 million in venture funding, and major clients for its femtocell technology. He is now with Chippenham-based wireless company Deltenna having left picoChip late last year.

Gary Steele

Gary Steele is a graduate of the University of Southampton who has been especially successful as a serial entrepreneur. He founded **Acapella** in 1990, the UK's first fabless chip company, which was sold to U.S. company Semtech in 1995. He then co-founded **Microcosm**, raising two rounds of venture capital, before selling in 2000 to Conexant Systems, the same company who acquired Oak Technology's Bristol design centre.

In 2003, Gary Steele moved on to found another new venture, **Nanotech Semiconductor**, with several former Microcosm employees. The company designs and supplies integrated circuits for the fibre optic communications industry. The company has so far attracted $11 million in funding, and was able to acquire an experienced design team when Intel sold off its fibre optic business.

He was also involved in the early days of **picoChip** and the creation of **PhyWorks** in 2001, and successfully raised further venture capital investment in 2003. PhyWorks was ranked the 5th fastest growing technology company in the UK in 2009, and was sold in September 2010 to NASDAQ-listed Maxim Integrated Products.

Financing new start-ups

Venture capital firms are often eager to back managers and technology experts who have already proved themselves with a successful venture, as highlighted above. This can lead to patterns of investment, where the same funds will invest in a series of ventures that have the same founders.

Stan Boland and Simon Knowles had offers from many VCs after they sold Element 14, for consulting and due diligence work as well as for funding. This gave them a receptive audience when they needed funding for Icera.

Amadeus Partners' Hermann Hauser put money into Element 14, and then followed up by funding Icera, so he recognised the importance of backing successful entrepreneurs. Similarly, Pond Ventures were one of the early backers of Microcosm, and subsequently led the first round of funding for Gary Steele's Nanotech Semiconductor.

There are a number of mechanisms through which government provides support to early-stage technology companies. R&D tax credits seem to be widely used in the sector, and professional bodies offer training sessions on them, along with ways to access other R&D funding and grants, both national and European. These all play a part in the financing of semiconductor companies but because the sums of money needed in this industry are so large (primarily to fund early research), the majority of company funding has generally come from venture capital sources.

Another way to support start-up financing is to provide access to resources for free or at low cost, reducing the amount of money that they need to raise. Mentor Graphics has been a supporter of this model, offering its design tools at low cost, as an investment in the future custom of these companies. Universities also have a role to play in giving start-ups access to their equipment and resources.

Broader network support

A group of far-sighted universities, specifically Bristol, Bath, Southampton and Surrey,[21] have worked hard to create networks which bring together companies and academics. From the start, the universities have sought to collaborate with each other and more importantly with local companies. Key activities have been led by the universities who have worked hard to cultivate links with companies. The focus has been on establishing common ground, rather than securing contracts or income. In this way, government funding is used to work with the grain of private sector activity rather than creating an alternative provider of services. This is illustrated by examining the links between companies and local universities (see Figure 2).

The presence of research expertise at local universities has helped to anchor some of these companies in the area. Professor Joe McGeehan joined the University of Bath in 1985, bringing his communications research expertise and links with industry; he is also Managing Director for Toshiba Research Europe. Professor David May was architect of the transputer at Inmos, and was appointed by the University of Bristol in 1995. He connects the university with industry very effectively, influencing the development of Bristol's Computer Science course towards more practical work, as well as providing feedback to investors on a range of companies over the years,[22] and starting XMOS to continue the transputer legacy.

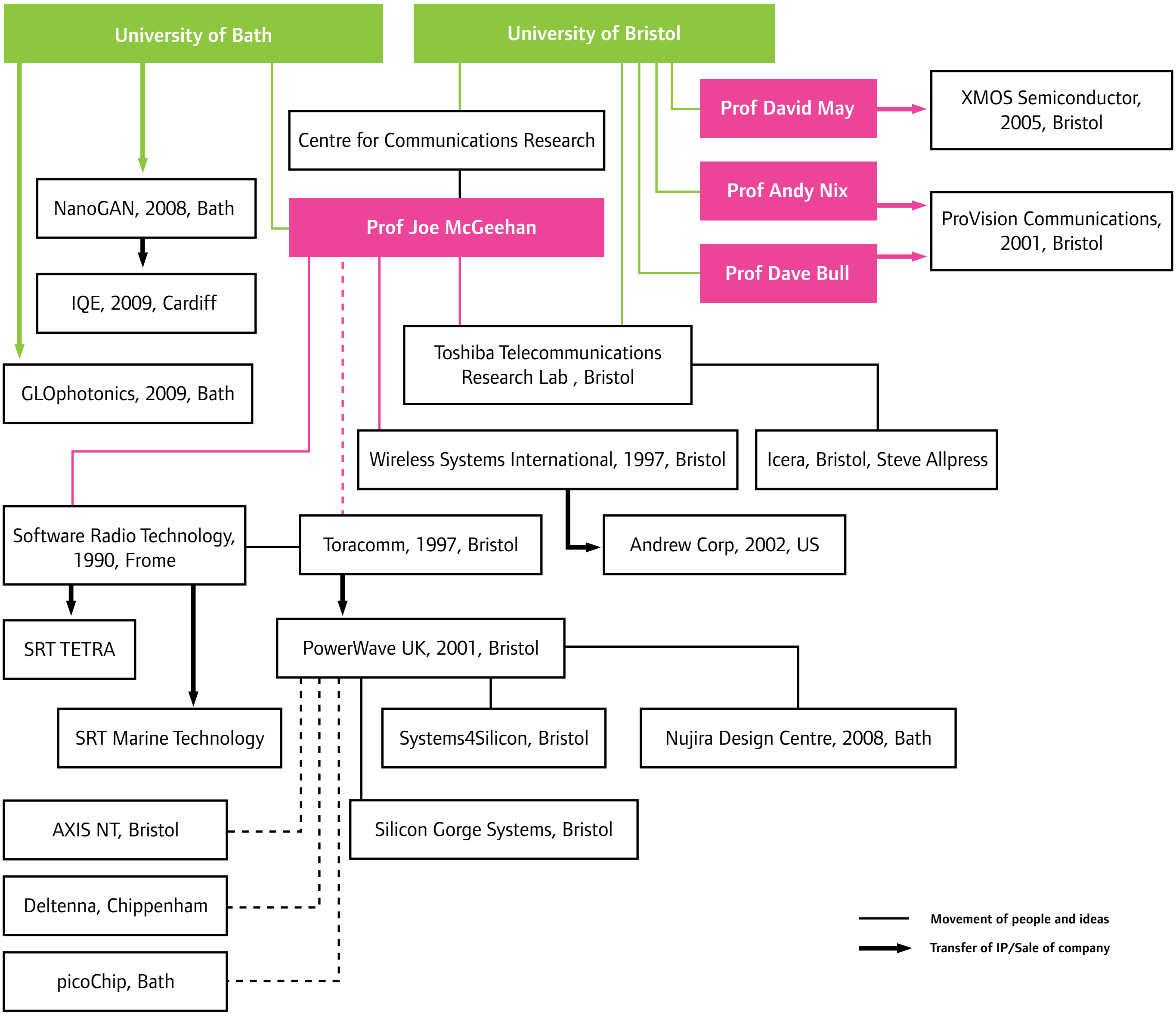
These universities are very outward-facing. Silicon South West was established by Bath Ventures, the technology transfer unit of Bath University. Working with private sector partners, Silicon South West organises networking events, conferences and industry and technology updates for semiconductor companies in the region. They have also created a test lab in Bath to allow early-stage companies to access expensive testing equipment at low cost, that would otherwise require a significant capital outlay. Government funding for Silicon South West is relatively small, in the form of occasional sponsorship from SWRDA and UKTI, and support for overheads via the University of Bath incubator programme. Staff have leveraged private sector funding through sponsorship and partnerships from semiconductor and associated companies. This effectively seeds private sector-led activity and facilitates an open network of entrepreneurs, companies, investors and university researchers.

The SETsquared partnership

Another key publicly backed investment has been in the SETsquared partnership. SETsquared is unusual as a collaboration

21. Funding sources include the Higher Education Innovation Fund, distributed by HEFCE, and the local RDA, the South West of England Regional Development Agency.
22. Reference: NESTA interviews.

Figure 2: Connections between companies and the universities of Bristol and Bath



between the universities of Bath, Bristol, Southampton and Surrey, where incubators from all four universities have been developed under the same programme, integrating their enterprise activities. It develops partnerships in enterprise activities and collectively supports the growth and success of new business opportunities through spin-outs, licensing and incubation. The incubation element enables companies to keep initial costs down and build a strong business case. It also works with industry through research collaboration and consultancy. They provide services, and a focus for service-provision companies such as IP lawyers and accountants. This is not specific to semiconductors. However, as microelectronics is a local industry, they support a number of such companies in this area, and their mentor network is biased towards the industry.

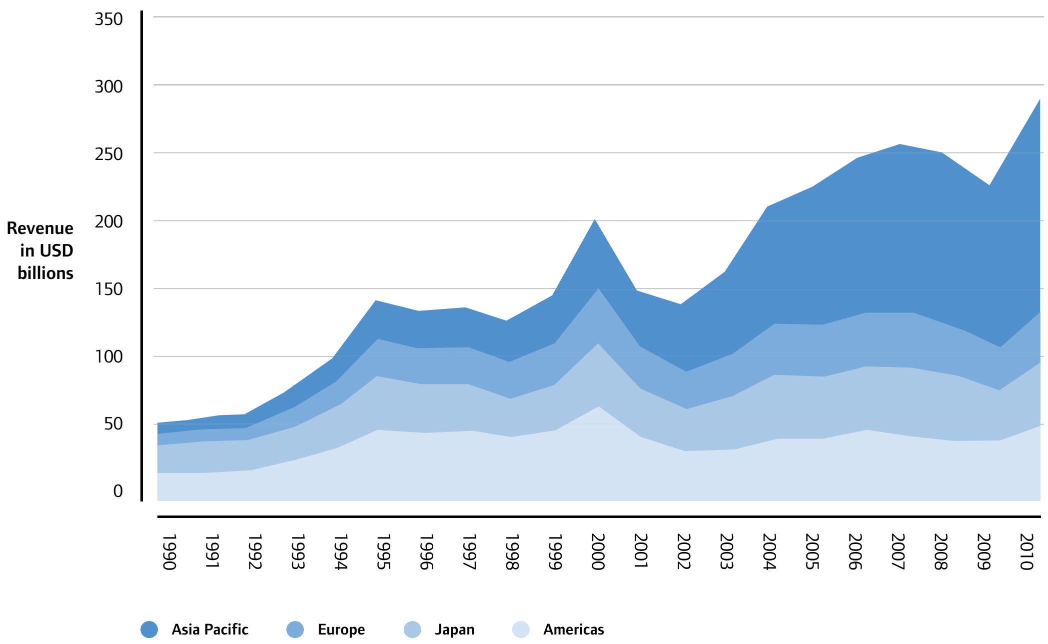
The partnership has incubated XMOS, a venture capital-backed company established by Professor David May, from the University of Bristol and a core member of the Inmos transputer team, and James Foster, former CEO of Oxford Semiconductor. It is currently housing and helping some promising companies, and more recently nurtured Gnodal, a company developing innovative networking technology to improve the performance of next generation data centres. Another graduate of SETsquared is Ubiquisys, a globally-recognised femtocell company based in Swindon with backing from leading venture capital firms Accel Partners, Atlas Ventures and Advent Venture Partners.

Part 3: Challenges for the semiconductor industry

Despite its exposure to economic cycles and fluctuating consumer demand, the semiconductor industry continues to show strong underlying growth and this was seen through the recent recession with demand for semiconductors holding throughout the industry (Figure 3). UK companies, particularly those firms at the design end of the process, appear to have been less affected by the recession than other parts of industry. As innovation continues to drive the industry forward, the services they provide remain in demand.

The success of UK companies and the South West cluster should not be taken for granted. The ability of firms to innovate is influenced by the business and policy environment in the UK. The current business environment is obviously very challenging, but there are some specific policy areas that are throwing up challenges for the industry. Some of the challenges faced are industry specific, but most go wider and are similar to those that often arise in conversations with UK entrepreneurs and corporate executives. These wider challenges are outlined below.

Figure 3: Global semiconductor market by region



Source: OECD data, based on World Semiconductor Trade Statistics (WSTS)

Skills

Recruiting in the UK is becoming challenging as the pool of graduate electronic engineers continues to shrink. These companies also need to be able to access and attract global talent, many of whom are being trained in UK universities.

While UK universities are conducting leading research, and providing courses in microelectronics, large numbers of those taking them are not UK residents, and may not remain in the UK when they graduate. In 2007/08, 68 per cent of electronic and electrical engineering undergraduates and 21 per cent of postgraduates were UK residents. Overall numbers of electronic and electrical engineering graduates have fallen by 25 per cent since 2002/03.[23] Although semiconductor companies often recruit globally, it can be hard to attract people to the UK if they are also able to work in California, South Korea, Taiwan or any other centre of the industry.

23. Higher Education Statistics Agency data.

The shortage of skills reflects not just the pool of current graduates, but also those with industrial experience and business skills. Not everyone in the industry has a degree. A generation of engineers were trained at large companies like Plessey and Inmos, and those are the people who now lead UK companies. Training is costly, and too few companies are able to fund it now, leaving a skills gap. There can also be 'too much' emphasis on engineering skills: leadership, vision, and business skills are also essential. Apprenticeships and funded work placements may be part of the solution.

This shrinking pool of trained people endangers the skills base of the South West cluster, and as the generation of engineers trained at Inmos start to retire, there may be a critical shortage of up-and-coming talent to replace them.

Access to finance

A critical issue for a high-tech cluster is attracting investors to provide financial support for the high-risk, high-cost endeavours that these companies undertake. While start-up activities in a sector such as semiconductors are inherently risky, and expensive to test, many things can be done to mitigate the risks associated with a new venture. The semiconductor industry, unlike some other sectors such as digital media, has a more acute problem in that start-up costs are high, with £3 million+ required simply to get a design implemented in silicon. The Innovation

Innovation in semiconductors

Innovation is critical to success in this industry, with a very competitive market and a demanding customer base. Innovations in process and production lead to lower prices, which make new applications viable, which leads to further product innovation. However, innovation is expensive, because even the design tools needed to create a new chip design are expensive, and a modern manufacturing plant can cost $3 billion or more. This leads to a position where incumbents are best placed to innovate, because the knowledge and resources are cumulative, making it very hard for start-ups to penetrate.

The high costs are a result of:

- Masking costs for patterning the silicon wafers that have risen to around $500,000.
- Complex design tools needed to handle design tasks that make the best use of chip real-estate, whilst operating at nanometre scales.
- A demanding customer base which seeks smaller, more powerful, lower cost and lower power use chips from each generation of technology.
- A complicated, and expensive production process, requiring clean rooms and very high precision manufacture. A semiconductor fabrication plant can cost $3 billion or more.

Investment Fund (IIF) launched last year should support some investment in this area.

Incentives for R&D and manufacturing
Several industry players have argued that the current tax framework does not incentivise companies to invest in R&D and manufacturing, and arguably recent changes to capital allowances further tilts the tax system away from more capital-intensive companies.

While the case for greater incentives for R&D and manufacturing need to be considered as part of the UK Government's review of taxation of Intellectual Property and the support R&D tax credits provide for innovation, this should not ignore other areas where government could play a role in supporting high-tech industries, including semiconductors. Specifically the role of procurement and EU grant funding is considered below.

The best form of financing for a growing company is its order book: securing a large contract from government has been the making of many firms. The Small Business Innovation Research (SBIR) scheme in the United States, established under the Reagan administration, has been very successful at channelling government R&D spending to small companies, and stimulating growth by doing so. The UK has a similar scheme, the Small Business Research Initiative (SBRI). After a slow start, the programme was reformed in 2009, and now seems to be making progress, as highlighted in a recent NESTA report.[24] There are examples of how procurement by international governments has helped semiconductor companies.

Japan provided support for local procurement of semiconductors from the 1960s onwards, to encourage a local industry. Low-cost financing was also made available, as well as co-investment in R&D. Qualcomm, now one of the leading fabless semiconductor companies, benefited from the US Small Business Innovation Research programme in the early days of the company.

As well as funding, such initiatives also provide a motivator for companies to work with partners and construct both local and global supply chains to respond to a public service challenge.

More widely, the UK government could play a role in ensuring that European initiatives have more impact. Companies flagged that EU joint technology initiatives should be bigger and more market-targeted, rather than aimed at pure blue sky research, and should seek to build consortia across Europe which are capable of competing with Far East ones. Equally, funding criteria for EU projects are often confusing, with criteria difficult to understand or contradictory ("you only qualify for this money if you don't need it"). Companies felt that UK organisations, such as the Technology Strategy Board, also strayed into this territory.

With the UK public purse firmly shut over the next few years, ensuring that EU funding is fit for purpose and can be accessed by UK companies will be important if the UK is to maintain a steady stream of new entrants into the semiconductor market.

No large companies in the UK
An underlying structural problem appears to be the lack of large companies in the UK who are active acquirers. Large companies play a number of important roles in the industry, from training engineers to acquiring promising small businesses to developing the next wave of entrepreneurs. The UK's lack of large player in this area is a frequent source of frustration, leading many talented people to go overseas. A lack of ambition is cited, as is the desire for many UK entrepreneurs to cash out early and get out of the business.

It is also a reflection of a mainly venture-funded industry, where access to the markets has become very difficult, so the main exit route is through a trade sale. When the only companies large enough to become acquirers are based overseas, this inevitably means that companies are under pressure to create an exit for investors that involves control of the company leaving the UK.

Industry is leading the way

Industry is not standing still. Many companies have recognised that these challenges need to be addressed as an industry, and a number of initiatives seek to do this.

Standards and regulation are long-standing roles for industry bodies. An example of this is Femto Forum, a not-for-profit organisation conceived by Ubiquisys CTO Will Franks, with global membership. This pushes for standardisation and agreement on common interfaces, encourages deployment and adoption of femtocell technologies, and develops the market.

24. Bound, K. and Puttick, R. (2010) 'Buying Power? Is the Small Business Research Initiative for procuring R&D driving innovation in the UK?' London: NESTA.

In research, the Semiconductor Research Corporation is a leading technology research consortium, involving industry, academics and government bodies in its research programmes, in the U.S. and around the world. It sponsors pre-competitive university research of long-term benefit to the industry. SRC was created in 1982 to boost the contributions of university research for the semiconductor industry. EPSRC is a member of the Global Research Collaboration programme within SRC, connecting academics and industry researchers. This programme directs research towards long-term goals for the industry.

The UK Electronics Skills Foundation was launched this year to improve the quality and supply of employment-ready graduates to industry. The National Microelectronics Institute was instrumental in putting together this collaboration, but critical to its creation has been the willingness of industry to commit resources to the Foundation and to sponsoring individual students. Even a company as small as five employees is sponsoring a student through this scheme. The activities of the Foundation extend from student sponsorship through to summer schools, scholarships and encouraging employers to work with schools.

The European Microelectronics Academy

Industry is also playing a leading role in the creation of the European Microelectronics Academy (EMA) to overcome issues raised by high start-up costs and foster greater entrepreneurship. Successful entrepreneurs also attract venture capital firms, which are essential for the industry.

The founding partners in the EMA will be Mentor Graphics and NESTA. Mentor Graphics is one of three Electronic Design Automation (EDA) tool giants whose customers are microelectronics companies. Mentor has very successfully operated a business development unit, Cre8Ventures, for the last eight years. This was set up to give them early access to companies that could become the 'next Cisco' – i.e. a multi-million account for their EDA tools – via sharing the risk at the start-up phase

The Academy extends the risk-sharing approach to other partners, to try to increase the chances of these companies becoming 'Ciscos'. It is an incubator business that aims to de-risk microelectronics start-ups through partnering with their supply chain and providing access to quality people. This would reduce the seed capital required to get the company to a first major investment round.

The cost of getting to a first product has increased exponentially for microelectronics start-ups, and it is now common to need to raise £3 million or more simply to test a design in silicon. This level of risk is off-putting for investors, and too large for more risk-friendly seed investors and angels.

The EMA aims to get a start-up to its first product and initial customer engagement through brokering risk-sharing relations with all of the critical and costly components of the microelectronics supply chain:

- 'Platinum Partners' – suppliers and manufacturers such as foundry, EDA tools and IP companies.
- 'Blue Chip Partners' – who provide access to the end customer and market intelligence.
- 'Knowledge Partners' – such as universities and Knowledge Transfer Networks (KTNs).

Alongside these relationships, the Academy has access to an 'alumni network' of entrepreneurs, leaders and experts to help build teams, to validate opportunities, and potentially to invest. The Academy aims to tackle some of the specific challenges facing the UK semiconductor industry:

- Funding: by providing access to tools and expertise that would be too costly for a start-up to acquire, the cost of getting to the first product will be lowered.
- Entrepreneurship: Access to a network of key people and customers will provide support to new ventures.
- Skills: Provide access to experienced people to help support skills.

It will also help to reinforce the inter-company relationships which are a characteristic of the South West cluster.

What next for the South West cluster?

The South West semiconductor cluster highlights how a successful cluster can grow with targeted, low level support:

- Investment in private sector led networks.

- Support for incubators and shared facilities.

The next step for the South West semiconductor cluster is uncertain. There is a shortage of venture funding for small companies, and with some investment firms pulling out of the sector altogether, the climate appears to be worsening. Start-up capital is in short supply, but a greater problem may be a lack of growth funding to develop the big companies of the future. Several companies in the cluster have the potential to develop to that size or larger, but it is not clear how they can do this in the current environment. While some of this may be addressed by the Innovation Investment Fund, established in 2009, there are other proposals which address the other barriers faced by companies in the South West which deserve some attention.

The SPark Science Park
SETsquared and Silicon South West are effective at bringing on ideas and small teams, getting some seed funding in place and getting companies off to a good start. However, the planned SPark Science Park outside Bristol is the next stepping stone. It is planned to offer a good sized incubator that can help start-ups move up, the kind of facility that will turn good ideas into global businesses. To be successful, it will need access to good transport infrastructure, given the critical role of global supply chains and funding in the semiconductor industry.

Shared facilities
Silicon South West set up its test labs from second-hand equipment donated by a down-sizing multinational. Shared facilities are an effective way of supporting small companies, allowing them to pay only for usage, and save on capital expenditure. Mentor Graphics/Cre8 ventures has been good at doing this with EDA design tools and the Silicon South West Labs are doing the same with test facilities, but there are other areas such as verification, first silicon shuttle runs from Taiwan, trade show attendance and marketing that could benefit from this approach. Indeed, the National Microelectronics Institute has already convened discussions on industry co-operation in the area of verification.

Part 4: Broader implications for government clusters policy

At a time where clusters have again come to the forefront of policy discussions, it is worth considering what lessons can be learned from the growth of the South West cluster. In particular, it is worth asking the question: what should governments do when faced with an existing cluster, to support its growth?

Not a new industrial strategy

An industrial strategy approach to cluster development appears to be a high risk strategy. A brief glance at the semiconductor industry across the globe shows that this strategy is high risk and more prone to failure than success. Whilst McKinsey Global Institute points out that no successful semiconductor cluster has been created without government intervention, there are far too many examples of governments investing heavily and still not creating a successful industry in their country.[25] No semiconductor clusters created in the last 15 years have demonstrated sustained growth, despite significant efforts and investment in a number of countries.

McKinsey Global Institute's estimates of the levels of government investment are shown in Table 1.

- In South Korea, unrestrained subsidised government investment led to the financial crisis that followed, with the *chaebol* left with large debts, and oversupply in the industry.
- Taiwan also supported its industry, but insisted on each company having a niche and business model, making it much more robust when memory chip prices fell dramatically.

25. McKinsey Global Institute (2010) 'How to compete and grow: A sector guide to policy.' McKinsey & Company.
26. Ibid.

Table 1: Selected countries' investment and market share in semiconductors

	Estimated cumulative government incentives to 2008 ($ billion)[26]	Estimated current global market share
United States	12 - 36	16%
Japan	19 - 54	16%
Taiwan	15 - 43	5%
South Korea	9 - 26	12%
Singapore	5 - 16	n/a
Germany	2 - 7	2%
China	6 - 17	21%
Malaysia	1 - 3	n/a

Those countries that have intervened successfully have had fortunate timing – when few competitors existed, or by introducing innovation, as in Taiwan's new 'foundry' model. The industry as a whole is highly cyclical, so it is important for companies to be able to survive through periodic downswings, without preventing Schumpeter's 'creative destruction' from taking place. With funding extremely tight in the UK, seeking to repeat the investments of Inmos and Plessey is not an option open to anyone.

Academic theories on clusters

Cluster research is rich with case studies and hypotheses for how clusters start and grow. As early as 1890, Alfred Marshall, the precursor to modern cluster exponents, identified three factors that make geographic clusters beneficial:[27]

- Sharing of inputs: allows firms to procure inputs at a lower price as part of a cluster than they can in isolation.
- Labour market pooling: Flexibility and mobility of labour is a key characteristic, lowering recruiting costs for companies and allowing knowledge spillovers to be shared more actively.
- Knowledge spillovers: Workers learn from each other; companies have ready access to the latest ideas and innovations; close proximity to customers and suppliers makes it easier to understand customer needs and trends. This is combined with the ability to act flexibly and rapidly in response to this knowledge; being part of a cluster confers some of the scale benefits of a large vertically-integrated company, without the disadvantages of being slow to act.

More recently, other researchers who have studied clusters include AnnaLee Saxenian, who examined clusters in Silicon Valley and Boston's Route 128 and concluded that the greater success of Silicon Valley was due to a more entrepreneurial and open culture, in contrast to the large, closed firms that dominated the Boston cluster.[28] Richard Florida's thesis is that clusters and innovation are positively correlated with tolerance and the presence of creative people.[29]

Michael Porter is widely associated with cluster research and policy. He argues that proximity creates competitive pressures that improve productivity and innovation, while customers and suppliers that are clustered together support the existence of specialist providers.[30]

Porter recognises the problems with industrial policy, but argues that cluster policies can reinforce the development of all clusters. Targeting government support to clusters is a controversial policy. In defining the boundaries of a cluster, industrial definitions are often used, which can lead cluster policy to become industrial policy by another name. This can mean targeting a specific industry at the expense of others through subsidies, tariffs or specific R&D funding.

So what works?

Government involvement in clusters has a mixed history. In a Harvard meta-study of 833 clusters,[31] government or chance was identified as a contributing factor in only in 3.4 per cent of successful clusters. The study identifies that government or chance contributions are observed far more frequently in unsuccessful clusters (22 per cent), although the more important factor seems to be having a balance of input conditions, competition, demand and related industries.

Government therefore has a poor record at creating clusters. Most successful clusters emerge spontaneously, based on some geographic or historical advantage. Governments can only identify clusters once they have emerged, and seek to provide the infrastructure and facilitation that make it easier for organisations within the cluster to operate, and for the cluster to become better known.

In addition to the usual suspects of skills and transport infrastructure, our research in the South West highlights two important, low cost approaches to supporting cluster development – backing industry-led intermediaries and facilitating movement between universities and industry.

Intermediaries

Clusters consist of many different types of organisation, from the core businesses to support service businesses, universities, trade associations, and the customers and suppliers. Van der Linde's analysis[32] suggests that competition, demand and supporting industries are almost equally important in the successful

27. Marshall, A. (1890) 'Principles of Economics.' London: Macmillan and Co.
28. Saxenian, A. (1996) 'Regional Advantage: Culture and Competition in Silicon Valley and Route 128.' Cambridge, MA: Harvard University Press.
29. Florida, R. (2002) 'The Rise of the Creative Class. And How It's Transforming Work, Leisure and Everyday Life.' New York: Basic Books.
30. Porter, M. (1998) 'Clusters and the New Economics of Competition.' Cambridge, MA: Harvard Business Review.
31. Van der Linde, C. (2002) 'Findings from the Cluster Meta-Study.' Cambridge, MA: Institute for Strategy and Competitiveness, Harvard Business School. Available at: http://www.isc.hbs.edu/MetaStudy2002Prz.pdf [Accessed 30 July 2010].
32. Ibid.

Intermediary research centres – the example of the Interuniversity Microelectronics Centre in Leuven, Belgium (IMEC)

A very different kind of government support is through research centres, such as IMEC in Belgium, a major European centre for semiconductor research that has been successful at attracting funding from industry as well as government.

In recent months, both Hermann Hauser and Sir James Dyson have suggested that the government should consider developing new technology research centres as a means to facilitating the development of products from research ideas and stimulating greater exchanges of researchers between academia and industry. IMEC is often cited as a model for these centres.

IMEC is a world-leading interdisciplinary research centre, and often held up as a successful example of a public-private research institute. The centre continues to receive government support from the Flemish government, amounting to around 16 per cent of revenue in 2008. The government has supported IMEC since its creation in 1984, but it was ten years before the centre developed substantial external revenues, which come from companies and academic institutions that want to access IMEC's leading-edge research. Key elements include:

- The centre seconds researchers from partner companies to work at the institute. Of its 1,700 staff, about 30 per cent are guest researchers and residents. More than 40 per cent of staff come from outside Belgium.
- IMEC has created a classification system for IP which allows both open sharing and retention of private rights for IMEC's industrial partners.
- IMEC has successfully created a centre for expertise which attracts partners and generates an environment for co-operative research. They work with 600 companies and 175 universities.
- They aim to lower the costs in certain technology areas by focusing their development. Research programs are organised into two main streams: 'More Moore' – to examine ways to scale the existing CMOS technology into ever smaller sizes; and 'More than Moore' – looking at application-oriented research.

growth of a cluster. Porter suggests a number of roles that a trade association or other intermediary can play to support a cluster:[33]

- Provide a forum for the exchange of ideas and a focal point for collective action.
- Establish university-based testing facilities and/or specialist training programmes.
- Collect information and data relating to the cluster.
- Offer help on common managerial problems.
- Investigate solutions to environmental issues.
- Organise trade fairs and delegations.
- Manage purchasing consortia.

The key elements are to help organisations to organise into supply chains; to seek out the infrastructure and services that there is a collective need for; and to help promote and market the cluster, to ensure it becomes better known as a source of expertise and output. The South West highlights how intermediaries can provide links to mentors and management talent, and the industry working together can make equipment or resources available at favourable rates to allow companies to test ideas or prototypes at lower cost.

The success of university/industry partnership approaches in the South West, whether through Silicon South West or the SETsquared partnership, highlight how Porter and Van der Linde's theories can be applied in practice. Equally given the relative low cost models adopted in these partnerships, these are the sorts of investments that government can usefully make in a fiscally constrained environment.

33. Porter, M. (1998) 'Clusters and the New Economics of Competition.' Cambridge, MA: Harvard Business Review.

Facilitating movement between universities and industry

There is a high level of job mobility in Silicon Valley,[34] due to a number of factors, including the modular nature of the computer industry, where external economies of scale are particularly important; a 'California' effect due to the unenforceability of non-compete agreements in California law; and an industry where gains from new innovations are both large and uncertain.

The origin of the South West silicon design cluster was arguably the opening of the Fairchild Semiconductor design office in Bristol, which was said to be motivated by a desire by Fairchild to open offices in locations where it was easier to retain engineers, because they would not be lured away by local competitors. Ironically, one of the original members of that office went on to become Design Manager of Inmos.

As the cluster has developed, this movement of individuals across companies has been supplemented by movement of individuals between universities and the private sector. For example, Professor David May was initially at Inmos, later joined the University of Bristol and has now also established his own company, XMOS. This movement has been facilitated by the work of far-sighted universities who have actively facilitated this lateral movement (see Figure 2).

The movement of people between companies and institutions supports and defines the cluster, and can lead to greater levels of collaboration. A number of measures can help to support greater mobility:

- Events that bring the community together around a common purpose are where much of the 'gossip' that sustains mobility occurs: who is starting something new, who is an authority, who is good to work for. Sharing a task, such as building a consortium for a bid can create deeper links than more general networking.

- Opportunities for work placements and training build links between companies and institutions, as well as increase the pool of skills. While confidentiality is a major concern in an IP industry, there are many companies whose skills are complementary rather than being rivals.

- University courses which combine technology training with business can help to provide the graduates that are most sought after, as well as providing an opportunity to engage the businesses themselves with the curriculum and even delivery.

34. Fallick, B., Fleischmann, C. and Rebitzer, J. (2005) 'Job Hopping in Silicon Valley: Some evidence concerning the micro-foundations of a high-technology cluster.' NBER Working Paper Series, No. 11710. Cambridge, MA: NBER.

Part 5: Conclusions

Semiconductors are not considered a particular strength in the UK – we don't have an Intel or a Samsung here. And yet, semiconductor design is considered a real UK strength by the global industry, and contributes to regional growth in several areas of the UK, but most notably in the South West, attracting significant investment and people into the area.

This cluster is anchored on an historic skills base dating back several decades. But the cluster would not be sustained on that basis alone. It survives because those skills are retained in the area, the expertise is renewed, and new companies continue to be formed. With the retirement of a generation of Inmos-trained engineers, the South West will face a new challenge in finding skilled engineers who understand the processes involved as well as the business issues.

As this report highlights, many of the issues of the semiconductor industry are shared with other industries. Connecting the university courses to the demands of employers is a common theme in many science and engineering industries, and sector-spanning people like Professor David May can be invaluable in opening up these links.

Mobility is a key attribute of a cluster: freedom of people to move between companies, and between industry and academia, creates greater innovation and enhances the attractiveness of the cluster as a whole. A critical mass of similar companies means that people can locate there with confidence that if any given company fails, there will be others who are seeking the same skills.

Clusters can be reinforced by measures and institutions that anchor the industry to the area, and promote the inter-industry links that promote the cluster and support smaller companies. Intermediaries can rally companies around common causes such as promotion and standards; incubators provide support to smaller companies and make critical connections to people who can make a difference to the business; shared resources between companies or provided by academia can lower costs for companies in an industry where every part of the process is characterised by incredibly expensive tools and processes.

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